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SECTION CANDIDATES ON BACHELORS OF SCIENCE

Roofing material determination with hyperspectral data

Dávid Abriha¹

¹Department of Physical Geography and Geoinformatics University of Debrecen, Egyetem tér 1
4032 Debrecen, Hungary
abrihadavid@gmail.com

Abstract

Multi- and hyperspectral imaging represents a popular tool in the monitoring of the environment in terms of the identification of the objects and to follow their changes. This technique can also be used in natural areas and urban environment. In my work I performed my analysis in an urban environment, the study area was located within Debrecen city. My aim was to investigate the buildings focusing on the roofing materials with remote sensing. It can be important from the aspect of fire risk evaluation, and also can have environmental risk issues. The main environmental issue of the existing roofing is that asbestos panels can cause serious lung disease and cancer, furthermore people does not know the consequences of the health risk and if they recover their houses with other types of tiles, the waste is not handled as dangerous; i.e. they use the AC-panels for several further purposes (e.g. as fence or covering smaller objects in the garden) or dump them as non-dangerous waste.

Keywords: image classification, roofs, hyperspectral remote sensing, PCA

Introduction

Due to the accelerated development of urban areas during the recent decades, it's necessary to perform various analysis and comprehensive databases in order to study these areas [10].

Remote sensing has made the data acquisition faster and also provides numerous applications for a wide range of studies, making it an effective tool in the mapping of urban surfaces [16]. However, there are difficulties: in these areas, different materials such as wood, concrete, tiles can be found close to each other [7], therefore images with lower spatial resolution (10-30 m; Sentinel, Landsat satellite data) cannot be used for the analysis. Spectral resolution is another important factor: multispectral images contain 4-10 wider bands, while hyperspectral sensors provide hundreds of narrow bands [5]. These images with high spatial and spectral resolution, ensure great mapping capability in urban areas [17].

Methods

Study area

The selected study area is located in Debrecen which is the second largest city in Hungary [11]. The area contains a mixture of older and modern buildings and comprises typical urban structures, such as detached houses, blocks of flats or recreational areas.

Residential areas have a large variety of roofing types. Newer buildings have tile or metal roofing, while many houses in the older regions of the city still have asbestos as roofing material.

Dataset

Analysis was conducted on a hyperspectral dataset of 7 km² section of Debrecen city, surveyed with an AISA Eagle II camera (400-1000 nm, 126 spectral bands). A previous LiDAR survey ensured the Digital Surface and Digital Terrain Models (DSM and DTM) to determine building heights.

Due to the fact that processing the whole aerial survey would be very time and resource consuming, my study area was a smaller one having a large variety of roofing materials.

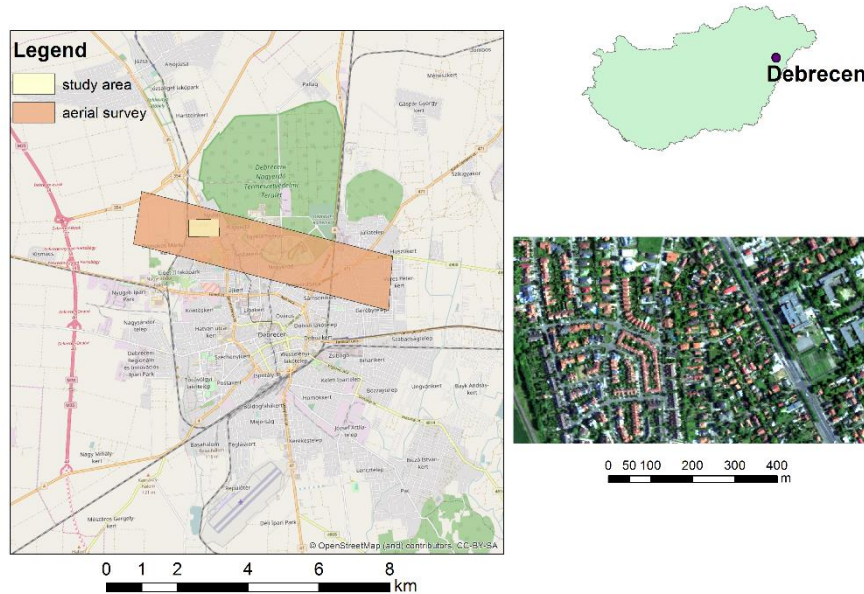


Fig. 1. Location of the study area

Data preparation

Train and test data was collected based on field observation and an aerial image for each roofing material. However, there were some types that only appeared on one or two houses. Therefore, I omitted these not representative types from the analysis in order to get better results. For the classification I used 7 classes: red tile, dark tile (brown and black), asbestos and the top of flats separating the pixels being in sunlight and in shadow.

Classifications were conducted with a mask layer based on a normalized Digital Surface Model (nDSM = DSM-DTM; i.e. relative height) of the area and the NDVI image (using bands in the red (676 nm) and near-infrared (801 nm) wavebands [15]). Buildings are higher than 3 m (nDSM > 3 meters), and their NDVI value is under 0, thus, mask coverage was built using these Boolean layers.

Beside the several advantages of the hyperspectral images in the more accurate classification results, due to their higher geometrical and spectral resolution there are disadvantages, too as more data means longer processing time. Bands contain highly correlated data, thus, in order to reduce the dimensionality of the data Principal Component Analysis (PCA) was applied on it [14]. PCA helps to reduce the dimensionality by computing new bands. Only those bands were used in the classifications which had the largest variance.

In this study 3 different classification methods were applied: Support Vector Machine (SVM), Spectral Angle Mapper (SAM) and Maximum Likelihood (ML). Classifications were performed in ENVI 5.2 software.

Classification with SVM

The SVM classifier is a modern supervised classification method. This classifier fits an optimal hyperplane between the classes [13]. Although several hyperplanes can be drawn to separate the classes, there will always be one, from which the classes' distance is the possible largest [2]. I used the SVM classifier with Radial Basis Function kernel and all pixels were classified.

Classification with SAM

Just like SVM, SAM is also a widely used supervised classifier, which have already been applied successfully in studies regarding the mapping of urban environments [3], [9].

SAM classifies the pixels based on their spectral similarity [6] which is determined by calculating the angle between two spectra and treats them as vectors in a space where the dimensionality is equal to the number of the input bands [4]. A maximum angle threshold is set for the classification and if a pixel's angle is larger than the threshold, it will not be classified.

It is possible to set a maximum angle threshold for the classification. If a pixel's angle is larger than the threshold, it will not be classified.

At first I tested a single threshold value for all classes, but it resulted an overclassification of two roof materials. Defining multiple values found to classify the image best.

Table 1. Multiple threshold values used in the SAM classification

Class	Maximum angle threshold (rad)
Asbestos	0.3
Asbestos in shadow	0.1
Red tile	0.5
Red tile in shadow	0.6
Dark tile	0.5
Dark tile in shadow	0.6
Top, block of flats	0.4

Classification with ML

The Maximum Likelihood method assumes that the classes in each and every bands are normally distributed. This classifier guesses the probability with which a pixel belongs to a specific class and it assigns the pixels to the classes with the highest probabilities [13]. ML classification was performed without probability threshold, therefore, every pixels were given a specific class.

Accuracy assessment

Classification accuracy was performed using the test dataset with error matrices. Overall accuracy (OA), user's accuracy (UA), producer's accuracy (PA) and Kappa index were calculated [8].

Results

The result of the PCA showed, that the first five Principal Components (newly computed bands) contained the 99.03% of the total variance. These uncorrelated bands contained almost the whole variance of the original dataset, therefore, only these bands were involved in the classification.

Table 2. Statistical characteristics of Principal Components

PC	Eigenvalue	Percent	Cumulative percent
1	223376304.63	65.11	65.11
2	78483217.0862	22.88	87.99
3	29167722.76	8.50	96.49
4	6556414.94	1.91	98.40
5	2175322.14	0.63	99.03

SAM provided the worst results (OA: 66.76%, kappa: 0.59; Table 3). A large amount of pixels (more than 30% for asbestos and red tile) remained unclassified and also asbestos roofs in shadow were misclassified as dark tiles, in general. Better results were gained with the SVM method (OA: 74.33%, kappa: 0.66). However, its performance was the worst considering the roof classes with sunlight and shadow position.

I achieved the best results with the ML classifier (OA: 78.95%, kappa: 0.72).

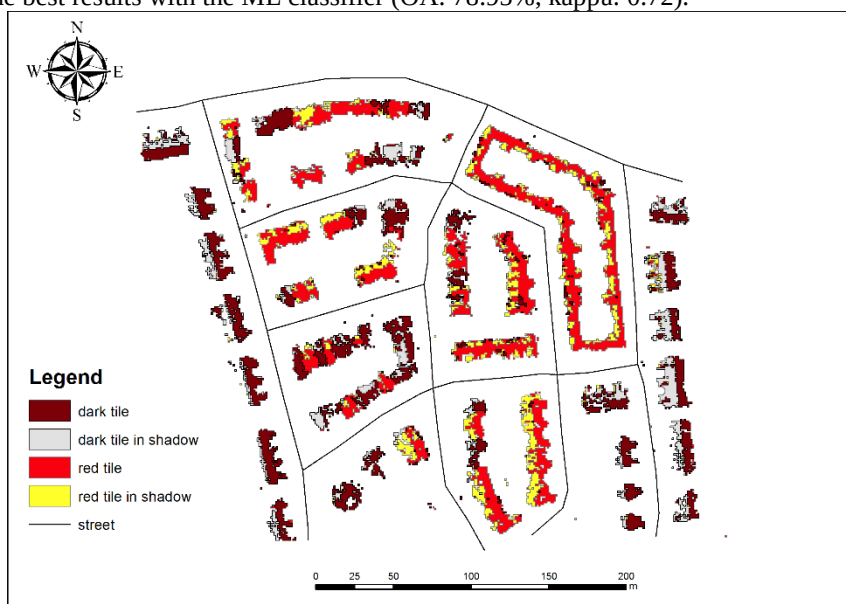


Fig. 2. Roofing types in a part of the test area based on the ML classification

Table 3. The accuracy of the classifications (UA: users's accuracy; PA: producer's accuracy)

Class	SAM (%)		SVM (%)		ML (%)	
	PA	UA	PA	UA	PA	UA
Asbestos	67.31	89.74	98.08	91.07	98.08	100.00
Asbestos in shadow	2.00	100.00	12.00	42.86	28.00	100.00
Red tile	78.83	97.89	90.75	84.20	89.78	86.42
Red tile in shadow	42.02	83.16	54.26	90.27	65.43	89.13
Dark tile	53.68	79.69	82.11	66.10	87.37	72.17
Dark tile in shadow	65.22	52.64	55.43	59.30	63.04	76.32
Top, block of flats	100.00	92.14	73.64	96.34	81.40	98.13
Overall accuracy	66.76		74.33		78.95	
Kappa index	0.59		0.66		0.72	

The classification accuracy was the lowest for the asbestos in shadow. The main reason can be that asbestos roofings are rare in this specific area, thus, the available training pixels were limited. However, the identification of asbestos roofings play an important role in the mapping of urban environments [12], [15].

Conclusions

In general, hyperspectral data can be used well to identify different roof materials. Although some of the classes did not reach the minimum level of accuracy (85% according to [1]), by widening the study area, more training pixels can be collected for each classes thus making the classifications' accuracy better.

Acknowledgements

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Elaboration of the map of underwater objects on the bottom of the Narew river between historical Granary of Polish Bank and Modlin Fortress

Marta Augustynowicz¹, Dariusz Popielarczyk²

¹Faculty of Geodesy, Geospatial and Civil Engineering, University of Warmia and Mazury in Olsztyn, Oczapowskiego 2,
10-719 Olsztyn, Poland

Contact marta.augustynowicz@wp.pl

²Department of Satellite Geodesy and Navigation, Faculty of Geodesy, Geospatial and Civil Engineering, University of Warmia and Mazury in Olsztyn, Oczapowskiego 2,
10-719 Olsztyn, Poland

Contact dariusz.popielarczyk@uwm.edu.pl

Abstract. The Modlin Fortress and the Granary on the Narew river funded by the Polish bank are both well-known historical places in Poland. As we read in the literature, the surroundings of Modlin Fortress were a reason for wheat granary construction. Archaeologists and historians are still analyzing

the history of these buildings, but nobody has explored the Narew river which separates both buildings.

The main objective of the work was to elaborate a map of underwater objects on the bottom of the Narew river between the granary and the fortress.

The necessary data for elaborations was collected during the measurement campaign in April 2016. The hydro-acoustic survey was done by using Integrated Bathymetric System which was built by team from Department of Satellite Geodesy and Navigation from University of Warmia and Mazury in Olsztyn. During the survey two systems were correlated: bottom detection system and positioning system. The first is a single-beam echo sounder and the second one is a DGNSS positioning system. The research has been done with cooperation with the archaeologists from the University of Warsaw. Except for the realization of the main objective of the project it was also created three-dimensional bottom shape visualization by using ESRI ArcMap software.

In the paper a short history of research objects and the Integrated Bathymetric System were described. Then the process of map realization of underwater objects in the Narew river and two and three dimensional models of river bottom are presented.

The elaborated map can be used by archeologists to investigate and finally get out the underwater objects. These things are a very important basics to explore history of the unique Granary and the Modlin Fortress. Additionally, the created database includes an echogram preview for each underwater object, description of the element, depth and height of target above the bottom.

The presented work shows that Geographic Information System (GIS) based on the data from modern GNSS and hydroacoustic systems can be applied in many fields of science, industry and administration. This project is a brilliant example to show the interdisciplinarity of Geographic Information System.

Keywords: Bathymetry, GNSS, SBES, Modlin Fortress, Map

1 Introduction

The Modlin Fortress and the Granary on the Narew river funded by the Polish Bank are both well-known historical places in Poland. As we read in the literature, the surroundings of Modlin Fortress were a reason for wheat granary construction. Archaeologists and historians are still analyzing the history of these buildings, but nobody has explored the Narew river which separates both buildings. In the past both buildings were among the most important military objects in Poland. However after the First and the Second World War a lot of elements of buildings were destroyed. These elements are very valuable for historians to build a history of fortress and granary. A lot of historical vehicles and constructions were sunk on the bottom of Narew in different places. To investigate these objects it is necessary to specify their location. This challenge was taken up by team of students

and scientists from University of Warmia and Mazury in Olsztyn. The field research has been done with cooperation with the archaeologists from the University of Warsaw.

2 Study area

The Narew river runs through the north-eastern part of Poland. The beginning of the river is located outside the country, in Belarus, but the larger surface area is located in Poland. It is the right tributary of the Vistula river and the discharge is located in Nowy Dwór Mazowiecki city, just after the Modlin Fortress and Granary. The Modlin Fortress is a European-wide unique complex of fortified buildings and structures showing a cross-section of the European fortification architecture of the 19th century (bastion) and the beginning of the 20th century (scattered fort). The concept of the construction was put forward by Napoleon Bonaparte, who ordered a design of a semi-oval fortress with five bastions opened from the side of the river in 1806. The fortress was meant to be located on a high northern bank at the mouth of the Narew and the Vistula. The old Granary of Modlin Fortress originally built in 1838-1844 opposite the fortress at the south mouth of the river (founded by the Polish Bank). The granary besides storage tasks could fulfill functions of defense, because the first floor was provided with holes adapted to conduct artillery and gun fire. Between granary and fortress there was built a bridge in 1836 by J.H. Singels. The bridge was based on stone/brick foundations, wooden pylons and wire ropes. Construction of bridge was too weak and it was break down. During the first weeks of the second World War (the tragic events of September 1939 connected with defence actions around the Modlin Fortress) the granary was seriously damaged and fell into ruins. Bottom of the Narew river between Modlin Fortress and Granary was an object of presented research.



Fig. 1. Narew river - the location of study area.

3 Measurements

3.1.1 The experimental measurement campaign was conducted in April 2016. The main objective of the work was to collect raw geodetic and bathymetric data and elaborate a map of underwater objects on the bottom of the

Narew river between the granary and the fortress. Integrated Bathymetric System was used to investigate underwater objects and to specify their location.

3.2 Methodology

The hydro-acoustic survey was done using Integrated Bathymetric System which was built by the team from Department of Satellite Geodesy and Navigation from University of Warmia and Mazury in Olsztyn. During the survey two systems were correlated: bottom detection system and positioning system. The first is a single-beam echo sounder (SBES) and the second one is a DGNSS positioning system. [2] Additionally Side Scan Sonar (SSS) was used to identify some objects on the bottom.

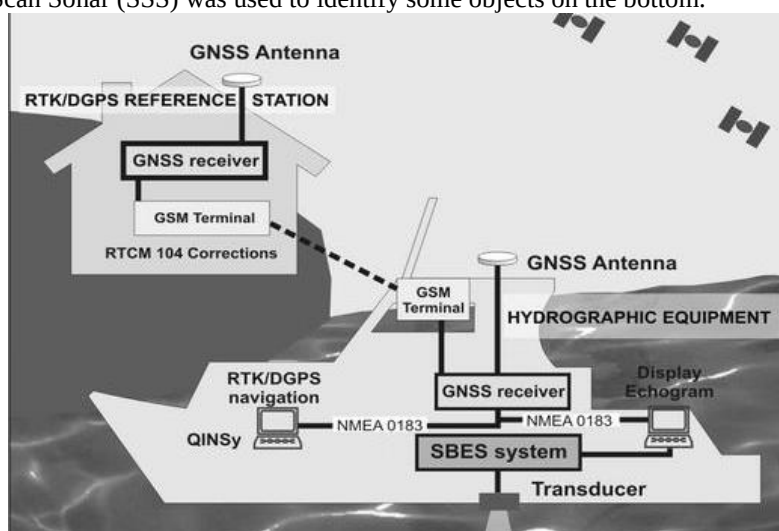


Fig. 2. Integrated Bathymetric System. [3]

The Differential GNSS positioning system uses geodetic receiver supported by Ground Based Augmentation System (GBAS). There can be used the permanent reference station or a local station set up only for the dedicated project. The base station receiver determines the errors of measurement data between fixed and observed station position (corrections). The DGNSS corrections in RTCM format are sent via GSM terminal to the rover GNSS receiver in unknown and can be applied to measurement data.

The hydrographic equipment includes EA 501 P Simrad single frequency digital hydrographic echo sounder, Side Scan Sonar Imagenex SportScan and YSI 600R sonde for water quality sampling. The EA 501 P system basically consists

of transducer, transceiver and personal computer. [4] The collected data are processed on-line for generation of colour echograms and tables.

3.3 Bathymetric measurements

3.3.1 At the beginning of the field experiment the team made the project of measuring profiles, launched the bathymetric boat, carried out the configuration of GNSS receivers and calibrated single beam echo sounder. In order to create the database of objects on the Narew river bottom, the profiles have to be designed very close. This can increase the chances of finding all sunk objects. Survey profiles were spaced every 5 meters. The project of measurement lines was made in the ArcGIS applications using Open Street Map and orthophotomap as a background. Geodetic Topcon HiperPro receivers were set up in DGNSS mode. Pseudorange corrections were receiving from GBAS TPI NETpro using IGTS-R GSM terminals. To properly configure hydroacoustic system the sound speed in water should be properly determined. Water in Narew river was melted, because the river is constantly in motion. In addition, the maximum depth in the area of measurement was only 6.3 m. Measurements were planned in the Spring in April. The water temperature was 12°C. The speed of sound in the water calculated

using the Miedwin formula was 1430 m/s. The calibrated single beam hydroacoustic system provides few centimeter depth detection accuracy. After testing the correctness of DGNSS positioning navigation and following calibration of the single beam depth measurement system, the field survey work was started. In order to collect enough data boat had to move at the speed of approx. 2-3 m/s. To control the speed Thales Mobile Mapper receiver was used. Navigating a boat on survey profiles was carried out using ArcGIS application. Hydroacoustic survey covered a fragment of the Narew river located between the Granary and the Modlin Fortress. The choice of this location was not accidental because in this part of the river there are the most objects related to the destroyed Granary building and sunk bridge.

3.4 Raw data elaboration

Hydroacoustic and geodetic surveys took two days of field work. All collected bathymetric and GNSS raw data was initially processed and edited on the field and then recorded for further elaboration. Hydroacoustic raw data, along survey lines, were recorded as binary echogram files.

Raw data elaboration process was divided into a few basic stages:

1. Verification of the bathymetric echograms,
2. Water level investigation,
3. Echograms analysis and creation of database of underwater objects,
4. Creating TIN and GRID models,
5. Bathymetric map elaboration.

Each echogram contains bottom visualization, depth, position and information about the SBES configuration. The graphical bottom representation was used for depth raw data verification using special applications Echo Converter. During depth editing, the digital depth record should be compared to the analog echo sounder trace. Bad depths and coordinates data can be shown, filtered or removed. The bottom surface of Narew river presents unequivocal bottom with ripple marks. The maximum detected depth was 6.3 m at the mouth of the Narew river to the Vistula river

3.5 Reference water level

During bathymetric and geodesic surveys the water level was changing slightly over the time. It was necessary to adjust the verified hydrographic data to the common water level. To determine the final water level, GNSS antenna ellipsoidal heights computed in On The Fly (OTF) post-processing mode and static measurements were considered. All observed ellipsoidal heights were transformed to the normal heights using the Polish gravimetric quasi-geoid model PL-ETRF2000 (epoch 2011). For conversion of ellipsoid heights to the system of normal heights the quasigeoid undulation of 31.40 m was applied. The final water level was determined as 70.07 m above sea level (Kronsztadt'86).

Additionally the water level heights obtained from OTF and classical measurements were confirmed by digital readings from the local level indicator.

Table 1. Heights which were used for calculations

Description of height	Value [m]
Ellipsoidal height of GNSS antenna	103,07
Undulation	31,40
Distance between GNSS ARP and water level	1,60
Final water level	70,07
Modlin IMGW gauge reading	3,61
IMGW gauge zero level	66,51
Final water level from IMGW	70,12

4. Results

As a result of processing the raw measurement data, the set of points was converted to common water level. These points formed the database set for development of the DEM of Narew river.

4.1 Interpretation of echograms

The underwater objects database was created on the basis of echograms. The database contains basic information of elements e.g. longitude, latitude, depth and height above the bottom. Additionally each object is connected to the individual image on echogram. Generally 253 elements were detected. All objects were divided into four class of significance: 0, 1, 2, 3. The most important objects are in the 0 class. The class number depends on localization, size and shape. In the close surroundings of granary there are usually stone blocks and bricks from damaged granary (low significance).

The biggest elements (class 0 and 1) were detected in many places, also in surroundings of granary. The comparison between 0 and 2 class objects is shown on echogram (Fig. 3.).

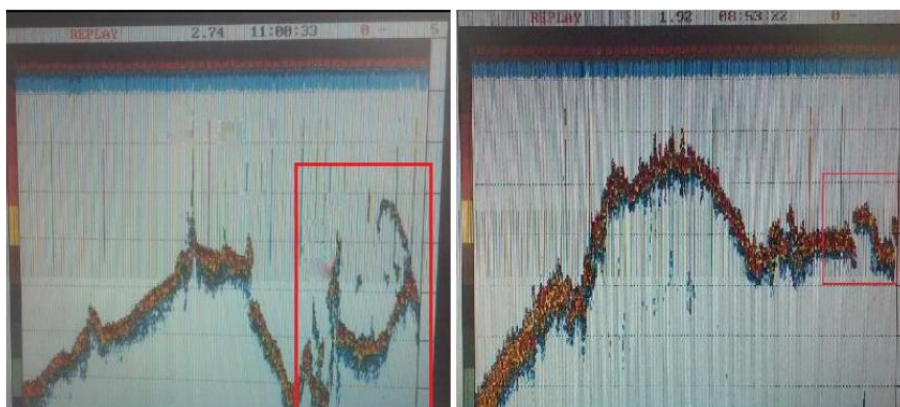


Fig. 3. Objects of „0” class (on the left) and objects of “2” class (on the right).

Fig. 4 and 5 show underwater objects on the bottom of Narew river between granary and Modlin Fortress. Some of the identified on echograms elements were chosen for direct underwater investigation by a diver. These objects are marked in the Fig. 4 by numbers 1, 2 and 3. In the first place the old bridge foundation was identified. Historical photo confirms the location of J.H. Singels bridge in this place. The next investigated place is near the opposite riverbank. There are drowned river barges. In the third place there is the rest of bridge which was destroyed during the First World War.



Fig. 4. The most important underwater objects between Modlin Fortress and Granary.

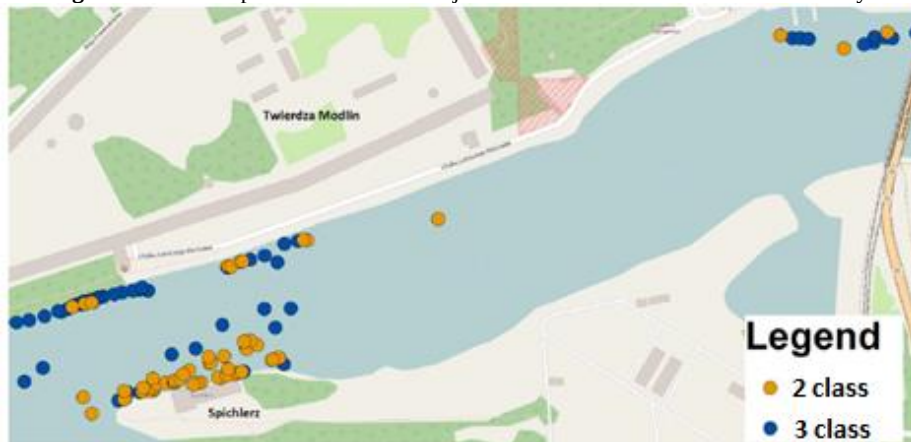


Fig. 5. Less important underwater objects between Modlin Fortress and Granary.

During the project the Imagenex SportScan Side Scan Sonar was also used. Some interesting objects on sonogram are shown in Fig. 6. The shapes of object number 3 and 4 look like boat wrecks. Other objects are very difficult to identify.

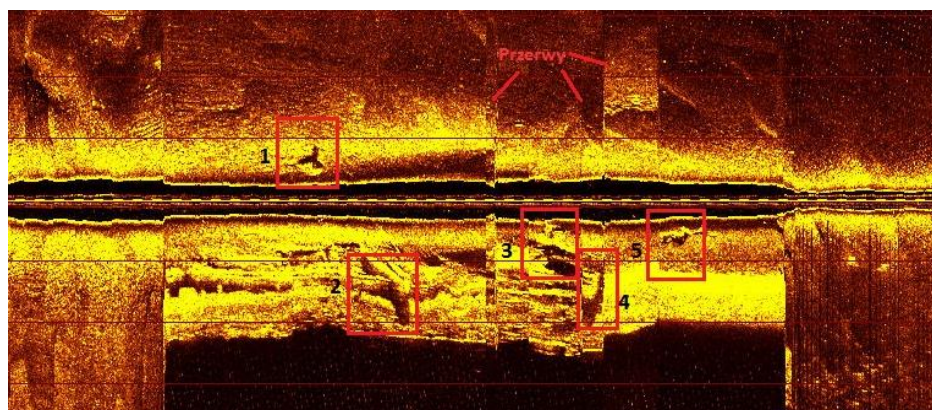


Fig. 6. Imagenex SportScan sonogram.

4.2 DEM generation

There is a number of methods for modeling 3D data, such as terrain models. The most popular among them is the Triangulated Irregular Network (TIN) and regular grid surface (Grid). Both of them are commonly used for creating and representing surfaces in GIS. Special feature of TIN is that modeled surface is divided into small triangles. Each vertex of triangle has known coordinates since each vertex is measurement point. Delunay algorithm is the most popular algorithm which is used to create triangles in TIN [5]. TIN surface model of Narew bottom was shown in Fig. 7.

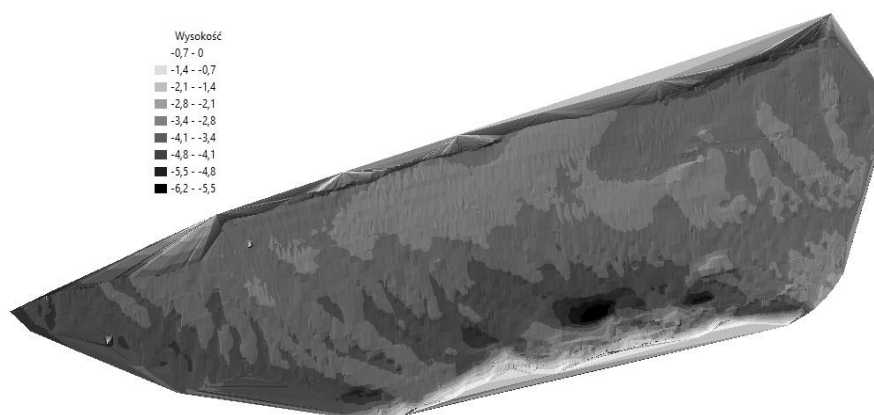


Fig. 7. TIN model of Narew bottom.

Created TIN model was loaded to ArcScene tool (Fig. 8). Using this program the spatial representation of the bottom is possible. Fig. 8. and Fig. 9 show shallow areas in the surroundings of granary.

In Fig. 8. a bridge fundament is marked by a red rectangle. Along the waterfront of the granary there are some deeper regions (marked by red arrows).

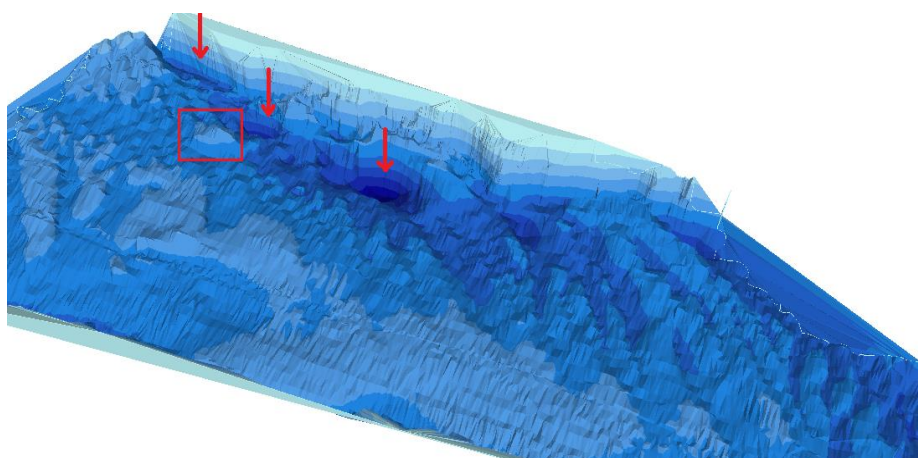


Fig. 8. Spatial TIN model of Narew bottom.

GRID model is less accurate than TIN model since heights of points are estimated. [1] On the other hand contours derived from DEM grid are more smooth. Fig. 9 presents grid created using ArMap Topo to Raster Tool with a spatial resolution of 2,5 m. The contours were created at a 1-m sampling interval using ArcMap Contour Tool.

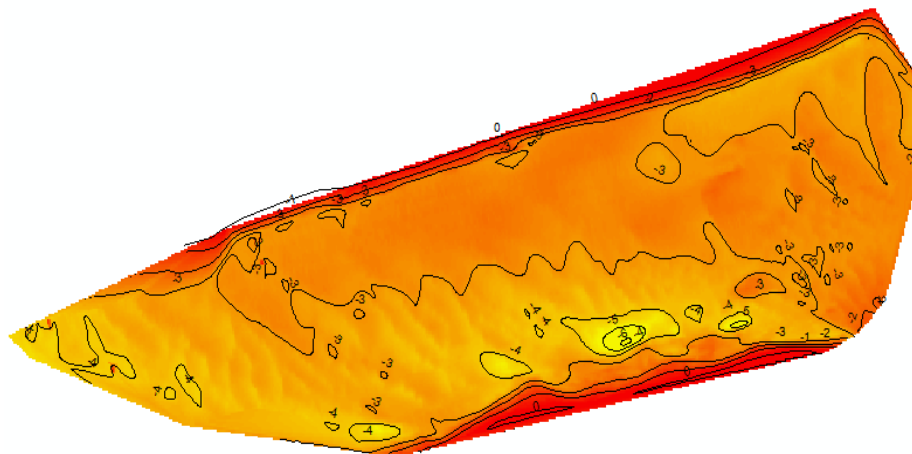


Fig. 9. GRID model of Narew bottom.

5. Summary

The main objective of described work was to elaborate a map of underwater objects on the bottom of the Narew river between the Modlin Fortress and Granary. The geodetic and bathymetric measurements were conducted in April 2016. During the research 102 measurement profiles were completed and 16652 raw bathymetric measurements were collected. These amount of data is sufficient for creating reliable bathymetric map and bottom Digital Elevation Model.

The paper presents a process of field surveys and map realization of underwater objects in the Narew river. Then two and three dimensional models of river bottom were elaborated.

The elaborated map can be used by archeologists to investigate and finally get out the underwater objects. These things are a very important basis to explore history of the unique Granary and the Modlin Fortress. Additionally, the created database includes an echogram preview for each underwater object, description of the element, depth and high of target above the bottom. In the near future it is planned to continue described project. Side Scan Sonar will be used to precise bottom investigation and sonar mosaic map creation. The presented work shows that Geographic Information System (GIS) based on the data from modern GNSS and hydroacoustic systems can be applied in many fields of science, industry and administration.

This project is a very good example to show the interdisciplinarity of Geographic Information System.

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Creating animation of battle in GIS

Bc. Jakub Báča¹

¹Department of Applied Geoinformatics and Cartography
Faculty of Science, Charles University, Albertov 6
128 43, Prague 2, Czech Republic
bacajak@natur.cuni.cz

Abstract. The paper is focused on creating animation of specific battles in GIS. It consists of theoretical and practical part with two digital animations of chosen battles as results.

At the beginning there is a short theoretical introduction to basic relation between time and cartography and its specific and problematic representation in maps. After that there is an introduction of possibilities of cartographic animations and examples of basic software for its creation. Next part explains basic principles of creating cartographic animations in specific GIS software. For this study, ArcMap has been used as a representative of commercial GIS software and QGIS as a representative of free GIS software. Last topic of this part looks at battle maps and their specific parameters and content.

After these theoretical topics there comes first practical part which is focused on analysis of old basemaps of a chosen battle. This work uses the battle at Chotusice which was an important clash between Prussian and Austrian armies on 17th May 1742. These old paper maps were created during 19th century in Austria and were provided in digital format by Map Collection of Charles University in Prague. At first it was necessary to make some corrections between maps and historical records about this battle. After that, topographical background from these old maps has been created and default positions of both armies have been set up. The most important part was to establish a methodical procedure of creating an animation of the battle from these basemaps in both programs. This procedure results in two animations of the battle at Chotusice which are then used to compare options, advantages and disadvantages of both GIS software. At the end there is a decision which of these pieces of GIS software is better for creating animations of battles and what are its possible improvements in the future.

Keywords: GIS, animation, animation of battle, QGIS, ArcMap

1 Introduction

In the last few years, we were witnesses of big expansion of new information technologies which also influenced cartography. Because of that we got new possibilities and instruments for map creation and after that it has been started founding out answer to one of the fundamental questions of cartography – how can be time attached as the fourth dimension to cartographic works?

The answer to this question is by cartographic animation which is mostly part of digital cartoproducts. This term includes dynamic, multimedia and interactive maps, map servers and virtual scenes [12]. Cartoproducts are today very popular, but even there is a topic that isn't too much explored. And this topic is creating cartographic animations in GIS software which is also the main theme of this paper.

2 Theoretical concepts

In this chapter, there are explained all necessary concepts and topics which are important for understanding the rest of the work.

2.1 Time in cartography

As everyone knows, cartography is a science of making maps which are composite from objects and their relation in space. There are two basic types of space – two dimensional and three dimensional. Two sizes are positional coordinates and the third possible size is elevation. But there is also a fourth dimension – time. Time is a physical quantity and has many different definitions [2]. Time can be attached to digital map through cartographic animation. After that, dynamic events and changes can be visualised when time is passing inside digital map.

There are two basic methods of visualization of time in maps – static and dynamic [3]. In static method, there are no visual changes in map field. It means that there are often used tables, graphs or diagrams [1]. But with dynamic

method, there are changes right in the map field during time and best tools for this method are cartographic animations.

2.2 Cartographic animations

So what is cartographic animation? It is visualisation of changes or process of symbols in the map field. The basic principle of animation is playing row of pictures in specific speed which then gives the illusion of movement [9]. This speed is called frame per second (fps) and its standard value for cartography is 24 fps [4].

Cartographic animations can be divided into two segments – presentation and interactive [5]. To the first category belong animations that can't be editing or controlled by user. Most of them are in GIF or AVI format and they are used in many disciplines like weather forecast. The second category includes animations that can be edited or controlled – for example, user can stop them, zoom in or out or select data.

Next segregation consists from changing one of three basic attributes. There are timeseries (change of time), areal (change of area), thematic (change of time and specific value) and process animations (change of all attributes) [5].

The last part of this subchapter will be focused on available methods and software for creation of cartographic animations. There are basically four different methods – script language (e.g. AGIS for Windows), Temporal GIS (e.g. ArcGIS or QGIS), web map applications (e.g. ArcGIS online or Google Earth) or vector graphics (e.g. Adobe Flash) [10]. Each of these software applications has its own advantages and disadvantages and its choice depends on specific task or usage of the animation.

2.3 Temporal GIS

What is Temporal GIS and what are its differences from regular GIS? Temporal GIS is GIS software that can work with the fourth dimension. There is a lot of these software applications but for this research were used only two of them – ArcMap as an example of commercial GIS and QGIS as an example of Open GIS. Each of these pieces of software has its own specific parameters and tools for creating cartographic animations. But they have one thing common – both of them are rarely used for work with animations.

ArcMap is commercial GIS from ESRI and it is one of the most popular commercial GIS. Animations are created by tool *Animation* in *Toolbar* bookmark. As an input, there are needed dynamic data and its attribute table with time data in specific format. After that, bookmark *Time* in *Layer Properties* is activated and there is set up of all necessary parameters. For playing animation is used tool *Time Slider*. Animations can be also exported as row of frames or in AVI video format.

QGIS is one of the most popular Open GIS and one of its biggest advantages is possibility of adding and using specific modules. Its tool for creating animations is called *Time Manager*. Input data must have special column with time data and name timestamp. Through this tool, animations can be played and export in PNG format.

The main difference between these programmes is in method of creating animation. The basic principle in ArcMap is representation of an object based on the time and duration of its visibility, which is determined by the interval between the start and the end time element. In QGIS, animations are created by interpolating points between key points in specific time interval.

2.4 Battle maps

Battle maps are thematic maps with specific content focused on battles or situation before or after it. This type of maps has long history and first battle maps come from medieval times [8]. Every battle map consists of two parts – topographic and thematic content [11]. Topographic background is influenced by scale and need of terrain details. Thematic content consists of combination of point, line and area symbology. This symbology can be used to visualize army units, front lines or occupied areas.

Battle maps can be divided into three categories – classic maps, 3D models and dynamic maps [11]. For this work, the last class is important because dynamic battle maps use cartographic animations for visualisation of movement and combat. And on creation of these dynamic battle maps is focused the main part of this paper.

3 Battle at Chotusice 1742

Before determining procedure of creating animation of battle in ArcMap and QGIS, there was necessary to choose model battle. After short research was chosen battle at Chotusice. This clash between Prussian and Austrian armies happened on 17th May 1742 near city of Chotusice. The main reason for choosing this battle was fact that this clash isn't too much known in public even it was very important for war progress. Also the process of battle was very interesting and challenging for animating.

In 1742, Austria was in war with Prussia and its allies. War wasn't going well for monarchy and Prague was occupied by French. Because of that, Austrians gathered army on Moravia and marched to capital. But Prussian army knew about this and set up defence near Chotusice city. Both armies had about 28 thousands of men including strong cavalry [7].

In the morning on 17th May, scouts saw an incoming Austrian army. After that, Prussian artillery started with bombarding Austrian cavalry which tried to counterattack but it was put on retreat with the rest of Austrian army. After regrouping, Austrians attacked on right side, broke Prussian lines and started fighting over city. Meanwhile all cavalry of both armies fought outside the city which concluded to retreat of Prussian cavalry. It looked that Austrian will easily win this battle but they made two mistakes – first they set up on fire all city and then their cavalry fled from battle and started with sacking Prussian camps. These two mistakes concluded to regrouping of Prussian army which made big counterattack. Austrians had no chance to stop them and after fight they retreated to nearby city of Čáslav. In the afternoon, they fell back to south and Prussians captured Čáslav.

The result of battle was indecisive. Prussians lost about 4 thousands of men and a lot of horses, Austrians lost about 6 thousands of men [7]. Few days after battle were as winners called Austrians because they captured a lot of loot in enemy camps. But one month after battle was made a peace treatment which concluded to loss of big part of monarchy territory, so in fact the winners were Prussians. And that also caused continuing of war for next few years.

4 Data and methodical process

For every work and research, there are always needed input data. In this case was necessary to gathered detailed information about battle and also found appropriate basemaps of this battle. After that could be suggested and compiled methodical process of creating animation of battle in both GIS programs.

4.1 Data

Archives and military books were used for getting information about battle. Basemaps of this battle were found in old atlas from 19th century which was archived in Map Collection of Charles University in Prague. There were three maps in scale about 1:30 000 with German text and drawings of units composition and their movement. These maps were lent by Map Collection in digital format on CD-ROM.

After gathering all sources and its study, next part of work was focused on completing all information from these sources into one complex to know which units did which movement or action.

4.2 Methodical process

Next part focused on setting up methodical process of how to make digital animation of battle from these data. This process consists of three parts – creation of topographical background, creation of animation of battle and its final completion.

Topographical background was created from one of the old basemaps. At first, it was necessary to transform this basemap to S-JTSK_Krovak_East_North cartographic projection by affine transformation. There were some problems like the fact that the basemap had no projection and there was a quite big geometric distortion in some parts of map, but these problems were eliminated by standard processing procedure [6]. When transformation was done, work continued with vectorization of specific topographic categories like rivers, roads, buildings, forests etc. In next step, it was important to join elevation info. But basemaps had elevation expressed by hachures which was hard to convert into digital map. Instead of this, modern contours from ZABAGED dataset were used to create hypsometric tints – this could be done because present terrain is almost the same as in 18th century.

After finishing creation of topographical background, work continued by creation of animation of battle in both GIS applications. There were some differences in progress and methods, but let's talk about common things at first.

At the beginning, map symbol legend was designed. There was one specific legend for topographical objects and one for military objects. Same type and size of symbols was used for units of both armies but they were distinguished by its colour – Austrians had red colour and Prussians had blue colour. There were some little differences in symbology between ArcMap and QGIS, but it was only cosmetic detail.

One of the biggest complications was fact that it was not possible to exactly determined time or duration of all movements. All three basemaps gave basic information about positioning of each unit at the beginning and at the end of specific time period (e.g. during one hour). But it was impossible to say how fast did each unit move or when it came to its position. This problem comes with every battle except fights from recent time (e.g. Gulf War). At this moment, there is no clear and simple solution of this – in this work, there was used one of possibilities that gave units specific movement speed depending on their type and size. For example, infantry unit moved slower than cavalry units and smaller units moved faster than large units. One of main factors for using this option was the fact that this battle didn't take longer than few hours, so specific time of moves could be easily calculated or estimated. Applying these settings gave animation realistic feeling of movements and helped to ensure animation's continuity.

Starting placement of all units was get from visualisation in the first basemap. After that it could be started with animating of all movements. There were used three basic types of animations – movement, change of visibility and change of symbology.

Motion animation was applied on situations when unit changed its position. That means movement from point A to point B during some time period. This type of animation was one of the most used in both animations of battle.

Change of visibility was used in situations when was necessary to show or hide objects for some time. It was used for visualisation of destroying unit or for combat symbols.

Change of symbology was applied on objects that changed their shape during battle. For example, if large unit divided into two smaller units, its visualisation changed according to map legend.

The final phase of creation consisted of adding compositional elements by cartographic rules. It was the graphical and numerical scale, north arrow, legend and title with battle name and date. Last move was the export of both animations to specified format.

5 Animation in QGIS

Work with cartographic animations in QGIS has some specific needs and rules. These rules will be described on one movement animation and are applicable on all types of animations.

At the beginning, there is necessary to have correct input data. Chosen unit had set up its movement line by key points which were defined by one object for one point. That procedure resulted into one layer which has few objects with specific ID in attribute table. Time information is joined by adding column named "timestamp" which

is next fill with time data for each symbol. Important thing is to keep same time format that is showed on the *Time Manager* time bar.

Next move is loading this prepared layer into *Time Manager*. Basic dialog module is opening by pressing *Settings* button and allows uploading layers and setting up animation parameters. These parameters include duration of one frame, time visualisation and repeating of animation. After layer upload, there is option to choose Start Time (column timestamp), End Time (default) and Offset (default).

One of the most important functions is *Interpolation*. This function allows interpolating points between each two key points which consequence into continuous animation. Rate of continuous is defined by used time units which should be one level below units in attribute table – for example, if minutes are used in table, then the interpolation units should be seconds. There are two types of *Interpolation* but it has no influence on result. Anyway, most often is used *Linear Interpolation*.

After confirmation of these settings, new layers with interpolated points are created. These layers have default symbology, so it is necessary to join symbology from map legend. Then they can be check by pressing *Play* button which will play all created animations in one moment. Export is available through function *Export animation* and it saves animation to format of individually PNG frames in specific frame rate.

This basic process can be used on every type of animations. Similar rules were applied on change of symbology and change of visibility. Creation of all animations by this procedure resulted into final animation of battle at Chotusice which can be found on this link: <https://youtu.be/PuZPdUyM5e0>

6 Animation of battle in ArcMap

As in QGIS, also ArcMap has some specific needs and rules, too, and these rules will be again described on movement animation.

ArcMap requires input data with specific parameters. Movement line for chosen unit was set up by inserting key points which were defined by one object for one point. This procedure created layer which has few objects with specific ID in attribute table. Time information is joined into two columns – one for start time and one for end time. This fits to principle of animations in ArcMap which was explained in previous chapters – start time gives information about displaying the object and end time gives information about hiding the object. Both of time information must be in specific format which is shown in bookmark *Properties* of selected layer.

Next step after entering all time values is passing time in selected layer. This is done by bookmark *Time* in layer properties. There can be set up what columns contain start and end time, format of time data and frame of animation which can be also automatic set up. There can be also selected accumulation of passed data but that wasn't suitable choice in this example.

After finishing all settings, there is necessary to allow time data in top of the bookmark. This move activates function *Time Slider* which allows controlling and playing animations in map field. *Time Slider* also provides some other options for customizing final visualisation of all animated objects. Animation export is available through this function and can be saved into AVI video format or into individual frames in JPEG and BMP format.

This is basic process that can be used on every type of animations. Similar procedure was applied on change of symbology and change of visibility. Completion of all animations created by this procedure gave final animation of battle at Chotusice which can be found on this link: <https://youtu.be/h1xBkyNouxk>.

7 Comparing of animations

After finishing both animations of battle, there could be approached to their comparison and to judgment which of Temporal GIS is better for this work. There is comparison of visual form, working environment and procedures in both programs. The fact that QGIS is freeware and ArcMap commercial is not important at this comparison.

Let's start with comparison of work environment. ArcMap and QGIS have a user-friendly environment which is similar in many aspects. Generally it can be said that ArcMap is more complex and provide more working tools than QGIS. On the other side, QGIS supports additional plugins and modules that allow individual customization and adding extra tools. Its indisputable advantage is also Czech localization. So the working environment in both programs is equal and user can choose software by his personal preferences.

Working with vector graphic was definitely better in ArcMap than in QGIS. ArcMap offers wider range of vector and raster tools. QGIS could use a lot of modules but many of them didn't work right and there were some problems with them. So ArcMap has a point in this category.

But better tools don't mean that ArcMap was also better in creation of animations. Basic principles and methodology in both applications are basically the same - each layer has objects with time data in table. The main difference is in way how software process and understand animations – QGIS does interpolation between key points, ArcMap does changes of visibility of key points.

By this basic principle, QGIS is ideal for creating motion animation. It allows creating more complex motion animations which have also secured an appropriate fluidity and continuity. However, it's not good choice for animation of visibility or symbology changes because there are created duplicate points with different times.

Biggest advantage of ArcMap is possibility of determining length of objects visibility and no need of duplicating points. On the other side, using it to create motion animations is really bad idea because its basic animation principle doesn't allow creating nice and smooth animations. Also making this type of animation is in fact very difficult and there will be never such continuity of movement like in QGIS. And animation of battle is mostly made from motion animation, so there is clear that QGIS is winner of this category.

Playing animation is fine in both programs, but exporting animations is quite big problem. QGIS allows only export into picture format and when you want to play it outside the software, there is necessary to use additional software to get it into video format. ArcMap offers option to export into video file, but it didn't work during this research. So it had to be played and recorded by external application. So this category is a draw.

Last category is impression and appearance of both animations of battle. Animation from QGIS is aesthetically better, movements are smooth and only problems are with representation of fighting and explosions. Animation created in ArcMap is much worse and the feeling from it isn't good. Movement is choppy and confusing. On the other side, visualisation of fighting and explosions is better than in QGIS. But final appearance is still better in QGIS.

So, the final verdict is that QGIS is better choice for creating animations of battle. Due to its basic animation principle, it gives good-looking animations and even it has some little problems, it is still better than commercial ArcMap.

8 Final conclusion

The main goal of this paper was to analyse and compare possibilities of creating cartographic animations in selected GIS software and suggest methodological procedure of creating animation of the battle from old basemaps. Secondary goal was to introduce the issue of representation time in maps and perform a detailed analysis of cartographic animations and methods of its creation.

At the end of this work, it can be said that both of these goals were fulfilled. Analysis of theoretical background gave enough information to create functional methodical procedure of creating animations which was tested in both GIS applications.

From final animations of battle at Chotusice is evident that GIS is great tool for creating cartographic animations. It was found out that for animation of battle, QGIS gives more options and better results. But there are still some questions and problems that will be necessary to resolve to fully utilize this GIS potential in future work.

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Measurements of The Church in Wigry Using GPR Measurement Technique

Paulina Dąbrowska¹

¹Institute, Faculty, University in Warmia and Mazury, Michała Oczapowskiego 2
10-719, Olsztyn, Poland
Contact pinkad@vp.pl

Abstract

Thesis entitled „Measurements of the church in Wigry using GPR measurement techniques” was based on the design and execution of GPR profiles in the church in Wigry. Research was made during a scientific camp, organized by students from Scientific Society of Satellite Geodesy and Navigation "GeoSiN" University of Warmia and Mazury in Olsztyn. The aim was to check whether under the floor of the temple is the crypt. The work describes results that have been obtained from GPR. To perform the measurement, GPR Mala ProEx System with 500MHz frequency antenna were used. Field measurements included the execution of 54 profiles in the church Niepokalanego Poczęcia NMP in Wigry. The basic research was made in the nave of the church, in the catacombs and in the chapter. During the project Reflexw program was also used to process the data. The important thing for the analysis was to obtain information from the literature. The results are presented graphically in the form of drawings. Therefore GPR traces were analyzed in detail, and the conclusions drawn. The use of GPR was a very useful tool, because the results of measurement is very surprising and impressive. Although during the process of GPR measurements we can see the preliminary visualization of results, it is necessary to process the data. For this purpose it is necessary to use professional software: e.g. Reflexw application. The main advantage of the GPR technique is that during the measurement it does not cause any damage. Therefore, the research can be performed inside a building, bridges, and roads.

Keywords: Reflexw, GPR, church in Wigry

1 Introduction

The first Ground Penetrating Radar was created in the early seventies. In the time, this equipment is very popular and a lot of people will interest to use GPR. Technique has improved and therefore it has used to variety of technology. This is due to the rapid pace of technological development of computers and software. The information technology has allowed to improve a quality and interpretation of the results, that they obtained from device [6]. Ground Penetrating Radar is many applications in various fields such as construction, geology, archeology, surveying and geodesy. It is use to scientific research or detect things hidden under the surface of the earth, that is not visible to the human eye.

GPR can deliver precise information about buried objects. This is device, that can be operated in boreholes [2]. The advantage of measuring the GPR is a fast obtain measurement results. You can identify on the fast way what is something under the ground. Operation GPR is very complicated. A radar system has transmissioned and receptioned of signals. The transmitter is suitable electromagnetic waves that are reflected from the object. Then they are transmitted by the receiver. As a result, it is registered the time difference between the moments of transmitting and receiving a signals. It defines the location of the facility [5]. The measurement result is obtained radargram, that shows to measured values of the amplitudes. They received wave at the time. At the beginning, it is processing. This procedure make to locate a specific object and determine subsurface structures [4].

2 THEORETICAL ASPECTS OF GPR

Attenuation of electromagnetic waves in the geological environment is a key effect on the range of depth GPR method. The conductivity of geological medium has effect on the parameters of the attenuation coefficient [3]. The most important physical element is a propagation delay, which depends on the source of emitted signal and time. The delay time is described as the difference between the time of transmission and receive a signal. Wave velocity is an important parameter, which is located at the resort. The speed of movement plane in the direction of wave propagation is defined as phase velocity [1]:

$$v = \frac{\omega}{\beta}$$

Where:

ω – pulsation,

β – factor phase.

Formula for the speed of electromagnetic wave in a lossless medium:

$$v = \frac{c}{\sqrt{\varepsilon_r}} \quad [m \cdot s^{-1}]$$

where:

c – speed of light,

ε_r – relative dielectric constant.

3 GPR technology

Ground Penetrating Radar consists of control unit, and antennas, where the waves in the form of pulses are generated with a specific frequency. Scheme of construction is showed on the Fig 1:



Fig. 1. Construction elements GPR

Many GPR is based on the pulse system. The pulse energy is greater, then the penetration range is greater. The duration of one pulse is about 0.5 - 10 nanoseconds.

The control unit is connected to two antennas: receiver and transmitter by means of fibre glass. The central unit is responsible for recording the data and the sampling frequency. When we receipt of the signal control, the transmitter produces an electrical pulse, which is delivered to transmitting antenna. When is produced power, antenna emits waves to the medium. The wave brakas on the border medium, then he returns to the receiver. The received signal is exchanged to digital form. In this way, sample value is transmitted to the central unit. For the correct the operation of GPR is needed to connect the central unit to the laptop. This hardware should have software for data acquisition. This is way, you can set proper measurement parametrs and see results.

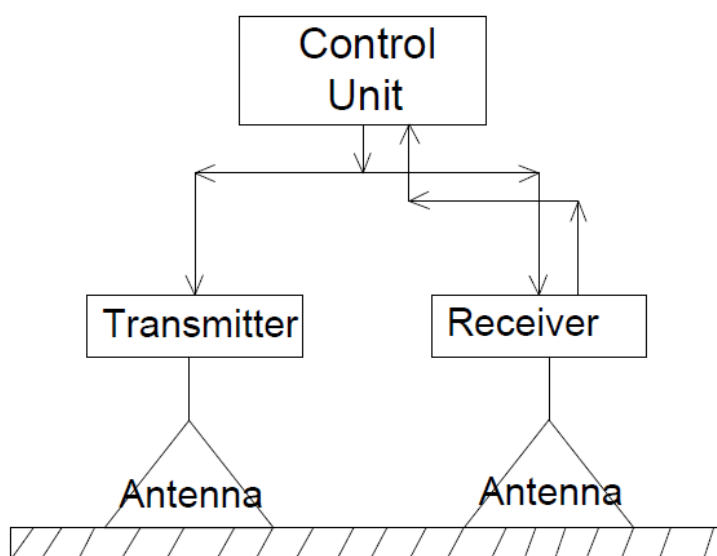


Fig. 2. Diagram of equipment GPR

4 Case study

Measurements made on 27 September 2016 during a scientific camp for students from Scientific Society of Satellite Geodesy and Navigation "GeoSiN" University of Warmia and Mazury in Olsztyn. We used GPR Mala ProEx System antenna on the frequency of 500MHz and a maximum range of 5m. The aim of the research was to test the usefulness of GPR method in inventory of crypts and verify the hypothesis of the existence of the catacombs under the floor the church. The measurements carried out in a graticule of parallel lines, with an interval of at a distance of 5 cm. Inside the church made 54 profiles. Most of them are designed in the nave of the church. Other profiles were in the chapter and the discovered, available crypt.

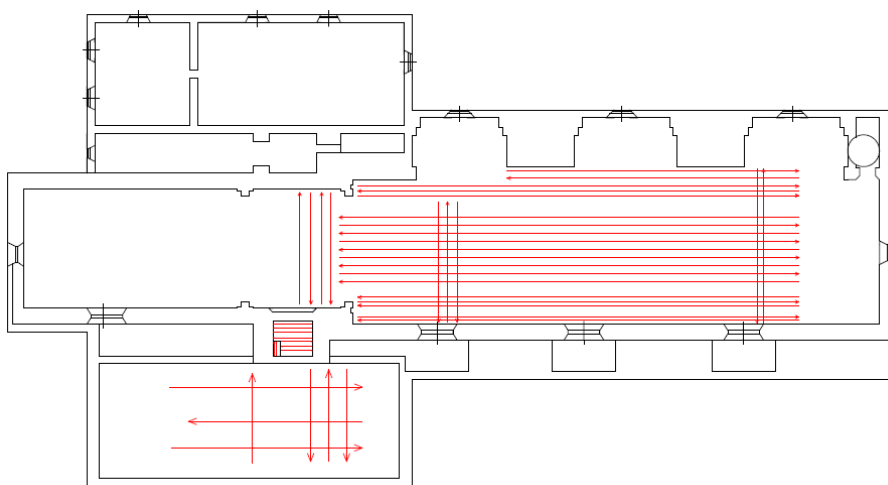


Fig. 3. Sketch designed and constructed profiles inside the church

5 Results

The Analysis of profile was performed by Reflexw program, company Sandmeier. It is a powerful program that is used for data processing. The software modifies the recorded data, which were made using GPR. It is also used for processing and visualization of three-dimensional seismic and GPR.

5.1.1 The first radargram was recorded along the main nave of the church.

5.1.2 The picture 4 was showed this radargram. You can see that at distance of 3.5-5.5 meters, there are strong anomalies. They have about 1 meters depth. Next to you can see interesting structures profile. At 6 meters wide, you can see visible anomalies which pass freely through the given part profile. It looks like the floor was the only air. It shows that in this place is probably the hatch. In a place where there are strong reflections on the length of about 3.5 meters, there is probably going down to the room where maybe the crypt. This statement is not accidental, because of the many sources shows that the catacombs are located under the whole church. The most of catacombs was buried during War II.

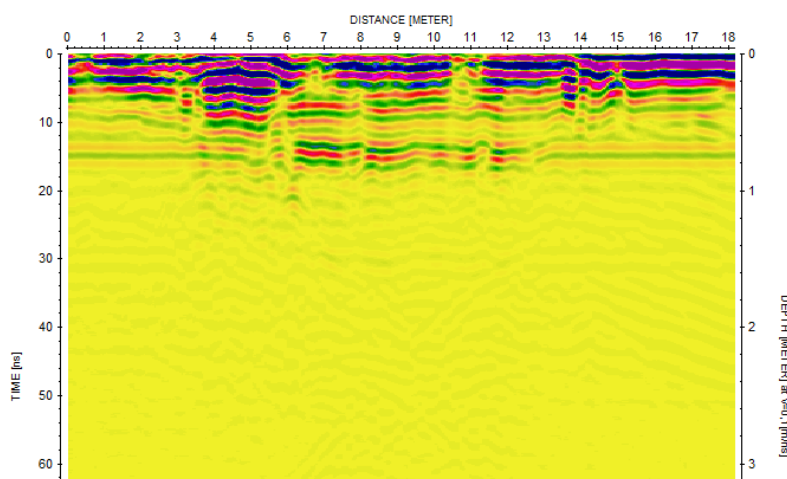


Fig. 4. The longitudinal profile performed in the main nave of the church

The following is the cross profile (Fig 5). It intersects with the previous profile. It was made by the middle of the church. On the picture is present very clearly parabola. Its top is at a depth of 1 meter, and the ends reach 2 meters. It can therefore confirm the hypothesis that in this place is probably the basement. It is room, where the dead were buried. This room has a semi-circular vault, as discovered crypt. For the reason, the radargram shows parabola.

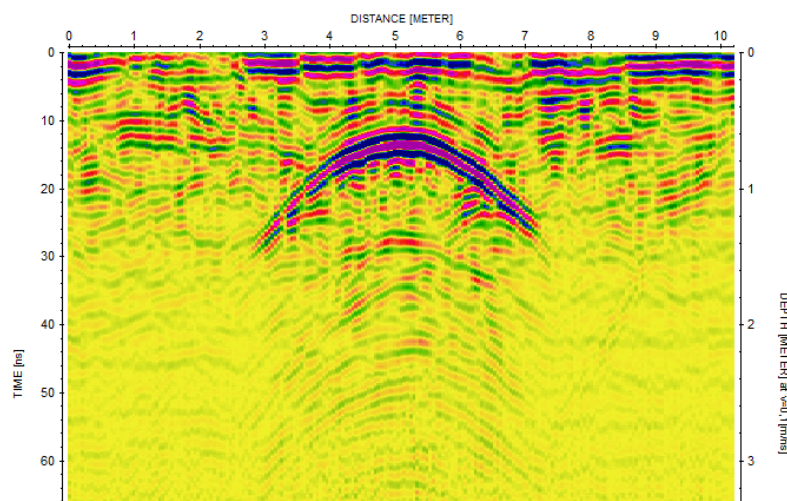


Fig. 5. Cross profile performed in the nave of the church

Figure 6 shows the longitudinal profile, which was made on the left side of the church, between the benches, and three small chapels. Parabola is visible at a width of about 3.5 meters. You may have noticed a dependence between radargram, which was presented on Fig 4. There is appeared strong reflections a similar place. All profiles taken along the aisle showed a similar relationship. In each profile was visible parabola or strong visible reflections. It can therefore be concluded that in this place for a width of about 2 meters there is a tunnel. Perhaps it is overwhelmed in part.

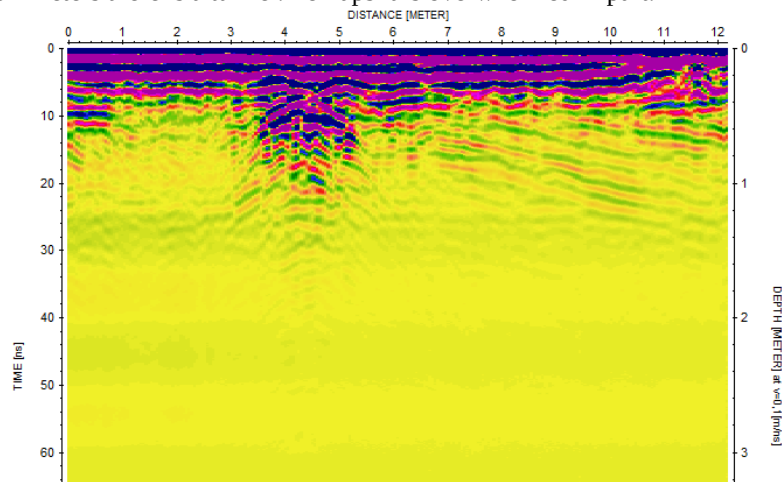


Fig. 6. The longitudinal profile performed in the main nave of the church

Before the chancel are the stairs. They lead to an underground vault, where they buried the dead monks. It was made vertically along the wall (Fig. 7), Starting from the bottom.



Fig. 7. Wall, who find in the present and available crypt

In Figure 8 shows measuring the wall, which has been shown above. You can see 3 positions at radargram, which can observe reflections. At a height of 20 cm, 1 meter and 1.8 meters. The monks were buried in these places. They were not buried in coffins. Their bodies were put on board, and his head was based on brick. This reflections are quite intense. Evidence of a burial, It is that you can see place on the wall, where they were buried.

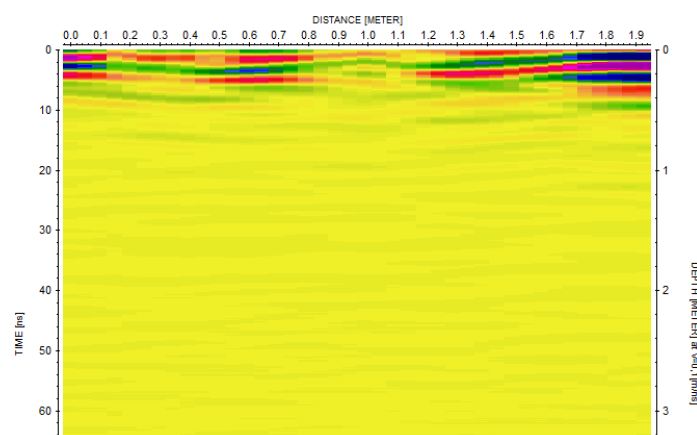


Fig. 8. The longitudinal profile performed in the main nave of the church

6 Conclusion

The following figure 9 was presented to the system, which is resulting from the analysis of the profiles. The red color shows wall, and likely layout of the premises, which are located under the church. The wall, which is exposed in the crypt located the place where the dead were buried. They were buried on board, which was about 40 centimeters in width.

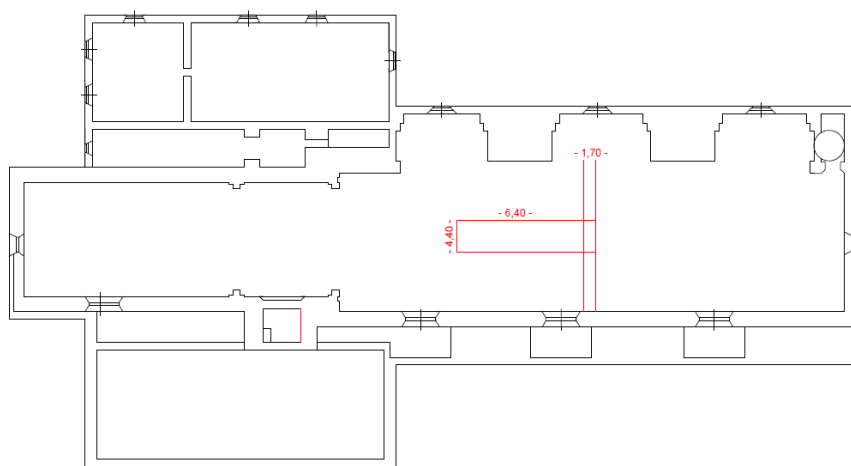


Fig. 9. The sketch result from analyzes profiles

6.1.1 In the middle of the church, the nave was shown a tunnel. It extends from one chapel to the other. It has a width of about 1.7 meters. It is connected to the entrance to the room where you are probably buried monk.

The entrance to the basement probably reaches a width of 1.7 meters and is located at a depth of 0.80 meter. The room has a width of 4.4 metres and 6.40 meters in length. This probably is at a depth of 1 meter.

Unfortunately, in the basement of the church and the chapter on radargram did not find. There is not a parabola and strong reflections, which suggest to the existence of vaults or tunnel. In summary, we can conclude that the results obtained from GPR measurements are very useful to locate the object. In addition to determine the distance profile, you can also define the dimensions and the depth. In the article were necessary photos and history of the church, which could confirm hypothesis. Clays and silts in the substrate cause the dispersion of the signal during the measurement. This is a big problem when we can interpret the data. The article present to measurement floor

of the church, which was covered concrete. It was a plus, since radargram was not burdened with additional error. The professional software is necessary to process GPR profiles. Radargram will be cleared of noise to use of appropriate procedures.

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The Impact Assessment of Changes in Spatial Development on Water Resources

Jakub Chruściński¹

¹ Department of Spatial Economy, The Faculty of Environmental Engineering and Geodesy, Wrocław University of Environmental and Life Sciences, C.K. Norwida 25,
50-375, Wrocław, Poland
Contact kuba.chruscinski@gmail.com

Abstract. Changing climate directly or indirectly relate to every aspect of human life. One of the climate change impacts recorded in recent decades is a significant increase of the number weather extremes. Natural disasters, as a direct consequence of such weather events, were responsible for losses amounting at 50 billion zlotys for the last decade in Poland. The analysis of the consequences and frequency of such events in Poland suggests floods causing the biggest material and social damages [5]. Therefore, it is necessary to recognise processes that increase probability and scope of floods. In this work, the attempt to assess the impact of the human pressure on water resources in the each municipalities has been taken. The changes in the spatial development and in the value of effective precipitation in the period 2006-2012 has been considered. The effective precipitation has been calculated with the use of the Soil Conservation Service model. The analyses have been carried out in a GIS environment. The results of the research are presented in the form of the risk map indicating areas in the municipalities being at risk of flash floods.

Keywords: flash flood, GIS, SCS, risk analysis

1 Introduction - climate change

One of the noticeable aspects of climate change considered in the actions of many countries is implementation of strategic adaptation plans within a defined timeframe. Taking into account the fact that in the subsequent stage the strategic documents are accompanied by national instruments for execution of the policies, programs connected with adaptation of each area of human life to climate change can be expected in the next years. This direction is undoubtedly connected with the growing number of extreme weather phenomena forecast in the nearest future and risks resulting from this fact [2]. Social and environmental damage caused by natural disasters so far can be estimated in the billions of zlotys, this shows the scale of the current problem requiring immediate intervention [5]. Therefore, the attempt undertaken in this study to determine and evaluate risks for areas endangered by the occurrence of local flash floods seems justified.

2 Methodology

The aim of this study was to develop a map of risks facing areas exposed to local flash floods. For this purpose, the analyses of land development changes and calculations of changes in the values of effective rainfalls during the analysed period of 2006-2012 based on the Soil Conservation Service model were used. The ArcGIS software package with dedicated extensions constituted the main environment for the author's work and was used to conduct most of the analyses according to the following scheme.

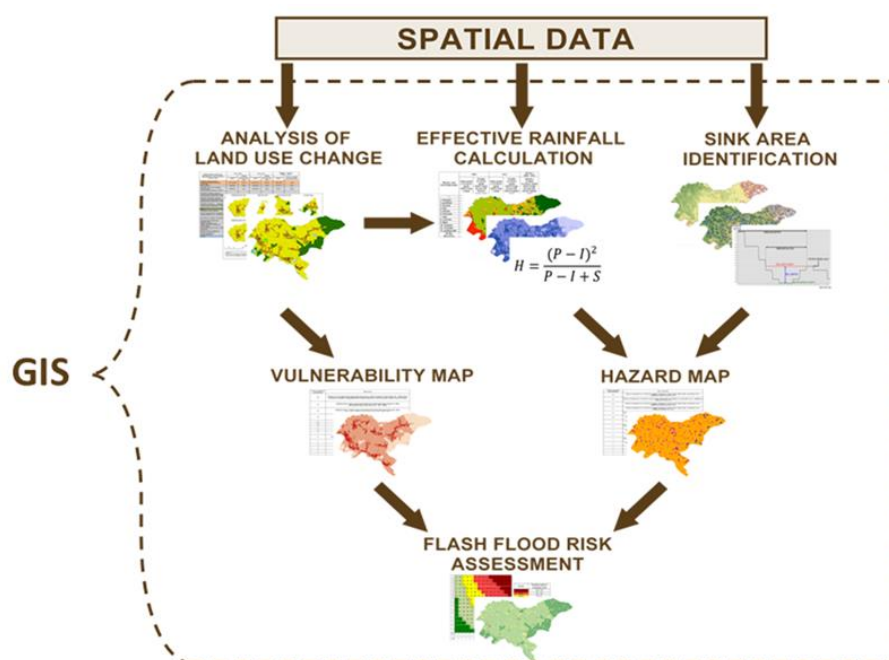


Fig. 1. Scheme of research.

2.1 Analysis of changes in land use and land cover

In order to evaluate the effect of land development on water conditions, it was necessary to define a reference point and trends appearing in the space. For this purpose, a comparative analysis of changes in land development for the area covered by the study was performed. Spatial data presenting the cover and use of the area as well as limits of territorial units were used for this. The Urban Atlas land cover and use maps examined in the research are created in a systematic and repeatable way thanks to which it is possible to compare the use and cover of the land in various towns of the European Union. In addition, since the maps are made for two time perspectives – 2006 and 2012, it is possible to analyse changes in land development over time. Currently, in the literature regarding this topic there are not any publications using the SCS methods and covering the process of determining the CN parameter in a systematic approach based on the Urban Atlas land use and cover maps. Therefore, the author of this study, using the characteristics of individual land cover and uses classes included in technical instructions - the Mapping Guide for a European Urban Atlas [3] and Urban Hydrology for Small Watersheds [7], assigned the categories of Urban Atlas land use and cover to the land use and cover categories specified in the SCS method. While doing this, he tried to make sure that the land use and cover classes and their infiltration capacities were as much as possible compliant with the actual condition.

2.2 Calculation of effective rainfall

For calculation of effective rainfall, the Soil Conservation Service (SCS) model described in technical magazine number 55 entitled Urban Hydrology for Small Watersheds developed by the Natural Resource Protection Services – Department of Agriculture of the United States of America was used. This model uses the value of rainfall losses taken into account as the Runoff Curve Number (CN) parameter determined based on soil infiltration capacities, humidity conditions and the type of cover and use of the land within the analysed catchment basin – in this case the area covered by the study. For the purpose of the study, Antecedent Moisture Conditions, AMC II [7] were assumed in all calculations. The model can be expressed by the following formula:

$$H = \frac{(P - I)^2}{(P - I + S)} \quad (1)$$

where: H – runoff [mm]; P – rainfall [mm]; I – initial abstraction [mm]; S – potential maximum retention [mm]

The amount of the maximum potential retention can be expressed by the following formula:

$$S = 25,4 \times \left(\frac{1000}{CN} - 10 \right) \quad (2)$$

where: S – potential maximum retention [mm]; CN – Runoff Curve Number in the range of 0 to 100;

The initial abstraction value is variable, but generally correlated with the parameters of the soil and its way of use. The equation can be expressed by the following formula:

$$I = \mu \times S \quad (3)$$

where: I – initial abstraction [mm]; μ – coefficient depending on the CN parameter; S – potential maximum retention [mm]

Way of categorize the coefficient μ depending to the range of the curve number used in the calculation is presented in the table below.

Table 1. Value of the coefficient μ depending on the CN parameter [6].

CN	μ
$CN < 70$	0.075
$70 \leq CN < 80$	0.100
$80 \leq CN < 90$	0.150
$90 \leq CN$	0.200

The Runoff Curve Number parameter - CN depends on the type of use and permeability of soils existing in the catchment basin. In order to determine the filtration capacities of soil, the classification method developed by Ignar was used which adapts the SCS method to Polish conditions [4]. Based on soil names defined by the Polish Pedological Association and information in literature concerning mechanical composition and infiltration capacities of soils, Ignar distinguished four groups of soils identified using letters: "A", "B", "C" and "D" [1].

2.3 Delineation of areas without outflow

In the subsequent stage of work, it was necessary to define locations of depressions without outflow on the modified height map. The Arc Hydro tool package was used for this. Apart from surfaces of bottoms in zones without outflow, the following information was also obtained:

- bottom elevation – height expressed in meters above sea level of the bottom in the deepest point of the reservoir
- fill elevation – height in meters above sea level for the point at which water overflows over the crest of the reservoir walls
- fill depth – height from water surface to the deepest point of the reservoir
- fill volume – volume of water stored in the reservoir required for maximum filling of the reservoir expressed in cubic meters

In this way, we receive the real scope of flooding zones without outflow, filled with water to the maximum up to the level in which water overflows over the crest of the walls of the reservoir without outflow.

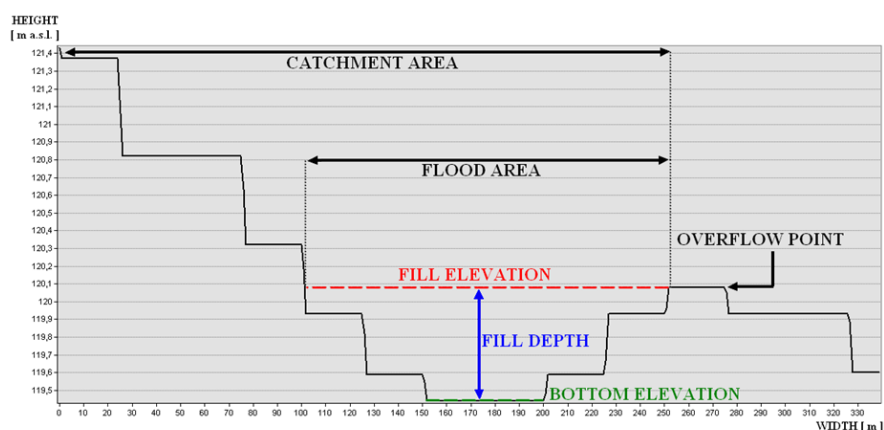


Fig. 2. An example graph of profile.

2.4 Analysis of the flash flood risk

It was assumed that the element determining the degree of rainfall flash flood hazard is the resultant of the effective rainfall and areas without outflow. Both these factors in a positively correlated way may have an effect both on the degree of hazard and on the vulnerability. However, for the purpose of this study, the author decided to use these factors for hazard identification. In order to estimate the occurrence of flood hazard, a fifteen-degree scale was developed where the maximum value should be interpreted as the highest hazard, and the minimum as the lowest hazard.

Table 2. The scale of flash flood hazard with description of favorable conditions.

Level of flood hazard	Description of favorable environmental conditions
15	Areas without outflow where the value of effective rainfall has increased and the maximum fill depth is above 1.5 m
14	Areas without outflow where the value of effective rainfall has not changed and the maximum fill depth is above 1.5 m
13	Areas without outflow where the value of effective rainfall has decreased and the maximum fill depth is above 1.5 m
12	Areas without outflow where the value of effective rainfall has increased and the maximum fill depth is 1.5 m
11	Areas without outflow where the value of effective rainfall has not changed and the maximum fill depth is 1.5 m
10	Areas without outflow where the value of effective rainfall has decreased and the maximum fill depth is 1.5 m
9	Areas without outflow where the value of effective rainfall has increased and the maximum fill depth is 40 cm
8	Areas without outflow where the value of effective rainfall has not changed and the maximum fill depth is 40 cm

7	Areas without outflow where the value of effective rainfall has decreased and the maximum fill depth is 40 cm
6	Areas without outflow where the value of effective rainfall has increased and the maximum fill depth is 10 cm
5	Areas without outflow where the value of effective rainfall has not changed and the maximum fill depth is 10 cm
4	Areas without outflow where the value of effective rainfall has decreased and the maximum fill depth is 10 cm
3	Areas where the value of effective rainfall has increased
2	Areas where the value of effective rainfall has not changed
1	Areas where the value of effective rainfall has decreased

It was concluded that the elements decisive for vulnerability to impact are individual types of Urban Atlas land use and cover. Similarly, as in the case of flood hazard, a fifteen-degree scale was developed to estimate vulnerability. This scale was created based on the hierarchy of importance of human life, economic and environmental losses, where the maximum value of the scale should be interpreted as the biggest loss and the minimum as the lowest.

Table 3. The scale of flood vulnerability with description of land use and land cover class.

Level of flood vulnerability	Urban Atlas land use and land cover class
15	Continuous Urban Fabric (S.L. > 80%);
14	Industrial, commercial, public, military and private units
13	Discontinuous Dense Urban Fabric (S.L. : 50% - 80%)
12	Discontinuous Medium Density Urban Fabric (S.L. : 30% - 50%)
11	Discontinuous Low Density Urban Fabric (S.L. : 10% - 30%)
10	Isolated Structures
9	Construction Sites
8	Other roads and associated land
7	Railways and associated land
6	Sports and leisure facilities
5	Agricultural + Semi-natural areas + Wetlands
4	Mineral extraction and dump sites
3	Green urban areas
2	Land without current use
1	Forests

In order to analyse the risk of local flash floods, the matrix method based on the product of the hazard degree and vulnerability level was used. The risk acceptance limit was determined using the resultant of two factors. The first of these was the risk for people in the area covered by the study defined by potential frequency and number of people occupying individual classes of use. The assumption is that probably more people occupy in highly urbanized areas than in agricultural areas. Another factor taken into consideration for determination of the risk acceptance limit was an approximation error for maximum potential retention of the catchment basin defined by Banach [1]. Hence, it was concluded that areas with acceptable level of risk were areas with water level in the deepest place up to 10 cm and land use classes in which frequency of human functioning is relatively low.

Table 4. Range of risk level

Risk scale	Point ranges of risk
Very High	150 - 225
High	84 - 144
Medium	39 - 81
----- ← line of acceptable level of risk	
Low	10 - 36
Very Low	1 - 9

3 Results

When general changes in land development taking place in the area covered by the study in the timeframe of 2006-2012 are analysed, the growth of sealed artificial surfaces, made at the expense of broadly understood agricultural and semi-natural areas, is noticeable. However, regardless of the timeframe considered, incremental changes in effective rainfall can be noticed in the analysed period of 2006-2012. Please note also that for all individual months of the hydrological year, the growth of average effective rainfall value was also recorded. This growth should be associated with ongoing anthropogenic processes resulting in a growing share of sealed surfaces. Based on the characteristics of trends regarding changes in the effective rainfall value and changes of direction for land development taking place in the area covered by the study, mutual correlation between these two elements can be concluded. As a result of this, assumptions made in the land planning space may have a significant effect on water conditions in the given area in the future. The prepared flood hazard and flood vulnerability maps allowed preparation of a risk analysis map for areas endangered by local flash floods. On the basis of this, areas in which the risk value exceeded the risk acceptance line level were identified. For these areas, it is recommended to that restrictions concerning land development be implemented. Thanks to this, the process of further soil sealing in these areas in the future could be limited.

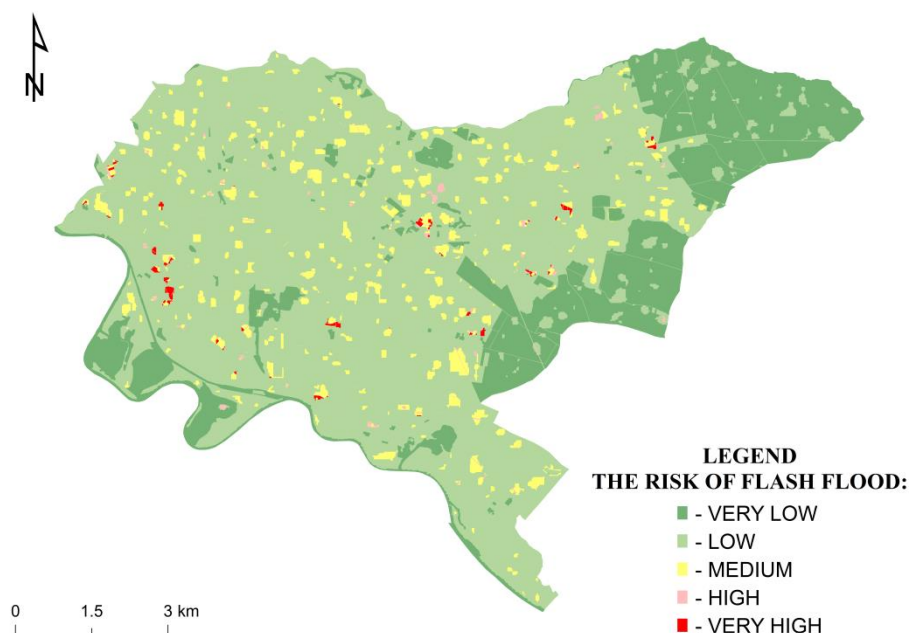


Fig. 3. The risk of flash flood map for the Czernica municipality.

4 Summary

The research conducted as a part of this study proves the possibility of using systems based on the GIS structure in environmental analyses of factors concerning the location of areas exposed to floods. The review of documents at the European and domestic level allows identification of the soil sealing issue as one of the leading environmental problems. This seems to be confirmed by the results of the author's research concerning changes in land development, which prove a considerable effect of soil sealing on the water resources of the area covered by the study. Please note, however, that the quantified descriptive features of the environment used by the author of the study constitute only some of the elements in the multi-aspect and complex issue of flash flood. Given their complexity, taking into consideration all environmental conditions would require a broad scope of knowledge and field measurement tests lasting many months. The uncertainty of the results is caused mainly by the quality of input data used in the analyses. The simple model presented in this study is supposed to enable its implementation during consultations with decision-making persons with respect to creation of development and risk management policies. This research may be also a contribution to the discussion regarding the methods of determining optimal location of built-up areas in the areas endangered with flood and legal possibilities of implementing them.

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Creation of geoinformatical system for mobile devices

Bc. Michal Jakl¹

¹Department of Applied Geoinformatics and Cartography

Charles University

Faculty of Science

Albertov 6, 128 43 Prague 2

Contact jaklmi@natur.cuni.cz



Abstract

The aim of this work is to design and create a complex community geoinformatical system for mobile devices with Android OS. The main core is to develop the client-server system, select and process data into databases and create algorithms, ensuring the entire system. Emphasis is also placed on an optimization for mobile devices, bilingualism and user friendliness. Security of the whole system is also an important question. Encoding of users private data and passwords, preparation for possible hacker attacks and many others security questions had to be answered.

The practical outcome and application of ideas is the creation of a mobile application DoPřírody!. The mobile application was created using Android Studio software. This software was selected as the most stable one and up-to-date. Mobile app is was created to be easy to use and usable even on older mobile devices or devices with slow mobile network connection speed. Application uses internal GPS module of a mobile device and communicates with server via mobile data network. It allows outdoor users to search the database of natural areas (park, forests, cemeteries and others) and is also able to navigate the user via the shortest route to the selected destination in real time. For registered users it is possible to rate, comment and edit existing areas and add some new ones.

The conclusion contains comparison with large map servers, the results of publishing the application on the Google Play website and conclusions of a testing in a community of users. Nowadays, the application is free for download for anyone with Android mobile phone (or people can use a web-browser version) and community system is still live and fresh.

Keywords: Android, network analysis, server, database, nature, mobile applications

1 Motivation

Big cities of the Czech Republic boast a significant proportion of green areas. Its beneficial effect on the quality of life of residents is indisputable [1] [18]. Even in the capital city of Prague, which was chosen as a model area for this application is possible to find some examples of near-natural habitats [9]. These areas in Prague offer essential habitat for many species of animals and plants, including several protected species [3]. Urban greenery is not just parks, but also historically valuable forests, trees, specially protected areas, natural parks and areas around watercourses. All of these areas create a unique character of the city and contribute to its attractiveness and exceptional atmosphere.

But how to find and select the nearest and the most appropriate area for your current needs? How to escape quickly from the busy streets? The answer to these questions was creation of a mobile application through which will city residents but even tourists from another country help with finding the opportunity to rest in secret greenery. On the internet it is possible to find several sites and map portals describing the urban greenery Prague, which are unfortunately not up-to-date. Application applicable in the field does not exist yet. So creation of the mobile application, built on the foundations of geospatial was directly offered.

2 Platform selection

The main reason for choosing Android OS as a target platform for mobile application was its spread between users and the availability of support and tools for programmers. The Android OS dominated the market with mobile devices in recent years, and currently holds over 80% of the market [14]. As a result the developer community focused on this platform and many useful tools were created, enabling easy and intuitive development of new applications with the support of countless tips and instructions on the developers forums.

Developing applications for the Android in Java programming language is a young and dynamic field in which new trends and practices arise very spontaneously and in rapid succession. The great virtue of the Android platform is the availability of a complete solution for device manufacturers and application developers. Free tutorials and effective tools for the development of new applications - Software Development Kit (SDK) - are affordable and still updated.

Not only forums, but also academic works produced at universities predominantly technical focus, such as the University of Brno [8], Palacky University in Olomouc [20] and University of Economics [12] became an useful source of inspiration and information about developing applications for this platform.

3 System architecture selection

Planned focus of the whole system required continuous communication between client application and a remote server. The corresponding architecture of the system was thus three-tier "client - server - database" model, where all data and calculations are performed by remote server (which is usually much more powerful than the client application), which, according to the inquiries of the client application, returns the user response [21]. The great advantage of this system is its centrality, and therefore easy updates performing. On the client application are placed only low demands, and thus system runs fluently even on elder devices. Web application and an Android application uses the same server core and user interface only adapts outputs graphically according to display capabilities and control options of specific devices.

The disadvantage of this model is necessity of hi-level security of the server part and database with the stored data. For the full functionality of the entire system is necessary availability of a stable internet connection between the client application and server. Server stability is also an important condition (as a major problem appeared relatively frequent blackouts of the database, caused by web-hosting-provider) - in case of connection failure is a client application (and therefore the entire system) unusable.

4 Database

A key element of the system are natural areas. To create a database of these areas is at first necessary to define the nature and the different types of areas with their properties clearly. In the scientific literature it is possible to find several definitions of nature [22] and natural areas. For the purposes of this system, it was regardless necessary to create a new definition. Since it is assumed community formation system, it is necessary that the definition is easily imaginable even for an average user. For this reason it was chosen following definition of natural areas:

"As the natural area is for the purpose of the DoPřírody! system meant public accessible area, that allows (or would be able to allow) the growth of 10 to 15 trees on an uninterrupted green surface. It is possible to hear the birds singing and feel (at least at some stage of the year), the smell of the plants there."

Verification in the field revealed that this definition also excludes some very extensive areas with scattered vegetation located between the asphalt and cobblestones, while it is suitable for some of the smaller, but valuable, parks and vegetation along the watercourses. Natural areas are subdivided into five subtypes (parks, forests, cemeteries, botanical gardens, others) that helps users in selection (it is possible to activate or deactivate these subtypes during the selection process).

Relational database MariaDB became the data storage of this system. MariaDB is a community developed branch of MySQL, which aims to maintain the free software license GNU GPL [23]. This database was chosen primarily for its compatibility with MySQL language and implementation on webzdarma.cz servers, where the system is hosted.

The structure of data stored in a relational database includes many tables [10]. The basic content consists of tables storing the data of natural areas and their entrances. The first of them contains data of natural areas with all information about them, but without positional designation of the areas. The second table on the contrary comprises only the position coordinates of specific entrances. Entrances and areas are across these two tables interconnected by IDs (primary keys) of areas. Networks data are divided into subnets and for each area are stored separately in a pair of tables for each subnet (tables of nodes and edges). These tables are linked using the ID of each node, where positional coordinates are stored. Each edge's record then contains only information about the initial and terminal node (for the needs of the algorithm could be start-node and end-node freely interchangeable). Division into subnets was chosen in order to reduce the amount of data with whom, when calculating the shortest route to the selected destination, navigation algorithm counts.

Other indispensable tables used by the various modules of the system are users-data-table, user opinions (and ratings) of each areas and table of users favorite areas. Non-public table used for monitoring users activity is a log table that with time-stamps records all users actions (insertion and editing of natural areas and entrances, registration of new users etc.).

5 Server

Another major component of the entire system is a server background. The server performs most calculations of the entire system, receives information from client applications and after communication with the database returns the results to individual users. To facilitate the creation and management of a server part were functional components divided into several modules, which are however strongly linked. Each module consists of one or more input, processing and output pages with algorithms, written in PHP language, and according to its needs accesses to tables stored in a database.

Output or input of some modules is a map. The aim was to use the same rendering services for the web-browser client and Android OS application. For that reason was chosen free and customizable Javascript library Leaflet, enriched by Maxim Petazzoni's plugin to work with GPX files [16], which finds great use in both client applications.

5.1 Navigation algorithm

The fundamental and the most complicated algorithm is an algorithm for finding the shortest path in the system of subnets stored in the database. It was possible to implement any of existing algorithms, but creation of a custom algorithm corresponding fully to the specific needs of the system, meant a challenge and an opportunity to try autor's own creative way to effectively solve the problems of navigation in the road network.

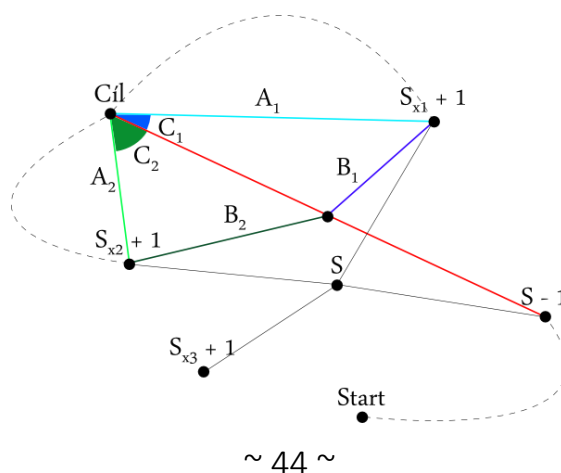


Fig. 1. One iteration step of navigation algorithm

The algorithm is run from a map created by an algorithm for finding areas after the user selects a destination to which the navigation is realised. In case of excessive distance from the road network (more than 500 meters) is navigation realized by calculation a beeline, accompanied by visualization of the route acquired over the OSM data tracing algorithm called Graphhopper. If the user is close enough to the road network stored in the system database, the algorithm will work in the following steps:

1. At the beginning the algorithm finds subnet's nodes nearest to the start and the finish. This algorithm "snaps" on specific nodes and can continue in searching. In order to next successful iterations, the algorithm could freely switch between different subnets during iterations, according to the name of the node or edge.
2. Movement in the subnets system works by iterations (Fig. 1.) until the algorithm reaches a node, which was initially identified as a calculation target (end-point). At the beginning of each loop, is the algorithm located at the station S. In the database, all edges which contains point S (either as the start or end point) are found. If the point S is included in less than three edges movement following the straight line will be processed. If a point is the nearest point to the user's position, algorithm will continue to a point which is closer to the target. In all the following cases the algorithm arrives from one direction (from point S-1) and will logically continue in its given direction (to the point S + 1), but not to return. Point S + 1 will become the new starting point S, its coordinates are recorded in GPX file, and if the node S + 1 is not a wanted destination node, there is another iteration.

If the node is involved with three or more edges, the algorithm is found at the crossroad and decision will be more complicated. If the node S is included e.g. at four edges, there are three additional directions of movement (S-1 node, from which the algorithm comes is omitted from the following calculation). The algorithm initially determines in how many edges the node Sx + 1 is included. However, if any of the Sx + 1 points is the end-point at the same time the algorithm jumps immediately to point 3.

In the case that the node Sx + 1 is included in only one edge, it is a blind edge. This node is omitted from the further calculations, and next from possible nodes is examined (in the example - a pair of S candidate points left).

It may happen that an algorithm has walked before through a node Sx + 1. In this case, this node is excluded from further calculations (this avoids infinite loop algorithm).

If the Sx + 1 node passes through previous criteria, its distance to the final position, distance to the center of connection between final-point and S-1 point and the angle formed by this line and a line connecting point Sx + 1 and the end-point, adjusted for preference of straight direction, is calculated. The sum of these three values determines the "final score" of each Sx + 1 node. The node with the lowest score (the one that is closest in the most direct way) is chosen as the new S-site and its coordinates are recorded in GPX file.

It may happen that the algorithm enters the direct path, which ends blindly after passing through several edges. It can also be the case that it is no longer possible to continue from the crossroad in any direction (mostly due to previous rules). Since it is not allowed to pass twice through the same node, the algorithm must take a step back. It returns to the last known junction (visited crossroads are recorded, this is the only exception where the algorithm is allowed to re-entry one node) and continue in another (yet untried) direction. If it is not possible to continue even from this "backup crossroad" because all the directions are already tried, the algorithm returns once again to the next in the list of visited crossroads. Thus, the algorithm is allowed to recede through several junctions before it finds a possible free path. Since the algorithm left wrong points in the generated GPX during the recede, quite confusing network had been created. Therefore it was necessary to delete unused points. So algorithm, after re-enters eg. the crossroads - node 2751 – delete all points recorded since the last visit of the node 2751. The final route is after the completion of the calculation smooth result of the successful steps of the algorithm.

3. After reaching the node that was selected as the final target, the user is redirected to the page with a map with visualized route. Using Leaflet plugin tools, the GPX plugin, the length of the route and the duration

(by an average walk) is shown. For the conversion the length to a time the assumption that the average walker moves at 4.5 km/h or 75 m / min was assumed. The time required for overcoming one meter of length was fixed at 0.8 second, i.e. 0.013 minute.

4. The collapse. This phenomenon is to certain conditions evoked intentionally and serves as a safety fuse. If the algorithm significantly "wanders" in the road network, ie. returned many times in a row, or calculation takes too long, the whole calculation process is terminated and an error message is shown to user. An error record of this fall is recorded into internal statistics.

6 Mobile client application

Mobile client application uses the same web pages and scripts as a client application for computer web-browsers. Due to diametrically different sizes of display surfaces (20" compared to 5") and different data connection speeds (often just a few tens of kb/s in GPRS / EDGE connections compared to hundreds MB/s), it was necessary to ensure the appropriate reformatting of pages if they are displayed on mobile devices. Therefore, the system includes a pair of CSS styles. One provides the appearance of a web application and the second is used for mobile application. Mobile application joins the requirement about the mobile-optimized result for each url query.

Communication with the remote server is realized using WebView feature that allows viewing web pages [2]. Using GET method to add values to the url or sending data via the POST method it is possible to create user-defined queries. WebView components are used in many activities and they are so integrated into the body of app activities so the user doesn't recognize which part is the generated website and which is the fixed part of the application layout.

Another important advantage of the mobile application is storing the user's login data. The user can take all advantages of registered members without having to re-fill the log-in form every time. When he logs in on another device, the system gives him an instant access to all his personalised data.

The advantage of the mobile client application for Android OS is an easy implementation of multilingualism. According to the language of device OS all labels are set either to Czech (for the Czech speaking users) or English (for all non-Czech languages). Likewise, information about the currently used language is sent with each query to the server, which according to this information, generates texts in appropriate language.

7 Community-based system

Thanks the module for adding new areas and user management module is allowed free growth of the entire system. Registered users can rate, comment each natural area and update the information connected with them. It is also possible to add new nature areas and entrances either from the comfort of user's home through a web application, or directly from the field using a mobile client application for mobile phones. Users can interact with the author of the project, report bugs and share their ideas for possible future improvements of the system.

However, with an opening the system for registered users and allowing an easy edition and modification of database objects is associated enormous risk of attack on the entire system in order to damage it. It was therefore necessary to create a robust multi-layered structure of data security. All user passwords are encrypted. All cases where the user enters data for communication with databases are protected against SQL-injection attack. Own security scripts were developed and integrated into the system. In the case of misbehavior is an user's IP address locked permanently without delay. Even the best security is not completely effective, and so the database is backedup periodically as well as all scripts of the system system.

8 Conclusion and comparsion

The fundamental features of the DoPřírody! system is the ability to find the shortest way to the selected destination. It is appropriate to compare the performance of own navigation algorithm with well-known mapping portals.

Since the internal data of algorithms and computational processes of services as Mapy.cz, Google Maps and are not free to explore, it was not possible to carry out a more detailed comparison. Therefore only comparison of calculated routes between several pairs of identical source and destination points for each service was done.

The performed comparison shows that computational algorithm provides results comparable with three large commercial project (Table 1). However, due to strictly governed effort to get in every step of calculation geographically as closely as possible, in some cases it means a few tens of meters more in final length of the route.

Table 1. Example of comparison method (from 50.073 N, 14.41 E to 50.077 N, 14.439 E)

Service	Route length (km)	Duration of walk (h)	Calculation (s)
Mapy.cz	2.4	0:42	1
Google mapy	2.4	0:33	2
Graphhopper	2.41	0:29	1
DoPřírody!	2.455	0:32	3

Compared to large projects with incomparably larger personnel, financial and hardware options DoPřírody!'s algorithm lags primarily in calculation speed. There is, however, possible in the future to increase the number by planned modifications. DoPřírody! system still can not guarantee 100% success of completing the route calculation (Fig. 2), but after the latest update crashes are already very rare phenomenon (success rate dropped to 92%). The vast majority of failed calculations is caused by incompleteness of the streets network. It can be stated that under ideal conditions, the algorithm is able to achieve accuracy of large projects.

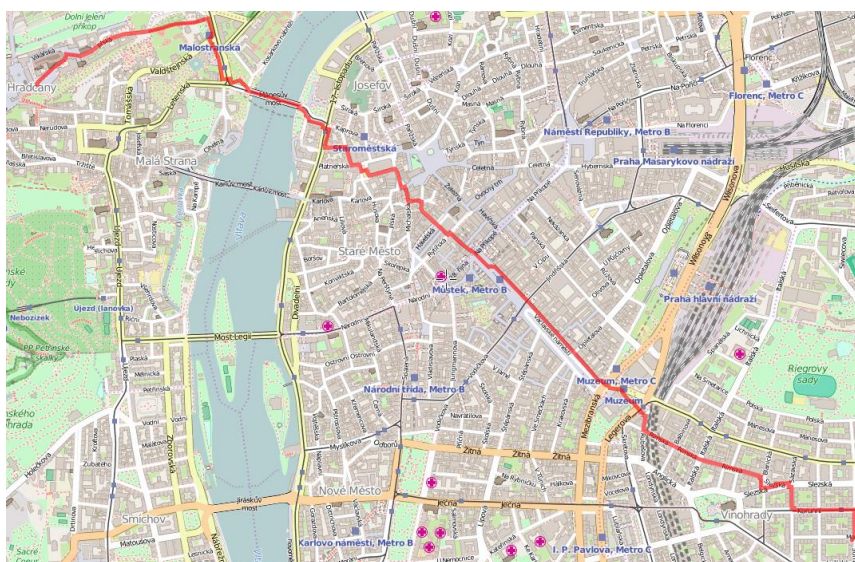


Fig. 2. Example of a route counted by navigation algorithm

At the beginning of a creation there were many unanswered questions and unclear points, but these in the course of progress of work disappeared. The more have been created, the easier and more enjoyable further work became. From a certain phase system became assistant in its own creation. Seemingly unnecessary "steps aside" during the entire work were often paid off. Some new modules and source code parts were involved by chance when nobody expected it.

Creation of the DoPřírody! system brought in exchange for hundreds of hours of work invaluable experiences with databases and programming for web and Android OS. According to the feedback of users, the system has potential for further development. This work became a springboard for the creation of many more (even commercial) mobile applications that are currently actively used by hundreds of users. It is possible to confirm the perspective of this dynamic field and stressed the need to reflect this trend in education.

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Sport activity data usage for urban planning

Andrea Kapounková

Department of Geoinformatics, Faculty of Science, Palacký University Olomouc, 17. Listopadu 50,
771 46, Olomouc, Czech Republic
andrea.kapounkova@gmail.com

Abstract

This bachelor thesis demonstrates the possibility of sport activity data usage for urban planning. The theoretical part presents, firstly, the most widely used mobile sport applications, secondly, the options of records and visualisations of routes, and lastly, the cities that utilised these data for its own development. The thesis includes a questionnaire, which was used in order to detect general information about (the sport application) users. Data were obtained from 21 users, overall 4181 record for the world. After the analysis, there were 720 records for the city of Olomouc and 1874 records around the city. Based on the obtained data, a case study for Olomouc city was created. This case study demonstrates that the data in question can indeed be utilised for urban planning. These studies were created:

- Identification the most common cycling paths and routes
- Identification the most widely used communications - searching for suitable sites for construction of new bike trails, bike paths or change existing paths and routes
- Identification of hazardous and non-compliant sites
- Statistical evaluation of data
- Analysis of users of sports applications

Thus, based on the data collected, workflows and recommendations were created, which show how the result of this thesis can be use in practice.

Keywords: bicycle path; biky trail; urban planning; sports applications

The aim of the work

The aim of the thesis is to present several case studies and possibilities of how to use records of sports activities for planning the development of towns and villages. Further develop a generic approach that helps cities and municipalities with the processing of data and with making a representative results usable for their own development.

Based on these studies, in the practical part are identified several key areas (eg. proposals for adjustments to the network of cycle paths, proposals to build a new paths, proposals to amend the city traffic, dangerous and inconvenient places etc.), which will be presented in the form of case and sample studies. As the main source of data are primarily collected data from active users and sample data (Meals Metro). Based on these outputs is create a general procedure and recommendations for municipalities. This procedure will be used primarily for visualization capabilities and subsequent data processing. Work procedure should help cities and municipalities take advantage of sporting records data as efficiently as possible, and through these data and results to improve the development of towns and villages.

Methods and procedures of processing

The first step for the creation of the thesis was to collect data from users using any sports application with routes recording. Data were collected mainly via social networks and via supervisor. Data were obtained using an Internet application Tapiriik.

Part of the data was a questionnaire to monitor general information about users and especially views on the state of cycling paths and routes Olomouc. First of all I had to find out, how many people will be willing to provide their data for purposes of the thesis. The aim was to collect the largest possible amount of data, but it has already been calculated in

advance with a small amount of data. Therefore, the collected data only served to demonstrate the use and creation of studies. So that the work could be considered accurate and representative, it would be necessary to collect data from thousands of users, which would have to precede big promotion, cooperation with the city, the university and other institutions.

Data were transfer to vector format shape file via model created in Model Builder, which kept their original names records. Model went through each record separately, transferred record into shape file format and each record has been transferred from point to line. After converting all data it was created geodatabase into which all data has been inserted.

Tracks were processed using tool Kernel Density and Line Density. These tools create so-called. "Heat maps", which are maps showing the intensity of the observed phenomenon. The settings of both instruments were frequently changed two performance- pixel size and radius, a distance at which the tool will calculate the density. After comparison of the results from both instruments revealed that best results corresponds tool Line Density with low radio and a small pixel size. For the result raster was used pixel size of 10 and was elected a radius of 150 m. The final results were created only for roads, which was in the settings entered as a mask. The results were to created maps that show the intensity of use of roads for Olomouc and the surrounding area by the two processing procedures. Further maps were created for visualization of cycle paths and bike trails and obtained records.

The main outcome of the work are case studies and possibilities, which were created on the base of created maps.

For the creation of appropriate outputs and demonstrations it was necessary to use bike paths and bike trails located within the city of Olomouc. This data was provided by Olomouc City Hall in format DWG (drawing format) and data about bike trails was downloaded from the website Open Street Map. Data from Hall and Open Street Map was current as of March 2016. The scale of the data has not been found, but corresponds to the approximate zoom 1: 10 000.

A statistical summary of the data, the total number of routes provided by users was 4181 records. Furthermore it was found:

- 720 trails for the city of Olomouc in the total length of 6511 km
- 1847 data to 30 kilometers from Olomouc in a total length of 43 884, 5 km
- 1614 outside the monitored area

The oldest dates are from the 25. 4. 2010 and the last from 31. 12. 2015, that day I ended with the data collection.

The survey has found that users who provide their data were mostly men, which were 16, women participated 5. All participants are of working age (22-40 years).

According to the survey is the most popular sport application Endomondo, which was mentioned by nineteen users. Next in line is the application Strava, which was mentioned 8 times. Among the results also appeared Runtastic and RunKeeper. Thirteen users are using also other sports equipment for recording sporting activities, most often a watch with chest belt.

Users frequently used applications per day, or 1 - 2 times a week and especially for recording sport activities. Less frequently for a record to any activity.

Each user has provided different amounts of data and the number of data in built-up area of Olomouc and surroundings also differ from user to user.

Theoretical part of the thesis

An example of the data usage from the sport activity is the city of Portland, Oregon. Transport Ministry agreed on cooperation and the use of data from the Strava. Data contained records from about 17,000 users, which has nearly 400,000 records from 2013. Data was used as an example for other ministries and transport agencies to work with such data, and for understanding the behavior of cyclists. The data can be used for planning and investment in cycling, construction of new trails and cycling safety. Oregon City in 2014 continued research data from the Strava and in the next year focused on the aforementioned studies [1].

Bike for Krakow (prepared according to [4])

Another example is the use of sports data for the project Bike for Krakow. The idea to create an application Bike for Krakow is an initiative of three inhabitants of Krakow - Luke Kowalski, Andrzej Milosz and Barbara Peek. The aim of these three cyclists and geographers was to create a database that contains data from the residents of Krakow.

The database contains records of cycling routes in Krakow and preferences and notes from cyclists. They were labeling trails as appropriate and inappropriate, and also those, which according to cyclists need some investment. The resulting project can be used for infrastructure development and it can be applied to any other city.

Data were collected from April to October 2014. The study involved 740 people. Those people marked 1300 routes on the map of Krakow, which they used the most. Furthermore, they marked 3000 paths as unsuitable, 1000 as suitable and 1200 as paths that need investment. The authors have created a website with a questionnaire. Via this website people also insert data into the database which was really quick and no time-consuming and that data was from a representative sample of the population.

Respondents marked routes on the map using points and lines. For these roads they joined attributes such as type of surface, then attribute as appropriate, inappropriate and need of investment and positive comments (flat surface, no hills, suitable for children).

When filling out the people had the opportunity to write even their own comments.

Obtaining information through a web application was divided into six parts. The first part included demographic data about the respondents. The second part contained a route for cyclists along with information about how often you go this way. The result of the study, a database containing 2,268 points, 4206 lines and 121 cycling areas. The aim of the study, however, was to get the best information on cycling infrastructure and their shortcomings. The research results were visualized into interactive maps (Fig. 1), which can be seen on the website <http://ankietarowerowa.pl/mapa.html#>.

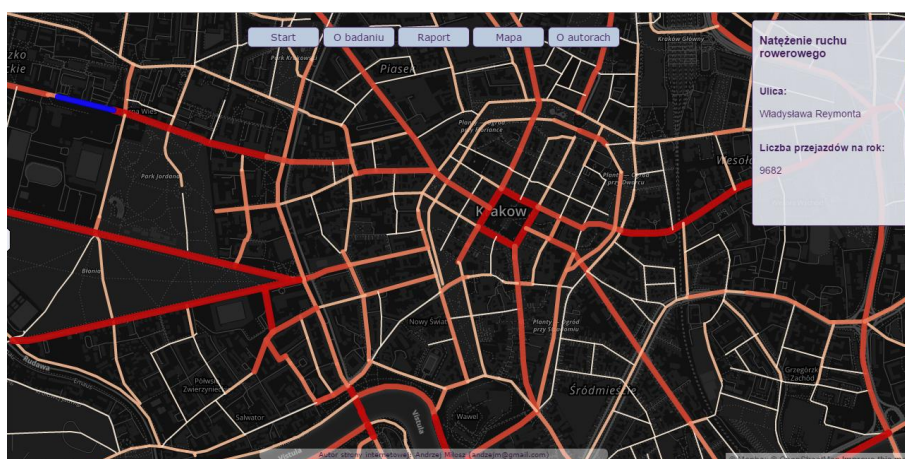


Fig. 1 Interactive cycling map Krakow (Source: <http://ankietarowerowa.pl/mapa.html#>).

Data processing

Before the start of data collection was important to determine from how many users it is needed to get the data. First, a survey was conducted, how many people are willing to provide data for the thesis. The total number of users was 21. This figure, and with it related to the number of routes, did not show representative results for the city of Olomouc. Therefore, it was decided that the main result of the work will be

demonstrations of case studies and general recommendations for working with sports data.

Part of my job was also a questionnaire to obtain additional information about users. The questionnaire was created in Survio and contained information about sex, education, applications, opinions about trails in Olomouc.

The questionnaire was answered by 30 users, of which only 21 users provided the data. Therefore, the 21 questionnaires were paired with data. For statistical summary of the data were used answers from all the responses from all the questionnaires.

Overall, the data gave 16 men and 5 women. Each user has provided different amounts of user data in total. It also differed in the amount of data provided for Olomouc and surroundings. The most important outcome of the questionnaire was the comments of users' satisfaction or dissatisfaction with bike paths and bike trails in Olomouc. These comments were also taken into account and it was made from them a case study.

Creating map outputs

For creating map layouts it was first necessary to visualize the data and see with what distance from the town of Olomouc I will work. This distance was determined partly-range data, but also a range of cycle paths provided in DWG format. The distance was then determined as 30 kilometers from the center point of the city.

Next step was the selection of routes throughout its length lies in completely built-up area of the town and data that lies within a radius of 30 km. All other outcomes were developed for this two areas- built-up area of the city and the area to 30 kilometers.

The first outcome of this work is a map showing the intensity of use of roads in Olomouc. Map view is shown in fig. 2.

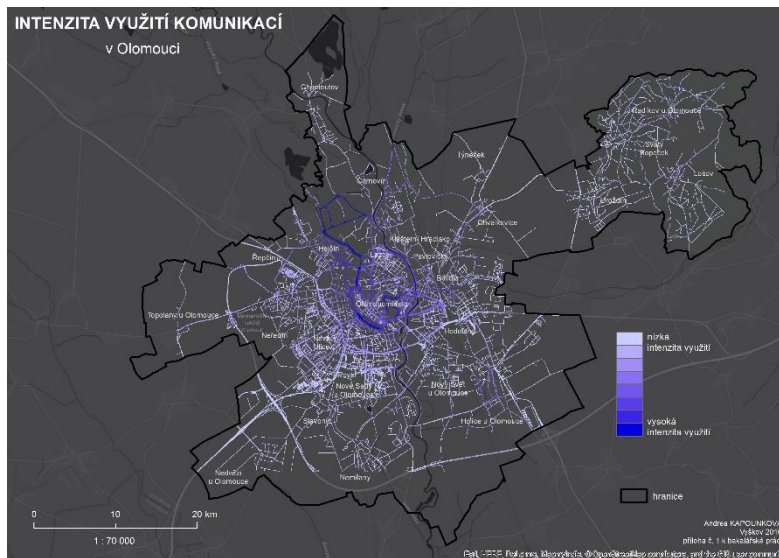


Fig. 2 Map of the intensity of use of roads in Olomouc.

Due to the small number of data in surrounding it was decided to create this map only for Olomouc because data visualization for the neighborhood would be inaccurate. Inaccuracies was especially in places where was no data available on the site or they were very few. This problem occurred in all the cities around Olomouc. Map was made using Kernel Density and Line Density, which allows you to create maps of density of a certain phenomenon. Instruments operate on the principle of calculating the density around the phenomenon. Kernel Density tool can process line and point geometry, tool Line Density line only. By comparing the outputs of the two tools (Fig. 3) it was decided to use the line density, because the same parameters shows better output data. Kernel Density tool generate results very smooth, and the kernel estimate was examined across space.

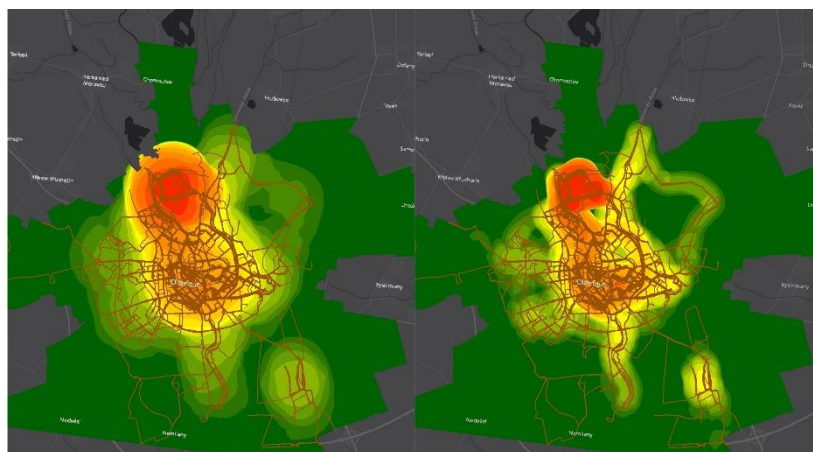


Fig. 3 Comparison of data visualization using Kernel Density and Line Density.

Production of case studies

To create representative results for the city of Olomouc were needed more data than that what was available, so the results are described using case studies (examples of possible use). These studies mainly describes how a given analysis might look like, what would they serve to and how can look the results of individual analyzes.

For the purpose of the thesis was chosen the themes of studies:

- Identification the most used cycling paths and routes
- Identification the most used communications - searching for suitable sites for construction of new bike trails, bike paths or change existing lines
- Identification of hazardous and non-compliant sites
- Statistical evaluation of data
- Analysis of users of sports applications

Case studies for the city of Olomouc

For the processing of data in a given area, it is possible to work with different dates. For comparison in Figure no. 4 you can see the same part of Olomouc - Hejčín in-line paths using original data - records tracks, further using visualization so called "heat maps", maps of intensity according to the number of passes and also according to the attribute table. When processing studies are always used only a certain cut-outs in the city.

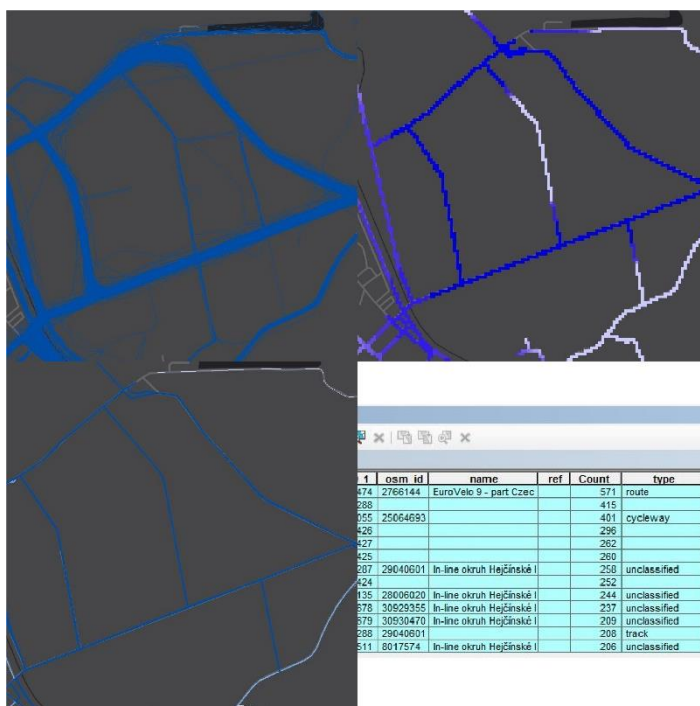


Fig. 4 Visualization and data analysis.

Identification of the most used cycling paths and routes

Among the routes through which cyclists rode at least 200 times during the reporting period (the 104 trips), only twenty appears already on implemented bicycle path. In seven other cases, it is a bike path that is only planned.

The most frequently used cycling route is EuroVelo 9 with the number of passages 571 and right behind it is the cycling route no. 51 Olomouc - Hanusovice with the number of journeys 544. Cycling trails lead across Olomouc parks and lead to in-line trails in Hejcin.

The most used route is in-line trails Hejčín meadows. In place of the circuit there were 478 real passes. This is partly a path for pedestrians and cyclists joint together and communication with the exclusion of motorized transport. But a large number of routes leading to this place across the street Lower Hejčinská. This street is in terms of the intensity of traffic very busy, every day passes nearly 9,000 cars. In the place is lit crosswalk for cyclists, but it is still partially dangerous. Much route leads right through this road to cyclists and other athletes get on in-line skating. More used trails are trails leading through Olomouc sets. In the orchards lead in most cases, paths for pedestrians and cyclists with a separate operation. These places was also frequently mentioned in the questionnaires as unsatisfactory. Although lanes for cyclists and pedestrians clearly marked, many pedestrians uses the entire width of the roads and preventing the smooth operation of athletes. But because the data from users can not distinguish between cycling data and data from runners or skater, for example, can not say with certainty that all the routes leading through the parks and outside marked trails and bike paths are using only cyclists, thereby obstruct the movement of pedestrians. Another very frequently used cycle route is from Bystrovany to Olomouc, with the number of passages 499. In 2015, the bike trail partially completed and connected to the street Jeremenkova. In this place was built safe crossing for cyclists in the intersection with the street Pavelčákova and footbridge for pedestrians and cyclists, in order to avoid the busy street Hodolanská. My recommendation is:

Based on the above findings, it is recommended to invest more in the safety of cyclists and joggers so that athletes easier can get from different parts of the city to the popular bicycle routes. It is therefore necessary, when planning new cycling routes, think about it, to be able to safely reach the trail. Furthermore, in places where the athletes must carry along busy roads, it is recommended to build a separate crossings with luminous markings for pedestrians and cyclists. It is also appropriate to watch the most frequently used bike routes more frequently, especially in terms of maintenance - there should be carried out frequent maintenance, repair, inspection of the surface.

Identification of the most frequently used communications - searching for suitable sites for construction of new bike trails, bike paths or change existing lines

Among the most popular road and off road cycling routes include street, located near the circuit Hejčín meadows. These include street Jarmila Glazarová, on which leading part of the cycling route. Outside of this cycle route is presently a real 135 passes. Furthermore, it is used Hejčínská Lower Street with the number of passes 67th. Interesting is the view of the communication cycle routes from Bystrovany to Olomouc. In this section is also realized trail, but also many examples, but also many examples which show that cyclists often use other routes, although the bike trails or bike trails are a few meters next. It is also clear that although it is often used bike path from Bystrovany (374 passes), but many people are choosing a path on the other side of the river where no path or trail leads. If we look at the passages closer, it is clear that cyclists use to connect to cycle route the communication and part of the cycle path is thus completely unused. In this case, therefore, for the athletes is more comfortable using a different route than the existing and implemented, it is possible to think about changing the existing routing paths. Třída Míru is another example of the place where the missing bike trail or bicycle path for safer movement of athletes. In the place is located 98 real passes. Communications joins cycling trail up to Neředín where it's not nearly exploited. It is an overpass over Highway 35. It is only a short stretch of cycle path, but its sequel is planned. On a map and according to cyclist routes it is clearly seen that more than half of routes (52) runs along communication routes and only 17 overpass leading on a bike path.

My recommendation is: Communications, which are often used by athletes should be frequently monitored or controlled by the Police to prevent accidents. Like the busiest cycle routes and paths and frequently used communications require more frequent maintenance, repair surface and check the status of communications.

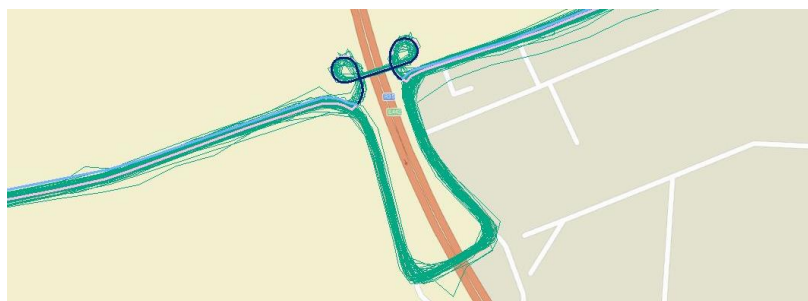


Fig. 5 Usage of the communication instead of an overpass built as a bicycle path

Identification of hazardous and non-compliant sites

Very often, accidents on the trails caused by the poor and uncared surface - potholes on the road, sliding leaves and so on. But in the questionnaires also many people said that with the quality and surface of Olomouc bike paths are satisfied. Because the routes in Olomouc do not follow each other and often it is only a short stretch, often they ending on the road type III. and the upper classes. In many cases it is nowhere indicated that the road enters cyclists and it becomes hazardous. An example might be a nature trail Cernovir fens, which leads to communication Chválkovická through which passes a day almost 15,000 cars. Because in this place is the newly constructed rest area not only for cyclists, but also for pedestrians and skaters lacking, in this place aren't sign or warning on the occurrence of cyclists and especially crossing or crossing for pedestrians and cyclists.

One of the sites, which together present several dangerous and inappropriate sites is located on the street Wolkerova and continues on the street Havlíčkova. Bicycle path leading to the street Wolkerova leads downhill and continues to the communicate with bi-directional traffic. On the site can lead to accidents due to carelessness of cyclists who did not give the right of way. Cyclists continuing down the street Roosevelt must then turn intricately linked to the bike path leading through a railway crossing equipped with warning lights. Right behind it again the bicycle path ends and with a short section continues on the other side of the street to street Poupětova. There is only the road signs indicating a crosswalk, moreover, it is also dangerous because of passing trams. My recommendation is: in areas with a high intensity cycling trails or bike trails that are located near busy roads, it is appropriate to position a sufficient amount of traffic signs. The markings should warn the driver of the possible presence of cyclists as well as cyclists that the end of the bike trails or bike paths is closer or it is connecting to the communication. To increase the safety of the athletes is generally suitable built illuminated transitions marking.

Statistical evaluation of data

Statistical evaluation of data confirms previous studies. It can thus find out the most frequently used bike trails, bike routes, communication and real number of passes. These data should be used primarily for better maintenance busy places and also for security from police or city (building crossings, overpasses, underpasses at busy locations).

The questionnaires often it shows that cyclists are in most cases with the concept of routes in Olomouc dissatisfied. The biggest problem most users see in illogically constructed in short sections, the shortest cycle route is 5.5 m, which are not linked to each other in any way, and people must also use ordinary roads.

"The total amount is OK, it is improving but still not perfect continuity. Often illogical leadership, unfinished connections, often only partial sections without continuity. Tragic maintenance over the winter and fall ... Much limits for daily commuting."

This is followed by another common problem, which the crossings through communication such as the already mentioned communication via Wolkerova. Part of the places in Olomouc already has traffic lights and crossings especially for cyclists and pedestrians. The comments from the questionnaire survey shows that most people are missing bicycle path towards Chomoutov and Holice.

"Status of the cycling where I live (Olomouc-Holice), but overall of our town is very bad! Especially bothers me that bike trails often lead just a short distance away and nothing. As if from nowhere to nowhere, not linked."

The plan of the municipality is to built three short sections in the Chomoutov that did not connect to each other. It is also planned to built paths for pedestrians and cyclists going from the in-line circuit ahead of Chomoutov where people must once again connect to the roads type II. At this point already very short section of the trail is located. But people often use for road transport second class with a traffic of over 5000 cars per day.

Conclusion

The main aim of the thesis was to create a demonstration and case studies and also general recommendations for working with recordings of sports applications. This goal was achieved by creating several examples of case studies and the establishment of procedures and suggestions for the city.

The practical part of the task was to obtain data from users in sports in the Olomouc region. Data were collected from 21 users. The result is a geodatabase routes, which contains records from all users, sorted into folders according to the user's surname. Part of the practical solution was to create a questionnaire to obtain information about users. This questionnaire was answered by 30 people. Data were further processed and visualized. It was created 7 maps, showing a preview of the situation in Olomouc. Another result of the practical part of the solution was the creation of six case studies and a general procedure and comments. This part should help cities that choose to use records routes from sports applications for their development planning.

Elaboration of digital terrain model of Wigry lake bottom

Katarzyna Sychała

Faculty of Geodesy, Geospatial and Civil Engineering, University of Warmian and Mazury in Olsztyn, Oczapowskiego 2,
10-719, Olsztyn, Poland

Contact spychala.katarzyna@wp.pl

Abstract..

The aim of this Engineer's Thesis is to present the lake bottom in the form of a digital terrain model (DTM). To accomplish this author performed all the preparations and bathymetric measurements of the specific fragment of Lake Wigry.

In the Thesis, the author describes the history of bathymetry, the techniques and systems used for the measurements, including GNSS satellite navigation system and the Integrated Bathymetric System that helped to make all the measurements. The author also introduced the issues associated with the digital terrain model. In subsequent chapters, Thesis presents the course of the work that the author had to do to achieve his goal. A number of programs and applications were used for the studies including ESRI ArcGIS software, and authorial application EchoConverter II.

In conclusion, the author describes all the results of his work, including how much data he was able to gather, the extremes of the measured fragment and the water level during the measurement.

Keywords: Digital terrain model, Integrated Bathymetric System, GNSS, Lake Wigry, ArcGIS

1 Introduction

The world hides many secrets but human curiosity knows no boundaries. Nowadays we are exploring the Universe and looking for signs of life beyond our planet. We begin to examine things that are found far from us although we know so little about things that surround us here on Earth.

Surface waters are very interesting research facilities. They occupy about 70% of Earth's surface. Especially important is the shape of the bottom of the basin since it brings a good deal of information. These information are valuable not only for the people which are merged with the branches of science about water but also for tourists resting in these areas. The understanding of what water hides and the knowledge about the structure of the bottom will make above-mentioned people more cautious so it's very important to widespread it.

Lakes are the best recognized water environment in Poland and there are nearly 9300 of them what make up about 1% (3200km²) of country surface. [2]

Lake Wigry which belong to Wigry National Park was chosen by author as object of measurement. During a science camp organized by scientists and students belonging to the science club MKN "GeoSiN" hydroacoustic measurement of Lake Wigry was made.

2 Characteristic of Lake Wigry

The Lake Wigry – this lake is located in north-eastern part of Poland, in Podlaskie Voivodeship, in the community of Suwałki and Nowinka. The eastern shore of the basin forms the border between counties: Suwałki and Sejny. The surface of the lake is around 22.3 km, its dimensions are 17.5 x 3.55 km. The Lake Wigry include 19 islands which occupy an area of 0.67 km². Coastline length equals 63.92 kilometer (not including the islands). Black Hańcza is the supply and flowing river. [4]



Fig. 1. Landscape of the Lake Wigry from a pier in village Rosochaty Róg.

The beginnings of the Lake Wigry go back to very remote times. This water basin is a tunnel-valley lake which is kind of a glacial lake. This kind is associated with the end of last glaciation on terrain of Poland which had place about 12 000 years ago. The Lake Wigry was divided into bigger water regions (so-called ploso in polish) and few smaller bays. The deepest place of Lake Wigry was localized in the bay Wigierki and ploso Szyja. These parts of the lake have character tunnel-valley lake and maximum depth there is equal to 74.2 meter (According to the measurement made by Choiński and Skowron in 1998). [3]

2.1 The morphology of the Lake Wigry

Old lake Wigry after the processes that accompanied the passage of a glacier was extended over large areas, about 30 km² (current area is 22.3 km²). This area had interesting coastline and diverse bottom morphology. The shape of the bottom of Lake Wigry was presented from the data which was gathered from measurement between 2009-2010. The measurement was made with manual probe in coastal zone and also a dense network of acoustic echo sounding. The conclusion of the measurement was that the shallower and deeper places are mostly next to each other. Slope of the bottom at these places sometimes equal about 30 degrees. Areas about 10-20 m, 20-40 m depth constitute 52.2% of the whole Lake Wigry surface and places with depth over 40 m constitute only 5%. The Wigry Lake have a six basic water reservoirs which are separated from each other by constrictions and by shallower places. Parts such as bay Wigierki, Ploso Bryzglowskie (another name Western Ploso), Ploso Zakątowskie (Center Ploso), Ploso Szyja, Ploso Wigierskie (Northern Ploso) and bay Zadworze can be distinguished. Bays and Plosa were presented in the picture 2. [3]



Fig. 2. The main reservoirs of Lake Wigry.

Measurement made by author was included in one part of the lake named Płoso Szyja. This part is extending over an area with following dimensions: 2.2 km of length and width from 0.4 up to 1.2 km. The bathymetric survey did not include the whole of this part (Fig. 3.). The area between boundary with Płoso Wigierskie and the deepest place this region was chosen. Particular attention has been paid on the deepest places and the measurement profiles were thickened there.

**Fig. 3.** Area measuring bathymetric.

3. Bathymetric Measurement and elaboration of gathered data

For the bathymetric survey author used Integrated Bathymetric System and manual water sounding probe (probe made from metallic chain). A number of programs and applications were used for the office work including ESRI ArcGIS software, application Topcon Tools and authorial application EchoConverter II.

3.1 Integrated Bathymetric System

Integrated Bathymetric System was constructed by the scientific team from Department of Satellite Geodesy and Navigation on the University Warmian and Mazury in Olsztyn. This system runs hydroacoustic sounding and determines the boat's position in the same time. The flow chart of the Integrated Bathymetric System is presented in the picture below (Fig. 4). This system have to have two receivers. Base Station must be the first receiver. Active reference stations are utilized for this. These stations are transmitting radio telegram in 1s interval in a continuous way. As a result, it is possible to work using DGPS and precise positioning phase RTK / OTF. Second receiver is mobile (rover). His task is receiving data packet from station and correcting the antenna position. The receiver's antenna is localized above echo sounder transducer and all is attached to hydro graphic motorboat. Utilizing DGPS technique it is possible to determine coordinates of the boat in real time with accuracy to 0.5 meters. While utilizing positioning phase RTK / OTF, receivers high class and calculation algorithms, accuracy can be equal to 1-2 cm for horizontal coordinate B, L and 1-5cm for vertical coordinate h. [5]

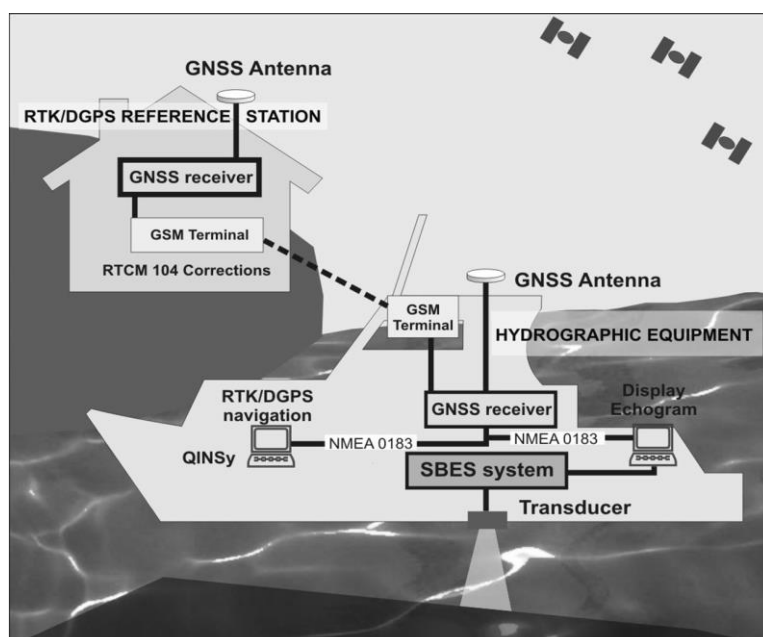


Fig. 4. Integrated Bathymetric System [1]

Digital ultrasonic probe is very important element in this system. The depth is defined by sound waves. Integrated Bathymetric System is using echo sounders such as Simrad EA 501P working on 200kHz frequency or Reason NS515.

Table1. Technical specifications of echo-sounder Simrad EA 501P [5]

Sound wave width	7°×7°
Measurement frequency	To10 pulses/second
Measurement range (for tanks of freshwater)	about 600m
Minimum depth	0.3m (for 200kHz)
The accuracy of the measuring range	0.25% (after taking into account the profile of the speed of sound in water)
Weight	7kg
Length	34cm
Width	35cm
Height	14cm
Supported	By the portable computer

Transmitted beam of 7°×7° width sound waves is responsible for the precise determination of the distance.

3.2 Boat and equipment preparations for bathymetric survey

The field work has begun from preparing the equipment. Primarily Integrated bathymetric system which was utilized to measurement. The components of this system were: ultrasound probes (used interchangeably) Simrad EA 501P frequency of about 200kHz and Simrad EA 501P frequency of about 710kHz with transducers, two TOPCON HiPer Pro receivers, GNSS, GSM/GPRS IGTS-R terminal, Thales Mobile Mapper GPS receiver and two portable computers. The individual elements of the system were attached to boat and calibrated. Transducer was located on the left side of the boat with receiver above him. This arrangement made it possible to determine the horizontal position of the echo sounder transducer based on the position of the GPS receiver's antenna. Arrangement of the equipment on the hydroacoustic motorboat was presented in the figure 5.



Fig. 5. Arrangement of the equipment on the hydro-acoustic motorboat.

Sound velocity in water is very important factor which have an influence on accuracy of depth measurement using hydro acoustic instruments. Temperature of the water was measured by author of this thesis and it equaled 16°C. It means that the sound velocity was 1465m/s. In the next step a manual sounding probe was used to check if the equipment is operating correctly.

3.3 Measurement profiles

2.1.1 Before the survey, a project with measurement profiles was elaborated in ESRI ArcGIS software. The project enabled the regular collection of data from the study area and facilitated the motion of boat at a specified interval. The distance between profiles depends on shape of the bottom. If bottom is more varied, cross sections will be thicker. In the figure 6. project with profiles and part of the bathymetric survey is presented.

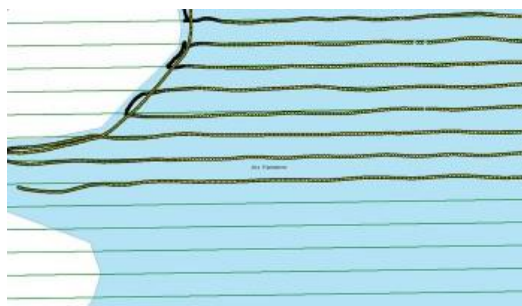


Fig. 6. Project with measurement profiles and part of the bathymetric survey. [6]

3.4 Hydroacoustic measurement

Bathymetric measurement requires a lot of concentration and attention. Observing the situation on the lake and control of the system is necessary at all time. Hydroacoustic motorboat was moving through the cross sections with about 6km/h. The depth data and position from the Topcon HiPer Pro receiver were simultaneously recorded. Position was corrected with data from a local reference station in Suwalki. All data was saved as echogram. Measurement profiles were in direction from east to west and there was about 100 of them. Distance between them was 20m. In deeper places profiles were denser. More accurate data was the aim of this.

3.5 Data verification in application EchoConverter II

Application EchoConverter II was helpful in data verification. It has many useful functions, for example: echogram review, correction of the transducer's immersion, change of character depth and other functions. Author of the thesis used a version of the application that has the basic options such as a preview of boats route, depth and filtration of incorrect depth. Application window is divided on the three parts. According to the figure 7., in the

upper part is the profile of the bottom, down on the right side is the trajectory of the boat and on the left is a table with gathered data. In the columns are: number of point, measurement time, geodetic coordinates and depth.

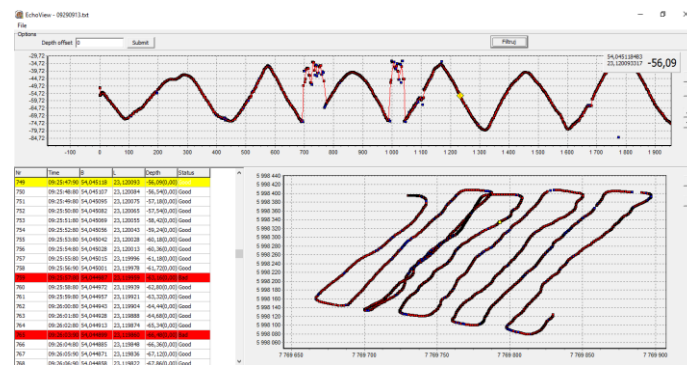


Fig. 7. Window Application EchoConvertr II.

Filtering is an option that shows incorrect data, which can be deleted. Files which are products of this application are ready to import to the ArcMap software.

3.6 Calculation of water level and determining geoid undulation

GNSS Static session took place during bathymetric measurement. Data was recorded by more than one and half hour by the Topcon HiPer Pro receiver which was on the pier. Antenna elevation above water level was 0.77 m. Position of the measured point was determined relative to the reference station in Suwalki which belong to the ASG-EUPOS. Post-processing was made in the program Topcon Tools in demo version. Ellipsoidal height was obtained after post-processing. Average from two configuration (GPS Only and GPS+) was equal 159.17 m. The result takes into account distance between receiver's antenna and level of the water. Then the program GEOIDPOL_2008CN (version 3.1) was utilized to calculate geoid undulation. The distance was 27.54 m. The normal height in Kronsztadt 86 was calculated by subtracting from ellipsoidal height of the geoid undulation what gave 131.63 m.

3.7 Data import to ArcMap software 10.3.1

In the next step author of the thesis proceeded to generate Digital Terrain Model of Lake Wigry bottom. ESRI ArcGIS software was very helpful.

At the beginning PUWG1992 was chosen as the coordinate system for the display area and next data in .xsl files (the application EchoConverter II product) was imported by the ArcCatalog. This enabled to choose geographical coordinate system WGS84 and select the appropriate input fields geographical coordinates and depth.

3.8 Digital Terrain Model of the bottom TIN and GRID, contour map

Coming to the end of elaborations, the author of this thesis created a Digital Terrain Model by utilizing ArcToolbox options. In the beginning, points from individual days were merged into one layer. Then Create TIN option was used. In the input class feature layer with all point and polygon with coastline of the Lake Wigry was chosen. Feature of Coastline was defined in column Type SF such as Soft Clip. It enabled creating boundary of the TIN which was clipped to the coastline. Next, WGS84 was chosen as coordinate system. On the figure 8. DTM TIN is presented. The resulting model was presented in the palette of colours, due to the clear design, which allowed a final, quick verification of the correctness of the data.

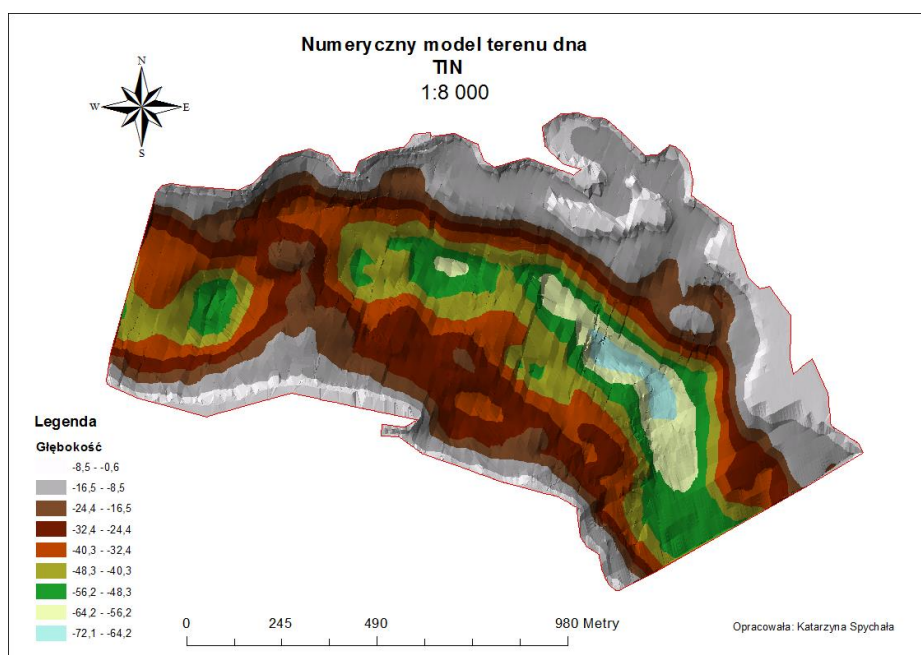


Fig. 8. Digital Terrain Model of the bottom TIN.

In the next steps TIN model was converted to raster. Then smoothed contours were generated from the GRID model. In the first version they were unnaturally sharpened. Digital Terrain Model of the bottom GRID with contours in 2 m intervals was presented on the figure 9.

To show the most approximated model of realistic terrain shape a three-dimensional model of the bottom was created. ArcScene program was used for this. Three dimensional model was created from DTM GRID and contours were re-created with 5 m intervals. It increased readability of the model. Then, base height was selected for model and contours. This model is shown on the figure 10.

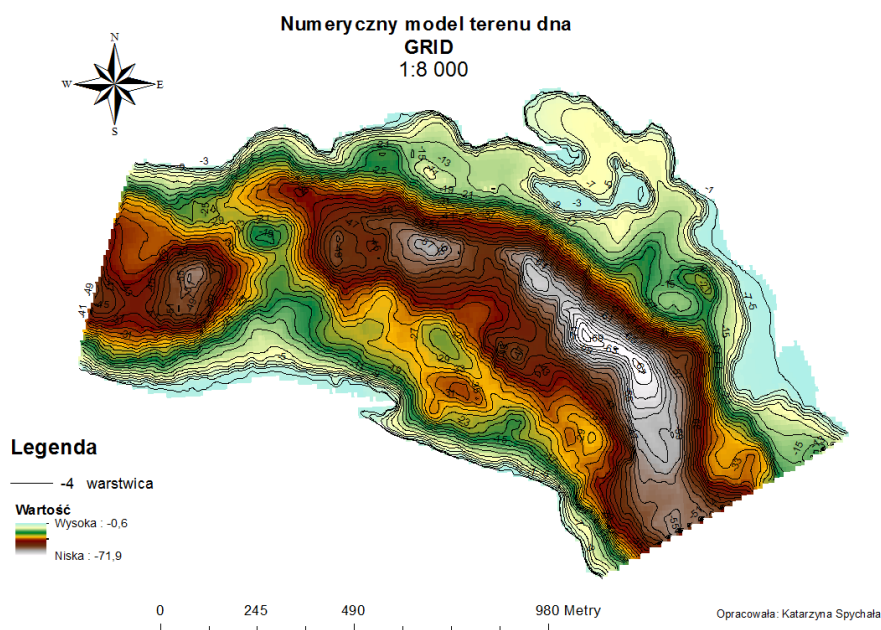


Fig. 9. Digital Terrain Model of the bottom GRID with contours (interval=2m).

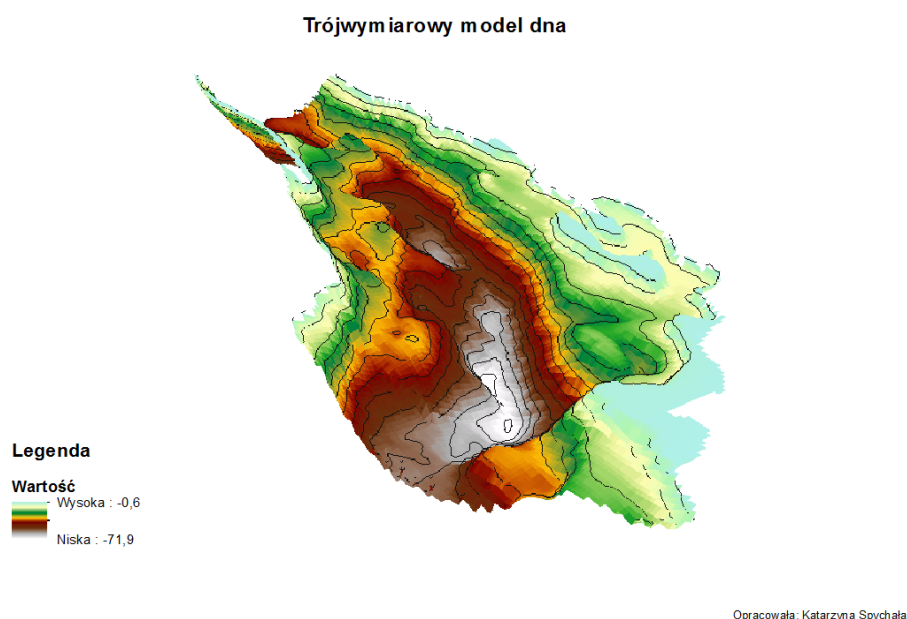


Fig. 10. A three-dimensional model of the bottom of the north side of the superimposed contour lines at 5 m in the map application ArcScene.

3 Summary and Conclusions

During the 6 days of research a big amount of data was collected. 40 binary files which contains 49416 raw bathymetric measurements were collected. Some part of raw data was deleted and finally 37858 points were used for elaboration of digital model of Wigry bottom. That amount of data is sufficient for creating reliable Digital Elevation Model in easy and clear way. The clear way of bottom model representation is very important since this model can be used by people who are not hydrographer.

Results of works:

- 100 measuring profiles was necessary for carry out measurement,
- Maximum depth of lake is 72,1 meters,
- Minimum depth of lake is 0,5 meter,
- Average depth of lake is 25,2 meters.

Determined water level was 131,63 meters over level of water in Kronsztadt 86.

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Navigation application for aerial photogrammetric imaging

Android navigation application

Jan Masopust

Department of Geoinformatics, Faculty of Science, Palacký University Olomouc,
17. listopadu 50, 771 46, Olomouc, Czech Republic
Contact masopust.jan@gmail.com

Abstract. This bachelor thesis describes a principal of navigation in aerial photogrammetric imaging, mobile solutions for this issue and process of building specific application for this usage. Nowadays there are only professional solutions or universal flight applications. These two solutions are not optimal for usage in small company or university department, which is oriented in aerial photogrammetry. In this project, it was created the highly specialized mobile application in Android operation system. This application allows comfortable navigation along the flight axes and work with these axes, tracklog record for computer post-processing. There is also a part, which describes a possibility of connecting external GPS modules. This application is usable in small companies and institutions working in aerial photogrammetric imaging like Department of geoinformatics of Palacký University in Olomouc.

Keywords: navigation, GPS, android, photogrammetry, application

1. Introduction

Navigation in aerial photogrammetric imaging is a very specific operation. Nowadays there are professional solutions, which cost big amounts about tens of thousands Euros. The other solutions are mobile applications for sport flying. These applications can be also used for an aerial photogrammetric imaging but there is many complications like bad application interface and complicated control. [5] In this bachelor thesis, which is written in Department of geoinformatics of Palacký University in Olomouc on, it is created the highly specialized mobile application in Android operation system. This application will allow comfortable navigation along the flight axes and work with these axes, tracklog record for computer post-processing. A possibility of connecting external GPS modules was also tested. This application will be suitable for use in small companies and institutions working in aerial photogrammetric imaging like Department of geoinformatics of Palacký University in Olomouc.

2. Navigation in aerial photogrammetry

The goal of aerial photogrammetry is to take a true image of an Earth surface and then i.e. make ortophoto maps, reconstruct the shapes, measure length and heights or identifying objects on the Earth's surface from photogrammetry images. [5]

Standard GNSS receivers mostly operate navigation in aerial photogrammetry but these receivers need a special application extension.

If a carrier of photogrammetry camera is an airplane, then a specialized device connected with both the camera and the airplane provides the navigation. The other possibility is a mobile application in a cell phone or a tablet. The carrier has to keep a constant altitude, bearing and flight along parallel axes. (Fig. 1) It is important that airplane have the same bearing like an axis. After completing the first axis, the airplane turn around and continue on the second axis. After the end of a whole flight, the success of the flight is evaluated and some axes could be flight for the second time due to bad image or bad track of the airplane.

The important part of a post-processing is joining geographical position with images. The most common method is based on accurate time – GPS time and camera time.

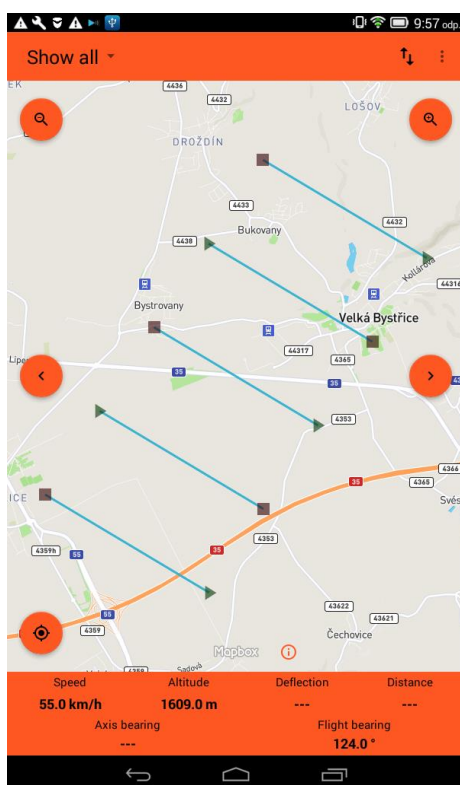


Fig. 1. Flight axes for aerial photogrammetry

2.1 Available solutions

Nowadays there are two possibilities of navigation in aerial photogrammetry.

The first one is a specialized device called IGI CNNS-5. (Fig. 2) This is one of the best solutions on the market. This device is connected to sensors and the control unit of the airplane and to the photogrammetric camera. These connections allow very precise positioning of images, taking images at given locations and very comfortable and accurate navigation thanks to sensors of airplane, which sends information to IGI device. It can compute bearings and turnings of the airplane. One of the few disadvantages is the economical site – very high price. For small business, it is impossible and not viable to use this professional device.

The second possibility is a mobile application, tablet or cell phone and GNSS receiver. Applications are mostly universally designed for flying or sport flying. If user can accept many limitations like uncomfortable control, low accuracy etc., it is a cheap or even free substitute of the IGI CNNS-5.

One of popular applications is “Fly is fun”, which is also nowadays use the Department of geoinformatics in Palacky University. [2]



Fig. 2. Professional navigation for aerial photogrammetry IGI CNNS-5

2.2 Requirements of ideal mobile application

Based on the principal of the aerial photogrammetry, there were given requirements for new mobile application. Application should work in three section.

The first section is a work with flight axes. This means load axes – they are determined by two points (start and end point) and name. In most cases, these axes are prepared on computer before the flight with the possibility of export. Each flight has more axes. The airplane flights along the first axis, then it turn around and flights the second axis. Thanks to that, the application could allow easily switch to another axis. After completing the whole flight, there is a possibility that some axes were taken inaccurately.

Then, there is a requirement of load a specific axis again and, if it is conveniently, to change the direction of an axis (this means to switch start point to end point or vice versa).

The second section is a navigation. The airplane starts from an airport and then it should flight to the start point. After reaching the start point, the airplane flight from the first start point to the first end point and then to the second start point (second axis) and then to the second end point etc. To the important data belong distance to the goal, deflection from the axis, current altitude, current bearing and bearing of the axis.

The third part is a record of a flown route. This is important for post-processing, for joining images with geographical position.

2.3 Platform for mobile application

In 2016, there were three main platforms operated on the mobile market. These are Android (81,7 %) operated by Google, iOS (17,9 %) by Apple and Windows (0,3 %) by Microsoft. Current developer tools do not allow developing an application for more platforms all at once. [7]

Aerial navigation requires a very accurate GNSS data. Build-in GNSS receivers of cell phones and tablets do not meet these requirements. Connect an external GNSS module is a solution. The best technology for it has an Android OS thanks to an open code and wide developers base.

Thanks to it and the largest share was chosen the Android OS.

3. Application

3.1 Development and user interface

For the development of application for the Android OS was chosen a software Android Studio. Applications for Android are written in the Java programming language and the design is defined in XML files. [5]

The user interface was design for use in difficult conditions inside the small airplane. This means a simply control during the flight and well-arranged information.

The application contents four activities.

- **MainActivity** – the most important part of application. About 80 % of the screen size takes a MapView with six control buttons for zooming map, switching axis (previous and next), button for orienting map to the north and another one for turning on a navigation mode and zooming to current location.
- **FlightActivity** – the activity for managing flight projects and axes. It allows creating or deleting axes and flight
- **TracklogActivity** – this activity is a list of recorded tracklogs, which can be exported to a GPX file and then used for post-processing.
- **SettingsActivity** – preferences of the user. The application allows to set color and with of axis and navigation line. Also is possible to turn off the map base and set parameters for recording tracklog and navigation

After completion the phase of testing, there will be also a **HelpActivity** with a simple user manual.

3.2 Functions

In this capitoll, there is a description of application based on a typical usage of a common user.

The work with application starts in a Flight activity. A new flight project can be created by importing a CSV file in the given format:

name of the axis, start lat, start lon, end lat, end lon

There is an example of a project:

First axis, 49.174282, 17.215576, 49.246054, 16.710205
 Second axis, 49.224282, 17.265576, 49.296054, 16.760205
 Last axis, 49.274282, 17.315576, 49.346054, 16.810205

After importing a project, user selects a required flight project. Then, MainActivity is called and a summary of the whole project is shown. That means all axes with their start points as green triangles and end points as red squares.

Then after selecting the required axis or clicking on a next button, the given axis is shown. Additionally the axis is extended at the both sides. This extension is called an “Endless axis”. In fact, the axis are not endless but the length of an extension is defined in settings. Then user can activate a GPS and navigation is started. At the bottom part of screen are shown flight data: speed in kilometers in hour or knots (depending on settings), altitude, deflection from the axis, distance to the start point of axis (green value) or distance to the end point of axis (red value), bearing of the axis and current bearing.

After reaching the start point (radius of a tolerance is given in settings) the navigation is automatically switched to the end point. After reaching the end point, the axis is switched to the next one (if possible) and navigation to the start point of the switched axis.

After completing the whole flight project, some axes can be flight again (if need) by choosing the required axis from the spinner in the top of screen and also there is possibility to change direction by the button.

After that, everything is completed and airplane can flight back to the airport. For post-processing, there is a recorded route (tracklog) of an airplane in TracklogActivity. (Recording started when the airplane reached the given speed in settings). This tracklog can be exported to the Download folder.

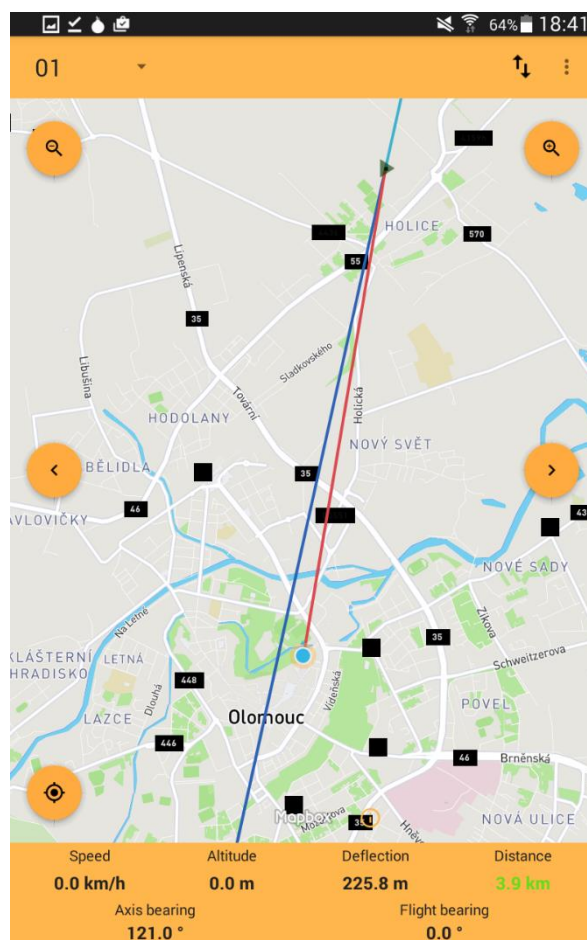


Fig. 3. Application interface

For the accurate work is not a build-in GNSS receiver suffice. There are two possibilities to improve it. The first one is a Bluetooth receiver – a separate device receives a GPS (or other GNSS data) and data, which are sent in form of NMEA sentences via Bluetooth to an Android device. The other similar device is an external GNSS receiver connected via micro USB port. Only some Android devices support this type of receiver, depending on equipment of device (USB host function has to be supported).

The NMEA sentences given by one of the mentioned devices are processed. Then the second condition is an activated mocking location - function, which enable fake positions. This functionality is available only in the developer mode. So for the common user this solution can be quite complicated.

These possibilities are not in march 2017 in this application included. After the accurate testing and users opinions, this functionality is planned to include by the third-party applications connected to this application.

3.3 Testing

The first testing of a user interface and map functions conducted on an Android emulator. Because of a testing of files and navigation is not at all comfortable at emulator. Next tests took place at a tablet Lenovo TAB-2 with GPS simulator. After creating a beta version of application, a real-time test took place in Olomouc and Ostrava, Czech Republic in form of car driving and walking. First test in an airplane was planned at the end of March 2017.

3.4 Availability

After the completing testing and creating manual, the application is planned to post on Google Play market. In March 2017, the application is available to download on page <http://maso.php5.cz/AerialPhotogrammetry.apk>.

4. Conclusion

Nowadays (2017) there is a professional solution for photogrammetry. The alternative is a universal application for fighting. There is not any suitable solution for small companies and academics institutions.

Due to this situation, the new application for Android OS was created. This application allow navigating along flight axes, working with flight projects and creating a route tracklog.

To get the accurate position is suitable to use an external GNSS receiver connected via Bluetooth or USB and use mocking location. This can be realized with the third-party applications.

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Multi- Criteria analysis of location of new housing areas in the Nysa commune

Morawska Kamila

Wroclaw University of Environmental and Life Sciences,

The Faculty of Environmental Engineering and Geodesy, Norwida 25,
50-375, Wroclaw, Poland

Contact mail: k.morawska4@gmail.com

Abstract. Spatial planning is very important for the development of urban and rural areas. Nowadays, the traditional ways of planning are insufficient. In recent years, the dynamic development of Geographic Information System has made some new technologies and tools. GIS technology offers a possibility to improve the process of preparing maps and spatial documents. GIS systems allow to analyze and visualize geographic information. Also, the integration of multi- criteria decision analysis and GIS tools improves processes in spatial planning.

The purpose of this research was to find the appropriate areas for housing development by using GIS technology in the Nysa commune, located in the Opole province, Poland. Two methods of analysis were used: the Boolean and the Weighted Linear Combination (WLC). The result of the first method is a constraint map. The effect of WLC analysis shows suitability of sites for housing development in the Nysa commune. The results of the first analysis were used to rate the possibility of using these results in the process of issuing decisions on land development conditions. Effects of the second method were compared with the Study of Conditions and Directions of Spatial Management document. Criteria were developed based on planning documents of the Nysa commune, legal provisions and other publications. Weights for criteria were assigned using the Saaty's scale.

The datasets used in this research were downloaded from websites of the Central Documentation Centre of Geodesy and Cartography, the General Director for Environmental Protection and Open Street Map.

Analysis of this study indicate a high efficiency of using these types of GIS technology for spatial planning. Results of the Boolean method show, which areas are suitable for housing development. The result the WLC analysis determines degrees of usefulness of these areas. They may be considered as a tool supporting the creation of planning studies.

Keywords: multi- criteria, spatial planning, GIS, AHP

1 Aim

The purpose of this research was to find appropriate sites for new residential areas by using the GIS technology and multi-criteria analysis in the Nysa commune. Multiple factors were selected to evaluate the suitability of sites.

2 Data sources

Datasets used in this research are the cadastral map and the Database of Topographic Objects. Beside that, additional data, as information about parcels of rural areas were taken from the LPIS system (The identification system for agricultural parcels). Information about location of Special Areas of Conservation and Special Protection Areas were downloaded from the website of the General Director for Environmental Protection.

3 Methods

It is difficult to find the most appropriate sites for a new housing development. It requires collecting suitable criteria and choosing the best method. The difficulty in identifying these areas arise from the need of taking

into account environmental, social and economic considerations. For this purpose two methods of multi-criteria analysis were used.

The first of them is the Boolean method. In this analysis, all of criteria are converted to binary maps. The result of this step is a constraint map (a value of 1- a site is suitable, a value of 0- a site is unsuitable)- to accept the area as an useful all of criteria must be true. Most of them are results of the relevant regulations of the law.

In the second part of this study, Weighted Linear Combination method was used. WLC method enables to assign weights to each criterion. Before this process, all criteria must be standardized. The result of this analysis is the map which shows the suitability rating for sites for housing purposes. The combined GIS- AHP approach was used to assign weights. The analytic hierarchy process (AHP) was developed by Thomas L. Saaty. This technique is used to solve a problem where there is a variety of criteria. In the WLC method, assigned weight for each criterion depends mainly on the knowledge of the decision maker. There are several steps in AHP process: defining the problem, establishing criteria, checking a consistency index of a matrix (**CI**) and the consistency ratio (**CR**). (Kobryń, 2014). Criteria was weighted using the scale from one to nine (table 1).

Table 1. Saaty's scale

This scale modified	Definition	Description	Intensity of importance	can be through
	Extreme importance	The "I"-th element is absolutely more important than the "j"-th element (absolute importance or preference of one element relative to the other)	9	
	Very strong importance	The "I"-th element is favored much stronger than "j"-th element (very strongly preference of one element relative to the other)	7	
	Strong importance	The "I"-th element is strongly favored than "j"-th element.	5	
	Moderate importance	The "I"-th element is moderately favored than "j"-th.	3	
	Equal importance	The "I"-th element is equally important as the "j"-th element.	1	

intermediate values: 2, 4, 6, 8. They are used in situations where a comparison is necessary between values from table above. Criteria are confronted in a matrix. The criteria in the row are compared with the criteria in the column. The matrix is symmetric, so there is no need to fill two parts of it. In one of these part, inverse values are entered (for example: 1/3, 1/7). Next, a normalized matrix comparison is created using a sum of its columns. Then, arithmetic means are calculated for each row of the matrix. These values create weight vector for criteria.

A very important step is to check the consistency index of the matrix. It is calculated based on the following formula:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

where: λ_{max} - the maximum value of the matrix
n- the degree matrix

Consistency ratio (CR) is calculated by dividing the Consistency Index (CI) by the value of RI.

$$CR = \frac{CI}{RI} \quad (2)$$

where: RI- Random Index

Table 2. Values of Random Index (RI)

n	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0,52	0,89	1,11	1,25	1,35	1,40	1,45	1,49	1,51	1,54	1,56	1,27	1,58

source: „Wielokryterialne wspomaganie decyzji w gospodarowaniu przestrzeni” Warszawa 2014

According to Saaty, the value of CR should not be greater than a value of 0,10. If the Consistency Ratio is greater than 0,10- the matrix should be checked. Finally, Weighted Sum tool is used to generate a factor map.

4 The study area

The study area is the Nysa commune. It has an area of 21 565 ha and population of 57 710 in 2015. It is an urban-rural commune, which means it includes the city and villages. The Nysa commune has a well- developed road system. There are 4 types of roads: national roads, provincial roads, district roads and commune roads. One of them leads from Nysa to the Czech Republic and the second- from Kudowa- Zdrój- Nachod to Częstochowa (through Nysa). Ring road (beltway) of the Nysa city is currently under construction and it is expected to open in the second part of this year.

This commune has an attractive geographical location, because it is located on the border of the Sudeten Foreland and the Silesian Lowland. Thanks to this, there are six forms of nature protection in the Nysa commune: Protected Landscape Areas (Otmuchowsko- Nyski Obszar Chronionego Krajobrazu), Nature reserve („Przyłęk”), Special areas of conservation („Habitats” Natura 2 000)- “Forty Nyskie” and “Jezioro Nyskie”, Special protection areas (“Bird” Natura 2 000)- Zbiornik Nyski, natural monuments.

5 The Boolean method

5.1 Criteria

For the Boolean method, I established 13 constraints that prevent the development of residential buildings. For most of them, it was necessary to establish buffer zones. The size of each zone resulted from the relevant legislation.

Table 3. Constraints considered in the Boolean method

	Classification	Constraints	Buffer zones
1.	residential areas	existing buildings	-
2.	roads	national roads	25 m
		provincial roads	20 m
		district roads commune roads	15 m
	designed roads	ring road under construction	25 m
3.	areas of railway transport	railway lines	20 m from border
4.	water areas	the Nysa Lake	100 m
		the Nysa Kłodzka (river)	50 m
		streams	-
5.	green areas	forest	-
6.	Recreation areas	for example: play grounds, parks	-
7.	areas for nature conservation (Natura 2000)	Special areas of conservation	-
		Special protection areas	
8.	cumbersome objects	cemeteries	50 m
		sewage treatment plant	100 m

5.2 The Boolean method

GIS system from ESRI was used to find the best areas for new housing development.

In this study, vector files were converted to raster format; the required information must be extracted from suitable source layers. Dimension of cell is 1 x 1 meters. It is a sufficient size to capture data in this research. Then specific layers were created, where all cells with data were assigned a value of 1. The rest of cells were assigned a “no data” character.

Next, it was necessary to create buffer zones for appropriate criteria (table number 3). Thanks to this procedure, the Boolean method was used to generate the constraint map for each criteria. They show suitable and unsuitable areas for new housing development. In the last stage, a *Boolean Or* tool was used to generate the resulting constraint map. The result of this stage are shown below. The red color represents constraints and the green color shows the potential areas for a housing purpose.

5.3 Results

The constraint map represents areas which will not be considered as new housing development sites. The sum of these areas is about 66 km². It is only 30% of the total area of the Nysa commune. Therefore, the potential sites for the new housing development are nearly about 160 km².

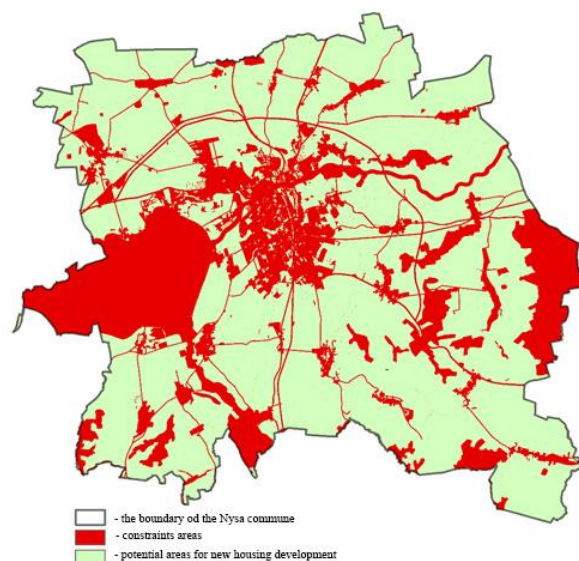


Fig. 1. The result of the Boolean method (source: own work)

6 The Weighted Linear Combination method

6.1 Criteria

For this method, criteria are the same as for the Boolean method, but they are defined differently. Criteria were divided into factors and constraints.

Table 4. Criteria considered in the WLC method

	Constraints	Factors	Standardized factors
1.	residential areas	distance from existing buildings	the level of suitability of land declines with increasing distance from the existing buildings
2.	existing areas of communication	distance from roads	the level of suitability of land decreases with increasing distance from the existing roads
3.	-	distance from primary schools and middle schools	the level of suitability of land decreases with increasing distance from educational establishments
4.	-	distance from health clinics and pharmacies	the level of suitability of land decreases with increasing distance from pharmacies and health clinics
5.	-	distance from grocery shops	the level of suitability of land decreases with increasing distance from grocery shops
6.	-	distance from sports and recreation facilities	the level of suitability of land decreases with increasing distance from sports and recreation facilities
7.	cemeteries with buffer zones of 50 m	distance from cemeteries	the level of suitability of the site increases with increasing distance from cemeteries
8.	sewage treatment plant with a buffer zone of 100 m	distance from sewage treatment	the level of suitability of the site increases with increasing distance from the sewage treatment
9.	the grounds of the designed communications	distance from ring road under construction	suitability of the site increases with increasing distance from bypass

10.	areas of railway transport with a buffer zone of 20 m	distance from railway lines	suitability of the site increases with increasing distance from railway lines
11.	area of the Nysa Lake with a buffer zone of 100 m	distance from the Nysa Lake	suitability of the site increases with increasing distance from the Nysa Lake
12.	the Nysa Kłodzka river with a buffer zone of 50 m and other rivers	distance from the Nysa Kłodzka (river)	suitability of the site increases with increasing distance from the Nysa Kłodzka river

Before this analysis, it was necessary to standardized factors to a 1-255 byte scale; the higher the value, the sites are more suitable for the location of a new housing development. This process allows comparison between factors.

6.2 The WLC method

WLC analysis was carried out in two variants. In the first option all criteria are equally important (each of them has the same weight). In the alternative, criteria have different weights -it shows the hierarchy. The suitability of sites of a new housing development depends on each criterion. In this variant, weights for each criterion were determined by the AHP method.

The starting point was a pairwise comparison method. Criteria were compared in a matrix, using the Saaty's scale.

Table 5. Matrix of pairwise comparisons

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1	1	3	4	4	5	7	7	7	7	8	8	9
2	1	1	2	2	2	3	7	7	7	7	8	8	9
3	1/3	1/2	1	2	2	3	5	5	5	5	6	6	7
4	1/4	1/2	1/2	1	1	2	3	3	3	3	4	4	5
5	1/4	1/2	1/2	1	1	2	3	3	3	3	4	4	5
6	1/5	1/3	1/3	1/2	1/2	1	3	1	1	1	2	2	3
7	1/7	1/7	1/5	1/3	1/3	1/3	1	1	1	1	2	2	3
8	1/7	1/7	1/5	1/3	1/3	1	1	1	1	1	2	2	3
9	1/7	1/7	1/5	1/3	1/3	1	1	1	1	1	2	2	3
10	1/7	1/7	1/5	1/3	1/3	1	1	1	1	1	2	2	3
11	1/8	1/8	1/6	1/4	1/4	1/2	1/2	1/2	1/2	1/2	1	1	2
12	1/8	1/8	1/6	1/4	1/4	1/2	1/2	1/2	1/2	1/2	1	1	2
13	1/9	1/9	1/7	1/5	1/5	1/3	1/3	1/3	1/3	1/3	1/2	1/2	1

1. existing residential areas
2. distance to country roads and commune roads
3. distance to national roads and provincial roads
4. distance to primary schools and middle school
5. distance to health clinics
6. distance to grocery shops
7. distance to sports and recreations areas
8. distance to bypass under construction

9. distance to the Nysa Lake
10. distance to Nysa Kłodzka river
11. distance to railway lines
12. distance to cemeteries
13. distance to a sewage treatment

Next, matrix form was adopted.

$$P = \begin{bmatrix} 1,00 & 1,00 & 3,00 & 4,00 & 4,00 & 5,00 & 7,00 & 7,00 & 7,00 & 7,00 & 8,00 & 8,00 & 9,00 \\ 1,00 & 1,00 & 2,00 & 2,00 & 2,00 & 3,00 & 7,00 & 7,00 & 7,00 & 7,00 & 8,00 & 8,00 & 9,00 \\ 0,33 & 0,50 & 1,00 & 2,00 & 2,00 & 3,00 & 5,00 & 5,00 & 5,00 & 5,00 & 6,00 & 6,00 & 7,00 \\ 0,25 & 0,50 & 0,50 & 1,00 & 1,00 & 2,00 & 3,00 & 3,00 & 3,00 & 3,00 & 4,00 & 4,00 & 5,00 \\ 0,25 & 0,50 & 0,50 & 1,00 & 1,00 & 2,00 & 3,00 & 3,00 & 3,00 & 3,00 & 4,00 & 4,00 & 5,00 \\ 0,20 & 0,33 & 0,3 & 0,50 & 0,50 & 1,00 & 3,00 & 1,00 & 1,00 & 1,00 & 2,00 & 2,00 & 3,00 \\ 0,14 & 0,14 & 0,20 & 0,33 & 0,33 & 0,33 & 1,00 & 1,00 & 1,00 & 1,00 & 2,00 & 2,00 & 3,00 \\ 0,14 & 0,14 & 0,20 & 0,33 & 0,33 & 1,00 & 1,00 & 1,00 & 1,00 & 1,00 & 2,00 & 2,00 & 3,00 \\ 0,14 & 0,14 & 0,20 & 0,33 & 0,33 & 1,00 & 1,00 & 1,00 & 1,00 & 1,00 & 2,00 & 2,00 & 3,00 \\ 0,14 & 0,14 & 0,20 & 0,33 & 0,33 & 1,00 & 1,00 & 1,00 & 1,00 & 1,00 & 2,00 & 2,00 & 3,00 \\ 0,13 & 0,13 & 0,17 & 0,25 & 0,25 & 0,50 & 0,50 & 0,50 & 0,50 & 0,50 & 1,00 & 1,00 & 2,00 \\ 0,13 & 0,13 & 0,17 & 0,25 & 0,25 & 0,50 & 0,50 & 0,50 & 0,50 & 0,50 & 1,00 & 1,00 & 2,00 \\ 0,11 & 0,11 & 0,14 & 0,20 & 0,20 & 0,33 & 0,33 & 0,33 & 0,33 & 0,33 & 0,50 & 0,50 & 1,00 \end{bmatrix}$$

Next, a normalized weight vector was calculated ($\mathbf{w}^T$) using the matrix above. Then the vector was transposed, which means that it was formed by changed all the rows into columns. The vector is the result of arithmetic means in each row. It determines weights for each criterion.

$$\mathbf{w}^T = [0,24 \quad 0,20 \quad 0,14 \quad 0,09 \quad 0,09 \quad 0,04 \quad 0,03 \quad 0,04 \quad 0,04 \quad 0,04 \quad 0,02 \quad 0,02 \quad 0,01]$$

The vector $\mathbf{w}^T$ shows that the most important criteria for the house purpose are a distance from the existing residential area and a distance from district and commune roads. The least important are distance from cemeteries and the sewage treatment plant.

In order to verify the cohesion of the matrix, the consistency index of the matrix was calculated according to formula (1).

$$\lambda_{max} = [3,96 \quad 4,77 \quad 8,61 \quad 12,53 \quad 12,53 \quad 20,67 \quad 33,33 \quad 31,33 \quad 31,33 \quad 31,33 \quad 42,5 \quad 42,5 \quad 55,0] * \begin{bmatrix} 0,24 \\ 0,20 \\ 0,14 \\ 0,09 \\ 0,09 \\ 0,04 \\ 0,03 \\ 0,04 \\ 0,04 \\ 0,04 \\ 0,02 \\ 0,02 \\ 0,01 \end{bmatrix}$$

$$\lambda_{max}=13,20$$

The above value substituted into the formula for CI index:

$$CI = \frac{13,20 - 13}{13 - 1} = 0,0167$$

Next, the consistency ratio was calculated using a formula (2).

$$CR = \frac{0,0167}{1,56} = 0,01$$

The value of CR is less than 0,10. It means that the matrix is correct, and it should not be reconstructed.

The final step of this study was to analyze a suitability of sites according to variants included in the table 6. The *Weighted Sum* tool was used to overlay rasters. This tool provides the ability to multiply “each raster by their given weight and summing them together”. (source: *resources.acgis.com*). If criterion has a factor and a constraint, the product of these values was used.

Table 6. Weights for each factor

L.p.	Factors	Weight (variant I)	Weight (variant II)
1.	distance to existing buildings	0,08	0,24
2.	distance to roads:	0,08	0,20
	a) district and commune roads		
	b) national and provincial roads	0,08	0,14
3.	distance to primary schools and middle school	0,08	0,09
4.	distance to health clinics and pharmacies	0,08	0,09
5.	distance to grocery shops	0,08	0,04
6.	distance to sports and recreation facilities	0,08	0,03
7.	distance to cemeteries	0,08	0,04
8.	distance to sewage treatment	0,08	0,04
9.	distance to bypass under construction	0,08	0,04
10.	distance to railway lines	0,08	0,02
11.	distance to the Jezioro Nyskie	0,08	0,02
12.	distance to the Nysa Kłodzka river	0,08	0,01

6.3 Results of the WLC method

The Weighted Linear Combination provides the ability to obtain a housing development suitability map. Six classes of a suitability of areas were defined, using histograms of maps. The classes are defined as follows:

- areas of very high suitability for the residential development,
- areas of high suitability for the residential development,
- areas of moderate suitability for the residential development,
- areas of low suitability for the residential development,
- areas of very low suitability for the residential development,
- constraints.

The last class includes constraints- areas that are already developed or sites where buildings cannot be localized. Span ranges of classes are not equally. The Natural Breaks (Jenks) Distribution was used to classify these values. This method provides the ability to maximize the variance between classes and reduce difference between values in each class. In other words, this method takes into account natural breakdowns occurring in histograms.

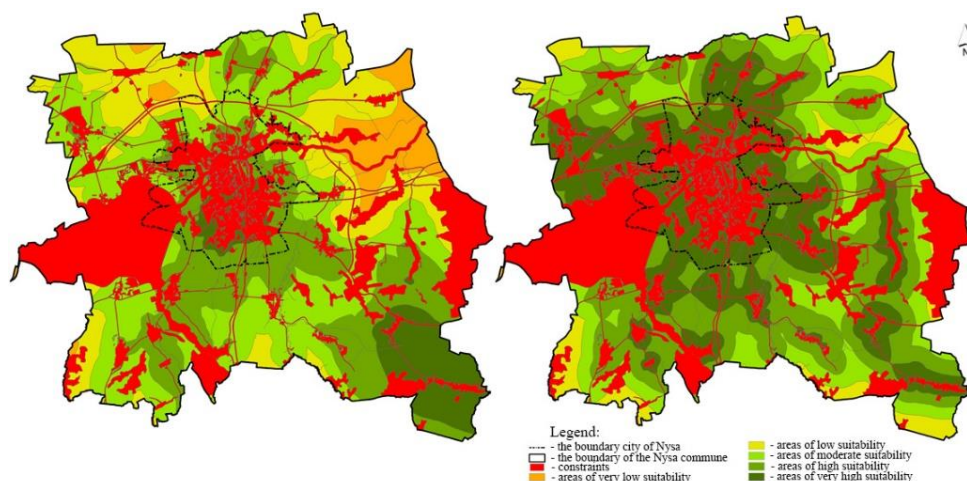


Fig. 2. Results of the WLC analysis- variant I **Fig. 3. Results of the WLC analysis- variant II**

source: own work

The analysis of the suitability of areas for new residential development (figures 2. and 3. and the table below) indicates the fact that results depend on the assigned weights. In the first variant, each of the criteria have the same value equal to 0,08. The percentage of sites of a very high suitability for housing development is four times smaller than in variant II, where weights for criteria were established based on the mathematical analysis.

Table 7. The WLC method- summary of results

	The suitability of land	Variant I		Variant II	
		area [ha]	percentage [%]	area [ha]	percentage [%]
1.	areas of very high suitability for residential development	1 364,39	6,3	5 040,37	23,1
2.	areas of high suitability for residential development	3 927,66	18,0	5 448,60	25,0
3.	areas of moderate suitability for residential development	5 440,57	25,0	3 337,42	15,4
4.	areas of low suitability for residential development	3 272,23	15,1	1 301,59	6,0
5.	areas of very low suitability for residential development	1 129,58	5,2	6,45	0,03
6.	constraints	6 600,26	30,4	6 600,26	30,4

source: own work

7 Conclusions

This research shows that multi- criteria analysis and GIS technology are useful and effective in spatial planning. Integration of multi- criteria decision analysis and GIS tools improves decision-making process. Results of such analysis may be helpful in a process of creating planning documents.

Results of Boolean method are simple to interpret. These products allow to find areas which are useful and useless for housing development. This method takes into account the legal regulations and therefore, it is extremely effective.

The second was the Weighted Linear Combination. AHP method was used to assign the correction weight to each criterion. Integration of these methods allowed to create more reliable results. The WLC method uses soft (factors) and hard (constraints) criteria. The result was the housing development suitability map. Results of WLC method refer to all areas in the Nysa commune, which means they may be helpful to prepare new planning documents.

Both methods used in this study, show high efficiency in spatial planning. GIS technology with multi- criteria analysis offer a means of supporting decisions, involving multiple criteria. Results are the most appropriate areas for the location of the investment. Depending on the situation, GIS offers the possibility to prepare the constraint map or a map, which show suitable and unless areas for definite purpose.

8 References

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A creek's hydrological model's generates in HEC-RAS

Nagy Bálint¹

¹Institute of Earth Sciences, Faculty of Science and Technology, University of Debrecen, Egyetem tér 1.,
4032, Debrecen, Hungary
nb.geo.1994@gmail.com

Abstract. During my research I have studied the Ronyva creek's 3.7 kilometers long stage and the Ronyva-spillway, both are located in Sátoraljaújhely. The area had significant flood damages in 2010 which resulted great reconstructions along both beds. During my work I used all the available data, I have made the hydrological model of the streams, then I ran flood models according to real and hypothetic flowrate in the built-out model-environment. By the help of the models the mostly endangered areas during an inundation can be predicted, and the bed's ability of excess water control can be studied.

The collection of significant amount of data is required to create the model-environment. To build the geometrical frame of the model a DEM (Digital Elevation Model) was needed which covered the whole study area including the riverbed. Based on field survey and satellite images the Manning's Roughness Coefficients of the bed and the surface has been identified. The further components have been measured on the basis of topographical maps in 1:10000 scale and the results of the field surveys. The built-in modul of ArcGIS, the HEC-GeoRAS was used to develop the geometrical frame. Further modelling processes were performed in HEC-RAS.

I have added the flowrate to the geometrical frame in HEC-RAS. The 1D permanent models have been run with the value of 160 m³/s and 142 m³/s flowrates. I have studied both bed's ability of excess water control. The first given value is the specified design discharge from the studies of '70s, the second value is the highest measured flowrate. As the results showed, in the case of both defined flowrates the flood was not successfully drained. The water covered a significant part of the study area. The generated flood maps can support the watermanagement and the decision-makers to elaborate prevention plans for floodings.

Keywords: flood, HEC-GeoRAS, HEC-RAS, hydrological modelling, Ronyva,

1 Introduction

In the last years and decades larger and larger climatic extremities affected by the climate change have characterized Hungary and the Carpathian basin. Due to this and the different anthropogenic effects the flow regime of the rivers and the creeks are altering. The increasing size of highwaters mean steady risks. The records of the flowrates fall after each, therefore the service of the flood barriers and the up-to-date protective plans stand first. For assistance of these, more and more hydrologic models started to be used in more and more projects also in Hungary in the last one and a half decade. I refer to the HEC-RAS software models, since I used them in this work: Kocsis (2013), Koncsos et al. (2011), Nagy (2009), Pregun et al. (1999), Réti (2012).

1.1 The hydrological modelling

First of all, the relevant discipline, the hydrology has to be defined. According to Urbanovszky (2002) the hydrology investigates the occurrence, the distribution, the exploration and the recording of the water on Earth, furthermore the circulation of the water in the nature. The processes of the nature are considerably different, as well as their modelling processes. The hydrological modelling is a more and more significant auxiliary science of the hydrology. This is also a complex process, like all the model-using sciences. Passed processes can be reproduced and serious water management problems can be answered by means of the complex hydrological models, they can facilitate the decision-making of the engineers (Sztatmári, 2013). According to Sztatmári (2013) the category of the hydrological modelling is considered wider. It includes the collecting, storing, assimilation, modelling, analysis of the data, respectively the presentation of the gained data and the drawn conclusions, therefore he nominates as hydroinformatics. The working phases mentioned above constitute the process of the mapping of the reality.

1.2 The Ronyva creek and its problem

The Ronyva creek, the subject of my research is a stream located in Borsod-Abaúj-Zemplén County, in the North-eastern part of Hungary (Fig. 1). Its major length represents the border line between Slovakia and Hungary. It belongs to the catchment area of the river Tisza via river Bodrog. In this paper I concentrate the stage of the creek

in the area of Sátoraljaújhely. By the border of the town, the stream branches two arms: the main arm of the border bed (Határ-meder) and the Ronyva-spillway. The modelling process dwell on the 3,7 km stage of the former, between the 2+601–6+338 RKM's so long, as the entirety 2,2 km of the latter.

The floods of the stream meant a constant hazard to the deeper situated parts of the settlement also in the middle ages. The main reason of this is the very torrent character of the stream. The flowrate of the creek use to rarely exceed the $1 \text{ m}^3/\text{s}$, whereas it could reach the $300 \text{ m}^3/\text{s}$ during its flood periods. The present stages and shapes of the beds are completely resulted by anthropogenic impact (Serf 1941).

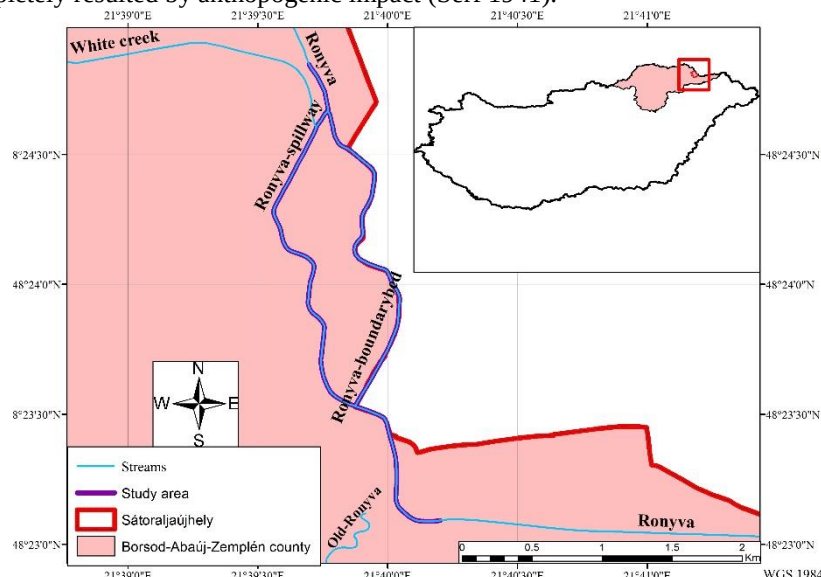


Fig. 1. The location of the study area in Hungary.

The first control works carried out in the 19th century. The channel, born with the building of the embankment of the railway line (presently belongs to Slovakia) was originally meant to spillway, still the creek relocated its bed by the cutting the parting. After some corrections, nowadays this means the so-called border bed of the Ronyva. From that time the White Creek (Fehér-patak) run across the town in the former bed. However it did not mean solution for the flood problems, since it could drain off merely a $100 \text{ m}^3/\text{s}$ flood without overflow. The adequate control of the stream was aggravated by the building directly to the banks and the railway line on the Slovakian bank (Serf 1941).

Because of the flood exposure the stream was controlled in the 1970s. The first step was the cutting of the bed in the southern part of the settlement; therefore the so-called Old Ronyva (Ó-Ronyva) was disconnected. Instead of that, new bed was dug in direction of East, which streams to river Bodrog. In parallel with the narrow bed, a spillway was built; furthermore the bed of the border was corrected. During the implementation, $160 \text{ m}^3/\text{s}$ $Q_{1\%}$ rate of great flow was considered in the segment of the waterworks building of Sátoraljaújhely at the Ronyva. The Establishment of principles was that the flow splitter above the border and the spillway divides the water of the creek between the two beds in the ratio of $1/3-2/3$. This means 106 and $54 \text{ m}^3/\text{s}$ in this particular case. These steps accelerated the floods, as regards increased the flow capacity of the beds (Molnár, 2011).

In 2010 May and June, considerably amount of sudden precipitation fall on the catchment area, a large parts of the town was inundated by the increased water level 3 times. In the next year a number of reconstructions were initiated. The embankments were heightened, however they was raised by parapet walls where the buildings located too close (Molnár, 2011).

2 Subject and method

The first step of the modelling was the building of the geometrical frame. The adequate description of the surface is required for the accuracy of the HEC-RAS calculations. The steps of these are the follows:

- generating a digital elevation model (DEM) about the streams and the surroundings
- determination of the Manning's Roughness Coefficients of the surface and the bed
- subsequent data registrations in HEC-GeoRAS: river stream centerlines, banks, flowpaths, cross-sections, bridges, ineffective flow areas, blocked obstructions
- concatenation of the above mentioned data to a homogenous frame in HEC-RAS

2.1 The generating of the DEM

In order to plot the altitudes of the surface 1:10 000 scaled topographic maps were applied. The depth of the beds and the height of the embankments do not appear at these maps, therefore the data were gained by the processing of the paper-based line-, and cross-sections, which were received from the North-Hungarian Water Conservancy Directorate (Észak-magyarországi Vízügyi Igazgatóság). During the data gaining maps and sections were digitized in ArcGIS software. The TIN (Triangulated Irregular Network) model was generated from the shape files. Using this model in HEC-RAS is inexpedient, so it was transferred to GRID format. The software is capable of managing more types of GRIDs, still my experiences say the Binary Floating Point Raster (*.flt) format is easiest to import. The resolution of the model is 1 metre, because of the weakness of the bed, since the relatively small size of the sample area allows the using of so small resolution. The resolution of the hydrologic model is also 1 metre.

2.2 The determination of the Manning's Roughness Coefficients

The texture, the shape and the vegetation-cover of the surface have essential effect to the stream of the surface water. The cover, direction, and vegetation of the bed especially modify the stream. The roughness of the surface and the bed is expressed with the Manning's Roughness Coefficients (Chow, 1959). The equation of Manning is used to the exemplification of the energy wastes caused by the surface friction. Among the elements of the equation, the most difficult to determine is the roughness coefficients, the n value. This has to represent those factors, what can obstruct the stream. In order to define the most accurate n value possible, relying on the results of the persons with the greatest experience is recommended (Phillips-Tadayon, 2007).

In order to determine the roughness value, two methods were applied. To investigate the greater surroundings of the sample area, a LANDSAT-8 OLI satellite image (photographed on 5th July 2015.) was used, the analysis of that has happened in IDRISI softwares. The satellite image has 30 m resolution, thus it was perfect to identify the arable lands, fields and forests in the surroundings of the town. The interpretation was completed by the methods of the monitored classification and the Maximum Likelihood Classification. The former operation provides six types: surface waters, forests, fields and grasslands, arable lands1, arable lands2, arable lands3. The gained thematic surface cover map was transferred to a vector file in ArcGIS, and the correspondent roughness coefficients were assigned.

The different surfaces couldn't be exactly identified in the municipal area of Sátoraljaújhely, because the satellite image has 30 m resolution. Therefore the classification was manual here on the basis of a World Imagery image. Those areas were concerned, what are covered by the cross-sections recorded in HEC-GeoRAS. The same method was used in classification of the beds and the inundation areas, moreover it was completed with the own empiric surveys. Then the three files were integrated, thus the data base of the roughness coefficients of the area was completed.

2.3 The HEC-GeoRAS

The HEC GeoRAS is a free built-in module of the ArcGIS, it was collectively developed by the HEC (Hydrologic Engineering Center) and the Esri. It can be applied to the importation of the geometric data to the HEC-RAS, and the procession of the simulations exported from the HEC-RAS (Internet-1).

The HEC-GeoRAS is capable to integrate the former components of the geometric frame to a packet, which is perfectly interpreted by the HEC-RAS (Fig. 2). This program was applied to convert the DEM and the Manning's Roughness Coefficients to the HEC-RAS. The DEM represents the basis of the altitude data of the different layers. After saving, the module creates a geodatabase in the ArcGIS, where all the recorded files can be managed (Merwade, 2012).

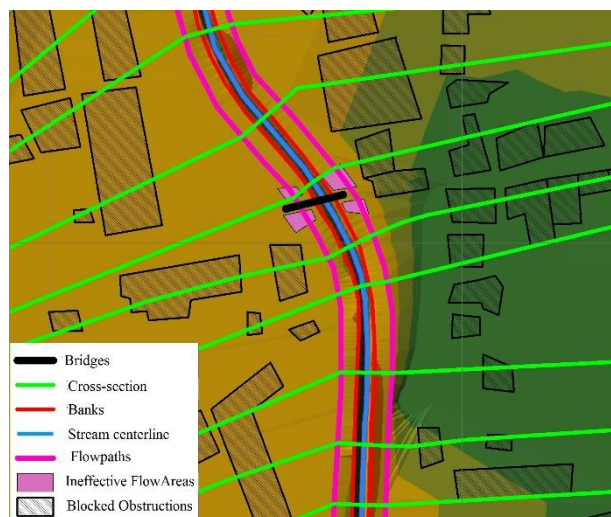


Fig. 2. A detail of the geometric frame in HEC-GeoRAS.

The next step was to record the stream centerlines. In the research area the flow splitter divides the Ronyva, it branches and then joins again therefore three sections were separated: the Ronyva has upper, middle and lower sections. The Ronyva-spillway was managed equally with the Ronyva, because it streams the water of that. The banks and the flowpaths were checked by the topographic maps, the individual surveys and the Google Earth images. The banks distinguish the main bed from the higher parts of the inundation areas. Locating the banks helps the ordering of the different features to the cross sections (Merwade, 2012).

The most important items of the geometric survey of a stream are the cross-sections. More HEC-RAS attributes can be counted and located by the help of the stream centerlines and flowpaths. For instance, the bank points can be generated in the crossings of the cross-section and the banks. They specify the border of the main bed and the inundation area (Merwade, 2012). The lines of the cross-sections were specified manually, because the cross-sections couldn't meet, furthermore this helped to the gaining of the most possible information about the research area. The cross-sections were specified thickly in the more important inhabited areas, while they were specified sparsely in the outskirts. The maximum distance between two cross-sections was 60 m; the average distance was 40 m with 10 m deviation. They were specified directly before and after the bridges, because the stream is deeply influenced by the bridges, therefore exact information is required about them.

Moreover, different structures, objects, perhaps special areas can be specified in the HEC-GeoRAS: the eight bridges, the accidentally threatened buildings in the surroundings of the streams as blocked objects, the areas behind the piers as ineffective flow areas were identified in the geometric model. The piers tighten the stream as long as the blocked objects have diversionary effect. The value of the stream is 0 in their areas, because the way of the water is obstructed. The houses can hydrate some amount of water during the floods, but it was disregarded in the models (Merwade, 2012). The World Imagery image was used again during the digitizing of the former elements.

2.4 Modelling in HEC-RAS

The Hydrologic Engineering Center of the Department of US Army Corps of Engineers has been developing the HEC-RAS software since 1964. It is available free for everyone, since it has been developed at public expense. It has more separated modules. Permanent streams in 1D or non-permanent streams in 1D and 2D can be investigated by the help of it (Internet-2).

In order to run a HEC-RAS model 3 files have to be created:

- A geometric file
- A file with the boundary conditions of the stream, it can be permanent, non permanent or quasi-non-permanent (based on the used data)
- The two files above are joined by a "Plan" type file. This can contain the determining data for the running of the model.

After the importing into the HEC-RAS, the entered geometric data can be edited and upgraded by new data in the Geometric Data menu of the HEC-RAS. Only the localization of the bridge can be achieved in HEC-GeoRAS, the subsequent data must be entered in HEC-RAS. The border section of the bridges and more data (e.g. number of piers, width and height of the bridge) are required to model the bridges (Bonner-Brunner, 1996). The altitude data

were found in the Nort-Hungarian Water Conservancy Directorate's hydrologic line sections, they have centimetre accuracy.

The profiles (in case of 1D) and the boundary conditions (in case of 2D) what shows, where the stream step in and out from the model area are entered to the geometric file. The types of them can be given in the marginal condition file. The type is determined by character of the flow: is it inflow, outflow or interflow. The Flow Hydrograph type requires time-based streamflow data; the Stage Hydrograph type needs water stage data. The general value of falling gradient in the sample area is required to the Normal Depth type, used in the case of discharge.

The Plan files contain the temporal pass of the modelling, they give the temporal scales of calculations and output data. These files have to connect the geometric file and a marginal condition file (depended on the type of the modelling).

The permanent stream tests don't require temporal limit, however one rate of flow value have to be assigned to all sections. The test is used to the hydrologic investigation of the streamflow, the foreshore and the inundation area. Molnár's (2011) referent streamflow values were used in these works. The 142 and 160 m³/s streamflow values were divided between the border bed and the spillway in the ratio of $1/3-2/3$ as it determined in the time of the building. The boundary conditions were the upper and lower end of the Ronyva. In case of the latter, 0,001 value of the Normal Depth was given, as the general gradient of the relief.

3 Conclusions

The height above the sea level is between 95,5 and 107 m in the research area. According to my hypothesis, the most threatened area by the floods are the area between the two beds and the 300–400 m width stripe on the right bank of the Ronyva-spillway. The height is gently declining in the direction of South. The depth of the beds varies between 96,94 and 100,16 m in the spillway, while it varies between 95,00 and 100,35 m in the border bed of the Ronyva. The height difference is generally 3–4 m between the dike and the bottom.

The manually categorized land cover data distinguish the build-up areas and the roads within the town. The sections with different roughness were represented with the same method in the case of bed and inundation plains, too. After the union of the two land cover database, the Manning's Roughness Coefficients values were assigned to the different categories (Table 1). Roughness Coefficients in winter were used in the case of vegetation, where it was possible.

In order to find the most endangered areas, extreme values were taken for basis during the modelling (Fig. 3). The greatest difference between the two basis streamflows is that the border bed also inundates some areas. In case of 160 m³/s streamflow, almost 6,8 hectares more area could be flooded.

Table 1. The Manning's Roughness Coefficients of the surface and the bed (Chow, 1959).

Code	Channel type and description	<i>n</i>
Short grass	Short grass	0.025
High grass	High grass	0.035
Light brush and trees	Light brush and tress, in winter	0.035
Medium brush 1	Medium to dense brush, in winter (minimum)	0.045
Medium brush 2	Medium to dense brush, in winter (normal)	0.070
Fields and grasslands	Scattered brush, heavy weeds	0.035
Weald (city)	Cleared land with tree stump, no sprouts	0.030
Forest	Same as above, but with heavy growth of sprouts	0.060
<i>Cultivated areas:</i>		
Arable lands 1	Mature field crops	0.030
Arable lands 2	Mature row crops	0.025
Arable lands 3	Mature field crops	0.030
Roads	Asphalt, rough	0.016
Built-up area	Houses, courts, difficult definable gardens	0,030
Waters	Lakes and streams	0
Bed 1	Sluggish reaches, weedy, deep pools	0.050
Bed 2	Dense weeds or aquatic plants in deep channels	0.035
Bed 3	Clean, winding, some pools and shoals, some weed and stones	0.035
Bed 4	Clean, straight, full stage, no rifts or deep poolswith more stones and weeds	0.040

Bed 5	Dragline-excavated or dredged, no vegetation	0.025
Bed 6	Stony bottom and weedy banks	0.025

The model had to be validated by real data (Fig. 4). The map of in 2010 inundated streets was used, which was received from the city government. The map was not entirely accurate, but we can see, they are the same (in the polygon of the inundated areas all is not flooded). The streamflow could be probably more than $142 \text{ m}^3/\text{s}$. Inadequate functioning of the flow splitter could causes the large-scale inundations along the border bed.

On the basis of the available databases a model-environment was built and models were run there. These models can help in the defence and location of the most threatened areas and real-estate properties in case of the further possible floods. It can be determined, that the model of the spillway bed is not capable to discharge greater inundations, however the age of the available data can affect this. After the join, the bed is more available to discharge the floods. Due to the broader foreshores, the volume and the capacity of the bed increase. The narrowness of the spillway in the built-up area can causes the large-scale inundations is case of extreme streamflows. Actually, the foreshore of the border bed has typically 20–25 m width; the same value of the spillway is less than 10 m. After the join of the two sections, the foreshore can be 35–50 wide.

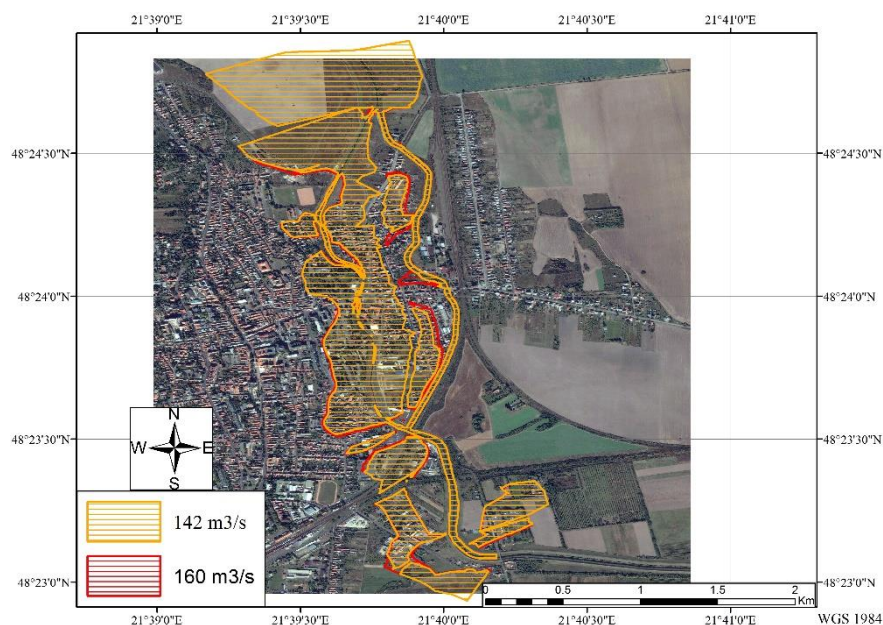


Fig. 3. The inundated areas in case of $142 \text{ m}^3/\text{s}$ and $160 \text{ m}^3/\text{s}$ streamflow.

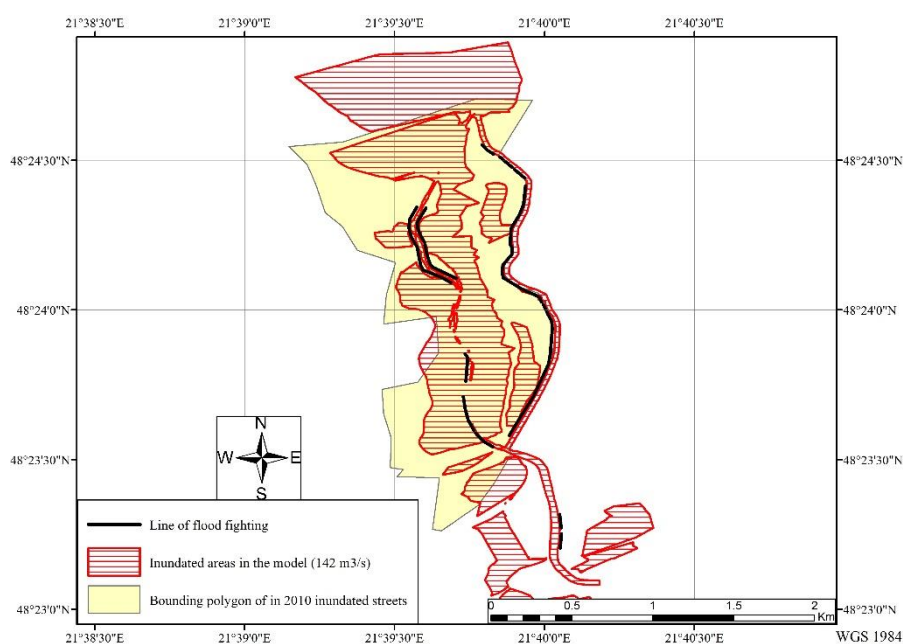


Fig. 4. Validation of the model with flooding data from 2010.

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3.1.1 Reference of Internet

INTERNET-1: US Army Corps of Engineers, Hydrologic Engineering Center, HEC-GeoRAS software URL: <http://www.hec.usace.army.mil/software/hec-georas/>

INTERNET-2: US Army Corps of Engineers, Hydrologic Engineering Center, HEC-RAS software URL: <http://www.hec.usace.army.mil/software/hec-ras/>

Analysis of the potential of solar energy in urban space for example Wrocław (province. Lower Silesia, Poland)

Maciej Nickarz

Wrocław University of Environment and Life Sciences

Contact: maciej.nickarz@gmail.com

Abstract:

The drastic increase of city contamination by smog, oxides of carbon and nitrogen are often the result of the production of energy and heat from traditional fuels - fossil fuels. Solutions for this situation is seen in the production of energy from renewable sources that do not cause such a significant burden on the environment. Nowadays, there is more and more often propagating the idea of production and use of clean energy by citizen, known as prosumer. This model is very well known in Western Europe, and for several years attempts are being made to transfer it to the Polish realities.

Therefore, this work assess the availability of alternative energy sources in the urban area of Wrocław (province Lower Silesia, Poland). The analyzes focused on the possibilities of location of solar panels on the roofs of buildings and estimation of the solar potential. The placement of solar panels on the buildings roofs allows the use of existing space, without the need to arrange the extra space in the urban tissue.

The analysis of the solar potential were conducted for Grunwaldzki square area (in the central part of the city), characterized by a variety of residential and service buildings (from former German tenement by skyscrapers, shopping mall ending). There was made a selection of 1km² testing area from Grunwaldzki square, which was used to map the potential of solar energy. The analysis uses 3D models of buildings and Digital Terrain Model. There were also used assumptions, that the roofs, where could be localize solar panels, should be exposed south (from 150 ° to 210 °), the decline in the roof slope should be from 20 ° to 40 °, the sunlight of selected objects should be at least 1000kWh / m² / year and the recommended area of building roof was adopted as 70m². Moreover, a decrease of the land on which the buildings are located should be in the range of 0 ° to 6 °.

The conducted research allowed to determine the potential of solar energy in selected part of the city. The variety of buildings allowed also to analyze the relationship between the type of building, size and the type of roof of it and the possibilities of the energy of the building.

Keywords: the potential of solar, renewable energy, urban space

1 Introduction

Air quality in Wrocław getting worse. A big impact on this situation have been seen in increasing number of cars and obsolete heating installations, but also in quantity of electricity consumed by residents of Wrocław. This energy comes largely from coal-fired power plant and heat and power plant[1]. The solution for this situation is seen in the production of energy from renewable resources, as these are not a source of emission of harmful substances or noise, do not increase the greenhouse effect, which may contribute to environmental protection and energy security[2].

These assumptions contained in Directive 2009/28/WE. This Directive, as one of the main objectives, puts a 20% share of renewable energy in overall EU energy consumption by 2020[3]. Moreover, the share of renewable energy in overall energy consumption is determined for each EU country. For Polish this target was set at 15%[4]. The investment in this sector and the discharge of EU renewable energy sources guidelines could be achieved ie. prosumers[5].

Polish amendment to the Act on Renewable Energy Resources (adopted in June 2016) determines prosumer as a person simultaneously produces and uses energy (eg. electricity). According to this amendment, prosumers will receive the so-called prosumer discounts, which is connect with settlement of the difference between the amount of energy that prosumer produced (eg. using photovoltaic panels) and used (when the sun does not shine and the panel does not produce electricity)[6]. The concept of prosumer energy development may be a chance for the high-density urban space in context of the use of renewable resources. The same, there could be conducted analyzes of the potential of solar energy in cities, aiming to identify the buildings, which could

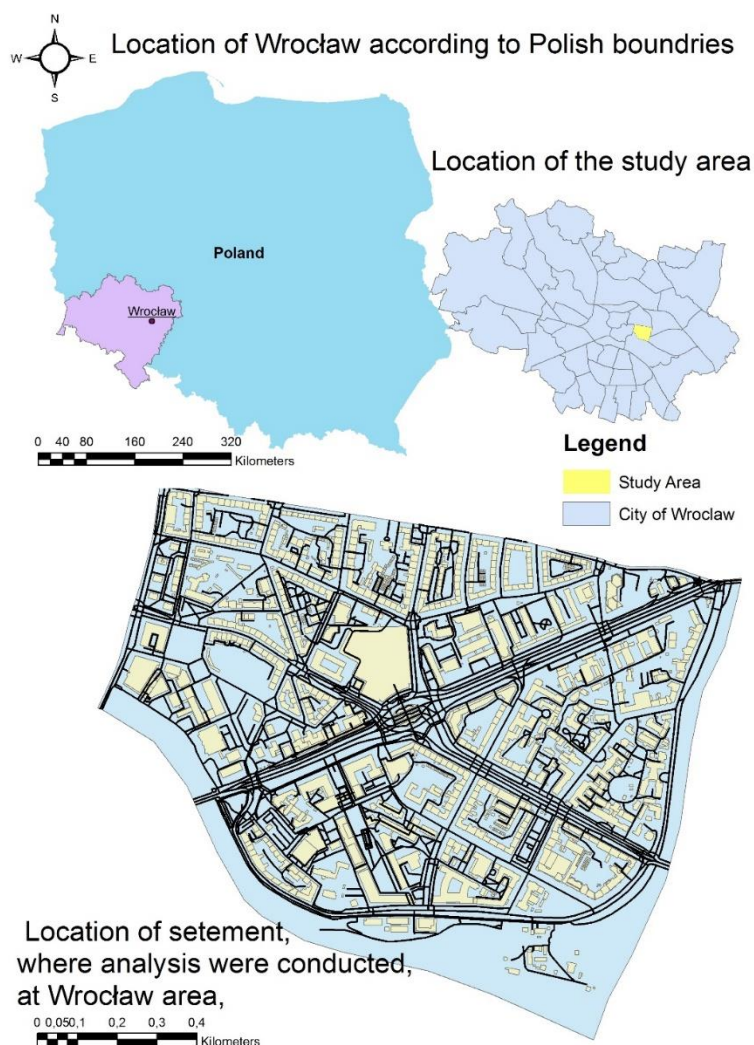
be invested by photovoltaics contribution. Especially, that nearly 70% of European energy is produced and consumed in cities[7].

Therefore, the aim of this study is to determine the potential of solar energy in selected part of the city. The variety of construction also allowed to examine the relationship between building type, size, type of roof and the possibilities of energy building.

2 Metodology

2.1 Research Area

The analysis of the potential of solar is conducted in the area of Grunwaldzki square located in the central part of the Wrocław city. This area is characterized by a variety of residential and service ie. former German tenement,skyscrapers or shopping mall. It should also be mentioned that this place is the largest academic centers in Wrocław.



Map 1 Location of the study area

2.2 Data

The analysis were conducted based on a digital terrain model derived from the European Environment Agency (EEA), available at Copernicus Land Monitoring Service, and part of three-dimensional models of buildings from 2006 for Square Grunwaldzki settlement, which were obtained from the Information Department of Wrocław Spatial Development Office.

2.3 Methodology

The first step of the analysis was the appropriate data preparation and acquisition of walls and roofs geometry of the building models using City Engine software.

Thus obtained materials allowed to make further analysis.

Some of used methodological assumptions (ie. features taking into account for this analysis or changing of some rasters into point cloud in order to create spatial join with roof layer) are based on the Caroline Carl doctoral thesis from the University of Southern California^[12].

The analysis of potential solar includes such features as:

- 1) The roofs declines
- 2) The exposition of buildings
- 3) The surface of the roof
- 4) The buildingsinsolation

Therefore, the second step was connected with calculations of roof declines using a *Slope* tool available at ArcGIS software. The resulting raster was turned into a point cloud using the *Raster to Point* tool. This action allowed to join obtained point layer with a vector layer of buildings based on spatial join which allowed to estimate the average decline for the roof. This resulted with a vector layer, which had to be converted to raster layer for further analysis. This conversion was made using *Polygon to Raster* tool. The resulting raster were reclassified with *Reclassify* tool based on assumptions for the installation of solar panels in the Polish conditions. These assumptions indicate that the installation could be made for the roof declines from 30° up to 60°.

Therefore, the reclassification of the raster was made based on the following values:

- up to 30° - value of 1;
- 30°-40° - value of 3;
- from 40° to 60° - 2;
- more than 60° - 1.

The next step of the analysis was to determine exposure of buildings. This analysis was performed by using the *Aspect* tool, thereby obtaining information regarding the location of buildings in relation to the directions of the world. The obtained raster was reclassified by assigning values to individual exposures depending on the direction. Thus, 5pts obtained buildings with southern exposure, 4 points south-east and south-west, 2 pts. exposure to the north-west and north-east and 1 point for northern exposure. Simillary as in the case of estimating declines, there have to be done reclassification of raster interface layer into a point cloud, spatial join of it with vector layer of roofs, which allowed to calculate the average exposure of the roof. The resultant spatial information was turned back to a raster layer.

A later stage of the analysis was to calculate roof surfaces using the *Calculate Geometry* tool. Such a study was necessary because of the profitable assumption of photovoltaic investments. The realization of such system becomes profitable when roof area has approx. 70m². After estimating the area of roofs, this vector layer was turned into a raster layer. Then, using a tool *Reclass*, the area was divided into three categories:

- up to 60m² - 1 point
- 60-70m² - 2 points
- over 70m² - 3 points

The last point of this part of the analysis was to determine the solar radiation using *Area Solar Radiation* tools. This analysis calculated solar radiation for 2006, the same year as building. Furthermore, there were needs to change obtained raster into point cloud using *Raster to Point* tool, which were then spatially joined with roofs and finally converted into a raster and- reclassified.

Thereby gained the last of the components of the analysis of the potential of solar energy. The reclassified rasters of roofs declines, sunlight, exposure and the surface of the roof were the same input features to obtain synthetic information regarding to the possibility of location solar panels on the roofs of buildings. Therefore, this

step of analysis were made by using *Weighted Sum* tool, which allowed to summarize value of the rasters from previous analyzes. The weight of each of them was determined as 1. The obtained result showed conditions of buildings to install a photovoltaic system. Obtained summary values were classified into following compartments, ie,:

- less than 4 points - areas not suitable
- 4-7 points - areas suitable poorly
- 7-8 points - areas suitable half
- 12 points - areas suitable fully

3 The results of the analyzes

A Large part of the buildings in the study area are suitable for photovoltaic installations. This is due to their proper exposure and a small percentage of shading caused by proximity to higher buildings. Such conditions could exist, because in the area outweigh the high multi-family buildings, where the roofs are flat or inclined at a slight angle, and above all, occupy a lot of space.

Research area also consists of medium and low service buildings, and these two groups poorly, or not at all suited to the installation. This synergistic combination of components allows for maximum utilization of the installation locations marked on the map in red and half-hearted performance marked on map as yellow. In places marked on the map in blue - plant capacity would be too low to pay during the life cycle of the panels. The white areas do not meet the relevant requirements. The map below shows the results of analyzes.



Fig.1.: The results of the analyzes
Source: Own elaboration

Despite the fact, that the analysis of solar building potential did not obtain the maximum results, there is still a lot of suitable buildings for photovoltaic panels installation. Hence it could be concluded, that multi-family housing has a greater potential to established panels than single-family housing. This conclusion could be seen on analyzed parcel of Grunwaldzki Square area.

4 Conclusion

Taking into account obtained results, the use of photovoltaic cells would create prosumer activity, in which electricity consumers are also the producers. This solution has already been used, among others, on the roof of a block on Świeradowska 65 street in Wrocław, located outside analyzed area, which belongs to the cooperative residents who pay lower electricity bills.

In this approach, according to a greater number of buildings, their distribution and exposure, the benefits would be even greater.

The use of this technology on a larger scale would allow to limit production of energy from power plants or electro-heating plants, which are coal-fired. This would result in reducing emissions of harmful dust, which are responsible ie. for the effect of smog.

The combination of a pair of thermal solar technology with steam coal power plant cycle gives possibility of conversion up to 40% of solar energy into electrical energy (for the larger scale of photovoltaic systems, which have much higher cost of capital, this share is approx. 13%)[9].

This solar solution could allow to get additional benefits for Wrocław city. Especially during the time of applying to become European Green Capital 2019. Therefore, the conditions for the grant of such a title is dependent on:

- cooperation and partnership between the government, businesses and citizens aimed at the development and improvement of living conditions in the city,
- innovative solutions for pollution reduction,
- an integrated approach to urban management to ensure a positive and long-term effects. [11]

Poland produces more than 8 tons of CO₂ per capita. The installation of solar panels could allow to reduce the burning of fossil fuels and contributes to a significant reduction in CO₂ emissions. The medium-sized installation of solar collectors (6 m², ie. approx. 3 solar panels) could reduce the average emissions of 1 ton of CO₂, which is as much as produce a car within year (at approx. 7 thousand. km driven). One home solar system is similar with reduction of 1 tonne of CO₂ / year [12]

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Designing maps for colorblind users - the usability of an alternative color coding system

Dajana Snopková^{1*}, Petr Kubíček¹

¹Department of Geography, Faculty of Science, Masaryk University, Kotlářská 2,
602 00 Brno, Czech Republic

*dajana.snopkova@gmail.com

Abstract. When working with inappropriately designed maps, colorblind people often experience difficulties with quick and correct inference of visualised information. There have been several researches carried out, which try to solve this problem by designing adapted maps, including modified color scales or different visualization methods (for example hatching). Presented paper provides testing of the ColorAdd color coding system's potential as another visualization method in cartography. The logical color coding system, in its origin, replaces colors with point symbols. Since the designed research was explorative and included specific population sample, an Eye Tracking method enabling collection of both qualitative and quantitative data was chosen. The test itself consisted of two map types, one colored and one with symbols representing colors. The test was carried out on sample of 10 persons with color vision impairment and 10 persons with standard vision. Results of the study revealed that there are statistically significant differences between compared groups in case of fixation count and Scan Path length. During the interviews subjects admitted that most of them were able to imagine using Color Add system in everyday use, some of them with slight modifications. Half of the tested persons with color vision impairment preferred coded variant.

Keywords: color-blindness, ColorAdd color coding system, Eye Tracking, cognitive experiment, map design

With the rise of technological revolution, the production of maps became cheaper and less time-consuming. Therefore, it is easier to accommodate maps for the needs of individuals or specific minorities. Colorblind people are one of many minorities.

Considering a soccer game, it is almost certain, that at least two men in the field are colorblind. Although this impairment does not prevent them from playing soccer professionally, they experience numerous difficulties in everyday life, from buying ripe bananas to inability to drive in certain countries, including reading maps. Approximately 8.5 % of world-wide population (mostly men) is affected by color vision impairment. There are more types of color-blindness, the most common being deuteranopy – impairment of green cones [8].

There have been several studies carried out ([7], [3], [2], [9], [4], [6], [5]) providing advices for colorblind-friendly map design or suggestions of alternative visualization techniques, including modified color scales or for example hatching.

In 1983 Bertin published his work on semiology of graphics. Although Bertin himself has not supported his theories with practical research (only with his experience from praxis), his work has influenced map design greatly. Mostly cited was his definition of retinal graphic variables: size, shape, value, color, orientation, and texture with their characteristics: selectiveness, associativeness, quantity, order, and length. Definition of these retinal variables became essential in map design and motivated this research. Although color and shape are by human eye perceived differently, Bertin assigned them similar characteristics. Thus, it is possible to encode the same information in variation of color or shape. According to several authors ([4], [6]) color vision impaired individuals are better in distinguishing shapes and structures than colors. This assumption was the main impulse for empirical study testing the performance of users on shape variable versus color variable visualization of the same dataset.

The problematics of replacing color with variation of shape was resolved by finding existing color coding systems. The ColorAdd color coding system [1] was chosen for this purpose as it uses encoding motivated in mixing paint colors. This study represents the initial testing of the potential of ColorAdd color coding system as another visualization method in cartography.

Since the designed research was explorative and included only specific population sample, an Eye Tracking method enabling collection of both qualitative and quantitative data was chosen. Combined with interviews, it provided complex data from the conducted testing. The within subject test consisted of two map types, one colored and one with symbols representing colors. The maps were representing spatial distribution of four different characteristics (criminality, unemployment, religiosity, and attained university education) on fictional administrative units. Each characteristic had a value on a scale high-average-low, represented with three color shades. Cartographic visualization method of diagram map (quartered circles) was chosen. The quarter was either colored with specific color, or obtained a specific color coding symbol. The test was carried out on sample of 10 persons with color vision impairment and 10 persons with standard vision, so it was possible to mutually compare their performance.

Results of the study revealed that there are statistically significant differences between compared groups in case of fixation count and Scan Path length. With increasing difficulty of questions, colorblind subjects performed

better on coded map variants. During the interviews subjects admitted that most of them were able to imagine using ColorAdd system in everyday use, some of them with slight modifications. Half of the tested persons with color vision impairment preferred coded variant. Most of the tested subjects did not create association between colors and color coding system during testing. However, the knowledge of color was not needed to correctly answer given questions.

We can conclude that color coding system ColorAdd proved to have potential in cartography. Most of the subjects found it logical and easy to understand. Presented exploratory study offers the initial contribution of the alternative coding system usability and serves as a base for further research.

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Comparative analysis of potential solar radiation on rooftops for different types of land use. A case study in Wrocław city (Lower Silesia, Poland)

Tomasz Stula

Wrocław University of Environmental and Life Sciences

Contact: tomasz.stula@gmail.com

Abstract. More than 80% of people, who live in cities breath polluted air. Primarily pollution comes from power stations (mostly coal power stations) and car engines. According to European guidelines, every member of EU should strive to minimalism air pollution, and initiate ecological tools and solutions, which would allow to keep air quality on proper standards. This policy assumes abandoning from producing energy from fossil sources for so called clean energy. Base of this challenge, there could be conducted analysis in the field of energy potential e.g. solar potential. Those analysis could be a decision support tool used for renewable resources management and increase of its' use in cities.

The purpose of this research was to define the solar energy potential for solar collectors' localisations. This analysis take into account land use, types of buildings and roof types in the specific part of city. The calculation of solar potential was based on digital terrain model and 3D building models data.

This analysis was conducted for three areas, characterized by different land use. First of analysed areas is characterized by dominance of low, high-density detached house buildings, with small ratio of high apartment blocks. The second area is typified by majority of high, compact apartment blocks and commercial buildings. Third area is characterized by detached house buildings in big rectangular arteries. Each type of building is characterized by different surface, angle and exposure of roofs.

Analysis of solar potential were conducted using ArcGIS software and its Desktop Tools, which includes tools for solar potential analysis. Research let to estimate solar potential for each of analysed areas, what was a base of comparative analysis.

Conducted research could be decision support tool for process of planning the development of new or modernization of existing investments. It may have effect on reducing power-drain from conventional sources to unconventional, causing reduce of pollution in cities.

Keywords: solar power, renewable source of power, urban spaces

1. Introduction

Nowadays people live in an worsening condition of the environment. The number of contaminated air is still increasing, and the result of it is often a phenomenon of smog in cities. It creates mainly in the areas with a large development of industry, heavy car traffic and related with them exhaust and pollution emissions[1]. An example of such a city is Wrocław. A lot of contaminations came from coal burning in power plant and cogeneration power station. Electricity consumption per person per year is still increasing. According to data of the Ministry of Economy in Poland in the year 2000, the average power consumption was 3592 kWh per capita and during period 2008-2012, it exceed the level of 4000 kWh per capita[2]. An alternative to traditional methods for energy production could be renewable resources of power such as wind farm, solar or hydropower. The level of use of these generators is still very low. In Poland in 2009, the production of energy from renewable resources was 253 153 Terajoules, which represents 9% of total primary energy. The largest share of this production is energy from biomass (85,8%). Furthermore, the proportion of solar energy was just 0.033%, which was almost the last position from all energy production based on renewable resources[3].

According to these aspects, the purpose of this analysis is to compare the potential of solar energy for different types of buildings in different parts of Wrocław city. Especially, that in Poland this kind of power production is consider as uneconomic, so there is general reluctance to invest in this type of solution[4]. The results of this research have to verified the potential of buildings to locate on their rooftops photovoltaic cells to produce electricity. This efficacy depends on criteria as: the type of building, roof area, slope and aspect relative to the directions of world. The solution for photovoltaic panels use is very beneficial, especially during the times when cities getting a greater density and solar panels could utilize existing space for the production of renewable sources of energy. This analysis could be reason to the expand this type of power generators, and in the results to increase the general use of unconventional energy resources. It is envisaged, in particular, that according to the directive of

the European Union, Poland has to increase the share of energy sources to 15% of the overall power consumption[5].

2. Materials and methods

2.1 Study area

The comparative analysis of the solar potential was conducted for three areas of Wrocław with a different type of land use. The city is located in the south-western part in Poland (Lower Silesian). One of the research areas is Grunwaldzki square, located in the center of the city, which is characterized by compact mixed construction. There are several blocks of flats, old German buildings, as well as service buildings-shopping center, an office building and a number of buildings of universities. Another area is in estate called Biskupin (eastern part of the city), where is located low detached house buildings and high apartment blocks. Each of that types of buildings is in the form of rectangular artery. According to research, it is an area of bad quality of air, exceeding the legal limit of dust concentration. The majority of inhabitants claimed also that there is a bad air conditions [6]. The last of the analyzed areas is the estate Nowy Dwór, located in the western part of Wrocław. It is characterized by high apartment blocks. In this studies was considered a parcel of each of these area of about 1 km² (square 1 x 1 km).

2.2 Data base/ materials

The main data used in the analysis is a Numerical Terrain Model and model 3D buildings, for each of the tested areas. Raster terrain model was downloaded from the website the European Environmental Agency (EEA). While the geometry of the 3D buildings in 2006 was obtained from the Department of Spatial Information in Office Development of Wrocław.

2.3 Methods

At the beginning of the analysis separated the roof geometry from the walls of buildings in the CityEngine programme. The shape of the roof was the basis for later research. In the analysis of the potential solar power contain of such features as: area of roofs, their slope, aspect and solar irradiation which was carried out in ArcGIS. Each step was repeated for all three areas of comparative analysis, assuming the same compartments and values for each of these. Some of the methodological assumptions are based on the Caroline Carl doctoral thesis from the University of Southern California[7].

The first component of the analysis was involved with the calculation of the area of roofs (calculate geometry tools). Assume that the installation of photovoltaic cells begins to be profitable when the roof has minimum 70 square meters[8]. Then converted rasters into vector layers by area value and using *Reclassify* which created the following range of values: (1) to 65 sq. m -1; (2) 65-75 sq. m -2; (3) above 75 m -3 points.

The next step was the designation of the aspect buildings, using tool called *Aspect*. Obtained information about position of the buildings in relation to the world. The output rasters were converted into points cloud using *Raster to Point*. Then were made the spatial joins (*Join data from another layer base on spatial location*) points layers with a roof's polygon layers. After the combined obtained average values of aspect and there were had to be converted with the vector to raster, using tool *Polygone to Raster*. The resulting layers were reclassified by assigning values depending on the exposure roofs of the world. This much, because 5 points obtain buildings with South aspect, 4 South-East and South-West, 3 point for East and West alignment, 2 for exposure of the North-West and North-East, and 1 point for Northern aspect.

Then were calculated slopes of the roofs, using *Slope* tool. As in the case of assuming of aspect, the output rasters were converted into points cloud, which was spatially joined with a vector layer, which allowed to calculate average slope of roofs. Obtained vector layer was changed into raster layer, which has been reclassified, by assigning appropriate values: (1) up to 30 ° - 1 point; (2) from 30 ° - 40 ° - 3; (3) from 40 ° to 60 ° - 2; (4) above 60 ° - 1 point.

This evaluation was based on assumptions about the installation of solar panels in the Polish conditions. It informs that photovoltaic cells could be most optimally make for roofs with slope from 30 ° to 60 °[9].

Next step of this analysis was the calculation of solar irradiation for 2006, using tool called *Area of Solar Radiation*. The output raster were created under the same way and conditions as slope and aspect. Reclassification of these were obtained three compartments by the natural break range class of data.

Obtained rasters were the basis for use of the final tool -*Weighted Overlay*, the data inserted in the range of 1 to 3 by 1, and each is assigned the value of 25%. The result was an another raster present classified area to install a photovoltaic system. Obtained summary values are classified in three compartments : (1) 0-1, what represent bad conditions for solar panel installations; (2) beyond 1 to 2, specified as good; (3) beyond 2 to 3 - very good.

Then the resulting raster were converted into vector layer, which have been spatially joined with the roofs. Spatial join made it possible to determine what proportion of buildings in each location was selected to the proper class of solar potential.

3. Results

As a result of the analysis, there could be compared potential of solar roofs for three settlements in Wrocław. The results were classified into three groups: bad, good and very good conditions to installed solar panels.

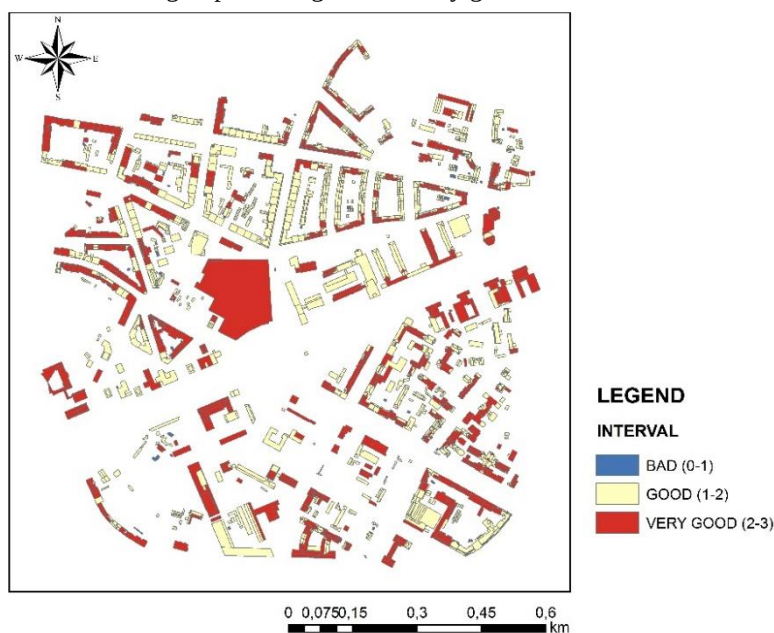


Fig. 1: Solar potential for photovoltaic installations on rooftops in Grunwaldzki Square, Wrocław.

The area with the best average efficiency of solar energy is Grunwald square (Fig. 1), instead the worst result was obtained for Biskupin. Also the largest number of buildings that are very good solar power is an area of Grunwald square. About 79% of this buildings comply with the input criteria, which placed it in the best solar potential group.

The smallest percentage of roofs in good potential was acquire for Biskupin (Fig.2) - 34%, while the Nowy Dwór (Fig. 3) has obtained similar value -34%.

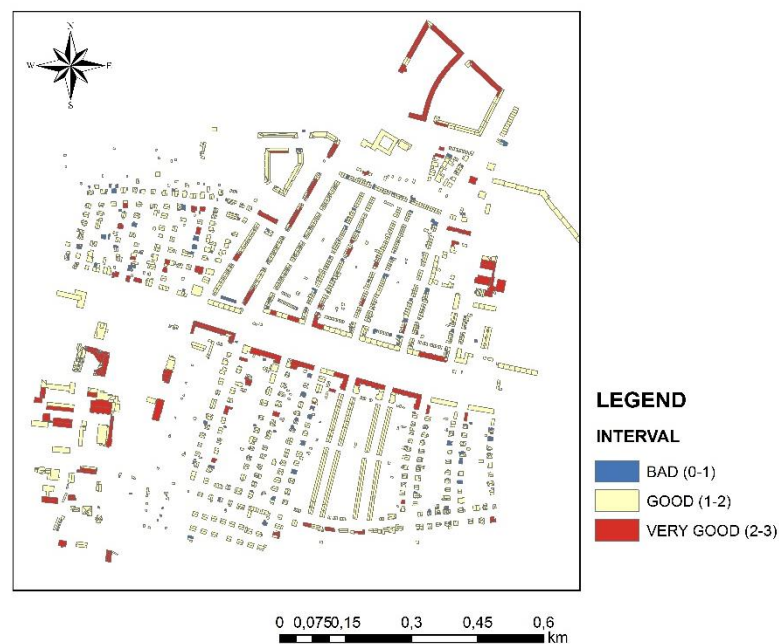


Fig.2. Solar potential for photovoltaic installations on rooftops for Biskupin estate, Wrocław.

These buildings, located on the East of the city area, has the largest percentage of low potential of solar energy (34%). The city center is characterized by 12% of buildings, which could be classify also as the building with smallest potential for solar location . Therefore, there were no buildings in the area of Nowy Dwór, which could be classify to this group - group with the smallest potential for solar investments.

Nowy Dwór area also has the largest share of the average potential for the installation of photovoltaic (62%). In the rest of the range is 9% and 34% for Grunwald square and Biskupin.

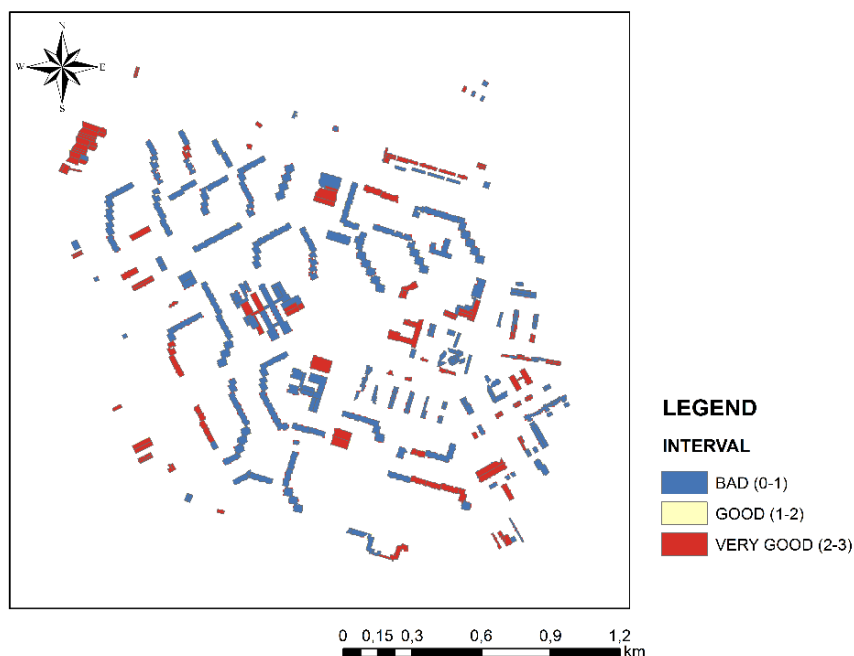


Fig.3. Solar potential for photovoltaic installations on rooftops for Nowy Dwór estate, Wrocław.

The western area is characterized by buildings of adverse roofs aspect and their small slope, which had significant influence on the final results of the analysis. However, the positive influence for analysis has a lot of roof with large area. In the city center, there could be noticed the smallest value of Area solar radiation analysis for buildings

due to the compact development and wide variety of function. Also there are a large roof area, what as a result, classify this area as the best for installation of solar panels. However, the estate Biskupin is characterized by the worst result, the impact on this is mainly seen in a large share of small area roofs. A positive aspect of the analysis for this area are quite beneficial roof slope angles in the houses, which in turn not affected the results of the potential for this area.

There could be noticed, that a different type of buildings in other way influence on the efficiency of solar potential. The significant contributions in this analysis had a size and exposure to the world of buildings. These aspect was important due to the possibility of optimal reception energy and a larger area for the installation of solar panels. The average solar radiation which gets to the building is worse on the detached house. There is noticeable, that the roof slope are larger for low buildings, due to the often quite flat roofs of apartment blocks. Therefore, there could be concluded that block of flats has a greater potential than single buildings.

4. Discussion and conclusions

The proposed solution for the design of the renewable resources of energy could contribute to increase of the amount of prosumer- people who produce and use energy both. After the amendment to the Polish Act on Renewable Energy Sources, these people could obtain the money from difference between the energy produced (such as solar panels) and its storage to the power plant regards to the current consumption of the power [10]. The increase of prosumers could contribute to reduce of the energy demand from cogeneration power stations or heat and power plants on one hand, which could lead to reduction of the charges for power for residents on the other. The results of solar potential analyses could affect on the consciousness of the people living in cities. A lot of them are not familiar with such solutions and their efficiency, so not use them for their buildings. Therefore, conducting such of studies could help to increase the individual installations of solar collectors, and the same the amount of energy from renewable sources. Furthermore, the increase in the level of use of solar energy could achieve the levels of energy production from unconventional sources (20% by 2030 determined in Polish energy strategy until 2030) [11]. This analysis of solar potential could be an alternative for other types of "green tools", such as wind farms, which need more of space for new investment. On the other hand, such solutions could contribute to increase interest in renewable energy by the society, which might create greater acceptance of this infestations in the cities areas.

The results of conducted analysis could be helpful for planning of new buildings. The information about right aspect and slope for solar panels location on building, could be a taking into account during planning such a infestations. Moreover, it could help to increase the potential of the solar rooftops, which is associated also with growth in the use of renewable resources in the cities. This kind of information could be also useful for planning and mixing different type of buildings, which impact on the potential of solar energy. Cities ought to be development in way, which will reduce limitations that might cause geometry of buildings in getting energy from it. This type actions could affect on the promotion of the city and creating special organizations of municipalities to support them. This aspect ought to be taken into account for the revitalization of urban areas process to adopt Polish cities to the idea of *smart cities* [12].

The use of existing area in the roofs do not bring further problems with the location of the new investment in the increasingly built-up urban area. It is possible that the use of the potential of solar energy could reduce the level of CO₂ emissions in Poland and reduce the phenomenon of smog in cities, which currently suffers Wrocław city.

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The application of polar coordinate transformation on the cinder cones of the San Francisco Volcanic Field

Fanni Vörös¹, Zsófia Koma², Balázs Székely^{2,3,4}

¹Institute of Geography and Earth Sciences, Eötvös University, 1117 Pázmány Péter stny. 1/c, Budapest, Hungary
vorosfanni@map.elte.hu

²Institute of Geography and Earth Sciences, Department of Geophysics and Space Science, Eötvös University, 1117 Pázmány Péter stny. 1/c, Budapest, Hungary

³Interdisciplinary Ecological Centre, TU Bergakademie Freiberg, Freiberg, Germany

⁴Department of Geodesy and Geoinformation, Vienna University of Technology, Vienna, Austria

Abstract. Geomorphometric and traditional GIS methods are widely used for studying volcanic forms, e.g. cinder (scoria) cones, which have usually symmetric shapes, but they can be asymmetrical, as well. Their asymmetry may stem of volcanogenic processes or result of erosional processes. Studying asymmetry one can imply to the denudation, denudation rate, and, to some extent, to the age of the volcanic edifice. However, original asymmetries related to formation (e.g. rifting, emplacement on slope, eruption variations etc.) are difficult to separate from erosional features. With the application of polar coordinate transformation (PCT, introduced earlier in volcano-geomorphic studies [1]), we can define new derivatives of the morphometric parameters.

In the study area, the San Francisco Volcanic Field (SFVF), there are roughly 600 cinder cones as well as the central stratovolcano, the San Francisco Mountain. Our goal is the geomorphometric analysis of the cinder cones of the SFVF. SFVF area is well-studied volcanic field with evidence of eastward younging trend of the cinder cones.

Traditional parameter maps (aspect, slope histograms, cone height/width ratio) were PCT-transformed. The results show characteristic separation of the regular cones (the values are more or less constant at given radial distance); some asymmetric cones, however, show sectorial differences or irregular patterns in the transformed images. As the cones are getting younger in a west-east direction, the PCT images enhance the tendency of the erosion of the edifices: the slope is decreases in context of the age.

As an improvement of the method we plan automatic extraction and classification of the features, in order to group similar scoria cones and relate the age to the destruction of the edifices.

Keywords: scoria cones, volcano geomorphometry, polar coordinate transformation, San Francisco Volcanic Field, digital elevation models

1 Geological and Volcanological Setting

Our study area, the San Francisco Volcanic Field (SFVF) is located in the south of Colorado Plateau, near Flagstaff, Arizona, USA. The field contains more than 600 scoria cones, lava domes, lava flows, extended ash and cinder sediments [6]. The dominant rock is alkali basalt [11]. In alkaline igneous rocks the Na- and K-containing silicate minerals are presented in a larger percentage than Ca-containing silicate minerals. Basalt is SiO₂ poor (45–52% SiO₂ substance) so it has low viscosity: it travels a long distance, but in a thin layer. Most of the volcanoes are formed in the subduction zone of the plate boundary, but SFVF is in the middle of Arizona. Most likely under SFVF there is a hot spot. From the deepest mantle plumes rises: it's "head" part spread under the surface, the "tail" part reaches down to the mantle.

The scoria cones of the SFVF (Fig. 1) consist of loose volcanic debris: scoria or ash [11]. These forms are monogenetic forms: they erupt only once, and during the eruption the whole volcanic superstructure is created. They can be even 700 meters, but the average elevation is 30–300 m. These symmetrical forms' slope initially 30° but decreases over time. Most of the scones were created by Strombolian eruption, so the main rock is basalt, too. The geological history of the area is relatively short; the volcanic activity is less than 6 million years.

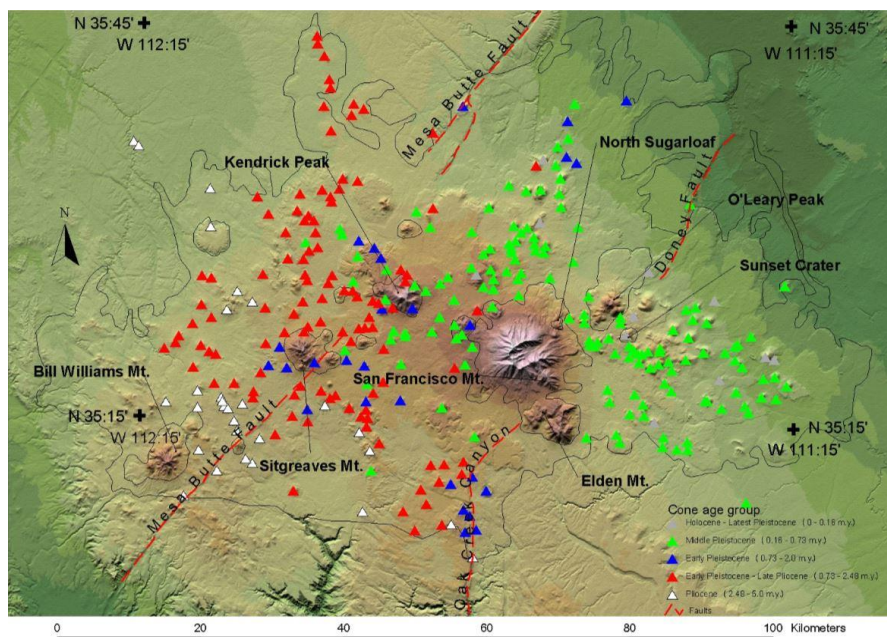


Fig. 1. Location of the scoria cones, based on their age [1]: grey: 1. age group, green: 2. age group, blue: 3. age group, red: 4. age group, white: 5. age group

The ages of the cones are cover a couple of thousands years from about 5–6 million years. We distinguish five age groups [1]:

1. Holocene – Late Pleistocene (0–0.16 Ma)
2. Middle Pleistocene (0.16–0.73 Ma)
3. Early Pleistocene (0.73–2.0 Ma)
4. Early Pleistocene – Late Pliocene (2.0–2.48 Ma)
5. Late Pliocene (2.48–5.0 Ma)

An eastward younging trend is observable in SFVF (Fig.1): Late Pliocene cones are found in the west, southwest and the ages of the cones are younger eastwards (Late Pliocene and Holocene) [9].

2 Previous Studies

The first geomorphometric studies of the area were carried out by COLTON [2]. He classified the basalt cones and lava flows based on the erosion rate and weathering. TANAKA *et al.* [9] specified the cones' palaeomagnetism with K-Ar dating supplemented with rock and stratigraphic studies proving the wandering of the volcanic activity. They examined the accidental pattern of the area's cones' location and scattered volcanic material's quantity. Based on morphometric analysis the fresh scoria cones of Mauna Kea, Hawaii PORTER [5] established the idea of scoria cone evolution based on morphometric volcano-parameter correlations (Fig. 2). Later these relationships were used as standard approach.

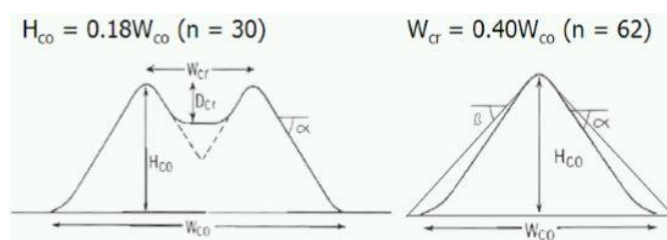


Fig.2. Derivation of the basic geomorphometric properties, H_{co} , W_{co} , H_{cr} and W_{cr} [5]

By analyzing numerous volcanic cones worldwide, Wood [12] evidenced that the approximate age of the cones can be implied by simple morphometrical analysis. Examining other volcanic fields like SFVF (Nevada, Oregon, Italy, Reunion) he stated [12] that the elevation of the cone, the proportion of elevation and diameter and the slope of the cone are decreasing with time, but the proportion of the diameter of the crater and the cone do not change with the erosion. Later, comparative morphometric studies were made of the semiarid SFVF and Springerville volcanic field (southeast from SFVF) [4] by modelling the surface's erosional processes with an ideal scoria cone. The analysis covered cone elevation, elevation-diameter ratio, crater depth-crater diameter ratio, slope. The conclusion was that the basis of relative dating is the analysis of the constantly decreasing morphological parameters [4].

3 Data and Methods

The SRTM (Shuttle Radar Topography Mission; [3], [7]) Digital Surface Model [10] has been used in our study. As the study area is arid, the vegetation is practically negligible, so from our point of view the DSM can be also considered as a Digital Terrain Model, with a resolution of ca. 30 m in the region. In order to calculate various geomorphometric parameters of the scoria cones, it is necessary to define their extents. Digitized polygons of a previous project [1] have been used as outlines. The DTM data were imported to Quantum Geographic Information System and slope and aspect maps were derived from the original DTM. The processing has been implemented in Python language.

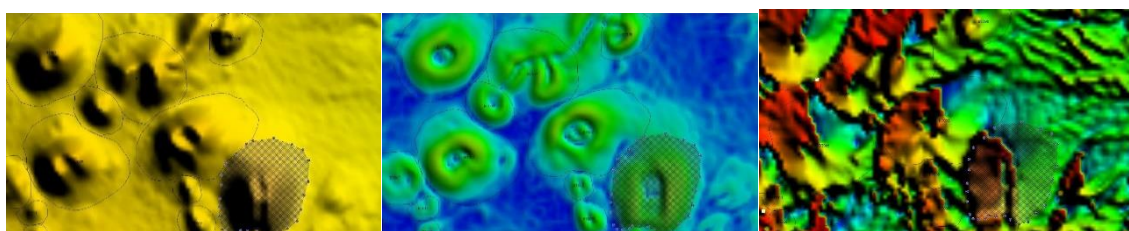


Fig. 3. Shaded relief (top left), slope (top right) and aspect maps (bottom) with the polygons.

For a better visualization of non-circular features we performed a polar coordinate transformation (PCT) applied on the original elevation data [8]. The digitized points in the original, Cartesian coordinate system (x,y) have been transformed using x_0 , y_0 (Cartesian) coordinates of the projection center (center point of a cone). After the transformation, the same points can be represented by r radial distance (m) and ϕ azimuth ($^\circ$) values. It is important to define the center point precisely, because biased choice may lead to distorted pattern. The center points were chosen manually.

$$r = ((x - x_0)^2 + (y - y_0)^2)^{0.5} \quad (1)$$

$$\varphi^* = \arctan ((x - x_0) / (y - y_0)) \quad (2)$$

$$\varphi_{\text{deg}} = (180^\circ / \pi \times \varphi^*) \quad (3)$$

As the resolution of the DTMs is ca. 30 m, there are too few data for the smaller cones. To enhance visual appearance, the elevation values (example in Fig. 5) were interpolated to a regular grid in the PCT image as well (Fig. 6).

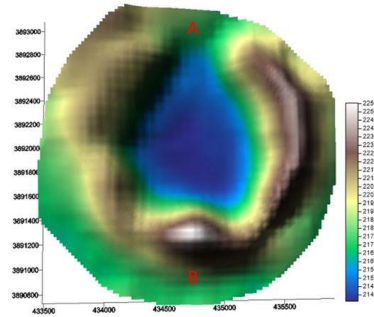


Fig. 5. Map view of the “BT090” cone (visualized in Golden Software’s Surfer)

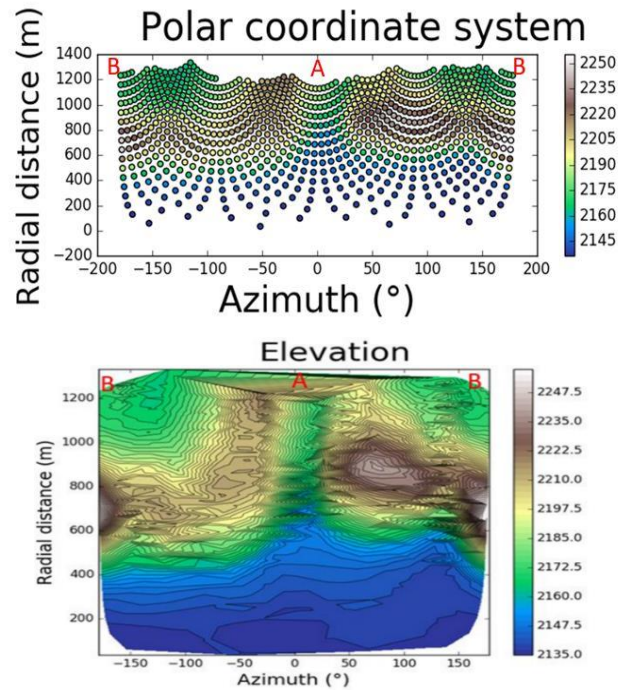


Fig. 6. (a) The PCT transformed point cloud of cone “BT090”. (b) Interpolated PCT.

The relief of the cone is calculated using the expression (4), where z is elevation.

$$\text{absolute1} = \text{np.absolute}(\text{np.max}(z) - \text{np.min}(z)) \quad (4)$$

Average values and standard deviations were calculated using the PCT grid, i.e., averaging and standard deviation calculation were performed at constant radial steps started at 10 m radial distance (variable `start`) repeated in every 50 m (variable `stepsize`). Because of the different size of the cones (`mr` is maximum radius), this results in various numbers of values.

```
for d in range(int(start),int(mr),int(stepsize)):
    ziii=zii(d)
    average=np.nanmean(ziii)
    deviation=np.nanstd(ziii)
```

With the help of this script average, standard deviation, elevation and slope values were calculated that reflect their radial distributions. It is to be emphasized that the extents of the figures presented here are not standardized.

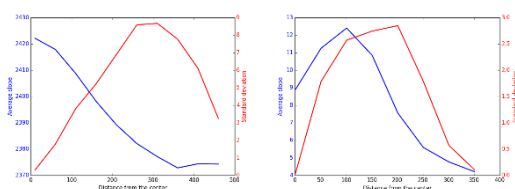


Fig. 7. Examples for average-standard deviation figures (left: elevation; right: slope), blue curves: average, red curves: standard deviation

4 Results

308 cones have been processed (PCT, slope calculation, averaging, calculation of standard deviation). Despite the very wide range of age, similarities can be discovered by analyzing the results. Cones with varying ages can be grouped based on their shapes, nevertheless, there are a lot of exceptions. A few typical examples are presented here.

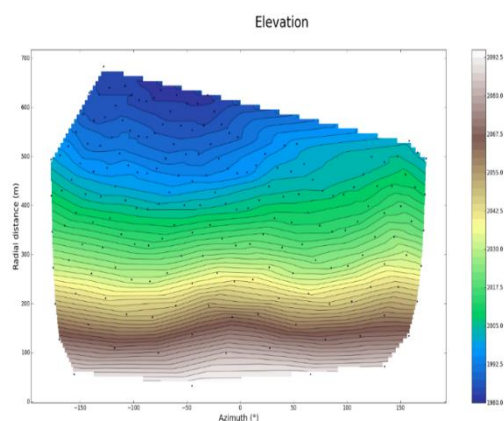


Fig. 8. Interpolated PCT of cone "BT217". Note the radial uniformity of the cone.

In the visualized PCT images it is easier to analyze the symmetry of the cones. E.g., in Fig.6b. there is a lower zone near the center (0-500 m radial distance) followed by a higher (brown) area. The former is the crater; the latter zone is the crater rim of the cone. At 0° there is a gap in the crater rim. The crater rim is roughly parallel to the azimuth axis as the cone is almost symmetric. In case of a symmetric cone, all contour lines are parallel to the azimuth axis (Fig. 7).

In the following a few examples of average and standard deviation curves are presented. Axis y (blue line) is the elevation (m asl.), x is the radial distance from the center point (m). Blue lines indicate the average curves, red-lines show the standard deviation of the average elevation. In the theoretical case of a completely symmetric cone, the 3D cone shape can be achieved by rotating the blue curve along y axis.

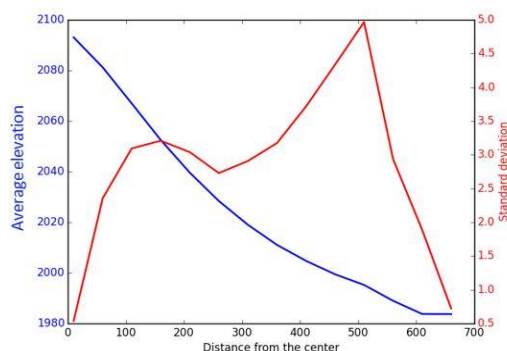


Fig. 9. Average elevation and its standard deviation of cone “BT217”

With maximum 5 m standard deviation, “BT217” is one of the most symmetric cones. It has a typical polyconic shape.

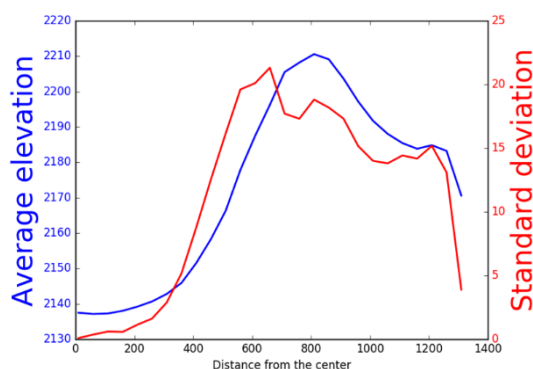


Fig. 10. Average elevation-standard deviation figure of “BT090”

As an example the results for the cone “BT090” (see Figs. 5 and 6) is shown (Fig. 9). The crater rim is clearly visible at ~800 m. The interesting supplement is the standard deviation values in this area. The first outlier at 600 m shows the highest area of the cone (Fig. 5/B), the second (850–900 m) is the rim’s other protrusion (in Fig. 6 the values between 50°–120°).

The shapes of the scoria cones can be even better analyzed using the slope curves (Fig. 11). If a cone is perfectly conical, the average is a constant value. The variation of the average slope and its standard deviation indicates the asymmetry of a cone.

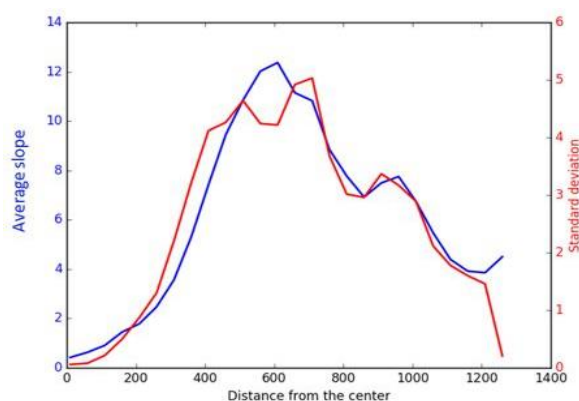


Fig. 11. Average slope-standard deviation figure of “BT090”

5 Interpretation of Averaged Curves

Every cone is unique, so the derived data and figures show considerable variations. Moving outwards from the cone center, the values of the parameters on the graphs give a good approximation of the real shape of the cone. Although more than 300 scoria cones were examined from 5 age groups, some similarity is noticeable on the PCT and average-standard deviation figures (25 examples are presented in Fig. 12). Based on these, an age-to-shape evaluation diagram was created (Fig. 13).

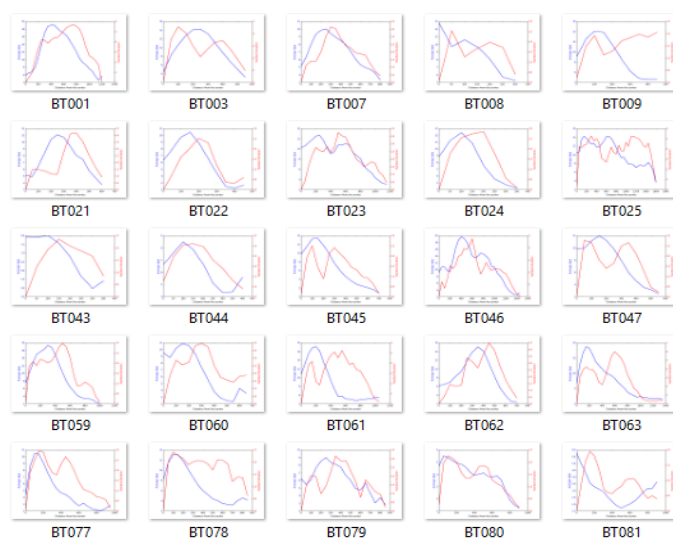


Fig. 12. 25 examples for average – standard deviation diagram

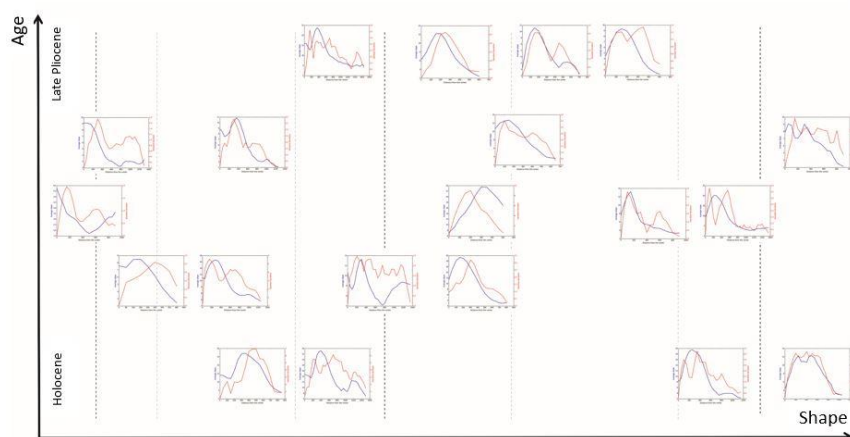


Fig. 13. A possible evaluation arrangement of selected cone's diagram reflecting the age (y axis) to shape (x axis, increasing asymmetry) relationship. See explanation in the text.

Along the two axes five age groups and shape were represented. Along Axis y the five age categories are arranged (Late Pliocene, Early Pleistocene–Late Pliocene, Early Pleistocene, Middle Pleistocene, Holocene–Late Pleistocene). The position along the x axis is determined by the symmetry of the cone as represented in the average values–standard deviation figures. The tentative groups are separated by the black dashed lines.

Cones with average slope lines that start at the maximum and constantly decrease are placed in the leftmost zone. The second area contains charts with a decreasing-increasing-decreasing trend. The smaller parts inside this (bounded with grey dashed lines) are determined by the standard deviation. In the third part, the line rises from the center point, and after reaching the maximum it decreases again. The last part contains cones with multimodal slope curves.

6 Conclusion

Having examined a large number of cones, it can be concluded that the majority of the cones can be classified visually by their shape using radial slope angle averages. However, there are a number of outliers not following this trend: there are very young cones, which are eroded or otherwise modified; on the other hand there are older ones with a regular shape.

The analysis of the current parameter graphs shows that it is not enough to use two parameters to group a cone in a proper category. More sophisticated parameters need to be deduced in order to define more clear (age related) cone categories.

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SECTION CANDIDATES ON MASTERS OF SCIENCE

Simulation of geometric distortions in SAR images implemented in MATLAB and published online

Bc. Richard Czikhardt¹

¹Dept. of Theoretical Geodesy, Faculty of Civil Engineering, Slovak University of Technology, Radlinského 11, 810 05, Bratislava, Slovak Republic
Contact czikhardt.richard@gmail.com

Abstract. Satellite radar images obtained by synthetic aperture radar (SAR) are nowadays an integral part of the Earth observation, with wide range of applications in environmental monitoring and GIS, including the ones concerning geodesy, such as InSAR deformation monitoring or digital terrain model creation. This application capability is recently emphasized by full operational programme of Sentinel-1 mission, providing open access for worldwide SAR imagery within high temporal resolution.

Image acquisition of spaceborne SAR is characteristic by its specific side-looking geometry, that is the Earth's surface is irradiated under look angle off nadir. Relief variation in satellite's line-of-sight therefore results in geometric distortions in the SAR image, which in some extent limit its usage.

The aim of this paper is to present MATLAB based graphical user interface with functionality to simulate geometric distortions in the SAR image for the selected area of interest. Simulation is based on the idea of easily moldable acquisition geometry and digital terrain models with sufficient resolution currently freely available. Created tool allows to identify and analyse areas potentially affected by geometrical distortions, which serves as a preliminary analysis before application of multi-temporal InSAR processing technique and appropriate SAR imagery selection.

In conclusion, effectiveness of created tool is verified by comparison between masks of geometric distortions generated on the basis of SRTM-1 with Sentinel-1 SAR imagery of Slovak mountainous regions. Simulation results for Sentinel-1 swaths in scope of Slovakia are published online via simple web map using OpenLayers 3 API.

Keywords: Synthetic aperture radar, geometric distortions, MATLAB, DEM based simulation, Sentinel-1, Web map

1 Introduction

Wide geoscientific application capability of radar remote sensing is currently emphasised by operational programme of Sentinel-1 mission providing free worldwide SAR imagery within high temporal resolution. Those images are systematically used in environmental monitoring and safety management (e.g. land-surface motion risks or routine sea-ice mapping for marine transport). The most relevant geodetic radar interferometry technique InSAR is capable of producing digital elevation models and millimetre precision deformation maps. SAR images however differ from generally familiar satellite images in visible spectrum in terms of geometry representation, what is closely related to limitations introduced by geometrical distortions.

2 Basic principles of SAR image acquisition

Principle of RADAR (RADio Detection And Ranging) system is based on detection and determination of distances of objects using radio (microwave) radiation, which is electromagnetic radiation (EMR) within microwave spectrum, specifically at X, C or L band (wavelengths of 2 – 30 cm). Compared to visible spectrum, the advantage of using such wavelength lies in their different interactions with objects. Such as penetration of clouds, which makes the system weather independent. Moreover, radio atmospheric window allows to position the radar outside the atmosphere – on the satellite. Given the low level of natural microwave emission from the Earth's surface, radar systems are generally active, equipped with their own source of radiation. Thus imaging is independent of the daytime. Radar (transmitter) on the satellite platform transmits a narrow, coherent radio signal pulses towards the Earth's surface. The backscattered signal is received in form of energy by antenna (receiver) on the same satellite. This is referred to as monostatic principle [3].

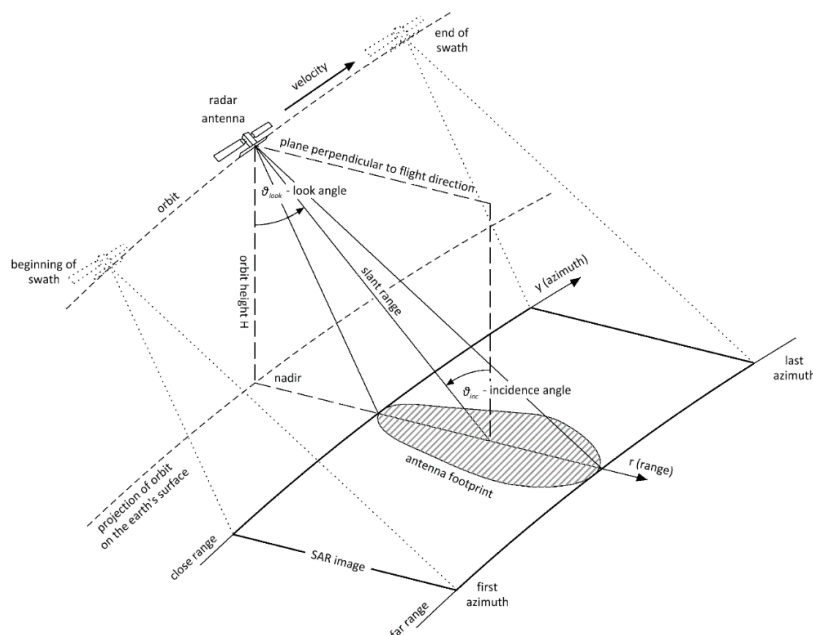


Fig. 1. Acquisition geometry of SAR image (according to: [2])

Two characteristics of backscattered pulse are obtained: namely time delay and intensity, which depends mainly on structure, roughness and dielectric properties of backscatter surface. In terms of physical interpretation those characteristics are:

- *amplitude* (A) – which describes the intensity of backscattered pulse,
- *phase* (ϕ) – relative quantity wrapping the distance between backscatter and sensor (only modulo radians), mainly used in radar interferometry.

From amplitude perspective, SAR image represents map of swath's backscatters intensity. In general, dark places represent low reflection intensity, reflection scattered away from radar respectively (smooth surfaces, e.g. calm water). Brighter places represent high reflection intensity, that is concentration of the reflected energy towards the radar (e.g. rock and urbanized areas).

2.1 Acquisition geometry from satellite platform

Radar antenna is aligned along the satellite's flight orbit and directs sideways and downwards to nadir (Fig. 1). Such alignment is called side-looking geometry in plane perpendicular to flight's direction. During satellite's flight, radar irradiates the Earth's surface at look angle ϑ_{look} to obtain strips of imagery of about tens to hundreds km in width, depending on acquisition mode. Imaged area is referred to as swath. SAR satellite missions generally work at near-polar low-earth orbit. Earth is irradiated during satellite's ascending and also during its descending track. As a result of Earth's rotation, it's every place is imaged from both perspectives within certain time interval. SAR sensors differ in wavelengths, polarisation of transmitted and received signal or image acquisition modes. Acquisition modes determine swath width and its look angle interval.

Primary detected image contains pulses organised parallel in 2D matrix referenced by a pair of orthogonal coordinates. Those coordinates are determined by acquisition geometry (Fig. 1):

- *slant range* (R) – distance from backscatterer to radar in line of sight (LOS) direction,
- *azimuth* (x) – the identifier of pulse with its corresponding satellite position on orbit along track direction.

The SAR technology synthesizes an apparently long antenna by making use of forward motion of the satellite (generating phase Doppler shift between respective satellite positions for particular backscatter), in order to achieve high resolution (several metres) in azimuth direction.

2.2 Geometric distortions in SAR image

As evident, side-looking acquisition geometry is necessary for radar to obtain the resolution in range direction. However, its secondary and negative result are geometric distortions in SAR image, caused by height variation of the imaged areas topography in a plane perpendicular to the direction of flight. Referring to Fig. 2, radar pulses are recorded in concentric circles (red), which indicate near to close range. Due to such acquisition geometry and depending on the terrain slope in LOS direction we can distinguish following geometric distortions, generally referred to as the artefacts [2]:

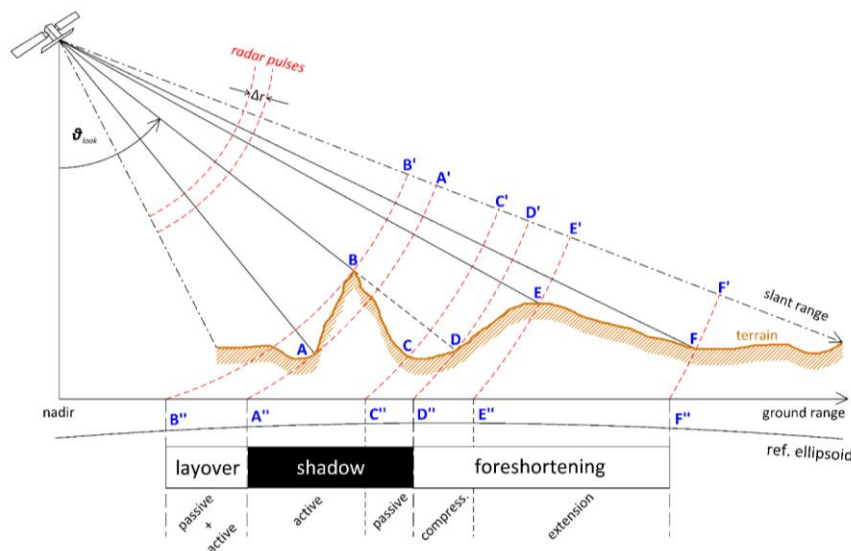


Fig. 2. SAR acquisition geometry and geometric distortions in SAR image (according to: [2])

- A.) Foreshortening** is caused by the slope in the direction of LOS. In case of positive inclination (DE) the compression ($D'E'$) occurs by shortening the range with the consequent rise in the relative intensity of the received signal per lesser number of pixels. Compressed areas are therefore displayed seemingly brighter. The overall result is a characteristic overexposure and relief displacement towards the radar. In the reverse case (EF), imaged area is lengthened ($E'F'$).
- B.) Layover** occurs if the radar pulse is reflected from the top of the terrain structure prior to its foot. The pulse reflected from the top (B) is received by sensor sooner and therefore closer (B') than the places near the foot (A, A'), hence the image inversion. It produces a superimposed overlay, with characteristic “ghost image” appearance. Layover is an extreme case of foreshortening.
- C.) Shadow** indicates the surfaces that have not been irradiated by radar pulses. In such areas there is a complete loss of radiometric information. Practically, active and passive shadow is distinguishable. Active shadow as a result of slope exceeding the local incidence angle of LOS in negative sense. Passive shadow, in analogy to optical imaging, caused by physical barrier between a hypothetical point of illumination and sensor.

It is important to point out that the presence of distortion has a significant impact on the intensity of affected areas. For example, in case of foreshortening, one pixel corresponds to greater ground resolution cell which contains more scatters that reflect more energy. The sensor suggests that the object has a higher backscattering coefficient, whereas the information in fact comes from different objects [3].

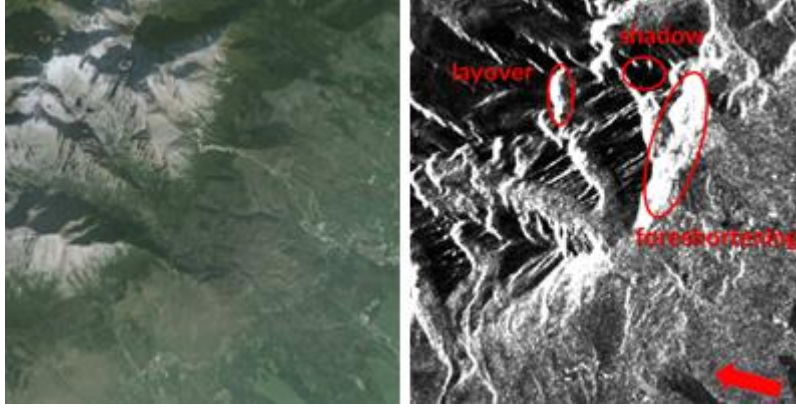


Fig. 3. Geometric distortions demonstrated on Sentinel-1 A descending SAR image of eastern part of the High Tatras main ridge (arrow indicates the direction of acquisition, left satellite image in visible spectrum is adapted from © GoogleMaps)

3 Tool for the simulation of geometric distortions in SAR image

Modelling of SAR imaging geometry requires a different approach than conventional visibility analysis, regarding in some ways similar principles of Doppler-range terrain correction algorithms, well-described in [3]. Certain specifications are taken into account:

- assumption of parallel, line-by-line acquisition perpendicular to the satellite flight direction, i.e. image is 2D matrix, referenced by SAR coordinates with an orientation towards global north defined by satellite's look azimuth A_{LOS} ,
- satellite's coordinates are not required apriori for modelling purposes,
- look angle ϑ_{look} changes linearly in a LOS direction, therefore it is sufficient to know its minimum and maximum value for whole swath,
- difference between look angle and incidence angle, considering the curvature of the imaged Earth surface.

3.1 Mathematical formulation

Solving the problem as a line of sight between two points satellite – Earth with iteration throughout whole swath would result in high computational requirements. In hereby proposed simple and effective solution, active and passive artefacts (see the difference on Fig. 2) are modelled separately. Digital elevation model is at given point P defined by positional function $f(P) = f(\varphi, \lambda)$. Magnitude and direction of DEM's maximum slope is defined by the gradient vector function:

$$\nabla f(P) = \left[\frac{\partial f(P)}{\partial \varphi} \quad \frac{\partial f(P)}{\partial \lambda} \right]. \quad (1)$$

Unit vector of LOS in horizontal plane can be expressed via LOS azimuth A_{LOS} , approximately modelled for specific satellite mission and mean latitude of swath:

$$\mathbf{u} = \begin{bmatrix} \sin A_{LOS} \\ \cos A_{LOS} \end{bmatrix}. \quad (2)$$

The projection of gradient's components into the LOS direction is evaluated by directional derivative D_u of the function f as a scalar product of position function gradient and unit vector of LOS:

$$D_u f(P) = \nabla f(P) \cdot \mathbf{u} \quad (3)$$

DEM's slope at point P in direction $\mathbf{u}$ can be then expressed as:

$$slope_u(P) = \arctan [D_u f(P)] \quad (4)$$

Positive slope corresponds to hillsides oriented towards the LOS, remote hillsides have negative slope. Decision on the presence of a particular artefact in a resolution cell (pixel) is based on the basic trio of geometric conditions, specified in Table 1. Their corresponding graphical representation is illustrated in Fig. 4.

Table 1. Intervals defining occurrence of artefacts in dependence of terrain's slope

Condition	Artefact
$slope_u(P) \leq [\vartheta(P) - \pi/2]$	shadow
$slope_u(P) \geq \vartheta(P)$	layover
$-\vartheta(P) \leq slope_u(P) \leq \vartheta(P)$	foreshortening

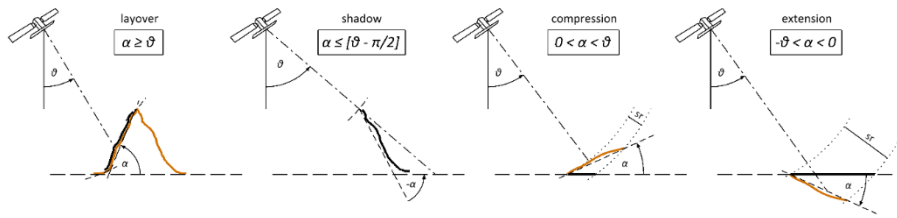


Fig. 4. Geometric conditions of artefacts occurrence

Intervals specified in modelled case (Tab. 1) are considered discrete, therefore occurrence of particular artefact is understood as a boolean value. In fact, several aspects bring a certain degree of uncertainty into formulated conditions. For example, uncertainty of local incidence angle, DEM precision and other approximation errors. Hence implementation of uncertainty into modelling is a vital step. Foreshortening near its extreme values at the boundary of the shadow or layover is thus modelled by continuous scale of synthetic intensity, calculated from the simple ratios. In case of foreshortening close to layover as well as close to shadow:

$$I_{\text{compression}} = \log\left(\frac{slope_u(P)}{\vartheta(P)}\right), \quad I_{\text{extension}} = \log\left(1 - \frac{slope_u(P)}{[\vartheta(P) - \pi/2]}\right). \quad (5)$$

Modelling result is a mask of specific geometric distortion in the colour palette with a downward trend, representing significance of artefacts occurrence, with associated transparency, corresponding to model intensity. Such an approach is harsh form of uncertainty representation. So far only the active artefacts were considered. The presence of passive shadow is tested through the projection used in line of sight analysis. Calculation is not carried out for each pixel, but only in close neighbourhood of already determined occurrence of active shadow. Passive overlay is tested in similar way. This approach significantly reduces the computational time.

3.2 Graphical user interface in MATLAB

As part of this work, MATLAB based Graphical User Interface (Fig. 5) providing the functionality to simulate geometrical distortions in SAR images and to generate related image masks was developed.

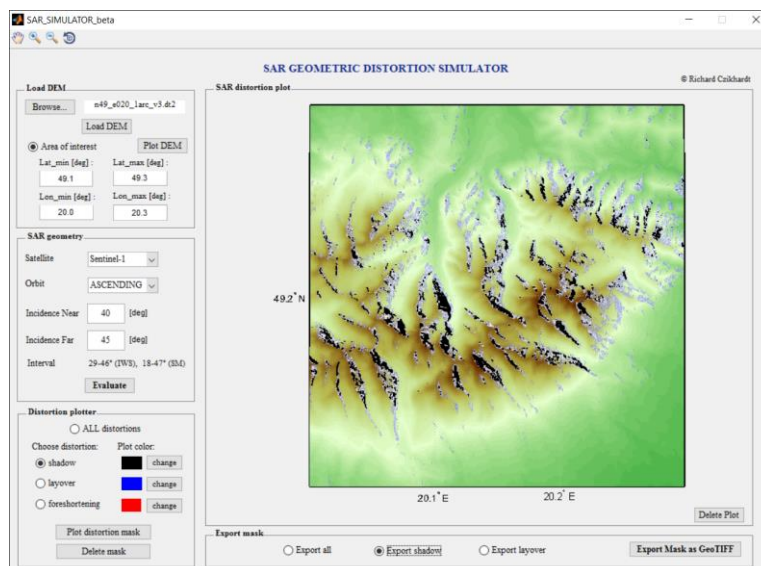


Fig. 5. Graphical user interface developed in MATLAB

Since simulation is based on DEM, first necessary step is to load one. Program currently supports standard formats: .dat (binary), .grd (Arc ASCII), .dt2 (DTED), .hgt (USGS SRTM3), .tif (GeoTIFF). Loaded DEM is renderable in a form of colour textured map for a specific rectangular area of interest (AOI).

Imaging geometry is defined by selection of satellite mission (determines orbital height and LOS azimuth), ascending or descending orbit and look angle interval corresponding to acquisition mode (or defined AOI).

Simulated distortions are optionally plotted directly in matlab. Exported result is GeoTIFF mask for chosen distortion in 8-bit representation with adjacent colour map and alpha band. The current status of optimization is approximately 30 seconds for SRTM1 1 x 1 arc degree grid.

4 Practical application on Sentinel-1 images of Slovakia

Sentinel-1 mission is a radar observatory segment of Sentinel satellites initiative under ESA's and EC's Copernicus programme. Mission consists of two near-polar low-earth-orbit satellite constellation (Sentinel-1A since April 2014 & Sentinel-1B since April 2016) carrying C-band SAR. Sentinel-1 twins jointly provide unprecedented temporal resolution of 6 days for almost the entire Earth's landmass.

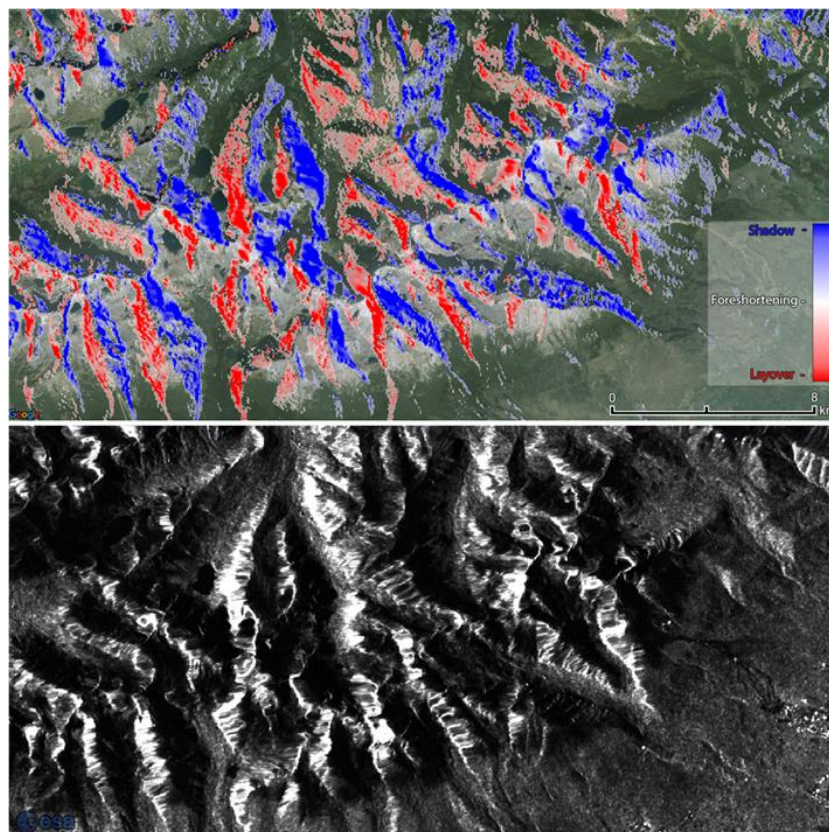


Fig. 6. Distortion mask for the High Tatras area generated on the basis of SRTM-1 (upper), Sentinel-1A IWS-GRD ascending SAR image of the same area (lower). Look angle: (30°,45°)

Primary acquisition mode of Sentinel-1 over European continent is Interferometric Wide Swath (IWS) mode, which uses progressive TOPS technique of electronic beam tilting to acquire separate image bursts, merged later in processing. The result is a large swath of 250 km in width with a resolution of 5 x 20 m. In order to reduce noise for purposes not requiring phase information, images are resampled to 40 x 40 m pixel [1]. This systematic product is referred to as GRD image in ground-range system of reference ellipsoid (e.g. WGS-84), though still affected by geometric distortions.

Altogether, use of SRTM 1 arc second DEM for simulation is sufficient in respect of resolution as well as fact, that SRTM was also a radar mission. Simulated artefacts masks are compared with Sentinel-1 GRD image over High Tatras mountains in Fig. 6.

4.1 Online visualisation tool using OpenLayers 3

All the available ascending and descending Sentinel-1 swaths within Slovakia with corresponding simulation masks were published via simple web map visualization tool using web mapping API OpenLayers 3. Masks are served from GeoServer in form of WMS OGC standard. Web map interface (Fig. 7) includes collapsible layer switcher for swath borders and distortion masks, legend and basic interactivity.

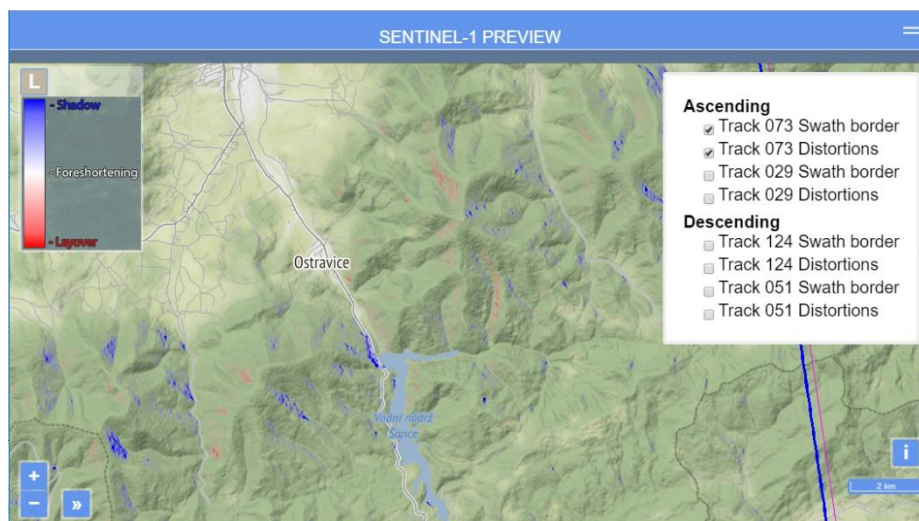


Fig. 7. Sentinel-1 preview web map (with stamen-terrain basemap) hosted on <https://memorid.github.io/Sentinel1preview/>

5 Conclusion

We present MATLAB GUI tool with functionality to simulate the geometrical distortions in SAR images through GeoTIFF image masks, allocating areas affected by those artefacts, according to imaging geometry parameters defined by the user. Presented modelling approach can be considered effective in terms of short computational time, as well as sufficient for the resolution of Sentinel-1 imagery.

Reliability, accuracy and detail of masks depends on several factors, particularly the desired resolution of simulated image and therefore the resolution of DEM used. Other effects may include DEM height precision and the fact, whether DEM or DSM is used. Comparison based on the intensity deviations of specific sites has its limitations for the urban areas. In such case, it is hard to distinguish the origin of intensity deviation, whether it is a result of strong reflection (e.g. metal bridge) or geometric distortion. This problem is superior for high resolution SAR images (as for TerraSAR-X). Altogether, effectiveness of the developed tool is still open to further testing.

Practical applications include analysis of the dependence between distortions and imaging geometry. Moreover, it can serve as preliminary analysis tool before the use of multi-temporal InSAR processing technique, since the density of persistent scatters in distortion (e.g. foreshortening) affected areas is significantly reduced. Last but not least, considering the growing utilization of Sentinel-1 operational capability even for naive users, it might be essential to develop a simple web map application (e.g. based on OpenLayers, as proposed) for visualisation of available image swaths and their extent throughout the particular country (in our case Slovakia), along with simulated geometrical distortion masks of whole swaths.

Integration with web processing service, use of open-source GIS environment, handling the high resolution data or better implementation of uncertainty modelling can all be reconsidered a possible future steps.

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Paralellization of r.sun and r.sim.water GRASS GIS modules using Open MP library

Michal Lacko

Institute of Geography, Faculty of Science, Pavol Jozef Šafárik University in Košice, 04001, Slovak Republic
Contact lacko.mi@gmail.com

Abstract. The aim of this paper is a description of parallelization of two computationally intensive modules of open source GRASS GIS using Open MP libraries to eliminate the time required to calculate the necessary models. The first module is r.sun which counts distribution of solar radiation on the earth's surface, the other is r.sim.water simulating the flow of water over the surface. Both these modules are intensively used by members of the Institute of Geography and with ever more massive, computationally intensive data there was a need for faster execution of these modules. The obtained results indicate a reduction of time taken for the calculation of more than 40 percent. Compared to the sequential operations of the CPU per core this result achieved significant improvement. The result are parallelized r.sim.water and r.sun modules implemented in the GRASS GIS, which are designed for computers with multi-core data processors. Along with the v.surf.rst module which we parallelized some time ago, we have three parallelized modules. While working on these modules we have already created a standardized procedure parallelization. This procedure is applicable to virtually any GRASS GIS module. In the future, we plan to expand the number of paralleled modules.

Keywords: parallelization; OpenMP; interpolation; solar radiation; overland flow simulation; GRASS GIS

Creating mobile geoapplication for visually impaired

Tomáš Liczka¹

¹ Department of Geoinformatics, Faculty of Science, Palacký University Olomouc,
17. listopadu 50, 771 46, Olomouc, Czech Republic
liczkat@seznam.cz

Abstract. The main objective of this master's thesis was to create a mobile Geo-application, adapted to the blind and working in the operating system Android. The first step in the development of the application was getting familiar with the general principles of the Java programming language which is used for creating applications in the Android studio development environment. After that it was necessary to make a research on specific aspects of creating mobile applications for the blind. Furthermore, the research mentioned possible global data sources that can be used in this type of application. The application is designed as a support tool for planning the movement of a blind person in the urban environment. The user should be able to intuitively operate the application, for example via Text-To-Speech and instructions describing the application environment. The application retrieves information from multiple online map and data sources, such as Open Street Map, Wikipedia and Google. The user has the option to look for a route using two addresses or by entering two coordinates. He/she can obtain information about the length and the number of breaking points in the route. The user can plan movement on the route by using individual segments, their size and their orientation to the cardinal points. One of the other functionalities is the POI searching in the immediate vicinity of the selected point. Routes and points which were obtained in the application can be stored for future use, or sharing between friends. The user can use a compass and GPS coordinates directly in the field for reverse geocoding to locate the nearest addresses in the area. As the modelled area the city of Olomouc was selected, where the application has been tested and where full functionality of the application is ensured. Despite of the fact that it uses global data sources and it can be used anywhere in the world. This diploma thesis also contains results of the application testing within the blind who helped in its development with their comments and advices.

Keywords: Android application, blind, navigation, geolocation

1 Introduction

In the world there are about 39 million blind people [17]. These people are dependent on help from their surroundings and on utilities enabling them to perform activities of daily life. Human assistance and utilities for the blind that users can take advantage of are in many cases cost-prohibitive for the blind. Despite all donations, to purchase such an equipment is very often not possible for blind people.

Blind users have no problem with the use of mobile phones tailored to their needs [16]. You can use its functionality of receiving data from various sensors, of processing the data and you can create apps that support the blind in their daily activities.

If we focus on the themes of blind people and their orientation in space, it is possible to create a mobile application that uses information from GPS, digital compass and accelerometer to locate the user. By a subsequent localization it is possible to help the blind with their motion and orientation in unfamiliar surroundings. Such a structured application should be created in order to help the blind and in order to take into account all their needs to control and obtain useful information. Through the application at their mobile device a blind user can feel more free from the help of others and enjoy a greater sense of independence which a lot of the blind desire to increase their quality of life.

The application is developed for Android OS, which is included in most devices in the world [15]. Devices using Android OS are more affordable than those with other operating systems. According to these facts the developing applications for the blind should be directed to help as many people as possible.

2 Research

The first part was focused on getting information on issues of the blind and their movement in space. Then it was necessary to obtain information about the already created mobile Android OS applications for the blind and their free accessibility for blind users.

1.1. Blind people and their motion in an unfamiliar environment

Every person perceives their surroundings through sensory receptors or sensory organs. Humans have five basic senses: sight, hearing, touch, smell and taste. Sensory receptors transmit information through nerve pathways to the brain, where all the information is further processed. This process is called perception of the environment. However, if the receptor, the neural pathway, or the sensory center in the brain is dysfunctional, the person loses one of the related senses [8].

Sources say that a human with no physical disability uses eyesight approximately by 80% for their orientation in the nearby area [8], [1]. Blind people in unfamiliar environments use tactile and auditory sense the most [16].

2.1.1 Supporting resources for orientation and motion of the blind

Facilitating orientation and motion guidance in an unfamiliar environment can be done in several ways, such as: providing a guide who can stay constantly with the blind person. It is very expensive and there occur problems with invasion of privacy. Another available solution we know is utilities for the blind, such as a *cane* which is also the most common tool for the visually impaired. Blind people with canes indicate to the society that they are visually impaired or blind and people should mind their way. The cane also serves as an extension of touch and the blind person gets an overview of the obstacles located in front of him/her. Another helper in the blind motion in an unfamiliar environment is a seeing eye dog, which mainly serves to detect obstacles such as stairs. The guiding line is another support to the blind in unfamiliar surroundings. The guiding line can be represented by railings on the stairs, by grooves on the floor located in the underground [16]. Another assistive device for orientation in unfamiliar surroundings may be *tactile maps* [9]. A common feature of tactile maps is the displacement of geographical information into materials such as paper, metal, or plastic [18]. As electrical equipment among the utilities for the blind *acoustic beacons* can be included, which are located at the entrances into the underground. An audible signal guides the blind [16]. Tyflosonar is an alternative to the cane. It works on the basis of ultrasound which makes the blind able to indicate an obstacle in front of him/her. Tyflosonar is also able to detect light intensity [10]. In this way it also supports orientation. Mobile devices such as mobile phones and smart devices are further helpers which support blind people in their orientation in unfamiliar surroundings. One way may be also navigating a blind person by a mobile phone and an external GPS which sends location information to a center. This Center navigates the user then [16]. Another solution is to use the sensors of the mobile devices and subsequent processing of data into information needed for orienting and navigating the blind [3].

2.1.2 Navigating the blind people in space

Common voice GPS navigation uses two basic pillars for navigating the distance and direction to the next waypoint [4]. The development of navigation for the blind, which is described in the article "Navigation System for the Blind: Auditory Display Modes and Guidance", was founded on this theory. The article discusses communicating the information about the distance to the waypoint and the direction the blind person should go. In case of communicating orientation to the user four approaches have been tried (see Fig. 1). The first approach called Virtual communicates via headphones with the user and tells him the name of the waypoint, with a space effect that echoes from 80° to the left of the user. The second approach is called Left / Right. The user only gets information, if he/she should go to the left, to the right or straight. The third approach called Bearing uses a compass to determine the orientation and notifies users of the relative left / right direction and rotation in degrees. The last approach No Compass

uses changes in location from which it calculates a similar orientation as in the previous approach. If the user moves in the same direction (straight), the system will tell him information about the relative direction of rotation (left or right) and the size of the rotation in degrees. According to the testing, the most appropriate approach is Virtual and the approach Bearing was chosen the second best [12].

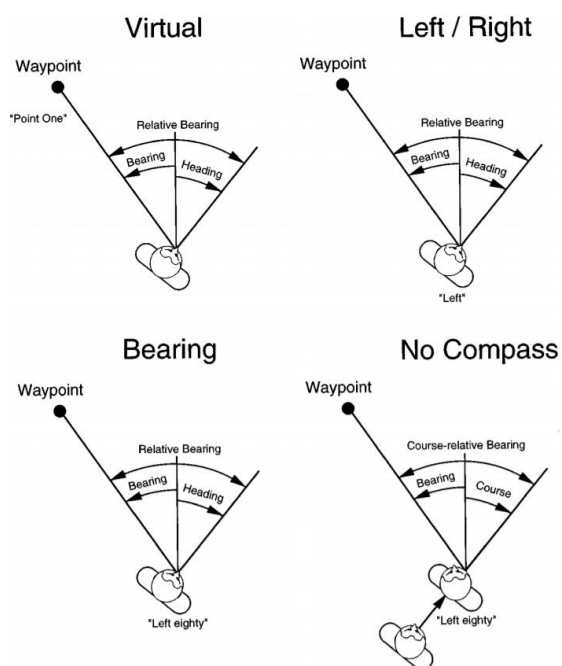


Fig. 1. Approaches to communicating orientation to the user [12].

In his article Kopic [7] presents an approach in communicating orientation, which seems to be more appropriate than the approach in which the user gets information about angle size and direction in which to go. The described approach communicates the clock as indicator of orientation. Usually it is known as clock navigation.. As an example of the clock navigation we can use the following message: "Change the direction by ten hours." instead of "Change the direction by 300 degrees.", which is worse imaginable for users and therefore more time consuming.

The new calculated distance and orientation to the next waypoint from the newly acquired locations can be communicated as a support in navigating the blind user. According to Loomis [12] the information about the orientation and the distance to the next waypoint should be communicated to the blind user every 10 seconds. This interval provides enough time for thinking about the information and for making a decision in the field.

2.2. Adaptation of the mobile application to the blind

According to Kane et al. [6], touch gestures are one of the possibilities to facilitate control devices with touch screens. In the above mentioned article, the author mentions touch gestures on the screen, such as a move of your finger from the right side to the left side of the screen, which is assigned to the action *Back*. Move of the finger from the bottom to the top of the screen invokes an action that the device moves to the *Home screen*.

In the article by Marešová and Doležal [13], the emphasis is put on the contrast difference of onscreen buttons, which is useful for visually impaired users. From the article we can gain an impression that large buttons that use the overall size of the display effectively are also important elements of the application.

A blind or visually impaired user needs feedback of the work with electronic devices which replaces visual perception. This feedback can be either audible or tactile [3]. Among the general functions in

Android OS we can find text-to-speech and haptic feedback. Furthermore, there is the possibility of TalkBack, which helps the blind when working with unfamiliar screens [5].

2.1.3 2.2.1 Text To Speech (TTS)

TTS is a function of Android OS that converts typed text to speech. Applications can use this functionality and transmit information to spoken form. As an example of this application we may present Google TalkBack, which helps the blind and visually impaired people to control Android OS. The TTS feature is also incorporated in Google Maps. It describes step by step the parts of the route. Using TTS it is possible to read the whole books [14].

2.3.2 2.2.2 Speech To Text (STT)

Using Speech-To-Text can facilitate entering text into editable form fields, such as input fields for email address, text message or input for search. When using Speech-To-Text, a pop-up window with a microphone icon appears. After pressing the button, the system begins recording the voice and converting it into text. The final text after entry appears in the final input field. When using the Speech To Text system, we may record nonsense expressions, either because of unfamiliarity of the input words, because of noise around or because of mispronunciation [14].

2.3.3 2.2.3 Google TalkBack

Google TalkBack is a service that helps the blind and visually impaired to control a mobile device with Android OS. This service is available for download as an app in the Play Store. TalkBack includes communication logics, using spoken instructions (TTS) and vibration feedback which tell the user how he/she works with the device and what actions he/she invokes. For example, the user gets information on which buttons are selected, or either a pop-up window or a text box is read. The service also allows to communicate with Android OS using touch gestures on the screen (back gesture, movement in the scroll menu), or control the device using the hardware buttons on the device (moving in the text box using buttons designed to increase/decrease volume) [2].

This service is often required in applications designed for the visually impaired, it ensures all the communication with the user. The developer does not need to create their own application logics that communicates user's own action such as in getThere [11].

3 MOBILE GEO APPLICATION – GeoBlindGuide

The practical work was the most time-consuming due to getting familiar with the development environment, studying JAVA and last but not least testing the functionality of applications in terms of technical accuracy. Also testing the application from the perspective of the blind and tailoring to their needs was time consuming.

3.1. Development of the application

Studied documents and tested mobile applications were necessary to be analyzed and the concept of the application needed to be developed. The prepared concept of the application was discussed with the blind and visually impaired in Tyflocentrum Olomouc, who considered the proposed concept and made comments which created a discussion about the functionality of the resulting application. During the discussion ideas for possible improvements arose that have innovative character. After the discussion the concept of the application was finalized and proceeded to the development phase.

Development of the mobile geo-application GeoBlindGuide was conducted at the Android studio, version 2.2.2., which is designed for developing applications for Android OS. In the first phase of the development an application framework was created, which focused on the layout of individual activities the application is made of. The main emphasis was put on intuitive operations, which includes large buttons and non-duplication of controls.

In the second phase the functional content of the application started to get developed. This contains forward and reverse geocoding, which is implemented using an HTTP request to the Google service. It sends back the processed information in JSON format, which is then parsed by the application. Furthermore, for the search of a route, the service Mapbox Direction API was chosen, which returns the result after sending an HTTP request. The response comes in JSON format and contains breakpoints of the route and additional information about it. Another service, which is used in the application, is the Overpass API, which returns the HTTP location of objects from the database Open Street Map. The answer is again in the JSON format, which is parsed and the data are used for navigation and display in the map. For more information about POIs the application uses Google Place API, which again uses the HTTP request and returns a text response in JSON format, from which the information is obtained and properly communicated to the user. For getting additional information about found places the application uses the MediaWiki service, working on the same principle as the previous service.

In the next step it was necessary to invent the application logics for navigating the blind users. As one of the best solution it was decided to use navigation always to the breakpoints of the route, where the direction is changed. Thus, an algorithm was prepared for obtaining the direction of the user location to the next breakpoint of the route and also to calculate the distance between these points. To store the setting, the points of interest and also the found routes, an SQLite database was designed and created. This database stores all data and processes them for the subsequent use. As a reaction to the user request for sharing the points and routes, a system for exporting and importing the points and routes to a text file (TXT) was designed. Users can easily share this information by using conventional Android menu for sharing. In this way the user can send the file to someone else who in GeoBlindGuide via the importing interface, imports the points, routes, or the entire database to the application at another device.

3.2. Testing of the application

During the development the GeoBlindGuide several testings were done. Testing the utility correctness of the application was performed by the blind users in Olomouc (see Fig. 2). When testing, the greatest emphasis was put on navigation, which should serve the blind users in their orientation in unfamiliar surroundings. Then the emphasis was put on the control features of the application, specifically on clarity of the control elements, their overlapping and understanding the description of activities and elements. With this testing the application was continuously improved and adapted, as for functioning, to the blind.

The testing of the application in terms of functionality even ran on multiple devices, the app was tested on different devices with different Android OS versions and with different hardware equipment. During this testing emphasis was put on the full functionality of the application as well as on any of the application errors that were causing its collapse.



Fig. 2. Blind users testing GeoBlindGuide app in Olomouc (author: Tomáš Liczka).

3.3. Functionality of the application

When you start GeoBlindGuide, the application tests if the aforementioned Google TalkBack is running. After this testing the application is adapted and if TalkBack is off the application informs the user via TTS about customization of the application for Google TalkBack. If Google TalkBack is turned on, the application moves the user to the main menu and reads pop-up windows which describe the interface. This functionality can be seen as an improvement in comparison to other applications which do not perform any of the testing and do not inform users about this option. Another difference compared to other applications is a verbal presentation of all display activity for quicker orientation in the GeoBlindGuide environment .

Under the Compass button an activity with two buttons is hidden. The first button, after pressing, checks the current location, and if the device knows its location, the app uses reverse geocoding for getting an address in the nearby area. The second button is used for communicating orientation to the cardinal.

Under the second button Routes, there are two more buttons for searching the route and for showing saved routes. The second button is used to display a list of saved routes and to manage them (open, rename, delete and share). While the user wants to find a route, he/she must enter the address or coordinates of the starting and destination points of the route. The starting point of the route is possible to be input by pressing the button for inserting the current position. To enter text values the user can use the buttons for the function of STT and the voice input is transformed to the text and inserted to the input text box. After a successful route search the application starts a new activity that contains the plotted route on the map, which may be used for a check by a person without visual impairment. Further on, there are also buttons for switching between breakpoints of the route and a button for navigating the blind user, which communicates the direction and the distance to the next breakpoint. The navigation activity also includes buttons for showing additional information about the route and a button for the route options, such as its saving. When running the navigation activity and when the GPS is turned on, the device vibrates if the user does not follow the direction of the next point within an arc of 60°. This functionality again does not appear in any of the tested mobile applications for the blind for Android OS.

Under the third button dedicated to Points, there are again two buttons. The first button is used to view the activities at searching the points of interest within the defined area around the user. The second button shows views of the list of saved points and manages them (navigate to a point, share, rename and delete). When the user wants to search for points of interest, it is necessary to define the point (address, coordinate, or the current position), aerial distance at which the user wants to search from the defined point, and then also to choose which type of points of interest the user wants to search. If the searching finishes successfully, the application opens an activity with a map field with a maximum of three results in the nearby area. Under the mapping field, there are buttons corresponding to points on the map and after the user chooses one, the application gives the options to find more information about the point, or to save the point.

Under the fourth Options button an additional menu hides, incl. buttons for file import to GeoBlindGuide. Then, there is a button for menu of the setup in the application, where you can set vibration during navigating, display captions describing each activity and set the source for obtaining Points of Interest. Furthermore, in the Options menu there is a button About, which provides basic information about the application and the last button which is called Share all. It creates a text file with all saved routes and points in the application for the case that the user changes his/her device.

4 Conclusion

The project, which is focused on creating a mobile geo-application for the blind, consisted of several component parts, which were necessary to be accomplished in chronological order for the most possible objectivity at assessing and proposing solutions that would improve blind mobility in an unfamiliar surroundings.

In the first part it was necessary to get familiar with the problem being solved. For this reason, a research was created dealing with the problems of the blind, the possibilities of their motion and orientation in unfamiliar surroundings. Further on, already created geo-mobile applications for Android OS were tested, which are available for free in the Play Store.

The second part is based on practical solutions of this project. It was necessary to understand the basic principles of development for Android OS and the principles of the entire developing environment. Consequently, the developing of the application GeoBlindGuide was started, which is also the main objective of the project. Used online data sources were described as well as application of specific elements necessary for the control by blind users. The application was developed for the Android OS and adapted for the blind. It communicates with the user by TTS, despite the fact that the logics of the application is set to cooperation with Google TalkBack. The application provides the user with information from multiple online data and mapping resources, such as OSM, Google Places and Wikipedia. The application is designed for planning and orientation in the urban environment and specifically in Olomouc (as a regional capital). But thanks to the online data sources it can be used anywhere where there is a sufficient amount of data for application functionality. The application was localized into Czech, English, German and Russian language. After finishing the development of the geo-application, testing was conducted, which guarantees technical functionality across multiple devices. The application was tested by the blind, who tested the usefulness of the offered functionality.

The potential of the GeoBlindGuide is huge, not just because of the different language mutations, but also because of the possible worldwide spread among the blind users who may use the application on their Android OS devices. Improvements that have been incorporated to the application during the project contribute to the great potential.

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3D parcels as a solution to selected situations in the cadastre of real estates

Jan Málek

Department of Geomatics, Faculty of Applied Sciences, University of West Bohemia, Technická 2967, 306 14, Pilsen, Czechia

malek@students.zcu.cz

Abstract. The main goal of this work was to develop a model of existing objects in cadastre using 3D parcels. The fact that the current possibilities of 2D registry are not satisfactory for capturing complex situations is the main driving force for this work. By using axioms, we clarify the concept of a 3D parcel, which can be used to model the legal state by using explicitly defined 3D volumes. We also extend the terms of data validity, defined by the international standard ISO 19107. The practical part of this work concentrates on the implementation of the data model that supports the storage of 3D parcels as well as the topological relationship with the existing 2D data. An important aspect of the data model is its compatibility with the international standard ISO 19152 (Land Administration Domain Model). A special conversion tool has been made to load the data model with the existing 2D data of the Czech cadastral registry. These data have then been integrated with 3D parcels. In this work we also solve the visualization of the modelled 3D parcels. A visualisation tool, that can display the 3D parcels (along with 2D data) by accessing the data model, has been created for that purpose.

Keywords: 3D cadastre, 3D parcel, 3D visualization, LADM, Oracle

1 Introduction

Throughout the last century, there has been a population increase in big cities, which led to denser city centres and more complex building structures being built. While the registration of simple buildings can be done easily via 2D cadastral evidence, the situation in dense city centres might become quite complicated and creates a motivation for space division in the third dimension. But as well as making the cadastre 3D a demand for a standardised model has existed for several decades and gained international importance in the beginning of 21st century. As an answer to that a standard supporting 3D cadastral information has been delivered by ISO/TC 211 as ISO 19152 in 2012 [4].

This thesis focuses on the spatial part of 3D cadastre - 3D parcels, or more generally, spatial units where Stoter gives great general overview of 3D cadastre matters in [10]. Firstly we describe the ISO 19152 standard and the geometric concepts it introduces as defined in [4] and summarized by Lemmen and van Oosterom in [8] and Janečka in [6]. Then we define the term of 3D parcel and discuss the issue of its geometric validity introduced by Ledoux in [7] and Thompson in [12, 13]. We then proceed to the practical part of the work, where we use 3D parcels to model specific situations in the cadastre, where the 2D representation is not sufficient. Afterwards we show the data model we used and describe how it was filled with data. Finally, we visualize the data and present the results.

2 Land administration domain model

Land administration domain model or LADM is an international standard for land administration that has been published under ISO 19152 in 2012. It provides an abstract conceptual schema and a terminology, based on various national and international systems, which can be adapted to local situations and enables combining land administration information from different sources [8]. The model deals with the legal space of physical objects. [6]

2.1 Boundary face string

LADM also solves the problem of integrating 2D land parcels in 3D cadastre by introducing the Boundary-face-string concept, see fig. 1. The principle lies in replacing the 2D boundary line segments with vertical 3D faces, defining a prism with unlimited vertical extent. This reflects the situation in many jurisdictions, where the 2D parcels have no legally defined top or bottom. [13]

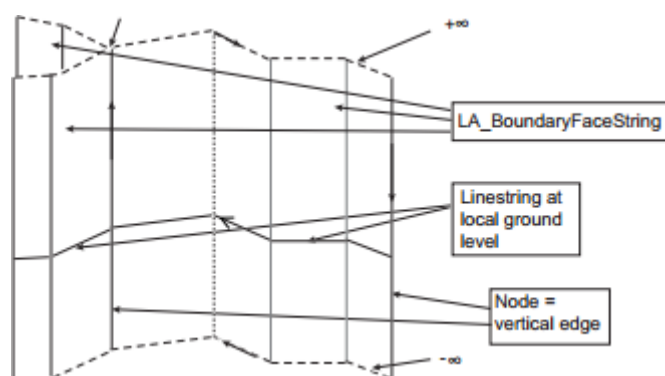


Fig. 1. Boundary face string concept. [4]

2.2 Boundary face

LADM introduces the term boundary-face, which represents the faces of spatial units in 3D. Boundary-faces are used, when the implementation of boundary-face-strings is not sufficient for representing the geometry of a spatial unit. Unlike boundary-face-string it can be oriented in any direction in 3D space, allowing a full enclosure of a 3D spatial unit.

Obviously when both concepts are used in DBMS, there are cases of parcels having both of those boundary representations. Such parcels are called liminal, see fig. 2. [4] These cases must be taken into account when building database queries.

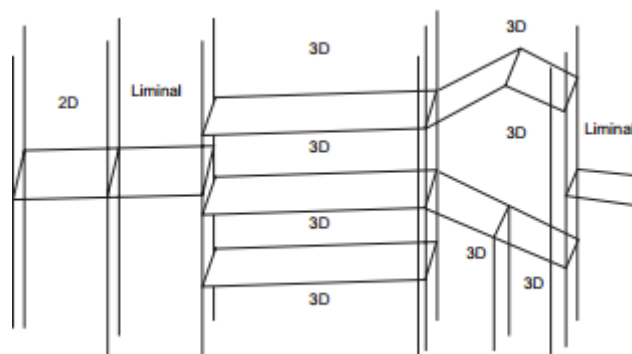


Fig. 2. Side view showing the mixed use of boundary face strings and boundary faces to define both bounded and unbounded 3D volumes. [4]

3 3D Spatial unit

The term spatial unit used in this thesis comes from the terminology of the ISO 19152 standard and is also called a “parcel”, but unlike the parcel defined by the Czech State Administration of Land Surveying and Cadastre as a *land lot* projected onto a cadastral map with an assigned parcel number, whereas the spatial unit can also represent legal space below and above surface, water and even a safe zone around an object. [5]

3.1 Data validity

It is important that the data to be inserted or updated in the cadastral DBMS (Database management system) need to be validated. This is necessary to make sure that the objects can be manipulated in a correct way. While the process may seem to be quite easy for humans, a computer needs an explicit set of rules to check the spatial data [10]. Such a set has been defined by Rod Thompson in [12, 13]. These rules (or axioms) define how spatial units can be constructed, for example: Lines can only intersect in a node. But while there are legal and geometric definitions of a spatial unit, there exist many varying definitions of valid 3D objects. So even when a program is dealing with valid a 3D spatial unit, it may not be evaluated as such [13]. One of the examples are the non-

manifolds see fig. 3.). They are valid 3D spatial units according to the ISO 19152 definition, but are not recognized as valid by many systems, for example the Oracle database. [7]

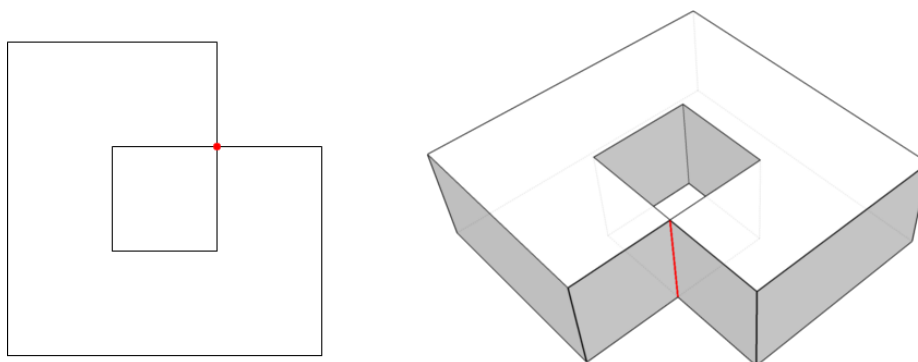


Fig. 3. Examples of non-manifold geometric objects, that are valid parcels.

4 Case study

In this chapter, we present the modelled building structures. Both of the following cases have one similarity: Some of the legal objects in the situation, projected on 2D plane overlap.

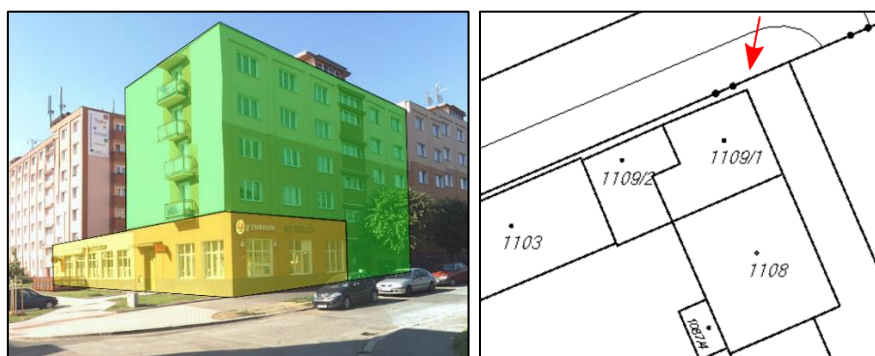


Fig. 4. Left: The building complex, the restaurant is highlighted in yellow colour and the apartment block is highlighted in green colour. Right: Situation in cadastre. Red arrow represents the location and orientation of the camera in the left-hand picture.

4.1 A complex structure

This case is located in Pilsen, Czechia. There are two buildings, where an apartment block is built on top of a restaurant, see fig. 4. The owner of the restaurant building owns both land lot number 1108 and number 1109/1. An Easement is currently applied to lot number 1109/1, implying that the owner of the restaurant will tolerate the apartment buildings existence.

A request came from the resort of ČÚZK (Czech State Administration of Land Surveying and Cadastre) for making the situation more transparent by using 3D parcels.

4.2 Building bridge

This building is located in Ostrava, Czechia and represents a use case of building bridge over a street which can be found in many places in Czechia. Similar examples are the building complex at Hague [10] or ‘De Brug’ at Rotterdam in Netherlands [11]. Such cases can’t be easily understood or visualized outside the domain of highly

specialized professional land surveyors [4]. This situation can be represented with just one 3D parcel but it crosses the space delimited by a 2D land lot.

Furthermore, some of the faces of the 3D parcel are neither vertical, nor horizontal.



Fig. 5. Left: A portal in Ostrava - Poruba. Right: Situation in cadastral map. Red arrow represents position and angle of camera in the last picture. [6] edited.

5 Data model

The design of a data model is a complex task and there are many ways it can be made. This task has been in scope of several researchers in the world, such as Ding, et al. who created the model based on footprint extrusion [2], Thompson, with his model based on the combination of boundary-face and boundary-face-string concepts [13, 14] or Penninga with a model based on constrained tetrahedronization of 3D objects [9], so there has been no need for creating a model from zero.

We gathered the models and evaluated them with a set of criteria:

- **The volume of the data stored** - Various data models save different amounts of data for the same data sets. For example, a topological data model would store less data than a geometric model, where boundaries would be stored separately for each object, resulting in duplicities.
- **How the data is stored** - As described in [15] there are several ways to store the combination of 2D a 3D parcel data. We prefer all data to be integrated in the same database.
- **Computing power needed for spatial queries**
- **Level of spatial unit complexity allowed**

On top of that the model had to be ISO 19152 compliant. The goal was not to find a model excelling in all these criteria, but rather a good compromise.

Eventually we used the data model, created by Thompson, published in [14], see fig. 6. This model integrates 2D and 3D spatial units in the same database with topological relationships even between the two datasets. In comparison with the model described in [2] it allows faces to have any possible orientation.

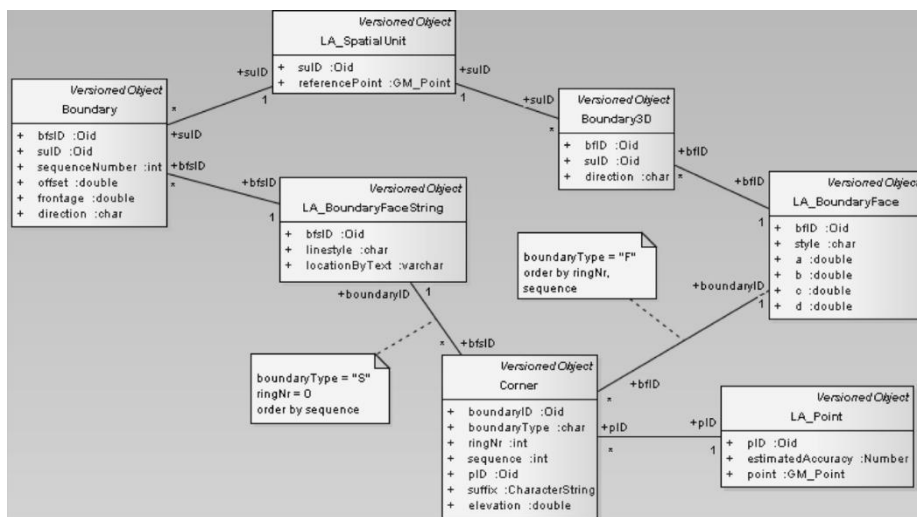


Fig. 6. Suggested data model, based on proof of concept database piloted using the Queensland DCDB (Digital cadastral database) data. [14]

5.1 Implementation

For the actual implementation of the data model, Oracle spatial database has been used, because it has also been used by ČÚZK for storing the data of the cadastre.

As 2D data source, the original Czech cadastral exchange format VFK [1] has been used. This is a data format not derived from any of the usual formats like XML or JSON so a brand new conversion program had to be made for the data to be loaded into the database. 3D parcels have been modelled semi-automatically.

For storing point elevation, we use the relative values above surface, since as analysed in [10], absolute heights would require storing terrain model in database to preserve the topological relationship of 3D spatial units and the Earth surface.

6 Visualization

After the data had been loaded into the database the remaining task was to visualize the integrated 2D and 3D parcels. The intent was to make a program that would load the data directly from the database, without the need of any middleware. Originally an existing 3D visualization program written in Java had been extended, but this was a dead end, as the code was very time consuming to extend any further. Also, the original program only showed the 3D parcels with a wireframe representation instead of drawing the boundary faces. Therefore, a program has been made from zero with the intention to make a more extendable solution.

For the new program C# has been used instead of Java, since it offers better performance and seemingly better engines, although it is not as portable. For the creation of this program a 3D game engine called Unity has been used, which comes with its own programming environment. So instead of writing a complete program, the solution changed to writing scripts that create and manipulate elements in this environment. This proved to be useful as extensions such as camera movement or object colouring can be added easily.

We encountered trouble, when trying to load the cadastral data from the database, because Unity engine does not support the .NET version needed for the usage of ODBC (Open database connectivity). Eventually we came to a workaround of creating an Executable program, using Oracle managed data access library and using this program in Unity script with specific parameters to retrieve requested parcels.

Results can be seen on fig. 7.

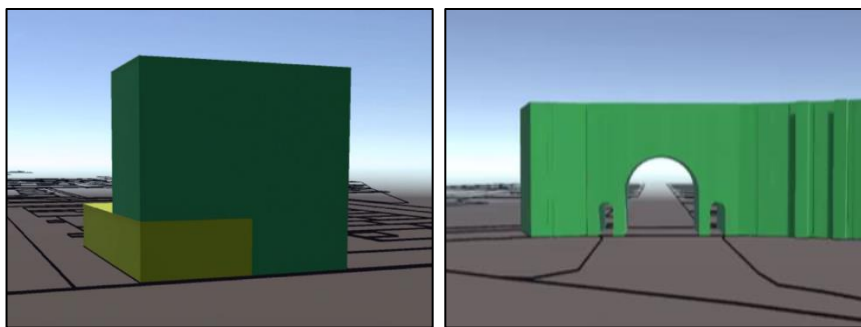


Fig. 7. Visualization, using the Unity engine.

6.1 Database query optimization

When working with a database containing real data, such as a whole cadastral administrative unit or more, it is necessary to optimize the way the data in the database are queried. The solution we used was to create an indexing table that tiled the space into tiles 200m x 200m large and was related to spatial units. This way only spatial units on nearby tiles are loaded while browsing the data.

7 Conclusion and future work

The LADM is a data model that is able to integrate 2D and 3D parcels. We extended the Thompson's model, which is an implementation of LADM and used real data to fill it. For that purpose, current Czech cadastral data were transformed and loaded into the database. Also a program has been made to visualize the data saved in this database. Because the program has been designed to retrieve the data directly from the database, using ODBC API, it has been possible to debug the database functionality.

In future we will be exploring the possibilities of 3D and 2D cadastral data visualisation with the intention of making it easier for a user to browse the data of a cadastral database implementing the standard LADM.

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The Examination of the influence of the environment on the soils conditions

Eva Mertová

Department of Military Geography and Meteorology, Faculty of Military Technology, University of Defence, Kounicova 65,
662 10, Brno, Czech Republic

Contact eva.mertova@unob.cz

Abstract. Soils are one of many very important landscape elements having a crucial effect on a person's life. Soils influence food production, the appearance of the environment, water retention in the landscape. One of very important influence especially for the Army and Integrated Rescue System is the influence of soils on the movement of vehicles off the road. For this reason, it is really very important to focus also on examination of the influence of meteorological conditions on the movement of vehicles off the road. The topic of this thesis is The Examination of the influence of the environment on the soils conditions. The first part of this work theoretically describes allowable bearing capacity and the ways of its measurements. Allowable bearing capacity is influenced by the meteorological conditions so that is the reason, why 3 meteorological elements were more deeply tested. The focus was put on precipitation, temperature and soil moisture. Thanks to this it should be possible to get comprehensive results and evaluate the dependence of the movement of vehicles off the road on the meteorological conditions.

Keywords: Soils, Penetrometric measurements, Meteorological conditions, GIS, Modelling

1 Introduction

Soils are one of the major landscape elements, they have relevant influence on human's life, affects produce of food, appearance of environment, holds water in lands and also participate in movement of vehicles off the road. Conditions of soils are constantly changing based on the location, meteorological and climate conditions or other factors like outflow ratios, etc. The most important abilities concerning the off-road vehicle movement is allowable bearing capacity. From this reason, there have been realized penetrometric measurements of the allowable bearing capacity. Collected result were analyzed with regard to available meteorological information related to the specific terms of measurement and compared by analytical method for movement of vehicles off the road for these terms. Target of my work is to verify the analytical method and to design improvements.

2 Examination of allowable bearing capacity

Allowable bearing capacity is a general parameter which expresses hardness of object against action of external effects. Allowable bearing capacity can be determined by several ways [7]:

- measuring level of soil resistance against transmitted pressure (static penetration test, endurance board test, vane shear test of soil cohesion, pressuremeter tests);
- analytically using the database with information about soil types and soil kinds (model GeoS ACR, model NIMA).

2.1 Measurement of allowable bearing capacity

One of the options for measurement of allowable bearing capacity is to use cone penetrometer and forming set (kit for measurement of movement of vehicles off the road E 910) [2]. Principle of cone penetrometer is based on measuring the resistance of soils against penetration of the cone – based metal peak continuously pushed into the ground. Resistance of the soil is directly proportional to soils concretion, structure and immediate humidity. Measurement procedure and its outcome of the allowable bearing capacity from cone penetrometer is based on regulation FM 5 – 430 – 00 – 1 [2]. This method is based on determination of Rating cone index RCI calculated from measured values and its comparison against Vehicle cone index VCI. Collation of these values will states if the surface is passable ($RCI > VCI$) or impassable ($RCI < VCI$) [2].

The task of discovering the influences of the soils on movement of vehicles off the road have been solved at the Department of Military Geography and Meteorology at University of Defence. During the last several years there have been done measurements of the allowable bearing capacity at 9 different locations (Fig. 1). Measurements have started at the end of year 2014 and are continually measured until present. Unfortunately there have been

executed only 15 different measurements despite the long time as the last one was at the end of year 2016. Dates of measurements and serial number as used further in my work:

1	9. 12. 2014	6	19. 11. 2015	11	3. 3. 2016
2	26. 3. 2015	7	26. 11. 2015	12	14. 4. 2016
3	13. 8. 2015	8	10. 12. 2015	13	16. 6. 2016
4	14. 10. 2015	9	19. 1. 2016	14	6. 9. 2016
5	21. 10. 2015	10	17. 2. 2016	15	11. 10. 2016

Together with these measurements some soil samples for laboratory analysis were also collected. Discovered soil types were compared with soil types gathered with different means used for soils data gathering. Compared databases are Specialized military database of soils (UDBP) used by the Czech Army and Digital soil map 1 : 50 000 (DPM 50) made by Czech Geological Survey. DPM 50 is according to my previous research better and more accurate soil map product (Table 1) [1].

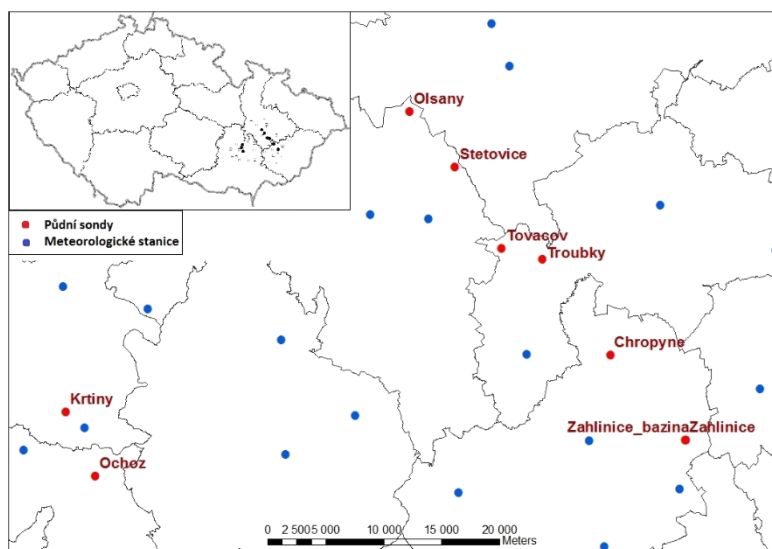


Fig. 1. Locations of measurements.

Table 1. Results of laboratory analysis and soil types of locations stated in ÚDBP and DPM50

Locality	Soil type (sample)	ÚDBP	DPM50
Záhlinice	Phaeozem	Phaeozem	Phaeozem
Záhlinice – bažina	Gleysol	Phaeozem	Gleysol
Chropyně	Fluvisol	Fluvisol	Fluvisol
Troubky	Fluvisol	Fluvisol	Fluvisol
Tovačov	Phaeozem	Phaeozem	Phaeozem
Štětovice	Peat	Peat	Peat
Olšany	Chernozem	Phaeozem	Chernozem
Křtiny	Gleysol	Cambisol	Gleysol
Ochoz	Pseudogleysol	Cambisol	Luvisol

As was already stated, conditions of soils are influenced by many factors. Amongst the most important are meteorological conditions and mainly the precipitation. Weather during the measurements was rather different than the usual climate levels. All together this season was dry, precipitation was substandard against long – term normal. Except the low precipitation, temperature was above average.

Measured allowable bearing capacity gives us a quite different result that depends on soil conditions and meteorological conditions. In some regions calculated values of the RCI are very low throughout the whole season, meaning that they are hardly passable with all of the military vehicles. In the other regions is the reality opposite although most of the locations should have problems with vehicle passing, at least when there are harsh weather conditions (Table 2).

Based on calculated RCI values compared to VCI we can determine which soils are passable and which ones are not. In Table 2 there is overall throughput for the wheeled vehicles based on passable abilities of specific types of vehicles. Black dots mean impassable terrain, white ones are symbols for passable terrain.

Table 2. Evaluation of the off-road movement of vehicles during the measuring period.

Lokalita	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Záhlinice	●	●	●	○	○	●	●	○	○	●	●	●	○	●	●
Záhl. – b.	●	●	●	●	●	●	●	●	○	●	●	●	●	○	●
Chropyně	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●
Troubky	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Tovačov	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Štětovice	○	●	○	●	●	●	○	○	○	●	○	○	○	○	○
Olšany	○	○	○	○	○	●	●	●	○	●	●	●	○	○	○
Křtiny	●	●	○	●	●	○	●	●	○	●	●	●	●	○	○
Ochoz	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Locations Záhlinice – bažina and Křtiny (soil type gleysol) are impassable or at the edge of throughput throughout the whole year (Table 2). On the other hand, the best throughputs are in locations Chropyně and Troubky (soil type fluvisol). Only in one case there was the situation when the location Chropyně was impassable (Table 2). If we compared the laboratory results of soils in locations Tovačov and Záhlinice, we found out that the soil types are the same (phaeozem), but their throughput is quite different. Location Tovačov was valued as passable but Záhlinice was in most of the cases impassable. With big probability, it was caused by different soil kinds in these locations. In the other locations there were not similar soil type, but we can see that the location Ochoz was passable throughout the whole season with no problems.

2.2 Analytical determination of soils bearing capacity (model GeoS ACR)

Another mean of determination of soils bearing capacity in the Czech Army is analytical method based on determination of soils throughput by ÚDBP (Model GeoS ACR). This database with information about soil areas provides its own methodology based on the season and precipitation during the last 3 days. Meteorological conditions are divided into 2 categories: normal and harsh meteorological conditions, where normal meteorological conditions in summer season (May – September) are characterized by 3 days precipitation value of 60 (70) mm and in months October – April (winter season) are lower than 40 mm. With the combination of data about precipitation values and attributes of soils (soil type and soil kind), there is a possibility to determine soils bearing capacity [6].

Based on rainfall in year 2014 – 2016 (see next chapter: Meteorological conditions affecting off-road movement of vehicles) it was discovered that in the measured terms there were only normal meteorological conditions. With regard to it, only location Štětovice (soil type peat) was defined as impassable. This type is determined as impassable throughout whole year. Other locations were valued as passable.

Discovered values of the soils bearing capacity based on ÚDBP methodology are not in correlation with measured values of the soils bearing capacity. In 4 cases when ÚDBP gave us passable result, the measured values were impassable (locations: Záhlinice, Záhlinice – bažina, Olšany, Křtiny). For location Štětovice, where ÚDBP gave us impassable result for whole year, the measured values gave us in more than half cases passable result. Locations: Chropyně, Troubky, Tovačov and Ochoz were passable based on both methods of analysis (Table 2).

Comparing soil types gathered from ÚDBP and DPM 50 in location Záhlinice – bažina, different bearing capacity was discovered. While the soil type phaeozem as stated in ÚDBP is passable the other one soil type gleysol stated in DPM 50 is impassable. This location based on the measured values is closer to the bad and impassable throughput so the DPM 50 is once again more accurate.

This method for evaluating the soils bearing capacity has its advantages and disadvantages. Main advantage is that the evaluation is made without actual measurements and without being in the field and it is quite fast. Thanks to available data sources, we can analyze even hard to reach locations. Main disadvantage is that the soil areas aren't correctly stationed in the database and so the soil types and soil kinds will result in even greater mistake to soils bearing capacity. It is also normal to assess whether the threshold value of precipitation in the last 3 days is correct to different soil types. If we look at the different results of both methods, it is correct to assess except from precipitation value, the proper time interval or other meteorological conditions.

3 Meteorological conditions affecting off-road movement of vehicles

One of the main factors determining movement of vehicles off the road is weather. It often proves in case of soils, which dependence on weather (especially during precipitation) causes changes in soils conditions influencing movement of vehicles off the road.

Main meteorological element influencing movement of vehicles off the road is precipitation. Precipitations are measured in mm/time period [3] and they influence the movement of vehicles off the road in a long-term perspective. Another significant meteorological element, influencing soils conditions, is temperature. It, especially during winter time, influences drain parameters of precipitation. Furthermore, we can talk about soil moisture (saturation of soil with water), evaporation of water from the soils surface and quantity of sunshine.

3.1 Dependence of movement of vehicles off the road on precipitation

When researching dependence of movement of vehicles off the road on meteorological conditions, it is important to examine especially the influence of precipitation on changes of soil conditions. It is possible to get information about precipitation from various sources. One of them is data measured on meteorological stations. These data are only in discrete distribution and it is vital to get the data for the whole region with use of appropriate interpolation method. Based on testing of various interpolation methods, using program ArcGIS, the IDW method was chosen as the best (Fig 2). Testing was run on data sample of 3 precipitation different dates in March 2015. Firstly the interpolation of all data from all meteorological stations was made and then it was confronted with interpolation of data from 2/3 of selective population of local meteorological stations. The rest 1/3 of stations served as control points. Based on deviations of measured values compared to interpolated raster was later on the IDW method valued as the most appropriate one (Fig 3).

Fig 2. Interpolation methods Kriging, Spline and IDW – date 26. 3. 2015.

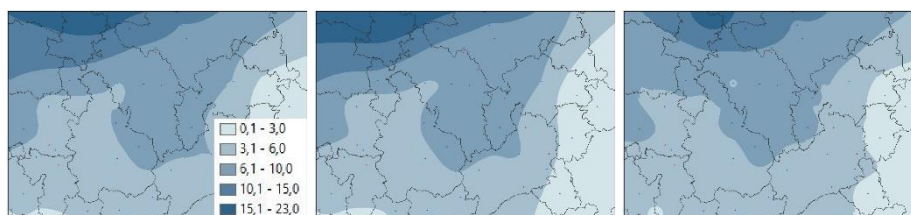
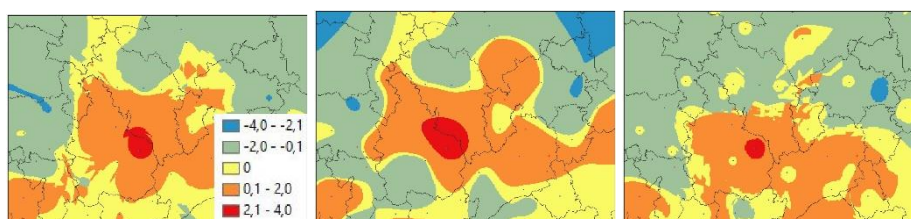


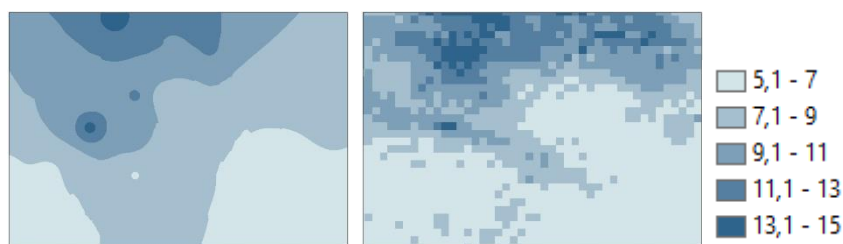
Fig 3. Deviations of interpolated rastered methods Kriging, Spline and IDW – date 26. 3. 2015.



Information about precipitation is also possible to get from meteorological radars (detection of precipitation clouds by radar). These estimates of intensity of precipitation are in continuous distribution so it is no needed to modify them. Measuring with meteorological radars is weighted with errors such as detection of non-meteorological objects (terrain, airplanes, birds), signal noise level, instability of transmitter of radar or influence of Wi-Fi network. While these data are weighted with errors, their continuous distribution offers more realistic information about precipitation (Fig.4). When using these data it is vital to eliminate errors of radar. One option to eliminate these errors is correction of radar images with use of gathered data from precipitation-measuring stations. Because of this the dependence of precipitation data gathered by radar images and data from meteorological stations was examined. Firstly, with use of ArcGIS program, precipitation data for chosen dates from radar images were calculated (5 minute interval) and then the precipitation data from meteorological stations were determined for the same dates. Then the results were confronted and linear regression was calculated. According to regression, equation radar images were corrected with use of ArcGIS program and thus

were obtained information about precipitation in locations where penetrometric measurements were made. Results provide more realistic information than values obtained with just interpolation.

Fig 4. Interpolation method IDW and radar image from the same region – date 31. 3. 2015.



For the Czech Republic, it is possible to use more accurate precipitation data. There are surface estimates of precipitation calculated with combination of measured values from surface precipitation-measuring devices and determined radar reflectance of meteorological radiolocators which belong to radar network of Czech Hydrometeorological Institute. Their combination is more sophisticated than pure correction with use of regression. In the Czech Republic these surface estimates of precipitation are considered as the most accurate information about precipitation which is available. These data were obtained in the later part of experiment and now they are the main source of information about precipitation. Specialized military database of soils states, in its methodology for evaluation of movement of vehicles off the road, three-day time interval. As results of the comparison of movement of vehicles off the road obtained with calculation and measurements show, this interval is probably wrong as well as critical value of precipitation stated in ÚDBP. After generating graphs for RCI dependence the dispersion of RCI values was huge while amount of precipitation was just small. Because of this reason the dependence of five-day and ten-day intervals of precipitation on RCI was investigated.

Based on this investigation, it is possible to state that soil type paheozem became passable with more difficulties because of long term high precipitation. Movement of vehicles off the road in soil type gleysol is difficult all year long with no influence of precipitation. Other analyzed soil types showed no connection to amount of precipitation. Because of this reason, further examination of dependence of movement of vehicles off the road on other meteorological elements was made.

3.2 Dependence of movement of vehicles off the road on temperature

Another meteorological element which was analyzed is temperature. Temperature influences not only outflow parameters of precipitation but also evaporation of water from earth surface. It is measured in °C (or °F) in primary and secondary observation terms [3]. Off-road movement is also partly affected by temperature of soils.

Information about temperatures was available only in areas of meteorological stations where these temperatures were measured. Data were again only in discrete distribution. For examination of the dependence of movement of vehicles off the road on temperature were chosen only average day temperatures. From these temperatures it was vital to get information in locations of measurements (to get continuous data).

One assumption was that temperature is affected by altitude of the area so for the interpolation was used two parametric model of orthographic interpolation. This is linear regression between measured temperature and altitude [5]. Altitude was obtained from Digital Relief Model of the Czech Republic Generation 4. After data interpolation were again obtained temperatures in areas of measurements. Next step was to obtain dependence of RCI values on temperature.

Initial hypothesis was that with increasing temperature (only plus values) the movement of vehicles off the road will also increase because soil types will be less influenced by precipitation (water will evaporate faster from soil). This theory was partially confirmed. Soil type paheozem shows direct proportion between temperature and RCI values. Same results were obtained for fluvisol soil type. The most problematic soil type, gleysol, showed no evidence of dependence of movement of vehicles off the road on temperature because RCI values remained very low during the whole measuring period. It is possible to say that this soil type increased very slightly its level of throughput with increasing temperature. Rest of soil types proved same behaviour as previous ones but with minor dependence. Dependence was examined again for 3, 5 and 10 days before the day of measurement. It is possible to say that 10 day temperatures show higher dependence of movement of vehicles off the road on temperature. Even though there was found out that the influence of temperature on movement of vehicles off the road is impossible to parameterize without considering precipitation. That is why analysis of another parameter, soil moisture, was made.

3.3 Dependence of movement of vehicles off the road on soil moisture

Soil moisture is, simply formulated, water content in soil (in pores). It is possible to explain it in many ways: like a ratio of water content to soil content (content moisture), ratio of water content to total soil porosity (relative moisture) or as a ratio of water mass to dry soil mass (mass moisture) [3]. Soil moisture is fast changing element dependant on meteorological and pedological factors. When soil moisture is increasing, the air content in soil is decreasing. Measuring could be done many ways and results are often expressed in percentage which tells us how much pores in soil are filled (saturated) with water. Information about measured values in the Czech Republic can be found in graphic form online on web page of the Czech Hydrometeorological Institute [3] or on web portal Intersucho [4]. Data provided by portal Intersucho were used for this thesis because of their details. Start of cooperation and acquiring of data was made at the end of year 2016. Processed data provide only three chosen terms (with measured different precipitation), which were used to judge suitability of data type for further processing.

Data are processed and provided in week intervals. To record changes of soil moisture on precipitation for all terms of measurements data about drought intensity, relative soil saturation and content of water in soil were acquired always two weeks before measurements and on week afterwards. Data were acquired in form of raster which meant easy processing in ArcGIS program. After loading data characteristics of soil moisture were obtained for given locations and terms. Obtained data were analyzed in connection to measured values of movement of vehicles off the road and amount of precipitation.

Based on accomplished analysis, it is obvious that soil moisture greatly influences movement of vehicles off the road. In table 3 you can see that with increasing soil moisture and increasing precipitation the movement of vehicles off the road is decreasing. Off-road movement is influenced also by other meteorological elements as it can be seen in time change of relative soil moisture.

Table 3. Influence of the relative soil saturation on RCI for 3 chosen locations.

Term	Locality	Precipitation [mm]	RCI	Relative soil saturation [%]		
				Before	Term	Afterwards
13	Záhlinice	5	106	40	29	24
14	Záhlinice	16	39	32	24	32
15	Záhlinice	23	53	25	44	45
13	Chropyně	15	348	43	31	29
14	Chropyně	9	56	39	31	35
15	Chropyně	18	41	27	42	44
13	Štetovice	6	63	44	32	31
14	Štetovice	5	134	40	32	30
15	Štetovice	10	131	29	34	38

It is impossible to state the dependence according to just three tested terms. It means that another step of this thesis will be analysis of soil moisture in all terms of measurements and evaluation of dependence on all analyzed meteorological effects.

4 Conclusion and further research

The target of my work was evaluation of the influence of the environment on the soils conditions. In first phase, analysis of repeated penetrometric measurements in several locations was conducted. Measured values were compared with ÚDBP ratings of soils bearing capacity. Comparison showed us unreliability of the ÚDBP methodology. That is why soils throughput based on meteorological conditions was investigated in the second phase. Gradually we picked and analyzed influence of precipitations, temperature and soil moisture. Gathered meteorological data were adjusted so we could gather values far away from the meteorological stations. Based on this analysis, there wasn't conclusively defined relation between soil bearing capacity and meteorological conditions. But there have been given several assumptions. From the analysis it is clearly demonstrated that the main aspect of soils bearing capacity will be data about precipitations and soil moisture. Further research in the next years will be streamlined this way.

Except from that, it would be appropriate to make a model of runoff regime behavior and based on soils bearing capacity model the impact of relief on movement of vehicles off the road. Attributes of soils except from meteorological elements are affected by its location, whether it is on lowland, plain or slope. Target of whole research is to specify new way of modeling the probability of soils bearing capacity, more accurate to real values.

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The Impact of Green Infrastructure on Urban Heat Island in Košice

Bc. Katarína Onáčillová

Institute of Geography, Faculty of Science, Pavol Jozef Šafárik University
Jesenná 5, 040 13 Košice, Slovak Republic
onacillova.katarina@gmail.com

Abstract. The main objective of this paper is analysis of the vegetation impact on the urban heat island (UHI) phenomenon in Košice, on the basis of Landsat images and ground-based weather station data. For this purpose, Landsat 7 and Landsat 8 satellite images depicting the study area of Košice, the second largest city in Slovakia and metropolis of Eastern Slovakia, were obtained from the United States Geological Survey (USGS) website. Data from meteorological observations were provided by Slovak Hydrometeorological Institute and personal weather station Boženy Němcovej 3.

Selected images were processed using ArcGIS software. Landsat sensors store the information on the Top of the Atmosphere brightness temperature in a form of digital numbers, so it was necessary to convert obtained values to decimal numbers in the first step of data processing. Then, the Top of the Atmosphere radiance was transferred to Black body surface leaving radiance by removing atmospheric effects, employing statistical data and using Atmospheric Correction Calculator developed by Barsi. Land surface emissivity method using vegetation index values was used to calculate the emissivity of the real surface and after that the black body surface radiance values were recalculated to the land surface temperature (LST) values in degrees Celsius.

From processed images in the 2013-2015 period, spatial and time distribution of the UHI phenomenon in the city is demonstrated. The results show that the lowest LSTs are spread across a wide area of greenery - Košice forest park in the north with a significant percentage of vegetation cover and low human intervention in nature. On the contrary, the highest values, that reach sometimes up to 50 °C are visible in the city core, areas of shopping centres, urban fabrics on the outskirts of the city and in the industrial zone U.S. Steel. According to Corine Land Cover classification, the lowest mean LST values in Košice are recorded in the forest areas, areas of water bodies, lands principally occupied by agriculture and areas of urban greenery. Difference between these values compared to those in urban and industrial areas with a minimal percentage cover of greenery, can be more than 10 °C during one day.

To characterize the spatial extent of the UHI in detail, two profile graphs through LST and Corine land cover patterns on August 6, 2015 were made. The A-A' profile crosses the city from the north-west to south-east, which gives distance between the start and end point 25.2 km. The minimum LST values were reached by areas of pastures. Significantly lower LST values and impact to reduce the LST in the middle of the city-centre had Košice city park. The maximum LST values in this profile were reached in the area of non-irrigated land. In the second, the B-B' profile that gives distance from the south-west to the north-east 22.7 km, maximum LSTs were reached in the industrial area of U.S. Steel, where the LST values reach up to 50 °C. Other temperature increases were connected with warm areas of the airport, shopping centres, city-centre and railway network. On the contrary, drops in temperature were caused by areas of transitional woodland shrubs and agriculture land. Rapid LST decrease – about 5 °C – was observed in the area of Košice city park.

Next, according to time-series maps of Spatial distribution of the LST standard deviations, which result from processing Landsat images using focal statistics for selected months in the 2013-2015 period, it was observed that majority of differences between areas with high and low vegetation cover occur in May and August, or in so-called growing season. On the contrary, low LST differences were related to the dormant season - selected months March and November.

Also clear correlation between LSTs and NDVI values for selected localities of historical centre was observed. In areas with higher percentage of greenery, vegetation index was higher and LSTs lower. Moreover, significant differences in the LSTs before and after construction were recorded. In the area of constructed urban fabrics and shopping centres maximum LST in 2015, higher about 10 °C compared to previous situation in 2000, was observed.

It has been shown that notable effect on the temperature distribution within the UHI have weather characteristics, such as relative humidity and cloud cover. In most cases there was the correlation - lower the relative humidity and cloud cover - higher temperature differences within the UHI.

Several constructions made during last years magnify the heat island effect, so the effort for balanced presence of built-up areas and greenery should be a priority for the upcoming years.

Keywords: urban heat island, Košice city, Landsat, LST

Mean dynamic topography as a product of satellite altimetry

Bc. Daniela Piačková¹

¹Department of Theoretical Geodesy, Faculty of Civil Engineering, Slovak University of Technology, Radlinského 11,
810 05, Bratislava, Slovakia

Contact d.piacokova1@gmail.com

Abstract.

This study focuses on the satellite altimetry missions, their products and corresponding applications in geodesy and other geosciences. We analyse the particular products referred to as mean sea surface, which is a displacement of the sea surface relative to a mathematical model of the Earth.

One of its many applications include computation of mean dynamic topography (MDT), subsequently used in determination of ocean currents or global geoid. However, there is correlation between MDT and global geopotential model (GGM) used for computation. That depends, whether satellite-only or combined GGM (also including satellite altimetry data) is used. If satellite-only GGM is used, there is no correlation, but lower resolution is expected. On the other hand, combined GGM provides a lot higher resolution.

We compare results using GGMs such as EIGEN-6C4 and GO_CONS_GCF_2_TIM_R5. Primarily, we focus on satellite-only model, in which case filtering of resultant MDT is necessary. For filtering we use application called GeoFilter, implementing linear and Perona-Malik nonlinear diffusion filtering.

The main objective of this study is to show the significance of filtering and to determine which filtering is most appropriate.

Keywords: Satellite Altimetry, Mean Sea Surface, Global Geopotential Model, GOCE, Mean Dynamic Topography, Perona-Malik nonlinear diffusion filtering

1 Introduction

Satellite altimetry is one of the methods of satellite geodesy and its significant development has come in last decades, by missions such as Topex/Poseidon, Envisat, Jason, CryoSat or Sentinel 3. Altimetry has the interdisciplinary nature and the primary application areas are geodesy, geophysics and oceanology. This technique offers possibility for global monitoring of sea surface and determination of mean sea surface (MSS) from the measured altimetric height above the instantaneous sea surface. Radar altimeter scans the sea surface directly and hence, we can approximately derive the ocean geoid. For this reason, satellite altimetry is considered a useful geodetic tool for direct mapping of the marine geoid and for modeling of gravity anomalies.

We discuss the relation between the geoid, the MSS and the mean dynamic topography (MDT), i.e. quantity which bridges the MSS and the geoid [1]. By use of global geopotential model (GGM), we can deduce MDT and subsequently compute surface ocean currents. In this study, we focus on comparison between the resultant MDTs computed from two different MSS models and two geoids. We use model DTU15MSS produced by DTU Space (Denmark's national space institute) and model MSS_CNES_CLS_11 provided by CLS Space Oceanographic Division. The time series of the first model span more than 20 years, including Cryosat-2 data (4 years). The second model has been computed from a 16-year period of altimetry data. We apply GGMs such as EIGEN-6C4 (combined model, i.e. terrestrial, satellite, altimetry data) and GO_CONS_GCF_2_TIM_R5 (satellite-only model). They are provided by International Center for Global Gravity Field Models (ICGEM). The model EIGEN-6C4 was computed from satellite tracking data (missions GOCE, GRACE, LAGEOS), gravity data and altimetry data. Second model includes data from GOCE mission and it is derived using the so-called time wise approach (TIM) [5].

The MSS is known with centimetre accuracy. Moreover, precision of geoid determination is the limiting factor in estimating the ocean's geostrophic circulation. The MSS data contain information with higher spatial resolution than those included in the geoid model, which causes artefacts. These features have to be removed by filtering. Filtering ensures consistency between the MDT and the geoid. For filtering, we use an application GeoFilter [3]. Evaluation of this experiment is based on the comparison of the computed MDT and well-known model produced by Maximenko et al. (2009) [8]. Our MDT model would also be compared with each other. In the conclusion, we apply MDT to compute velocities of geostrophic currents in particular locality.

2 Computation of the mean dynamic topography

MDT is defined as the height of the sea surface above its rest-state (the geoid). Knowledge of the ocean dynamic topography would allow to study the absolute circulation of the oceans and determine the associated geostrophic surface currents that help to regulate the Earth's climate [7]. The MDT defines a motion of ocean currents, because geostrophic flow directs parallel to isolines of sea surface topography. Stated differently, geostrophic currents flow perpendicular to sea surface gradients and they are proportional to the sea surface gradient.

The basic concept of computing the MDT from the MSS and the geoid is very simple. We can express the MDT via equation:

$$\zeta = \bar{h} - N \quad (1)$$

where $\bar{h}$ is the height of the MSS above the reference ellipsoid and N is the geoid height relative to the same reference ellipsoid [6]. The input data (the MSS and the geoid) have fundamentally different characteristics and are defined with different spatial resolution. Data are usually not consistent, hence it requires special attention and we have to follow certain requirements in order to obtain a reasonable MDT product. Geoid and sea surface heights must refer to a same geodetic reference system, tide system, and spectral content [4].

2.1 Consistency of data between MSS and geoid

A geometrical part of data consistency includes issues, such as reference system (reference ellipsoid) and tide system. While data used from both MSSs are computed relative to the TOPEX/POSEIDON ellipsoid and are in the mean-tide system, the models of geoids are related to the GRS80 ellipsoid and are tide-free.

The MSS and the geoid heights refer to an ellipsoidal reference system identified by four constants - gravitational constant times mass of the earth (GM), equatorial radius (a), angular velocity (ω) and flattening (f). Due to different the dimensions of the reference ellipsoids ($REF1$ and $REF2$), we change ellipsoidal heights using equation [4]

$$h_{REF2} = h_{REF1} - (a_{REF1} - a_{REF2}) + a_{REF1} \sin^2 \varphi (f_{REF1} - f_{REF2}). \quad (2)$$

Geoid heights and mean sea surface heights also differ depending on what tidal system is implemented to deal with the permanent tide effects. The impact of not unified tide systems on the resulting MDT cause difference between the tide free and the mean tide reference systems from -15 cm to 30 cm [2]. Data that are 'tidal' height fields can be transformed between tide-systems using GOCE User Toolbox (GUT). During the computation of the MDTs, we follow recommendations from the GUT tutorials [2].

Particularly important is a spectral consistency between MSS and geoid. Altimetric MSSs and geoid models are not characteristic by the same spectral content. Typically, MSSs are known with a centimetre accuracy at spatial scales down to a few kilometres. On the other hand, same accuracy of the geoid is achieved using GOCE data at scales down to around 100 - 200 km [2]. It means that the MSS contains information with a lot higher spatial resolution than ones included in the geoid model.

The altimetric MSS contains short scale geoid information. After subtraction of the geoid model from the MSS this short scale geoid features would be misinterpreted as being part of the dynamic ocean topography. For this reason, we have to filter the data to eliminate short scale geoid signals to obtain a useful estimate of the MDT. The filtering can be done either in geographical space, where the MSS is usually represented, or in spectral (spherical harmonic) space [4].

2.2 Satellite-only mean dynamic topography

We compute global MDTs as combination of models DTU15MSS and MSS_CNES_CLS_11 with model of geoid GO_CONS_GCF_2_TIM_R5. We also choose smaller areas which are affected by significant currents, i.e. Agulhas current, Gulf current and Kuroshio current. Fig. 1 represents map of the MDT (based on DTU15MSS) and Fig. 2 shows area of South Africa where Antarctic circumpolar current is also displayed, too. This Fig. shows MDTs calculated from Danish model MSS and model MSS provided by CLS.

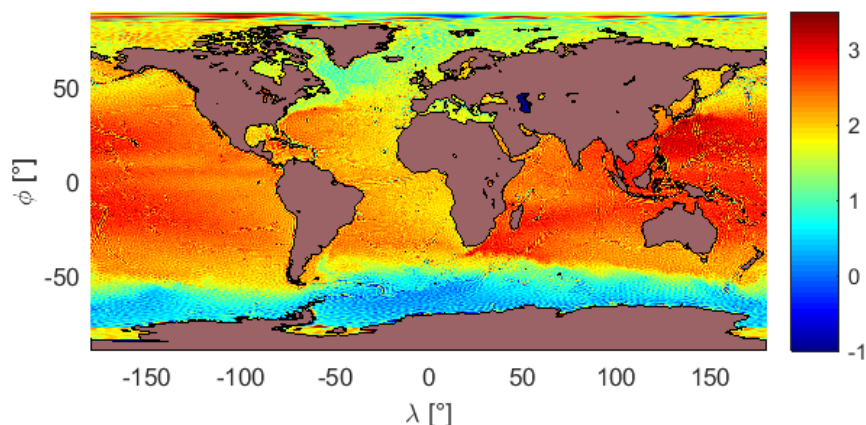


Fig. 1 Map of mean dynamic topography computed from models DTU15MSS and GO_CONS_GCF_2_TIM_R5. Units are meters.

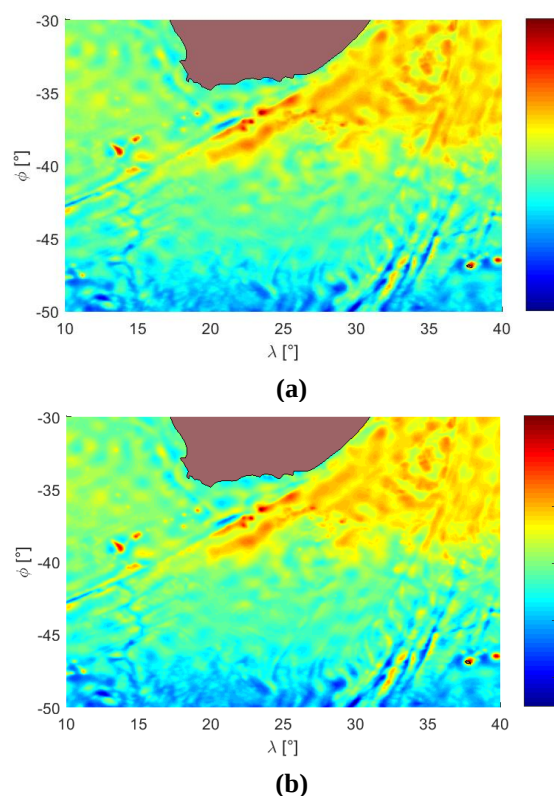


Fig. 2 Satellite – only MDT in the area of Agulhas current – (a) based on DTU15MSS, (b) based on MSS_CNES_CLS_11. Units are meters.

We compare these two models of MDT. Both MDTs are computed as a subtraction of geoid heights from same satellite-only GGM and heights of mean sea surface. It means that behavior of these MDTs is very similar and it is limited by particular geoid. The satellite gravity models with highest resolution are derived from GOCE measurements. They can be completely described only on a grid $30' \times 30'$, because the maximum harmonic degree of their harmonic representation is 250 [4]. The values of both our MDTs are in interval from -1m to 4 m. Residuals between MDTs from DTU15MSS and MSS_CNES_CLS11 are minimal. It is shown in the area of Agulhas current close to coast of South Afrika (Fig. 2 a, b). The Antarctic Circumpolar Currents is well identified by these MDTs.

Our satellite-only MDTs are compared with an independent MDT model computed by Maximenko et al. [8]. In generally, this well-known model (Fig. 3) is used for evaluation of another MDT models. Maximenko's maps have been created as a base for the continued ocean monitoring with in situ instruments or satellites. For comparison,

we use the map of MDT calculated from combined data. The combination of the drifter and satellite data yields ocean dynamic topography patterns at a spatial resolution higher than results from satellite data alone and drifter data alone [8].

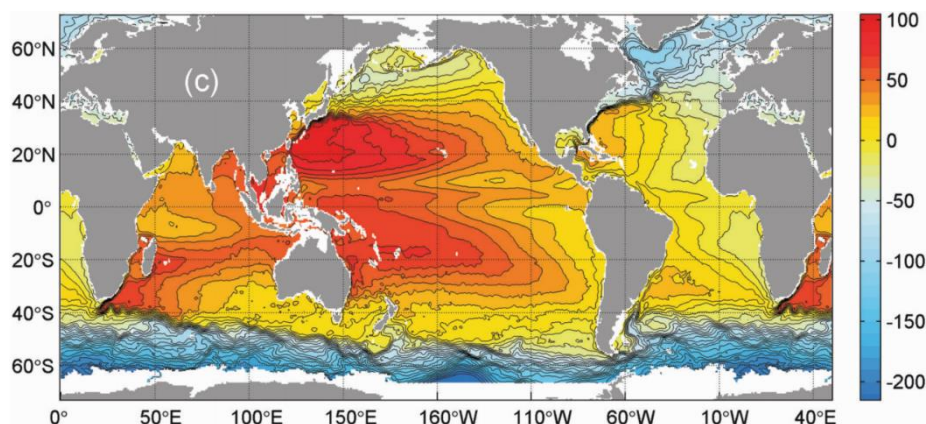


Fig. 3 – Map of mean dynamic topography by Maximenko et al. [8]. The figure is adjusted to the period 1993-2002 and the contour interval is 10 cm.

The MDT computed by Maximenko and the MDTs from DTU15MSS, MSS_CNES_CLS_11 and geoid GO_CONS_GCF_2_TIM_R5 consider different land masks. This fact can cause the diversity of results. Our resultant heights of MDT are expressed in meters. Variations between models are visible on the scale bar. Our values of MDT are in interval -1 m to 3.5 m. Upper limit differs about 2.5 m. We suppose that it is caused by different land masks. As you can see, highest values are along the coast (Fig. 1). On the other hand, significant differences of sea surface have a similar behaviour in Maximenko's model and our models.

3 Filtering of the satellite-only MDT

We have already presented the importance of filtering. Our aim is to reduce stripping noise, which is result of omission errors in gravity field modeling, while we try to preserve important gradients that correspond to the main ocean geostrophic currents.

The MDT, which is computed only over the oceans needs to be completed over the continents in order to cover the entire Earth's surface before the filtering [2]. We artificially extend heights of MDT model to land areas by flexible gridding method so-called Kriging. This process is mainly important in order to avoid boundary effects at the land and ocean transition [4].

3.1 Geofilter and Perona-Malik nonlinear diffusion filtering

Application GeoFilter is developed at Department of Mathematics and Descriptive Geometry in Slovak University of Technology. It provides functionality to perform a nonuniform smoothing of data on surfaces. For now it offers two options of filtering, i.e. linear diffusion and Perona-Malik filtration. In future, more types of filtering will be added. For our purpose, we primarily use Perona-Malik filtering. The main idea is that the appropriate diffusion coefficient in diffusion partial differential equations should not be a constant but a nonlinear function of differential characteristics of data [3]. The approach of the nonlinear diffusion depending on the surface gradient-regularized surface Perona-Malik model was originally developed in Cunderlik et al. [9].

Perona-Malik nonlinear diffusion filtering is based on the estimation of the best value of an edge sensitivity parameter K . This parameter K determines how sensitive will be the edge detector to high values of a smoothed surface gradient. It offers a possibility to decide which gradients would be preserved. If the values of edge detector are close to zero, the diffusion process is strongly slowed down, on the other hand, if the values are close to 1, the process is similar to the linear diffusion. This allows the adaptive smoothing according to surface gradients of the

solution. The edge detector is evolving in time step-wise. It gives an opportunity to preserve main structures in the data and effectively reduce the noise. A significant part of data filtering is finding the optimal values for the edge detector function parameters K , the time step τ and number of iterative (filtering) time steps. In general, the parameters for the edge detector depend on gradients of processed data [3].

3.2 Process of filtering

Our task is to estimate the optimal values of parameters for the filtering. Mainly, we have to know characteristics features of chosen locality because these parameters are dependent on gradient of processed data. According to behavior of MDT, we decide which elements would be preserve and smoothed.

Filtering is performed only on specific areas. Process of filtering requires in powerful hardware and application GeoFilter is not adapted to data of global MDT with resolution $2' \times 2'$.

In Fig. 4 behavior of satellite-only MDT from model DTU15MSS in 3D space is shown. Middle top is identifiable land – South Afrika. It performs interpolated values of MDT which are extended to land. Below the land is significantly structure of MDT which correspond with Agulhas currents. It means that these artefacts should be preserve. Furthermore, the route of Antarctic circumpolar current is visible at the bottom of Fig. 4.

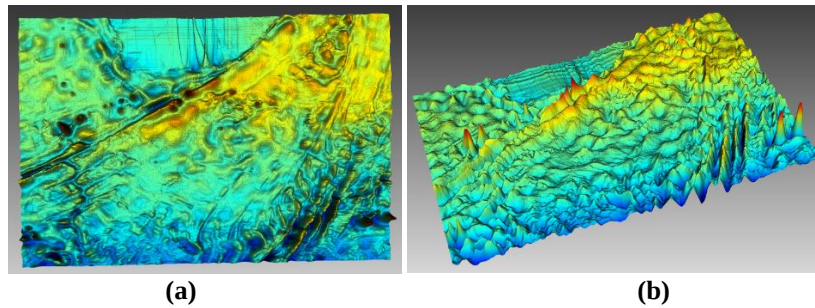


Fig. 4 Unfiltered satellite – only MDT model obtained from model DTU15MSS viewed in application GeoFilter. Area of Agulhas currents - **(a)** view from above, **(b)** side view

4 Geostrophic currents

In general, the ocean circulation is function of depth and geographical location. We discuss geostrophic currents which are a result of the balance between the pressure gradient force and Coriolis force. They perform horizontal component of ocean circulation. Velocity of surface geostrophic currents is associated with the slope of the MDT. Geostrophic flow in a subtropical gyre is clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. However, the negative values of MDT cause opposite behaviour of geostrophic flows. The high spatial resolution of geoid is even more important for the computation of the velocity field than for the MDT itself [4].

We compute geostrophic velocities that are represented as vector field with horizontal components u and v . These components of surface geostrophic currents can be obtained from the MDT via equation:

$$u = -\frac{g}{fR} \frac{\partial \zeta}{\partial \varphi}, \quad v = \frac{g}{fR \cos \varphi} \frac{\partial \zeta}{\partial \lambda}, \quad (3)$$

where $f = 2\omega_e \sin \varphi$ is the Coriolis force coefficient, ω_e is the angular velocity of the Earth, R is the mean radius of the Earth, φ is the latitude, λ is the longitude and g is the gravity [6]. Subsequently, we compute resultant velocity of geostrophic currents.

Our computation is based on the spatial discrete gradients that are computed at grid points. Because the Coriolis factor is zero at the equator, this approach is not applicable to determine velocities in location near the equator ($\pm 50km$) [2].

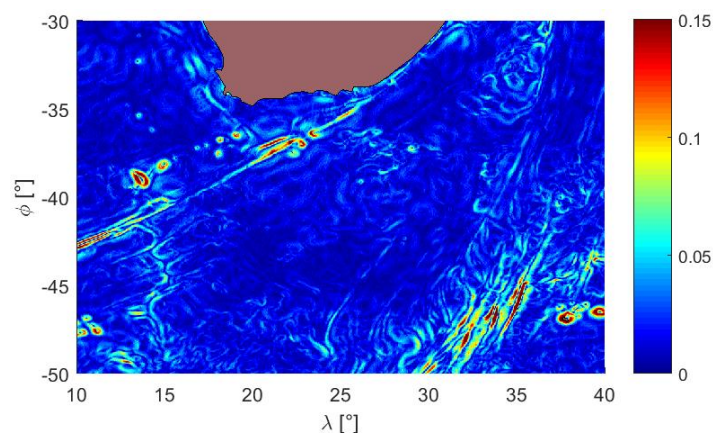


Fig. 5 Velocities of geostrophic currents in area of Agulhas current. Behaviour of geostrophic currents is computed from unfiltered MDT data. Units are $m \cdot s^{-1}$.

5 Conclusions

In this study we presented the computation of the mean dynamic topography, requirements to calculation and importance of useful results for subsequent application. We focused on the satellite-only models because the MDT computed using only satellite data from GOCE and altimetry, is of increased accuracy and resolution. On the other hand, we solved problem with omission errors by filtering.

We determined behavior of significant geostrophic currents from unfiltered data (Fig.5). These routes of streams were featureless, hard identifiable and velocities was not real. It shows us that filtering is necessary fundamental step of the computation of MDT. Our aim is continue with estimate of the optimal approach to receive proper MDT.

The proper representation of MDT is needed in order to describe the ocean geostrophic currents. From the MDT, direction and velocities are derived. For example, the patterns of the near-surface geostrophic velocity is also interesting because it is expected to have subsurface extension, perhaps, well into the ocean thermocline [8].

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Configurable Import of Open Street Map Data to PostGIS

Saeed Sharifi

Institute of Geoinformatics, Faculty of Mining and geology, VŠB – Technical University of Ostrava, 17. listopadu 15/2172,
708 33, Ostrava - Poruba, Czech Republic
Contact email: sharifi.vsb@gmail.com

Abstract

The main goal of the project is to create and developed a web application that allows automatic import of data from OpenStreetMap to Postgres/PostGIS database according to specific classification of the user. This application is designed for administration users, which they can select data from Openstreetmap source database, according to their classification needs and send them to the database. The project will consist several section and parts as following 1) Introduction 2) describe OpenStreetMap 3) identified main methods of import data from OSM to PostgreSQL/PostGIS 4) create a web application with following these parts 4.1) data analysis and selection tags 4.2) data statistics report 4.4) map visualizatio 5) conclusion.

Keywords:

OSM-OpenStreetMap

XML-Extensible Markup Language

PBF-Protocolbuffer Binary Format

WMS-Web Map Service

JSON-JavaScript Object Notation

GDAL-Geospatial Data Abstraction Library

1 Introduction

In today's live, databases are significantly important, it seems that it is not possible to handle and managed big company and even small business without have a database, OSM is a one of the popular source database, which provides geographical information data for free, these data can be essential for many businesses and environmental porous, for example just imagine, that you need list of all school of your city with all it's attributes like geographical position, area, name and etc. as database for your future purpose, so at first look it seems a little complicated, but with OSM free database source and a tools that you can extract your specific data, it is very easy, you just need to write your table name, select your feature tags eg. School and/or hospital and addressing your database location. Just click submit and that's all, your data is ready in your PostGIS database, this project is present this tools which is web based application.

2 OpenStreetMap

What is the open street map? this is a free and open project, OSM license says that user can always copy our data for free, this database provides geographical informant data. OSM database is created and increase by local people voluntarily. (over 1,000,000 signed up so far, and growing every day). They are many online and desktop application which users can create and post data to OSM database. OSM has free tagging system which means that each feature can take unlimited attribute for describing. The database has rich, accurate and updated data. with the compare of the commercial database which updates their data in most case each month, OSM is always update and you can access to update data every day, every hour or even every minute. the format of data in OSM is XML and PBF

2.1 OSM Data Model

OSM data has a 3 main elements(Fig .1), which each one can consist one or more Tage

1. Node
2. Way
 - a. Open poly line
 - b. Close poly line
 - c. Area
3. Relation

Each teg has one key and value which describe features of map.

Tag →K-V (eg. Amenity-Cafe)

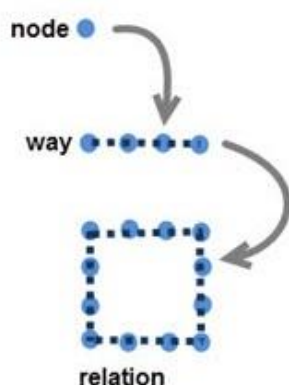


Fig. 1. OpenStreetMap Data model .

3 Main methods of import data from OSM to PostgreSQL/PostGIS

They are 4 most popular tools for import data from osm to PostgreSQL/PostGIS (Table 1.)

Table 1. Main Import methods for import OSM to PostgreSQL

tools	Primary use case	Database
imposm3	Rendering	PostgreSQL
ogr2ogr	Analysis	Various
osm2pgsql	Rendering	PostgreSQL
smosis	Analysis	PostgreSQL/MySQL

1. Imposm3

- Imposm3 is fastest importer for OSM data into PostgreSQL/PostGIS
- High-performance
- It can update the database from diff files
- It is designed to create databases that are optimized for rendering (i.e. generating tiles or for WMS services)
- Filter by tags and values
- Data Mapping(JSON)

2. ogr2ogr

This is a utility that comes with the GDAL library that can read OSM data and write.

3. osm2pgsql

- Conversion of OSM tags to database columns is configurable in the style file
- Can apply diffs to keep the database up to data
- Supports the choice of output projection
- Configurable table names
- Support for hstore field type to store the complete set of tags in one database field if desired

4. Osmosis

- Generate planet dumps from a database
- Load planet dumps into a database
- Produce change sets using database history tables
- Apply change sets to a local database
- Compare two planet dump files and produce a change set
- Re-sort the data contained in planet dump files
- Extract data inside a bounding box or polygon

By comparing these methods of importing OSM data, the method which is provided by `imposm3` tools has been selected as a method for using in project application, main reasons for selecting `imposm3` are: much faster than other method, support updates from diff files, data format and data mapping (JSON).

4 Create a web application

The web application is created on programming language java with help of spring framework, and also using a bootstrap framework, javascript, HTML, CSS for structure and styling pages and for visualization map, it is used leaflet API. Model of application has been described (Fig .2)

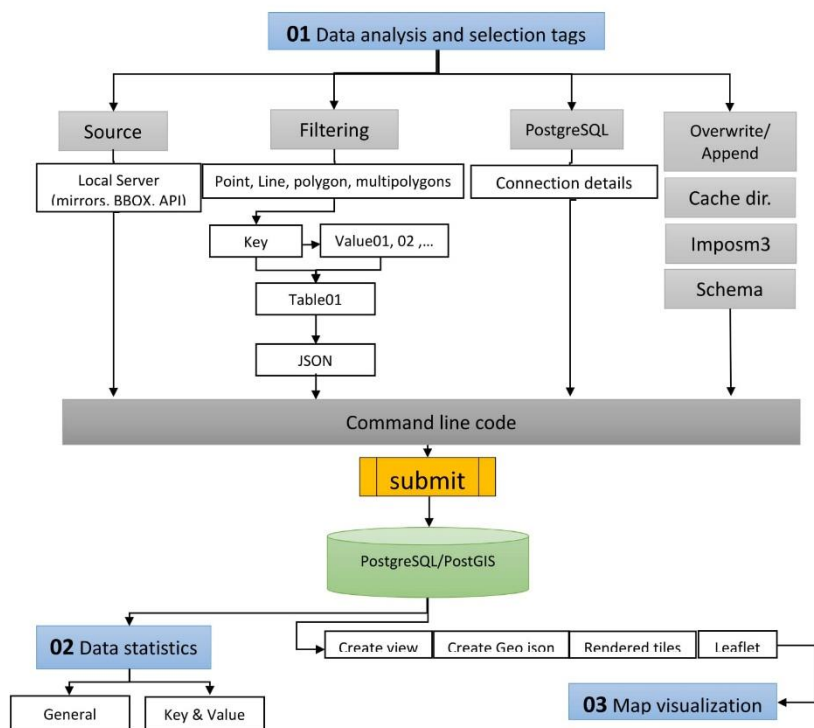


Fig. 2. Application model

This web application has three main part which are separated in three different pages, as following,

1. Data analysis and selction tag
2. Data statistics
3. Map visulalization

4.1 Data analysis and selection tags page

this part is divided into three sections, which is sapared by following tabs

- 1) Data config tab (Fig .3.)
 1. this tab has 4 input box
 1. Data source (select the source PBF file eg. Ostrava, Prague, etc.)

2. Json (application will create a json file from the section query and user can specify the location of this json file)
3. Geometry (selecting the geometry type eg. Point, line, polygon)
4. Table (name of table which will create into database)

Fig. 3. Data config tab

- 2) Key and value tab (Fig.4.)

This tab is for selecting specific tag according to the needs of the user, OSM has unlimited tags but in this application, the post popular tags has been added which is more than 30 key and for each key, the most popular value is also added.

eg. User can select amenity as key and bar, cafe, restaurant as values.

Fig. 4. Key and value selection tab

- 3) PostgreSQL/PostGIS tab (Fig.5.)

In this tab user insert the information of PostgreSQL/PostGIS database(eg. host name,database name, username,password) to post selected key and value to database, and also as imposm3 store data into cache folder it is possible to specify the directory of cache folder, as well as select schema database and possibility of select overwrite or append data.

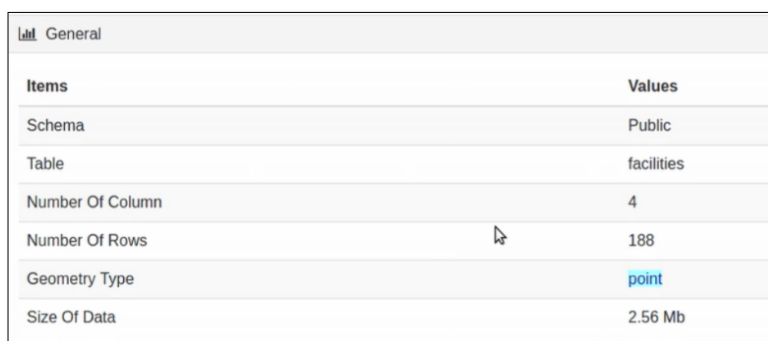
Fig. 5. PostgreSQL/PostGIS tab

4.2 Data statistics report page

With clicking on submit button in the last section automatically page changes into this section, in this section two tabs is determined

1) General tab (Fig .6.)

This tab displays some general statistic of selected data in the last section, (eg. Name of schema in database, name of created table, number of rows, geometry type, size of data source, etc.)

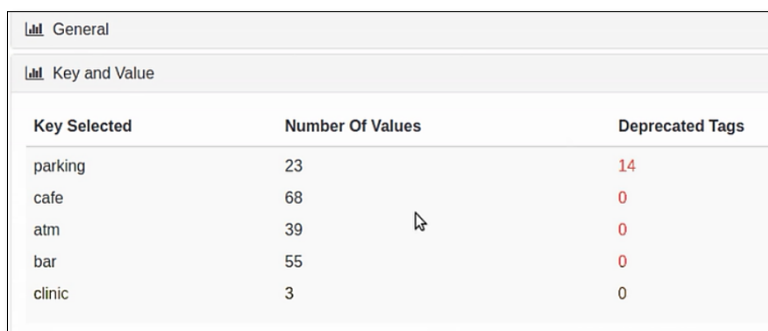


General	
Items	Values
Schema	Public
Table	facilities
Number Of Column	4
Number Of Rows	188
Geometry Type	point
Size Of Data	2.56 Mb

Fig. 6. General statistic tab

1) Key and value tab (Fig.7.)

This tab displays the total number of each value which is select in the last section, it is also displays the total number of deprecated tags (deprecate tags are those tags which are determined as a key feature which is not correct, eg. In Fig.07. parking has 14 deprecated tags it means parking 14 times in database determined as key, but base on the documentation of OSM parking must be tag as a value not key)



General		
Key and Value		
Key Selected	Number Of Values	Deprecated Tags
parking	23	14
cafe	68	0
atm	39	0
bar	55	0
clinic	3	0

Fig. 7. Key and value statistic tab

4.3 Map visualization (Fig .8.)

In this section user can display it's created table from database into map, application can display point, line, and polygons as graphic with its location information like name or any tags which user determined to display as info window, in this section for visualization data a simple form should fill, for display data on map user must create a view of specific data from its table and then click submit to display all data into map, the application is also created the geo JSON file from the created view.

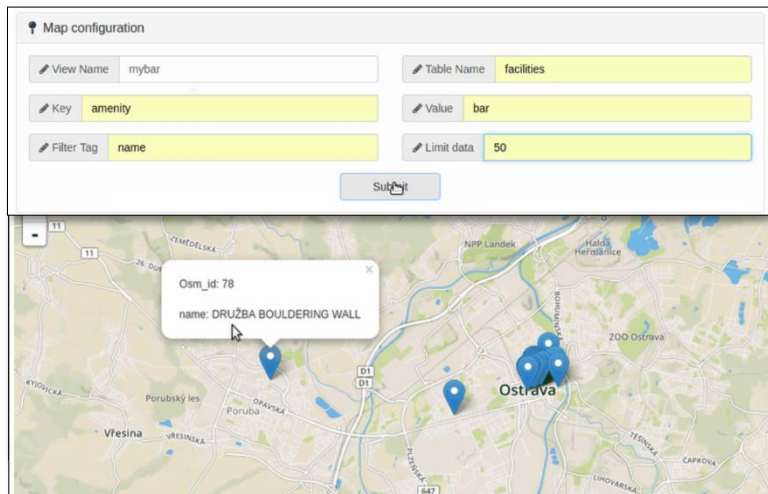


Fig. 8. Map visualization page

5 Conclusion

With using this web based application administration users can configure import data from one of the best free source geographical information database(OSM) by selecting whatever tags they needed for their business and then save their selection in Database as custom table, for designing of this application has been tried to make as much as clear and simple user interface. the more detail about the project and also link to GitHub of the project can be fine on this website <http://www.geomap.ml/thesis.html>

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Decentralised pumped hydro energy storage potential in a Hungarian research area

Tamás Soha¹

¹Department of Environmental and Landscape Geography, Faculty of Science, Eötvös Loránd Science University, Pázmány Péter stny. 2.,
1117, Budapest, Hungary
tamas.soha@gmail.com

Abstract: In the background of this energy related GIS-research is the European energy revolution, which influenced mainly by the effects of the Chernobyl disaster and the global climate change, and resulted the rapidly growing capacity of intermittent renewable energy technologies, especially solar PV and wind energy. This is the explanation of the increasing importance of energy storage, in which the most mature technology is the pumped-hydro (PHES). These systems have 3 major elements: a pair of water reservoirs in different elevation connected with a pressure tunnel and a pump/generator facility. Most of the world's PHES facilities are reaching several hundreds of megawatt capacity, which requires larger flooded areas for the water reservoirs. In this context, finding such places is complicated, moreover, destruction caused by the flooding of natural areas can be a major environmental problem. Therefore in case of Hungary, where most of the mountainous areas are protected, locating large-scale, centralised PHES facilities can be challenging, but it does not have to be an exclusion (like the Dlouhé Stráně PHES in protected natural area in the Czech Republic). However, new water bodies can be proper sites for wetland ecosystems and can take positive effect on local microclimate. This research aims on resolving this issue by highlighting smaller size systems, which - at the same time - is a new paradigm of the 21th century energy revolution, preferring decentralized solutions. GIS methodology was used to calculate the storage potential in 5 steps in a North Hungarian study area. In the first step, raster data was used to build digital terrain model of the study area. After making slope categories, the nearly flat areas ($<5^\circ$ and $<7,5^\circ$ by different model versions) were selected and transformed into vector data. The second step was calculating with vector data only. The former polygons were cut by the elements of infrastructure, settlements, surface water bodies, parts of the CLC50 database, etc. The cut polygons got elevation and area values, and the neighbouring polygons were compared to each other. In the third step, proper pairs of areas were selected by water head, distance, the head/distance ratio and amount of energy stored by water in the reservoirs, through different table calculations. These suitable sites were compared with natural protection areas in the fourth step. In the last step, results were examined by two and three dimensional visualisation. With the model presented in the study, suitable sites has been chosen, which has the opportunity to construct small-scale (10-20 MW) PHES facilities. Despite the restrictive conditions (e.g. distance to electricity grid and water access, minimum capacities, etc.) there are several appropriate sites in the study area. For the $<5^\circ$ model version 12, while using the $<7,5^\circ$ slope category version 40 sites are suitable, with 7 hectares per reservoir in average. Changing the conditions used by the model the results can be different, furthermore, it can be applied to investigate the potentials for other mountainous regions in Europe.

Keywords: decentralised energy system; electricity storage; seasonal storage; GIS; environmental burden

6 Introduction

The current increase in the deployment of new renewable electricity generation systems is making the energy storage and other methods (demand side management; energy mix optimization; energy system optimization with involvement of heat and transportation solutions; import and export) more and more important in order to secure the supply of electricity. The decentralization in the field of the energy production especially highlights the importance of small scale storage solutions, as batteries. On the other hand, the popular and simple battery storage seems an expensive technology so far. This paper focuses on its main alternatives.

7 Pumped-hydro Energy Storage

Pumped Hydro Energy Storage (PHES) is currently the most widely used large scale energy storage technology, providing 99% of the world's ES capacity [1] with 164,630 MW of total installed capacity and around 320 projects worldwide [2]. The advantages of this system are:

- mature technology (over 120 years experience);
- long lifetime (40-80 years);

- limited quantity of pollutant emissions (methane - from biodegradation; CO₂ - considering the whole lifecycle);
- provide ancillary grid services (e.g. grid frequency and voltage regulation).

As for the disadvantages, large capacity usually demands large flooded areas, which can be a major environmental problem. Solutions with small size applications can reduce the environmental impacts and also can provide the possibility of decentralised utilisations in microgrids.

PHES requires two water reservoirs in different elevations, connected with a pressure tunnel (Fig. 1.). Operational projects have 100-500 m water level difference in average, with maximum 2-3 km horizontal distance. Ratio of these two parameters can not exceed 1:10 to keep up the optimal water flowing speed to run the turbines. Reservoirs can be natural (lakes or rivers) or artificial water bodies, even existing ones. Just like other storage technologies, PHES uses electricity to pump water to the upper reservoir in off-peak periods, or when the renewable energy sources generate more electricity than the consumption of the demand side. This can be converted back (so-called „discharging”) when it is needed, e. g. peak-periods or when grid regulation is required [3]. Their efficiency is from 65% up to 85% at recent projects [4]. The newest pumped storage stations use reversible pump-turbine/motor-generator assemblies, in which case water can flow in both directions according to charging or recharging phases. In general, the running projects have a generating capacity between 100 MW and 1000 MW, however it could be 3000 MW [5]. The amount of stored energy is mainly based on the volume of the water reservoirs. Other factors are

- the head difference of the reservoirs;
- turbine efficiency;
- the ratio of total length of the pressure tunnel and the height difference between the water levels of the reservoirs [6] [7].

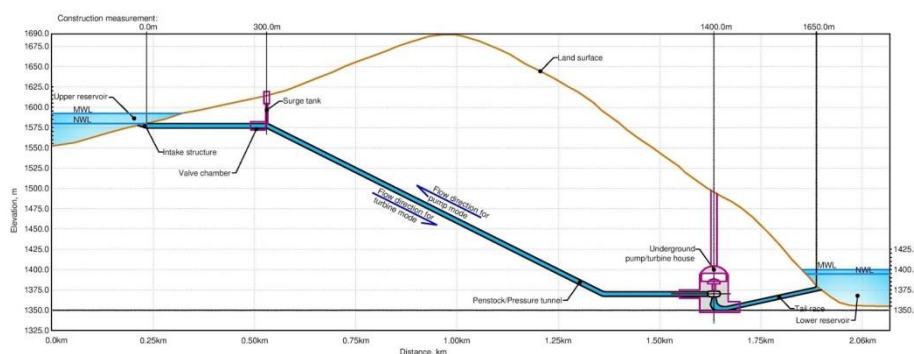


Fig. 1. Basic scheme of a PHES plant [8]

8 Recent situation in Hungary

Despite many PHES construction plans from the 1970's to recent days, Hungary still doesn't have any operating plant. In the background there are mainly financial shortages and the negative environmental effects of the planned projects. The suitable construction sites are situated mainly in the mountainous regions of Hungary, among others in the Danube-band and in the Zemplén Mountains [9]. Due to the significant planned capacity, the water reservoirs would take large flooded areas as well (38-169 hectares), which also means higher environmental impact on natural areas, some of them are protected.

9 Study Area

The latter focuses on special geographical areas in Hungary, namely the vicinity (10 km buffer) of the Bükk LEADER rural development region (Fig. 2.).



Fig. 2. The Bükk LEADER rural development region and the study area in Hungary. (Edited by Soha, T. 2017)

10 Metodology

Using GIS applications, it is possible to effectively investigate ideal sites, due to raster-based remote sensing and other vectorized data. Using the above mentioned information, GIS methods can be used to specify the suitable sites for the water reservoirs.

In European level calculations have already been made for Croatia and Turkey by the European Commission's Joint Research Centre (JRC). The JRC has developed a GIS tool to find the existing water reservoirs which can be transformed as potential parts of PHES [10]. In this research, the GIS model used to investigate pumped storage potentials was similar to the methodology of the JRC. However it was not limited to the existing water bodies, but more focused on smaller storage reservoir sites in order to redound the integration into the future microgrids, preferring the decentralised aspect. The data used were:

- Digital terrain model;
- Land use – Corine Land Cover (CLC 50) database;
- Settlements;
- Infrastructure components (roads, railway lines, transmission lines);
- Surface hydrography;
- protected natural areas in regional, national and EU level.

The study was made by using ArcGIS 10.2 software, containing 32 major steps. The main steps, in a shortened way, were the following:

- creation of the digital terrain model and slope maps of the study area;
- erasing the area of settlements, infrastructure, and other land use categories, except agriculture and natural habitats;
- selecting of the polygons close enough to water and transmission lines access (2 km and 10 km respectively), and creating pairs by filtering their head/length ratio (min. 1:10) and energy capacity (min. 60 MWh, calculating by 6 hours of operation with a 10 MW turbine capacity);

- reconsidering the results with all the protected natural areas (national parks, NATURA 2000 etc.) in order to promote the energy related developments without the loss of ecological values, moreover, creating higher ecological diversity within the existing ecosystems with new water bodies [11].

11 Results

According to the results, the study area contains significant amount of suitable sites as a potential to construct small scale PHES water reservoirs. The exact quantity correlates with the slope category, therefore two different calculations were made considering $<5^\circ$ and $<7.5^\circ$ slope categories, respectively. It was also important to consider an appropriate elevation (at least 100 metres) as well as a maximum distance (2500 metres) between the potential reservoirs (Table 1.).

Table 1. Small scale PHES reservoir potentials at the total study areas (with 10 km buffer zone of the Bükk LEADER region), and different assumptions on slope

	$<5^\circ$	$<7.5^\circ$
Total (number of sites)	78	160
Total area (hectares)	5,852	7,584
Protected (number of sites)	53	109
Not protected (number of sites)	25	51

The “ $<5^\circ$ sites” represent 1.6%, the “ $<7.5^\circ$ sites” represent 2.5% of the whole study area (92,563 hectares). Despite the high amount of protected natural areas, there are enough sites remaining for construct in both cases. Based on the $<5^\circ$ model version, suitable sites are mainly occur near valleys and ridges, such as vicinity of Sajókápolna, Tardona and Tibolddaróc. Average capacities are 10-15 MW with 100-180 m head between the PHES reservoir pairs. To the south of Tibolddaróc, the large suitable area presented by the model means that it is possible to choose the best site for construction within (Fig. 3).

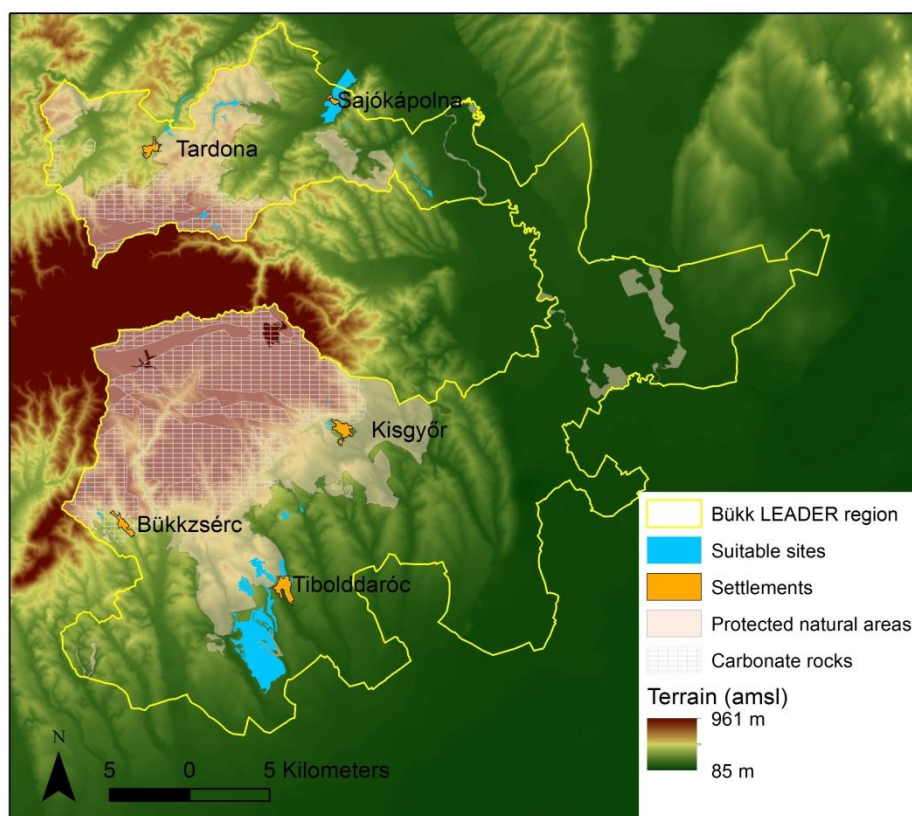


Fig. 3. Map of potential reservoir sites ($<5^\circ$) for PHES in the Bükk LEADER rural development region (Edited by Soha, T. 2017).

12 Conclusions

In comparison to large-scale solutions, the methodology provides much more results in case of small size reservoirs. It also means that the site selection proved to be much easier in case of smaller projects. The small scale PHES seems to be a proper solution for the integration of intermittent renewable energy sources, such as wind and photovoltaic sources. Furthermore, thanks to the limited area demand, negative environmental effects can be minimised. The presented model can be developed in many ways:

- more versions can be made by modifying the calculation criterias;
- with the data of the existing water reservoirs (location, volume) the model can more focus on existing water storage basins (JRC method) in order to reduce the construction costs;
- using ArcMap Model Builder function, the methodology could be applied to any areas to investigate PHES water reservoir potentials.

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Application of Urban Planner model in Czechia

Markéta Stachová¹

¹ Department of Geoinformatics, Faculty of Science, Palacký University Olomouc,
17. Listopadu 50, Postal Code, Olomouc, The Czech Republic
Stachova.marketka@gmail.com

Abstract

The diploma thesis “Application of Urban Planner model in Czechia” is focused on using of Urban Planner model. Urban Planner is Add-In for ArcGIS for Desktop. The diploma thesis has three main parts and three main aims.

The first part is focused on detailed literature review of existing models used for analysis, modelling and simulation of urban environment.

Practical part is divided into two sections. The first section deals with the testing the sensitivity of Urban Planner model. The necessity of all input factors (26 factors) was tested for Olomouc region. The only one category of land-use (housing) was considered.

In the second step, the sensitivity to grid resolution was tested. Default grid resolution (10 m/px) with new grid resolutions 5 m/px, 25 m/px, 50 m/px and 100 m/px was evaluated.

The final part was the calculation of the land suitability for housing for the whole Czech Republic. The most important data sets were derived from OpenStreetMap, RÚIAN, HEIS VÚV TGM, WFS AOPK, BPEJ from Department of Agriculture or Open Land-Use Map and Minerals 4EU. The data were harmonised to the Urban Planner data model. After this step, the calculation of the land suitability for housing with grid resolution 50 m/px was performed. This layer was visualised by the simple web map application in ArcGIS Online.

Keywords: Urban Planner, land suitability, housing, testing of model.

1 Introduction

Land suitability is specified by Collins et al., 2011 and Hopkins, 1977 as the process focused on identifying the most appropriate spatial pattern for future land uses according to specify requirements, preferences, or predictors of some activity.

Liu et al., 2006 defined land suitability as the suitability of a given type of land to support a defined land use, either in its current state or after improvements. Land suitability evaluation means the process of appraisal and grouping of specific areas of land in terms of their suitability for defined uses.

Malczewski, 2004 wrote about use land suitability modelling in many different fields. He states, that the GIS-based land-use suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability/habitant for animal and plant species, geological favorability, suitability of land for agricultural activities, landscape evaluation and planning, environmental impact assessment, selecting the best site for the public and private sector facilities and regional planning.

Quinn et al., 2014 defined the multi-criteria analysis (MCA) as the most popular method for used as a tool to find suitable sites for development. A standard approach for determining land suitability is used which involves determining weightings for the MCA using the Analytic Hierarchy Process (AHP) method and mapping site suitability using geographical information systems (GIS).

For Urban planning exists a lot of type of urban models, for example UrbanSIM, DUEM, MEPLAN, LADSS or What If? and other. Totally was describes 22 urban models in my diploma thesis.

The main aim of my diploma thesis was to test the possibility of applying the model Urban Planner in the territory of a larger scale, ideally whole Czech Republic. The first part was focused on introduction Urban Planner model and description of individual academic work, which tested the model in several areas in the Czech Republic. The second part was focused on testing of importance of individual input factors and evaluation the sensitivity of the model calculation to the input data. Part of the testing also evaluated the differences in the grid resolution of output data.

Last section of the thesis was focused on collection of data available for the whole country (mainly from free sources) and calculation of land suitability for development for the entire Czech Republic.

2 Urban Planner

Urban Planner is an analytic extension for Esri ArcGIS for Desktop designed to evaluate the land suitability (Fig. 1) and to detect the most suitable areas for spatial development (Fig. 2). The extension uses a multi-criteria analysis and respects the principles of sustainable development and allows to create several land use and land suitability scenarios.

The core of the extension focuses on evaluation of land suitability according to input data, its values and weights (Fig. 3). Land suitability is analyzed in three levels (pillars, factors, and layers) for the following six default categories of land use:

- Housing/Residential,
- Recreation,
- Commercial/Public Services,
- Heavy Industry,
- Light Industry and Warehousing,
- Transportation (Burian et al., 2015).

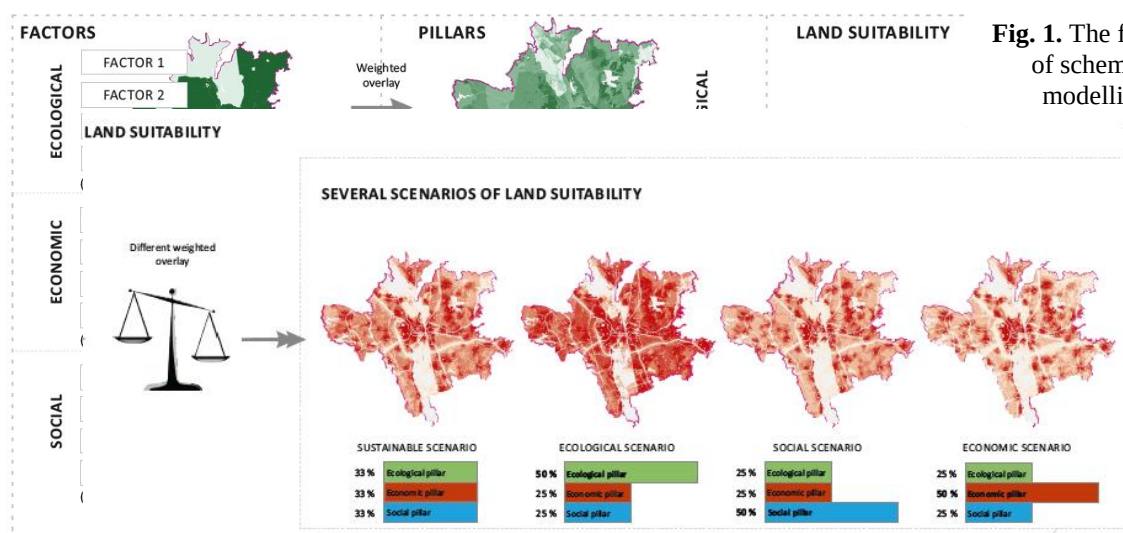


Fig. 1. The first part of scheme of modelling.

Fig. 2. The

second part of scheme of modelling.

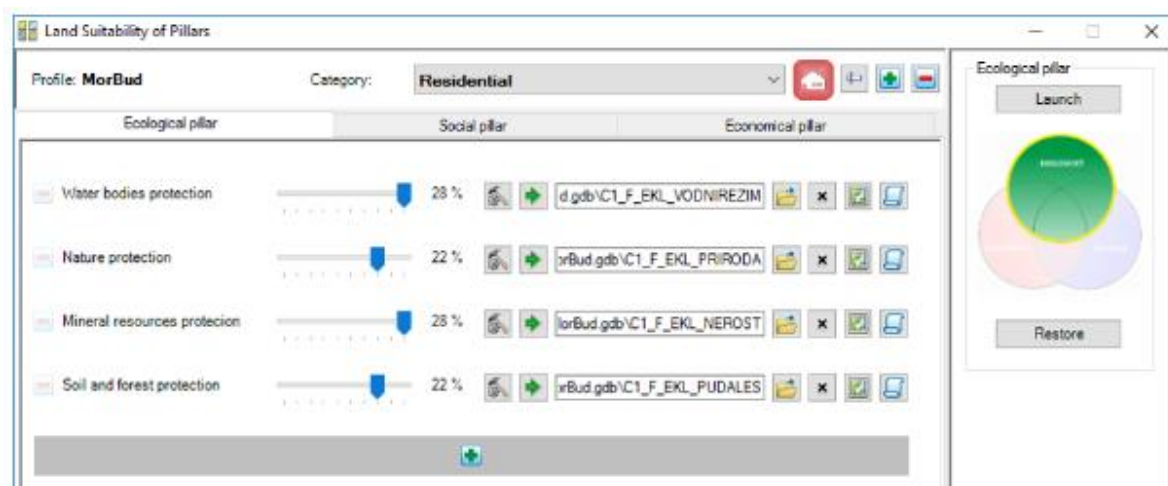


Fig. 3. The environment of model.

For the practical part of the diploma thesis, ArcGIS for Desktop with Add-In Urban Planner was used. The Urban Planner version used in this diploma thesis was 3.1.1. and higher.

3 The main parts and aim of thesis

The diploma thesis has three main parts. Every part has different aim that fits to the general concept.

3.1 The first part

The first part is focused on detailed literature review of existing models used for analysis, modelling and simulation of urban environment. Totally 22 models were evaluated (e.g. UrbanSIM, What If, DUEM, IDUEM, Land Use Scanner, etc.).

3.2 Second part

The second part is practical and is divided into two sections. The first section deals with the testing the sensitivity of Urban Planner model. The necessity of all input factors (26 factors) was tested for Olomouc region. The only one category of land-use (housing) was considered.

In the second step, the sensitivity to grid resolution was tested. Default grid resolution (10 m/px) with new grid resolutions 5 m/px, 25 m/px, 50 m/px and 100 m/px was evaluated for Olomouc region. Again the only one category of land-use was considered, again housing with sustainable scenario (Fig.4).

33 %	Ecological pillar
33 %	Economic pillar
33 %	Social pillar

Fig. 4. Weight ratio of pillars used in the second step.

3.3 Third part

The final part was the calculation of the land suitability for housing for the whole Czech Republic with grid resolution 50 m/px. According to the availability of input datasets, several factors were eliminated from the calculation. Based on the sensitivity testing, these factors should not have significant influence to the final result. The final layer was visualised by the simple web map application in ArcGIS Online.

4 Data

For the second part of this diploma thesis, Planning Analytical Material of Olomoc Region (UAP of ORP Olomouc) was used as input data.

For the third part of this diploma thesis, the most important data sets were derived from OpenStreetMap, RÚIAN, HEIS VÚV TGM, WFS AOPK, BPEJ from Department of Agriculture or Open Land-Use Map and Minerals 4EU. The data were harmonised to the Urban Planner data model.

Table 1. Table with input factors from Urban Planner data model in the third part of diploma thesis. Factors that were used are green. Factors marked by red colour were not available for this thesis for the whole Czech Republic

<i>Pillars</i>	<i>Factors</i>	<i>Layers</i>
ECOLOGICAL	Water bodies protection	13/16
	Nature protection	30/35
	Mineral resources protection	4/11
	Soil and forest protection	6/8
ECONOMIC	Slope	1/1
	Electric power supply	8/11
	Drinking water supply	
	Gas supply	
	Waste water management	
	Distance from roads	6/11
	Flood hazard	4/6
	Geological hazard	
	Specific infrastructure protection	5/14
	Slope aspect	1/1
SOCIAL	Kindergarten accessibility	1/1
	Elementary school accessibility	1/1
	Public spaces accessibility	
	Bus stops and public transport accessibility	3/3
	Trains stops accessibility	1/1
	Distance of rivers	1/1
	Air pollution	5/8
	Noise pollution	12/15
	Population density	1/1
	Radon risk	
	Cultural and social protection	

5 Results

Overview cards from the first part were prepared for each model. Cards consist of basic information about the functionality and focus of the model, availability, cost and also examples of the use in practice (Fig.5).

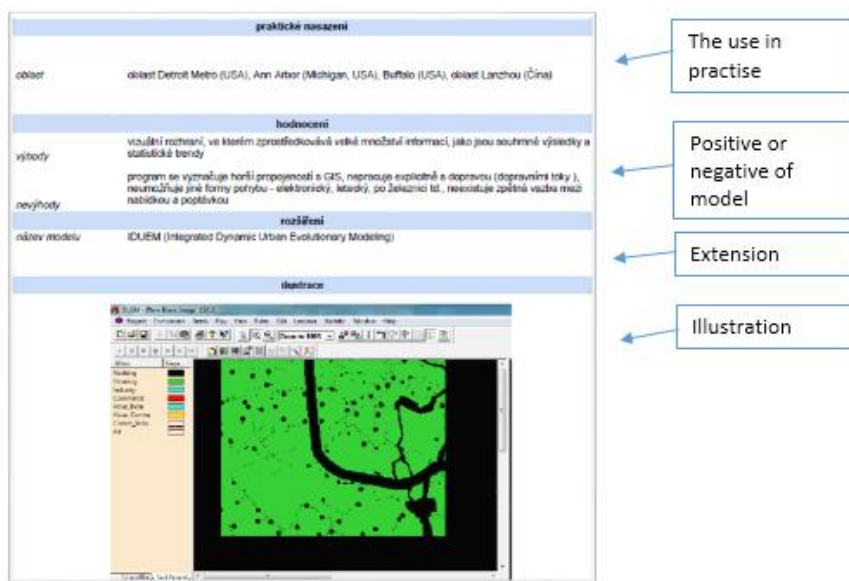


Fig. 5. The part of example for overview card.

The results of the sensitivity testing were visualised by the “comparison cards” (Fig. 6). Cards show each pillar (raster layer) with all input factors and raster of pillar without one input factor. The ecological pillar has 4 input factors, the economic pillar has 13 factors, and the social pillar has 9 input factors. Results were compared from a visual standpoint, and by statistical approach (the correlation matrix, and zonal statistics, where the zone area was the area of the tested factor).

Totally 30 cards were prepared in second part.

Fig. 6.



Exemple de comparaison card from the testing.

The result from the third part is calculation of land suitability for the whole Czech Republic with sustainable scenario and for category Housing (Fig.7). The grid resolution of this result is 50 m/px.

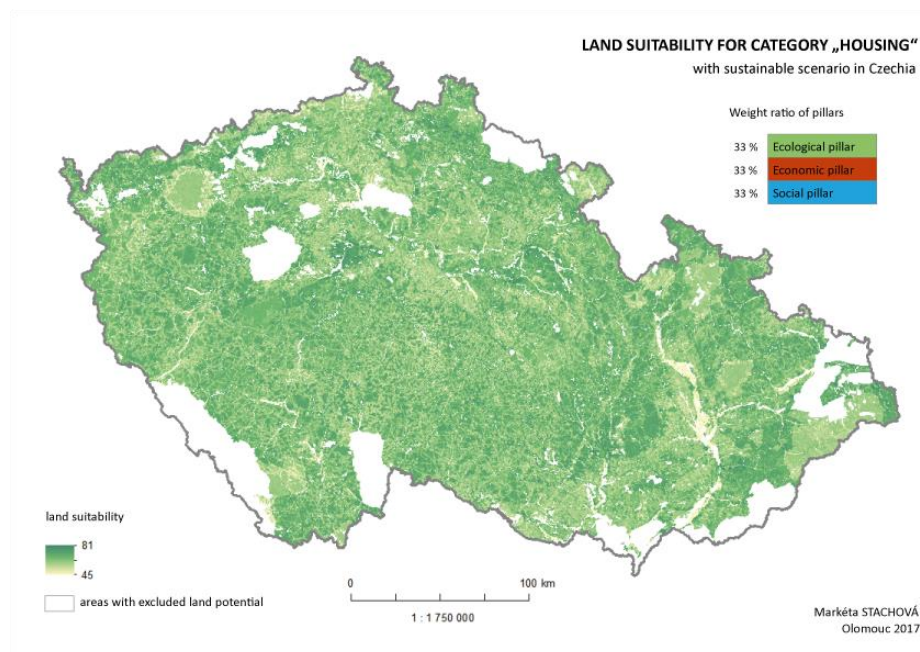


Fig. 7. Land suitability for category “Housing” with sustainable scenario in Czechia with grid resolution 50 m/px.

6 Conclusion

The main conclusion from the first testing is the information about importance of each input factor. These factors had weight ratio in the modelling of the pillar was bigger than 10 % (Nature protection, Soil and forest protection, Mineral resources protection, Water bodies protection, Geological hazard, Distance from roads, Flood hazard, Noise pollution, Slope aspect, Radon risk, Population density and Air pollution).

The main conclusion from the second testing is that the most similar as default grid resolution is resolution 5 m/px and vice versa the most different is 100 m/px.

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Population in detail: machine learning for spatial disaggregation

Jan Šimbera¹

¹Charles University, Faculty of Science, Institute of Applied Geoinformatics and Cartography,
Albertov 6, 128 43 Praha 2, Czechia

Contact simberaj@natur.cuni.cz

Abstract. Accurate spatial population data are an important requirement in many applications but are frequently only available in coarse resolution. This contribution deals with the problem of disaggregating the spatial distribution of population density to street level using a machine learning model. An approach based on freely available ancillary data such as OpenStreetMap and Urban Atlas is proposed and implemented in the form of an automated Python toolbox for ArcGIS. The applications on the urban areas of Prague, Brno and Ljubljana show promising results, overperforming the competing population disaggregation solutions in spatial resolution and accuracy while displaying a satisfying degree of transferability across countries.

Keywords: disaggregation, machine learning, GIS, regression, OpenStreetMap, Urban Atlas

1 Main recommendation

An increasing number of applications and studies have been developed recently that use detailed population distribution data, e. g. [2], quantifying the impacts of population density on forest fire risk, [7], assessing accessibility to services in rural areas or [13], planning emergency response scenarios. Using more detailed spatial data mitigates some common undesirable effects such as ecological fallacies [16] or modifiable areal unit problem (MAUP – [21, 25]), especially its scale effect.

However, detailed population distribution data are also considerably hard to acquire. Either the data is not collected at all – the case of [38], or the access is restricted due to personal data protection laws [22].

On the other hand, in the past few years, a number of new free (open) geodata sources have appeared [19] that have sufficient spatial resolution, mainly in the field of basic topographic data, and correlate with population distribution (e. g. data about buildings). Using them, a model can be derived to estimate the population distribution. The results would no longer be restrained by personal data protection, being merely a more or less accurate estimation. This article presents an attempt to construct such a model using spatial disaggregation and evaluate its predictive power on Central European cities using freely accessible data sources.

2 Spatial disaggregation

Spatial disaggregation is a subdiscipline of areal interpolation [15] that tries to estimate values for a set of target zones from the values of a set of source zones that are their aggregates – for example, we can disaggregate population data from the regional level down to the municipality level. Disaggregation, by taking into account some local information (the distribution from the source zones), is able to partially circumvent the issue of spatial non-stationarity [10] that states the laws governing a particular spatial distribution are not uniform across space. The main idea of disaggregation lies in assigning different weights w_i to different target zones so that their population is calculated using the formula

$$\hat{m}_i = M \frac{w_i}{\sum_i w_i}$$

where M is the population of the source zone and i are its subzones. The trivial variant, where the target zone areas are taken as weights, is known as areal weighting.

Therefore, two problems must be solved:

- Acquire the value for the source zones (M). In this study, we use the GEOSTAT European 1 kilometre grid from the 2011 censuses that is freely available [8].
- Find the weights for the target zones (w_i). These have to be computed from ancillary data sources (which are described in the next section) using an appropriate statistical framework such as machine learning.

3 Ancillary data

3.1 Data sources

In this study, we focus on freely obtainable (open) sources of ancillary data with coverage that warrants a wide applicability of the result.

OpenStreetMap [26] is an open crowd-sourced database of vector topographic data [17]. In principle, it has worldwide coverage; in practice, the richness of its content highly varies with the number of mappers entering the particular location, the city centers being mapped thoroughly while the rural areas are much less complete or precise [24]. This results in problems with the application of some statistical methods [9]. On the other hand, the spatial accuracy of the data is reliably high [40] as the contributors add data in high precision, be it through vectorization of detailed aerial imagery or contribution of GPS traces.

From the very wide base of OSM data, buildings and points of interest that signal functional use of the locations have been used. Some researchers [18] warn against using OSM buildings in analyses due to their incompleteness; while this is still an issue in Southern Europe, the Central European cities seem to be almost completely mapped as of 2016. Building heights, however, while they would be highly beneficial [43], are still mapped scarcely and are thus unusable.

The current version is used; OSM has, for the most part, no notion of temporality yet and its “history” in current sense is merely its development towards completeness [29].

Urban Atlas is one of the products of the European Copernicus program [23] derived mainly from remote sensing data combined with local topographic sources such as street networks. It classifies land use using a five-digit code into thematic classes according to the extended CORINE Land Cover nomenclature with an extension for artificial surfaces, distinguishing five degrees of urban fabric density while having lower thematic resolution in the natural classes. It has a minimum mapping unit of 0,25 ha in urban areas. While [23] claims positional accuracy within 5 m, but in some places all over Prague, deviations higher than 15 meters were observed, mostly of systematic nature. The minimum overall accuracy is put to 80 %; in most cities, the validation check for the 2012 version reported similar values, but most of the error was concentrated into natural surfaces and confusion between urban fabric and public buildings (classes 111/121 – [1]). As the GEOSTAT layer dates to 2011, the 2012 version was used.

Land use data are the most commonly used ancillary source for population modelling as its correlation to population density is obvious and proven [12, 20, 33].

SRTM [5] – Shuttle Radar Topography Mission digital elevation model (DEM) is a global elevation model with 1-arcsecond resolution provided for free by NASA and USGS [32]. It has a good combination of precision and coverage [40], the errors and voids being mostly concentrated into highly mountainous areas [28]. Terrain is one of the elements determining population density; clearly, steeper slopes are often less populated than flat areas.

The usage of Urban Atlas limits the applicability of the solution to European urban areas as the data only covers functional urban areas [23, 39] around cities; however, the increase in precision compared to other land use sources such as CORINE land cover outweighs the dropping of less populated rural areas.

3.2 Features

In order to be able to use commonly developed machine learning frameworks, the information from ancillary data sources has to be processed and transformed into features – numerical attributes of the target zones. The following features were devised for the regression and computed for each of the target zones using overlay and aggregation:

- Land use categories (from Urban Atlas) by fraction of zone covered – 111 (dense urban fabric), 112 (loose urban fabric), 113 (isolated inhabited structures), 121 (public and industrial buildings), 122 (railways and roads), 14 (urban green), 2 (agricultural land), 3 (natural areas) and 5 (water).
- Density of functional use points (from OSM) by category – accommodation, residential, road-associated, military installations, public and civic objects, public transport stops, recreational facilities, restaurants, shops and workplaces.
- Slope (from SRTM).
- Fraction of target zone covered by buildings (from OSM).
- Average area and perimeter index of building footprints in the target zone. Perimeter index is a measure

of building shape complexity given by $p = \frac{o}{2\sqrt{\pi S}}$ [37].

Building area and perimeter index measures should serve to distinguish industrial buildings (large but with simple shapes) from the public (complex shapes) and residential ones (often simple shapes and much smaller). The density

of functional use points from nonresidential categories should decrease the modeled density where other than residential functional use dominates.

3.3 Comparable studies

A similar approach to disaggregate population density has been undertaken e. g. by [11], who used CORINE Land Cover to produce a Europe-wide population layer, [38], who focused on developing countries using night-time light imagery or climate data (in coarser resolution) or [30], focusing on Central Europe.

4 Model design and implementation

The solution was designed as an automated Reconfigurable Urban Modeler toolbox for ArcGIS 10, written in Python and available from github.com/simberaj/rum (together with more detailed documentation). It works sequentially in a number of steps.

Integration incorporates all the data from input sources and converts them into a common known format into a single geodatabase. The coordinate system is unified to ETRS-89/LAEA (EPSG:3035), a projection commonly used for Europe-wide datasets. OSM XML is converted using a custom converter into feature classes; it can also be automatically downloaded through Overpass API for a given extent (the Urban Atlas layer extent is used by default).

Target zone creation creates target zones. Two options are possible – a 100 meter regular grid (aligned to the LAEA grid to comply with the European standard) or irregular polygons determined from the Urban Atlas classes 111, 112 and 121. In the latter case, the polygons are split by source zone boundaries (so that each target zone falls entirely into a single source zone) and too large polygons are subdivided. The grid has the advantage of simpler manipulation as all the zones have the same area and the calculation of neighbourhood features can be performed by raster low-pass filtering; the polygon patches conform more to the real urban fabric.

Only the zones that contain a fraction of the aforementioned three land use categories are allowed for population density calculation; the others are deemed to be empty, otherwise they would significantly increase tool runtime and also possibly deteriorate the result [14]. The 121 class is problematic in this regard because it mixes together purely industrial and military zones with inner city public building blocks with significant population. [30] argues against excluding any land use classes a priori; however, he deals with much coarser data such as CORINE Land Cover where some settlements are not represented at all due to the larger minimum mapping unit of 25 ha and therefore would completely be left out if the other land use classes were excluded.

Feature calculation involves calculating the described features from the ancillary layers for each target zone. The result is a feature matrix. Apart from simply calculating each feature for each zone, the surrounding zones' values are considered for each zone and calculated as neighbourhood features. This describes the zone together with its neighborhood in accordance with the first law of geography [41]. By including the effects of the segment surroundings, spatial autocorrelation is addressed in a similar way to geographically weighted regression [35]. The neighbouring zones' values are averaged using a Gaussian kernel with a defined standard deviation $\sigma = 50, 300$ and 1000 meters are used by default.

Model application applies a pre-trained machine learning model to each target zone and produces the disaggregation weights. The source zone values are then disaggregated using the disaggregation equation. The machine learning model is trained using a dedicated tool on an area for which detailed spatial distribution of population is known (supervised learning). The population densities in the training zones are then used as disaggregation weights and the model tries to approximate the relationship between them and the zone features, essentially performing advanced regression.

Since ArcGIS 10.4, it is easy to incorporate machine learning models via the Python package scikit-learn that provides several regression methods. After some experiments, the random forest regressor [4] turned out to be the best-fitting alternative. However, the user can also choose the gradient boosted tree, k-neighbours or perceptron regressors.

For older versions of ArcGIS, scikit-learn is incompatible with the provided version of Python environment. Therefore, a different method called general regression [34] is used in that case that essentially performs weighted averaging over the training sample weights according to the similarity of the zone features to the training sample ones. However, with this method, the regression performance is reduced.

Before entering the regression, the feature values are rescaled to zero mean and uniform variances using the scikit-learn's Robust Scaler. The output values from the regression are population densities and thus need to be multiplied by the zone area to get the actual disaggregation weights.

Validation is a possible step if comparable data to be used for validation exist. There are two main criteria for areal interpolation accuracy [31]:

- Overall magnitude of the error, usually measured with total absolute error (TAE) [30]:

$$TAE = \sum_i |\hat{m}_i - m_i|$$

where $\hat{m}_i$ is the modeled (disaggregated) value and m_i the real (ground truth) value.

To compare across different datasets, TAE is divided by the total population of the region to obtain relative TAE: $RTAE \in [0;2]$ (0 is a perfect match and 2 means that all the population was assigned to areas with zero real population). [30] also suggests using a multi-scale accuracy profile to assess the changes of the error with different area sizes.

- Uniformity of the spatial distribution of the error. This was evaluated using the following error ratio

$$\delta_i = \frac{\hat{m}_i - m_i}{\hat{m}_i + m_i}$$

which is also used for map visualisation.

The toolbox provides an HTML-based validation report with a correlation plot to assess the successfulness of the disaggregation. Matplotlib (bundled with ArcGIS by default as of 10.2) is required to produce the plot.

The whole workflow is relatively time-consuming, with the most time spent in the integration and feature calculation steps. It usually takes a few hours on a typical desktop computer for an average area.

5 Case study

To test the developed model and validate its accuracy and transferability across countries, a regression model was trained on Prague data and applied to disaggregate population count data for Prague, Ljubljana and Brno FUAs.

5.1 Obtained data and training

Training data for Czechia have been obtained as a dataset containing permanently residing population counts for address points within the municipal boundaries of Prague for 2011, provided by the city of Prague. These counts were summed for the target zones to create approximately 12 000 training samples that also include suburban settlements thanks to the relatively wide administrative definition of Prague.

Validation data for Czechia have been obtained from the data of the 2011 census [6] for aggregated basic settlement units (A-ZSJ); in rural areas, this unit usually corresponds to a single settlement whereas in urban areas the unit usually contains a single morphologically uniform segment of the urban fabric (such as a single neighborhood). The A-ZSJ were produced by aggregating the common ZSJ so that none of them has less than 50 inhabitants or 20 households.

Validation data for Slovenia were downloaded from the Slovenian national statistics portal [36] as a 100 meter grid containing population counts from the 2011 census.

5.2 Application on Ljubljana

The population density model was tested on the FUA of the Slovenian capital as captured by the Urban Atlas 2012. The resulting distribution, disaggregated from the GEOSTAT 1 km grid using the general regression model, is portrayed in Fig. 1. The results were validated using the 100 m grid reference dataset. A multi-scale accuracy profile was constructed at the scales of¹ 200 m, 500 m and 1 000 m. The results are summarized in Table 1.

¹ The lower bound was determined from the average size of the segments; it does not make sense to validate the result using a finer resolution. The upper bound is determined by the source unit size.

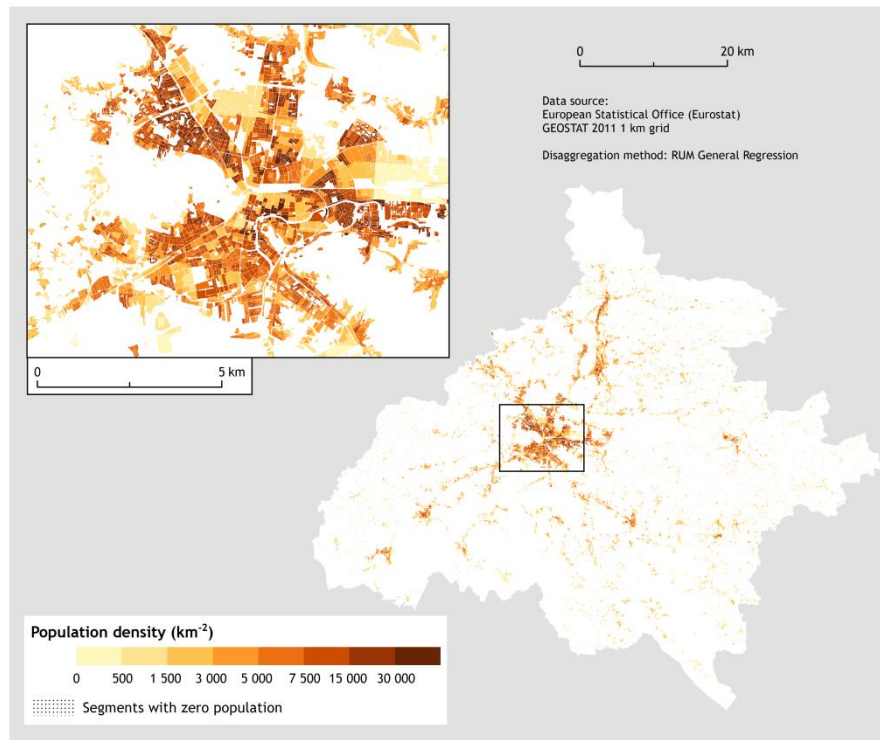


Fig. 1. Population distribution for the Ljubljana FUA disaggregated from the GEOSTAT 1 km grid using the general regression model.

Table 1. Population disaggregation multi-scale accuracy profile for Ljubljana. The disaggregated population grid by JRC [27] is given for comparison.

Validation cell size	General regression		JRC [27]	
	TAE	RTAE	TAE	RTAE
200 m	316 637	57,63 %	475 703	86,59 %
500 m	190 342	34,65 %	362 096	65,91 %
1000 m	105 037	19,12 %	282 389	51,40 %

The RTAE achieved by general regression is still considerably high but lower than the best result of 62,44 % achieved by [30] for Slovenia at the 1 km level. Although that approach used larger municipalities instead of the GEOSTAT grid as source zones, it can still be argued that the presented method results in a more accurate population distribution map.

The spatial distribution of the δ relative error is shown in Figure 2. The commission error is mostly concentrated to industrial areas where higher than real population densities are modeled, whereas the omission error is the highest in rural areas with sparse settlements.

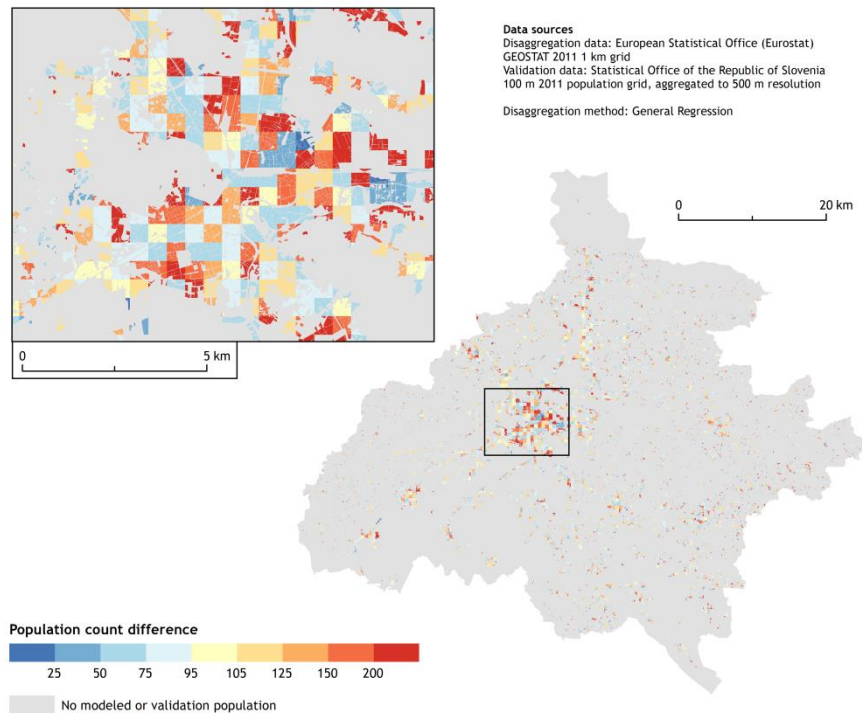


Fig. 2. Relative disaggregation error distribution (δ) for the Ljubljana FUA as compared to the aggregated 500 m Slovenian national grid.

5.3 Application on Brno

In Brno, the second largest city of Czechia, the general regression model trained on Prague was used to disaggregate population from the GEOSTAT grid. The results, visualised in Fig. 3, were validated using the A-ZSJ dataset. The RTAE on this level was 22,31 % without any significant spatial autocorrelation of the relative errors. This confirms that the ability of the model to generalize is sufficient.

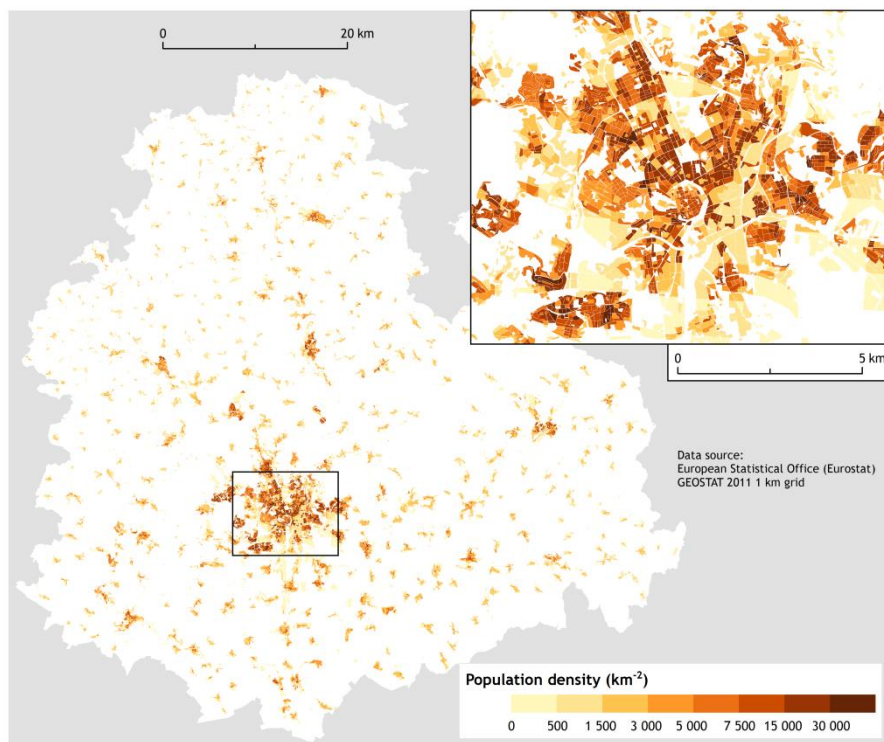


Fig. 3. Population distribution for the Brno FUA disaggregated from the GEOSTAT 1 km grid using the general regression model.

6 Discussion

The proposed modelling method is able to produce a reasonable estimation of population density in high resolution, even after transferring to a different country. The result overperforms the JRC grid [11] in terms of overall accuracy.

The aim of the thesis was to adapt the previous approaches so that only freely available ancillary data need to be used. Other known methods mostly use data that are not freely available [42, 43]. However, the drawbacks of the freely available data used have a clear impact on the model performance. The model is inaccurate where some data such as OSM are not well mapped (e. g. missing buildings). This aligns with the findings of other researchers that used free data [12, 30].

The low training data availability, although it serves as a justification for the model existence, may be partially to blame for the model inaccuracies. Clearly, training the model on more cities than just Prague would improve the result. In this regard, the purchase and usage of a 100 m population grid from the Austrian statistical agency could be an option.

The main focus of the study is not on machine learning and the models are mostly used as out-of-the-box tools. However, more finetuning and perhaps the use of deep learning could improve the accuracy.

The area where the model could be applied without modification is limited by the Urban Atlas coverage (although that has improved from the 2006 to the 2012 version). Calling it sufficient would be an insult to rural geography; moreover, some of the extents (as in the case of Prague) do not align with the FUAs delimited by other researchers [39], which could be undesirable in some cases. In this regard, Urban Atlas data could be supplemented with the CORINE Land Cover refined with Copernicus HRL as proposed by [3].

There are also new interesting sources available such as the European Settlement Layer that could be included as model inputs, even continuing the disaggregation down to the 10 meter level.

The model is designed to be reconfigurable, for example by substituting the sources of the building and points layer, or by manual editing; however, some of the options such as neighbourhood size parameters are still hidden in the scripts. It remains a question if presenting the user with more configuration could have better results as most of them will use the defaults anyway.

7 Conclusion

This article proposes a new method to disaggregate population distribution data in urban areas down to approximately 100 meter resolution. Compared to the previous studies, it incorporates more types of ancillary data sources, all of which are available for free on the Internet. The whole workflow is provided to the user as a toolbox in ArcGIS 10. The user only needs to download the ancillary data for the concerned study area from the specified websites, provide the data to be disaggregated, and run the tools sequentially, without the need of any additional editing or geoprocessing. The output is presented to the user in the form of a vector layer with the disaggregated attribute field, which can easily enter other analyses.

A number of case studies was performed with the models trained on data for Prague. The disaggregated population distribution for the Ljubljana region outperformed the comparable disaggregated datasets [27, 30]. The same model, applied for Brno, also provides reasonably accurate data.

The model is merely another approach to a common problem of obtaining detailed population data and as such it can be hoped to become obsolete by the advances in the field of data disclosure by the national and European statistical offices.

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Multidimensional modelling of air temperate in the ice-cave of Silická ľadnica Automatization of data processing

Peter Štec¹

¹Institute of Geography, Faculty of Science, Pavol Jozef Šafárik University in Košice, Jesenná 5,
040 01, Košice, Slovak Republic

Contact peter261stec@gmail.com

Abstract. The main objective of the paper is to characterize the methodology of generating and processing a 4D time-series digital model, created from raw air temperature measurements recorded by automated data loggers. The dynamic modelling of air temperature is performed in the open-source GRASS GIS. This tabular data were processed in MS Excel and further processed by Python - a programming language, which can extend functionality of any GIS-software and merge data, created from other software with them. We speeded up our work by creating a script, which can automatize importing and processing data. Using multidimensional regularized spline with tension and smoothing, we created a digital model of temperature in the Silická ľadnica Cave, where this temperature values were measured for one year. Our goal was to visualize the temperature changes in this cave to better understand the dynamics of air and formation of ice.

Keywords: 4D, time series, Python, Silická ľadnica, automatization

Spatial and non-spatial evaluation of innovations of companies in the Czech Republic 2008 - 2012

Barbora Švarcová¹, Vít Pászto², Marek Vaculík³

¹ Faculty of Science, Palacký University Olomouc, 17. Listopadu 710/50,
779 00, Olomouc, Czech Republic
B.svarcova@seznam.cz

² Faculty of Science, Palacký University Olomouc, 17. Listopadu 710/50,
779 00, Olomouc, Czech Republic
vit.paszto@gmail.com

³ Olomoucký klastr inovací, tř. Kosmonautů 1288/1,
779 00, Olomouc, Czech Republic
Marek.Vaculik@o-k-i.cz

Abstract. Innovation in well-established companies is vital to encourage their development, competitiveness and job creation. However, they are also closely associated with the risk, that invested capital will have an expectant result. In recent years, innovation is a very hot topic in the both private and public sector at various levels. The decision-makers got actively involved in the design and implementation process of various innovation support systems on regional, national and even EU level. This diploma thesis is focused on describing the spatial distribution of innovation activities of companies in the Czechia in the period 2008 – 2012. The data about innovation from the Community Innovation Survey (CIS) for the Czech Republic were used. The data include more than 10,000 respondents during the period. In the CIS database, the data is divided on the LAU1 level, as the most detailed resolution available for public use. First, basic statistical nongeographic information was identified (e.g. count of innovation companies in the district, distribution by size of companies or industry). Second, the dataset evaluation was done from the geospatial perspective. Data were divided into four main categories of technical, non-technical, radical innovations, and Research and Development intensity. Attribute part of the data was assessed using an innovation score index by which they were displayed on the map. Finally, a spatial pattern of innovation activities was recognised by introducing spatial techniques within GIS.

Keywords: Innovation activity, Community innovation survey, geographical distribution, spatial concentration, Czech Republic,

1 Introduction

Innovation in well-established companies is vital to encourage their development, competitiveness and job creation. Innovation in the company is closely linked to the risk that the invested capital to innovative techniques will be awaiting the outcome or if the company will have sufficient funds to complete the innovation. On the other hand innovation can have positive effects on improving the functionality of enterprise. Innovations are directly linked to research and development. Research can be carried out within each enterprise or externally. External research and development contain new discoveries in universities, research institutions and laboratories.

The nature of innovation research is very broad, and the research results are inconsistent due to the lack of generalizability of innovation studies (Wolfe 1994 [6]). We should, therefore, differentiate among various types and attributes of innovation. As regards different types of innovation we can find in the literature enormous number of distinctions such as incremental vs. radical (Ettlie, J.E. et al. 1984 [3]), technical vs. non-technical (OECD 2005[4]) or autonomous vs. systemic (Chesbrough and Teece 1996 [2]). As with types, there is many possibilities how to measure innovation activity.

2 Data and measures

2.1 Data

I use the results of the sixth and seventh round of the Community Innovation Survey for the Czech Republic on the data from 2008-2010 (CIS 2010) and 2010-2012 (CIS 2012). The CIS uses harmonized questionnaire for all

EU members stats and as such presents unique and reliable source of data regarding innovation activities of enterprises of different size, age and industry. The huge advantage of the CIS is the long-term experience with methodological issues related to the innovation activities using revised version of Oslo Manual 2005.

Data for CIS 2010 were gathered in 2011 by questionnaire sent to all enterprises with ten or more employees, stratified by size and economic activity. The survey cover manufacturing as well as service firms. In total 5,151 responses were received with 83% rate of useful answers. Data for CIS 2012 were gathered in 2013 and in total 5449 responses were received with 80% rate of useful answers.

From a geospatial perspective, it is beneficiary having data at the most detailed level in the sense of geographical scale. Although the CIS survey is realized at the firm-level, the resulting data set is anonymized. So, it is not possible to identify and individual subject for accurate localization. Besides, Czech statistical office offers data the LAU 1 level and there are 77 LAU1 districts in the Czech Republic and all of them are represented in the both of CIS datasets.

2.2 Measures

As we want to obtain a full picture of the innovation activity of Czech firms we use four different types of measures which belong to two broader groups of innovation measures. The first one relates to the investments in the innovation process and is measured by the inputs utilized in the innovation process (in our case R&D investments). The second group of measures focuses on the final output of the innovative work e.g. new products and/or processes introduced.

a) Technical innovation

Technical innovation is a composite binary variable merging information on product and process innovations. In both CIS the product innovation is the market introduction of a new or significantly improved good or service with respect to its capabilities, user-friendliness, components or sub-systems. It must be new to the respondent but not necessarily to their market. The process innovation, on the other hand, is the implementation of a new or significantly improved production process, distribution method, or supporting activity.

b) Non-technical innovation

This measure is again a composite binary variable consisting of organizational and marketing innovations. The organizational innovation is a new organizational method in respondents' business practices (including knowledge management), workplace organization or external relations that have not been previously used. It must be the result of strategic decisions taken by management excluding mergers and acquisitions. The marketing innovation is the implementation of a new marketing concept or strategy that differs significantly from respondent' existing marketing methods and which has not been used before. It requires significant changes in product design or packaging, product placement, product promotion or pricing excluding seasonal, regular and other routine changes in market methods.

c) Radical innovation

Radical innovation is a binary variable referring to a new or significantly improved product (good or service) introduced during 2008-2012 which was new-to-the-market (it may have already been available in other markets). Radical encompass higher order innovations that have an enormous market potential, and that comprise technological advances so significant that no increase in scale, efficiency, or design can make older technologies competitive (Tushman and Anderson 1986 [5]). In this context, we use this measure as a clear indicator of highly innovative activities of a firm.

d) R&D intensity

Intensity of R&D activities is shown as a crucial measure of innovativeness of individual companies. Many studies demonstrated a clear positive impact of these activities on business performance measured as the number of new products to market and financial terms. We calculated the variable as a proportion of total R&D costs on turnover of the companies within districts in 2010 and 2012.

3 Methods

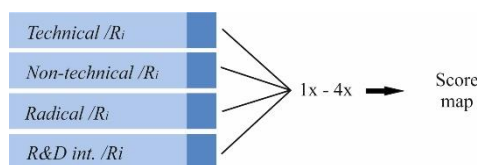
Methods are divided into spatial, non-spatial descriptive statistics and complex method of geospatial distribution (intensity of innovation). For non-spatial distribution statistics is used many graphs created by MS Excel software. Spatial statistics and distributions is provided by the ArcGIS for Desktop 10.2 software.

Our approach for overall innovation evaluation stems from a method used originally by Adams (2011 [1]) for determining the distribution of innovation activity in the UK. The concentration of innovative activities is determined by proportions at the level of LAU1 district. First, scores S for each LAU1 district (i) across a range $q=\{a, b, c, d\}$ of abovementioned innovation measures (q), are calculated as follows:

$$S_{iq} = \frac{I_{iq}}{R_i}$$

Where for each LAU1 district I_{iq} is the number of companies from LAU1 district i registering any level of activity in innovation measure q , and R_i is the total number of respondents R from given LAU1 district i .

Then the scores S_{iq} are ranked, the LAU1 districts that comprise the upper decile of each innovation measure can be identified. Each time a LAU1 district appears in upper decile of the innovation measure rankings receives one point. The final ranking of LAU1 districts is made in order to see whether there are any LAU1 districts consistently appearing in the upper decile of innovation measures.

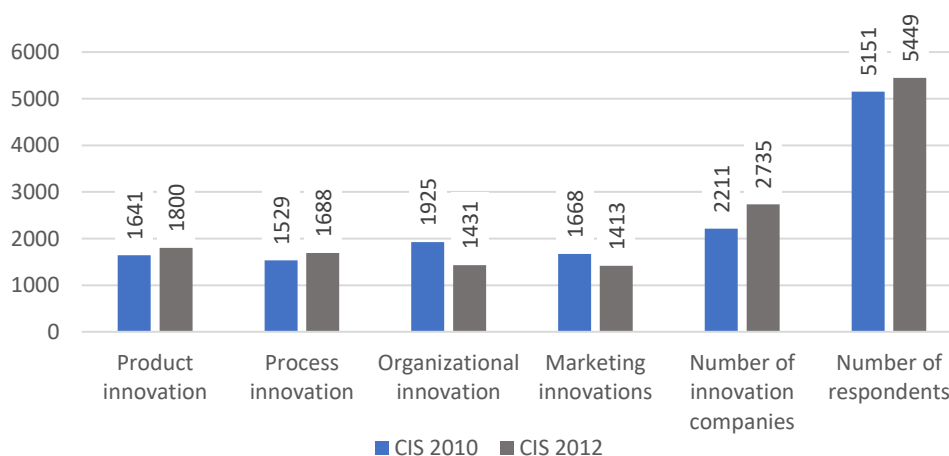


Picture 1. Technique of Score map making

4 Descriptive statistics

4.1 Non-spatial descriptive statistics

Above both of CIS datasets was created statistical evaluation of basic data. At the graph number 1. We can see information about numbers of respondents, numbers of innovative companies and the distribution of the main categories of innovation activities.

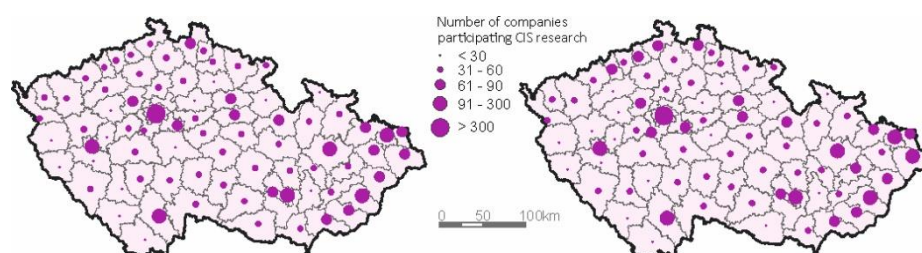


Graph 1. Categories of innovative companies in 2010 and 2012

In 2012, the overall increase in the number of companies that participated in the survey CIS and the number of companies that are in any way involved in the innovation process. In 2010 it was involved in the innovation process around 43% of companies surveyed in 2012 were involved in the process of innovation for over 50% of the participating companies the survey. In the categories of product and process innovations was to increase innovative activities in 2012, but in organizational and marketing innovation occurred in 2012, a significant drop in the number of companies that innovate in these categories.

4.2 Spatial descriptive statistics

Spatial descriptive was created by ArcGis Desktop 10.2 software. Both maps (2010, 2012) are similar in distribution of companies participating CIS research. But there are some LAU1 districts where was increased or decreased numbers of respondents. We can mention increased regions, for example Most, Ústí nad Labem, Děčín and Benešov. On the other hand we can mention some LAU 1 districts which decreased number of respondents, for example, Frýdek Místek, Kutný hora or Písek.



Map 1. Number of respondents to attend CIS 2010 and 2012

5 Results of spatial distribution of innovation activities

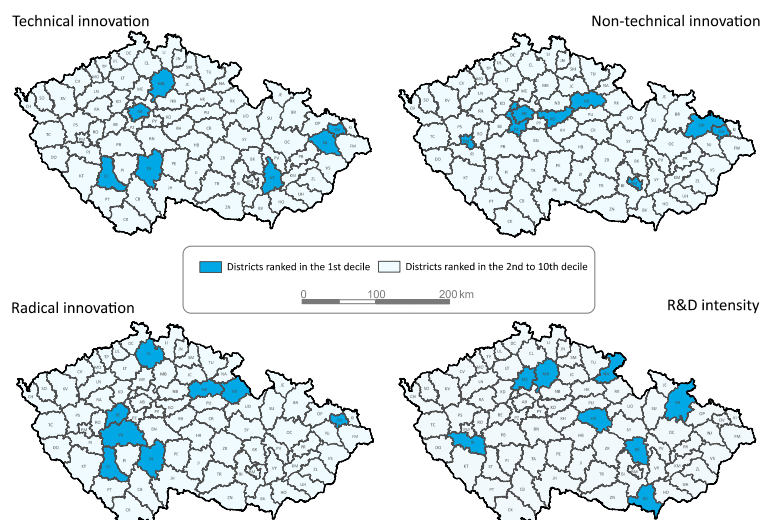
The major outputs of the diploma thesis is geovisualization of companies innovation activities. Individual measures are displayed at the maps number 2. and 3., where only those LAU1 districts ranked in upper decile are depicted. At first glance, there is no distinct pattern of innovations' spatial concentration at both years (2010, 2012). However when we combine all four maps together, there will to see some spatial pattern (map 4.)

When looking at technical innovations, it can be seen in which LAU1 districts the most of these innovations took place. At the year 2010 two districts, north ones on the map in the west part of Czech Republic, are centres of high-tech and automotive industry. Another two districts in the eastern part of Czech Republic, are associated with heavy industry. At the year 2012 only one district has a same high of innovation activities like in previous year. Another the northernmost district is associated with sport activities.

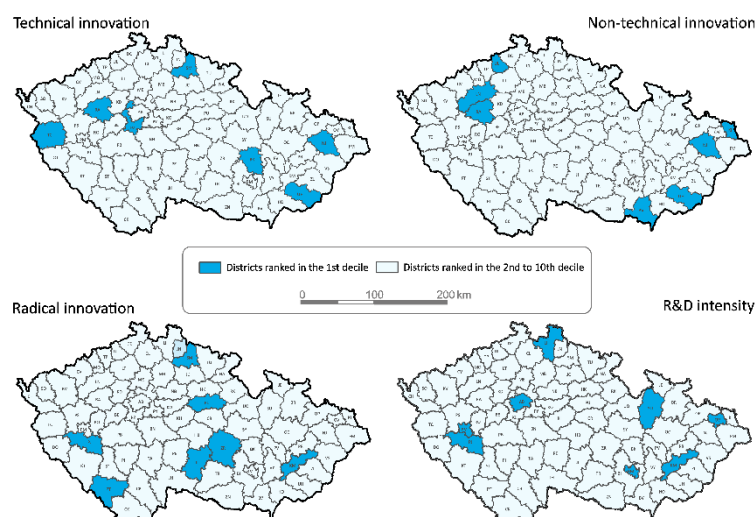
Non-technical innovation at the year 2010, show higher concentration, especially in the central part of the Czech Republic. This pattern includes the biggest cities of the Czech Republic. On the other hand, at the year 2012 there are no big cities included. This may be due more distinct selection of companies.

Radical innovations represent new or significantly improved product introduced to the market. From the geospatial point of view, districts with highest scores in this measure are located outside the most populated regions at both years (except the district on the east of the Czech Republic at the year 2010). It is the question, whether the firms in these districts are striving to introduce a greater amount of radical innovations in order to increase their competitiveness, or the reason is completely different.

Spatial distribution of research and development (R&D) intensity shows no distinct spatial pattern at the year 2010. Only two of districts with automotive industry maybe cooperate with some universities. At the year 2012 the map shows higher concentration on R&D intensity in the university cities.

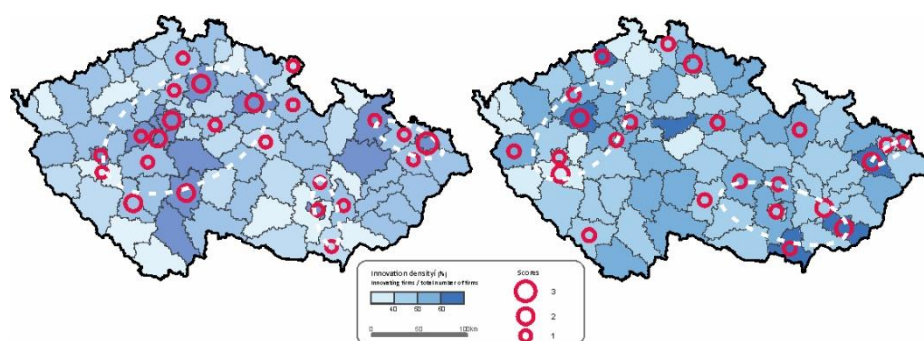


Map 2. Spatial distribution of LAU1 districts ranked in the upper decile according to individual measures 2010



Map 3. Spatial distribution of LAU1 districts ranked in the upper decile according to individual measures 2012

Overall spatial distribution of innovation activities intensity is depicted at the Map number 4. The maps show a total number of points per districts ranked in upper decile at each year. It represents a synthesis of maps in map 2. and 3. In 2010 the greatest cluster is neighbouring the capital city of Prague (white dashed line). The other big clusters are surrounding of cities Brno and Ostrava. In 2012 the cluster surrounding of Prague was shifted to western part. The cluster around the Brno city was amended from the north-east to the south-west direction.



Map 4. Intensity of innovation activities in LAU1 districts 2010 and 2012

6 Conclusion

This Diploma thesis discusses the spatial distribution of innovation activities in the Czech Republic in 2008 – 2012. The main aim was to search for spatial patterns that would resemble the most innovative LAU1 districts. As the Enabling environment for innovation and industrial Activities is a very hot topic among policymakers especial, we see abundant Possibilities for Further Research. And there are some results of spatial clusters which are high innovative. Based on this results, we can say where are the most prosperous or highly developing companies.

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Detection of volumetric changes in a mining area using UAV

Matúš Vasil'

Institute of geography, Faculty of Science, Pavol Jozef Šafárik University in Košice,
Jesenná 5, Košice

Contact: matusv.vasil@gmail.com

Tutor: RNDr. Ján Kaňuk, PhD. jan.kanuk@upjs.sk

Abstract. Mining areas are highly dynamic type of landscape. Actual data and maps of mining areas play crucial role in management of mining procedures. Traditionally, survey technics such as levelling, positioning, and GNSS provide high accuracy, but on the other hand they have limited capabilities to capture all mining features in sufficient spatial detail, they are time-consuming and involve and increased likelihood of injury for the surveyors. The UAV technology overcomes these limitations and provides high-resolution and high-precision digital 3D models with time-efficiently data acquisition. Processing of data is automatically implemented in various kinds of software and it is based on image matching approach. The resulting data comprise high density 3D point cloud based on which a digital surface model is derived. Mining maps exhibit substantial deviation which lead to determination of available raw material for mining which do not correspond with actual volume. Laser scanning generates a remarkably accurate output which is compromised by high costs of the technology. On one hand, we see a time saving, inexpensive method with relatively precise output in attaching photogrammetry device to an unmanned aerial vehicle (UAV). On the other hand, this method is limited in carrying capacity of an UAV. In this study, we used the device DJI PHANTOM 3 and DJI PHANTOM 4, which are equipped with a standard 10 -12 megapixel cameras. In such aerial photogrammetry, we are capable to collect high definition data and with use of software generate high quality and dense point cloud. The points are used to create a digital elevation model, which can be modified for our needs to hypsographic DTM or DTM with contour lines and other features. We measured a bentonite pit in Lastovce, located in eastern Slovakia in the district Trebišov, which is a property of LB Minerals. The aim of our measurements and the actual research is to see whether we can bring close precision, or to replace traditional surveying methods of mine surveying with the use of UAV photogrammetry.

Keywords: UAV; Photogrammetry; DJI PHANTOM 3; ArcGIS; Cloud Compare; Mining