

Cost-effective hand gesture computer control interface

Gergely Sziládi

IT Service Center
University of Dunaujváros
Dunaujváros, Hungary
sziladig@uniduna.hu

Tibor Ujbányi, József Katona

Institute of Computer Engineering
University of Dunaujváros
Dunaujváros, Hungary
ujbanyit@uniduna.hu, katonaj@uniduna.hu

Abstract— The article shows the design and implementation of a gesture control system, which determines the gesture from the movement of the hands. The presented gesture controller system can be built relatively easy from cheap components, so it is ideal development goal in case of a students' project also in the field of project based learning. The movement detected with distance measurement sensors, and the presented control interface determines the assigned gesture according to the hand's movement. The distance sensors are built into a box, along with a microcontroller. This controller did the signal pre-processing, which is an Arduino based unit. The signal post processing, filtering, and classification of gestures and the control of the computer are managed by a desktop application. The article presents the usability test of the gesture controlling system based on study carried out by test subjects.

Keywords—gesture control; signal processing; Arduino;

I. INTRODUCTION

Nowadays, there are plenty of options to control the computers with input devices. The human – machine interactions are the key components of the controlling infrastructure. The most widespread solution is a keyboard, in combination with a mouse. Other controlling options, such as mobile devices or built-in touchscreens are very popular, as well as the next generation virtual – reality gears.

In human-machine interactions most of the input devices are hand controlled. One of the options is the gesture control, which becomes more common in the past few years. This artificial cognitive "sensing" or capability is a communication channel between humans and computers [14], [15].

Before these recently developed solutions, many keyboard and mouse concepts and designs were built. One of these was the so called "Trackball", which was a half hand sized ball, built right into the keyboard. The mechanism is similar to the old, mechanical mouse's. When the user rolls the ball in a specific way, the movement can be detected and the cursor follows that path on the screen. This solution rendered the standalone mouse concept unnecessary in some cases, but it did not become a huge success.

Similar devices – which based on the physical movement and its measurement – were designed and built in many sizes

with wide range of functionality and compatibility, such as the joystick and the steering wheel.

More advanced controllers are using cameras and image processing algorithms to determine the user position as well as the movement of the body parts, like hand and finger movement in front of the sensors. The processed data can be used to associate gestures with controlling events and commands which execute via the controlling and processing software.

One of the most popular solution is Microsoft's Kinect system, which contains multiple image and audio sensors, therefore can be controlled via movement and audio commands as well.

A. Gesture Control Systems

Controlling solutions based on gestures are not a brand new topic. Eye, hand and body movement and gestures measurement ideas become popular decades before, but only the last ten years brought major breakthroughs to become known for the majority.

Mainly the so called smart devices releases and the spreading of the touch sensitive surfaces like monitors and digital boards set the developments and inventions on a new, solid ground. Multiple gaming platforms were built on these technologies: Microsoft's Kinect, or the Nintendo's WiiRemote controller device.

The gesture controllers can be divided into two groups by the processing methods they're using [1]:

- **offline gestures:** the processing starts after the user's interaction. Menu or function activation can be a good example for this controlling method.
- **online gestures:** when the user starts an interaction, the processing begins and the controlling solution can be achieved in real time, with minimal lateness. This kind of method used in the Kinect system, as well as in any VR controlling software.

A gesture controller solution always need a physical device which follows and recognize the body language or movements, so the processing device (e.g. a computer) can interpret them.

II. GESTURE CONTROL DEVICES

The DataGlove (Figure 1) device was developed in the 1980's. It measured the finger movement and position with a flexible sensor in combination with a hand movement detection sensor which has six degree of freedom.

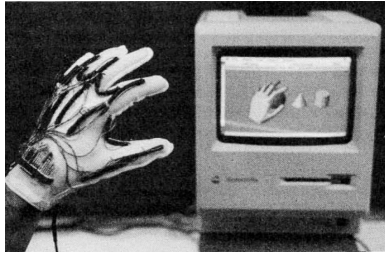


Fig. 1. DataGlove controller [2].

Hand signs and hand positions can be detected with camera systems which use a depth sensing solution or structured light patterns. (Figure 2)

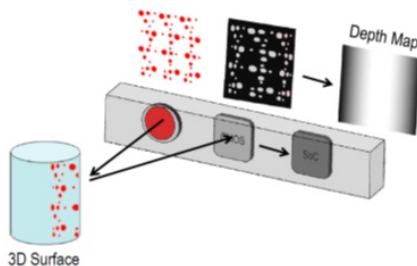


Fig. 2. 3D surface detection method using light patterns [3].

The most popular gesture sensing solution which uses cameras is the Kinect device, a full body scale motion detection sensor system. It's available for Microsoft's Xbox gaming consoles – the Xbox 360 or the new generation Xbox One – as well as for PCs.

The Kinect unites multiple sensors – cameras and microphones – accessible by an Xbox console or the processing software which runs on a computer.

Built-in cameras and infra sensors – use structured infrared light grid emitted by infrared projector – used to achieve depth sensing, therefore the form of an item or a person can be detected (Fig. 3). The microphones used to detect the origin of the soundwaves.

With these techniques and sensors, the Kinect can detect the movement of the user's whole body. In addition, it's a fully functional face and voice recognition solution.

The WiiRemote and its different types are also a good example of a gesture sensing control systems. (Figure 4.)

WiiRemote is a wireless controller which held in the user's hand and controls a Nintendo Wii console. The system follows the hand motion in the 3D space via the movement data provided by the controller. It's also measures the user's pulse and the velocity of the hand movement by the built-in sensors.



Fig. 3. Kinect device [4].



Fig. 4. Wii Remote device [5].

The Leap Motion controller system [6] (Figure 5.) a hand and finger movement and position detection system, which developed by the Leap Motion Inc. in 2010. The system also measures the fingers movements separately, so the computer can be controlled with slow and tiny gestures as well.

Two high-speed, monochrome infrared cameras were built into the two sides of the controller with three infrared LEDs (Fig. 5). The cameras and LEDs covers a hemispherical area with approximately a diameter of one meter. The Leap Motion software process the images and measures the fingers exact position and location in space.



Fig. 5. Leap Motion device [6].

In the following chapter a gesture controller system is presented, which capable of hand movement detection. The system's main advantage is its simple hardware design and price. The gesture control system uses three distance sensors to detect the position of the hand. This type of gesture control system is not applied before. The implementation was organized as computer technology students' project in University of Dunaujváros supported by teacher A. Kovari.

III. DESIGN AND IMPLEMENTATION OF THE GESTURE CONTROL SYSTEM

Gesture controlling based on hand position analysis in specific position can be achieved relatively easy with cheap signal processing units and distance measurement sensors (Figure 6.).

To connect the sensor to a computer and process their raw data, a microcontroller base unit, an Arduino UNO controller is need. The microcontroller transfers the processed, calculated distance values provided by the sensors to the computer via a USB connection. The processing software runs on the PC which filters and processes the distance data, then categorize the calculated gestures by their mathematical representation.

The controlling function based on these representations – a list of decimal numbers – and their associations with previously specified commands and multiple key combinations. The gesture control system's architecture can be seen on Figure 7.

The microcontroller connects and controls three ultrasonic sensors which measures hand position above the detector. With the echo of the ultrasonic sound waves – reflected from the user's hand – the microcontroller can calculate a distance based on the time interval between the sound wave emission and the echo detection. Then the distances sorted into three levels which represented by a single number. One list of number represents a single measurement result (e.g. 0,1,0).

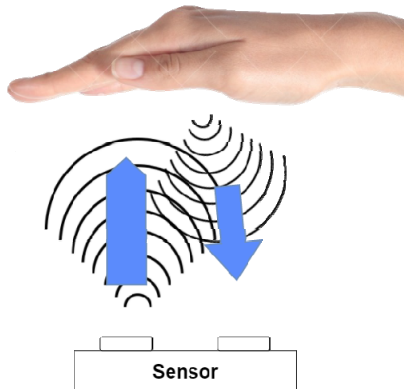


Fig. 6. Hand distance detection.

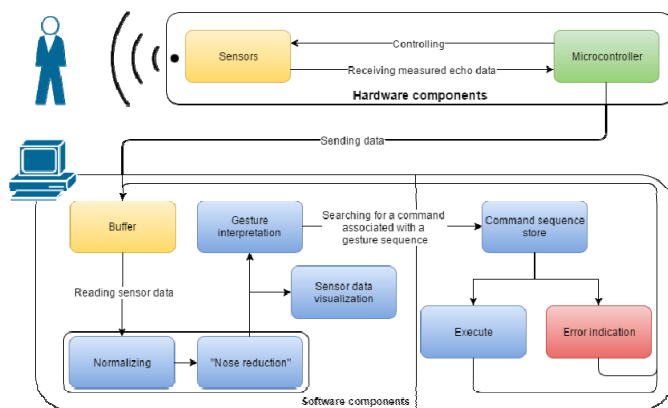


Fig. 7. Gesture Control System overview.

For a usable controlling method, the software filters and unites numerous representations – approximately 30 times per second – till a hand or an item can be detected above the sensors. The result is a single numerical sequence which used to search in the program's database for associated gesture commands.

The controlling system has a hardware component; a sensor unit that contains three HCSR-04 ultrasonic distance measurement sensors connected to an Arduino UNO microcontroller. Figure 8 shows the hardware's circuit diagram and its components as well as the sensor unit prototype.

The system's software component is a WPF desktop application runs on Windows OS. Its main functions are the following: data processing and categorization, gesture calculation and detection, execute command associated with the representations, provide GUI for the controlling and diagnostic methods as well as provide solution for gesture representation and command association settings. The controlling software's class component model is presented on Figure 9.

The program menu contains three controlling options (Figure 10.) to run the software with the default and example commands with predefined gestures. A user defined gestures setup and a practice mode which is similar with the first two option, except the commands will not be executed.

A user manual can be accessed from the menu as well, which presents the basic functions and architecture of the hardware components and shows a gesture and command settings example.

The main window of the program works as the software's controlling and diagnostic interface, which presents a real time representation of the unfiltered distance values and operating states via diagrams. (Figure 11.)

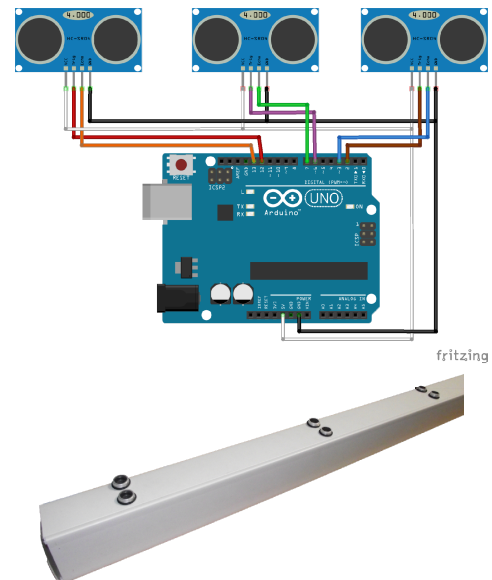


Fig. 8. Hand position detection hardware

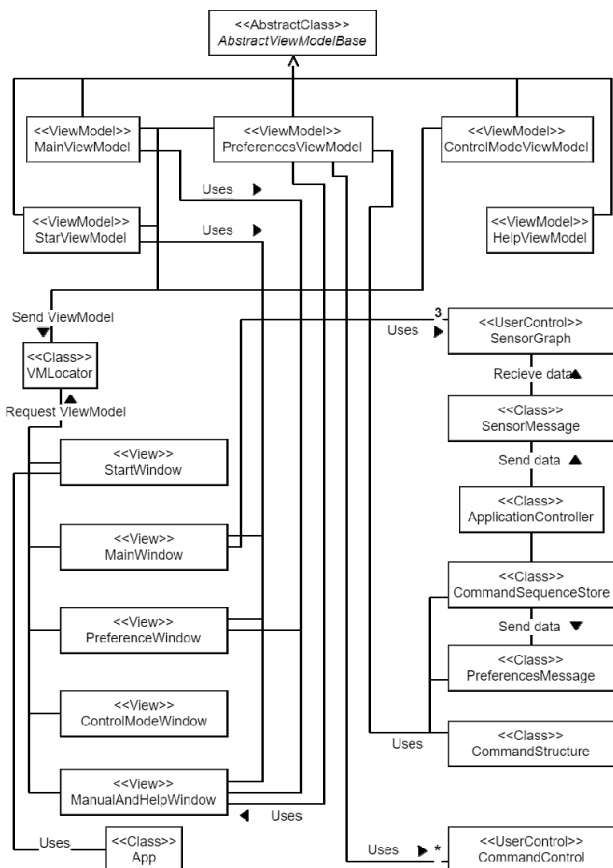


Fig. 9. Software class component model.



Fig. 10. Application start screen.

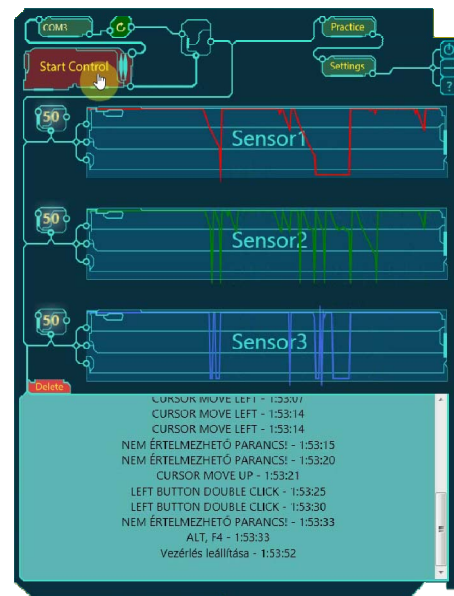


Fig. 11. Diagnostic screen.

IV. USABILITY TEST

The developed gesture control system was tested by twelve volunteers. Five of them were under the age of 25 (3 men, 2 women), five of them were between 25 and 50 (4 men, 1 woman) and the last two of them were over the age of 50 (1 man, 1 woman).

In the testing phase, the subjects were asked to use the system to control the Google Maps web-based and the Windows Media Player MS Windows-based applications. First of all, the controller system was presented in a 15 minutes' interval so they could practice the usage. Then they had to control the applications mentioned above for at least 15 minutes.

After the test, the subjects were asked to fill a questionnaire form to evaluate the usability of the system. The results can be seen in Table I.

TABLE I.
RESULTS OF QUESTIONNAIRE

Questions	Results (average)
Total system usability (1-10)	7,08
Hardware usability (1-10)	6,25
Software usability (1-10)	7,58
Recommends the further development of the system (1-10)	8,5
Plan to use the upgraded device in the future (1-10)	7,91
Recommend the gesture control system to others (0 - no, 1 - yes)	0,92
Purchase the gesture control system if the price is less than 20 USD (0 - no, 1 - yes)	0,83

The answers were positive on the whole, but it has been cleared that it has to be upgraded to a more accurate and user friendly solution for the hardware. Opinion indicates the good usability of the system in specific controlling exercises, but the susceptibility of the hardware to false echo detection.

This glitch caused by the sensor when it perceives an echo deflected by the user's hand which is above the other sensor. Therefore, the processing method calculates a wrong gesture sequence. The errors can be reduced by a solution which presented on Figure 12.

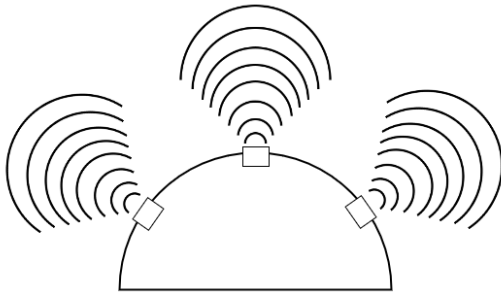


Fig. 12. Modified system hardware.

V. CONCLUSION

This article presented some of the most popular gesture controlling solutions as well as a hand gesture controller system's concept which can be built from a few, cheap components. The system is based on Arduino UNO controller and ultrasonic distance sensors. These components are widely used in several cost-effective projects and adequate devices to create new gesture control solutions to achieve different processing and controlling methods.

The solution presented is a good demonstration of a simple, but usable system for gesture control. The gesture controller can be rebuild easily and could be an appropriate project who is interested in embedded systems and its development and realization. This kind of student's projects could be a good basis of project based learning also, for example in the topic of signals and systems or measurement and control technology, similar to other projects and developments in different fields of computer applications [7-13].

REFERENCES

- [1] D. Kammer, M. Keck, G. Freitag, M. Wacker, "Taxonomy and Overview of Multi-touch Frameworks:Architecture, Scope and Features," Proceeding of ITS '10 ACM International Conference on Interactive Tabletops and Surfaces, ACM New York, NY, USA, pp. 49-58, 2010
- [2] P. Premaratne, Human Computer Interaction Using Hand Gestures, Cognitive Science and Technology, Historical Development of Hand Gesture Recognition, Springer Science+Business Media Singapore, pp. 5-29, 2014
- [3] Centre for Sports Engineering Research, Sheffield Hallam University. (2016, July 15). *Depth Biomechanics* [Online]. Available: <http://www.depthbiomechanics.co.uk/?p=100>
- [4] Wenjun Zeng, "Microsoft Kinect Sensor, and Its Effect," IEEE MultiMedia, Vol. 19, Issue No. 02, pp. 4-10, April-June 2012
- [5] (2016, July 15). *Wii* [Online]. Available: <https://en.wikipedia.org/wiki/Wii>
- [6] F. Weichert, D. Bachmann, B. Rudak and D. Fisseler, "Analysis of the Accuracy and Robustness of the Leap Motion Controller," Sensors, Vol. 13, pp. 6380-6393, 2013
- [7] P. Dukan, A. Kovari, "Cloud-based smart metering system," Proceeding of the 14th IEEE International Symposium on Computational Intelligence and Informatics, pp. 499-502, 2013
- [8] A. Kovari, "Hardwer-in-the-Loop Testing of an Electrohydraulic Servo System," Proceedings of the 10th International Symposium of Hungarian Researchers on Computational Intelligence and Informatics, pp. 631-642, 2009
- [9] A. Kovari, "Effect of Leakage in Electrohydraulic Servo Systems Based on Complex Nonlinear Mathematical Model and Experimental Results", Acta Polytechnica Hungarica, Vol. 12, No. 3, pp. 129-146, 2015.
- [10] A. Kovari, "Real-Time Modeling of an Electro-hydraulic Servo System", Computational Intelligence in Engineering, Springer, pp. 301-311, 2010.
- [11] A. Kővári, "Hybrid Current Control Algorithm for Voltage Source Inverters", Proceedings of the First IEEE Eastern European Conference on the Engineering of Computer-Based Systems, pp. 65-70, 2009.
- [12] A. Kővári, "Influence of cylinder leakage on dynamic behavior of electrohydraulic servo system", Proceedings of the IEEE 7th International Symposium on Intelligent Systems and Informatics, pp. 375-379, 2009.
- [13] A. Kővári, I. Kádár, S. Halász, "The Influence of Inverter Control Algorithm and DC Link Voltage on the Inverter Switching Loss", Proceedings of the IEEE International Conference on Industrial Technology, pp. 590.595, 2004.
- [14] P. Baranyi, Á. Csapó, "Definition and Synergies of Cognitive Infocommunications", Acta Polytechnica Hungarica, Vol. 9, No. 1, pp. 67-83, 2012
- [15] P. Baranyi, A. Csapo, Gy. Sallai, Cognitive Infocommunications (CogInfoCom), Springer International, 2015

