

The development of a soil-movement measurement system to create more precise numeric soil models

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Introduction

A well developed and industrialized agriculture system is one of the bases of our modern society, but it introduces a problem, as it also is a large contributor to climate change. Even only the pulling in the soil of unoptimized tool geometry in itself has a multidimensional impact. The soil-tillage requires nowadays more energy (and thus more fuel) than necessary. Furthermore during soil-tillage the amount of CO₂ emissions and the water retention of the soil also depend on the movement of the soil. This last phenomenon also causes a decline in yield and that can increase the level of deforestation.

Goals

Our grand goal is to create a measurement and modelling system which would offer a cost-effective way of determining the effectiveness of soil tools. The movements of the inner soil layers can be analyzed by numerical simulations. However, for simulations, physical measurements are needed to calibrate the soil model. We determine the correctness of the model by its capability to recreate movements in the soil which we estimate from data collected during laboratory measurements.

In this poster shows the “evolution” of the tasks listed below.

- Creating an environment for measurements
- Creating a device which can be put into the soil during measurements and is capable of tracking its own movement during measurements (*DCD – data collection device*)
- Processing the data collected by the DCD to recreate the movement
- Creating a model of the soil
- Developing a method which can automatically calibrate the soil model based on the calculated movement data

Data collection device

The key component of our measurement system is the data collection device (DCD). These allow us to collect IMU data during the measurements. There are two iterations of the DCD. The first iteration (figure 1) was made using almost exclusively off-the-self components, such as an ESP8266 development board and a Bosch BNO055 sensor breakout panel, within an 3D printed housing.

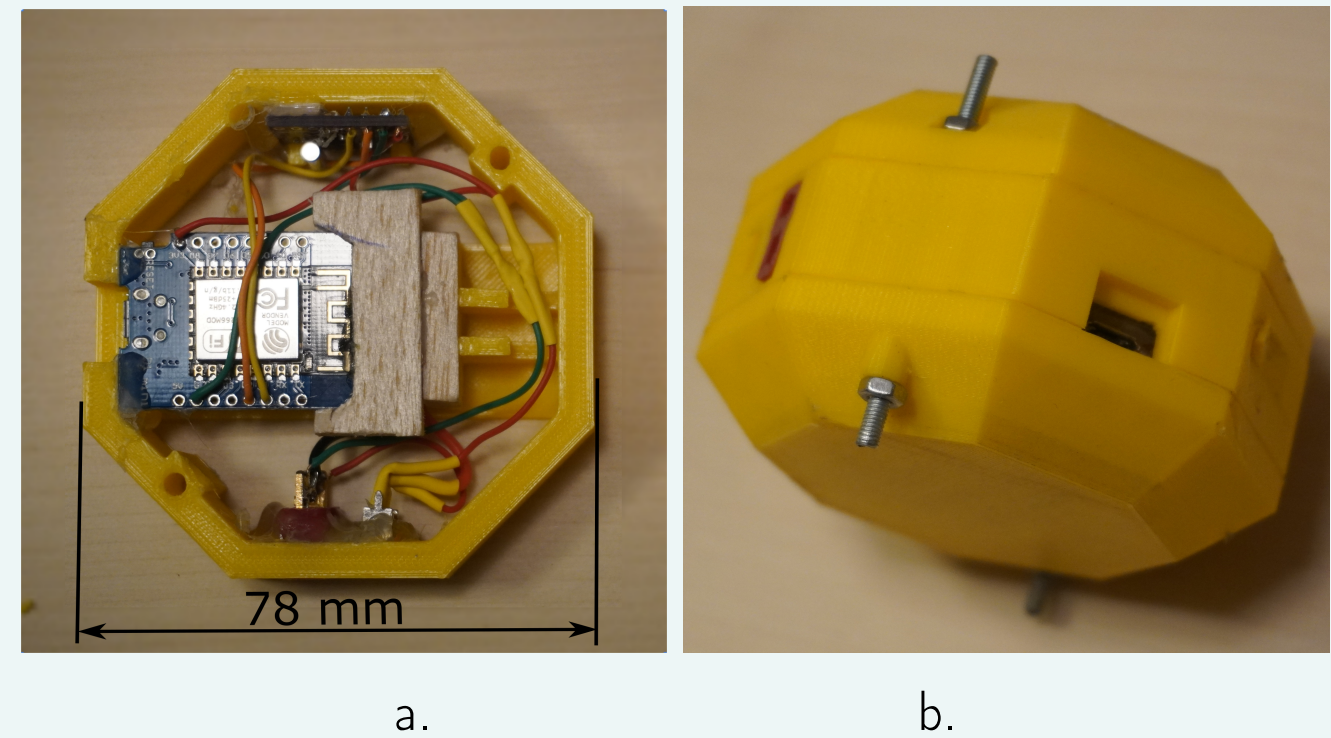


Figure 1: The 1st iteration of the DCD. a) The middle section and b) the assembled housing.

One of the goals with the second version (see figure 2) was to reduce the size of the DCD.

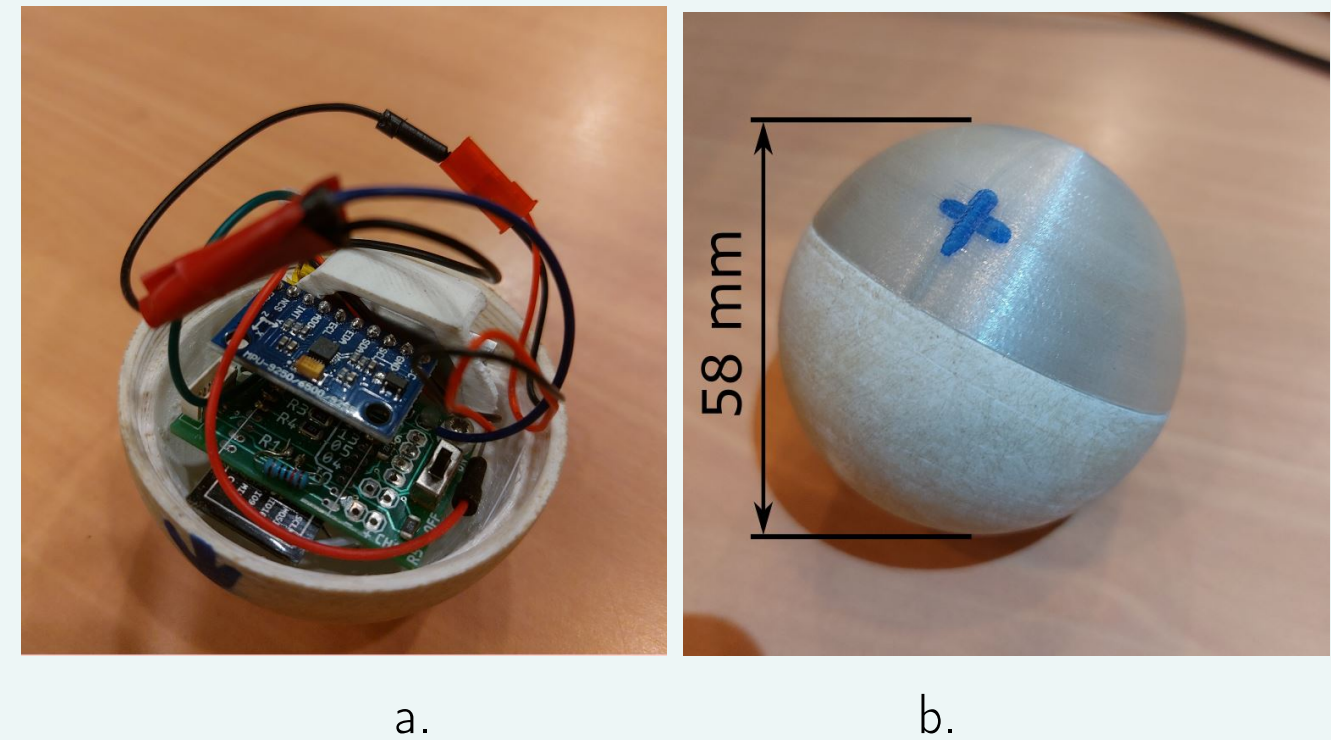


Figure 2: The 2nd iteration of the DCD. a) The PCB and b) the housing.

The second version (figure 2) has a smaller size due to a custom PCB that holds together the parts. The BNO055 sensor was replaced with the less capable but faster MPU-9250, but a breakout panel is still required. The IMU was placed in the centre point of the new spherical housing, which is partially semi-transparent to allow for a color LED status feedback.

Measurement environment

Two kinds of measurements were carried out. The first type (figure 3) is done in a larger (30m long and 2m wide) laboratory soil bin with cultivator tool, but is locked to the place of said bin, while the other uses a mobile soil bin but has some disadvantages due to the bin’s smaller size.

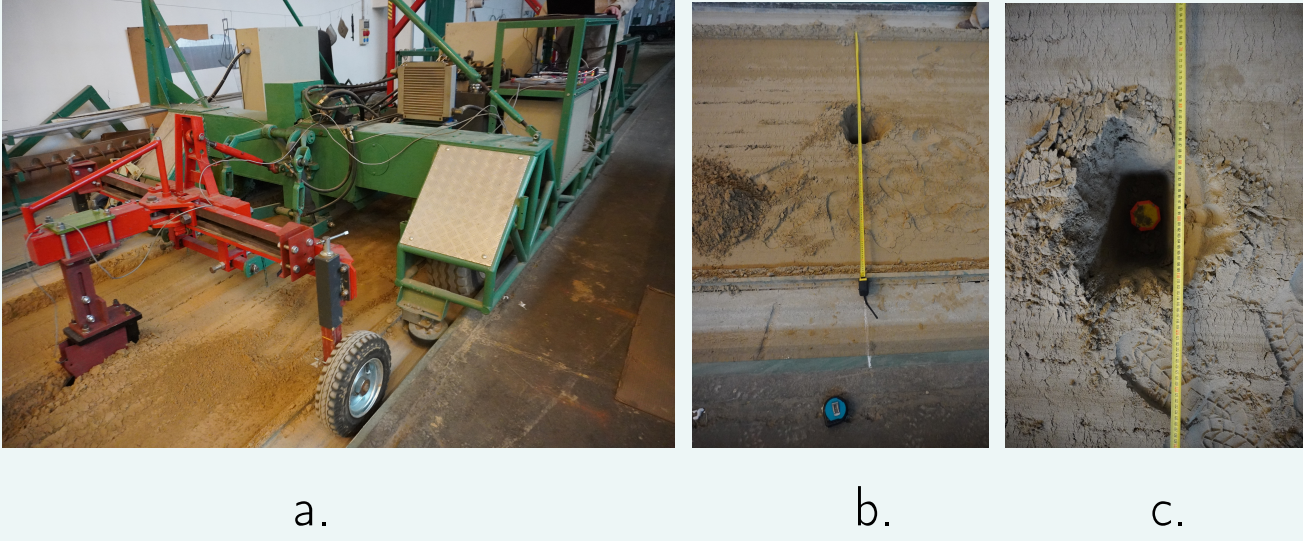


Figure 3: Early measurements in the NARIC Institute of Agricultural Engineering laboratory. a) Soil bin. b),c) Position measurement of DCD.

For the better manageability of the measurements a smaller (900×450×190 mm) soil bin was created (figure 4). This made it possible to carry out measurements with 3D printed tools without a huge effort.

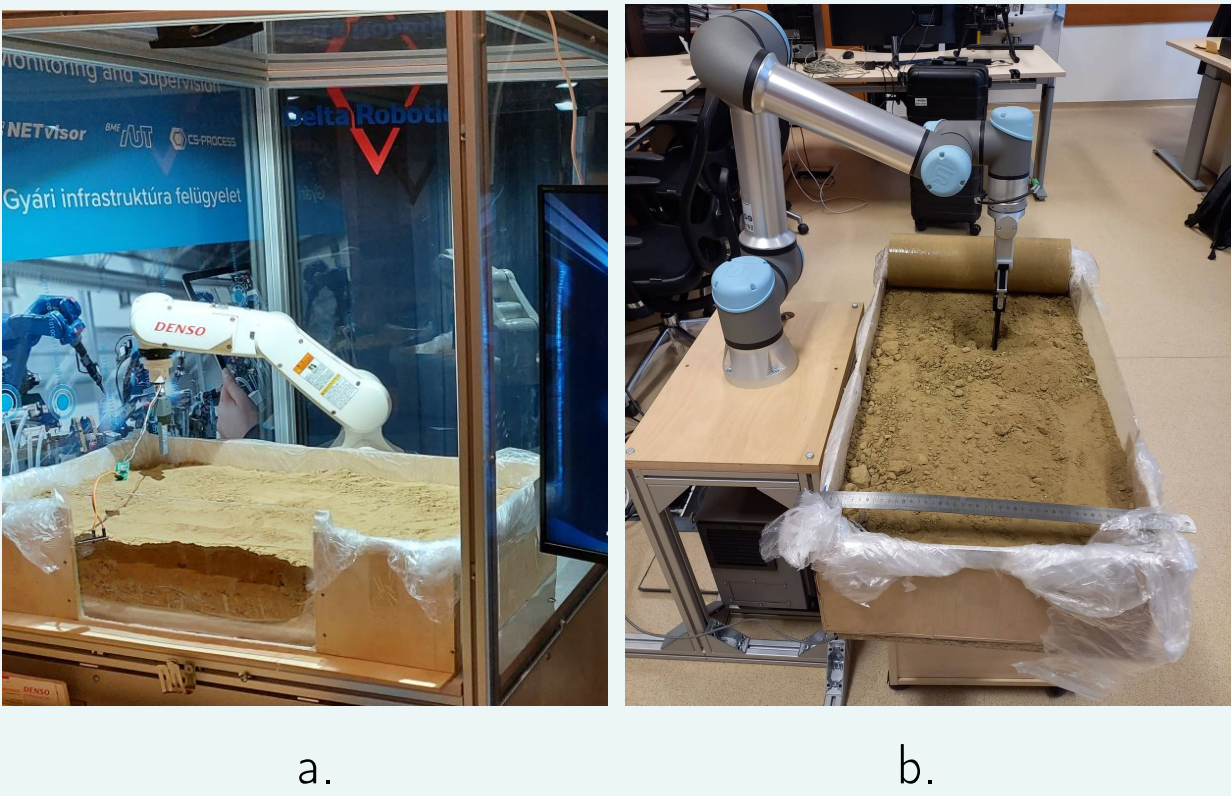


Figure 4: Measurements in smaller soil bin. a) Five axis robotic arm. b) Six axis robotic arm.

Artificial intelligence (AI) was also used as a data processing tool. For this to work properly, it is important to have a sufficient amount of training data, which can be used to teach the AI. For this, a closed-chain mechanism (figure 5) was created which can transform circular motion to a non-circular closed path.

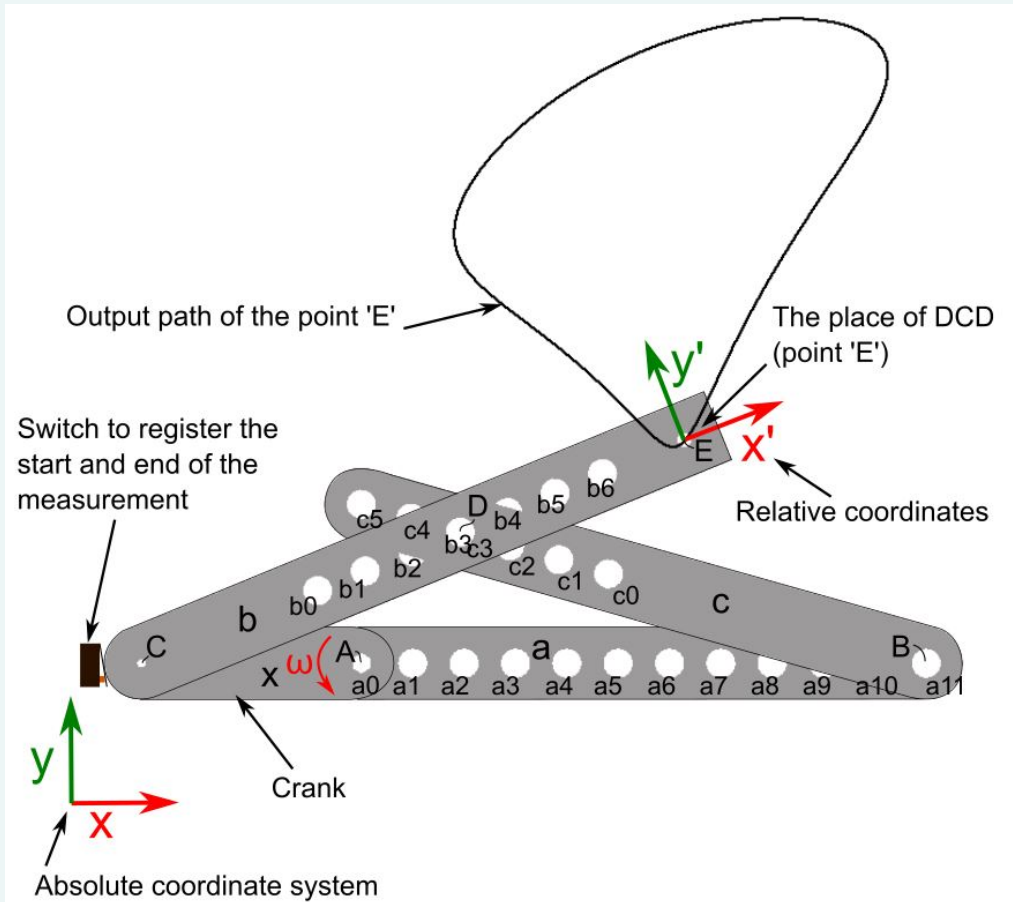


Figure 5: The closed-chain mechanism's plan.

The path of the 'E' point of the mechanism was simulated using Matlab and the data gathered from it is used as the expected output of the AI (figure 6).

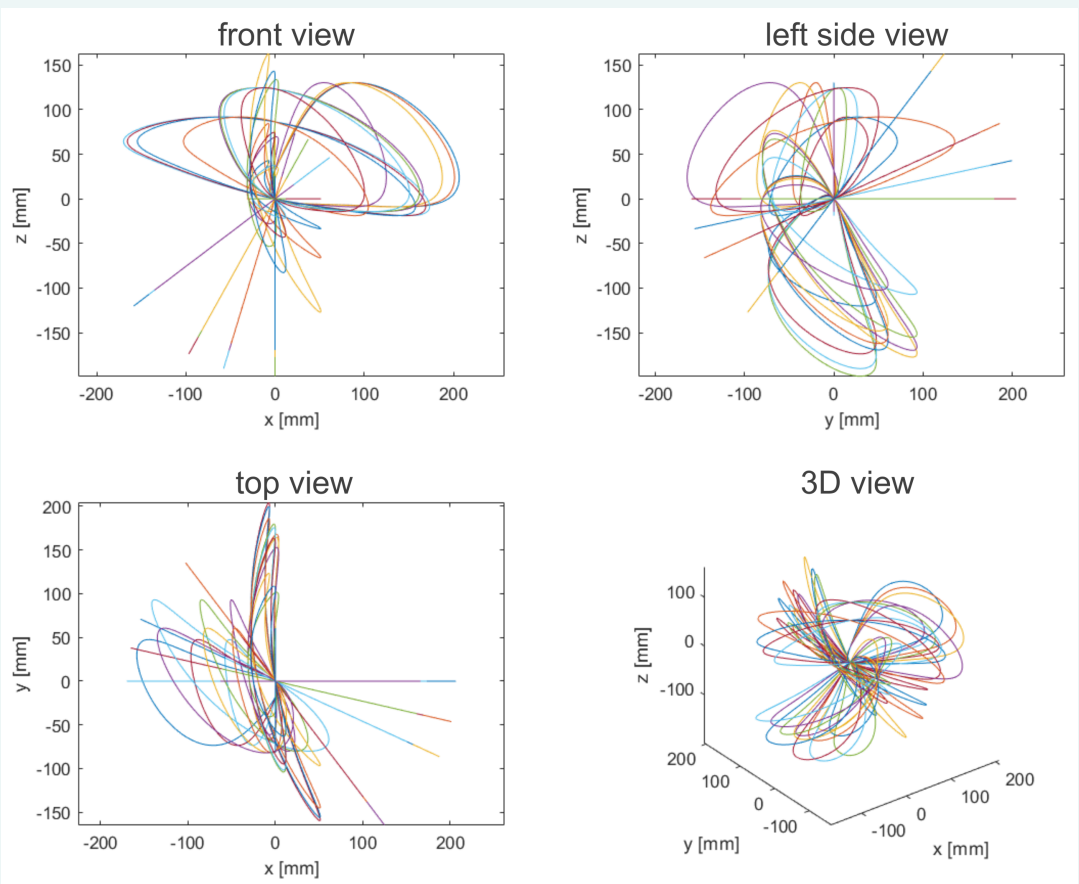


Figure 6: Some simulated possible movement curves.

Soil model

A numerical model of soil-tool interactions was created using the YADE software, which uses the discrete element method (DEM). This model follows the geometry and structure of laboratory measurements. The properties of the material in the model need to be calibrated, for this the genetic algorithm was used.

Data processing

Plenty of methods were used for processing the data (figure 7). First, a P-controller-like algorithm was developed to adjust the calculated endpoint of a measured movement to a given endpoint. The results of this method were useful but further enhancements were needed. Because of this, artificial intelligence was used to enhance results (amongst other methods).

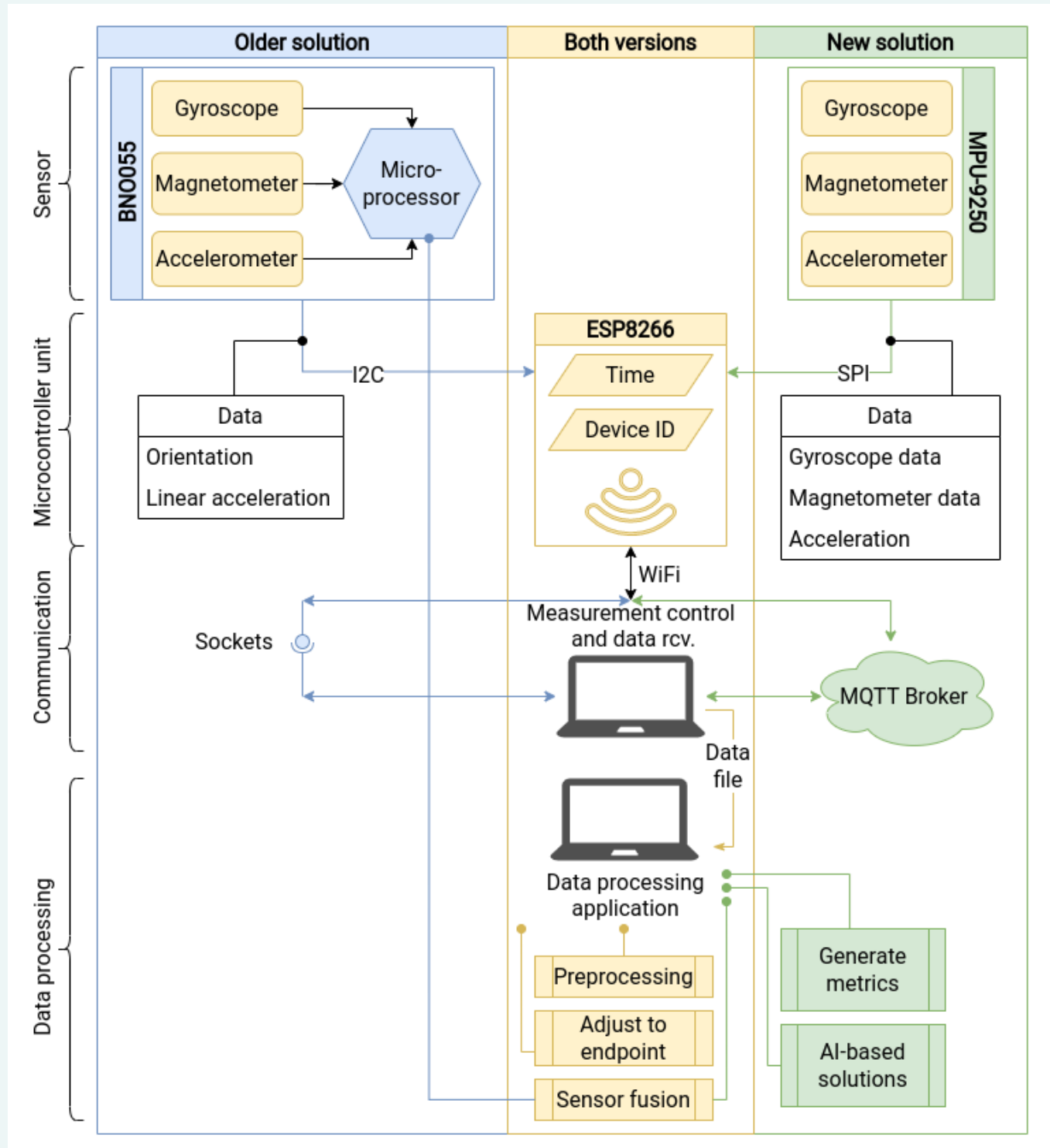


Figure 7: Comparison between the data flows of the older and newer versions.

Results

In the first iteration only the algorithmical solution was used (along with manually adjusted data processing techniques)(figure 8).

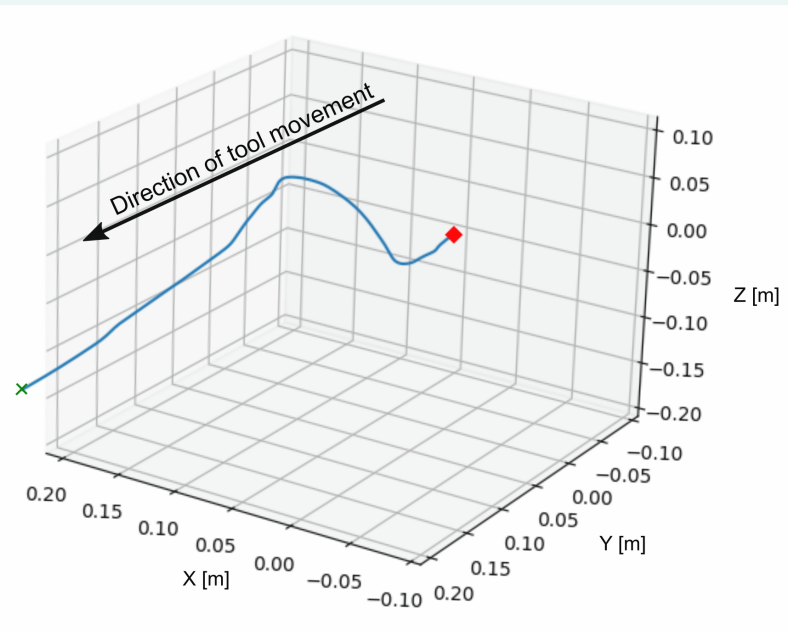


Figure 8: A result from the algorithmical method.

Later the toolbox of data processing was extended with AI, and even within this multiple models were made using different metrics (figure 9).

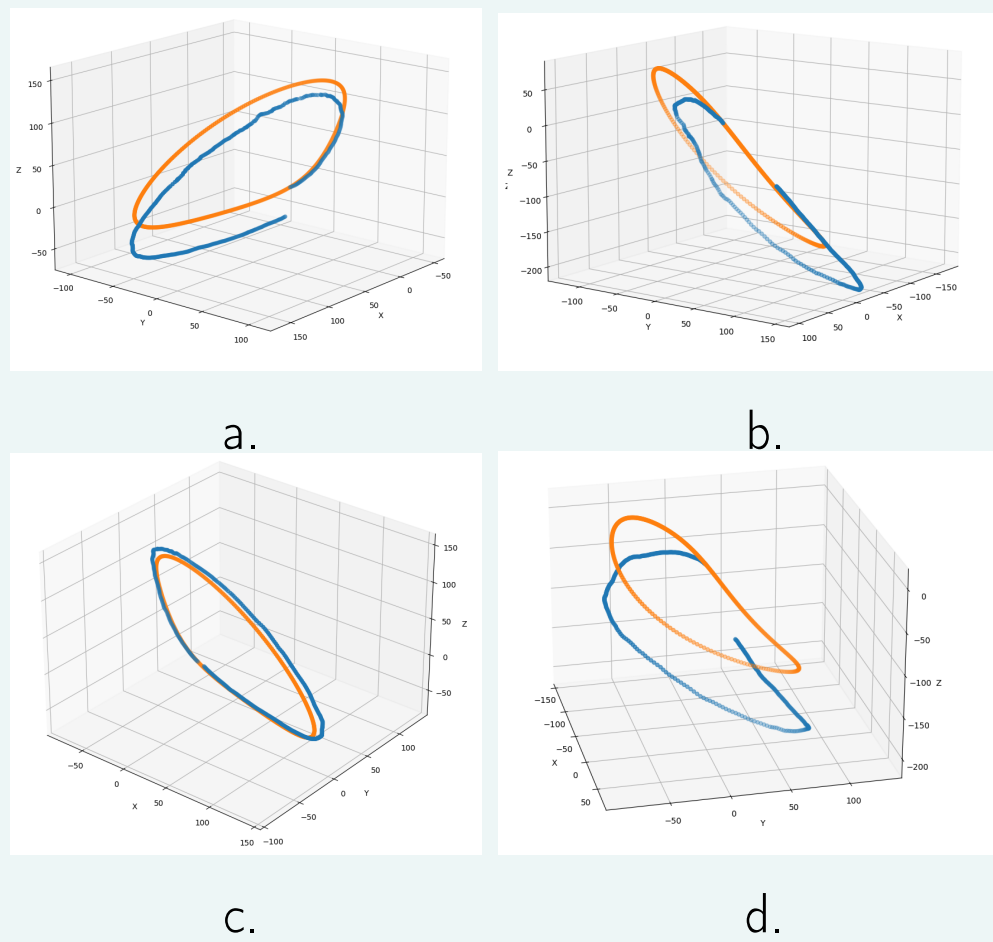


Figure 9: The AI's output using different models (sizes in mm, orange – expected values, blue – calculated values). a),b) Without and c),d) with the results of the algorithmical solution as an input.

Conclusion

The main novelty value of our research is a measurement system that can enable us to analyze the inner movements of granular materials. The results from the measurement system can serve as a basis for the calibration of DEM-based models of soil. During our research a laboratory environment for the study of soil-tool interactions was created, example soil tools were planned and manufactured. Artificial intelligence was also used to determine the paths taken by the DCDs during such interactions, but further measurements and developments are needed to enhance the performance of the method.