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Soil sampling automation using mobile robotic platform

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Abstract. Land based drone technology has considerable potential for usage in different areas of agriculture. Here a novel robotic soil sampling device is being introduced. Unmanned mobile technology implementation for soil sampling automation is significantly increasing the efficiency of the process. This automated and remotely controlled technology is enabling more frequent sample collection than traditional human operated manual methods. In this publication universal mobile robotic platform is adapted and modified to collect and store soil samples from fields and measure soil parameters simultaneously. The platform navigates and operates autonomously with dedicated software and remote server connection. Mechanical design of the soil sampling device and control software is introduced and discussed.

Key words: soil sampling, unmanned ground vehicle, autonomous navigation.

INTRODUCTION

Properly collecting soil samples is important step in any field soil fertility management program. Soil deterioration can be a considerable problem that builds up when fertility management is neglected in long term perspective. Trends toward reduced or zero tillage and technology for variable rate fertilization (VRF) have especially demanded that soil samples should be taken more comprehensively and intensively. Leading for more accurate fertilizer and soil amendment application. In general, soil sampling should reflect tillage, past fertilizer amendment placement, cropping patterns, soil type and texture including drainage and slopes (Oliver, 2010). Simultaneously compaction and moisture level should be measured.

Usefulness and accuracy of precision farming techniques are often dependent on soil sampling approach. Any error during extraction and analysistend to have cumulative effects and distort the soil maps and results. Soil samples are highly dependent of actual situation and conditions on the field which requires higher data acquisition frequency and precision. Conventional soil sampling procedure consists of driving through the fields with all-terrain-vehicle (ATV) and manually probing the soil and collecting the samples into the container (Fig. 1). As there is increasing demand to collect more soil samples, the traditional manual methods are cumbersome to carry out.

In precision agriculture, robotic research is mainly focused on mapping and sampling and is a research area with great potential impact (Bechar & Vigneault, 2017). Distribution of soil sampling points on test area has great effect on result quality. Grid sampling is usually preferred method for sample collection for soil fertility analysis (Ferguson & Hergert, 2000). As sampling pattern generation is a crucial task, automating the process has here clear benefits. To achieve better efficiency and quality, there is a great need for entire soil sampling process automation (Krishna, 2016).

Figure 1. Soil sampling in traditional way.

Several semi-automated commercial solutions are in use, meaning the sample taking is automated but the sampler is transported with ordinary vehicle (ATV or tractor) while human operator determines trajectory (Autoprobe, Falcon, Wintex, Magictec, Agriprobe etc.). They are claimed roughly to double probing speed in comparison with human operator and manual process. In some cases, soil sampling system is accompanied with penetrometer (Ghaffari et al., 2005). Being still monotonous and repetitive process for qualified personnel, it has suitable preconditions being conducted using autonomously navigating unmanned ground vehicle (UGV).

The scope of the current research is the development and implementation of an automated soil sampling system. Novelty is introduced here with proposed sampling system layout – mid-size autonomous UGV platform is to implement to carry soil sampling and storage apparatus. The hypothesis is set that automated fast acting collecting and storing mechanism is an efficient replacement for traditional manual method. Furthermore, accompanied with autonomous navigation technology and cloud-based data processing system, also conceivable replacement for current semi-automatic commercial solutions.

MATERIALS AND METHODS

Test platform

The articulated steering universal mobile robotic platform (Fig. 2) was developed in the Estonian University of Life Sciences for the purpose of practical testing of unmanned technologies and navigation for agricultural activities (Väljaots, 2017). While being somewhat similar to full-size unmanned tractor platforms (Oksanen, 2015), this UGV is classified as mid-size and weights 470 kg. It suits

Figure 2. Articulated steering UGV platform prototype with soil sampling mechanism.

perfectly for automating repeated light tasks usually carried out by humans like automated measurements and sampling.

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UGV layout is modular, consisting of identical modules that are connected with each other through steering linkage. In comparison, different attempts are made to create modular agricultural robotic vehicle (Grimstad, 2017). All wheel drive (AWD) with differential axes is achieved by routing hydraulics lines to every wheel and body module. For powering the hydraulic pump, Kohler 15 kW 2-cylinder internal combustion engine is used. As it works continuously approximately 3 h and minimal pause is required for filling the tank, is well suited for agricultural tasks. The power unit is situated in one module, while the second is free for soil sampling or other useful equipment.

Soil sampling system

The soil sampling and collecting system is integrated into separate body module (Fig. 3, left). For robotic sampling, often drilling is used, especially in harder or variable grounds (Zhang et al., 2017). However, for soft field soils, sample probing with 25 mm diameter and 300 mm length tubular probe (pink in Fig. 3) is simple and durable.

Figure 3. Soil sampling mechanism CAD-model (left) and sample storage system from the prototype.

As secondary actions use hydraulic cylinders, screw mechanism on probe maintains constant process speed and enables to integrate penetrometer drive with the probe. To measure the sampler mechanism position, the motor and screw mechanisms were fitted with rotary encoders and limit position detection with inductive sensors. As only fraction of soil amount in core is taken to container due to volume restriction, container end position is adjusted under the probe while the cleaner rod pushes collected core out of probe.

For automating sample handling and storage, other solutions use often robotic manipulator arm (Deusdado et al., 2016). The current solution uses simpler electric 3-axis coordinate system (Fig. 3, right) instead which is built into second body module. The separate multi-servo unit unpacks the standard carton container covers for sample feeding. The container block includes 140 slots for containers.

Software

The purpose of software development is to enable flexible functionality during autonomous soil sampling operation and solving the following tasks:

- creating the test plan, definition of test area and assigning sample points;
- optimal navigation trajectory generation between sample points;
- preventing the collision with obstacles in trajectory;
- probing for soil sample in test point, collecting the sample;

The input for creating the work tasks is GeoJSON data file with pre-agreed attribute marking. This file is used for creating area borders, restrictions and calculating the path segments for driving between sample points. The software is divided into two separate independent systems: firmware for driving the hardware and remote management system in server, including user interface (UI) for operator (Fig. 4). For achieving the maximum flexibility, the software uses service-oriented architecture. The remote management system software in server is based on NodeJS run-time environment and AngularJS framework. Using the separate library for communicating with operator, the server software manages robot tasks, work process, analyses telemetry and enables also manual control. Software system for the soil sampling device developed in this research is able to work with maps and spatial data.

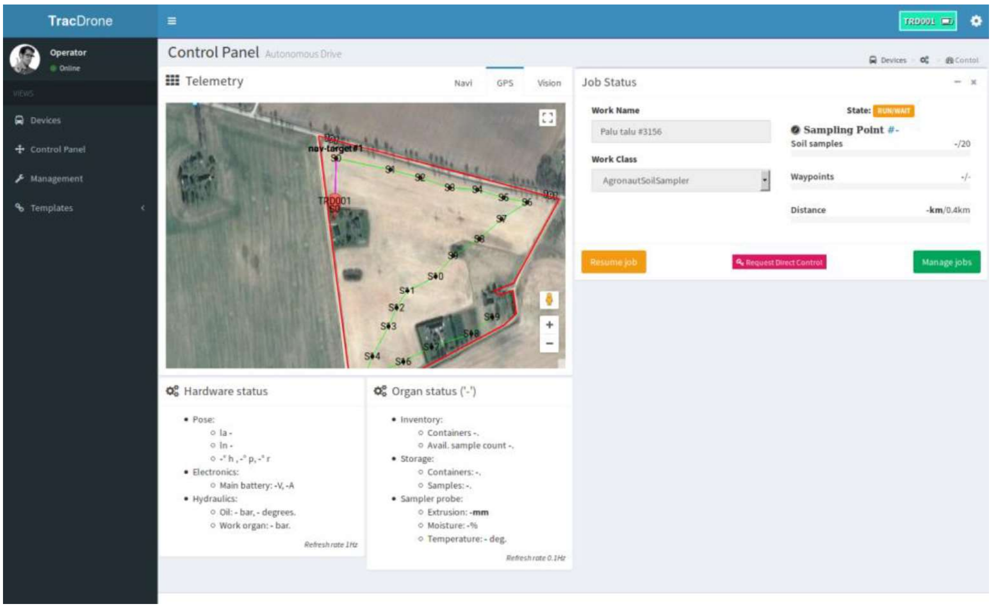

Figure 4. Soil sampling UI for work plan configuration view.

Test method

To observe the performance of the robotic platform equipped with soil sampling system and controlled by corresponding software, the was tested in real-conditions. The performance test was carried out in comparison with traditional method with human operator with ATV and manual probe. Operation speed as performance indicator is measured with sample count per time unit which depends on sample taking time and driving time between grid points. Sampling quality is determined how good representation of soil mean composition the collected samples are and is solved by control software during sampling path generation.

As initial testing was carried out in October after the field was harvested. For initial testing, flat field was chosen with good weather conditions. Sampling path is generated by operator in UI using iterative shortest path calculation algorithm. The resulting GeoJSON data file is transmitted to UGV for processing by its Nvidia control unit. One hour of sampling time was tested.

RESULTS AND DISCUSSION

In order to achieve best possible performance from sampling mechanism, the control unit is programmed to act in sequence presented on Fig. 5. Mean acting times were measured to calculate the summary sample taking times. While the robot platform navigation is still experimental, its control unit can navigate it between the sampling points approximately 2 times slower than operator with ATV. However, if human operator with ATV and manual probe can collect maximum 50 composite samples per hour, robot can collect 75 samples per hour due to faster process and beat traditional method while driving much slower.

Vehicle act.	Driving		Stopped		Driving			
Turret act.	Turn to sampl. pos							Turn to transp. pos
Cleaner act.		Cleaner up				Cleaner down		
Probe act.			Probe into soil	Probe up				Probe down
Support act.		Support down		Support up				
Container act.					Container forward		Container back	
Duration, s	4.80	1.30	1.80	4.30	1.10	1.30	1.10	4.80

Figure 5. Soil sampling mechanism tested action durations.

Further testing should include comparison with semi-automatic system fitted to car trailer, provided by Agricon company. In general, high speed systems that can used without stopping the vehicle, can take only short cores under 150 mm due to angular movement of probe during operation. As the current system probes 300 mm deep, it must be stopped, therefore having much slower collecting speed, yet can collect more measures from each spot.

CONCLUSIONS

A solution was proposed for automating the soil sampling process and mounted to mid-size mobile robot platform. Using cloud based control software, this hydraulic electro-mechanical device was tested for speed and efficiency. During testing, the current system was found out to be 50% faster of a traditional method. It does not require human intervention during the process, only the process planning, robot transportation and handling of collected samples is carried out by operator.

As the purpose of current project is sample collecting method and technical solution research, the system durability and efficiency can be improved further during the planned product development:

- As hydraulic actuators offer good speed and force capability, they should be kept on future development.
- Due to navigation system great impact on overall efficiency, process could also be improved much with validation of different path calculation algorithms.
- As the vehicle is stopped for probing, several soil parameters can be measured simultaneously with additional instruments: humidity, density, temperature etc.

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