A CONCEPT NOTE ON A ROBOTIC SYSTEM FOR ORCHARDS ESTABLISHMENT

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ABSTRACT

In the dawn of the Agriculture 4.0 era orchard establishment remains a manual and empirically executed task even though it affects the performance of the agricultural holding throughout its service life. The typical workflow involves a significant amount of manual labour, requiring teams of workers operating within a narrow window of availability. The narrow application time window is a major hindrance that is intensified by the decline of workforce availability in the developed countries. The work presented aims to alleviate these factors by introducing contemporary technological advancements. Furthermore, these features will be integrated in a fully autonomous framework. The compatibility and seamless integration of subsystems is insured by software, hardware and communication protocol choices. The system will be designed on available and widely used technologies, taking advantage of the open source community and contributing back to it the applied developed solutions. A central pillar of development will be the Robotic Operating System (ROS), ensuring compatibility and expandability of software and hardware components. Ubiquitous sensors can be used to control the system and add an increased level of unmanned operational capacity. On the mechanical design aspect of the system the framework for product development will be based on the functional design paradigm and will be grounded by the Quality Function Deployment framework. The resulting system is going to be designed to fit an array of Unmanned Ground Vehicles (UGV) and standardized conventional machinery. The operation is divided in stages and developed subsystems are going to be part of a modular architecture. Therefore, the system is flexible and adaptable to the diversified needs of spatially dispersed locations. Positive results are expected both on the pure operational performance, due to the automated nature of the system and on the future operations planning, due to the precise georeferenced planting maps.

Keywords*:* orchard, establishment, robot, UGV, planting

1. INTRODUCTION

Agriculture has supported world growth since the begging of time. To achieve this, cultivating techniques, cultivars and tools evolved and fueled further advances in the agricultural sector and influenced heavily all other sectors. As world population growth is expected to increase substantially (Gerland et al., 2014) and exert pressure on agri-food production, environmental change impacts negatively yield capacity and land availability, sustainability isn't achievable with conventional agricultural practices. Precision agriculture (PA) offers a framework of resource handling that promises rationalized and optimized use of resources (McBratney et al., 2005). This enables farming with reduction of ineffective inputs preserving resources, e.g. fresh water, and simultaneously increases yield capacities and product quality (Blackmore, Godwin and Fountas, 2003). To implement a PA framework use of tools like Information and Communication Technology (ICT), automatization and robotic vehicles can be used to achieve the accuracy level of operations prescribed by PA (Sørensen et al., 2010).

Robots, ICT and automation in agriculture are expanding their field of applicability rapidly, ranging from retro-fitting existing conventional equipment with auto-steering systems and Real-Time Kinematic (RTK) Global Navigation Satellite System (GNSS) to disruptive development of fully robotic platforms capable of executing tasks in the field. Blackmore et al. (2009) suggested a classification scheme for task-oriented robots in arable farming. Numerous robotic systems have been introduced in recent years, some of which aimed specifically for orchard cultivation. Especially for surveying work that can be executed both by UGVs and Unmanned Aerial Vehicles (UAVs) with the use of relatively inexpensive sensors (Pravakar et al., 2015). Several other developed systems are deployed for agricultural tasks (Bergerman et al., 2013; Ball et al., 2015) also in a very active field of development and research. The need for fully automized, planned, controlled, measurable and documented operations is strong, even though farmers tend to perceive them as an inconvenience rather than solution. To abate this perception, systems need to be able to operate autonomously and with a comprehensive to the farmer workflow.

Establishment is a corner stone operation for a multiyear orchard cultivation and can benefit significantly from the introduction of ICT and automatization. Furthermore, the ability to alleviate consequences of mistakes in this step is notably limited, if not impossible, underlining the need for documented and controlled operations. In this work we expand the integration of Unmanned Ground Vehicles (UGV) in orchard cultivation through the proposed robotic system that is to be developed to serve the needs of orchard establishment.

2. System Requirements

Orchard establishment is a labor-intensive task that usually involves numerous workers. The farm manager has to decide on planting pattern and parameters depending on cultivar and field. After this preparatory stage, typical workflow includes staking the field, hole drilling and transplanting the young tree.

In order to operate in this environment, the proposed system dictates the use of a carrying vehicle. A critical requirement is the ICT compliant platform. This is a prerequisite for a fully automated and remote-controlled operation of both the vehicle and the proposed earth drill. Furthermore, the vehicle needs to carry the equipment and provide a rigid support structure to fulfill the mission.

Even though GNSS boards are an integrated feature for almost all modern machinery, the way that this module interfaces with the rest of the system is a system requirement for this concept. Direct access to localization data through popular protocols is needed for the mission planner to be able to utilize it and provide the positioning accuracy needed for the operation. Accuracy needs to be at centimeter level in order to achieve an increased level of operation.

Autonomy is another requirement that needs to be considered by designing a system that is both energy and operational efficient. Field operations demand high levels of autonomy in order for systems to be considered as economically feasible and in many cases to utilize the limited time window available for the operation.

Drilling depth is a function that influences design of the physical system heavily. Apart from the physical dimensions of the auger, the energy consumed is also dependent on the type of soil that is to be processed. Hence, various soil types need to be considered from easy to process loamy soils to compacted clay soils.

3. SYSTEM DESIGN

Evaluating the above requirements, the architecture proposed is analyzed in the following paragraphs. The resulting system is a compilation of elements that aim to simplify construction as well as utilize technologies that are at a high readiness level and therefore applicable out of the shelf. The proposed system is illustrated in **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**.

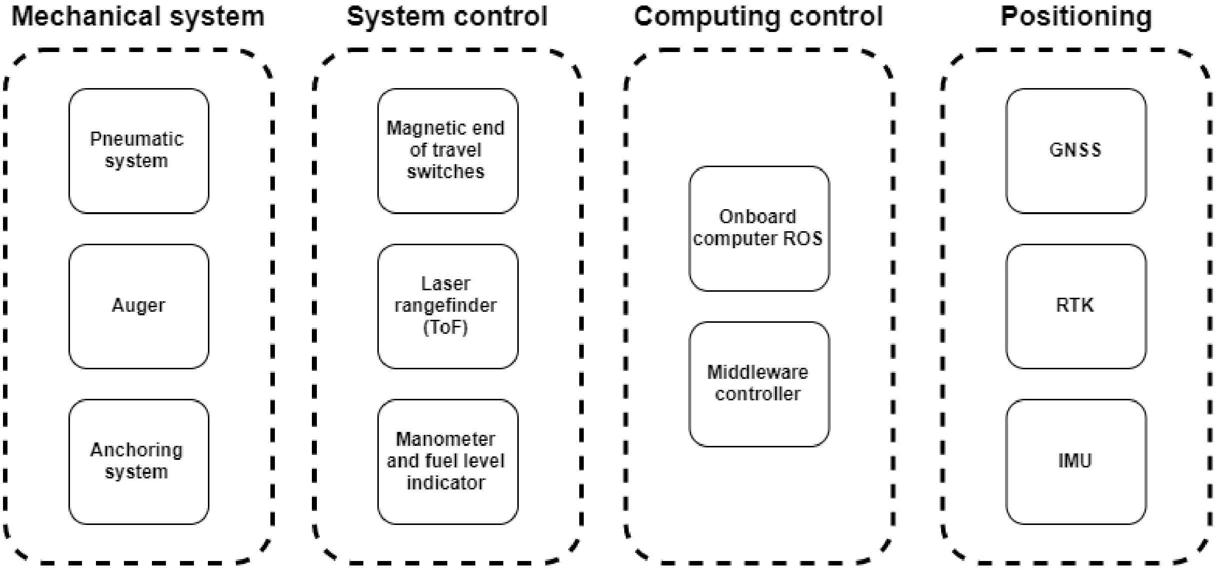

Figure 1. System Architecture

3.1 Architecture

The proposed architecture is based on the Thorvald autonomous robotic vehicle. This platform has physical features that simplify the design and integration process significantly, namely the hollow in the middle frame and its ability to adjust the width. The first enables the design of a compact and rigid system with a footprint similar to that of a UGV without a fully functional implement engaged. Additionally, the smaller footprint allows turns in less space, easier transport to and from the field. The latter is important in future scaling of operations to multi-agent systems executing the task simultaneously. Having an adjustable platform from the conceptualization stage is that the implement can be optimally designed with less restrictions.

As mentioned above, the system needs to navigate and localize with high precision in open fields. The technological solutions for this task are a GNSS board with RTK corrections to increase accuracy. Furthermore, an Inertial Movement Unit (IMU) is used to monitor heading and contribute to accuracy of movement.

The core task is going to be executed using a modified petrol-powered auger. The use of a petrol-powered auger offers great advantages in terms of autonomy levels. The Internal Combustion (IC) engine is going to provide sufficient power to the auger and ensure that the electrically powered UGV isn't going to be deprived of power resources needed for movement to application points. The second power source is also going to be used to drive the air compressor module that is needed to alter the height of the implement. This will increase its efficiency as the IC will essentially be engaged in either drilling or air compressing work, reducing significantly idle time.

To achieve stability the system is going to exploit the kinematic features of the platform and when the auger is in operation the wheels will turn 45° degrees to immobilize the vehicle and counteract to some extend the torque generated by the soil displacement. To further ensure stability during the operation, a retractable dedicated system is designed to anchor the robot during drilling and be disengaged when not needed.

The physical components need to be coordinated and monitored. This role is served by the connecting framework for all these functions, the Robotic Operational System (ROS) that controls the UGV, the GNSS and communicates with the middleware controller that connects the sensors and monitors the implement. This can be a single board computer or a programmable microcontroller that can read incoming signals, process them at a basic level onboard and output serially the status of the system.

3.2 Mechanical system

In more detail the auger is going to be dimensioned according to experimental data that are going to be collected to determine the optimal design parameters for these operational conditions. Flute angle, nose angle, number of flutes and other parameters are to be determined according to the force and consequently the torque that they are going to exert on the structure. A preliminary version of this assembly can be seen in **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** and Figure 3.

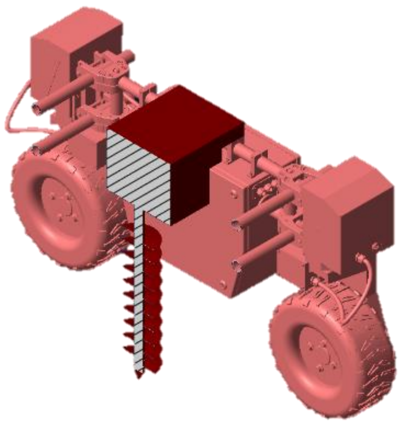

Figure 2. Section view of auger on UGV

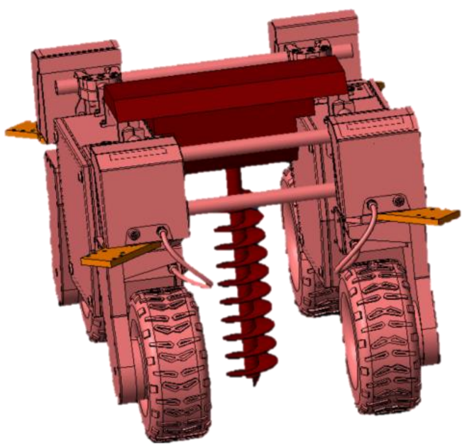

Figure 3. Auger integration

The abovementioned procedure is going to determine the number of anchor points that the system needs to achieve stability during operation. The anchoring system is going to be retractable and utilize a preloaded subframe that aids in traction between the system and the soil.

The operation of the system relies on components being retracted and deployed as needed. The pneumatic system providing this functionality is going to use compressed air linear actuators. The system will use energy generated by the IC engine that drives the auger. This contributes to system autonomy notably since compressed air is one of the most energy consuming features of the concept.

3.3 System control

The moving subsystems need to be controlled and monitored by the middleware. Robustness is a primary factor to be considered, since the operating environment is adverse. Furthermore, the components need to be as simple and globally available as possible in order to be serviceable and replaceable. In this light, magnetic switches for reaching end of travel control are chosen. As the operating principle isn't relying on contact some misalignment and contamination levels are allowed.

To accurately measure travel position of the auger, an optical sensor is chosen that is based on time of flight measurements of a laser diode. Since this is also a non-contact sensor with no moving parts, it can be considered robust enough for operation in the field.

The compressed air tank manometer is also going to be monitored, as well as the fuel level for the IC engine using a simple fuel tank float switch.

3.4 Computing control

The controlling sensors described in Section 3.3 are to be connected to a programmable micro controller, that will be embedded in the implement. This primary control level is going to aid in reporting operational status and monitor the systems task progress. The need to have a middleware controller is also dictated by the requirement for the system to be transferable and easily integrated to other vehicles. Furthermore, lower level control can be dealt with internally, standardizing the equipment's features and procedures and allowing 3rd party integration or development.

The main computing resource is the onboard computer of the UGV that handles primarily all the functions of the vehicle. Since the UGV is running ROS the route planning of the operation is handled by ROS planners and communication with the middleware can be achieved by serial protocol. Consequently, there is a need to develop software that passes commands to the implement and vice versa, interprets the data transmitted by the middleware.

4. Discussion

The proposed concept is designed to automatize a labor-intensive procedure. To achieve this various component are utilized to assemble a novel implement that can be integrated in autonomous robotic vehicles. The system relies on two power sources, the batteries in the UGV and the petrol tank of the IC used for the auger and the air-compressor. Future design iterations should focus on a fully electrical version. In particular, the experimental procedure of defining the optimal auger geometrical parameters will also provide valuable input as for the real work and power requirements. These can be used to calculate a feasible autonomy level that fulfils the operational requirements of orchard establishing. Last, even though the system is task-specific designed, minor modifications can enhance its functionality to similar field work. e.g. soil sampling could also be executed using the proposed system, automatizing a tedious and expensive procedure, enabling farmers to include valuable soil analysis data in their decision processes.

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