INTEGRATED INFORMATION SYSTEM FOR ROBOTICS APPLICATIONS IN AGRICULTURE

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ABSTRACT

In the information era, focusing on the Agriculture modernization and introducing it to the new digital world, the most important elements of which are the online systems and cloud services, should be highly prioritized. Unfortunately it is not considered as vital when compared to the rest of the industry. Practices based on empirical observations and non-optimized methods for tasks, such as weed spraying, fertilizing, yield prediction or plant health monitoring, lead to inefficient resource use and provide undesired results with both economic and environmental negative impact. These are problems that could be alleviated with the help of the latest technological achievements. The developed information system presented is the framework that integrates all the different autonomously operating subsystems, ensuring bidirectional communication among them. State of the art Unmanned ground vehicles are combined with advanced hardware equipment and enable them to navigate autonomously inside fields. Laser-based sensors, that use the LIDAR technology, and Global Navigation Satellite System compatible devices, which provide centimeter-level accuracy, ensure that the robots are fully aware of their surroundings and location in the real world. Simultaneously, unmanned aerial vehicles fly above the work area and collect information that are input to the developed information system. Using the ground robots in the same framework with the unmanned aerial systems creates a network that consistently and reliably feeds the information system with data. This data is analyzed and stored on the cloud, in order to be compiled into applicable information and for future use.

Keywords*:* robotics, agriculture, sensors, UGV, UAV

1. INTRODUCTION

The world as it used to be known, has changed and evolved into an environment of digital information and data, structured within the framework of the internet. Dynamic as it has become, the need to upgrade the nature of its elements, from static to dynamic, is now of utmost importance than ever before. However, although this process has been in progress for quite a while now, not all sectors have received the appropriate attention in order to smoothly transition into the information era. Unfortunately, agriculture belongs to this list of sectors that have been overlooked and thus, have not managed to keep up with the latest technological advancements. As a result, many methods and practices that are used in agriculture are still tied to empirical observations and conclusions that lack efficiency and optimization. Nevertheless, there is great potential for improvements towards that direction, if the power of the latest technological advancements is harnessed effectively and methodically.

Such advances enable the integration of technologies tightly connected to mobile and wireless broadband and cloud computing, to Knowledge based Agriculture (Morgan and Murdoch, 2000) and manage to accomplish the automation of human labor requiring tasks, significantly dropping the final cost of such jobs. Consequently, resource usage is reduced while efficiency in yield production is increased achieving the goal of a much desired paradox balance. This sustainability defined goal, aiming at higher yield demands is thereby accomplished, positively affecting multiple aspects of the bio-economy industry, among which the most important are the environmental and economic ones (Von Wirén-Lehr, 2001). However, the ever growing population applying pressure towards production quantity, in conjunction with the inhibitory factors of soil compaction (Hamza and Anderson, 2005) and climate instability (Mueller et al., 2012), put extra weight on the demands. To make matters worse, a 20 years depth analysis which shows a 0.489% increase in calorific demands per capita annually, according to the Food and Agriculture Organization (FAO) of the United Nations, translated into a total of 10.25% in two decades, becomes a significant variable in the formula that indicates the urgency for further increase in supply to compensate for this demand.

Information Technology provides the infrastructure to create the much needed environment for Information driven Agriculture. Information systems aggregating and processing valuable agriculture related information serve purposes of improving the level of the intelligent management and decision of agricultural production (Sørensen et al., 2010; Yan-E, 2011). Input data to the information system regarding soil quality, field and cultivation state, plant health as well as a rich list of other precious metrics can be reliably and efficiently obtained with the use of automated robotic subsystems (Sorensen et al., 2010) combined with sophisticated hardware (sensors, cameras etc.) (Adamchuk et al., 2004). State of the art ground and aerial vehicles, equipped with equally advanced hardware, can be introduced to Information Agriculture through integrated information systems (Sørensen et al., 2011).

In this paper, an integrated information system collecting data via both Unmanned Ground Vehicles (UGV) and Unmanned Aerial Vehicles (UAV) is proposed. It aims at modernizing and automating some of the aforementioned sectors of agriculture and expects to tackle problems the source of which emanates from methods based on traditional practices and lack of centralized aggregated data.

2. Methodology

The framework that the UGV and UAV subsystems are integrated into is the presented developed information system. The information system's back-end is supported by the Amazon Web Services (AWS) cloud computing (Amazon, 2016) which offers a suitable platform to accommodate the needs of the information system's infrastructure (Figure 1). High reliability and great up-down scalability potential as well as the "serverless application" feature were the three decisive reasons why the AWS cloud computing was chosen to be the application host. The "serverless application" model removes the "server manual maintenance" variable out of the "human resources management" equation, accelerating the development speed of the application by focusing human labor directly to the front-end side of the application.

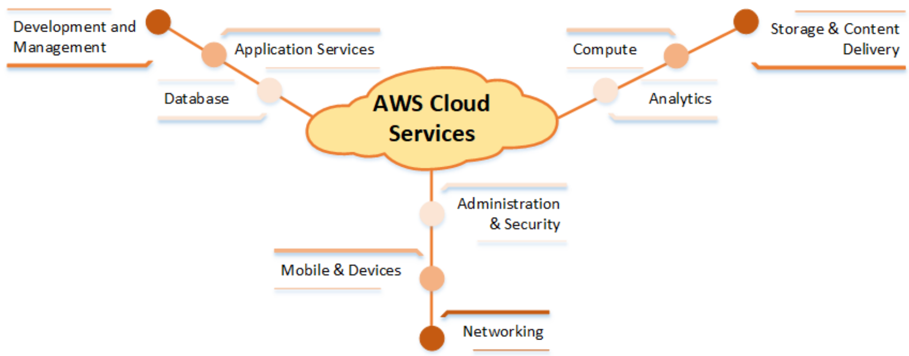

Figure 1. AWS cloud Infrastructure Services

For the front-end system development, it was necessary to use a set of different tools. ReactStrap (Hernandez, Burrell and Sharp, 2018), BootStrap (Otto et al., 2019), HTML and CSS is the combination that gives life to the user-side application by providing the Graphic User Interface (GUI) through which the information system can be accessed by its users. The data exchange between the application's front-end and back-end side is realized with the help of React language (Facebook Open Source, 2017). React is a JavaScript library, suitable for creating user interfaces, which is commonly used for developing webpages and web applications. BootStrap is a webpage style-tool that enables the interface to be easily transferred to a great list of portable devices without breaking the style format of the interface itself. ReactStrap is a tool that enables developers to use BootStrap objects alongside with React, easing the portability of the developed applications to numerous devices such as smartphones, computers and tablets.

UGVs are operated by Robot Operating System (ROS) (Quigley et al., 2009), which is a Linux based framework for writing and developing robot software. ROS has a modular character and a network structure. It consists of a central unit called Rosmaster and a network of nodes. This network is operated by the Rosmaster and has no limitations as for the number of nodes it can accommodate. These nodes are independent from one another, each serving different purposes, executing tasks of different priorities, in parallel. Nodes communicate with each other and all of them are coordinated by the Rosmaster (Figure 2). ROS is commonly used in the industry as a framework to operate robots, or fleets of robots, and it is so popular due to its Open Source nature as well as the large collection of software libraries and tools it offers that can be combined into various applications. Additionally, ROS comes with a large variety of implemented software drivers and eases the process of connecting industry, state of the art, equipment to the robot. Such equipment can be hardware devices i.e. GNSS receivers, laser-scan sensors, RGB/depth cameras, Inertial Measurement Units (IMU) etc. all used to set robots aware of their surroundings and give them real-world perception (Thrun, 2008).

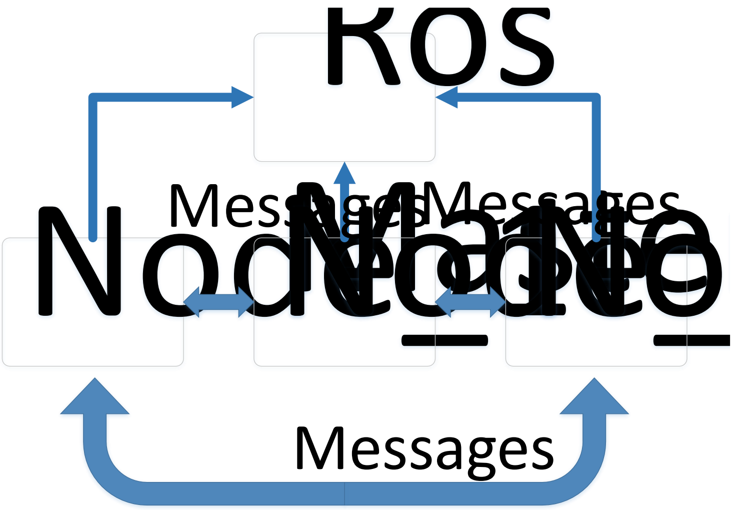

Figure 2. ROS network structure

UGVs equipped with such hardware operate autonomously inside the framework that the developed information system provides (Sørensen and Bochtis, 2010). Tasks can be assigned to the robots and will be executed according to the schedule, as set by the user. The information system constantly logs the current state of each robot, providing feedback that is used to keep track of the robot's general status. Data about robot's location, speed, battery level and health, task progress and uptime are live in order to keep the user updated and able to monitor the robot's current state. UGVs' autonomous navigation is assisted by UAVs that operate simultaneously above the working area, feeding the information system with real-time data about the working area (Ravankar et al., 2018).

The UAVs fly above the field, within which the UGVs operate, and collect photographic material that is used to determine the presence of terrestrial obstacles. These data feeds the information system from where the user can see the live aerial view of the respective field. Route plans are generated by analyzing the incoming data and UGVs are updated accordingly. UAVs assisted navigation sends alerts to the UGVs that indicate the existence of an obstacle at a specific area inside the field. By utilizing the sensing mounted hardware, UGVs can cross-examine the validity of these alerts, update their route plan and avoid areas inside the field that are blocked by obstacles.

As a result, important amount of data is aggregated in the information system, stored on the cloud and later compiled into applicable information. Photographic material acquired by UGVs, operating along their planned route, is suitable for use in numerous applications (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**).

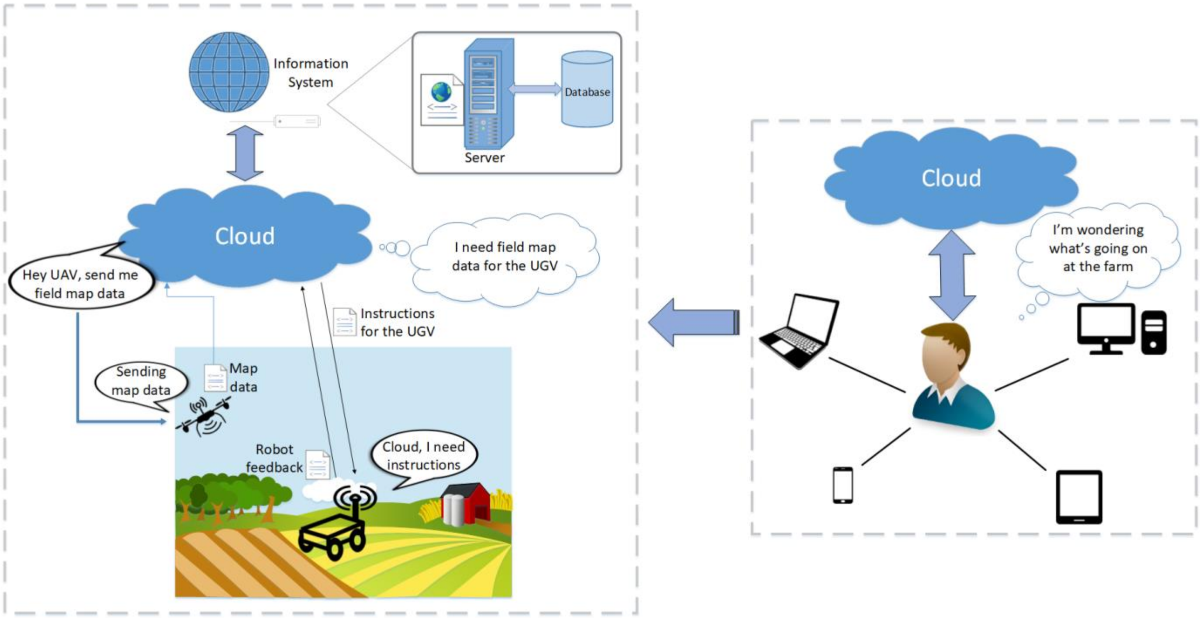

Figure 3. Interaction of information system's entities with the end user

Plant health monitoring becomes a trivial task (Liakos et al., 2018) with reduced human resource cost and greatly increased accuracy (Khirade and Patil, 2015). This leads to better and more reliable yield prediction, which in turn guarantees higher accuracy in economic estimations for the information system users. Weed spraying can now be scheduled for specific areas inside fields where the problem appears to be more intense, contributing in resource waste reduction and therefore, higher efficiency and smaller environmental negative impact (McFadyen et al., 2011).

3. Conclusions

The presented information system integrates unmanned ground and aerial vehicles in order to support the functions of a fleet of independent data collectors with further possibilities of generation-assignment and transmission of tasks to be executed. The automated interaction of UGVs and UAVs with the information system, targets at creating a sustainable network of constant data flow through the information system entities. Yield prediction is going to be supported by large amounts of analyzed photographic material and will no longer be subject to uncertain estimations. Plant health monitoring aims at informing the user for potential in-field disease-related hazards as well as reduce the error margin for diagnosis of common plant diseases. Finally, methodical tracking of fields for weed growth is expected to provide guidance for precision-spraying with the use of weed growth-zones information carrying heatmaps, generated by post-analyzing cloud stored data. Here, a brief concept of the system has been presented. Parts of the presented information system are already being implemented and the development status is in constant progress. The results derived from the so far use of the information system are greatly encouraging.

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