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An Analysis of the Possibilities to Develop and Implement a Modular and Scalable System Based on Mini-Aerial Robots for Precision Agriculture

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Abstract
The paper presents an analysis of the possibilities to develop and implement a modular and scalable system, based on mini aerial robots for precision agriculture. The recent developments in the field of UAVs (unmanned aerial vehicles) have created new applications in new domains of interest. The technological progress at electric engines, batteries, multispectral sensors and communications opens new directions also in the field of precision agriculture applications. The interest is now to test the opportunities and risks to develop and implement a new generation of a scalable integrated aerial system dedicated for activities in the field of precision agriculture. The focus is on the possible performances but also on qualitative intangibles including the costs on the entire life cycle of these systems. The typical modular and scalable system based on mini- aerial robots for precision agriculture is based on three critical sub-systems capable to work synergistically and that capture the advantages of the recent disruptive technological innovations.

Keywords
unmanned aerial vehicles (UAV), mini- aerial robots, precision agriculture, scalable system, modular system

1. Introduction

Precision agriculture (PA) is the science of improving crop yields and assisting management decisions using high technology sensor and analysis tools [1]. PA uses a large amount of data and information to improve the use of agricultural resources, yields, and the quality of crops [2]. According to Nigam et al. the rapid enhancement of precise monitoring of agricultural growth and its health assessment is important for sensible use of farming resources and as well as in managing crop yields [3].

In order to improve field monitoring and intervention procedures, some robotic applications have been considered, in agriculture. The recent developments in the field of unmanned aerial vehicles (UAVs) have created new applications in new domains of interest. The technological progress at electric engines, batteries, multispectral sensors and communications opens new directions also in the field of precision agriculture applications. The interest is now to test the opportunities and risks to develop and implement a new generation of a scalable integrated aerial system dedicated for activities in the field of precision agriculture. The focus is on the possible performances but also on qualitative intangibles including the costs on the entire life cycle of these systems.

The aim of the presented paper is to identify development and implementation possibilities for a modular and scalable system, based on mini-aerial robots for precision agriculture.

2. State of the Art in the Field of Robots for Precision Agriculture

An effective method for monitoring large acreages to assess crop conditions, increase precise management of crop inputs, allow efficient harvesting, evaluate high yielding and resource efficient crop varieties, and be more efficient in managing livestock is the use of agricultural robots combined with digital agriculture techniques [4]. In the literature are presented several generations of projects related to the use of aerial autonomous robots in agriculture:

a) G1- remote- control robots for crop fields applications equipped with earth observation (EO)/ infrared (IR) sensors for detection of drought, nutritional deficiencies;
b) G2- robots for scouting, identification and localization of the crops, with scalable capabilities (weeding using plant cutting arms or small sprays of herbicides) focused on transportation of high payload rate (insecticides spays and fertilizers) with connection possibilities to GPS systems;
c) G3- fully autonomous robots with dynamic capabilities (for example variable- rate applicators) based on digital maps provided by multispectral sensors;

The most used aerial autonomous robots are for general scouting [5]. Equipped with standard cameras, aerial robots can be used for weed, pest, and disease infestation, by observed changes in row crop color or physical structure [6-8]. According to Luciani et al., Unmanned Aerial Systems are used to quantify and document crop damage for making insurance claims [9].

Other applications expand upon image-based remote sensing by incorporating more expensive sensing and data analysis methods:

- spectral sensing [10-11];
- digital sensors – for the correct application of substances on the crown of trees by optimizing the dosage rate according to the characteristics of the crown [12];
- sensors for measuring morphological parameters, their mounting on machines at different heights and angles of inclination according to a good resolution and measurement frequency [13] (Dworak et al., 2011) and three-dimensional modeling [14];
-3D sensors and 3D smart cameras that have a built-in processor [15];
- ultrasonic sensors - for identifying the characters of the tree crown for optimizing the spraying of treatments in orchards and adapting the application rate [16];
- real-time positioning algorithm for air-assisted orchard sprayer with variable geometry [17];
- fruit recognition system on the branch using RGB images [18];
- management of hair orchards based on data collected with UAVs [19];
- monitoring system for horticultural ecosystems to reduce the workload and time involved in the process of identifying and recognizing diseases in the early stages based on images collected using UAVs [20].
- agricultural ecosystem monitoring system to identify abusive grazing and damage assessment based on images collected using UAVs [21];

The evolution of these generations of aerial robots for precision agriculture depends on the advantages of future automation and networking capabilities in terms of removal of human drudgery, costs and profits. Automatic sensing, harvesting, managing of grains will be focused on scalability, downsizing and modularity [22-23]. The new generations of aerial autonomous robots for precision agriculture should be better focused on the land preparation activities, on efficacy of spraying fertilizers and/ or pesticides, sprinkling precision irrigation and eco-harvesting.

Also, new generations of aerial robots for precision agriculture could be essential in the new future applications like multi-pruning of branches (grape wines), multi-spraying tree canopies, advanced wedding interrow spaces among the lines of trees, intelligent irrigation. The interest for precision agriculture aerial robots is to improve crop production performance (indirect but also total costs, labor shortage in peak crop activities).

The future generations of aerial robots for precision agriculture could represent scalable vectors of Push-button farming systems PBFS with a special purpose architecture with three pillars:

-autonomous transportation system equipped with specific capabilities for performing tasks in the agriculture (like crop field);
-scalable sensing system for measuring the properties of agricultural fields (the advantage of using scalable set of multispectral sensors);
-advanced decision-making instruments (the local station C3L that process data from sensors could be equipped with intelligent decision support systems IDSSs).

The next revolution in agriculture will almost certainly be driven by the introduction of new precision farming techniques and the forecast is that drones will play a key role.

The robotic aerial platforms for working in horticulture must be adapted to the current requirements in Romania related to the idea of an integrated modular and scalable system, easy to use, respectively miniaturization, thus offering a significant reduction of costs.

3. Toward a Scalable Integrated Aerial System for Agricultural Applications

The interest is to analyse the feasibility of a scalable integrated aerial system capable to capture the advantages offered by aerial vectors in precision agriculture at reasonable costs on the entire life cycle.

This integrated system could offer a lot of advantages like:

-a better efficiency in a lot of typical agricultural missions (capabilities to capture to agricultural culture samples, capabilities to collect and record specific data base, capabilities to analyse in quasi real time the typical portfolios of parameters of interest like qualitative growth rates, crop stand, nutrient -status);
- a consistent reducing of human implication in agricultural farm working in all seasons, 7/24;
- capabilities to offer a sustainable operational capacity based on a better accuracy of typical operations (fertilizer supply, precision irrigation, active monitoring for understanding the stages of crop evolution);
- a better control of the risks associated to human operators by replacing monotonous and dangerous drudgery;
-a better capability to select and classify in uniformly standardized sized and quality products (based on the advanced EO/ IR sensors);
-a better capability of optimization the timing (spray pesticides, harvest crop); a reduced amount of microbial contamination; a reduced impact on environment

The typical system, presented in Figure 1 is based on the integration and the synergies between the following specialized systems and software: the system of aerial vectors; data collected by ground sensors; data received from satellites; data analysis system; the software for analysing the data received from the sensors; data interpretation algorithm; spraying systems mounted on UAVs.

We propose a system consisting of two aerial vectors in a strategy based on a small quad equipped only with three sensor (multispectral, VIS, IR) and the second octorotor vector with aerial work transportation capabilities equipped with phytosanitary treatment application systems. This system of aerial vectors benefits by the technological progress for downsizing and performance (i.e., a higher endurance but also a better payload transportation capability), by a better set of performance indicators (i.e., endurance, speed) but also by an impressive payload- ratio.

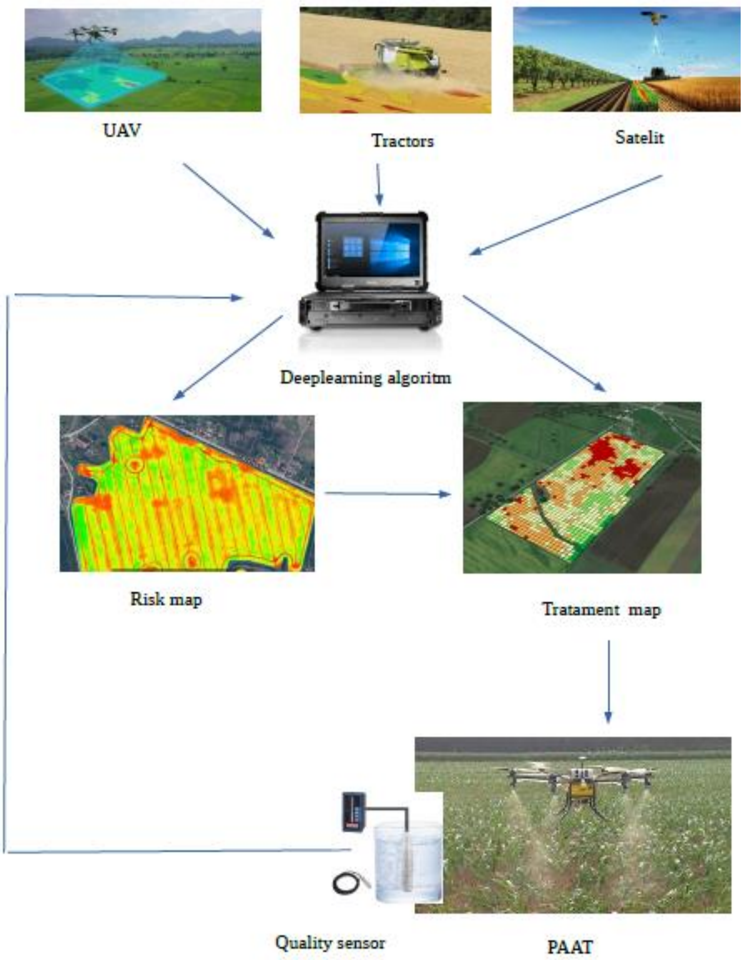

Fig. 1. The architecture of the system

The control communication system (C3L) benefits in the proposed setting primarily from the increase in accuracy, an increase in reliability and the significant reduction of initial costs.

The system of sensors, mounted on-board but also fixed on-site benefits from increased performance (accuracy, transmission speed) typical for an efficient multispectral analysis.

The specialized systems of payloads and sensors dedicated for agricultural applications benefits from superior performances and accuracy by technological progress specific to the field.

The system described in Figure 2 is an innovative system that combines the collection of data in different electromagnetic spectrums, their automatic processing and the generation of the flight plan, so that the application of phytosanitary treatment can be carried out only in problem areas.

The data collection is carried out with a microcopter type platform capable of simultaneously transporting the three sensors (Multispectral, VIS, Thermo). Image localization is based on the GPS RTK (real time kinematic) system, which receives position correction data as well as information about the 3D terrain model from the topographical cloud. The collected images are transferred in real time to the command and control station.

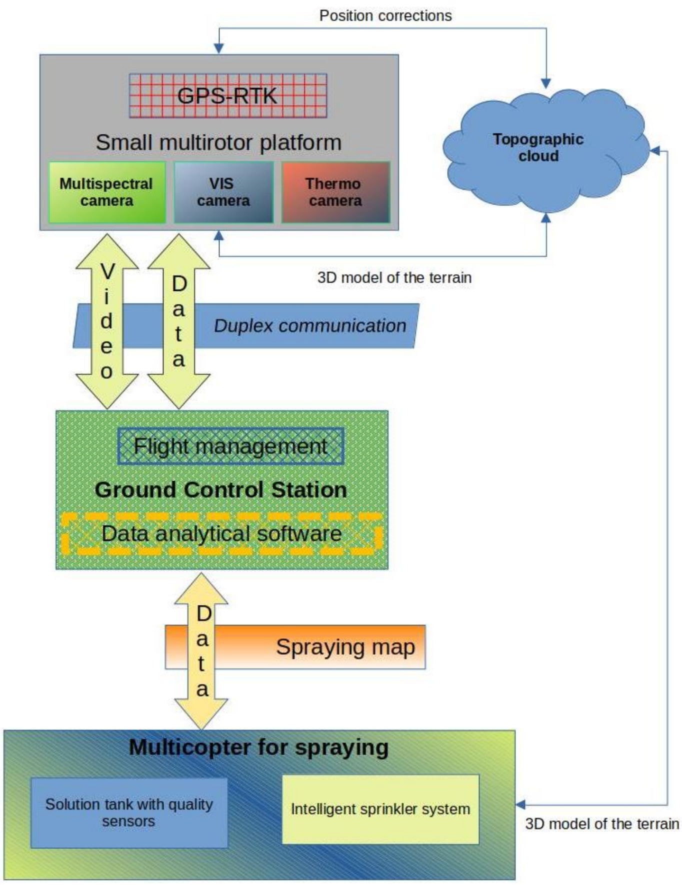

Fig. 2. A versatile aerial platform for precision agricultural applications

By processing the images, the areas suspected of having problems are determined with the help of the vegetative indices. These areas are identified by geolocation, subsequently generating the flight plan for the spraying drone.

Identifying the type of problem in the culture will implicitly lead to the choice of the spraying solution that will be applied. The sensor system in the tank of the spraying drone, as well as the electropneumatic application nozzles, ensure the distribution of a uniform amount of solution, punctually, without affecting the neighbouring plants.

Current technologies offer real opportunities for development of a scalable (with a special focus on downsizing) integrated aerial system for agricultural applications because all these specialized systems contribute together synergistically to a versatile adaptation to these new missions in precision agriculture.

4. Conclusions

With the disruptive development of UAS (unmanned aerial vehicles) systems, various new applications and missions have been proposed. We have identified the need for aerial robots for intelligent agriculture in the context of technological progress at the level of multispectral sensors several generations of projects related to the use of aerial autonomous robots in modern agriculture.

In this article it was proved the advantages and opportunities to develop and implement scalable integrated aerial system capable for activities related to the precision agriculture at impressive performances and at reasonable costs on the entire life cycle of these systems. There are a lot of advantages like: the efficiency in a lot of agricultural missions (including small areas of interest); an impressive shortage of human implication in agricultural activities; advanced capabilities to supply the sustainable operational capacity; a special capability to manage the portfolio of risks associated to human operators by replacing monotonous and dangerous drudgery; a special ability to analyse specific tasks related to the classification in several standardized sized and qualities of products; a special capability for optimizing the timing of activities in precision agriculture (spray pesticides, harvest crop); a reduced risk of microbial contamination; a reduced risk of the global impact on the environment.

The typical system and the sub-systems work synergistically and we express our optimism related to the future path of developing aerial systems for precision agriculture.

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