MODELING AND DEVELOPMENT OF AN AUTONOMOUS DRONE SWARM FOR PRECISION AGRICULTURE

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Abstract. *The thesis explores the impact of mass use of UAV (Unmanned Aerial Vehicles) technologies in the agricultural sector and orchard management. It provides research on the existing problems, technologies and products regarding autonomous data gathering in an orchard via a swarm of drones. It iterates over the security aspects of IoT networking providing strengths and weaknesses of the existing security architectures. A thorough analysis of the market of the IoT in the agricultural filed in Republic of Moldova is provided and conclusions are drawn about market state. Lastly, it contains insights about the integration of innovative artificial intelligence into autonomous drone missions.*

Key words: *Drone, IoT, Agriculture, Surveillance, Automation, AI (Artificial Intelligence).*

1. Introduction

Agriculture is fundamental to human survival and economic stability in every country across the globe but in today's world it faces a multitude of challenges that are yet to be solved using innovative approaches that will be sustainable, productive, and efficient. This following chapter we will delve into the current adversity that the agriculture industry is facing, more specifically the imperative for yield and quality optimization. The solution proposed integrates Internet of Things (IoT) technologies, with a specific emphasis on UAV commonly known as drones as a transformative approach to overcoming this specific challenge. Through a comprehensive analysis, this project illustrates how such technologies improve precision agriculture and optimizes crop yields and quality.

2. Problem definition

The main problem addressed by the drone swarm is the ineffectiveness of unassisted humans in agriculture management. Throughout history human beings have been using agriculture only to fulfill their personal needs - a few hundred or thousands of kilograms of crops per year from a small-sized garden. But with the evolution of humanity, farming became extremely loaded, i.e., a single farmer should provide to other people hundreds of thousands of tons of crops per year. Farmers went from the prevalent part of the population to small minorities that still need to somehow feed the entire society. This situation created an acute need to revolutionize technology in agriculture. A farmer now needs some technological assistance to manage thousands of tons of crops without the need of tens of workers.

This shift has necessitated a corresponding evolution in agricultural technology, as the traditional methods of unassisted human labor are no longer sufficient to meet these demands. In regions like the Republic of Moldova, where land resources are relatively limited, the pressure on orchard management is particularly acute.

Orchard management is not an exception. In fact, orchard management is one of the most technology requiring fields in agriculture, especially in the Republic of Moldova, where there is a relative deficit of appropriate land [1]. Orchard management in the Republic of Moldova is pressed

by high local and international concurrency, requiring a high yield rate at a low budget/price for the farmers. A way to automate data collection is essential because permanently supervising hundreds of hectares of orchards is both challenging and expensive for the farmers.

2.1 Domain Analysis

Drones are becoming more popular and reliable in the agricultural industry. Companies all over the world are using drones for increasing production efficiency, managing crop health, and preventing quality issues. The main focus is automatization of the drone processes through operating UAVs (Unmanned Aerial Vehicle) due to their high flexibility, ease of use, adaptability to different terrains and scalability. Different operations can be performed with UAVs such as air sowing, remote sensing detection and information collection [2]. Unlike international companies, it is unpopular to use drones for agriculture in the Republic of Moldova. Judging by the fact that Moldova's economy is based on agriculture, this domain has a lot of potential for the country.

The main agricultural branches where drones can be proven useful are fruticulture and viniculture. These branches are the easiest to develop reliable agricultural UAVs due to the fact that the plants are relatively large, compared for example to certain vegetables. The plants being large means that it will be easier to collect visual information from them. They are also aligned in rows, that means the information of their position is more predictable. Having as much information as possible about the positions of the plants means it is easier to plan missions for the drones. Agronomists have databases containing information about each plant and their coordinates, thus ensuring a scalable development of the drones.

A first step to implementing drone agricultural industry in the country is to develop cheap small drones that inspect the conditions of the plants. By attaching one or two cameras to the drones, a drone would fly by the plants and take pictures of them. Through a trained neural network, certain conclusions will be made based on the conditions of the plants. Cheap drones do not have a long battery life, being able to function in a time span of 15-20 minutes before needing to recharge, which may take double of that. Depending on the time of picture taking, velocity and acceleration of drones, outside conditions, it might take a lot of time to analyze an entire field of agricultural area. Thus, it is an important feature of UAVs to interoperate together to speed up the process of field scanning and gathering of information.

Drones can communicate with a central unit that tells them where they should go next, where they should take a photo, and when to return for a recharge break. Drones can communicate between themselves, though that raises the complexity of the algorithm. It is important to take into consideration the dangerous side of things, and the potential to cause damage to the crops, and to the drones. Programming the drones to not collide with the crops, or in case of using multiple, to not collide with each other, is a priority.

2.2 Existing Systems

The advent of Internet of Things (IoT) technologies, especially Unmanned Aerial Vehicles (UAVs), marks a pivotal shift in agricultural methodologies, introducing a new era of precision farming. This transition is not only reshaping agricultural practices on the global stage but also holds significant potential for local markets, including the Republic of Moldova. Despite a slower adoption rate in Moldova due to factors such as economic constraints, regulatory challenges, and technological accessibility, the trajectory indicates a promising integration path. This chapter delves into the comparative analysis of two pioneering solutions in the AgTech sector, one with an international footprint and another emerging from the local Moldovan context, highlighting their contributions, methodologies, and their impact on the agricultural domain.

UAVs, or drones, equipped with advanced sensors and imaging capabilities, are revolutionizing agricultural practices by enabling precise monitoring, analysis, and management of crops. These technologies facilitate data-driven decision-making, optimizing resources, and improving crop yields while minimizing environmental impact.

In the Republic of Moldova, the agricultural sector is a cornerstone of the economy, yet it faces challenges such as resource inefficiency and access to modern technologies. The gradual embrace of UAV technology signifies a transformative step towards overcoming these obstacles, propelled by both global innovations and local initiatives.

A French Tech Pioneer ClearSpot.ai [3]. ClearSpot.ai, has distinguished itself by specializing in computer vision and developing algorithms for precision farming. Their approach encompasses spectral analysis of crops, enabling farmers to make informed, data-driven decisions. Significantly, the company offers a Robotics as a Service (RaaS) solution, equipping drones with the necessary software for comprehensive agricultural analysis. This model allows for scalability and adaptability to various farming needs.

AgroDron.MD [4], a Moldovan enterprise, offers smart drones tailored for precision agriculture. They state that using their service lowers the cost of crop maintenance by 50%, lowers the amount of water used by up to 90%, lowers the use of chemicals by 30% to 40%, and eliminates diesel usage, while providing a precision on the rate of centimeters. Also, they estimate the productivity to 20 hectares per hour for spraying and 100 hectares per hour for scanning. The analysis and diagnostics are done in 48 hours. A big advantage of using drones, as they state, is the ability to navigate rough, extreme, slopy terrains, and the ability to perform the flights after rain. Those are huge benefits compared to terrestrial vehicles.

In general, the features in the existing products on the market are assessment of the general conditions, conduction of hydrological evaluations, nitrogen level identification, nutritional map development, smart scanning, weed locating, crop density evaluation, plant counting, loss assessment due to climate or pests.

3. Conclusion

By incorporating advanced IoT capabilities and artificial intelligence, drones are positioned to significantly enhance agricultural efficiency and productivity, as these UAVs have a critical role in automated data collection, optimizing resource use and improving crop management through precise monitoring and analysis. Despite the slower technological adoption in the Republic of Moldova it can bring quite the benefit in economic and operational areas.

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