MODELING AND DEVELOPMENT OF A TERRESTRIAL AUTONOMOUS DRONE FOR PRECISION AGRICULTURE - AGROBOT

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Abstract. *This paper delves into the modeling and development of a terrestrial autonomous drone tailored specifically for precision agriculture and mission planning. It explores the impact of robotics and automation on agriculture, focusing on precision farming techniques. Additionally, it examines current advancements such as IoT integration and navigation systems for agricultural robots. Through empirical research, the study aims to provide fresh insights into the transformative potential of robotics in agriculture, identifying scientific gaps for improvement. By proposing technology-driven solutions, the research aims to enhance sustainability and productivity in farming practices, ultimately paving the way for further innovation in agricultural robotics and precision agriculture.*

Keywords: *agricultural robotics, automation, IoT technologies, mission planning. remote sensing.*

Introduction

Precision agriculture has emerged as a transformative approach in modern farming, leveraging advanced technologies to optimize efficiency and sustainability. With the global precision agriculture market projected to reach USD 16.09 billion by 2028, there is a clear trajectory towards increased adoption fueled by technological innovations [1]. However, challenges persist, including crop losses due to imprecisions in agrobot functions. This paper addresses the need for precision in agricultural robotics, particularly focusing on the development of a terrestrial autonomous drone tailored for precision agriculture and mission planning.

Analysis of the situation in the field of precision agriculture

Precision agriculture has rapidly evolved as a pivotal approach to modern farming, integrating cutting-edge technologies to enhance agricultural efficiency and sustainability. The global precision agriculture market size was valued at USD 7.1 billion in 2020 and is projected to reach USD 16.09 billion by 2028, indicating a significant growth trajectory driven by technological advancements and increasing adoption by farmers worldwide [1].

Despite the numerous benefits offered by precision agriculture, several challenges remain, including loss of crops due to the lack of 100% precision in agrobot functions. The UN Food and Agriculture Organization (FAO) and other research studies estimate that 20–40% of global crops are lost due to plant pests and diseases [2]. Commercial robotic weeding machines employ various methods to eliminate weeds, such as mechanical removal, flame treatment, or herbicidal sprays. Accurately distinguishing between crops and weeds is challenging, with system precision reaching only about 70% even in optimal conditions. Numerous techniques exist for identifying crop plants in digital images. This is usually accomplished by first capturing an image and then classifying each pixel as either a plant or a non-plant part, often utilizing a green threshold technique. Herbicides are a global solution for controlling agricultural weeds, yet over 95% of these chemicals end up in places other than the intended crops because they are dispersed broadly across agricultural fields [3].

Technologies used for pathfinding and navigation

The firmware for autonomous unmanned systems is often created using ArduPilot, a widely utilized framework. ArduPilot, an open-source navigation software, facilitates the development of dependable autonomous systems for various vehicles, such as multirotor drones, fixed-wing and VTOL aircraft, helicopters, ground rovers, ships, submarines, and tracking antennas. To aid in using ArduPilot, the mission planner application serves as an interface with the controller, enabling setup, configuration, testing, and tuning of the vehicle. Mission planner, a comprehensive Ground Control System (GCS) application, is fully compatible with ArduPilot. Other compatible software includes APM Planner, QGroundControl, and others [4].

Agricultural robots and vehicles rely on various vision sensors and systems for navigation planning. Vision sensors are among the most frequently used robotic sensors, enabling non-contact measurement of the agricultural environment. Depending on the imaging principle, vision sensors can be categorized into 2D vision imaging sensors and 3D stereo vision imaging sensors. The 2D images captured by these sensors can reveal the shapes and structures of trees, crops, obstacles, and other elements within the agricultural setting. In contrast, 3D vision imaging sensors generate a three-dimensional coordinate map of the entire scene, detailing the spatial positions of the robot and other objects. Vision systems play a crucial role in the navigation process, and choosing the appropriate vision sensor and system depends on the specific environmental conditions and task requirements [5].

Sensor technologies used in existing solutions

Various sensors are capable of monitoring different plant characteristics such as color, texture, geometric shape, and specific wavelength radiation. The data collected by these sensors can be analyzed to observe key agricultural features throughout different growth stages, including soil moisture, plant biomass, and vegetation health. Previous research has employed a variety of sensors, such as visible light (RGB) sensors, multispectral sensors, hyperspectral sensors, and thermal sensors [6]. Drones equipped with specialized sensors are used to gather specific types of data necessary for particular tasks. These sensors are designed to capture images over large areas and can be selected based on the specific crop attributes that need continuous monitoring. Modern agricultural sensors typically include multispectral sensors, hyperspectral sensors, RGB sensors, thermal sensors, and pressure sensors.

Requirement elicitation

In order to achieve maximum efficiency and minimize operational burden, a semi-autonomous agricultural rover is required. This rover should possess the ability to follow user-specified commands while adapting to unforeseen circumstances. A user-friendly interface is paramount for ease of operation. The core functionality of the rover should encompass tasks such as applying pesticides, herbicides, and plowing the land. Additional functionalities such as real-time soil analysis and plant scanning are desirable for informed decision-making. The system should be operational throughout the growing season, including seeding/planting and harvesting periods. The rover and any collaborating drone system should be capable of rapid data exchange to facilitate real-time monitoring and adjustments. For safety reasons, a dedicated killswitch independent of the primary system is necessary. Finally, the drone should be equipped for high-precision land marking to ensure accurate field preparation and cultivation.

Architectural design

The system consists of several key components that facilitate communication and control. A user interacts with the system through a web app, which communicates with the Ardupilot software component. Ardupilot is the central processing unit for the robotic vehicle, and it controls the vehicle's actuators based on data received from various sensors and user commands. These sensors include LiDAR, which is used for object detection and navigation, and other sensors that measure environmental factors. The system also includes communication services that enable data exchange between the different components. Finally, a kill switch is shown to provide a safety mechanism for immediate shutdown of the robotic vehicle.

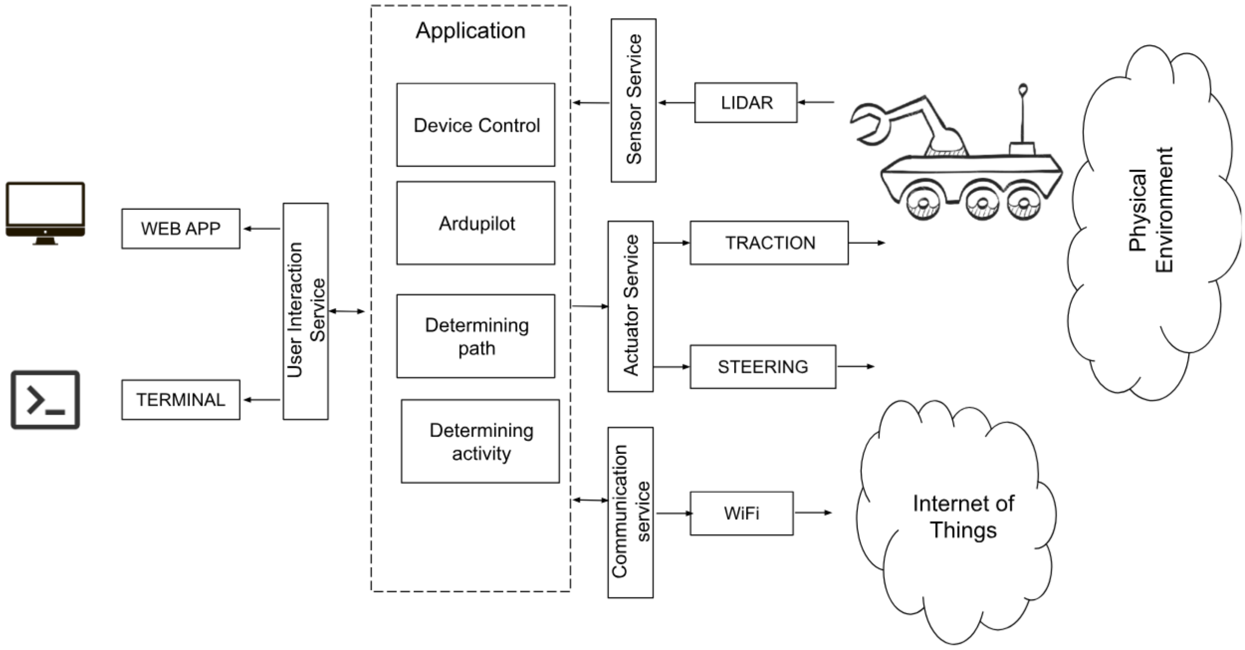

Figure 1. Diagram of the whole system

Conclusions

In conclusion, the development and modeling of a terrestrial autonomous drone for precision agriculture represent a significant step forward in leveraging robotics for sustainable farming practices. By integrating advanced technologies such as IoT and navigation systems, this research contributes to enhancing efficiency and productivity in agriculture. Moving forward, addressing scientific gaps identified in this study will further propel innovation in agricultural robotics, fostering a future of precision agriculture that maximizes yields while minimizing environmental impact.

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