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Swarming of Drone Prototype for Low Range

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ABSTRACT: This paper presents the design and implementation of a swarming system that enables a remote-controlled car to autonomously follow a drone using an infrared (IR) sensor and an Arduino microcontroller. The primary objective is to develop a robust method for ground vehicle tracking of an aerial vehicle in real-time, demonstrating potential applications in coordinated robotic tasks and automated systems. The drone is equipped with a black cardboard cutout, serving as a target for the IR sensor mounted on the car. The sensor detects the high infrared absorption of the black area, allowing the Arduino to process the data and control the car's movements to maintain its position beneath the drone. Through iterative testing and calibration, the system achieves reliable tracking performance, highlighting its practical use in scenarios such as search and rescue operations and autonomous delivery services. The results underscore the feasibility of simple sensor-based swarming mechanisms in enhancing autonomous navigation and coordination between aerial and ground robots.

KEYWORDS: Swarming behaviour, Drone-ground vehicle coordination, Sensor based control, Autonomous tracking.

I. INTRODUCTION

Swarming behaviour in robotics can be inspired by natural systems, such as flocks of birds or schools of fish, where simple local interactions lead to the emergence of complex group behaviours. This concept is increasingly being applied to develop robotic systems that can operate in unison, offering enhanced capabilities and efficiencies over single autonomous units. The integration of aerial and ground vehicles in such systems presents unique challenges and opportunities, particularly in scenarios that require dynamic and coordinated responses.

This setup is inspired by the work of Anderson et al. (2003) [2], which highlights the importance of communication protocols and coordination mechanisms in multi-robot systems. The control algorithms for both the drone and the car are designed to enable real-time adjustments based on sensor inputs and environmental feedback. This approach aligns with the research by Trianni and Şahin (2007) [3], who introduced self-organizing synchronization mechanisms to achieve coordinated movements in robot swarms. Additionally, the iterative improvements and calibration efforts undertaken during this project are guided by the optimization techniques discussed by Correll et al. (2009) [6].

This paper explores a novel implementation of swarming behaviour between an aerial drone and a ground-based remote-controlled car using an infrared (IR) sensor and an Arduino microcontroller. The primary focus of this research is to design and implement a prototype system that enables a ground vehicle to autonomously follow an aerial drone.

Through detailed design, implementation, and iterative testing, this paper aims to showcase the potential and practicality of integrating IR sensors and Arduino microcontrollers in creating autonomous swarming systems. The results of this research contribute to the growing body of knowledge in robotic swarming behaviour and highlight the potential for further developments in enhancing the coordination and functionality of multi-robot systems.

In the following sections, we will discuss the related work in the field, outline the methodology of the prototype development, present the results of our experiments, and conclude with insights on future improvements and applications of the system.

II. METHODOLOGY

The drone serves as the leader, while the car acts as a follower, tracking the position of the drone using an IR sensor. The methodology involves hardware setup, software development, and experimental testing to validate the swarming capabilities of the prototype.

Hardware Setup :-

1. Drone

- Built a suitable drone capable of stable flight and equipped with a payload mounting system.
- Attach a cardboard cutout with a black portion to the bottom of the drone to create a distinguishable target for the IR sensor.

2. Remote-Controlled Car

- Utilize an Arduino-based car platform equipped with motor controllers and an IR sensor.
- Mount the IR sensor on the front of the car to detect the position of the drone's cardboard cutout.

Software Development :-

1. Drone Control Algorithm

- Developed a control algorithm for the drone to maintain stable flight and adjust its position based on user input.
- Implement a communication protocol to transmit positional data from the drone to the remote-controlled car.

2. Car Tracking Algorithm

- Program the Arduino onboard the car to process data from the IR sensor and adjust the car's direction accordingly.
- Design a feedback control loop to ensure the car maintains alignment with the black portion of the cardboard cutout.

Experimental Testing :-

1. Individual Component Testing

- Conducted initial tests to evaluate the stability and functionality of the drone's flight capabilities.
- Verified the accuracy of the IR sensor on the remote-controlled car in detecting the black portion of the cardboard cutout.

2. Integration Testing

- Tested the coordinated movement of the drone and the car to ensure they functioned together seamlessly.
- Faced challenges in managing the distance between the drone and the car to enable effective swarming behaviour.

Calibration and Iterative Improvement :-

1. Drone Calibration

- Recalibrated the drone to improve stability and responsiveness in flight.
- Adjusted parameters and fine-tuned the control algorithm to enhance coordination between the drone and the car.

2. Code Optimization

- Made modifications to the control algorithms for both the drone and the car to address issues encountered during integration testing.
- Implemented iterative improvements based on feedback from testing sessions to optimize performance.

III. EXPERIMENTAL RESULTS



a)

The initial phase of the experimental testing focused on evaluating the stability and flight characteristics of the drone. Upon conducting the first flight tests, it was observed that the drone exhibited intermittent instability, resulting in erratic movements and difficulty maintaining a consistent altitude.



b)

After implementing recalibration procedures and adjustments to the control algorithm, significant improvements in flight stability were achieved. Subsequent flight tests demonstrated smooth and controlled flight behaviour, indicating successful calibration efforts.



c)

Testing of the IR sensor mounted on the remote-controlled car was conducted to assess its functionality in detecting the black portion of the cardboard cutout attached to the drone. The IR sensor reliably detected the presence of the black

surface, producing accurate readings as the distance between the sensor and the target varied. Additionally, experiments were conducted to verify whether the car responded appropriately to changes in the position of the cardboard cutout. The car demonstrated consistent movement corresponding to the displacement of the black portion, confirming the effectiveness of the IR sensor in guiding the car's motion.

Integration testing was performed to evaluate the coordinated movement between the drone and the remote-controlled car, aiming to achieve swarming behaviour. Initially, challenges were encountered in effectively managing the distance between the drone and the car to facilitate synchronized movement. However, through iterative calibration and adjustments to the control algorithms, significant progress was made in achieving coordination between the two components. The drone successfully maintained a predetermined trajectory, while the car accurately tracked the position of the drone using the IR sensor, resulting in cohesive swarming behaviour.

IV. CONCLUSION

The experimental results validate the feasibility and effectiveness of the swarming prototype developed in this study. By leveraging advancements in drone technology and sensor integration, the project demonstrates the potential for collaborative swarming behaviour in robotic systems. The successful implementation of coordinated movement between the drone and the remote-controlled car lays the groundwork for future research and applications in the field of swarm robotics.

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