The seven golden rules for using drones at the ECER

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***Abstract*—This paper explores the use of drones in robotics competitions, focusing on the ECER Open competition for students. It covers the basics of drone technology, including types and components, and discusses the design considerations for integrating drones and robots. Strategies for optimizing flight paths and avoiding common mistakes are presented to enable autonomous navigation. The software and hardware requirements for controlling the drone and integrating it with the robot's system are analyzed. The paper also includes graphics to aid in understanding. Overall, this guidebook aims to provide essential information for teams looking to incorporate drones into their robots and promote innovation and creativity in robotics competitions.**

***Keywords*: drone technology, robotics competition, flight optimization, autonomous navigation, aerial robotics**

I. Introduction

The ECER Open Robotics Competition is an exciting opportunity for student teams to showcase their skills in designing, building, and programming robots. With the increasing use of technology, drones have become a valuable asset in these competitions due to their versatility, agility, and ability to capture aerial data. Integrating drones with robots can enhance their capabilities, increase efficiency and help teams to achieve their goals in the competition.

In this paper, we present a guidebook for teams interested in using drones in the ECER Open robotics competition. Our goal is to provide a comprehensive resource that will enable teams to effectively integrate drones into their robot design and achieve success in the competition.

We will start by introducing the basics of drone technology, including the different types of drones and their components. Then the considerations for choosing drones over ground robots, such as weight, power, and communication requirements will be discussed. Furthermore, the software and hardware requirements for controlling the drone and integrating it with the robot's system, will be covered.

Finally, we will provide best practices for using drones in the competition, including strategies for optimizing flight paths, avoiding collisions, and maximizing the drone's functionality. In addition, we intend to highlight some of the common mistakes that robotics teams make when using drones and how to avoid them.

By following the guidelines outlined in this guidebook, student teams can effectively utilize drones to enhance their robot's capabilities and increase their chances of success in the ECER Open robotics competition.

II. Overview of Drone Types and Components

Drones, also known as unmanned aerial vehicles (UAVs), are operated remotely without a pilot on board. They are equipped with various sensors and components that allow them to capture images, videos, and other data from the air. In this section, we will introduce the basics of drone technology, including the different types of drones and their components.

A. Types of drones

There are several types of drones available on the market, each designed for different applications. We listed the most common ones.

Quadcopters: Quadcopters are the most common type of drone and are equipped with four rotors. They are widely used for aerial photography, surveillance, and hobby flying.

Fixed-wing drones: Fixed-wing drones are designed like airplanes, with wings and a single propeller. Use cases of them are, e.g., mapping, surveying, and agricultural applications.

Hybrid drones: Hybrid drones combine the features of quadcopters and fixed-wing drones. They are ideal for long-distance flights and can cover large areas quickly.

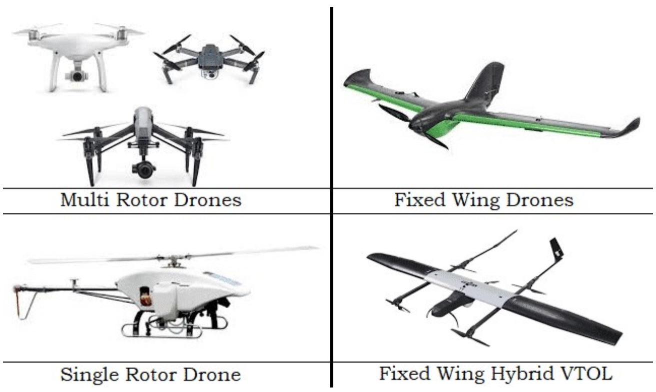

Fig. 1 Pictures of different drone types.

B. Drone Components

Frame: The frame is the physical structure of the drone and provides support for all the other components.

Motors: Motors are used to rotate the propellers and lift the drone off the ground.

Propellers: Propellers are attached to the motors and generate the lift that allows the drone to fly.

Battery: The battery provides power to the drone's components, including the motors and sensors.

Flight controller: The flight controller is the brain of the drone and controls the drone's movements, stability, and orientation.

Sensors: Drones are equipped with various sensors, such as GPS, cameras, and accelerometers, that allow them to gather data and navigate in the air.

Transmitter: The transmitter is used to control the drone remotely and send commands to the flight controller.

Receiver: The receiver receives the commands from the transmitter and sends them to the flight controller.

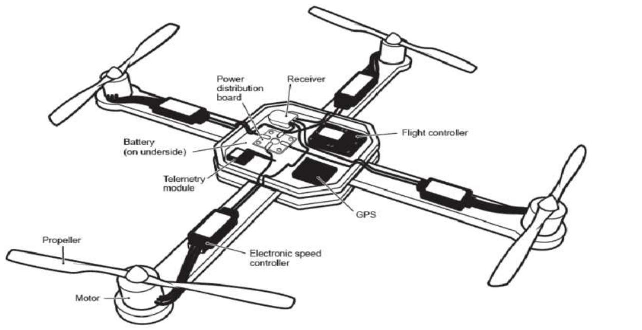

Fig. 2 A schematic representation of the components of a drone

In summary, drones are unmanned aerial vehicles that are equipped with various components and sensors that allow them to fly and capture data from the air. The type of drone and its components will vary depending on the application and desired performance.

III. Why use a drone

Rule 1: *Think of the advantages of drones.*

Drones have many usage options based on the specific use case and environment.

A. Versatility

Drones can operate in a variety of environments, including urban, rural, and maritime settings. [1] They are also capable of operating in challenging conditions, such as extreme temperatures, high altitudes, and hazardous areas.

B. Mobility

Drones can fly and cover large distances quickly, allowing them to access areas that may be difficult or impossible for ground robots to reach. This makes them well-suited for Botball tasks, which are mentioned in section 7. {VII Use cases of drones}

C. Flexibility

Drones can be equipped with a wide range of sensors and cameras, which can be helpful in many different tasks. They can be a versatile tool for data collection and analysis. A great way of making use of this fact is to access the camera stream of the drone and take it as a regularly updating map of the game table. That way it can give other robots instructions of what to do.

Fig. 3 The camera stream from a DJI/Ryze Tello drone

IV. Choose which drone to use

Rule 2*: Choose a drone based on the following points.*

There are a few criteria to choose the right drone for a non-aerial competition. Every drone has its advantages and disadvantages. Note the points below, before buying a drone.

A. Size

The size of a drone determines what it will later be used for. If it is a bigger drone, it can carry a lot of sensors or different gadgets to complete tasks but is harder to control them on a small area like the Botball game table. Another problem is that the start box, in which all the robots must fit in, then has not enough space to hold other robots. Therefore, choosing a smaller drone is a better option because it is easier to control and perform tasks faster. However, small drones have less thrust and therefore can hardly carry anything.

B. Power

Choosing a fast and powerful drone is not the best idea. It is difficult to control and move it precisely in a small area, which is necessary for every task. A disadvantage of less power is, that it results in less thrust.

C. Specifications

Before choosing a drone, you have to know about all of its functions, e.g., a camera that can be used to get an overview of an area or how many rotors the drone has. The camera can have different modes, e.g., infrared sight, multispectral view or night vision.

D. Altitude

Another point is how high the drone can fly. For our use in the ECER competition we did not need to reach high altitudes, as the game table is only a maximum of 50cm high and most of the tasks are close to the ground.

V. How to control The Drone

***Rule 3**: Find out how to control the chosen drone.*

After choosing a drone, you must find out how to control it. Regardless of the method you choose, it's important to understand the basics of drone programming, such as flight control algorithms, navigation, and obstacle avoidance.

A. GitHub

There are several GitHub repositories which focus on specific drones, e.g., the Tello repository [2]. It has all necessary modules and code ready to use. It is written in Python and after reviewing it, we added some of our own functions to complete several seeding tasks.

B. Drone APIs

Many drone manufacturers provide APIs that allow developers to access and control the drone's various functions and sensors. For example, the DJI SDK [3] provides a suite of APIs that allow developers to control the flight of a DJI drone, access the drone's camera and sensors, and perform other functions.

C. Drone Development Platforms

Drone development platforms such as ROS (Robot Operating System) and PX4 provide a comprehensive set of tools and libraries for developing drone applications. These platforms offer a high level of control over the drone's hardware and software, making it easier to develop custom applications. [4]

D. Drone Programming Languages

Many drones support programming in high-level programming languages such as Python or C++. These languages provide a more accessible way to program drones, allowing developers to write scripts and algorithms to control the drone's flight and functionality. Sometimes there are whole libraries focusing on that, which can be found on GitHub as mentioned in point {IV. A}.

VI. Navigation

***Rule 4:** Think of a system on how to navigate a drone.*

A navigation system is necessary for giving the drone instructions to move around. The drone needs to know where to go, and how to reach that position. Therefore, having a navigation system that can communicate with the drone is very important. Navigating a drone autonomously typically involves programming the drone to follow a predetermined flight plan or to use sensors and algorithms to navigate in real-time. Here are some common approaches to autonomous drone navigation.

A. DPS – Drone Positioning System

Airolos© has developed a system that can produce a Bezier curve with given coordinates in a three-dimensional system. The drone gets the coordinates from the DPS and flies to these specific points. With that, the drone can now reach points on the whole game table.

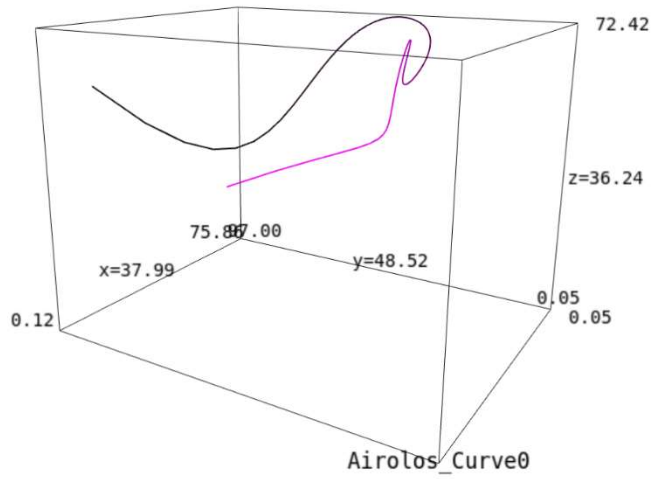

Fig. 4 DPS – Drone Positioning System; a Bezier curve is drawn by given coordinates.

B. GPS Navigation

Drones can use GPS coordinates to navigate autonomously by following pre-programmed waypoints or flying to specific locations. This approach is commonly used for surveying, mapping, and other applications where the drone needs to cover a large area.

C. Computer Vision

Drones equipped with cameras and computer vision algorithms can navigate autonomously by analyzing the environment and making decisions based on the visual input. Computer vision is commonly used for applications such as inspection, search and rescue, and agricultural monitoring. [5]

D. LiDAR Sensors

LiDAR sensors emit laser beams to create a 3D map of the environment, which the drone can use to navigate autonomously. This method is used in industrial and construction applications where the drone needs to navigate around obstacles and avoid collisions. [6] [7]

E. Machine Learning

Drones can be trained using machine learning algorithms to recognize specific objects, patterns, or environments, and navigate autonomously based on that training. [8] Deep Learning algorithms combined with drones find application in precision agriculture, wildlife monitoring, and surveillance.

In general, navigating a drone autonomously requires expertise in programming, algorithms, and sensors. It's essential to thoroughly test and debug the autonomous navigation system before using it in any real-world application. Additionally, it's crucial to comply with local regulations and safety guidelines when flying a drone autonomously.

VII. Use cases of drones

***Rule 5:** What tasks can a drone take care of? Look at the game document and pick the ones that bring you the most points.*

As mentioned, drones are very versatile, but what specific things can a drone do on the ECER game table?

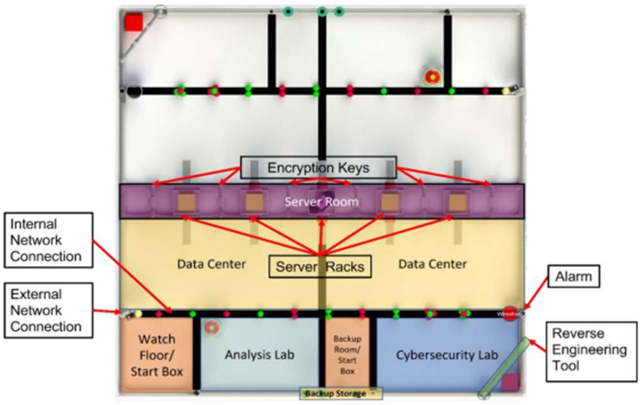

Fig. 5 ECER Botball game table 2023 (game document version 1.4)

A. *Throwing yellow cubes down*

In the server room of the ECER game table are four server racks on which yellow cubes are placed. All cubes have to be stacked on top of each other. A drone could get those cubes and place them in the middle of the game table where other bots can stack them as wished. One cube is worth 400 points and the sum of the points is multiplied by the stack height. In total it is possible to get 6.400 points in the "Analysis Lab".

B. *Get the BotGal*

Another task is to get the BotGal down form the server rack placed in the middle of the game table. The BotGal is a stuffed toy and gives double points in the zone it is in at the end of the seeding round.

These are just some examples which are based on the ECER game document version 1.4. [9] For detailed information you should check out the updated game document if necessary.

VIII. Common Problems

Rule 6: *Make a list of every problem that occurs during the integration process of a drone.*

Combining drones and robots can be a complex and challenging process, and there are several common mistakes that can occur during integration. We listed some of the most common mistakes to avoid.

A. *How to sysnc the drone and the robots*

A very important question that comes along is how the drone and the robots will communicate with each other. It is a significant difficulty, because there are not many ways to solve this problem as shown in point A of the next section {VII. A}.

B. *Lack of Integration Planning:*

Combining a drone and a robot requires careful planning and consideration of the specific requirements and limitations of both systems. Without a detailed integration plan, it's easy to overlook critical components or compatibility issues.

C. *Software Errors*

Errors in software can cause communication issues or affect the performance of either the drone or robot. It's essential to test and debug the software thoroughly before attempting to integrate the two systems.

IX. Solutions

Rule 7: *Try to find solutions that solve the gathered problems effectively.*

This section focuses on solving the problems mentioned in {VII. Problems}.

A. *How to sysnc the drone and the robots*

Controlling a drone using another robot would requires interfacing the control system of the drone with the control system of the robot. To do that you identify the communication protocol used by the drone's controller. This could be Wi-Fi, Bluetooth, or a proprietary radio frequency (RF) protocol. Test the connection and control the drone using the robot. This involves writing code to send different commands to the drone, such as takeoff, landing, or changing the drone's orientation. It is worth noting that controlling a drone using another robot can be a complex task and may requires a good understanding of both robotics and drone technology. Additionally, it can be a problem to connect a drone and a robot in a congested network. Solutions for this situation are mentioned in the next point {VIII. B}.

B. *Integration Planning*

Develop a detailed integration plan that considers the requirements and limitations of both systems. Test each component individually and then test the combined system to ensure it works as expected.

C. *Software Errors*

Thoroughly test and debug the software used to control both the drone and robot. This includes the software that communicates between the two systems, as well as the software used to control the drone and robot individually.

X. Strategies and Advice

Team Airolos made a few experiences when participating in the ECER Open would like to share some of them. There are several strategies that teams can use to optimize drones' performance. By using these best practices, teams can also increase their chances of success in the ECER Open robotics competition.

Plan ahead: Before the competition, teams should study the competition course and plan the drone's flight path accordingly. They should identify potential obstacles, such as trees or buildings, and plan routes that avoid these obstacles. This will ensure that the drone can navigate the course smoothly and efficiently.

Use waypoints: Waypoints are pre-defined locations that the drone must visit during its flight. By using waypoints, teams can ensure that the drone follows a specific path and avoids unnecessary detours. Waypoints can also be used to optimize the drone's flight time by creating a path that minimizes the distance the drone must travel.

Use obstacle avoidance sensors: Many drones come equipped with obstacle avoidance sensors that can detect and avoid obstacles in real-time. Teams should ensure that these sensors are properly calibrated and tested before the competition to prevent collisions and optimize the drone's flight path.

Consider wind and weather conditions: Wind and weather conditions can have a significant impact on a drone's flight path and efficiency. Teams should monitor weather conditions and adjust the drone's flight path accordingly to optimize its performance.

Use advanced flight modes: Many drones come equipped with advanced flight modes, such as follow-me mode or point-of-interest mode. These modes can be used to optimize the drone's flight path and ensure that it follows a specific path or object.

Practice, practice, practice: Like any other skill, flying a drone takes practice. Teams should spend a significant time practicing flying the drone, especially in challenging conditions such as high winds or confined spaces. This will help them gain confidence and reduce the risk of crashes or other accidents during the competition.

Keep the drone in sight: During the competition, teams should always keep the drone in their line of sight. This will help them maintain control of the drone and avoid collisions with obstacles or other drones.

Use a checklist: Before each flight, teams should use a checklist to ensure that the drone is properly calibrated, the batteries are charged, and all necessary equipment is in place. This will help them avoid common mistakes and ensure that the drone is ready for flight.

Communicate with other teams: In the competition, teams will be sharing the same airspace with other drones. It's important to communicate with other teams to avoid collisions and ensure everyone's safety.

Have a backup plan: Despite the best planning and preparation, unexpected things can happen during the competition. Teams should have a backup plan in case of emergencies, such as a spare drone or a contingency plan for the competition task.

Follow regulations and guidelines: Drones are subject to regulations and guidelines, such as altitude restrictions and no-fly zones. Teams should ensure that they are familiar with these regulations and follow them at all times.

Conclusion

In conclusion, the use of drones in robotics competitions has the potential to revolutionize the way we approach these tournaments. Drones bring a new stage of mobility and versatility to robotics competitions, allowing teams to explore new strategies and approaches. While the use of drones in these competitions presents unique challenges, such as the need to balance weight and power requirements, the rewards are significant. By incorporating drones into their designs and leveraging the latest software and hardware tools, teams can gain a competitive edge and take their robotics competitions to the next level. As the technology continues to evolve, we can expect to see even more exciting developments in this field in the years to come.

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