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Navigating Horizons - A Technical Exploration of Autonomous Drone Guidance

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Abstract

Our project focuses on creating a cutting-edge tool that recognizes barriers and dynamically maps out alternate routes for drone navigation. We've developed a virtual environment to simulate the drone's operations using Microsoft AirSim and Unreal Engine, enabling us to hone our strategy in a safe environment. A large sensor that is carefully positioned at the heart of our virtual drone acts as a watchful observer to catch movement along the intended path With the help of a voxel grid and the Informed RRT* algorithm, we have improved the drone's ability to navigate through various terrains without running into obstacles. The establishment of an autonomous drone system is our ultimate objective. The drone can hover and navigate on its own without direct piloting thanks to the integration of sophisticated large-scale cameras and sensors. This game-changing development in drone technology opens the door to more adaptable and productive aerial operations.

1. Introduction

Unmanned aerial vehicles (UAVs), sometimes known as drones, have grown in popularity in a variety of businesses in recent years. Warehouse management is one application where drones have showed considerable promise. Drones can now execute jobs that were previously difficult or time-consuming for people to complete. This paper focuses on the creation of a drone that can fly independently and count the quantity of items in a warehouse. The goal of this project is to create an effective and accurate approach for warehouse inventory management. The drone has sensors and software that allow it to roam the warehouse and collect data. When it comes to inventory management, drones can be used in a variety of different ways. For example, they can be used to measure the dimensions of your warehouse space so that you have an accurate idea of how much inventory you have available at any given time. They can also be used to count the number of items in each SKU (stock keeping unit) category stored in your warehouse, allowing you to determine what items need replenishing most urgently. Inventory management is an important part of any business. It ensures that you always have the right amount of inventory on hand, allowing you to avoid running out of stock and losing sales. While it may seem like a simple task, managing your inventory can be challenging if you don't have the right tools and systems in place. This is where drones for inventory management can help. The use of drones for inventory management can be particularly useful in the case of seasonal products.

For example, if your business sells Christmas decorations year-round, then you may want to use drones to monitor inventory levels and determine how many decorations need to be ordered from your supplier. You could also use drones to track which locations are selling more or less than expected so that you can adjust inventory levels accordingly.

The drone's data may be utilized to update inventory records and optimise stocking and restocking procedures. The paper describes the drone's design and development. This project's findings show the potential of drones in warehouse management and illustrate the advantages of employing drones for inventory management. This paper summarizes the findings of our attempt to develop an autonomous drone for warehouse inventory management.

2. Literature review

1). UAV environmental perception and autonomous obstacle avoidance: A deep learning and depth camera combined solution: The system combines deep-learning-based object identification, image processing, RGB-D information fusion, and a Task Control System (TCS) to enable UAVs to detect obstacles and their features, including category, profile, and 3D spatial location. The system uses the YOLO V3 object identification technique to train and assess the CNN model, which has 75 convolutional layers powered by the darknet-53 backbone. The CNN model has a mean Average Precision (DA) of 91.9% and an average detection accuracy of 75.4%, with optimal performance achieved when the camera is 7.5 meters away from the tree. However, the system's prediction accuracy depends on the relative distance between the camera and object, and it has limitations in unstructured farmland environments. Improvements can be made by considering unstructured farmland environments and improving control algorithms. The system's performance is further enhanced when the camera is 7.5 meters away from the tree.

2). Automatic Quadcopter Control Avoiding Obstacle Using Camera with Integrated Ultrasonic Sensor: This study introduces a technique that uses image processing and ultrasonic sensors to detect obstacles in drones. The process involves filtering, feature identification, and optical flow. The Shi-Tomasi approach is used for feature detection, with R acting as a threshold for corner and edge quality. The Lukas-Kanade method guides optical flow, with the gradient of two frame images representing the vector of optical flow. Ultrasonic sensors are used in PID control to detect obstacles, based on factors like orientation, reflectivity, curvature, and incoming echoes. Camera specifications with image processing and ultrasonic sensors are combined into a decision-making system based on data from both sensors. The algorithm starts with obstacle identification by the camera, and the ultrasonic sensor calculates the drone's distance in front. The method has advantages such as a simple drone framework and an 85% success rate at 50-200 cm distance. However, it also has disadvantages, such as drones not being able to avoid dynamic obstacles and camera resolution affecting obstacle tracking results.

3). Dynamic path planning for autonomous driving on various roads with avoidance of static and moving obstacles: This work presents a dynamic path planning system for autonomous driving that avoids both static and moving obstacles in real time. It uses a global route to create a center line and constructs a collection of path candidates in the s-p coordinate system. A unique cost function is created to choose the best approach, considering static safety, comfortability, and dynamic costs. Three algorithms were implemented for path planning, and a comparison between different algorithms was conducted. The drone delivery application and path optimization use an AI algorithm that uses Maps API to get a 3D street view and map the live location and destination, identifying the shortest path by avoiding obstacles. However, drone batteries are a major issue, and drone delivery and BVLOS technology are still in the development phase and not legally legal in many countries.

4). Optimal Sampling-based Path Planning Focused via · Direct Sampling of an Admissible Ellipsoidal Heuristic: The Informed RRT* algorithm is a robotics path planning method that uses a rapidly-exploring random tree (RRT) to efficiently search a high-dimensional configuration space. It aims to find an optimal path while minimizing computational effort. The algorithm uses an admissible ellipsoidal heuristic to guide the search towards the goal, estimating the minimum cost and focusing on promising areas. Direct sampling is also used to generate new nodes in the tree. The paper presents experiments demonstrating the algorithm's effectiveness, particularly in high-dimensional spaces with complex obstacles. It outperforms other state-of-the-art path planning algorithms in terms of speed and path quality.

3. Methodology

The two algorithms used in this paper are YOLO (You Only Look Once) for object detection and RRT* for path planning. The YOLO algorithm consists of the following steps:

1. Input image is divided into a grid of cells. Each cell is responsible for predicting bounding boxes for objects that are centred inside the cell.
2. Each bounding box is represented by a set of four coordinates (x, y, width, height) relative to the cell it is located in.
3. For each bounding box, the algorithm predicts the probability of an object being present inside it, as well as the probabilities for each object class.
4. The confidence score for each bounding box is calculated as the product of the probability of an object being present and the probability of the box having the correct coordinates.
5. Non-maximum suppression is applied to eliminate duplicate detections of the same object.
6. The final output of the algorithm is a list of bounding boxes with their class probabilities and confidence scores.
7.

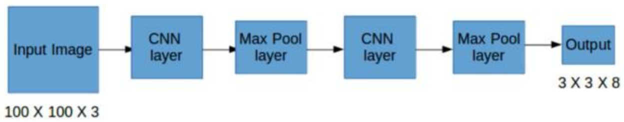


Fig. 3.1 – Working of YOLO algorithm

The Informed RRT* algorithm works as follows:

1. Initialize the tree with a single node at the start position.
2. Repeat until the goal node is reached or a timeout is reached:

- Sample a random configuration in the configuration space.
- Find the node in the tree that is closest to the sampled configuration.
- Generate a new node by extending the tree from the closest node towards the sampled
- configuration.

- If the new node is within a certain distance to the goal, add it to the goal region set.
- For all nodes in the goal region set, update their cost-to-go heuristic value based on the new node.
- For each node in the goal region set, attempt to rewire its neighbors in the tree to improve the path cost.
- If a solution path has been found, return it.

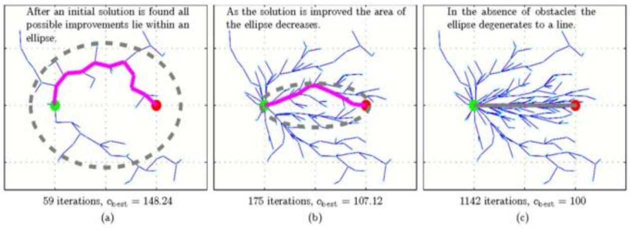


Fig. 3.2.1 – Working of RRT* algorithm

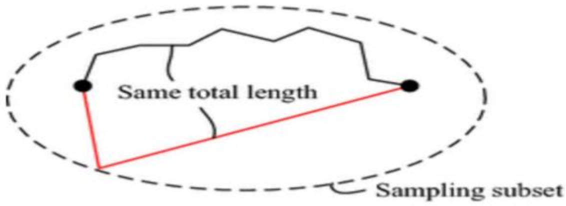


Fig. 3.2.2 – Working of RRT* algorithm

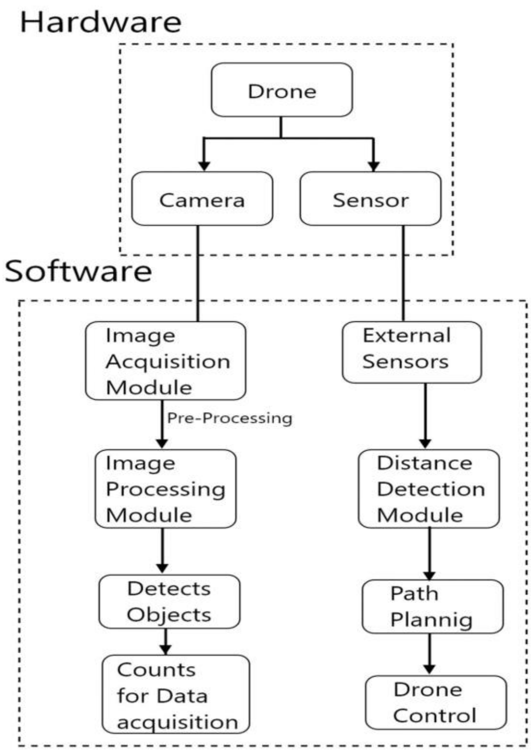


Fig 3. Block Diagram

Image Acquisition Module: This module is used to extract frames from video that was shot using the drone's camera. Along with the timestamp and the drone's coordinates with relation to its surroundings, the video frames are saved in a folder in the png format.

Image Processing Module: This module receives the images from the Image Acquisition Module one frame at a time. The Image Processing Module uses faster R-CNN to do object detection on these frames and distinguishes between obstacles and backgrounds.

Object Detection Module: This module receives the images from the Image Acquisition Module and detects the objects kept in the racks of the warehouse.

Data Acquisition: This is used to keep track of the number of filled and empty racks in the warehouse for smooth restocking of the Goods.

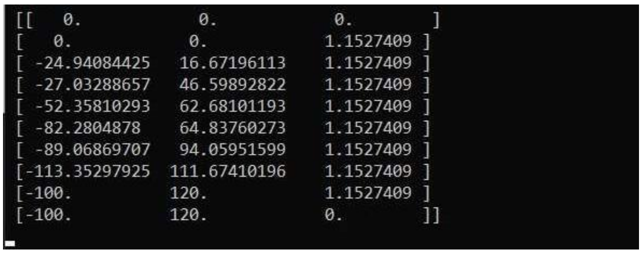
External Sensors: They are used to estimate object distances around the drone and relay that information to the distance detection module.

Distance Detection Module: This module applies a minimum distance parameter to the distances measured by the external sensors to look for potential collisions with the surrounding area.

Path Planning Module: If an obstacle is in the drone's route, the input from the distance detection and image processing modules is used to determine where it is, and Harris Hawks Optimization is then used to plan an optimal course around it (HHO)

Drone Control Module: The drone is guided by this module along the newly planned route.

4. Results



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 [ -52.35810293   62.68101193    1.1527409 ]
 [ -82.2804878    64.83760273    1.1527409 ]
 [ -89.06869707   94.05951599    1.1527409 ]
 [-113.35297925  111.67410196    1.1527409 ]
 [-100.          120.            1.1527409 ]
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Fig 4.1 Array of Possible Points Plot for Plath Planning in Simulated Environment

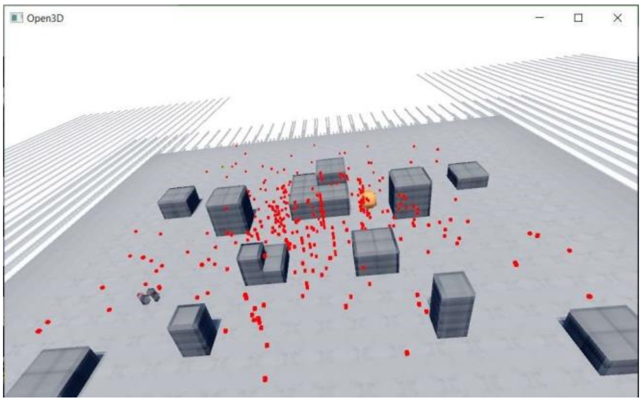

Fig 4.2 Visualization of Possible Points for Plath Planning in Simulated Environment

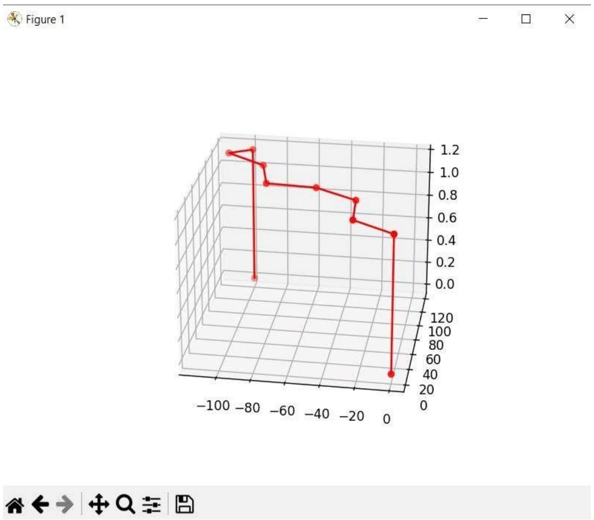

Fig 4.3 3D Graph Visualization of Path of Drone to be followed

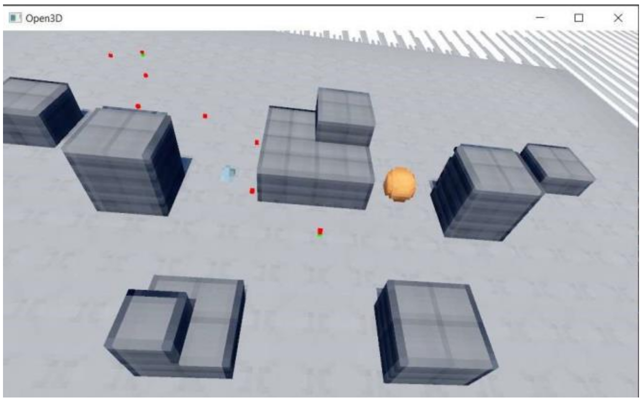

Fig 4.4 Final Plotting of Shortest Path to be followed by Drone

5. Conclusions

Warehouse management is one application where drones have showed considerable promise. The goal of this project is to create an effective and accurate approach for warehouse inventory management. When it comes to inventory management, drones can be used in a variety of different ways. For example, they can be used to measure the dimensions of your warehouse space so that you have an accurate idea of how much inventory you have available at any given time. They can also be used to count the number of items in each SKU (stock keeping unit) category stored in your warehouse, allowing you to determine what items need replenishing most urgently. This is where drones for inventory management can help. The use of drones for inventory management can be particularly useful in the case of seasonal products. For example, if your business sells Christmas decorations year-round, then you may want to use drones to monitor inventory levels and determine how many decorations need to be ordered from your supplier. You could also use drones to track which locations are selling more or less than expected so that you can adjust inventory levels accordingly. The drone's data may be utilized to update inventory records and optimise stocking and restocking procedures. This project's findings show the potential of drones in warehouse management and illustrate the advantages of employing drones for inventory management.

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