Developing a 2D LiDAR Collision Avoidance Algorithm for a Quadcopter

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Collision avoidance algorithms are essential to the development of autonomous drones [1], however, developing and testing a collision avoidance algorithm can be very complex. Physically testing the algorithm can permanently damage the drone; and simulations, though they have many benefits [2], can be complex to create and will likely fail to emulate all aspects of the physical world. This project suggests an approach to develop collision avoidance algorithms for a quadcopter. More specifically, every mechanical part is fabricated via 3D printing for the easy replacement of damaged parts from test flights. A method similar to the dynamic window approach (DWA) [3] is used as the basis of the algorithm.

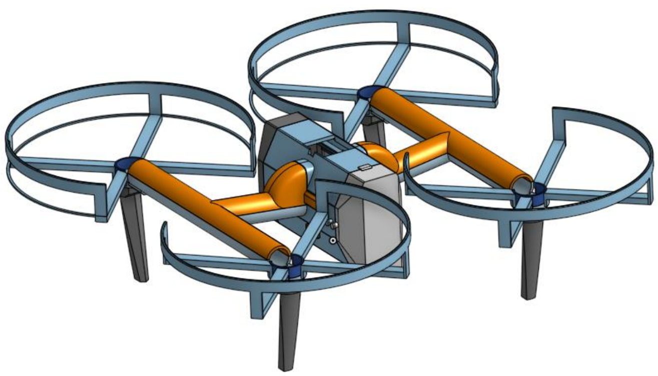

Figure 1: Drone Frame 3D Model

The drone's frame, shown in Figure 1, is a 445mm H-frame. The frame was designed using a CAD software and each part can be 3D printed. The LiDAR slots into an opening in the top of the frame where no other components block its line of sight. One major benefit of the entire drone frame being 3D printed is that the frame can be easily reparied in the event that it breaks. This is espcially important in this project because, as mentioned, the drone is being used to test and develop a collision avoidance algorithm. In the case of a failed test, rather than needing to buy a new frame or drone, any broken parts can be recreated in 2 – 4 hours.

The quadcopter's flight controller runs on an STM32H7 MCU and utilizes several peripherals, including an inertial measurement unit (IMU), electronic speed controller, radio, and 2D LiDAR. A system block diagram for the drone is illustrated in Figure 2. An extended Kalman filter is used to estimate the roll and pitch angles of the drone using the accelerometer and gyroscope data from the IMU. Three PID controllers in the flight-controller control the drone's roll angle, pitch angle, and yaw rotation rate. Adjustments to the throttle values of each motor are based on the output from the roll, pitch, and yaw PID controllers, as well as the output from the collision avoidance algorithm.

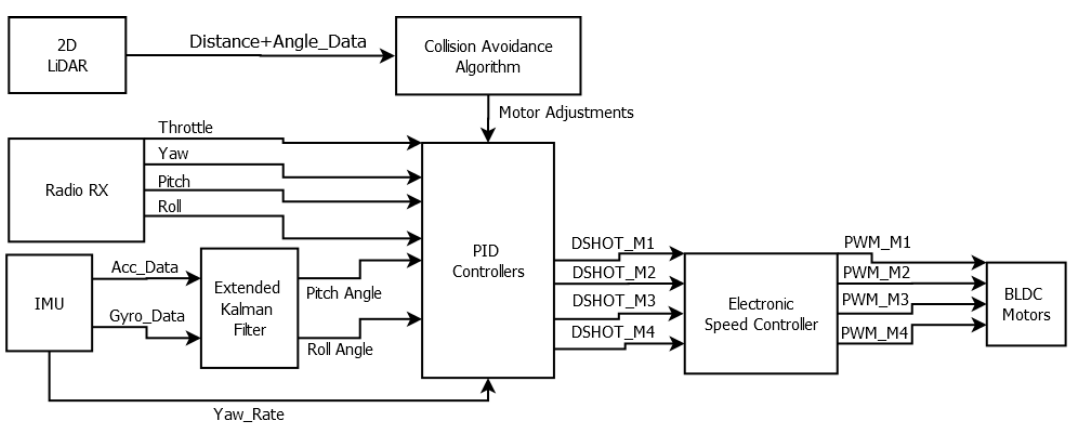

Figure 2: Drone System Block Diagram

Although the collision avoidance algorithm is still being developed, the algorithm will likely consist of three stages: obstacle detection, hazard assessment, and obstacle avoidance. In Figure 3, the angles around the drone are divided into sectors and each sector is bounded by a minimum allowed distance between the drone and obstacles. The obstacle detection stage determines the location of obstacles that are within the minimum distance; while the hazard assessment stage determines which of those obstacles the drone is most likely to collide with. Lastly, the obstacle avoidance stage calculates adjustments to the drone's motors to avoid the obstacles.

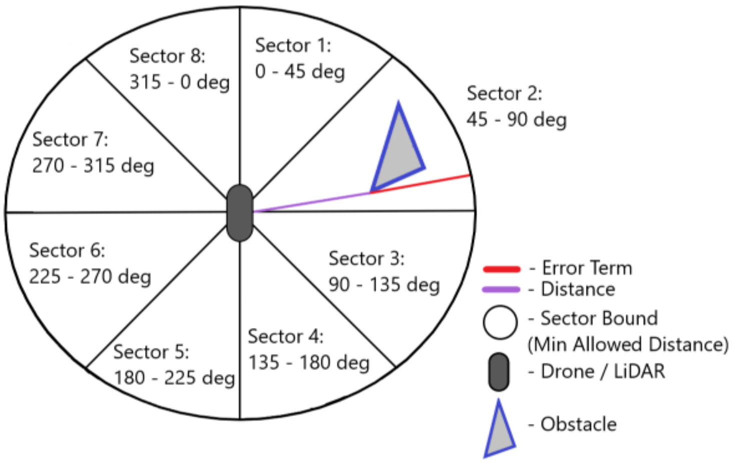

Figure 3: Collision Avoidance Algorithm Diagram

The algorithm being developed for this project is similar to DWA [3]. Both are dynamic collision avoidance algorithms that analyze a small area around the drone for potential hazards. The drone's velocity is also an important consideration when determining how the drone should avoid obstacles. Unlike the DWA, the collision avoidance algorithm being developed for this project has no components for path planning yet. Additionally, while the DWA uses velocity and acceleration to determine the area around the vehicle to analyze, the area analyzed by the algorithm in this project is based primarily on the size of the drone and measurement characteristics of the LiDAR. Detailed performance analysis will be done after the collision avoidance algorithm is developed further. Future improvements include implementing a path planning algorithm and other sensors to cover the 2D LiDAR's blind spots.

References

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[2] J. Yoon, B. Son, and D. Lee, "Comparative study of physics engines for robot simulation with mechanical interaction," *Applied Sciences*, vol. 13, no. 2, p. 680, Jan. 2023.

[3] D. Fox, W. Burgard, and S. Thurn, "Dynamic Window Approach to Collision Avoidance," Carnegie Mellon University Robotics Institute.