# Quadcopter – Obstacle Detection and Collision Avoidance

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***Abstract*—A simple approach for obstacle detection and collision avoidance of an autonomous flying quadcopter using low-cost ultrasonic sensors and simple data fusion is presented here. The approach has been implemented and tested in a self-developed quadcopter and its evaluation shows the general realizability as well as the drawbacks of this approach. In this paper, we propose a complete MICRO-UNMANNED AERIAL VEHICLE (MUAV) platform including hardware setup and processing pipeline-that is able to perceive obstacles in (almost) all directions in its surrounding. In this paper, we propose a complete micro aerial vehicle platform—including hardware setup and processing pipeline—that is able to perceive obstacles in (almost) all directions in its surrounding. Quadcopter is equipped with ultrasonic sensor. All signals from sensors are processed by Arduino microcontroller board. [5] Output from Arduino microcontroller board used to control Quadcopter propellers. [5]**

***Keywords*— Obstacle Detection, Collision Avoidance, PID controller programming, components.**

## I. Introduction

Quadcopter, a Micro Unmanned Aerial Vehicle(MUAV) are widespread in the hobby rooms and labs of model-makers, developers and researchers, [2] but not that common in public areas.Quadcopter has received considerable attention from researchers as the complex phenomena of the quadcopter has generated several areas of interest. The basic dynamical model of the quadcopter is the starting point for all of the studies but more complex aerodynamic properties has been introduced as well. [6] This may change in the future as many researchers are working on the improvement and developing applications of such systems. The possible field of applications for an autonomous drone may reach from emergency tool for firefighters and disaster controllers over observation and exploration for both known and unknown areas to many further domains, [2] where ever a flying machine can help humans in their daily work.

A quadcopter is an aerial vehicle that uses four propellers for lift and stabilization. The rotors are directed upwards and they are placed in a square formation with equal distance from the center of mass of the quadcopter. The quadcopter is controlled by adjusting the angular velocities of the rotors which are spun by electric motors. [7] To make this Quad copter autonomous, we used Arduino platform to program and applied PID algorithm to calculate the output values of motor commands by using input values from transmitter and sensors. We used an Inertial Measurement Unit (IMU) sensor which give values regarding angles and angular velocities of quad copter frame.We are using ultrasonic sensors for obstacle detection and collision avoidance, although the necessary obstacle sensors are becoming smaller and more feasible for MUAV use, most current research in this area is focusing on how to accomplish obstacle detection and collision avoidance in MUAV system rather than how to present this information to the operator in an intuitive manner to facilitate spatial awareness. By integrating a collision avoidance display into the control interface, operators can form a complete mental picture of the flight environment and pilot the vehicle more effectively. [8]

The basic concept of flight mechanism is as follows:

- Yaw (turning left and right) is controlled by turning up the speed of the regular rotating motors and taking away power from the counter rotating; by taking away the same amount that you put in on the regular rotors produces no extra lift (it won't go higher) but since the counter torque is now less, the quadcopter rotates. [9]

- Roll (tilting left and right) is controlled by increasing speed on one motor and lowering on the opposite one. [9]

- Pitch (moving up and down, similar to nodding) is controlled the same way as roll, but using the second set of motors. This may be confusing, but roll and pitch are determined from where the "front" of the drone is. [9]

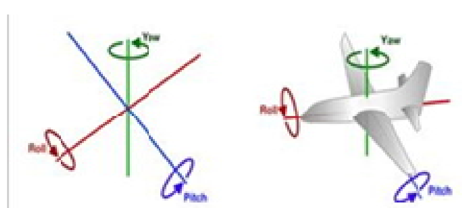

**Fig: Basic flight mechanism**

To roll or pitch, one rotor's thrust is decreased and the opposite rotor's thrust is increased by the same amount. This causes the quadcopter to tilt. When the quadcopter tilts, the force vector is split into a horizontal component and a vertical component. [9]

This causes two things to happen: First, the quadcopter will begin to travel opposite the direction of the newly created horizontal component. Second, because the force vector has been split, the vertical component will be smaller, causing the quadcopter to begin to fall. In order to keep the quadcopter from falling, the thrust of each rotor must then be increased to compensate. [9]

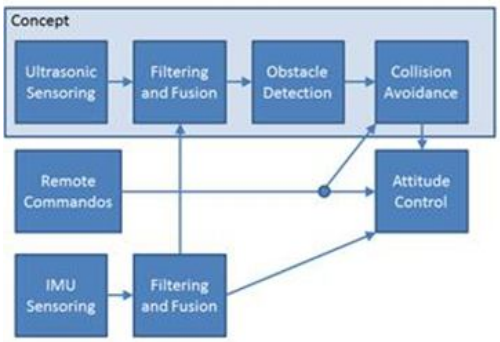


**Figure 1.2: Basic concept of obstacle detection and collision avoidance**

### Obstacle Detection

In the obstacle detection module, redundant ultrasonic sensors are used to increase detection resolution and sensor data reliability. Since ultrasonic sensors have a width dihedral detection angle, the resolution of detected obstacles is very low. The implemented approach uses always two ultrasonic sensors for one half of the same angle. Hence, though the double amount of sensors is needed, the redundancy and resolution is also doubled. Figure 3 shows the implemented constellation using 12 ultrasonic sensors for a 360 degree circle. For example sensor S0 and sensor S1 share one half of their total angle. [2]

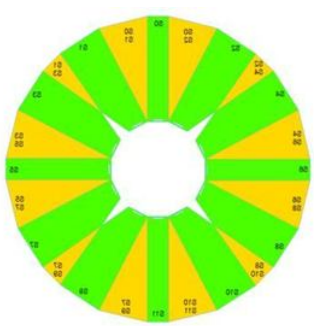

**Figure 1.3: Sectors of Obstacle Detection**

### Collision Avoidance

The collision avoidance module divides the area around the quadcopter dependent on the measured distance into three zones for each direction(Fig 1.4.1):

- Far or Safe zone (GREEN)
- Close zone (YELLOW)
- Dangerous zone (RED)

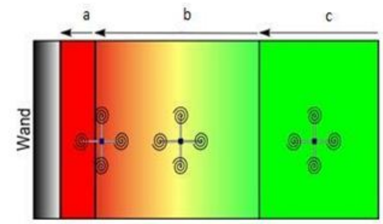


**Figure 1.4.1: Distance zones**

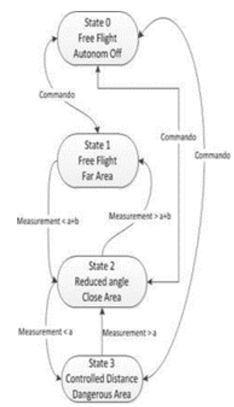


**Figure 1.4.2: Concept of collision avoidance**

The behaviour of the collision avoidance module can be described best with a state machine (Figure 1.3.2). Initially and if the autonomous collision avoidance is off, the quadcopter is in state 0. If the autonomous mode is activated, the quadcopter can switches between state 1, 2 or 3 depending on the measured distance to a nearby object. State 1 (safe zone) is active, if there is no obstacle nearby (object distance > a+b).If an obstacle is detected in the close zone (a > object distance > a+b), state 2 (close area) is activated and the corresponding pitch or roll angle towards the obstacle is limited depending on the measured distance reducing the speed of approach. In the dangerous zone (a < object distance), state 3 is activated and the distance to the obstacle is controlled using a PID controller, preventing a further approach to the obstacle. Hence, such a state machine is necessary for every direction. [2]

## II. IMPLEMENTATION

The presented concept has been implemented and integrated in the self-developed quadcopter of the chair. The SRF05 ultrasonic sensor has been chosen because of its low price, high range of measurement, and easy communication interface for several entrants using I2C interface. The sensors would be mounted using wooden plates cut with a CNC. One sensor holder with three ultrasonic sensors has been mounted on each side arm of the quadcopter. The three sensors of one side arm are fused to calculate the distance data for the collision avoidance of one direction. Hence the collision avoidance module uses four directions and consists of two collision avoidance state machines dedicated to the roll and pitch angles. [2]

The constellation and number of 12 ultrasonic sensors derives from the approach of redundancy as well as the 55° dihedral angle that the SRF05 ultrasonic sensor provides. At least 7 sensors are necessary to cover a 360° circle range. For double redundancy this leads to 14 ultrasonic sensors. [2]

However, the experimental results have shown that using 12 sensors in four groups of three sensors on each side gives better results. This simplifies the geometrical design and increases the possible sample time of the system. Furthermore each sensor has a 20° tipping angle from the perpendicular on the object. A higher tipping angle of an object is not detectable anymore, since there are not enough ultrasonic waves reflected from the surface of the object. With 27.5° between every sensor and 20° tipping angle, each three sensor combination of every arm covers 95° tipping angle. Hence all twelve sensors cover every horizontal angle within the minimum tipping angle of 20° and enabling the system to detect a wall at every yaw angle. [2]

One major issue on implementation would be the fact that the sensors could disturb each other. Though more sensors allow the raising of the sample time and the resolution of objects detection, more sensors also mean more noise and errors. Therefore a trade-off between sample time and accuracy has to be made. The best results were found by using 3 activation groups and activate those four sensors with 90° shift angle between each other at the same time. This leads to a group sample time of 30ms and a sensor sample time of 90ms.

Another problem is the fact, that the rotations of the quadcopter manipulate the ultrasonic measurements. Therefore measurements from the IMU like the angular rate from the gyroscope are used to detect rotations and dismiss incorrect measurements of the ultrasonic sensors. [2]

## III. FUTURE SCOPE

- This technique could be used along with a GPS module to allow the quadcopter to travel unambiguously between any two specified co-ordinates without colliding.

- The collision avoidance module is a boost in search and rescue operations. Natural disasters like earthquakes and floods leave certain areas inaccessible to human beings. Autonomous Drones could be used in such areas.Such modules are an integral part of drones used for reconnaissance.

- Using a Wireless workstation and a sophisticated GUI, the quadcopter can map it's surroundings and create a 3D map.

- Drones have always found a place in military applications. However, this drone could be fit with remote sensing light-weight weapons to pierce army bunkers and tanks alike.

- Nano-copter is another brilliant idea based on the existing quadcopters but with minimal size and power consumption.

## IV. LITERATURE REVIEW

1. Nils Gageik, Thilo Müller, Sergio Montenegro of University of Würzburg, Aerospace Information Technology(Germany) have done research on obstacle detection and collision avoidance of an autonomous quadcopter using low-cost ultrasonic sensors.

2. Michael Hoang and Kiral Poon have worked on a proposal for the ECE4600 – Group Design Project at the University of Manitoba, the Department of Electrical and Computer Engineering. The team designed and implemented a GPS system for the RTF quadcopter kit to perform instructions such as hold its current position, fly the quadcopter to a pre-determined location using GPS feedback, and return to controller location when the quadcopter flies out of communication range.

3. Dan Garber, Jacob Hindle and Bradley Lan have worked on Autonomous quadcopter with Human Tracking and Gesture Recognition.

4. According to Wei Wang and Gang Song, et al[2006] paper on Autonomous Control for Micro-Flying Robot and Small Wireless Helicopter X.R.B
autonomous control for Micro-Flying Robot and small helicopter X.R.B. In case of natural disaster like earthquake, a MAV will be very effective for surveying the site and environment in dangerous area or narrow space, where human cannot access safely.

5. According to Madani, T, Benallegue, al [2006] paper on Back stepping Control for a Quad rotor Helicopter, his paper presents a nonlinear dynamic model for a quad rotor helicopter in a form suited for back stepping control design.

6. Kıvrak, Arda Ozgur ‘s thesis reviews the Design of Control Systems for a Quad rotor Flight Vehicle Equipped with Inertial Sensors in detail. The control system is developed in Matlab/Simulink and real time implementation is achieved by using Simulink Real Time Windows Target utility. Linear Quadratic Regulator is designed for the stabilization of the attitude and shown to work in real time.

## V. COMPONENTS USED

- Brushless Rotors
- Propellors
- Electronic Speed Controller (ESC)
- IMU – Inertial Measurement Unit
- Flight Controller (ARDUINO board)
- SRF05 Ultrasonic Ranging Sensor
- 6 Channel RC Controller

## VI. APPLICATIONS

- Programmed drones could be used in synchronization to lift and transport heavy materials.
- By feeding mathematical models of objects, we could merge gesture control to control the quadcopter.
- Drones flying in programmed formations can lift objects and place them in desired orientation on inclined planes.
- Drones are being increasingly employed in firefighting and rescue operations.
- Quadcopters equipped with wireless speakers are being developed which could be used to relay messages.
- Aerial imagery is another field where quadcopters find applications.

## VII. CONCLUSION

As per the design specifications, the quadcopter stabilizes itself using the array of sensors integrated on it. The system is operational and capable to avoid obstacles and enables autonomous functions like collision avoidance and position hold and change. Thus it is a feasible design and build a quadcopter capable of mission support.

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