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Adaptive Autonomous Technology in Unmanned Aerial Vehicles for Parcel Delivery

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ABSTRACT

An Unmanned Aerial Vehicle (often called a Drone) is an aircraft that is not operated by a pilot on board. Drones are rapidly growing market and increasingly leverage. The Applications of these flying robots are limitless. This paper reviews and discusses about embedded vision and sensor technology which culminates in several innovative applications over drones. It introduces an industry alliance available to help product creators incorporate robust vision capabilities into their drones designs.This paper mainly deals on Autonomous Delivery of light weighted items along with the collision avoidance technology and also tracks the whereabouts of the vehicle in a cost effective approach. This can also be used for carrying out complex assignments such as rescue operations during disasters, mines surveying.

Keywords : Autonomous, Collision Avoidance, Delivery Service, Flight modes, Hexa copter, Navigation, Detect and Avoid.

I. INTRODUCTION

The Technology has been evolving over the past 30 years from the invention of the basic computers which uses the transistors for performing the mathematical calculations to the most advanced super computers whose performance is very intensive. The Size of the computer has been evolving since the first invention from the size of an average room to a credit card chip size. We are experiencing a huge Technological Evolution over the past decade. It reached its pace after the invention of the World Wide Web. Computer Systems are becoming more and more intelligent where they can be able to take the decisions on their own. There comes the concept of the Machine Learning. It revolutionized the existing robotic Technology to a greater extent. This improvised the mechanics of the flying robots as well. Here, Flying robots refer to the Unmanned Aerial Vehicles commonly called as Drones(male Bee) are now part of the emerging technologies. These Drones are piloted either by remote control or On Board Computers. Recently these drones became widely available in the commercial market place.Now a days, these robots are used in various purposes in health care industry, Construction industry, aerial photography, postal services and other commercial e-commerce organizations for delivery of products.

In December 2013, Amazon.com has announced that they were planning the rapid delivery of light weighted commercial products using UAVs. In the same year, in a research project of Deutsche Post AG subsidiary DHL, a sub kilogram quantity of medicine was delivered via a prototype micro drones called parcelcopter raising speculation that disaster relief may be the first place the company stated that it would use the technology. DHL Parcel copter is currently in trails in Germany.

Most recently, The Bangkok governor launched a fleet of large drones to spray water into the air in an attempt to reduce the smog that is blanketing the capital region. Five drones were used for dust reduction at Lan Khon Muang, in front of City Hall. The number would be increased and the operation widened. Each Drone could carry 5-10 litres of water and could be flown over a two square kilometer area for 15-20 minutes on one charge.

II. METHODS AND MATERIAL

This section includes the detailed implementation and infrastructure of the prototype vehicle which is used to test as a part of research.

A. Hardware Components and Design

For every custom built UAV, frame must be the chosen first. The frame acts as a backbone of the UAV. It is used to support all payload installed in UAV. The current prototype is equipped with HexaCopter Frame with 'X' frame arm configuration. Secondly, motors are the crucial components. This current prototype is equipped with Brushless DC Motors with a KV rating 960 and input voltage of 11.1V providing 10,656 rpm. 960 x 11.1=10,656 rpm.

These rotors are mounted on every end of the frame, with rotor shaft pointed towards top. The propellers are the top-end parts of all rotors. Electronic Speed Controllers play a prominent role in controlling the rotor speed. Brushless Electronic Speed Control with a Brushless Motor wiring was used.

In order to fly UAV, an energy source is needed.For Most UAV uses, lithium polymer batteries are used (LiPo Batteries) and they are known for their high power capacities and low pack weights. In the prototype, 3S 11.1V Orange 6200 mAh with a discharge rate of 4C. The flight controller is responsible for mostly all UAV actions and behaviors. In this prototype, a 3DR Pixhawk PX4 was used. The firmware was responsible for autonomous tasks and missions, real time data and control, UAV altitude hold, hovering stabilization and other features. PX4 firmware was used in the current prototype. Mission Planner Ground Control station was used in the current prototype for monitoring and controlling the UAV which includes obtaining relevant flight data read by flight controller sensors.

Distance sensing can be useful for many UAV applications such as ground altitude measurement, object detection and environment mapping etc. Light Detection and Ranging (LiDAR) sensor is one of the best choice for the Drones. LiDAR is based on a precise measurement of the time delay between the transmission of a pulsed optical laser light signal and its reception. It is used to analyze objects that are close or far from the UAV current position. An alternative choice of LiDAR is Sound Navigation and Ranging (SoNAR). In case of SoNAR, the distance from an object is measured by sound waves echo time delay.

Raspberry Pi is the intermediary companion hardware between user's command inputs from a ground control station and Pixhawk's flight controller. Raspberry Pi 3 runs on raspbian Operating System which is a Debian based Linux Operating System. Raspberry Pi 3 Model B was used and it is mounted on UAV's upper frame plate.

B. Connections and Final Build

Pixhawk flight controller will be installed on the inferior plate. After UAV full building, it's difficult to reach Pixhawk input connections, and to avoid that, some essential components need to be connected before mounting upper frame plate.

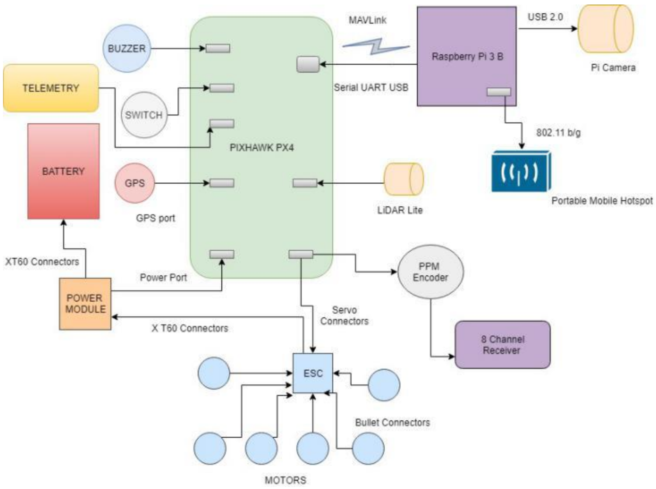

Figure 1: Connection Architecture Diagram of the current prototype vehicle

Raspberry pi can communicate with the Pix Hawk flight controller using the MAV Link protocol over a serial connection. Connection is established to Pix hawk's TELEM2 port to the Raspberry Pi's Ground, TX and RX pins. The Raspberry Pi3 was powered by connecting from the USB Serial UART Bridge.Python library Mavproxy is required for further communication from pixhawk to the UAV.

MAV Proxy was released under the GNU General Public License v3.After installing the mavproxy, connection is established using the controlling terminal dev/ttyAMA0 with custom baud rate 57600. Connection can be tested by using the mavproxy commands. Before connection to the vehicle, It is mandatory to set the Parameters of PIXHAWK. They are SERIAL2_PROTOCOL and SERIAL2_BAUD to 1 and 921 respectively. The Pixhawk will respond to MAV Link commands received through Telemetry 1 and Telemetry 2 ports meaning that both the Raspberry Pi and the regular ground station can be connected.

Pix hawk can be connected to the Ground Station using the COM 3 or COM 4 USB Serial Ports with a specific baud rate.

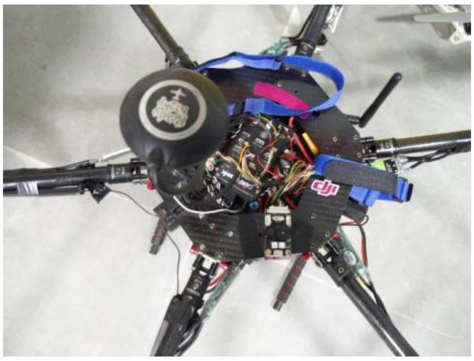

Figure 2: Final UAV Build

C. Autonomous Navigation

Autonomous Navigation was achieved using the dronekit-python API. DroneKit-Python is an open source and community-driven project. Dronekit-python was used to create powerful apps for UAVs. These apps run on a UAV's Companion Computer, and augment the autopilot by performing tasks that are both computationally intensive and require a low-latency link (e.g. computer vision). Dronekit-python provides the features such as connecting to a vehicle or multiple vehicles,get and set vehicle telemetry parameter information and guide a UAV to specific position in GUIDED mode.

Drone can be tracked with point to point using the mission planner. It can be tracked with the help of Telemetry radio of frequency (433Mhz) from the vehicle to the ground station. Telemetry receiver is connected to the ground station via COM4 port and accessed through mission planner.

Figure 3 : Mission Planner Ground Station Interface

D. Collision Avoidance

The drone must be able to accomplish its missions reliably without endangering people or damaging property. This converts the drone into a memory driven vehicle. Collision Avoidance can be attained in the vehicle using the distance measurement sensors. This current prototype consists of LiDAR Lite sensors which can be able to detect the obstacles within the range of 12 meters. Collision Avoidance is achieved using the Detect and Avoid Algorithm. The Detect and Avoid algorithm is shown in the below flowchart.

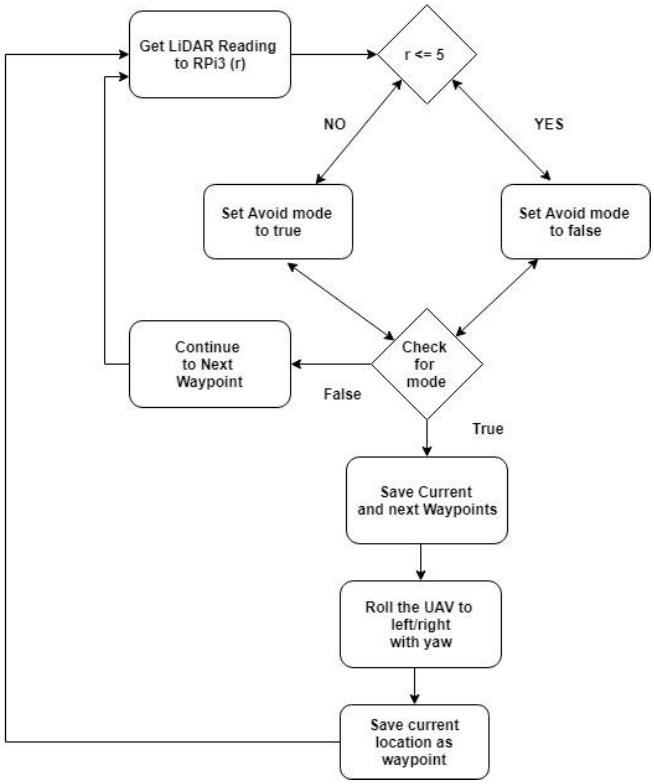

Figure 4: Detect and Avoid Algorithm for Collision Avoidance in UAVs

In this case, Raspberry pi receives the Distance reading from the LiDAR Lite attached to the Pixhawk using the MAVLink protocol, continuously.In addition to that, the Detect and Avoid Algorithm continuously runs in the Companion Computer simultaneously. There is a Avoid flag which is used to verify whether the result from the Detect mode is true or not. When there is any obstacle with in the 5 meters from the vehicle, Avoid mode is triggered and the vehicle is controlled in the guided mode. In this case, the vehicle dynamically adapt the situation and act along to carry out mission with out any disturbance in the mission. During the mission, the vehicle location is stored in the companion computer's permanent storage and also transmitted to the remote log storage present in the Ground Control Station using the portable mobile hotspot attached to the drone. This 5 meter threshold value is not fixed in every aspect, as this is an experimental value used in testing.

III. RESULTS AND DISCUSSION

A. Testing and Results

The Detect and Avoid algorithm for the collision avoidance is tested in a 3D simulation environment. This 3D simulation environment was secure, easy to deploy and close to real UAV behaviors. A 3D simulated environment was the perfect solution for test "Detect and Avoid" algorithm. Gazebo is an Apache 2.0 licensed open-source 3D environment simulator that is capable of simulating multi-robot behaviors on indoor or outdoor environments. It also features sensor readings (for object awareness) and "physically plausible interactions" between rigid objects.This simulator operates on Robot Operating System (ROS), which is BSD licensed open source library toolbox to develop robot based applications. The ROS toolbox allows installing third-party plugins in order to add extra features useful to simulate all UAV's flying requirements, such as control and communication methods. The Gazebo simulator makes it possible to test "Detect and Avoid" algorithm because it provides realistic scenarios, with 3D model inclusions and real physics simulation. The ROS/Gazebo implementation will work as an external simulator for Pixhawk's ArduCopter firmware (Erle Robotics). The ArduPilot SITL Gazebo plugin is responsible for interfacing the virtualcreated

UAV (ArduPilot SITL simulation) with Gazebo simulation. The MAVROS plugin package, or Micro Air Vehicle ROS, provides communication features between ArduPilot firmwares. The Rotors Simulation plugin provides Gazebo simulator the UAV kinematics and sensor readings (IMU and LiDAR / SoNAR)(ErleRobotics).

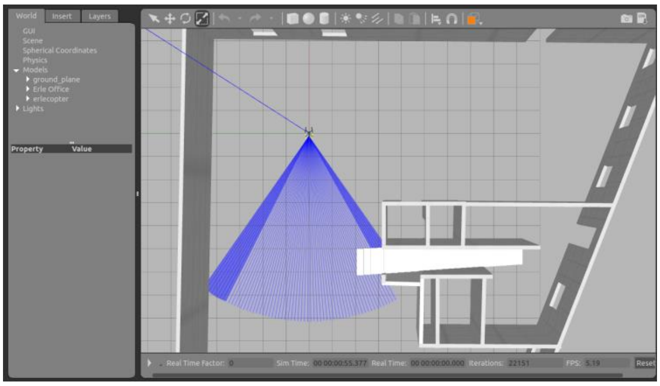

Figure 5 : UAV equipped with LiDAR Lite sensor present in 3D Indoor simulation Environment (Erle Robotics) using the Gazebo and ROS

The indoor environment used in the above figure is made using the Erle Robotics documentation. It is the 3D model of the office in First floor of Erle Robotics Organization.

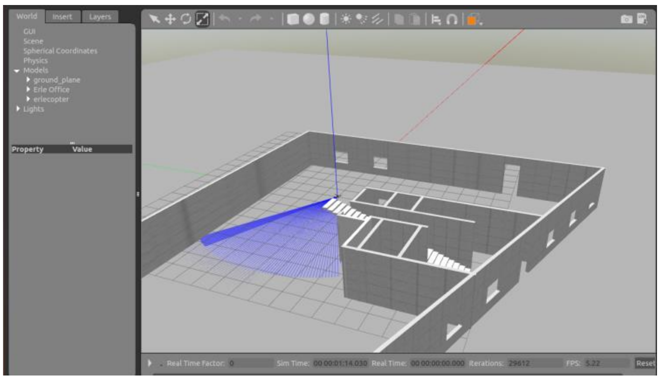

Figure 6 : Side view of the 3D Simulation model

The blue colored rays coming from the UAV indicates the LiDAR waves used to measure the distance between the object to he sensor. With all the obtained measurements and readings, a graph as plotted to demonstrate the Detect and Avoid Algorithm. The graph was plotted using the test results with the threshold value for LiDAR set to 7 meters.

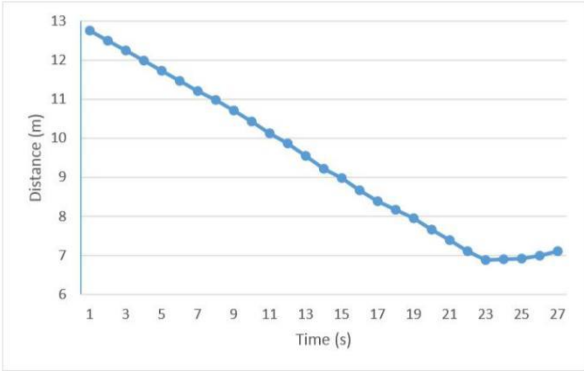

Figure 7 : LiDAR Readings during the Test

It avoided collision with the concrete wall, and proved its concept. The algorithm behaved as expected, changing flight modes and nullifying drift effect. There was no delay on communications from the sensors to companion computer. This means that it's expected to work on real case scenarios.

IV. CONCLUSION

The main of this dissertation was to develop a system that was capable of enabling the UAV to mode in Autopilot mode. "Detect and Avoid "Algorithm was developed to ensure the autonomous object collision avoidance maneuvers. The Collision Avoidance Mechanism worked flawlessly after a long number of trail and error tests. This feature can be useful for every UAV on carrying specific missions. This work can be improved by upgrading the hardware used in making the UAV. With the help of machine learning, this work can be further extend by training the vehicle in actual real time situations. This might improve the decisions and response behaviors of the Vehicle.

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