Antenna Tracker

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Abstract

Antenna Trackers are systems that track Unmanned Aerial Vehicle (UAV) location, and use this information to correctly align directional antenna. This approach significantly improves the range over which signals can be both sent and received from the ground station.

The tracker calculates the position of a remote vehicle using its own GPS (Global Positioning System) position and GPS telemetry from a vehicle running Copter, Rover or Plane. It then uses this information to aim a directional antenna at the vehicle. To achieve the target, we installed two GPS modules, one on the UAV and the other at the ground station. These GPS modules provide us the current GPS location of both the UAV and our tracking antenna. The GPS module of the ground station is directly connected to the development board while the GPS data from the UAV is communicated through radio module. Development board (Raspberry Pi) is programmed to calculate the relative difference between the positions of tracking antenna and the UAV. The difference in the position is given to the two servo motors, one for the pan and the other for the tilt. Servos are selected so that they can direct the tracking antenna efficiently and thus the problem of long range connectivity and communication is solved.

Introduction

An UAV is an autonomous aircraft commonly referred to as a drone which can also be controlled manually by a pilot.

These were designed for military and defense applications but eventually found their way into the fields such as agriculture, transportation, aerial surveillance and photography. Since their applications and demands are increasing, it is very important to ensure that the aerial systems have proper connectivity to the ground control station to avoid accidents.

In order to have better and long range connectivity between the UAV and the Ground Control Station (GCS), a highly directional antenna should track the UAV to maintain line of sight communication by means of a tracking controller.

Tracking capability depends on the beam width of the antennas and the speed of the UAV. Thus high gain and directional antennas need to track the UAV, in both azimuth and elevation direction.

This paper describes the antenna tracking system which is capable of computing the required amount of pan and tilt to position itself in the direction of the UAV.

Apparatus

To develop the antenna tracking system the following modules were used:

1. GPS Modules: Two GPS modules are fixated, one on the UAV and the other at the ground station.
2. Transmitter and Receiver Pair: Transmitter and receiver pair is used to maintain communication between the UAV and the GCS. Transmitting module on the UAV transmits the GPS position of the aerial vehicle. Receiver at the ground station

receives the GPS coordinates from the transmitter and forwards it to the development board.

3. Directional Antenna: It is used at the ground station to maintain long range connectivity between the aerial vehicle and the ground station.
4. Servo Motors: A servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. There are two servo motors being used, one for pan and the other for tilt.
5. Development Board (Raspberry Pi): It is a capable little computer which is used to compute the tilt and the pan angle of the servo.
6. Gimbal: Gimbal is a pivoted support that allows the rotation of an object about a single axis. Two axis gimbal is used in the project that will allow the antenna to rotate about the two axes i.e. pan and tilt respectively.

Searching Methods and Tracking Algorithm

There are two types of antenna tracking system: Mechanical and electrical. In the mechanical method, both azimuth and elevation angle of antenna are controlled by pressing elevation up and down keys or azimuth left and right keys to drive the motor system. Electrical tracking is done automatically by rotating the antenna according to the azimuth and elevation angle, which is calculated by a software program.

This paper discusses the latter method.

Tracking Method

The mount of the antenna position system consists of two servo motors connected to the axes for the elevation angle and the azimuth angle respectively.

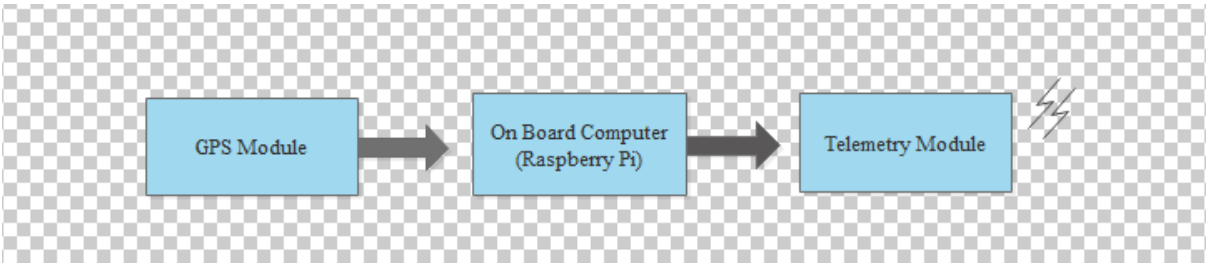

Figure 1 On-board Set-up

The UAV has an on-board GPS module that feeds the real time latitude, longitude and altitude of the UAV to the on board micro-controller (Raspberry Pi) which receives the data in NMEA (National Marine Electronics Association which sets a standard data type for GPS coordinates) format from the GPS module. Telemetry radio is also connected with the micro-controller. Raspberry Pi processes the information from the GPS module and forwards it to radio module. This radio module is used to transfer the GPS location of the UAV to the ground control station.

Figure 2 Ground Station Set Up

The ground control station has highly directional antenna that receives the GPS location of the UAV sent by the on board radio module. This GPS information is forwarded to another Raspberry Pi at the ground station. Another GPS module is fixed at the ground station that transfer the GPS coordinates of the ground station to Raspberry Pi. Raspberry Pi at the ground station is programmed so that it can compare the GPS coordinates of both the ground station and the UAV and calculate the azimuth and the elevation angle. After the required azimuth and elevation angle are calculated, they are fed to the azimuth and elevation servo respectively. According to the Pulse Width Modulation (PWM) data sent, the servo rotate and

fix the antenna in the direction of UAV and thus an almost line of sight communication is maintained between the UAV and the tracking antenna.

Calculation of Angle of Elevation

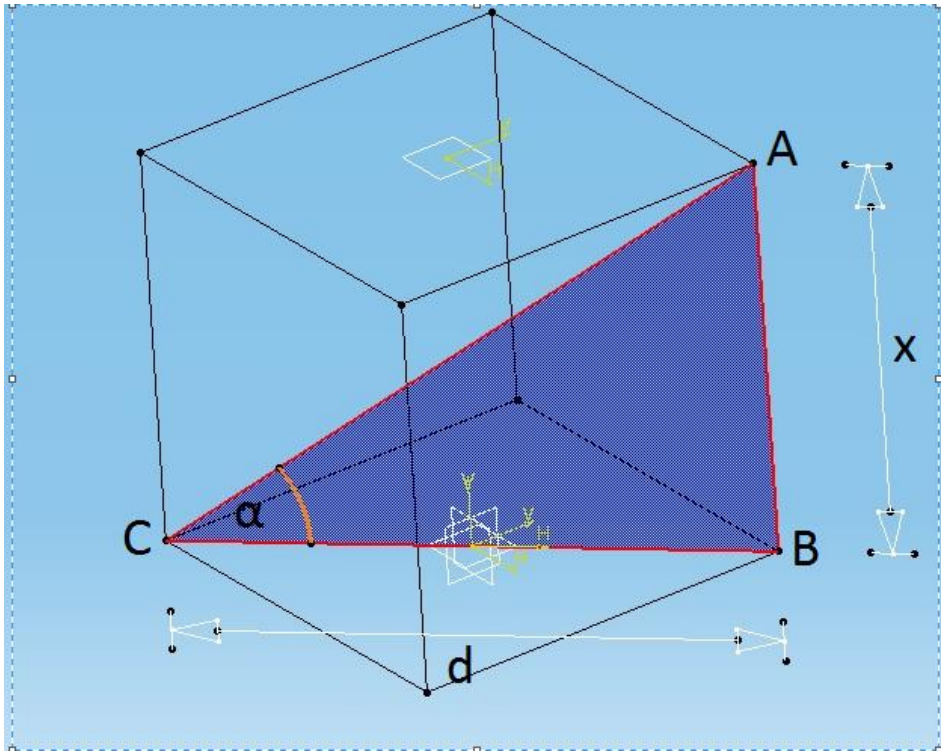

Figure 3 Calculating the Angle of Elevation

Let a point C denote the position of antenna tracking system or ground station and a point A denote the current position of the UAV. The point B is the projection of point A in XY plane or in the plane of ground station. Now the distance between point C and B is calculated using Haversine formula:

$$a = \sin^2(\Delta\varphi/2) + \cos\varphi_1 \cdot \cos\varphi_2 \cdot \sin^2(\Delta\lambda/2)$$

$$c = 2 \cdot \operatorname{atan2}(\sqrt{a}, \sqrt{(1-a)})$$

$$d = R \cdot c$$

Here φ is the latitude , λ is longitude , R is the earth's mean radius (6,371 km) and

d is the distance between point C and B.

Difference between the altitudes of the UAV and ground station is computed to calculate the distance between point A and B. Let this distance be denoted by x.

Now using the basic trigonometry, we can compute angle of elevation as:

$$\alpha = \tan^{-1}(x/d)$$

Hence, we now have the angle of elevation for the antenna tracking system. This angle is given as input to the servo through the development board to perform the elevation action.

Calculation of Azimuth Angle

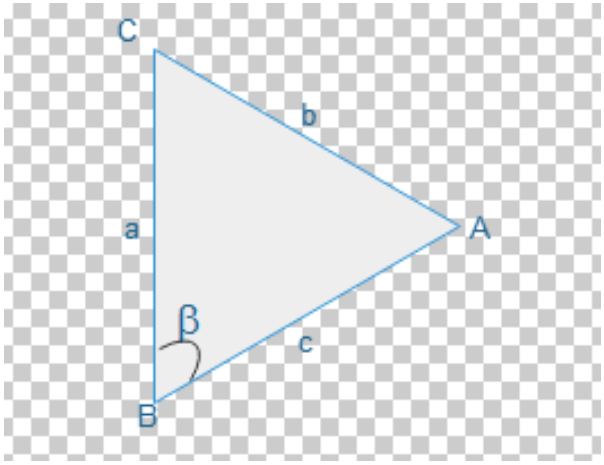

Figure 4 Calculation of Azimuth Angle

Let point C denote the position of antenna tracking system or ground system, point B be the projection of starting point of UAV and point A be the ground projection of current position of the UAV.

Points A, B and C form a triangle. Using Haversine formula we can calculate the length of the sides of the triangle ABC.

$a = \sin^2(\Delta\varphi/2) + \cos\varphi_1 \cdot \cos\varphi_2 \cdot \sin^2(\Delta\lambda/2)$

$c = 2 \cdot \text{atan2}(\sqrt{a}, \sqrt{(1-a)})$

$d = R \cdot c$

Here φ is the latitude, λ is longitude, R is the earth's mean radius (6,371 km)

Let the length of the sides be a, b and c. Now by using 'law of cosines':

$$c^2 = a^2 + b^2 - 2ab\cos\beta$$

We can calculate the azimuth angle (β). After the azimuth angle is calculated it is given as input to the pan servo motor through the development board to perform pan action.

Conclusion

This paper presented the study and design of antenna tracking system used to aid long range communication between the ground station and the UAV. Generally, antenna tracking system using the electronic method requires additional modules such as position information sensors, signal level sensors and PID controller to obtain a stable antenna tracking system and make the tracking faster. The requirement of additional modules and better controller would increase the cost of system in total.

In this paper we tried to design a system which is capable of tracking the UAV without the use of additional sensors and controllers. Further work is needed to improve the tracking algorithm by using minimum number of sensors in order that aerial system can communicate with the ground effectively.

References

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