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ALGORITHM DEVELOPMENT AND TESTING OF LOWCOST WAYPOINT NAVIGATION SYSTEM

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***Abstract*— Developing algorithm for Autonomous waypoint Navigation using GPS and Atmega-328P on-board controller with low cast indigenous waypoint navigation device and Implementing the developed algorithm with Quadrotor**

Introduction

The development of small autonomous aerial vehicles for outdoor and urban applications, which are able to perform agile flight maneuvers, is of significant importance. Such vehicles can also be used for establishing ad-hoc networks or in environments where direct or remote human assistance is not feasible, e.g. in contaminated areas or in urban search and rescue operations for locating earthquake-victims. Especially the ability to hover above a given fixed position and to maneuver with high agility at low speed is essential for the mentioned applications. For this reason it was decided to investigate four rotor vertical takeoff and landing (VTOL) quadrotor instead of fixed-wing aircrafts.

This project work is intended in developing algorithm for Autonomous waypoint Navigation using GPS and Atmega-328P on-board controller. The co-ordinates of the waypoints for pre-determined flight path are fed to the microcontroller. The algorithm in-turn calculates the distance between the current positions obtained from the GPS to the first waypoint and the heading angle of the current position with respect to geographical north. Similarly the same can be calculated for succeeding waypoints to perform return to home operation. From the calculated values the Pulse Width Modulated signal is generated by the controller which controls the quadrotor attitude. This function is useful in applications such as an autonomous security surveillance , fire suppression system, and a terrain-mapping vehicle.

NAVIGATION

Navigation is the process of directing and controlling the movement of a craft or vehicle from one place to another. It requires the determination of the direction in which it has to go to reach the desired destination. In other words, navigation is the determination of a physical body's position and velocity relative to some reference coordinate frame.

The mostly used methods of navigation are:

1. Navigation by pilotage (or visual contact)
2. Celestial or Astronomical navigation
3. Navigation by dead-reckoning
4. Radio navigation including satellite Navigation

WAYPOINT NAVIGATION

Waypoints are sets of coordinates that identify a point in physical space. Coordinates used can vary depending on the application. For terrestrial navigation these coordinates can include longitude and latitude. Air navigation also includes altitude. Waypoints have only become widespread for navigational use by the layman since the development of advanced navigational systems, such as the Global Positioning

System (GPS) and certain other types of radio navigation. Waypoints located on the surface of the Earth are usually defined in two dimensions (e.g., longitude and latitude); those used in the Earth's atmosphere or in outer space are defined in at least three dimensions (four if time is one of the coordinates, as it might be for some waypoints outside the Earth).

Fig(1.1)

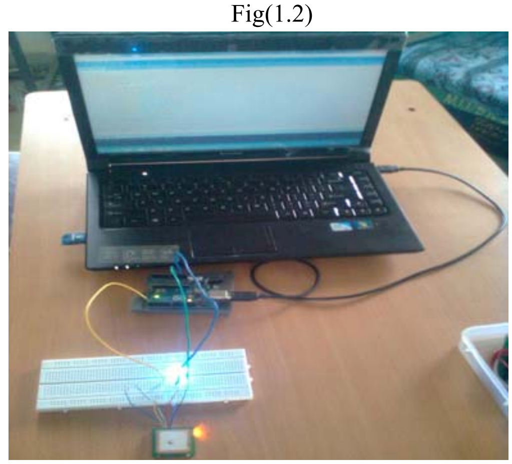
Although the term waypoint has only come into common use in recent years, the equivalent of a waypoint in all but name has existed for as long as human beings have navigated. Waypoints have traditionally been associated with distinctive features of the real world, such as rock formations, springs, oases, mountains, buildings, roadways, waterways, railways, and so on. Today, these associations persist, but waypoints are more often associated with physical artifacts created specifically for navigation, such as radio beacons, buoys, satellites, control points, etc.

In the modern world, waypoints are increasingly abstract, often having no obvious relationship to any distinctive features of the real world. These waypoints are used to help define invisible routing paths for navigation. For example, artificial airways—“highways in the sky” created specifically for purposes of air navigation—often have no clear connection to features of the real world, and consist only of a series of abstract waypoints in the sky through which pilots navigate; these airways are designed to facilitate air traffic control and routing of traffic between heavily traveled locations, and do not reference natural terrain features. Abstract waypoints of this kind have been made practical by modern navigation technologies, such as land-based radio beacons and the satellite-based GPS.

HARDWARE IMPLEMENTATION

In this project GPS used as an input sensor which feeds the latitude and longitude of the current position to the controller. The GPS data is processed by the ARDUINO controller kit which is loaded with control algorithm. The Destination point latitude and longitude are already loaded to the controller. So the controller calculates the distance between home and destination waypoint (WP1).The heading angle for the destination from the current position is also calculated by the algorithm with respect to geographical north. This chapter explains about the GPS functioning and interfacing of GPS with ARDUINO microcontroller kit.

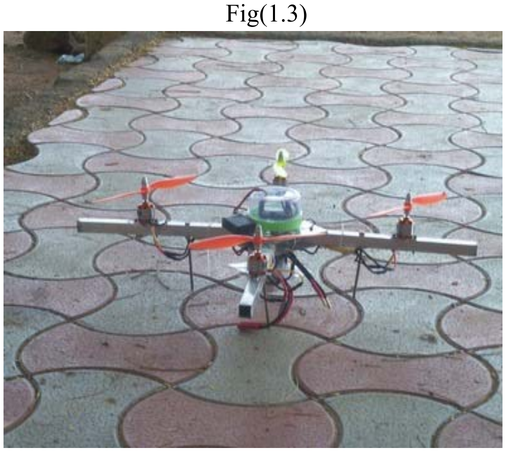
Fig(1.2)



GPS-634R” is a highly integrated smart GPS module with a ceramic GPS patch antenna. The antenna is connected to the module via an LNA. The module is with 51 channel acquisition engine and 14 channel track engine, which be capable of receiving signals from up to 65 GPS satellites and transferring them into the precise position and timing information that can be read over either UART port or RS232 serial port. Small size and high-end GPS functionality are at low power consumption, Both of the LVTTL-level and RS232 signal interface are provided on the interface connector, supply voltage of 3.6V~6.0V is supported. The smart GPS antenna module is available as an off-the-shelf component, 100% tested. The smart GPS antenna module can be offered for OEM applications with the versatile adaptation in form and connection. Additionally, the antenna can be tuned to the final systems' circumstances.

QUADROTOR DESIGN

Fig(1.3)



This chapter describes the different steps of designing, building, simulating, and testing an intelligent flight control module for an increasingly popular unmanned aerial vehicle (UAV), known as a quadrotor. It presents an in-depth view of the modeling of the Kinematics, dynamics, and control of such an interesting UAV. A quadrotor offers a challenging control problem due to its highly unstable nature. An effective control methodology is therefore needed for such a unique airborne vehicle. The chapter starts with a brief overview on the quadrotor's background and its applications, in light of its advantages. Comparisons with other UAVs are made to emphasize the versatile capabilities of this special design. For a better understanding of the vehicle's behavior, the quadrotor's kinematics and dynamics are then detailed. This yields the equations of motion, which are used later as a guideline for developing the proposed intelligent flight control scheme.

AERODYNAMIC FORCES AND TORQUES

Fig(1.4)

With the derived kinematic and dynamic model, we will now define the forces and torques acting on the quadrotor. The forces include the aerodynamic lift generated by each rotor, and the gravitational pull acting in counter to the total lift generated. The moments are the torques generated in order to achieve the roll, pitch and yaw movements. The following forces and torques are produced

FLIGHT CONTROL

Each rotor produces both a thrust and torque about its center of rotation, as well as a drag force opposite to the vehicle's direction of flight. If all rotors are spinning at the same angular velocity, with rotors one and three rotating clockwise and rotors two and four counterclockwise, the net aerodynamic torque, and hence the angular acceleration about the yaw axis is exactly zero, which implies that the yaw stabilizing rotor of conventional helicopters is not needed.

Yaw is induced by mismatching the balance in aerodynamic torques (i.e., by offsetting the cumulative thrust commands between the counter-rotating blade pairs)

RESULTS AND DISCUSSION

It is possible to receive latitude and longitude from GPS. If needed few more data's also can be fetched from GPS NMEA data such as heading, Velocity and altitude. Using haversine formula we can calculate the distance between predefined latitude and longitude points on the earth surface. Formula for distance calculation given below

R = earth's radius (mean radius = 6,371km)

Δlat = lat2−lat1

$\Delta long$ = long2− long1

a = $\sin^2(\Delta lat/2) + \cos(lat1).\cos(lat2).\sin^2(\Delta long/2)$

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

d = RC

X = $atan2((\sin(\Delta long).\cos(lat_2)),(\cos(lat_1).\sin(lat_2)$

Y = $\sin(lat_1).\cos(lat_2).\cos(\Delta long))$)

θ = X – Y

Even the heading Calculation also possible between two points Once the distance calculated we can calculate the time duration of flight by fixing the reference velocity to the quadcopter (Vr=40km/hr or 11.11m/sec) From the time we need to generate the pseudo PWM (Pulse width modulated) signal. This is used to control the quadcopter's attitude by means of varying the speed of four motors.

COMPUTATION

The basic idea of the main loop with 1 point in the path is:

- Get the co-ordinate of the WP1
- Get the current position using GPS
- Feed the received information to Flight controller
- Calculate the Distance between two waypoints and Heading to be followed
- Adjust heading in mission plan
- Cruise for a desired distance

Flying between two points in the known terrain area

The home point latitude and longitudes are

Latitude =12.941326

Longitude =80.136365

The destination point latitude and longitude are

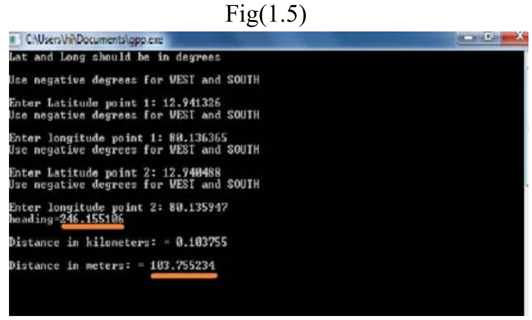
Latitude = 12.940488

Longitude = 80.135947

The pictures shown in Fig (1.6) are taken from the Google maps by providing the latitude and longitudes of Home, destination point.

Unlike fixed wing aircraft quadrotor are controlled by primary control surfaces like Rudder, Aileron and Elevator. Instead controlled by controlling the speed of four propellers.

Fig(1.5)



Fig(1.6)

CONCLUSION

This project deals about the development of control algorithm for autonomous waypoint navigation for a quadrotor using GPS. The control algorithm is implemented in a Arduino processor. The developed controller was tested successfully by simulating the flight path for predefined set of inputs. With this controller a quad rotor is able to deal with constant wind up-to 10m/s as well as with gusts. Furthermore, this controller can be applied to fly in urban scenarios due to its ability to fly along predefined tracks. The experiments were executed on basis of the real time GPS data obtained for a set of waypoints taken at MIT annex.

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