International Aerial Robotics Competition

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ABSTRACT

AMIBOT for International Arial Robotics Competition is ready to stand and complete the Mission 7 with its unique and latest technology to avoid collusion with the air as well as ground traffic without talking help of GPS or SLAM Technology. AMIBOT is using Milliwaves Radar which is used in Automobiles to detect and avoid collusion. Milliwaves works on the line of sight and are blocked by building walls and attenuated by foliage. This MilliWave Radar is used to navigate the AMIBOT in the competition arena. It is added with the vision module using Pixy Camera that will give AMIBOT an eye to get comfortable with the environment and Increase its precision and still keeping it fully autonomous. AMIBOT is made keeping in mind the safety and stability of the drone.

1. Introduction

Mission 7 of IARC is focused on finding the new ways to navigate the drones without using the conventional technologies like GPS & SLAM. At Present, autonomous aerial robots do not have a fluent, sleek and quick movement as the bees have. The problem now autonomous aerial robots face is “Navigation”. Navigation of the robots is conventional and this limits the application of the robots to use it for the development of the society.

With the navigation the stability and safety gets equal importance. With high precision and stable flight and a proper navigation the robot can have a fluent flight and perform its task without any glitch.

1.1 Milliwaves Radar

The sensors for monitoring robot driving environments embody important technology for the Intelligent Transport System (ITS). Sensing devices employed include the ultrasonic sensor, image-processing sensor, infrared lidar, microwave radar and millimeter-wave radar. Compared with other types of sensors, millimeter-wave radar has the advantage of providing stable detection of target seven under inclement weather conditions such as rain or snow. Thus, millimeter-wave radar has been marketed as, a vehicular collision warning sensor.This millimeter-wave radar incorporates a signal-processing unit in the radar head, resulting in a more compact, lightweight radar system that is easy to install on robots.

A 77 GHz transmitter emits signals reflected from objects ahead, at the side and to the rear of the robot and are captured by multiple receivers integrated throughout the robot. The radar system can detect and track objects in the frequency domain triggering a driver warning of an imminent collision and initiate electronic stability control intervention.

Item	**Performance**
Frequency	76 ~ 77GHz
Output power	10mW max
Range	0 ~ 120m
Range resolution	1m
Relative speed	-100 ~ +200km/h
Relative speed	1km/h
Detection angle	±8deg.
Multiple target detection	Possible
Data refresh rate	100msec

Table 1: Technical Specification of the Millimeter wave Radar.

Advancements in SiGe:C HBT technology pushed the emerging arena of high-frequency (>60 GHz) millimeter-wave (mm-wave) applications such as WLAN (60 GHz) and automotive radar (77 GHz) circuits into the reach of low-cost silicon technology.

Advantages of Freescale 77 GHz Technology:

Multi-mode, multi-application capability:

- Simultaneous long- and mid-range functionality
    - Allows one radar to be used for multiple safety systems:
        - Adaptive cruise control
        - Headway alert
        - Collision warning
        - Mitigation and brake support

Solid-state technology:

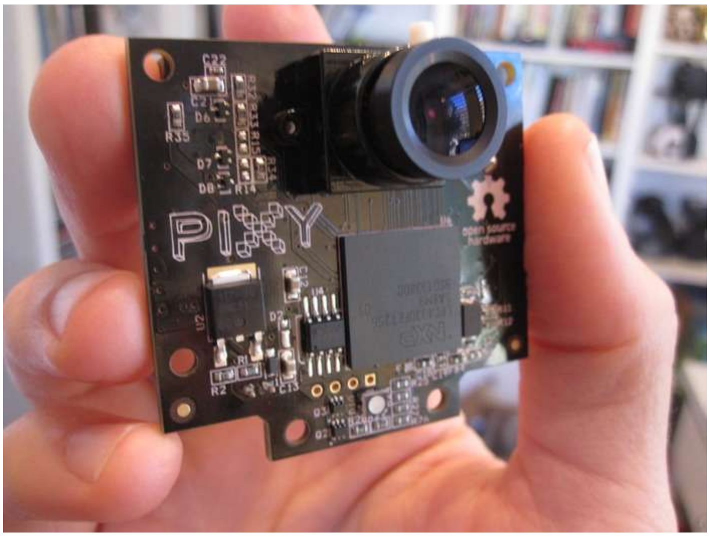
- Highest level integration
    - Most advanced SiGe technology with multi-channel transmitter and receiver chips
- No moving parts
- Extremely reliable

Class-leading performance and durability:

- Resistant to vibration and extremely robust
- Innovative design provides excellent multi-target discrimination
    - Including precise range, approach speed and angle data
- High speed FMCW waveform combined with 2D-FFT algorithm
    - Provides independent measurements of range and range rate
    - Provides superior detection of clustered stationary objects

1.2 Introducing Pixy (CMUcam5) Camera

- Small, fast, easy-to-use, low-cost, readily-available vision system
- Learns to detect objects that you teach it
- Outputs what it detects 50 times per second
- Connects to Arduino with included cable. Also works with Raspberry Pi, BeagleBone and similar controllers
- All libraries for Arduino, Raspberry Pi, etc. are provided
- C/C++ and Python are supported
- Communicates via one of several interfaces: SPI, I2C, UART, USB or analog/digital output



1.3 Yearly milestones

This is the first time Team Amibot is talking part in IARC. Vehicle and machine vision development and navigation will be emphasized in year 2015.

2. AMIBOT (Air Vehicle)

Basically a Quadcopter is a QUAD – ROTOR helicopter that is lifted and propelled by four rotors. A quadcopter is a flying vehicle possessing 4 identical rotors, evenly spaced around the central fuselage (hub).

Brushless DC motors are used as rotors & they use symmetrically pitched propellers.

Control of vehicle motion is achieved by altering the pitch and rotation rate of one or more motors, thereby changing its torque load and thrust/lift characteristics. Various movements are possible by varying the direction of rotation of propellers & by altering the speed of the motors.

2.1 Propulsion and Lift system

2.1.1 Frame

Frame is the most important basic part of a Quadcopter. As the name indicates, the copter has 4 arms. The frame should be light as well as rigid to host a LIPO battery, 4 BLDC motors ,4 ESC & controller.

The frame arms are made of ultra strength material to survive any crash. The frame boards are high strength compound PCB frames, which makes wiring of ESCs and battery safer and easier.

2.1.2 BLDC MOTORS

As the name implies, BLDC (Brushless DC) motors do not use brushes for commutation. They are electronically commutated & the advantages are :

- Better speed vs torque characteristics
- High efficiency with Noiseless operation
- Very high speed range with longer life.

Specifications of a BLDC motor

- KV(rpm/v): 1300
- Max Power: 190W
- Max Thrust: 920 grams
- Weight: 53 grams
- Shaft Diameter: 3.175mm
- Shaft Length: 45mm
- Recommended Propeller for battery: 12×4.5 for 2S battery; 10×4.5 for 4S battery
- Battery: 2S-4S Li-Po
- ESC(A): 30A

2.1.3 PROPELLERS

On each of the brushless motors there are mounted a propeller. The 4 propellers are actually not identical.

This reason for this is that the motor torque of and the law of physics will make the QuadCopter spin around itself if all the propellers were rotating the same way, without any chance of stabilizing it.

By making the propeller pairs spin in each direction, but also having opposite tilting, all of them will provide lifting thrust without spinning in the same direction. This makes it possible for the QuadCopter to stabilize the yaw rotation, which is the rotation around itself.

The propellers come in different diameters and pitches (tilting).

Larger propellers give more thrust per revolution from the motor.

2.2 Guidance, Navigation and Control

2.2.1 Attitude control

Pitch = controlled by differential thrust on fore/aft pairs of lift propellers

Yaw = controlled by differential torque on the 4 lift propellers

Roll = controlled by roll vanes = 1 forward and 1 aft.

2.2.2 Measuring Distance and Velocity

The method of measuring the distance from radar to a target robot and the robot's relative velocity depend on the type of radar system employed. Millimeter-wave radar systems for automotive application include pulse radar, frequency-modulated continuous-wave (FM-CW) radar and spread spectrum radar. The newly developed millimeter-wave radar is based on the FM-CW radar system.
The FM-CW radar system allows a simple construction of the RF circuit. Moreover, this system has often been adopted for automotive millimeter-wave radars because it can measure both the distance to a target and the target's relative velocity simultaneously. The measurement principle of the FM-CW radar system is shown in Fig. 1. The radar transmits a frequency modulated millimeter-wave signal, and the signal reflected by a target is received by the radar. By mixing the received and transmitted signals, the system obtains a beat signal having a frequency of f_b. This beat signal features a time delay due to the distance from the radar to the target and a Doppler shift due to the relative velocity of the target. The range to the target, R, and its relative velocity, V, are found with the following equations using the pair of beat signal frequencies, f_{b1} and f_{b2}. These beat signals are obtained from the pair of frequency-modulated waves having different time variations.

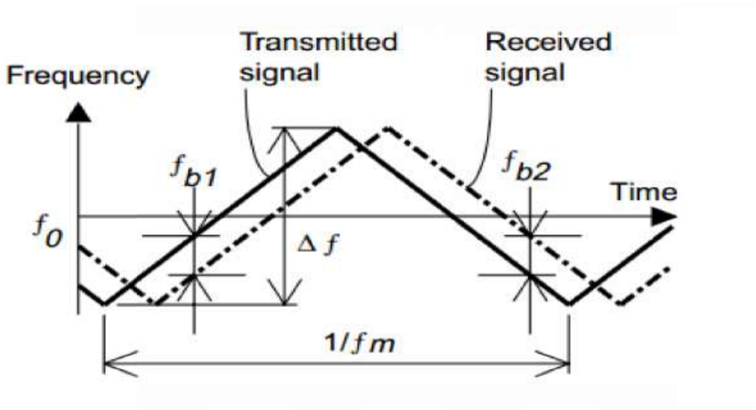


Fig. 1 Frequency-time relationships in FM-CW radar.

$$R = \frac{(f_{b1} + f_{b2})c}{8 f_m \Delta f} \quad \text{.............................} \quad \text{(Eq. 1)}$$

$$V = \frac{(f_{b2} - f_{b1})c}{4 f_0} \quad \text{.............................} \quad \text{(Eq. 2)}$$

where c is the velocity of light, f_0 is the center frequency, f_m is the modulation frequency and Δf is the maximum frequency deviation.

2.2.3 Masuring the Azimuth

The monopulse method illustrated in *Fig. 2* is often used to measure target azimuth. The reflected signals from the same target are received as two beams having different directions. The azimuth is determined according to the following procedure from the received field intensity of the two beams.

i. The difference and the sum of field intensities for the two beams are obtained for each angle. A discrimination curve that shows the relationship between the angular-error signal voltage ε and the azimuth θ is obtained. The angular-error signal voltage is obtained by normalizing the difference signal with the sum signal.
ii. The reflected signals from the same target are received as two beams having field intensities of α and β. The difference δ between these two intensities, and their sum σ, are then calculated.
iii. For these pairs of field intensities, the ratio of the difference to the sum (δ/σ) is compared with the angular-error signal voltage of the discrimination curve. And then the azimuth θt of the target is uniquely identified.

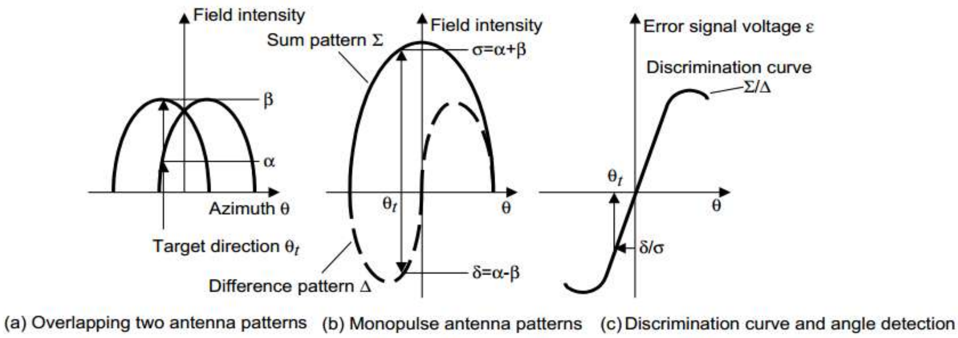


Fig. 2 Monopulse radar signal processing.

In order to obtain two beams, a sequential lobbing method is adopted in this radar for automotive use. For this purpose, a mechanical scanning method with an antenna radiating a single beam is adopted.

2.3 Flight Termination System

The Flight Termination of the Amibot is autonomous and after finishing its task it terminates and power supply cuts off automatically. And the robot lands from where it was started on its own. There is no requirement of interaction of Man in this system.

3. Payloads

3.1 Guidance, Navigation and Control Sensors

The vehicle is made from a 3DRobotics Iris quadcopter with the following equipment:

Flight Controller (FC):

- Pixhawk
- 32-bit STM32F427 Cortex M4 core with floating point unit.
- 32 bit STM32F103 failsafe co-processor
- 168 MHz/256 KB RAM/2 MB Flash
- OS: NuttX RTOS
- Firmware: APM:Copter 3.1 (open source)

Sensors:

- ST Micro L3GD20H 3-axis 16-bit gyroscope
- ST Micro LSM303D 3-axis 14-bit accelerometer / magnetometer
- Invensense MPU 6000 3-axis accelerometer/gyroscope
- MEAS MS5611 barometer

Power System:

- Ideal diode controller with automatic failover
- Servo rail high-power (7 V) and high-current ready
- All peripheral outputs over-current protected, all inputs ESD protected

ELECTRONIC SPEED CONTROLLERS (ESC)

The ESC as used in radio controlled craft performs two primary functions. The first is to act as a Battery Elimination Circuit (BEC) allowing both the motors and the receiver to be powered by a single battery. The second (and primary) function is to take the receiver’s and/or flight controller’s signals and apply the right current to the motors.

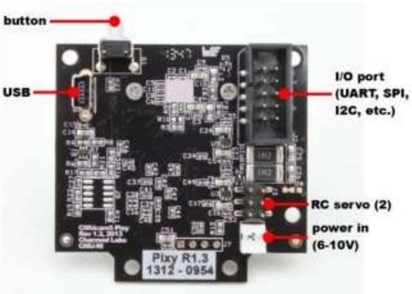
Each BLDC motor need an ESC .ESC Regulates power to the motor according to the input throttle level. It also provides +5V power for the flight electronics.ESC is built on 32 bit Microcontroller (ARM/AVR) & has an array of MosFets to drive BLDC motor. The Firmware of ESC is factory programmed.

3.2 Mission Sensors

The vehicle will have two control systems on board, a Pixhawk flight controller (FC) to keep the UAV stable and an autopilot (AP) to map and fly the UAV as well as accomplish target identification. With vision module of robot we can process the image of the target

CMUcam5 Pixy

- Processor: NXP LPC4330, 204 MHz, dual core
- Image sensor: Omnivision OV9715, 1/4", 1280x800
- Lens field-of-view: 75 degrees horizontal, 47 degrees vertical
- Lens type: standard M12 (several different types available)
- Power consumption: 140 mA typical
- Power input: USB input (5V) or unregulated input (6V to 10V)
- RAM: 264K bytes
- Flash: 1M bytes
- Available data outputs: UART serial, SPI, I2C, USB, digital, analog
- Dimensions: 2.1" x 2.0" x 1.4
- Weight: 27 grams



LITHIUM POLYMER BATTERY

Lithium Polymer –LIPO are a type of rechargeable battery that has taken the electric RC world by storm, especially for Quadcopters. They are the main reason electric flight is now a very viable option over fuel powered models.

LiPo batteries are light in weight & hold huge power in a small package. They have high discharge rates to meet the need of powering quadcopters.

4. OPERATIONS

4.1 Flight Preparations

Check List(s)

1. Make sure the power of battery is full
2. Check 77GHz connection
3. Check 4x motor controller
4. Check 4x motor blade orientation
5. Check RC radio
6. Check the status of quadrotor and the connection of avionics
7. Power on, check the switch of control rights
8. Check the communication between the quadrotor and the ground station

Once the physical check has been completed, a functionality test must be done:

1. Program the ON board computer flight controller
2. Power ON 2.4GHz transceiver
3. Power ON Radar and supply power to Pixy Camera
4. Check LED indicators
5. Run onboard self-diagnostic program
6. Run automated checklist
7. Test by making a simple flight

MAN/MACHINE INTERFACE

The Interaction between the Man and Machine is reduced to almost zero during the mission in process. And before launching and after finishing of the mission the Man has full control over the robot. During the mission the robot keeps on sending the stats and the report of the ground robots that are in the arena and those who have cleared the green line.

5. RISK REDUCTION

The Safety is first and the system is designed to be safe and secure for all the persons present around the arena during the flight of the robot. Many levels of risk reduction have been put in place in order to prevent personal injury and damage to hardware. The robot status is always monitored by ground station software module and our team of AMIBOT.

5.1 Vehicle Status

The ground station monitors many properties of the quad including roll, pitch, yaw, height, motor commands, laser scan data and camera images. The ground station will display the status and save them for further analysis.

Shock/Vibration Isolation

The primary source of vibration onboard vehicle is the propulsion system. The shock is from the rotation of motors, we use anti-vibration pad to reduce the shock. We also use rubber washers to retard the shock and at the same time filter in the software is being used to reduce the effect of shock. AMIBOT is balanced propellers to reduce the shock and vibrations.

Safety

To ensure the safety of people and the vehicle, a series of tests should be taken before the flight, as mentioned in checklist. We have already taken safety into account when designing the system. Firstly, we use small prop protection. Then we designed two emergency schemes. One is that we can stop the propellers via the data link between the ground station and quad. The other one is that we can take over the quad through one channel of RC controller. These two schemes uses different data link, improving the system security redundancy.

Modeling

Testing

The AMIBOT test flight is done and it is able to fly and gives a up time of 40 minutes maximum and when loaded it is giving performance as desired to stand in the mission till the end with full stability.

CONCLUSION

In this paper we have seen that there is another alternative solution for the navigation of the ROBOT. With the help of Milliwaves radar we can have highly precise navigation and as there is added vision sensors which is used by Pixy camera finding the targets are just as easy as cutting a pie. The propellers used are so made that they make the least vibration in the frames and the stability of the robot is as accurate as it is desired to get the required result.

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