UNMANNED FLYING BULLET BLOCKING ROBOT

Udhaya Kumar Senthil
Departement of Mechanical Engineering, MVJ College of Engineering, Bengaluru, India

ABSTRACT

The goal of this project is to create a bullet blocking robot which would protect a soldier infield. The role played by the robot is to detect a bullet, calculate the bullet's present position, estimate its trajectory and predict a future point to intercept the target by using a bullet proof material. The robot is constructed with raspberry pi zero microprocessor programmed using the NOOBS under the platform python. The distance to the target is measured using semi circulation technology with three CMOS cameras which are placed on an extended front part of a drone (hexacopter) that could cover an angle of 180 degree. Using a PID controller the target will always be under the cameras vision, allowing the high torque servomotor holding the bullet proof material to move in one direction while the cameras follows the bullet and its motion on the other hand. Another PID controller for the odometry is used together with two alpha-beta filters that improves the distance measurements by reducing noise in the measurements. The algorithms were successfully implemented and the accuracy depends on the fps of the camera. The bullet blocking robot is fixed to a hexacopter which has the ability to hold position in the air and to follow the soldier. The drone is constructed using arducopter flight controller programmed by various algorithms using the software mission-planner. The bullet proof material is made of combination of Kevlar fabric and special resins in an order.

KEY WORDS: Raspberry pi zero, CMOS, PID, ODOMETRY, FPS, Arducopter flight controller

I. INTRODUCTION

In the last decennium, robotics has grown from a simple vision to a reality; they now exist in industries and one among the common people. The level of detail that robots can extinguish, accuracy and the speed they operate in, as well as the ability to operate day and night differs greatly from what humans are capable of.

The idea is therefore seen with a great army concern perspective. The introduction of robotics has grown widely over the years and many are now trying to incorporate the concept to fit in with society. One of those steps is to try to introduce the concept of automation into defence.

A. Problem Formulation

The purpose of the project is to create a bullet blocking robot attached to an autonomous drone that intercepts a perfectly aimed bullet using raspberry pi zero. In order to do this, the robot needs to gather information and solve the following tasks.

1. Target (bullet) detection.
2. Always track (trace) the path of target, keeping visual contact.
3. Position and velocity determination of target.
4. Position determination of the bulletproof material.
5. Trajectory estimation and position prediction of the target.
6. Interception of target at predicted position

II. SPECIFICATION OF THE DRONE

The drone normally used here is a hexacopter which can lift up to 3 kg mass.

FRAME : F550
MOTOR : BR2212 1000Kv
PROPELLER : GEMFAN 1045 SF

BATTERY :ZOP LIPO 9000 MAH
FLIGHT CONTROLLER : APM 2.8
TRANSMITTER AND RECEIVER : FLYSKY i6
NUMBER OF CHANNELS PRESENT: 6
CHANNELS USED : 6

III. HARDWARE TOOLS

A. Raspberry pi zero

It is a 1GHz single-core CPU which has 512MB RAM. The various input ports are Mini HDMI port, Micro USB OTG port, Micro USB power HAT-compatible 40-pin header Composite video and reset header, CSI camera connector [6]. It has the capacity of taking input signals In, processing them and sending the output signals to the specified location.

B. Arducopter APM 2.8

The APM 2.8 is a complete open source autopilot system. It allows us to turn any fixed, rotary wing or multirotor vehicle into a fully autonomous vehicle; capable of performing programmed GPS missions with waypoint. This board has an onboard compass, which is designed for vehicles (especially multicopters) where the compass should be placed as far from power and motor sources as possible to avoid magnetic interference. (On fixed wing aircraft it's often easier to mount APM far enough away from the motors and ESCs to avoid magnetic interference, so this is not as critical, but APM 2.8 gives more flexibility in that positioning and is a good choice for them, too). This is designed to be used with the 3DR uBlox GPS with Compass, so that the GPS/Compass unit can be mounted further from noise sources than APM itself.
APM 2.8 requires a GPS unit for full autonomy [9][10].

C. CMOS Camera

CMOS sensor is a 13 Mp camera which can goes up to 900 fps in bright mode

1.Property Value Unit
2.Optical size 1/3.07 inch
3.Pixel size (μm) 1.12 micrometer
4.Number of pixels 13M pixels
5.Output pixels 4208(H)×3120(V) -
6.Frame rate (full) 30 (normal mode: progressive) fps
7.Frame rate (1080p) 120 (normal mode: progressive) / 240 (bright mode: interlace) fps
8.Frame rate (720p) 120 (normal mode: progressive) / 240 (bright mode: interlace) fps
9.Frame rate (QVGA) 480 (normal mode: progressive) / 900 (bright mode: interlace) fps
10.Frame rate (VGA) 240 (normal mode: progressive) / 480 (bright mode: interlace) fps
11.Power supply voltage (analog) 2.8 +/- 0.2 V
12.Power supply voltage (digital) 1.2 +/- 0.1 and 1.8 +/- 0.1 V
13.Power supply voltage (IO) 1.7 to 3.0 V
14.Operational Temperature(Topr) -20 to 60 degC
15.Storage Temperature(Tstg) -40 to 85 degC
16.I/F (serial) CSI-2 4lanes
17.Control interface I2C

Its frames per second vary according to the programming and resolution. Since, the position of the bullet to be tracked is as much as fast the velocity of the light, The fps should be maximum. So, that accuracy of the processing will be under manageable level [11].

D. Motors

The servo motors have built-in reduction gear assemblies with internal optical rotary encoders (tachometers) that sense their rotations within two degrees of accuracy. Here we use two 9g metal gear servo motors connected together opposite to each other.

IV. SOFTWARE TOOLS

A. Mission planner

Mission planner is software which converts the inputs to complicated algorithms and uploads them to the flight controller. It helps us to set the altitude hold mode to the specific channel, follow a specific path by waypoints, and switching of channels. This software is responsible for the autonomous flying of the drone which holds the robot.

B. Raspbian

Raspbian is an operating system in which the matlab and mission planner software run simultaneously. The programming's done in the raspberry pi zero works on this OS [1][2]. It plays a major role in the project, since the matlab sostware process the image obtained from the camera according to our program. This OS is installed into the microprocessor using a special

external device called "noobs". Before sending the OS to the raspberry pi zero, all the softwares are embedded in to this external device and attached to the raspberry pi zero.

C. Matlab

This software plays a major role in the working. The image so obtained from the CMOS camera is processed by this software according to the conditions set by us. The image is plotted in to grids and each grid is analyzed with the inputs given in the program. If the conditions are satisfied, then the output signals are sent to the specific hardware.

V. FILTERS AND REGULATORS

A. Alpha-Beta filter

The filters and regulators used in the project have been alpha-beta filters. As measurements often contain a lot of noise and errors it is of great importance to be able to parry such events. A simple and effective way to enhance a defence mechanism for these events would be to implement a filter. For position and velocity measurements, the simplest filter would be an alpha-beta filter.

VI. ROBOT CONSTRUCTION

The bullet blocking robot is a robot which blocks a bullet coming towards the soldier. The robot is attached to a drone which can fly autonomously. The drone is programmed in such a way that it can with hold its position in the air and follows the soldier when he moves. The drone can lift up to a weight of 3 kg. Three cameras are mounted on the third motor which is attached on the drone. Its rotational capacity is 150 degrees, 75 degrees in both directions. These cameras are connected to the raspberry pi zero (microprocessor) which process the image obtained from the camera. The middle (v4) camera is a more accurate but limited to short ranges, used only to center the target when able to detect. The outer cameras are separated from each other. The bullet proof block is controlled using two servo motors which are rotatable forwards and backwards according angular velocity. The signals for the operation of servo motor is given by the raspberry pi zero (microprocessor).

VII. BLOCK DIAGRAM

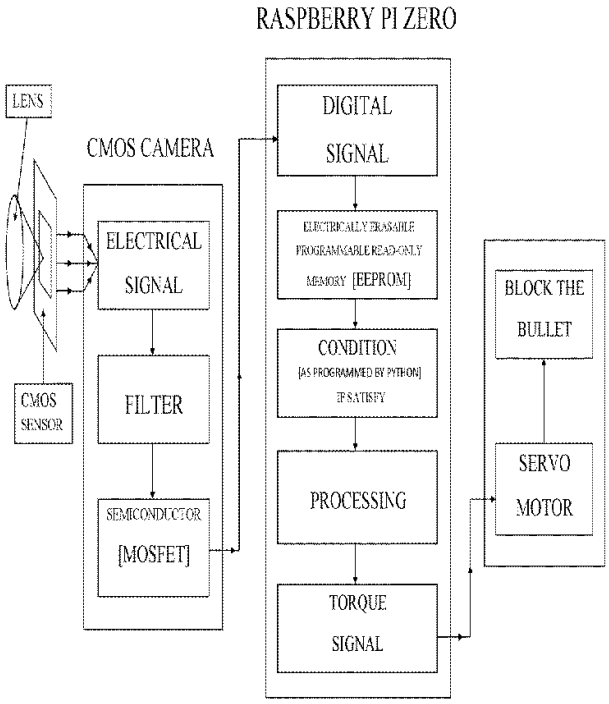

Figure.1.0 Processing of Unmanned Bullet Blocking Robot

A. Explanation

As represented in the figure 1.0 diagram, the main components involved are: the Lens of camera, CMOS Sensor, CMOS camera, Raspberry pi zero and the Servo motor.

The light from the object strikes the lens of the camera, the camera consists of several photo sensors that detect light and the semiconductors convert these light rays into electrical signals. There may be several such light rays that is detected by the photo sensors, so once converted into electrical signals, they are collected as a whole and amplified to obtain a uniform single range of electrical signal.

The signal so obtained is allowed to pass through filters; the filter used is a "α-β Filter". The signals or image so interpreted, might consists of some blurs or noise or errors , such noise or errors are cleared or enhanced by these filters. Hence filters play a major role in increasing the accuracy and enhancing the detected image.

MOSFET -Metal oxide semiconductor field effect transistor [4]. The MOSFET is connected parallel to the camera and the Raspberry Pi Zero. As the accuracy of image is

increased and enhanced, the heat generated and the power consumed is also high, hence the MOSFET plays a major role by consuming less voltage in such conditions. When the images taken passes through the gates, there are chances for the gates to function reversely, hence MOSFET also prevents any such reverse transition [5].

Raspberry Pi Zero is a microprocessor that is connected to the camera. The electrical signals obtained from the camera, is fetched into it. It converts and functions the signals according to the programming set into it. The input fetched into it is represented and interpreted graphically(x-y positions) and functioned according to the desired program.

The programming so used here, is the python program. The desired specifications required to detect an object is fed into it. Some specifications may include – pixels, color, velocity or any other conditions. If the condition as set in the program is satisfied, the desired object is detected and hence, further action can be executed.

The output so obtained is fed into the servo motor and the further execution takes place.

VIII. TARGET DETECTION

The matlab CamView software is used to configure the color maps used for object detection. Once the CMOS Cams are connected to the software they are ready to capture an image of the target. The target in the project is a 200 degree Celsius fast-moving bullet. After an image of the bullet has been captured, a color map is selected corresponding to all shades and colors of the Bullet. Colors are shown as ranges of red, green and blue. After the desired color ranges are selected they are uploaded to the matlabCam. Raspbian support functions to retrieve direct information from the cameras. Run them in the matlab. The image of the bullet in the air obtained is divided into grids by the matlab, then the calculation takes place as per the program we have done I the raspberry pi zero. Since the cameras tracking resolution are already known we can calculate in pixels how much the tracked object is to the left or right of the camera center.

If the bullet is to the right of the center the difference is positive, otherwise negative.

IX. POSITION DETERMINATION

Three positions are especially important to determine, relative a global reference system that is established at the start of a run. The bullet proof material position using odometry, the target bullet's position using semicirgulation and the predicted interception point using matlab[7][8].

A. Semicirgulation

The coordinates and distance to the target (bullet) relative to the bulletproof material's Cameras can be calculated with semicirgulation which is the process of determining the location of a point by measuring the angles to it from known multiple points . The three cameras mounted on the drone covers a certain angle in which the image of the bullet can be captured. The region covered by the camera is around 180 degree which forms a semicircle.

X. TRAJECTORY ESTIMATION AND INTERCEPTION

One important part of the work has been to find a good interception point for the bulletproof material to intercept the bullet, together with trajectory estimation. To do so, the accuracy plays a major role. The speed of the camera and the processing time taken by the microprocessor decides the perfect interception point.

A. Working of raspberry pi zero

Since the trajectory of the bullet is a straight line, theoretically, it becomes possible to measure the position of the bullet at different time points and estimate a trajectory all the way to the target line. This can be done by minimizing the least squares to determine the point of where the bullet will cross the target. Setting the speed of the bullet proof material accordingly to the bullet, the bullet proof material can either intercept at the final moment of when the bullet crosses the soldier or simply head for the interception point at maximum speed and wait for the bullet to arrive. When the camera sees the bullet for the first time, it starts a timer that ticks up at every iteration the bullet lies in the cameras field of vision. The program saves the position of the bullet at every iteration. When the timer hits a specific value for how many measurements to use, the algorithm fits a straight line to all measurement that was collected by minimizing

the least-squares. At this point the robot still has not moved, until the last measurement has been collected. The fact that the bullet will follow a straight line, and that the robot begins at the origin of every experiment, the trajectory can be calculated and where the interception point will be. Instead of intercepting the bullet at the last iteration, it is possible to minimize the distance which the robot will travel. This can be calculated by using the perpendicular distance to the estimated trajectory. Once again the speed of the bullet proof material can be set accordingly to the bullet, if the material should intercept the moment it reaches the interception point or simply by heading there first and wait for the bullet to arrive.

The basic idea of this intercept algorithm is to be able to predict a future position of the bullet and move the servo toward that position and reach it at the same time as the bullet At first, it might appear that the predicted interception point is simply the point along the trajectory of the bullet that is closest to the location of the robot. This is called the shortest-distance problem, where the shortest distance from a point to the line is along a line segment that is perpendicular to the line. This might not necessarily be the interception point because the shortest-distance problem does not consider the relative velocities between the material and the bullet. To find the point where the material and the bullet will meet at the same time, one must consider their relative velocities. So, instead of just knowing the bullet's current position, the robot also must know the bullet's current velocity, that is, its speed and heading. This information will be used to predict where the bullet will be at some time in the future. Then, that predicted position will become the target toward which the servo will head to make the interception.

The robot must then continuously monitor the bullet's position and velocity, along with it's own, and update the predicted interception point accordingly. This facilitates the robot changing course to adapt to any evasive maneuvers the bullet might make due to friction or inclination in the air. How far ahead the prediction the bullet's position should occur depends on the relative positions and velocities of both the robot and the bullet. With this information the bullet's velocity relative the global reference system is found.

XII. CONCLUSION

All theory in the software relied on the target detection and its measurements of position. If the detection were lost, last position and velocity would be

Presumed and the alpha-beta filter would estimate the next position. These measurements came strictly from the cameras and would only work when both cameras could detect the bullet. If only one camera could detect the bullet, the robot would follow the bullet using the angle between robot and bullet instead of the predicted intercept point.

When the bullet and servo was in motion at the same time, the outer cameras used for position determination had major difficulties detecting the bullet. Therefore no good measurements could be established in that aspect.

If the drone is targeted, then the whole system would be collapsed?

To avoid that, the propellers of the drone are secured with the bullet proof material and since the drone is flatter the probability of drone hit by a bullet is less.

What is the motivation behind participation?

The project is an inspired version of "Robot goalkeeper". The project is a modified form of Robot goalkeeper. The purpose of using this modified view in the field of defence, is to try and contribute for the wellness of the lives of people working for nation. This competition gives us a chance and platform to work as a team and present our idea to the nation. We wish to contribute to one of the most thriving body in nation, the Defence!

Futuristic scopes are Innovative idea through diagrams and explanation.Concept will be depicted through animation Concept paper presentation.Working model and finally implementing it on the field to save the ones who saves the nation.

Further advancements are infusing composites to the bullet proof material so that the impact of the bullet on the drone is reduced [3].

Built in armor for the drones so that it is able to target the bullet and strike it before head as of anti missiles.

XI. REFERENCE

[1] Python Reference Manual, 2006, [online] Available: http://docs.python.org/ref/ ref.html.

[2] D. Ascher, Numerical Python, 2001, [online] Available: http://numpy.scipy.org.

[3] D Varas, J A Artero-Guerrero, J Pernas-Sánchez, J. López-Puente, "Analysis of high velocity impacts of steel cylinders on thin carbon/ epoxy woven laminates", *Composite Structures*, vol. 95, pp. 623-629, Jan. 2013

[4] M. S. Merzoug, F. Naceri, "Comparison of Field-Oriented Control and Direct Torque Control for Permanent Magnet Synchronous Motor (PMSM)", World Academy of Science Engineering and Technology, 2008.

[5] Rosheila Darus, Josep Pou, Georgios Konstantinou, Salvador Ceballos, Ricard Picas, Vassilios G. Agelidis, "Modified Voltage Balancing Algorithm for the Modular Multilevel Converter: Evaluation for Staircase and Phase-Disposition PWM", IEEE Trans. Power Electron., vol. 30, pp. 4119-4127, August 2015.

[6]http://www.raspberrypi.org/products/raspberrypi-pi-zero/

[7] http://link.springer.com/chaptr/10.1007/978-3-540-25940-4_15

[8]http://www.iml.fraunhofer.de/de/en/fields_of_activity/machines_and_facilities/integration_of_sensor_systems/automatic_goal_keeper.html

[9] ardupilot.org/copter/docs/initial-setup.html

[10] ardupilot.org/copter/docs/mission-planner-overview.html

[11] http://www.mindsensors.com