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Personal Autonomous Non-Collision Based Hovering Robot(PANTHER)

Ashwini Iral Barboza, Jason Elroy Martis, Balasubramani R

Department of Information Science and Engineering, NMAM Institute of Technology, Nitte

Karkala, Karnataka, India

ABSTRACT This paper presents a framework for smart autonomous flying using image processing and an on-board camera implemented using AR Drone which allows the users to perform very specific missions in various fields. The main focus was on developing an intelligent application that recognizes objects and humans with colors and implements other operations of a drone. PANTHER synonym for Personal Autonomous Non-collision based Hovering Robot is a quadcopter which is intelligently programmed and is used to perform autonomous missions. PANTHER can be piloted effectively in urban environments for research and assist missions. The base for the project used is Parrot AR Drone 2.

KEYWORDS: AR Drone; PANTHER; Quadcopter; Image processing; Haar Cascade

I. INTRODUCTION

In today's environment, mobile devices are most preferred. The invention of new devices such as Google watches or drone offer new opportunities to the active researches which are used in various domains. Throughout the recent history, humans and robots have been the best of friends in various fields. Robots are constantly evolving, as a result we have ever more intelligent and human like robots. Drone is basically a flying robot which supports additional features.

An unmanned aerial vehicle (UAV), commonly known as a drone is an aircraft without a human pilot aboard which is controlled either autonomously by onboard computers or by the remote control of a pilot on the ground or in another vehicle [1]. In the recent years drones got smaller in size and their functionality increased rapidly. Personal robots and assist bots are very common nowadays. The idea of an intelligent hovering robot can open up various possibilities in every direction. PANTHER synonym for Personal Autonomous Non-collision based Hovering Robot is a drone which is intelligently programmed and used to perform autonomous missions which is implemented using AR Drone.

This paper demonstrates how a drone is used to track trajectory movements using a frontal camera and keep a safe distance from them using a Drone SDK on visual studio 2012.The main focus and motivation of this was to develop a ground control station for a drone, so that a user may dynamically control the drone. In computer vision applications, tracking objects is a problem. The drone detects the most appropriate shape and avoids itself from collision.

This is useful in variety of applications. The main ones are aerial photography, defense, journalism and civil applications.

II. CONCEPT

The primary objective of this project has been implemented using the Drone SDK 2.0.1 on visual studio 2012. Each control variable is set using the drone parameters such as the yaw, pitch and roll values. Object detection was implemented using AForge libraries and HSL color filters for accurately tracking colored objects. Haar Cascade Algorithms for image processing were used to detect and track a human. The Ffmpeg libraries help in video conversion and processing and allow record and playback applications.

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The Drone SDK helps to write applications to remotely control the drone. It is currently provided as an open source library with high level API's. It includes the AR.Drone Library (ARDroneLIB) that provides the APIs required to easily communicate and configure an AR Drone product; the AR.Drone Tool (ARDroneTool) library, which provides a fully functional drone client where developers only have to insert their custom application specific code; the AR.Drone

Fig. 1 Parrot AR DRONE 2

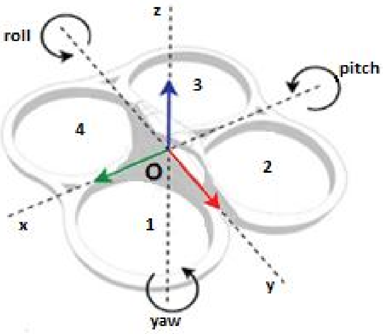

Fig.2 Helicopter quadcopter

Control Engine library which provides an intuitive control interface developed by Parrot for remotely controlling the AR Drone product[2].

III. AR DRONE QUADCOPTER

AR Drone as shown in Fig.1, is a project that was started by a French company Parrot which is a radio controlled flying quadcopter aimed at producing a micro Unmanned Aerial Vehicle(UAV).The drone is designed to be controlled by mobile or tablet operating systems such as the supported iOs or Android within their respective apps or the unofficial software[3].The flight of AR Drone depends on several factors such as speed, altitude which is set by the parameters and the surrounding factors such as existence of nearby objects.

The Parrot AR Drone 2 has 1GHz 32 bit ARM CortexA8 processor with 800MHz video DSP TMS320DMC64x, 60fps vertical QVGA camera for ground speed measurement, 4 brushless in-runner motors ,3 axis gyroscope 2000^o /second precision, 3 axis accelerometer +-50mg precision, 3 axis magnetometer 6^o precision and ultra-sensors for ground altitude measurements[4].

The quadcopter model is shown in Fig 2. Let us assume that the center of gravity for quadcopter is O. The movements are noted by:

- Pitch-Rotational movement along the x axis.
- Roll-Rotational movement along the y axis.
- Yaw-Rotational movement along the z axis.

Thus the drone can fly giving the sequence of movements by varying the above parameters.

IV. SYSTEM ARCHITECTURE

The base of this project is Parrot AR Drone 2 and a laptop with the following hardware specifications: Intel Pentium 41.4GHz or equivalent AMD processor, 2GB RAM, 2GB swap space, Wi-Fi enabled system, 4GB free hard drive space, graphics card and an onboard camera on quadcopter.

The software specifications used are: Microsoft Windows 7 Professional operating system, Visual Studio 2012, C# programming language with all required references, Direct X 10.0 or above, Windows development Toolkit, AR Drone 2.0 SDK.

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V. IMPLEMENTATION

The implementation of PANTHER is shown in Fig.3.The image is extracted from the live feed and is filtered using Euler's or HSL filters. Shape detection is done by recognizing the rectangular blob and then it is mapped onto the image coordinate system. Once the object is detected Drone automatically starts tracking the object or settles in hover. When the human tracking option is enabled, the done starts tracking the upper body of the humans in its vision range and draws a quadrilateral, the drone then moves according to the human's motion. The Speed of the Drone dynamically changes depending upon the speed of the object.

A. *Filtering*:

Two filters are used namely HSL filters and Euler filters.HSL stands for hue, saturation and lightness. The HSL filter operates in HSL color space and filters pixels, whose color is inside/outside of the specified HSL range . It keeps pixels

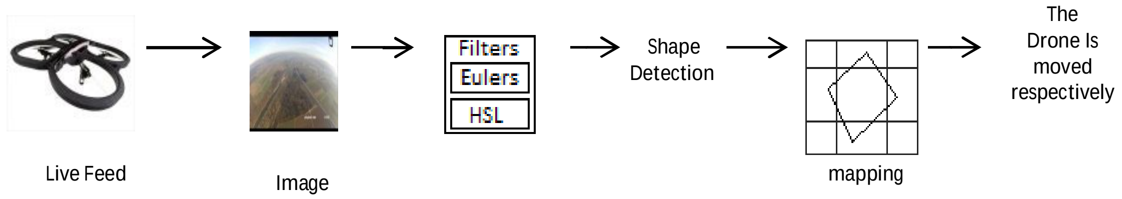

Fig. 3 Drone Implementation

with colors inside/outside of the specified range and fills the rest with specified color[5]. This filter is used to recognize the three basic colors red, blue, and green using the Aforge.Imaging.Filters namespace. The Euler filter chooses on a sample-by-sample basis between the possible Euler angles representation of each 3D rotation in the data set in such a way as to preserve the continuity of the Euler angle time series, without changing the actual 3D rotations [6].

B. *Shape Detection:*

Once the filtering is complete, shape detection is implemented using the Aforge.NET namespace. Aforge.NET is an open source C# framework designed for developers and researchers in the fields of image processing. The framework is comprised by the set of libraries and sample applications, which demonstrate their features. Aforge.Imaging is used for image processing routine; Aforge.Vision is used for computer vision library; Aforge.Video is used for video processing [7]. BLOB processing is used to extract the desired object by searching for separate object and manipulating them. This can be done by detecting regions in a digital image that differ in properties, such as brightness or color, compared to surrounding regions [8].

C. *Mapping:*

Mapping can be done in two ways:-

- Mapping with image coordinates using Distance Formula

$$d = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2} \quad (1)$$

Where d is the distance between (X_1, Y_1) and (X_2, Y_2).

- Mapping with real world coordinates using trial and error method can be done in the following way. The value of roll which is along the Y-axis is varied from -1 to 1. For every float value from -1 to 1 we find the distance covered in real world.

Mapping from image coordinates to the real world coordinates can be done using linear interpolation. For each float value of -1 to 1, we calculate the real distance and image distance. This gives the ratio, i.e.

$$\text{Ratio} = \frac{\text{Real Distance}}{\text{Image Distance}} \quad (2)$$

D. *Movement of the drone:*

The object would be moving .Hence the ratio obtained is multiplied with the image distance to get the real distance and select the corresponding float value.

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Real Distance=Ratio*Image Distance (3)

The application is designed to automatically map the speed of the drone to the speed in which the object is moved. The speed mapping is done using Linear Interpolation to successively identify the speed of the object. This value is then sent to the SDK and is the speed with which the Drone needs to be moved to capture the object.

Object detection:-To determine the direction of movement of the Drone the coordinate plane in divided into 9 unequal sections based on the bitmap quadrants and are numbered as shown in Fig 4.

Human Detection:-Haar Cascade is used along with OpenCV for human detection. A Haar-like feature considers adjacent rectangular regions at a specific location in a detection window, sums up the pixel intensities in each region and calculates the difference between these sums. This difference is then used to categorize subsections of an image[9]. The upper body is detected using upper body Haar cascading algorithm. The algorithm draws a quadrilateral around the upper body. This quadrilateral of the upper body is divided into 9 unequal subsections as shown in Fig 4.

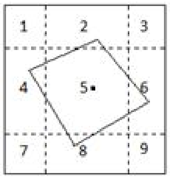

Fig. 4 Subsections of the quadrilateral

The center of the object is determined. The center of the object has to lie on the 5th section. The movement of the objects to the other sections from the 5th section determines the direction the Drone should move. The direction of movement of the Drone according to the direction the object is moved is found from the TABLE I given below.

The calculated values are passed to the drone, i.e. the speed, real distance and the direction. The drone then makes appropriate changes to its yaw, pitch and roll variables.

TABLE I
DIRECTION OF MOVEMENT OF DRONE

Movement from the 5th section	**Direction**
1	North-East
2	North
3	North-West
4	East
5	Hover
6	West
7	South-East
8	South-West

E. *Layered Diagram:*

The major components used in the implementation of PANTHER are shown in Fig 5. In the PANTHER application, the control of the drone movements such as yaw, pitch, roll is implemented using Drone SDK and these values are passed through Wi-Fi on a laptop as AT commands to the Drone. Object and human tracking is implemented using the Aforge libraries and EmguCV. EmguCV is a cross platform .Net wrapper to the OpenCV image processing library allowing OpenCV functions to be called from .NET compatible languages[10] .

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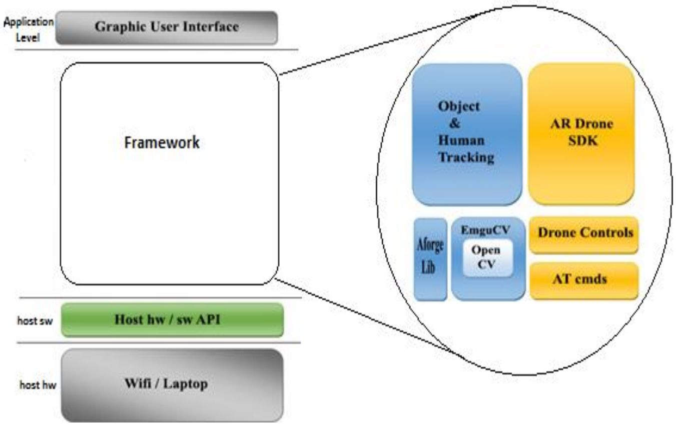

Fig. 5 Layer Diagram for PANTHER Implementation

VI. RESULTS

From trial and error method it can be noted that the ratio i.e. the real distance by image distance is equal to 4.0.Hence

Real Distance=4.0*Image Distance (4)

With the graphical representation of the distance versus float values calculated manually, it is concluded that the speed versus distance gives us a linear graph with small errors as shown in Fig. 6

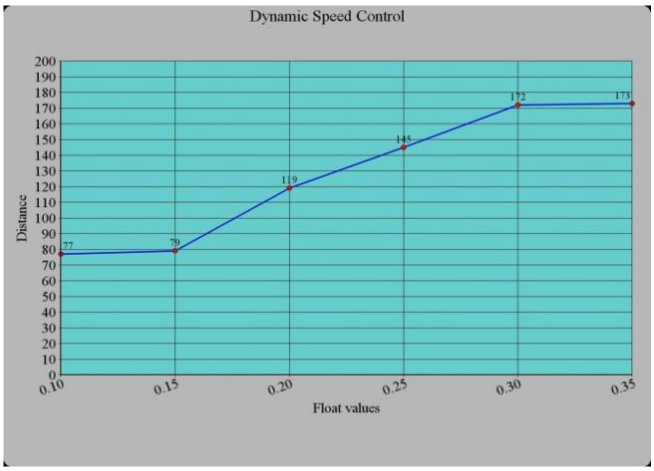

Fig. 6 Dynamic Speed Control in Object Tracking

The test cases for the various modules concluded the following results qualitatively as shown in the TABLE II.

TABLE II
TEST CASE RESULTS FOR THE MODULES

Module	Procedure	Accuracy
Object detection	Nil	20%
Object detection	Euler color Filters	50%-80%
Object detection	HSL color Filters	50%-80%
Object detection	BLOB processing	90%
Drone Movement Trajectory	Static	40%
Drone Movement Trajectory	Dynamic	89%
Human Detection	Haar Cascade	80%

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VII. CONCLUSION AND FUTURE WORK

Personal Autonomous Non-collision based Hovering Robot using AR Drone 2.0 can be piloted for various applications especially in search and assist missions. The colored object detection and tracking is tested in the indoor environments and is found to be 90%accurate using BLOB processing. Human Detection is 80% accurate for varying distances. The use of simple techniques makes the implementation simpler and effective.

Dynamic speed method can be further be improved by using depth sensors. Since Haar cascade have limitations, the efficiency can further be increased using HOG filters.

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BIOGRAPHY

Ashwini Iral Barboza is a Final year Engineering student of the Information Science Department, NMAM Institute Of Technology ,Nitte ,Karnataka, India. Her research interests are Algorithms, web 3.0 etc.