ISBN 978-93-84422-22-6
Proceedings of 2015 International Conference on Image Processing, Production and Computer Science (ICIPCS'2015)
Istanbul (Turkey), June 3-4, 2015 pp.68-74

Hardware Development and Implementation of an Object Tracking Algorithm for UAV Applications

Dr.Senthil Kumar K[1], Mohamed Rasheed A[2] Vairamanikandan K[3]
[1]Associate Professor, [2]Research Scholar, [3]P.G Scholar
Department of Aerospace Engineering, Division of Avionics,Madras Institute of Technology,
Anna University,Chennai,Tamil Nadu India.

Abstract: *The task of reliably detecting and tracking the moving objects in surveillance video forms a basis for higher level intelligence applications. This project aim is to develop the Hardware and to implement an object tracking algorithm. The tracking technique uses CAMSHIFT algorithm to detect moving objects and generate reliable tracks from real-time surveillance video. In mean shift algorithm there are many limitations and one of the most important is that the window remains the same size when object is farther away or very close to camera, so it is necessary to adapt the window size with target size and rotation. The solution for this problem is Continuously Adaptive Mean shift algorithm. It applies mean shift first, once mean shift converges it updates the size of the window. It also calculates the orientation of best fitting ellipse to it. Again it applies the mean shift with new scaled search window and previous window location. Window adaptation keeps continuing throughout of Tracking. This Tracking technique is implemented in arduino hardware with Pan-Tilt mechanism. Raspberry Pi is also used to implement CAMSHIFT algorithm here. Raspberry Pi is widely used for video processing and it is fit for UAV related surveillance applications as it has less weight with more functionality for video processing. Pan-Tilt mechanism is made by using two servo motors. Here, Pan-Tilt mechanism is used for real-time tracking of the target. For UAV application, overall communication for real-time tracking is also taken care by Raspberry Pi.*

Keywords: *Surveillance, Hardware, CAMSHIFT algorithm, Mean-shift algorithm, Raspberry Pi, Pan-tilt, UAV*

1. Introduction

Object tracking is an important task in the field of computer vision. The proliferation of high-powered computers, the availability of high quality and inexpensive video cameras, and the increasing need for automated video analysis has generated a great deal of interest in object tracking algorithms. There are three key steps in video analysis: detection of interesting moving objects, tracking of such objects from frame to frame, and analysis of object tracks to recognize their behaviour. In its simplest form, tracking can be defined as the problem of estimating the trajectory of an object in the image plane as it moves around a scene.

To address the challenging issues of object tracking and improve tracking accuracies, many tracking approaches have been proposed in the past, such as histogram-based mean-shift methods, contour based tracking method, feature-based tracking methods, and the tracking-by-detection method, that are quite popular in recent years. Objects are also represented by complex models so as to acquire more information, including feature points, primitive geometric shapes, object silhouette, etc. However, most of these methods are computationally intensive while achieving better tracking accuracy, and thus hardly be applied to real-time applications.

Histogram based mean shift methods are well known for their simplicity and high processing speed, which generally apply an iterative mean-shift procedure to find the local mode that is considered as the object's new location. One of them is the continuously adaptive mean-shift (CamShift) algorithm that can adapt to the object's scale and rotation changes. But due to its simplicity, CamShift is suffered from some challenging situations, e.g., confusing background and fast object motion. Some approaches have been presented in recent

http://dx.doi.org/10.17758/UR.U0615020

years to gain better performance by applying a modified version of CamShift or combining CamShift with other approaches. This work addresses the question of building an active tracking system consisting of the ordinary Pan-tilt mechanism to achieve the real-time tracking performance relying on color, density and spatial cues.

2. Object Tracking Using Camshift Algorithm

CAMSHIFT stands for the “Continuously Adaptive Mean-shift Tracking” algorithm. Figure 1.Summarizes this algorithm. For each video frame, the raw image is converted to a color probability distribution image via a color histogram model of the color being tracked, e.g., flesh color in the case of face tracking.

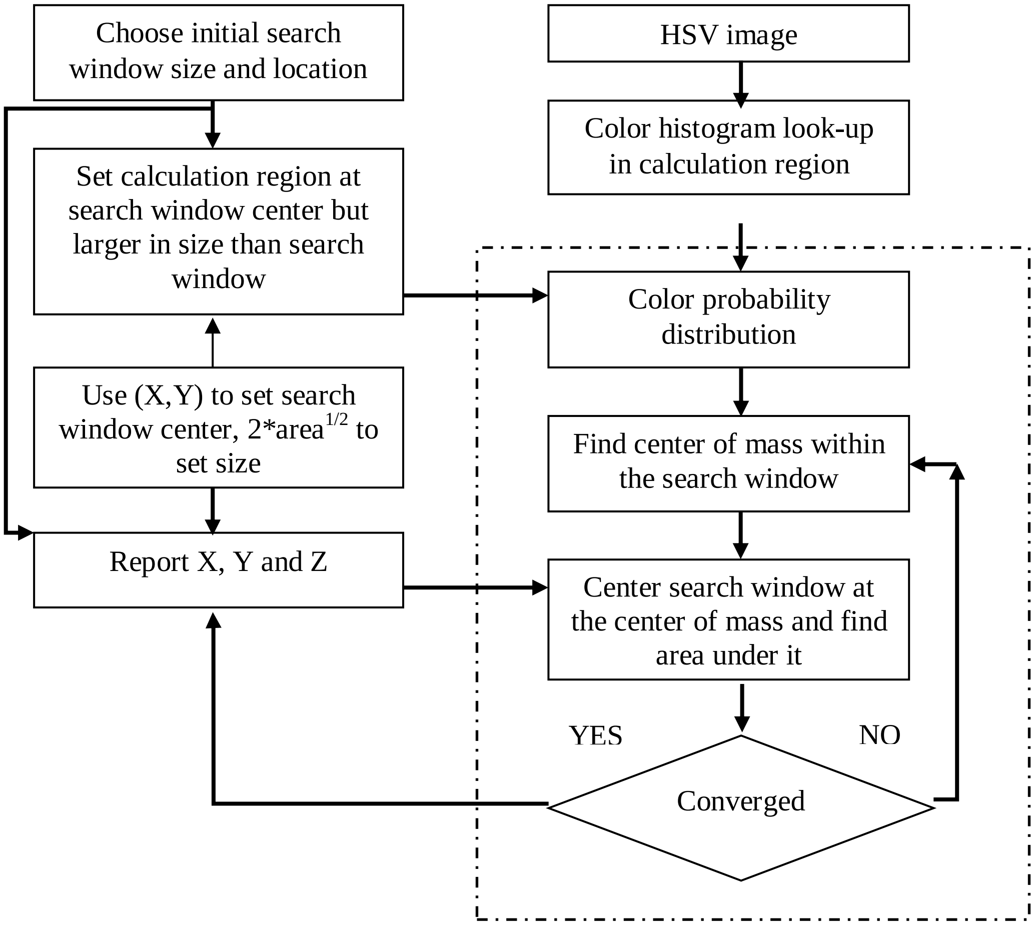
Choose initial search window size and location
HSV image
Set calculation region at search window center but larger in size than search window
Color histogram look-up in calculation region
Color probability distribution
Use (X,Y) to set search window center, 2*area$^{1/2}$ to set size
Find center of mass within the search window
Report X, Y and Z
Center search window at the center of mass and find area under it
YES
NO
Converged

Fig. 1: CAMSHIFT Algorithm

The Continuously Adaptive Mean Shift Algorithm (CAM Shift) is an adaptation of the Mean Shift algorithm for object tracking in an arbitrary number and type of feature spaces. The algorithm is based on modification of mean shift concept, calculates the probability density of the image of the distribution and iterates in the direction of the maximum probability density (mode). It computes probability distribution at each frame continuously.

The CAMSHIFT part of the Algorithm is as follows which is shown in Figure 1.

- Choose a search window size.
- Choose the initial location of the search window.
- Compute the mean location in the search window.
- Center the search window at the mean location computed in Step 3.
- Repeat Steps 3 and 4 until convergence (or until the mean location moves less than a preset threshold).

The orientation (θ) and scale is defined and the length (l) is defined based on the intermediate values as follows

$$a = \frac{M_{20}}{M_{00}} - x_c^2 \tag{1}$$

$$b = 2\left(\frac{M_{11}}{M_{00}} - x_c y_c\right) \tag{2}$$

$$c = \frac{M_{02}}{M_{00}} - y_c^2 \tag{3}$$

Where Xc and Yc are mean search window location.
Where M_{00} is the Zeroth moment and M_{11}, M_{20} and M_{02} are first and second moments of X and Y.
From these intermediate values the orientation and scale is defined as

$$\theta = \frac{1}{2}\tan^{-1}\left(\frac{b}{a-c}\right) \tag{4}$$

Where a,b and c are intermediate variables.
The distance l_1 and l_2 from the distribution is defined as

$$l_1 = \sqrt{\frac{(a+c)+\sqrt{b^2+(a-c)^2}}{2}} \tag{5}$$

$$l_2 = \sqrt{\frac{(a+c)-\sqrt{b^2+(a-c)^2}}{2}} \tag{6}$$

Based on these values of scale and orientation, the new position is determined and shifted.

3. Hardware Development

Initially MATLAB was used for implementing the CAMSHIFT tracking algorithm as it is a high-level language and interactive environment for numerical computation, visualization, and programming. But it lags for Real time applications so here OpenCV library is used with python programming language. OpenCV (Open Source Computer Vision) is a library of programming functions mainly aimed at real-time computer vision.Currently OpenCV is the most comprehensive open source library for computer vision and it has large user community. OpenCV has more functions for computer vision than Matlab. Many of its functions are implemented on GPU.

Here Arduino UNO Board is used with Pan-Tilt mechanism to implement CAMSHIFT algorithm and also it is implemented in Raspberry Pi for UAV related surveillance applications.Raspberry Pi is widely used for video processing and it is fit for UAV related surveillance applications as it has less weight with more functionality for video processing. Pan-Tilt mechanism is made by using two servo motors. Here, Pan-Tilt mechanism is used for Real-time tracking of the target. Thus overall communication for real-time tracking from UAV is also taken care by Raspberry P.

3.1 Tracking Objects with Arduino

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet) which has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

The Arduino integrated development environment (IDE) is a cross-platform application written in Java, and derives from the IDE for the Processing programming language and the Wiring projects. The Arduino Uno can be programmed with the Arduino IDE. The ATmega328 on the Arduino Uno comes preburned with a boot loader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol.

Arduino programs are written in C or C++. The Arduino IDE comes with a software library called "Wiring" from the original Wiring project, which makes many common input/output operations much easier. Users only need define two functions to make an executable cyclic executive program:

- setup(): a function run once at the start of a program that can initialize settings
- loop(): a function called repeatedly until the board powers off

3.1.1 Visual C++ IDE for Tracking

Microsoft Visual C++ (often abbreviated as MSVC or VC++) is a commercial (free version available), IDE product from Microsoft for the C, C++, and C++/CLI programming languages. It features tools for developing and debugging C++ code, especially code written for the Microsoft Windows API, the DirectX API, and the Microsoft .NET Framework. Here programming part is taken care by this IDE.

3.1.2 Pan-Tilt Platform

In the laboratory implemented tracking system Logitech Webcam C170 is used. Two servos are used for creating Pan-Tilt mechanism. Two Servos are used for tracking the object in both horizontal and vertical direction.

The Pan-Tilt platform with camera made is shown in Figure 2. The signal for servos will be sent from the Visual C++ IDE and it rotates the camera with 20ms delay for every angle or input given from the IDE.

3.1.3 Tracking Objects with Pan-Tilt Camera

Steps Followed in Tracking using Opencv, Visual Studio C++, Arduino and Servo:

- The Webcam sends video frames to the Microsoft Visual C++ compiler which contains Open CV library running on PC.
- The algorithm which is coded in c++ detects the image of the object from the webcam.
- The CAMSHIFT algorithm is compiled in Visual C++ IDE which calculates the co-ordinates in X, Y axis.
- The corresponding co-ordinates are sent to the servo motors.
- After receiving the co-ordinates the servo motors moves accordingly in X and Y direction and follows the object.

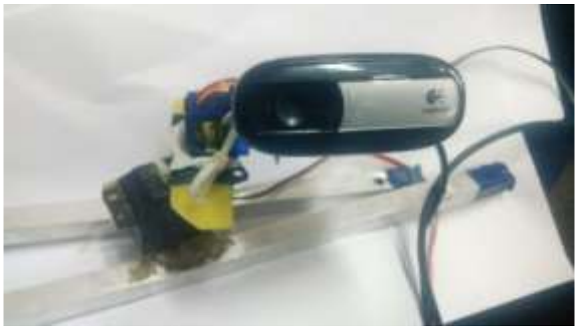

Fig. 2:Pan-Tilt Platform with Camera

3.2 Tracking Objects with Raspberry Pi

The Raspberry Pi is a credit-card sized computer that plugs into your TV and a keyboard. It is a capable little computer which can be used in electronics projects, and for many of the things that your desktop PC does, like spreadsheets, word-processing and games. It also plays high-definition video.

Raspberry Pi is the minicomputer which is capable of doing multi-tasking unlike micro-controller boards.So for image processing related applications processing speed will be high.The Raspberry Pi primarily uses Linux kernel-based operating systems. Python is the default programming language and also interfaces of python with Linux easy so it is quite possible to implement the algorithm in Raspberry Pi.

With the above setup, videos can be wirelessly transmitted through using VNC server and client software. Here Tight VNC server and client is used for transmitting wirelessly.

Steps followed in tracking objects using Raspberry Pi:

- Raspberry Pi is connected and the communication should be made wirelessly using the TightVNC software.
- Program is compiled through Python IDE.
- Region of interest for tracking is given remotely.
- Object will be Tracked based on CAMSHIFT algorithm.

4. Results

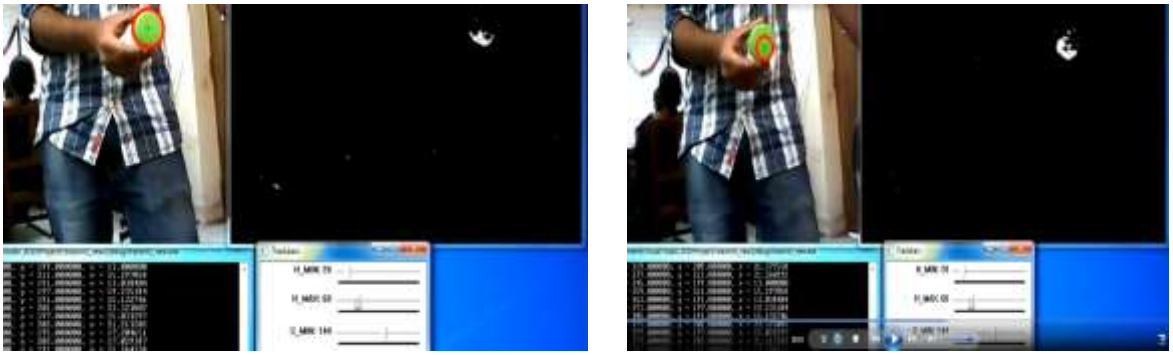

Fig. 3:Tracking results using Arduino

In above Figure 3, Green color object is tracked using Arduino. Using this whole setup in UAV tracking can be achieved using CAMSHIFT algorithm. To make it more independent Raspberry Pi is used to track the object wirelessly by placing it as a payload in UAV. In Figure 4, Book is tracked using Raspberry Pi. Thus, by using more resolution camera it can be implemented in UAV and the results will be better.

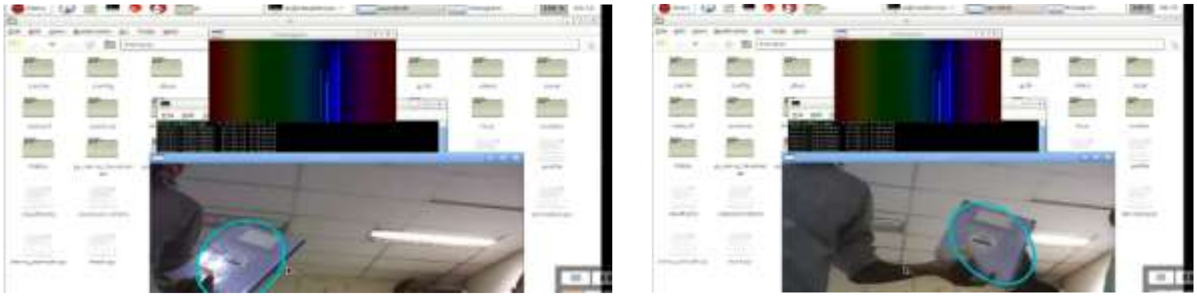

Fig. 4:Tracking results using Raspberry Pi

The set up is realized in hardware in a Quadcopter DHAKSHA shown in figure 5. Dhaksha is the Unmanned Aircraft System (UAS), developed by the faculty and research students team at Madras Institute of Technology (MIT) campus of Anna University, Chennai, Tamil Nadu, India. The vehicle is designed for higher endurance and to fly in high altitude to record and deliver stabilized and high definition data in real time.

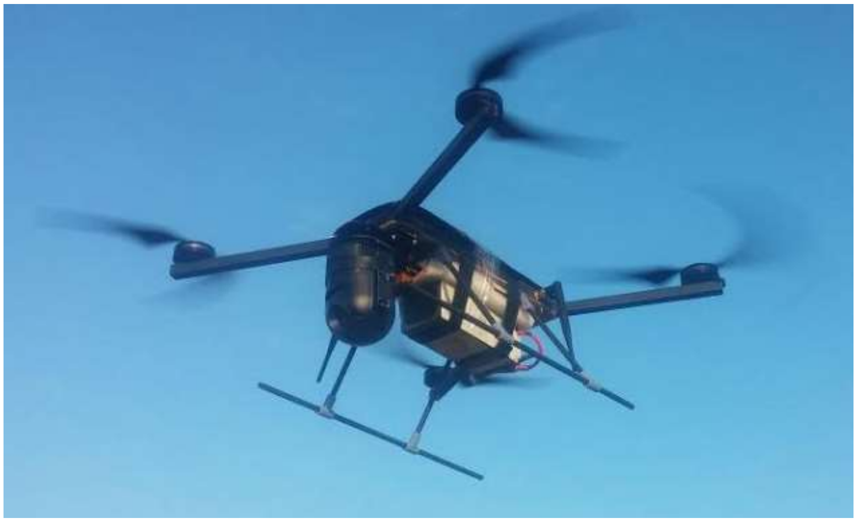

Fig. 5 :Quadrotor DHAKSHA

With the camera mounted in the UAV DHAKSHA, the video data is transmitted to the Ground control station and processed to track the objects in real time. The figure 6 and 7 shows sample frame of the proposed CAMSHIFT tracking algorithm.

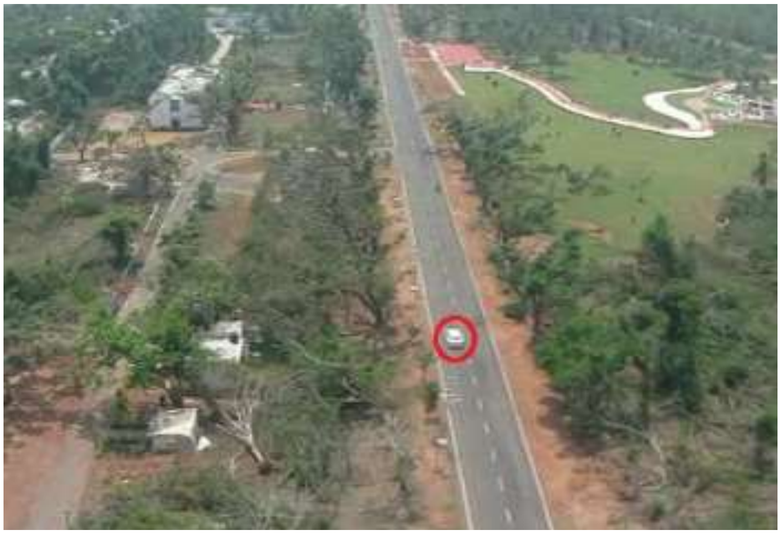

Fig 6: Target tracking – a car as target

http://dx.doi.org/10.17758/UR.U0615020

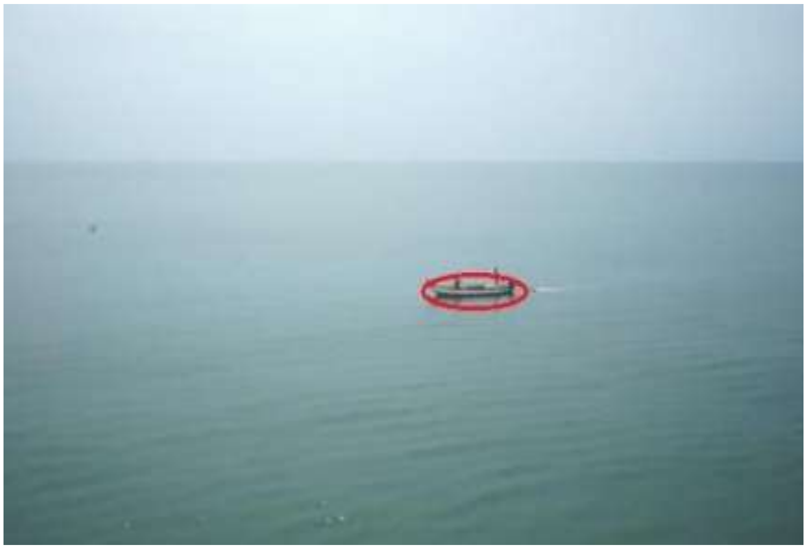

Fig 7 : Target tracking – a boat as target

In figure 6, a car on the highway is defined as target and tracked by the UAV. In figure 7, a boat is considered as target and tracked by UAV. The video is taken at Eastern coast of Chennai,Tami Nadu,India during the coastal surveillance operation to check the intruders via sea way.

5. Conclusion

Thus the Hardware was developed for object tracking and also implemented for tracking objects using CAMSHIFT. The algorithm is robust for the objects having high hue difference from the background. It also adapts for objects' variable size by altering its window based on the object movement. So, it is highly suitable for dynamic environment which is highly essential and also it has many uses right now in UAV video tracking, game, and 3D graphics' control. Arduino with Pan-Tilt mechanism for target tracking is implemented successfully. Raspberry Pi is used for UAV related surveillance applications.

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