A mean-shift algorithm based autonomous visual tracking for micro aerial vehicles

International Journal of Recent Trends in Engineering & Research
ISSN(ONLINE) : 2455-1457 IMPACT FACTOR : 3.344

A Mean-Shift Algorithm Based Autonomous Visual Tracking for Micro Aerial Vehicles

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Abstract—The main objective is to track the Ground Moving Target continuously with Mean-Shift Visual Tracking Algorithm from On-board Autonomous Visual Tracking System. On-board Autonomous Visual Tracking System contains Gimbaled Camera, Inertial Navigation System / Global Positioning System, Image Tracking Software, Micro Aerial Vehicle Guidance Law, Camera Control Law and Autopilot. A Mean-Shift Algorithm is incorporated in the Image Tracking Software. This Algorithm identifies and tracks the Ground Moving Target based on its 2D colour space histogram. A Graphical User Interface based tool was developed for simulation and test the Autonomous Visual Tracking with Mean-Shift Algorithm performance using MATLAB. The experimental results exhibits that the Mean-Shift Algorithm identifies and tracks the GMT very accurately.
Keywords—Autonomous Visual Tracking System; Global Positioning System; Graphical User Interface Development Environment; Ground Moving Target; Image Tracking Software; Inertial Navigation System; Mean Shift Visual Tracking Algorithm; Micro Aerial Vehicle; Small Unmanned Aerial Vehicle.

I. INTRODUCTION

Micro Aerial Vehicle (MAV) is a Small Unmanned Aerial Vehicle (SUAV) that has a size restriction and controlled by On-board Autonomous Visual Tracking System (AVTS). These MAVs are used to monitor the environment where human beings or ground vehicles are not accessible. These MAVs are built for various purposes such as military applications [1,2] and civil applications [3,4,5,6,7]. On-board AVTS [8,9,10,11,12] contains subsystems such as the Gimbaled Camera, INS / GPS, Image Tracking Software, MAV Guidance, Camera Control and Autopilot [13,14,15,16,17,18,19].

On-board AVTS receives the real-time video frame sequence from Gimbaled Camera. A Mean-Shift Algorithm is incorporated in the Image Tracking Software, which provides the GMT position and GMT velocity in the world coordinate frame. This visual tracking algorithm identifies the GMT based on its colour space histogram [20,21,22,23,24]. It searches the nearness of the previous position in the area that matches the best property [25,26,27,28,29]. On-board INS / GPS sensor is used for measures the MAV present position and velocity. Based on the above computed and measured GMT position and GMT velocity, On-board AVTS computes the MAV Guidance Law and Camera Control Law for continuous GMT tracking from MAV.

The main motivation is to identify the GMT in an image sequence and tracks the GMT continuously with the Mean-Shift Visual Tracking Algorithm [30,31,32,33,34].
A 3D Demonstration of AVTS is shown in Fig. 1.

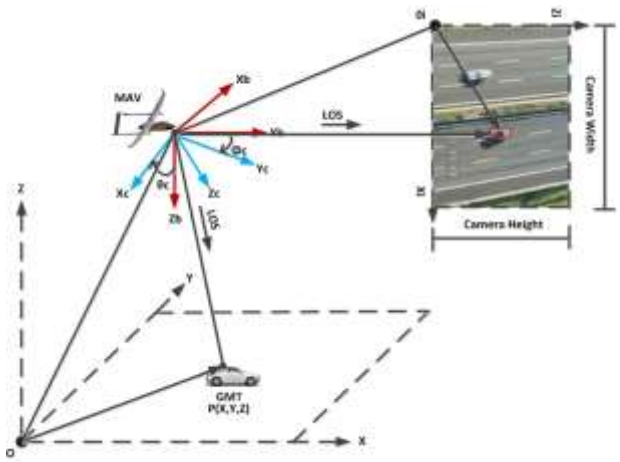

Figure 1. 3D Demonstration of AVTS.

The sections are structured as: Section II, A Mean-Shift Algorithm Based Autonomous Visual Tracking. Section III, On-board Autonomous Visual Tracking System Simulation. Section IV, Experimental Results. Section V, Conclusions.

II. A MEAN-SHIFT ALGORITHM BASED AUTONOMOUS VISUAL TRACKING

This Mean-Shift Algorithm identifies and tracks the Ground Moving Target (GMT) based on its 2D colour space histogram.
A Flow Chart of Mean-Shift is shown in Fig. 2.

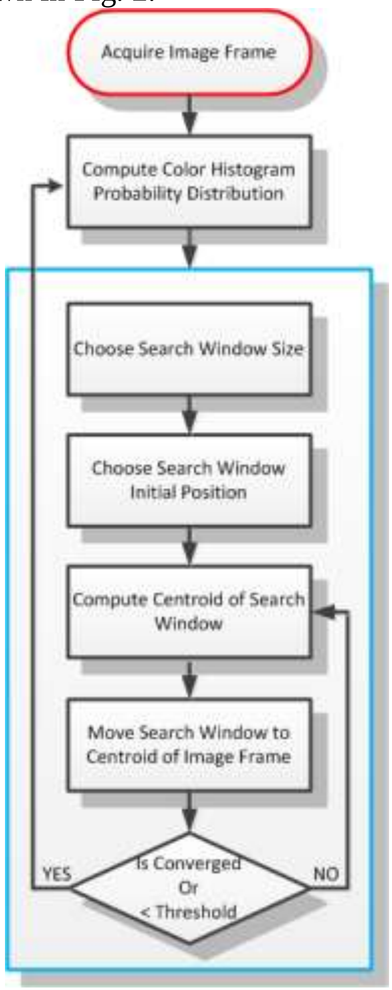

Figure 2. Flow Chart of Mean-Shift [35].

The Mean-Shift [35] steps are:

Step 1, Acquire Image Frame: Acquire the image frame from video sequences.
Step 2, Calculate Colour Histogram Probability Distribution: Calculates the colour histogram probability distribution.
Step 3, Select Size of Search Window: Select the size of the search window.
Step 4, Select Initial Position of Search Window: Select the initial position of the search window.
Step 5, Calculate Centroid of Search Window: Calculate the centroid position of the search window based on colour histogram probability, is as follows:
In the Image, Image(i, j) is a pixel colour histogram probability distribution value, i and j are the x-axis and y-axis values along the search window. The zeroth-order moment of GMT for the position (i, j), as follows:

$$GMT_{00} = \sum_i \sum_j \mathrm{Image}(i, j) \tag{1}$$

The first-order moment of GMT for the position i, as follows:

$$GMT_{10} = \sum_i \sum_j i * \mathrm{Image}(i, j) \tag{2}$$

The first-order moment of GMT for the position j, as follows:

$$GMT_{01} = \sum_i \sum_j j * \mathrm{Image}(i, j) \tag{3}$$

The search window centroid, S(i_c, j_c), as follows:

$$i_c = \frac{GMT_{10}}{GMT_{00}} \tag{4}$$

$$j_c = \frac{GMT_{01}}{GMT_{00}} \tag{5}$$

Step 6, Move Search Window to Centroid of Image Frame: Center the search window at the centroid position, S(i_c, j_c), computed in Step 3.
Step 7, Check Search Window Center Converged to Centroid of Image Frame or Less than Preset Threshold Value: Repeat Step 5 and Step 6 until the Search Window Center Converged to Centroid of Image Frame or the Search Window Center moved to a less than the given threshold value.
These steps are iteratively run in order to track GMT continuously.

III. ON-BOARD AUTONOMOUS VISUAL TRACKING SYSTEM SIMULATION

On-board Autonomous Visual Tracking System (AVTS) of Micro Aerial Vehicle (MAV) contains Gimbaled Camera, INS / GPS, Image Tracking Software, MAV Guidance Law, Camera Control Law and Autopilot [36,37,38,39,40,41,42,43,44,45,46,47,48,49,50].

A Simulation of AVTS is developed with MATLAB GUIDE R2011a tool as shown in Fig. 3.

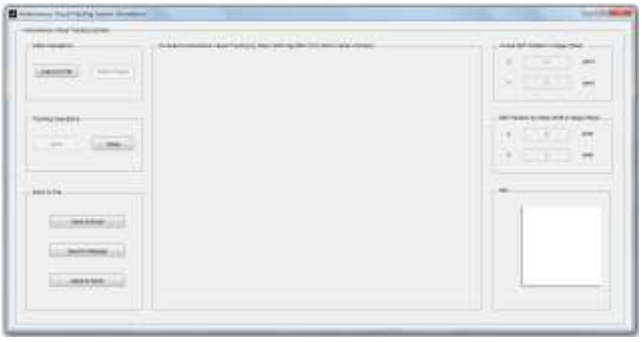

Figure 3. A Simulation of AVTS.

The main purpose of AVTS simulation is to identify and track the GMT continuously from MAV. We implemented Mean-Shift in MATLAB. The implemented algorithm is included in AVTS simulation.

IV. EXPERIMENTAL RESULTS

We have considered the aerial tracking video [51] as an input for the GMT tracking simulation purpose.
The GMT tracking by the Mean-Shift is shown in Fig. 4.

Figure 4. GMT tracking by the Mean-Shif.t

We considered the input video frame size (X, Y) as (640, 480) pixels, whereas input video frame resolution is 640x480 pixels. We have given 12 input video frame sequences in AVTS to experimental results analysis.
In AVTS, the actual GMT position in the video frame is marked with red "+" and stored the actual GMT position (X, Y) pixels. In AVTS, the computed the GMT position of Mean-Shift in the video frame is marked with red rectangle and stored GMT position by Mean-Shift as (U, V) pixels, is shown in a Table. 1.

Table 1 Actual GMT Position (X, Y) Vs GMT Position by Mean-Shift (U, V) (in Pixels).

Frame Number	Actual GMT Position (X, Y)	GMT Position by Mean-Shift Algorithm (U, V)	Error (δX, δY) = (Actual GMT Position - GMT Position by Mean-Shift Algorithm)
1st-Frame	(378, 234)	(357, 205)	(21, 29)
2nd-Frame	(381, 232)	(367, 206)	(14, 26)
3rd-Frame	(387, 233)	(366, 207)	(21, 26)
4th-Frame	(390, 234)	(373, 208)	(17, 26)
5th-Frame	(390, 234)	(367, 210)	(23, 24)
6th-Frame	(392, 236)	(364, 212)	(28, 24)
7th-Frame	(392, 237)	(369, 213)	(23, 24)
8th-Frame	(393, 237)	(371, 214)	(22, 23)
9th-Frame	(393, 237)	(369, 215)	(24, 22)
10th-Frame	(391, 239)	(371, 214)	(20, 25)
11th-Frame	(391, 239)	(369, 218)	(22, 21)
12th-Frame	(391, 241)	(370, 219)	(21, 22)

The captured results of GMT tracking by the Mean-Shift (Frame-by-Frame) is shown in Fig. 5.

Figure 5. GMT tracking by the Mean-Shift (Frame-by-Frame).

Using AVTS, we can export the actual GMT position data and the GMT position by Mean-Shift data to Microsoft Word, Microsoft Excel and Microsoft Notepad for off-line analysis.

We calculated the error in the GMT position (δX, δY) between the actual GMT position (X, Y) and the GMT position by Mean-Shift (U, V) in pixels.

In AVTS, the experimental results of the actual GMT position and the computed GMT position by Mean-Shift are plotted on a graph, as shown in Fig. 6.

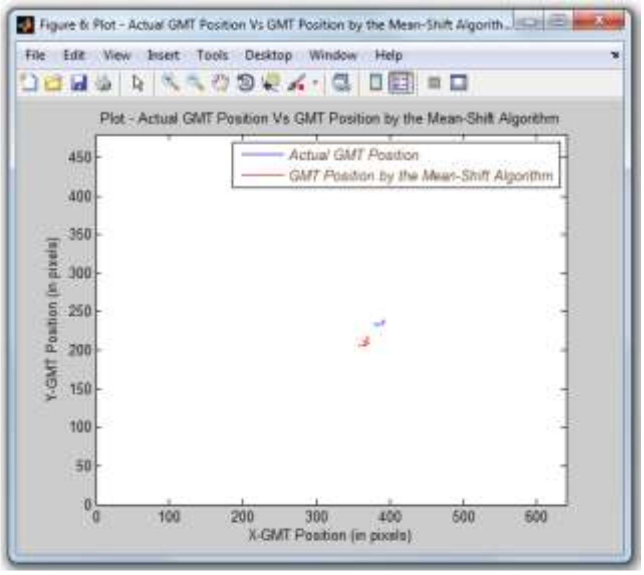

Figure 6. Actual GMT Position Vs GMT Position by the Mean-Shift.

On the graph, we considered the GMT position (X, Y) as (640, 480) pixels. The blue trajectory of the graph indicates the actual GMT position and the red trajectory GMT position by Mean-Shift.
The captured results prove that the Mean-Shift identifies and tracks the GMT very accurately.

V. CONCLUSIONS

A Mean-Shift is explained along with algorithm usage. A Simulation of Autonomous Visual Tracking System is developed using MATLAB. A Mean-Shift is implemented in MATLAB. The implemented algorithm is included in Autonomous Visual Tracking System simulation. The Autonomous Visual Tracking System is tested on the input video of aerial tracking and observed the Mean-Shift performance. The simulated results prove that the Mean-Shift identifies and tracks the GMT very accurately.

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