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Research Article

AN EFFICIENT APPROACH OF AUTONOMOUS VISUAL TRACKING FOR MICRO AERIAL VEHICLES

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ABSTRACT

An efficient image tracking algorithm plays a major role in an autonomous surveillance and monitoring the environment from micro aerial vehicle. An efficient approach of autonomous visual tracking algorithm is proposed and applied to an on-board autonomous visual tracking. This proposed algorithm identifies and tracks the ground moving target continuously based on its 2D color space histogram. A MATLAB based simulation tool is developed for determining the proposed autonomous visual tracking algorithm performance. The experimental results exhibit that the proposed approach of autonomous visual tracking algorithm tracks the ground moving target very accurately.

INTRODUCTION

The scope of computer vision usage is rapidly increasing from complex military applications [1] to commercial applications such as using Micro Aerial Vehicles (MAVs) [2], [3], [4], [5] or Small Unmanned Aerial Vehicles (SUAVs) [6], [7], [8] to perform surveillance [9], [10], [11] and monitoring the environment [12], [13], [14] where human beings are not accessible [15], [16], [17]. These MAVs are in very small size. These MAVs are operated by Autonomous Visual Tracking System (AVTS) from On-board or Ground Control System (GCS) [18], [19].

On-board AVTS contains small Gimballed Camera and along with an efficient approach of autonomous visual tracking algorithm [20], [21], [22], [23], [24]. Even though, the MAV guidance and Camera control algorithm are used to operate MAV autonomously in the real world environment, the computer vision based visual tracking algorithm [25], [26], [27], [28] also very useful in the autonomous surveillance and monitoring the environment. Due to the use of computer vision algorithm [29], [30], [31], [32], [33], we can reduce the expenses, improve quality and increase environmental safety.

The experimental simulation described in this paper allows determining the proposed autonomous visual tracking algorithm performance. The Ground Moving Target (GMT) is detected based on image processing techniques such as the template of the GMT or color space histogram. We considered an efficient approach of Cam-Shift algorithm in the autonomous visual tracking software, which identifies the GMT based on its color space histogram [34]. The autonomous visual tracking software extracts the object of interest or GMT from the video sequence. This autonomous visual tracking software draws a rectangular box around the object of interest or GMT. Later, this algorithm searches the neighborhood of the previous position in the region that best matches the property of GMT [35]. The autonomous visual tracking software provides the GMT state to the On-board AVTS. On-board GPS/INS measures and provides the present position and the velocity of MAV to the On-board AVTS. Based on the above computations, an On-board AVTS computes and provides the MAV Guidance, Camera Control to the MAV for operating the

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MAV such way that the GMT continuously in the range of vision of On-board Gimballed Camera.

The main motivation is to identify the GMT, apply the efficient approach of Cam-Shift algorithm and tracks the GMT continuously from an On-board AVTS.

The Block Diagram of an On-board AVTS is shown in Fig. 1.

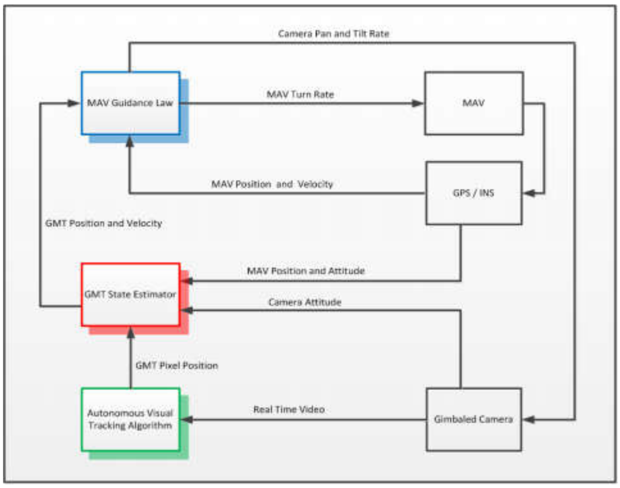

Fig. 1 A 3D Demonstration of an On-board AVTS

The paper contains the below sections: Section II, An Efficient Approach of Autonomous Visual Tracking Algorithm. Section III, An On-board AVTS Simulation. Section IV, Experimental Results. Section V, Conclusions.

An Efficient Approach of Autonomous Visual Tracking Algorithm

Acquire the input image frame from the camera, enhance the image frame using Retinex algorithm, apply the Cam-Shift algorithm and process the output image frame.

The Cam-Shift (Continuously Adaptive Mean-Shift) algorithm [36], [37], [38] computes the color histogram probability distribution to identify the GMT based on maximum density of the samples [39], [40].

The proposed efficient approach of autonomous visual tracking algorithm [41]:

Step 1, Acquire the Image Frame*:* Acquire the $\text{Image}(x_i, y_i)$ frame from video sequences.

Step 2, Apply the Image Pre-processing Algorithm*:* Enhance and improve the $\text{Image}(x_i, y_i)$ frame using a Retinex image pre-processing algorithm.

Step 3, Select the Initial Search Region Size and Position*:* Select the initial search region around the GMT in the Image (x_0, y_0) frame.

Step 4, Set the Calculatation Region of the Image Probability Distribution*:* Set the calculated region in the $\text{Image}(x_i, y_i)$ frame.

Step 5, Check the Color Histogram in the Image Calculation Region*:* Check the color histogram in the $\text{Image}(x_i, y_i)$ frame the calculation region of the HSV (Hue, Saturation, Value) image.

Step 6, Compute the Image Color Histogram Probability Distribution*:* Compute the $\text{Image}(x_i, y_i)$ frame color histogram probability distribution.

Step 7, Calculate the GMT Center in the Search Region*:* Calculate the GMT center (GMT_{11}, GMT_{20}, GMT_{02}) in the search region.

The pixel value of GMT position x in the $\text{Image}(x_i, y_i)$ is x_i, the pixel value of GMT position y in the $\text{Image}(x_i, y_i)$ is y_i, the pixel value of GMT position in the $\text{Image}(x_i, y_i)$ is (x_i, y_i), the GMT second-order moment is GMT_{11}, as follows:

$$GMT_{11} = \sum_{x_i}\sum_{y_i} x_i * y_i * \text{Image}(x_i, y_i) \tag{1}$$

The pixel value of GMT position x in the $\text{Image}(x_i, y_i)$ is x_i, the pixel value of GMT position in the $\text{Image}(x_i, y_i)$ is (x_i, y_i), the GMT second-order moment is GMT_{20}, as follows:

$$GMT_{20} = \sum_{x}\sum_{y} x_i^{2} * \text{Image}(x_i, y_i) \tag{2}$$

The pixel value of GMT position y in the $\text{Image}(x_i, y_i)$ is y_i, the pixel value of GMT position in the $\text{Image}(x_i, y_i)$ is (x_i, y_i), the GMT second-order moment is GMT_{02}, as follows:

$$GMT_{02} = \sum_{x}\sum_{y} y_i^{2} * \text{Image}(x_i, y_i) \tag{3}$$

Step 8, Calculate the Center of Search Region*:* Calculate the search region center (x_c, y_c) and the zeroth-order moment (GMT_{00}) using Mean-Shift.

The search region center position x in the $\text{Image}(x_i, y_i)$ is x_c, the GMT Scale Probability Distribution is SPD_{20}, as follows:

$$SPD_{20} = \frac{GMT_{20}}{GMT_{00}} - x_c^2 \quad (4)$$

The search region center position x in the Image(x_i, y_i) is x_c, the search region center position y in the Image(x_i, y_i) is y_c, the GMT Scale Probability Distribution is SPD_{11}, as follows:

$$SPD_{11} = 2 * (\frac{GMT_{11}}{GMT_{00}} - x_c * y_c) \quad (5)$$

The search region center position y in the Image(x_i, y_i) is y_c, the GMT Scale Probability Distribution is SPD_{02}, as follows:

$$SPD_{02} = \frac{GMT_{02}}{GMT_{00}} - y_c^2 \quad (6)$$

The orientation of GMT is O, as follows:

$$O = \frac{\arctan(\frac{SPD_{11}}{SPD_{20} - SPD_{02}})}{2} \quad (7)$$

The length of the search region is L, as follows:

$$L = \sqrt{\frac{A+B}{2}} \quad (8)$$

Where,

$$A = (SPD_{20} + SPD_{02})$$

$$B = \sqrt{SPD_{11}^2 + (SPD_{20} - SPD_{02})^2}$$

The width of the search region is W, as follows:

$$W = \sqrt{\frac{A-B}{2}} \quad (9)$$

Where,

$$A = (SPD_{20} + SPD_{02})$$

$$B = \sqrt{SPD_{11}^2 + (SPD_{20} - SPD_{02})^2}$$

Step 9, Move the Search Region to Center of Image Frame: Move the search region to the center position of Step 8. Set the search region size to the zeroth-order moment in Step 8.

Step 10, Check the Search Window Center Coincides with the GMT Center or within Acceptable Value: Compute Step 5 to Step 10 and check whether the search region center coincides with the GMT center or within acceptable value.

The flow diagram of proposed efficient approach of autonomous visual tracking algorithm is shown in Fig. 2.

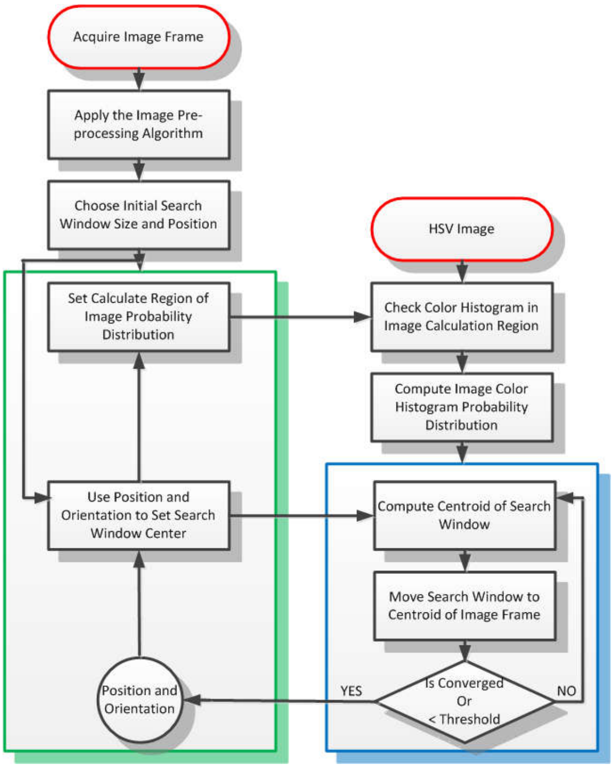

Fig. 2 The Flow Diagram of Proposed Efficient Approach of Autonomous Visual Tracking Algorithm.

An On-board AVTS Simulation

An On-board AVTS [42], [43], [44], [45] contains Gimballed Camera [46], INS/GPS [47], Proposed Efficient Approach of Autonomous Visual Tracking Algorithm [48], MAV Guidance [49], Camera Control [50] and Autopilot [51].

A MATLAB GUIDE R2011a based simulation tool is developed for determining the proposed efficient approach of autonomous visual tracking algorithm performance.
A Simulation of an On-board AVTS is shown in Fig. 3.

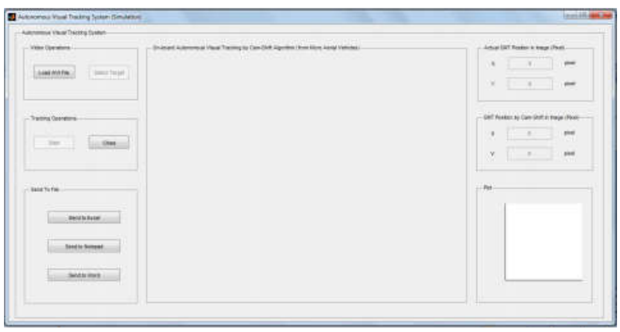

Fig. 3 A Simulation of an On-board AVTS.

This tool is to identify the GMT, enhance the image frame using Retinex algorithm, and apply the proposed algorithm and tracks the GMT.

The proposed algorithm is included in an On-board AVTS to determine the efficient approach of the proposed autonomous visual tracking algorithm [52] performance. This tool simulates the On-board AVTS [53] and receives the video frames from input video and autonomous visual tracking software based on an efficient approach of autonomous visual tracking algorithm.

Experimental Results

We have provided the aerial input video [54] as an image frame sequence to an On-board AVTS.

The GMT tracking of proposed autonomous visual tracking algorithm is shown in Fig. 4.

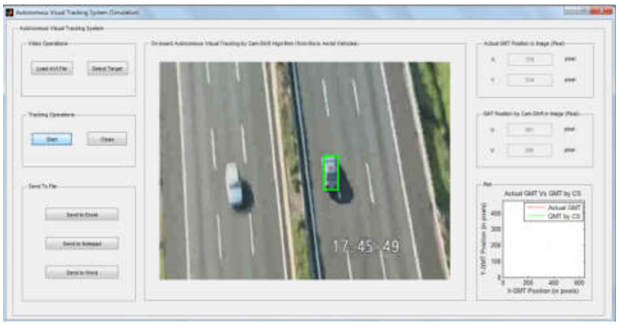

Fig. 4 The GMT Tracking of Proposed Efficient Approach of Autonomous Visual Tracking Algorithm.

The GMT tracking (Frame-by-Frame) of proposed autonomous visual tracking algorithm is shown in Fig. 5.

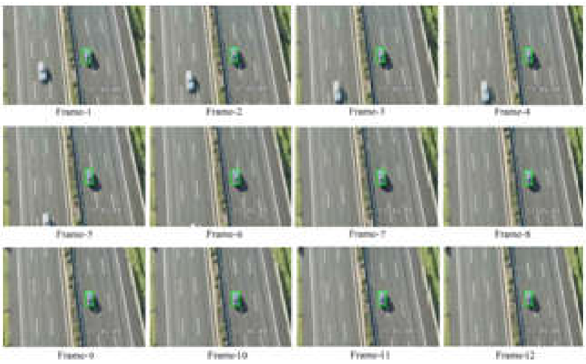

Fig. 5 The GMT Tracking (Frame-by-Frame) of Proposed Efficient Approach of Autonomous Visual Tracking Algorithm.

Table I The Calculated Error Results (In Pixels)

Input Image Frame Number	GMT Position (X, Y) (in Pixels)	GMT Position of Proposed Autonomous Visual Tracking Algorithm (U, V) (in Pixels)	Error (δX, δY) = ((X, Y) - (U, V)) (in Pixels)
1	(378, 234)	(361, 208)	(17, 26)
2	(381, 232)	(363, 205)	(18, 27)
3	(387, 233)	(368, 208)	(19, 25)
4	(390, 234)	(372, 211)	(18, 23)
5	(390, 234)	(368, 215)	(22, 19)
6	(392, 236)	(366, 219)	(26, 17)
7	(392, 237)	(375, 216)	(17, 21)
8	(393, 237)	(378, 216)	(15, 21)
9	(393, 237)	(380, 217)	(13, 20)
10	(391, 239)	(377, 218)	(14, 21)
11	(391, 239)	(367, 221)	(24, 18)
12	(391, 241)	(374, 221)	(17, 20)

The input image frame resolution is 640x480 pixels. We have considered the twelve input image frame sequences with an On-board AVTS for experimental analysis.

The calculated error results are shown in a Table. I.

We have plotted the results on a graph, as shown in Fig. 6.

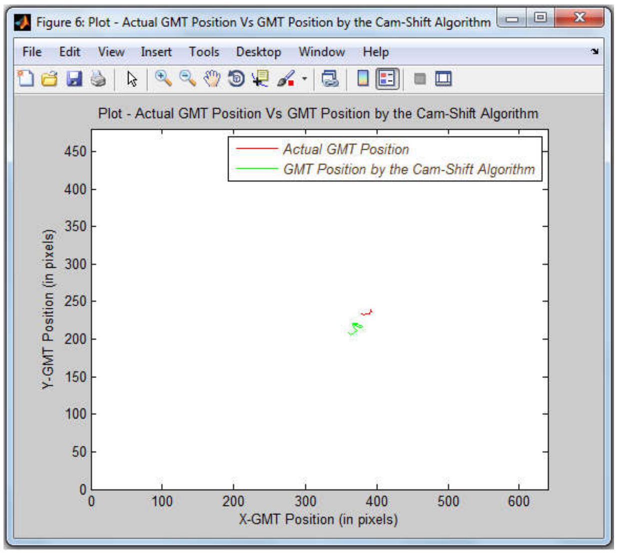

Fig. 6 A Graph between GMT Position and GMT Position of Proposed Efficient Approach of Autonomous Visual Tracking Algorithm.

We observed that the Proposed Autonomous Visual Tracking tracks the GMT very accurately.

CONCLUSIONS

An On-board AVTS provides the MAV Guidance, Camera Control to the MAV for the autonomous surveillance and monitoring the environment based on the computer vision visual tracking algorithm. An On-board AVTS Simulation is developed using the MATLAB GUIDE tool to identify the GMT, apply the proposed autonomous visual tracking algorithm and tracks the GMT continuously. The proposed autonomous visual tracking algorithm identifies the GMT based on its color space histogram. An On-board AVTS is tested with the aerial input image frame sequence and observed the proposed efficient approach of autonomous visual tracking algorithm performance. The results exhibit that the proposed efficient approach of autonomous visual tracking algorithm tracks the GMT very accurately.

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