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An Autonomous Visual Tracking Algorithm Based on Mean-Shift Algorithm and Extended Kalman Filter Estimator

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Key words: Extended Kalman Filter, Ground Moving Target, Image Tracking Software, Mean Shift Visual Tracking Algorithm, Micro Aerial Vehicle and Small Unmanned Aerial Vehicle.

ABSTRACT

An autonomous visual tracking algorithm based on mean-shift and extended kalman filter is proposed for micro aerial vehicle. This proposed algorithm is incorporated in the autonomous visual tracking software. This proposed algorithm identifies and tracks the ground moving target based on its 2D color space histogram. The implemented proposed algorithm is included in simulation to check whether the proposed algorithm identifies and tracks the GMT accurately or not from micro aerial vehicle. The captured results prove that the proposed autonomous visual tracking algorithm identifies and tracks the GMT very accurately.

INTRODUCTION

Micro Aerial Vehicle (MAV) is a Small Unmanned Aerial Vehicle (SUAV) that has a size restriction. These MAVs are used to monitor the environment where human beings or ground vehicles are not accessible. These MAVs are built for various usage of applications [1], [2], [3]. An on-board MAV contains the autonomous visual tracking system (AVTS). The AVTS contains various subsystems such as the Camera, INS / GPS, Tracking Software [4], [5], [6], [7], [8], MAV Guidance [9], [10], [11], Camera Control [12] and Autopilot [13].

A proposed algorithm based on Mean-Shift [4], [15], [16], [17] and Extended Kalman Filter (EKF) [18] is incorporated in the AVTS. This proposed autonomous visual tracking algorithm identifies the GMT based on its color space histogram [19], [20], [21], [22], [23], [24], [25]. It searches the nearness of the previous position in the area that matches the best property [26], [27], [28], [29], [30]. The main motivation is to check whether the proposed algorithm identifies and tracks the GMT accurately or not from micro aerial vehicle.

A 3D view of AVTS is shown in Fig. 1.

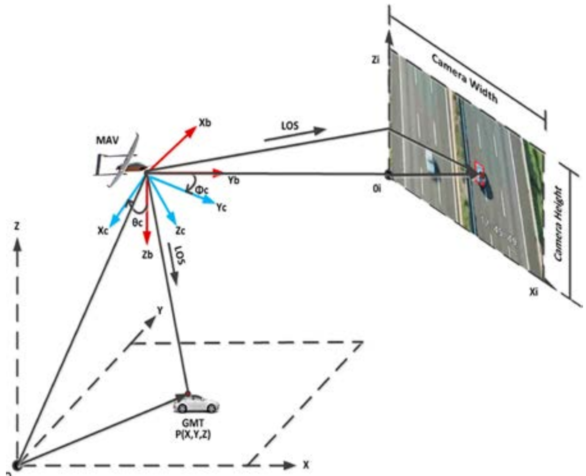

Figure 1: An AVTS 3D View.

II. A PROPOSED AUTONOMOUS VISUAL TRACKING ALGORITHM

A proposed autonomous visual tracking algorithm performs the following steps: acquisition, pre-processing, executes the algorithm and post-processing. The process of the proposed algorithm is shown in Fig.

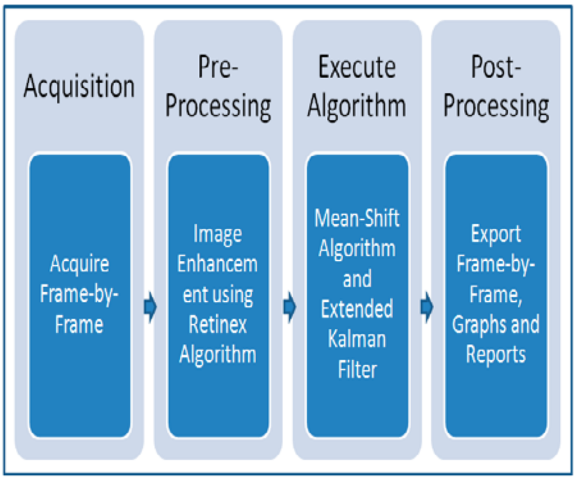

Figure 2: A Proposed Algorithm Process.

The acquired image frames from the camera using MATLAB Image Acquisition Toolbox [31], as frame by frame, are as shown in Fig. 3.

Figure 3: Acquired Image Frames (Frame-by-Frame) from the Camera.

The pre-processed and enhanced image frames using the Retinex algorithm [32], [33], [34], [35], [36], [37], [38], are shown in Fig. 4.

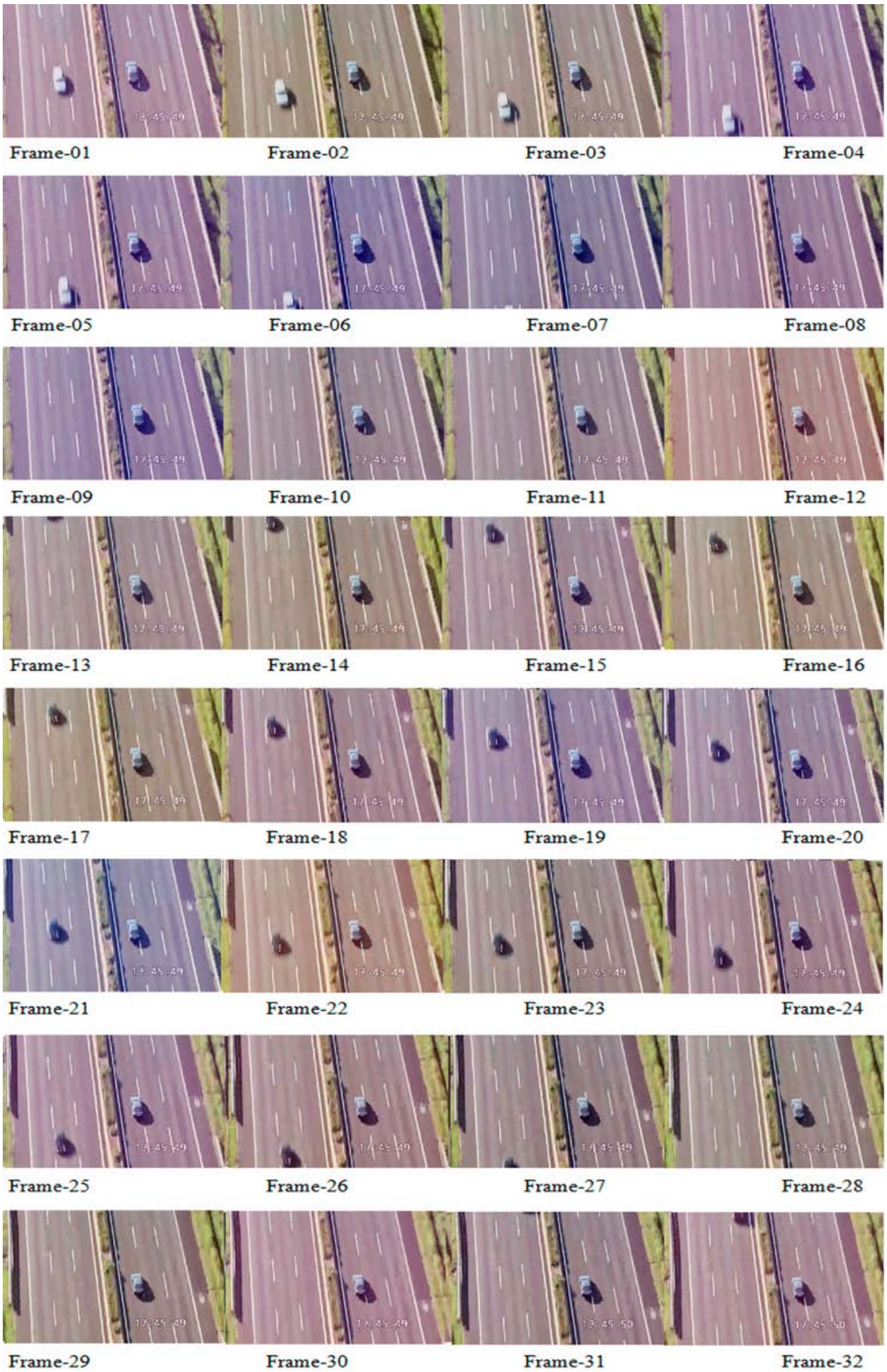

Figure 4: Enhanced Image Frames (Frame-by-Frame) by Pre-Processing Algorithm.

A Mean-Shift algorithm is computationally efficient, which results fast performance [39]. However, it is difficult to detect when a GMT moves out of the frame or not visible due to occlusions. To overcome this, a new algorithm based on Mean-Shift algorithm and EKF estimator is proposed for GMT tracking. The EKF estimates the next GMT position based on the previous GMT [40] position.

The proposed algorithm steps are as follows:

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

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

Step 3, Compute the Histogram Probability: Calculates the color histogram probability distribution.

Step 4, Select the Search Window Size: Select the search window size.

Step 5, Select the Search Window Initial Position: Select the search window initial position.

Step 6, Compute the Search Window Centroid: Calculate the search window centroid position, is as follows:

In the Image, $\text{Image}(i, j)$ is a pixel color 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):

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

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

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

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

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

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

$$i_c = \frac{GMT_{10}}{GMT_{00}} \qquad (4)$$

$$j_c = \frac{GMT_{01}}{GMT_{00}} \qquad (5)$$

Step 7, Move Search Window to Centroid of Image Frame: Center the search window at the centroid position, $S(i_c, j_c)$, computed in Step 6.

Step 8, Check Search Window Center Converged to Centroid of Image Frame or Less than Preset Threshold Value: Repeat Step 6 and Step 7 until the Search Window Center Converged to Centroid of Image Frame or the Search Window Center moved to a less than given threshold value.

Step 9, Apply the EKF Estimator: The EKF estimates the next position of GMT based on the previous position of GMT.

The flow diagram of the proposed algorithm, is shown in Fig. 5.

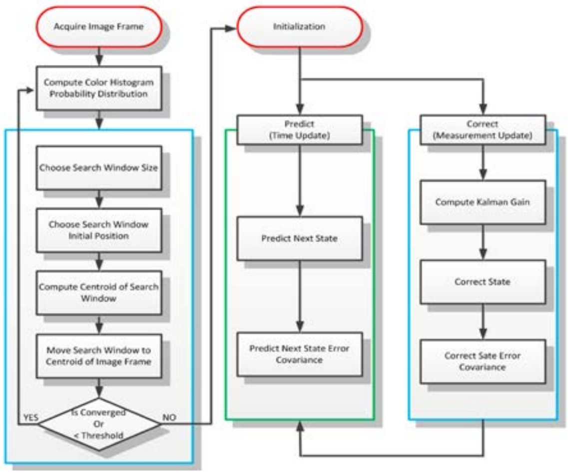

Figure 5: A Proposed Algorithm Flow Diagram.

III. AN EXPERIMENTAL SIMULATION

On-board AVTS contains Gimbaled Camera [41], Proposed Autonomous Visual Tracking Algorithm, Camera Control Law [42], MAV Guidance Law [43], [44], [45], [46], [47], [48], [49], [50], [51], INS/GPS [52], [53] and Autopilot [54], [55], [56], [57], [58].

An experimental simulation of AVTS [59], [60], [61], is shown in Fig. 6.

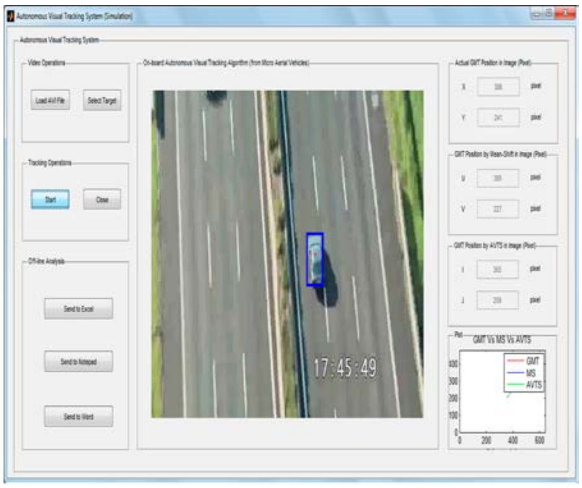

Figure 6: An AVTS Experimental Simulation (Prototype).

The implemented proposed algorithm is included in simulation to check whether the proposed algorithm identifies and tracks the GMT accurately or not from micro aerial vehicle.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

We have considered the aerial tracking video [62] as an input for the GMT tracking real-time simulation.

The GMT tracking by a proposed algorithm (Frame-by-Frame) is shown in Fig. 7.

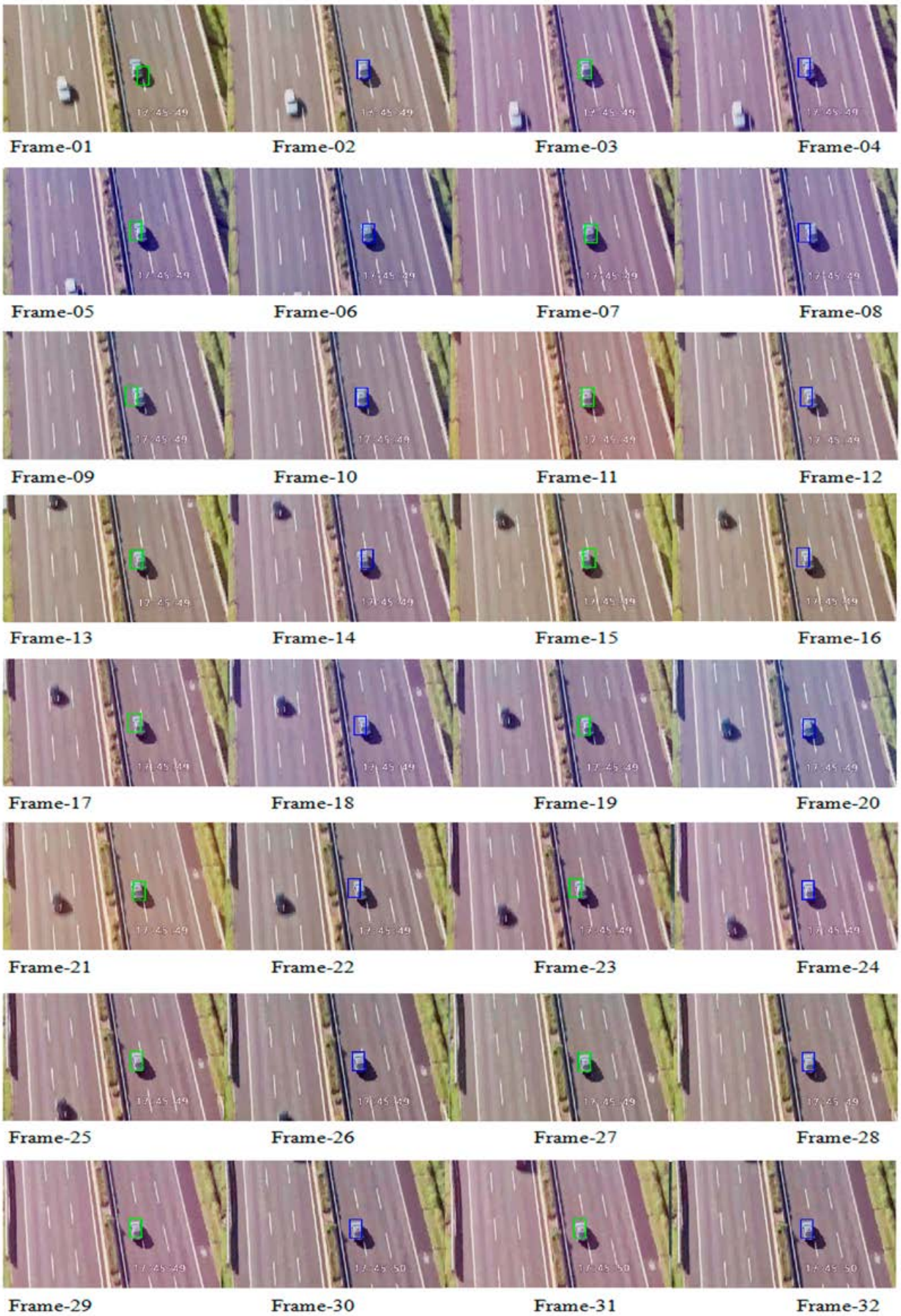

Figure 7: A Proposed Algorithm GMT Tracking (Frame-by-Frame).

The simulation PC configuration is as follows: 32-bit OS, 3 GB RAM, Intel i3, and CPU @ 2.40 GHz.
The computed error between the Mean-Shift and the computed proposed algorithm, as shown in a Table. 1.

Table 1: The Computed Error: Mean-Shift vs Proposed Algorithm (In Pixels).

Frame No.	GMT Position (X, Y)		Mean-Shift Algorithm (U, V)		Error (δX,δY)=((X,Y)–(U, V))		Proposed Algorithm (I, J)		Error (δI,δJ) =((X,Y)–(I, J))	
	X	Y	U	V	δX	δY	I	J	δI	δJ
1	382	232	357	205	25	27	367	215	15	17
2	385	236	361	206	24	30	371	221	14	15
3	388	233	366	208	22	25	374	218	14	15
4	388	231	370	210	18	21	374	218	14	13
5	395	237	372	211	23	26	380	225	15	12
6	392	238	375	214	17	24	380	227	12	11
7	395	237	374	215	21	22	382	225	13	12
8	392	238	376	217	16	21	382	227	10	11
9	390	238	378	218	12	20	381	228	9	10
10	391	239	381	221	10	18	383	229	8	10
11	389	240	383	224	6	16	382	232	7	8
12	387	240	384	225	3	15	382	233	5	7
13	386	241	385	227	1	14	381	235	5	6
14	387	242	386	228	1	14	382	236	5	6
15	387	242	388	230	-1	12	383	238	4	4
16	387	242	390	234	-3	8	383	237	4	5
17	386	243	391	235	-5	8	382	238	4	5
18	386	243	390	237	-4	6	383	239	3	4
19	384	244	392	238	-8	6	381	240	3	4
20	385	245	393	240	-8	5	382	241	3	4
21	385	248	395	241	-10	7	382	244	3	4
22	384	247	396	242	-12	5	381	243	3	4
23	385	249	398	243	-13	6	381	245	4	4
24	385	250	399	247	-14	3	382	246	3	4
25	386	250	400	250	-14	0	383	246	3	4
26	387	253	401	248	-14	5	384	250	3	3
27	388	255	402	250	-14	5	385	252	3	3
28	387	256	403	251	-16	5	385	253	2	3
29	388	257	404	251	-16	6	386	254	2	3
30	389	258	404	254	-15	4	387	256	2	2
31	391	261	405	255	-14	6	390	259	1	2
32	393	262	407	256	-14	6	392	261	1	1

The captured results are plotted on a graph, as shown in Fig. 8.

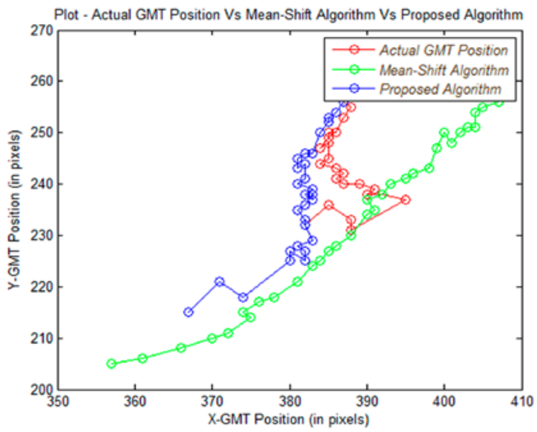

Figure 8: A Graph between GMT Position, Mean-Shift and Proposed Algorithm.

We can export the Mean-Shift and the proposed algorithm for off-line analysis. The execution time between the Mean-Shift and the proposed algorithm in seconds are shown in a Table. 2.

Table 2: The Execution Time: Mean-Shift and Proposed algorithm (In Seconds).

Frame No.	Execution Time of Mean-Shift Algorithm (Seconds)	Execution Time of the Proposed Algorithm (Seconds)
2	0.0308	0.0961
4	0.0091	0.0647
6	0.0055	0.0592
8	0.0074	0.0485
10	0.0056	0.0481
12	0.0066	0.0493
14	0.0066	0.0480
16	0.0057	0.0479
18	0.0067	0.0464
20	0.0054	0.0484
22	0.0063	0.0467
24	0.0081	0.0482
26	0.0061	0.0486
28	0.0065	0.0500
30	0.0051	0.0513
32	0.0064	0.0483

The error results are plotted on a graph, as shown in Fig. 9.

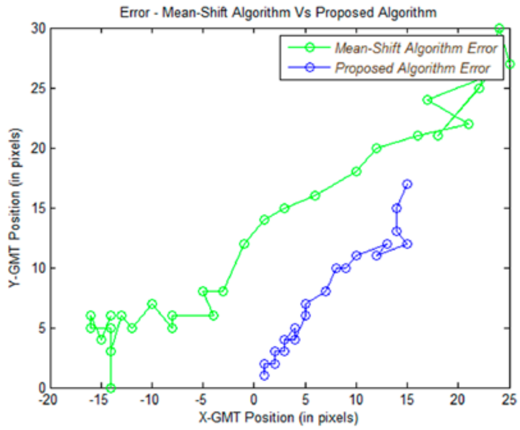

Figure 9: A Graph between Mean-Shift Error and Proposed Algorithm Error.

The captured results prove that the proposed autonomous visual tracking algorithm identifies and tracks the GMT very accurately.

V. CONCLUSIONS

A mean-shift and a proposed algorithm based on mean-shift and extended kalman filter are included in the simulation. The simulation is tested and observed the mean-shift and the proposed algorithm performance. The simulated results prove that the proposed autonomous visual tracking algorithm identifies and tracks the GMT very accurately.

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