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ICITEE2015

2015 The 7th International Conference on Information Technology and Electrical Engineering

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"Envisioning the Trend of Computer, Information and Engineering"

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29-30 October 2015

Organized by
Faculty of Information Technology
King Mongkut's Institute of Technology Ladkrabang, THAILAND

Co-organized by
Department of Electrical Engineering and Information Technology
Universitas Gadjah Mada, INDONESIA

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Welcome Message from the General Chair

On behalf of the Organizing Committee, we are delighted to welcome all delegates and their guests at the 7th International Conference on Information Technology and Electrical Engineering (ICITEE 2015) that will take place on 29-30 October 2015. Following the success of the previous six annual conferences of ICITEE in Indonesia, the ICITEE 2015 will be held for the first time in a location outside Indonesia. It will take place in Chiang Mai, the largest and one of the most legendary cities in northern Thailand. In addition, since the ICITEE has started linking with the Institute of Electrical & Electronics Engineers (IEEE) as a technical co-sponsorship in 2013, there has been a big jump in terms of the quality and the number of paper submissions. Currently, ICITEE proceedings have been continuously published in one of the world's most important scientific databases, i.e. IEEE Xplore since 2013.

The theme of this year's ICITEE is "envisioning the trend of computer, information and engineering". This event is hoped to strengthen the collaboration and provide a forum for academicians, professionals and researchers to discuss and exchange their research results, innovative ideas, and experiences in all aspects of intelligent and green technologies, as well as to identify emerging research topics and define future directions to achieve sustainable development.

We are pleased to have Prof. Dr. Pairash Thajchayapong (National Science and Technology Development Agency, Thailand), Prof. Dr. Monai Krairiksh (King Mongkut's Institute of Technology Ladkrabang, Thailand), Prof. Dr. Kazuhiko Hamamoto (Tokai University, Japan), Prof. Dr. Masanori Sugimoto (Hokkaido University, Japan) and Dr. David R. Hardoon (Azendian, Singapore) as the keynote speakers.

All of the members of the Local Organizing Committee from King Mongkut's Institute of Technology Ladkrabang and co-organizers from Gadjah Mada University would like to wish you a superb conference experience and a memorable stay in Chiang Mai, Thailand.

Sincerely yours,

Kuntpong Woraratpanya General Chair of ICITEE 2015

Welcome Message from the TPC Chair

On behalf of Technical Program Committee, it is our great pressure to welcome all participants to Chiang Mai, Thailand for the 7th International Conference on Information Technology and Electrical Engineering (ICITEE 2015). In this year, ICITEE 2015 has been organized under the theme of "Envisioning the Trend of Computer, Information and Engineering". The conference is divided into five different tracks: Information Technology; Communications and Vehicular Technology; Power Systems; Electronics, Circuits, and Systems; and Control Systems. This provides a forum for academicians, professionals and researchers to discuss and exchange their research results, innovative ideas, and experiences in all aspects of intelligent and green technologies, as well as to identify emerging research topics and define future directions to achieve sustainable development.

With continually growing community of ICITEE, ICITEE 2015 has been fortunately received 217 submitted papers from 18 countries. Each paper was assigned to three reviewers with double-blind review process. At last, 123 papers were selected and accepted to main technical program with an acceptance rate of 56.7%.

Beside the main technical program, we are especially pleased to have Prof. Dr. Pairash Thajchayapong from National Science and Technology Development Agency, Thailand to deliver the plenary keynote speech on "Science and Technology under HRH Princess Maha Chakri Sirindhorn's Initiatives," in honour of HRH Princess Maha Chakri Sirindhorn (also known as IT Princess) on the occasion of her fifth cycle birthday anniversary.

In addition, there are two plenary sessions on emerging research topics. We also have Prof. Dr. Monai Krairiksh from King Mongkut's Institute of Technology Ladkrabang, Thailand, Prof. Dr. Kazuhiko

Hamamoto from Tokai University, Japan, Prof. Dr. Masanori Sugimoto from Hokkaido University, Japan, and Dr. David R. Hardoon from Azendian, Singapore, to speech on emerging research topics.

We would like to thank all TPC chairs, TPC members, and external reviewers for their outstanding dedication and hard work.

Welcome to Chiang Mai and hope you will enjoy a wonderful experience in one of the most legendary cities in northern Thailand.

Sincerely yours,

Natapon Pantuwong TPC Chair of ICITEE 2015

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The Development of Image-based Algorithm to Identify Altitude Change of a Quadcopter

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***Abstract*—Quadcopter, a popular Unmanned Aerial Vehicle (UAV), is able to land, take off, hover, and move on 3D trajectory. The ability requires accurate control of the rotors velocity based on input from its sensors. One of the control mechanisms is the altitude control. This paper presents a new algorithm to identify altitude change of a quadcopter based on image processing techniques. The algorithm is designed to be simple and efficient in terms of computation and memory usage. The algorithm identifies altitude change by calculating correlation function of 10 sampled rows of pixels. This paper also presents some experiments conducted to investigate the performance of the algorithm. The results indicated that the algorithm is able to properly identify altitude change with accuracy of more than 96%.**

***Keywords*—Quadcopter; quadrotor; altitude control; image-based distance measurement**

I. Introduction

The research and development of Unmanned Aerial Vehicles (UAV) has become an interesting field since the 1990s [1]. The development was initially driven by military applications. In the recent years, small UAV has been developed for public applications such as traffic observations, rescue missions, environmental observations, photography, and other hobby related activities.

Quadcopter, a type of small UAV, has become popular among public users due to its size, price, and controllability [2]. Quadcopter is a four rotors helicopter as shown in Fig. 1. The rotors are directing upwards and arranged in a square formation. The movement of quadcopter is controlled by the angular velocity of the rotors. By properly controlling the velocity of each rotor, a quadcopter can move along a specific 3D trajectory and hover steadily. The accuracy of such movements is depending on its control systems and the accuracy of information from its sensors [3].

One of the important control mechanisms is the altitude control. Various control methods have been used, such as PID controllers [4-6] and fuzzy controllers [7-10]. These controllers need accurate altitude information from sensors. Some of the commonly used sensors are accelerometer, barometer, GPS, sonar, and laser sensor [2], [5], [11]. Camera, mounted on most quadcopters, can also be used as a sensor to provide position-related information, including altitude.

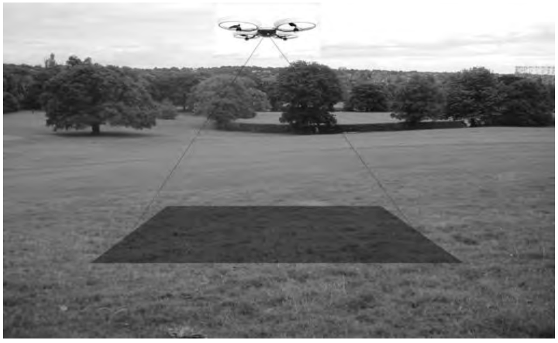

Fig. 1. Illustration of quadcopter with facing down camera.

This research is conducted to develop image-based algorithm that is able to sense altitude change. The algorithm is commonly known as image-based distance measurements system. Image–based distance measurement can be classified into three approaches. The parallax approaches [12-14] determine object distance by computing variance of position in two images captured by two cameras or combination of mirrors. The approach requires complex computation and a stereo camera arrangement. This approach is not suitable for a small quadcopter. The second approach measures object distance with an aid of some markers. Barreto [15] and Muljowidodo [16] based their algorithm on triangulation of a single laser beam, while Deng [12] and Lu [17] used two parallel laser beam projected to the object. The other approach is based on a priori knowledge of object physical size [19]. Such a requirement is not easily implemented in quadcopter. Quadcopters are designed to fly above different fields with various objects in different sizes.

This paper reports the development of an efficient image-based algorithm to identify the change of distance between camera and the captured object. The algorithm is designed to work on a single camera without the aid of image marker such as laser beam. The algorithm is to be applied in quadcopter as a sensor to provide information about altitude change to its controller. The current development reported in this paper shows a promising result. The algorithm can identify altitude change with a successful rate above 76% and altitude change accuracy of more than 96%.

This paper is organized into four sections. Section II introduces the algorithm with detailed explanation on each process in the algorithm. The experimental procedures and results are presented in Section III. The conclusions are presented in Section IV.

II. Proposed Method for Distance Change Measurement

The proposed image-based algorithm to identify altitude change of quadcopter is discussed in this section. The algorithm is based on image frames captured from a single, facing down camera, mounted on the body of a quadcopter as shown in Fig. 1. The algorithm is to be implemented inside a small processor carried by the quadcopter. As the consequent, the algorithm is designed to be simple and efficient in terms of computational complexity, computational time, and memory usage.

The basic idea of the algorithm is to detect the relative movement of objects in the captured frames. It is assumed that if the camera is getting closer to the ground, objects in the image move to the edge of the frame. Reversely, objects in the image move to the center of the frame if the altitude increases (the camera moves away from the ground).

A. Preprocessing

To detect this movement, the algorithm captured two frames, i.e., the reference frame and the comparing frame. The captured frames are in 8-bit RGB format with a resolution of 480 x 640 pixels. Since the algorithm is only interested on the movement of objects, the frames are converted to grayscale images.

To minimize memory usage, only 10 rows, with a length of 80 pixels, are stored from each frame. The ten rows are the first and the last 80 pixels at row number 200, 220, 240, 260, and 280 as shown in Fig. 2. Each row is stored as a function of grayscale data $f_1(x)$, $f_2(x)$, …, $f_{10}(x)$ as marked in the figure.

The rows are selected around the center of the frame's width, near the left and right edges of the frame. These are the areas where object movements due to altitude change are more observable.

B. Object Movement Calculation

The next step is to calculate the magnitude and direction of object movement in each recorded row. The movement is predicted by calculating the correlation function between corresponding rows in reference, $f_n(x)$, and compared frames, $f'_n(x)$:

$$C_n(\tau) = \langle f_n(x), f'_n(x) \rangle \qquad (1)$$

The shift, τ, in correlation function is ranging from -80 to 80, where $\tau = 0$ indicates that there is no shift between the two corresponding functions. The maxima point in correlation function is located by:

$$\boldsymbol{v}_n = argmax_\tau \; C_n(\tau) \qquad (2)$$

The argument, $\boldsymbol{v}_n$, is a vector that indicates the amount and direction of object movement, observed in row $f_n(x)$.

Fig. 2. Selected rows on captured image at row number 200, 220, 240, 260, and 280.

All the ten vectors, $\boldsymbol{v}_1$, $\boldsymbol{v}_2$, $\boldsymbol{v}_3$, …, $\boldsymbol{v}_{10}$, are calculated using (1) and (2). The calculation of object movement is illustrated in Fig. 3. In the figure, the object moved 20 pixels to the left as indicated by $\boldsymbol{v}_n$.

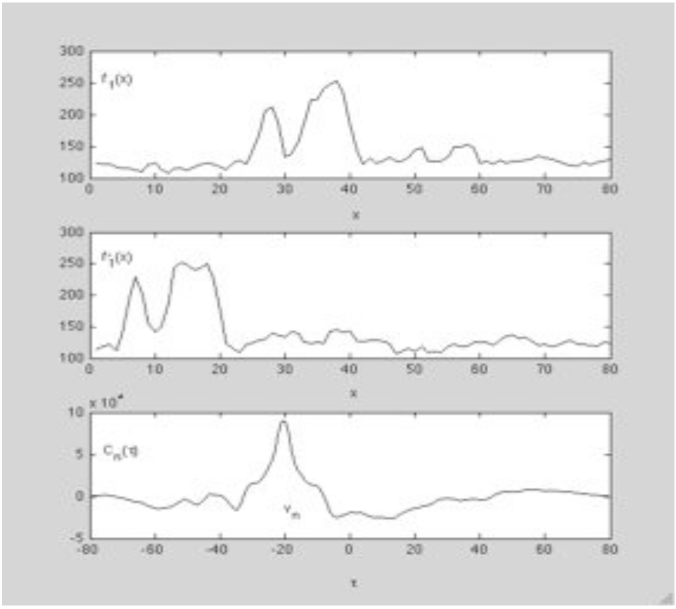

Fig. 3. Calculation of object movement based on correlation function.

C. Altitude Change Identification

The altitude change is identified by analyzing the ten vectors. The vectors are arranged into five pairs, {$\boldsymbol{v}_1$, $\boldsymbol{v}_2$}, {$\boldsymbol{v}_3$, $\boldsymbol{v}_4$}, {$\boldsymbol{v}_5$, $\boldsymbol{v}_6$}, {$\boldsymbol{v}_7$, $\boldsymbol{v}_8$}, and {$\boldsymbol{v}_9$, $\boldsymbol{v}_{10}$}, according to their row number as indicated in Fig. 2.

Each pair indicates altitude change if the two vectors in the pair are pointing to opposite directions. In other words, their dot product is negative. The altitude decreases if both vectors are pointing inward, while it increases if both vectors are pointing outwards. The amount of change is assumed to be proportional to the average of the magnitude of these two vectors. The altitude change is considered absent if both vectors in each pair are pointing to the same direction, or having zero magnitude.

The developed algorithm uses five pairs of vectors to compensate misjudgment by individual pair. The accuracy of each pair in identifying altitude change is depending on the type of object captured in the corresponding rows. If any of the rows capture a nearly flat image, the vector may indicate a wrong direction. To anticipate this error, the algorithm makes its decision based on three or more consistent pairs. The algorithm indicates an increase in altitude if at least there are three pairs that consistently indicate the change. Otherwise, the algorithm assumes that there is no change of altitude. Fig. 4 shows a decrease in altitude that is consistently indicated by the first three pairs of vectors. Fig. 5 shows an increase in altitude, since more than three vectors (four vectors) indicate the movement. In Fig. 6, only two pairs, $\{\boldsymbol{v}_5, \boldsymbol{v}_6\}$ and $\{\boldsymbol{v}_7, \boldsymbol{v}_8\}$, indicate a downward movement, while one pair, $\{\boldsymbol{v}_1, \boldsymbol{v}_2\}$, indicates upward movement. Since less than three pairs indicate any direction, it is assumed that no altitude change occurs.

Fig. 4. The algorithm identify a decrese in altitude as consistently indicated by the first three pairs of vectors.

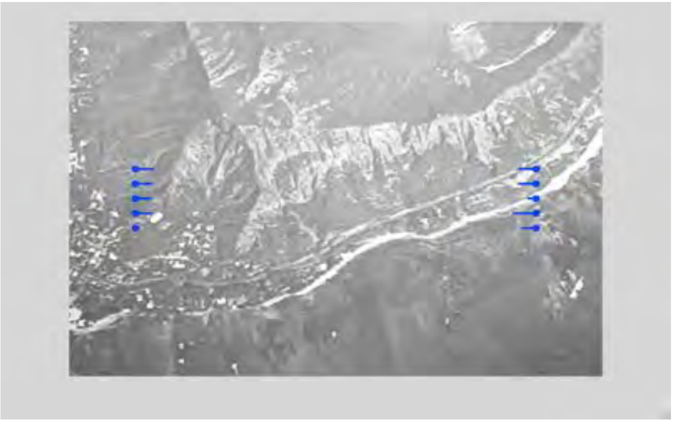

Fig. 5. The algorithm identify an increase in altitude as consistently indicated by the first four pairs of vectors.

Fig. 6. No altitude change is identified because less than three pairs of vectors indicate any altitude change.

D. The Magnitude of altitude change

The magnitude of altitude change, D, in meters, is calculated as proportional to the average of the magnitude of valid vectors.

$$D = k\,\frac{1}{N}\sum\left|v_{n_{valid}}\right| \tag{3}$$

The magnitude of D will be positive if altitude increases and negative if it decreases. The denominator, N, is the total number of valid vectors. The proportional coefficient, k, is determined by the initial altitude (altitude when the reference frame was captured), h, in meters, and the horizontal size of the image frame. It is defined as:

$$k = \frac{2h}{640} \tag{4}$$

In the case when the initial altitude, h, is unknown, the change magnitude, D, is expressed as the proportion of h.

E. Computation Complexity

The algorithm is to be implemented in a UAV processor. The algorithm is designed to be simple in terms of computational complexity, computational time, and memory usage. The algorithm has two main functions that determine its complexity. The functions are the calculation of correlation function, $C_n(\tau)$, and the '*argmax*' procedure. The complexity of correlation function is $O(N^2)$, while the complexity of '*argmax*' is $O(N)$. Since the two functions are calculated one after the other, the overall complexity of the algorithm is determined by the most complex function, $O(N^2)$. The complexity is still acceptable, given the fact that the amount of data to be processed is limited to a small number. The maximum number of data in this algorithm is 10 rows of 80 bytes.

The algorithm determines altitude change based on the 10 rows of 80 data. It does not need to store the whole captured image at all times. This approach is accommodated to ensure efficiency in memory usage.

III. Experimental Results and Discusion

The performance of the algorithm was examined using a simulated environment. The images were captured using LiveCam VX-800, 8-bit RGB web camera with a resolution of 480 x 640 pixels. The camera was mounted on a moveable platform that is able to simulate some movements of UAV. The simulated movements were the change of altitude (z-axis), rotation of UAV while maintaining its altitude, and horizontal translation to both the x-axis and y-axis. A poster of aerial view was placed in front of the camera at a predetermined distance (altitude) to simulate ground view. The simulated environment is shown in Fig. 7.

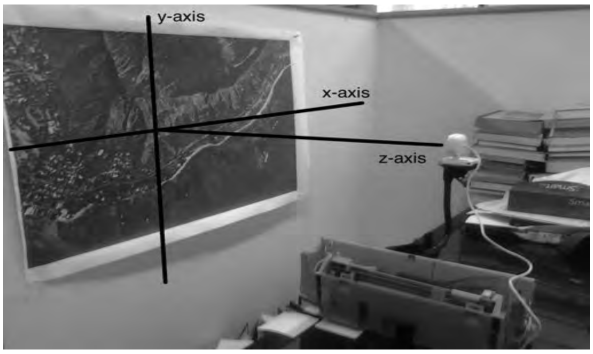

Fig. 7. The experiment environment.

A. *Experiment with decreasing altitude*

In the first experiment, 25 frames were recorded from the camera at various different altitudes (z-axis), while maintaining its rotation and translation. The first frame, recorded at an altitude of $h = 0.70$ meters, was used as the reference frame, while the other frames were used as the comparing frame. The algorithm was used to identify altitude change, D, of each frame. The predicted altitude was calculated as the initial altitude, h, plus the change. The results are shown in Table I and Fig. 8.

TABLE I. Experiment with Decreasing Altitude

Frame Number	Actual Altitude (m)	Predicted Altitude (m)	Error (m)	Error Rate (%)
1	0.700	0.700	0.000	0.0%
2	0.700	0.700	0.000	0.0%
3	0.700	0.700	0.000	0.0%
4	0.700	0.700	0.000	0.0%
5	0.700	0.700	0.000	0.0%
6	0.700	0.700	0.000	0.0%
7	0.695	0.696	0.001	0.1%
8	0.695	0.696	0.001	0.1%
9	0.690	0.690	0.000	0.1%
10	0.690	0.690	0.000	0.0%
11	0.685	0.686	0.001	0.1%
12	0.685	0.686	0.001	0.1%
13	0.680	0.674	-0.006	0.9%
14	0.680	0.674	-0.006	0.9%
15	0.675	0.676	0.001	0.1%
16	0.670	0.674	0.004	0.7%
17	0.665	0.670	0.005	0.8%
18	0.660	0.653	-0.007	1.0%
19	0.655	0.658	0.003	0.5%
20	0.650	0.657	0.007	1.1%
21	0.650	0.657	0.007	1.0%
22	0.650	0.657	0.007	1.1%
23	0.640	0.649	0.009	1.3%
24	0.630	0.645	0.015	2.4%
25	0.620	0.641	0.021	3.4%
Average Error Rate				0.6%

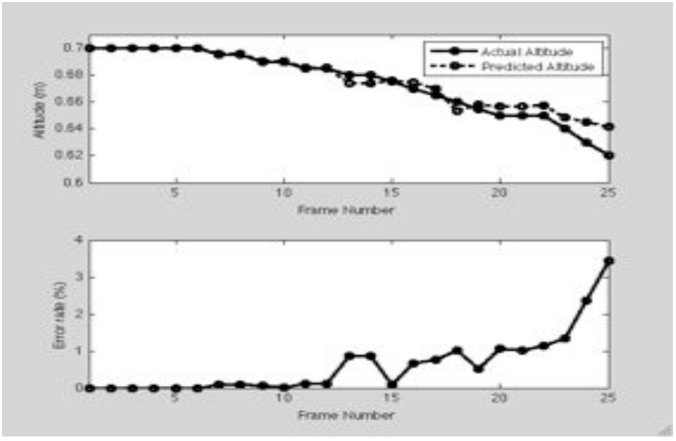

Fig. 8. The predicted altitude and error rate of experiment 1 to simulate altitude decreament.

The results show that the algorithm can predict altitude change accurately with an average error of 0.6%. The results also indicate that the error rate increases along with the altitude change.

B. *Experiment with increasing altitude*

This experiment was conducted with the similar setting as the previous experiment. The frames were recorded while the altitude increased from 0.620 meters to 0.700 meters. The first frame was used as the reference frame. The result is shown in Table II and Fig. 9.

TABLE II. Experiment with Increasing Altitude

Frame Number	Actual Altitude (m)	Predicted Altitude (m)	Error (m)	Error Rate (%)
1	0.620	0.620	0.000	0.0%
2	0.630	0.629	-0.001	0.2%
3	0.640	0.639	-0.001	0.2%
4	0.650	0.656	0.006	1.0%
5	0.650	0.652	0.002	0.4%
6	0.650	0.652	0.002	0.3%
7	0.655	NaN	NaN	NaN
8	0.660	0.656	-0.004	0.6%
9	0.665	0.658	-0.007	1.0%
10	0.670	0.663	-0.007	1.1%
11	0.675	0.667	-0.008	1.2%
12	0.680	0.670	-0.010	1.4%
13	0.680	0.665	-0.015	2.3%
14	0.685	NaN	NaN	NaN
15	0.685	NaN	NaN	NaN
16	0.690	NaN	NaN	NaN
17	0.690	NaN	NaN	NaN
18	0.695	NaN	NaN	NaN
19	0.695	0.673	-0.022	3.2%

Frame Number	Actual Altitude (m)	Predicted Altitude (m)	Error (m)	Error Rate (%)
20	0.700	0.672	-0.028	4.0%
21	0.700	0.673	-0.027	3.9%
22	0.700	0.672	-0.028	4.0%
23	0.700	0.671	-0.029	4.1%
24	0.700	0.672	-0.028	4.0%
25	0.700	0.672	-0.028	4.0%
Average Error Rate				1.9%

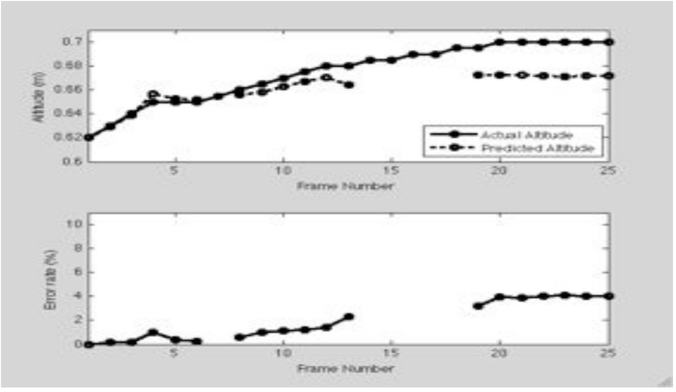

Fig. 9. The predicted altitude and error rate of experiment 2 to simulate altitude increament.

The results of experiment 2 indicate that the algorithm can predict and identify the increasing altitude with an average error rate of 1.9%. The result also shows that the algorithm failed to identify altitude change in 6 frames (frame number 7, 14, 15, 16, 17, and 18). The success rate was 76% (19 out of 25 frames).

C. Experiment with horizontal translation

In this experiment, 25 frames were recorded from the camera at a constant altitude (z-axis) of 0.60 meters, while translated to x-axis and y-axis. The first frame, recorded at an altitude of 0.60 meters, was used as the reference frame, while the other frames were used as the comparing frame. The experiment was conducted to investigate the algorithm's ability to compensate horizontal translation.

TABLE III. EXPERIMENT WITH HORIZONTAL TRANSLATION

Frame Number	x-axis	y-axis	Actual Altitude (m)	Predicted Altitude (m)	Error (m)	Error Rate (%)
1	0	0	0.600	0.600	0.000	0.00%
2	0	0	0.600	0.600	0.000	0.00%
3	0.005	0	0.600	0.600	0.000	0.00%
4	0.01	0	0.600	0.600	0.000	0.00%
5	0.015	0	0.600	0.652	0.052	8.65%
6	0.02	0	0.600	0.600	0.000	0.00%
7	0.02	0	0.600	0.600	0.000	0.00%
8	0.015	0	0.600	0.653	0.053	8.75%
9	0.01	0	0.600	0.600	0.000	0.00%
10	0.005	0	0.600	0.600	0.000	0.00%
11	0	0	0.600	0.600	0.000	0.00%
12	-0.005	0	0.600	0.600	0.000	0.00%
13	-0.01	0	0.600	0.600	0.000	0.00%
14	-0.015	0	0.600	0.600	0.000	0.00%
15	-0.02	0	0.600	0.600	0.000	0.00%
16	-0.02	0	0.600	0.600	0.000	0.00%
17	-0.015	0	0.600	0.600	0.000	0.00%
18	-0.01	0	0.600	0.600	0.000	0.00%
19	-0.005	0	0.600	0.600	0.000	0.00%
20	0	0	0.600	0.600	0.000	0.00%
21	0	0.01	0.600	0.600	0.000	0.00%
22	0	0.02	0.600	0.600	0.000	0.00%
23	0	0	0.600	0.600	0.000	0.00%
24	0	-0.01	0.600	0.600	0.000	0.00%
25	0	-0.02	0.600	0.600	0.000	0.00%
Average Error Rate						0.70%

The result in Table III confirms that the algorithm is capable to tolerate translational movement of the camera. Two of the 25 frames were wrongly identified as 0.05 meters altitude increment (identification successful rate of 92%).

D. Experiment with rotation

In the last experiment, 9 frames were recorded from the camera at a constant altitude (z-axis) of 0.50 meters, while rotating around z-axis (-45, -30, 0, 30, and 45 degrees). The initial altitude of 0.50 meters was selected to avoid empty edges of the aerial view poster. The frame, recorded at zero degree, was used as the reference frame. The experiment was conducted to investigate the algorithm's ability to compensate rotation movement. The result is presented in Table IV. The table shows that the algorithm can accurately tolerate rotational camera movement.

TABLE IV. EXPERIMENT WITH ROTATIONAL MOVEMENT

Frame Number	Rotation (degrees)	Actual Altitude (m)	Predicted Altitude (m)	Error (m)	Error Rate (%)
1	0	0.500	0.500	0.000	0.00%
2	-30	0.500	0.500	0.000	0.00%
3	-45	0.500	0.500	0.000	0.00%
4	-30	0.500	0.500	0.000	0.00%
5	0	0.500	0.500	0.000	0.00%
6	30	0.500	0.500	0.000	0.00%
7	45	0.500	0.500	0.000	0.00%
8	30	0.500	0.500	0.000	0.00%
9	0	0.500	0.500	0.000	0.00%
Average Error Rate					0.00%

IV. CONCLUSION

In this paper, an image-based distance-measuring algorithm is presented. The algorithm is developed to provide information about change in altitude of a quadcopter. The algorithm calculates distance change based on correlation of rows in image captured from a single, facing down camera, mounted on the body of quadcopter. The experiments, reported in this paper, demonstrate the ability of the algorithm to identify altitude change. The algorithm is able to identify altitude change with accuracy of more than 96%, and is able to compensate horizontal and rotational movement. The future suggested development of the algorithm would be the simplification of computational complexity from $O(N^2)$ to

O(N) and the improvement of the algorithm accuracy and success rate on nearly flat images.

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