Lecture Notes in Electrical Engineering 365

Felix Pasila
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Editors

Proceedings of Second International Conference on Electrical Systems, Technology and Information 2015 (ICESTI 2015)

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Contents

Part III Technology Innovation in Electrical Engineering, Electric Vehicle and Energy Management

Introduction

This book includes the original, peer-reviewed research papers from the 2nd International Conference on Electrical Systems, Technology and Information (ICESTI 2015), held during 9–12 September 2015, at Patra Jasa Resort & Villas Bali, Indonesia.

The primary objective of this book is to provide references for dissemination and discussion of the topics that have been presented in the conference. This volume is unique in that it includes work related to Electrical Engineering, Technology and Information towards their sustainable development. Engineers, researchers as well as lecturers from universities and professionals in industry and government will gain valuable insights into interdisciplinary solutions in the field of Electrical Systems, Technology and Information, and its applications.

The topics of ICESTI 2015 provide a forum for accessing the most up-to-date and authoritative knowledge and the best practices in the field of Electrical Engineering, Technology and Information towards their sustainable development. The editors selected high quality papers from the conference that passed through a minimum of three reviewers, with an acceptance rate of 50.6 %.

In the conference there were three invited papers from keynote speakers, whose papers are also included in this book, entitled: “Computational Intelligence based Regulation of the DC bus in the On-Grid Photovoltaic System”, “Virtual Prototyping of a Compliant Spindle for Robotic Deburring” and “A Concept of Multi Rough Sets Defined on Multi-Contextual Information Systems”.

The conference also classified the technology innovation topics into five parts: “Technology Innovation in Robotics, Image Recognition and Computational Intelligence Applications”, “Technology Innovation in Electrical Engineering, Electric Vehicle and Energy Management”, “Technology Innovation in Electronic, Manufacturing, Instrumentation and Material Engineering”, “Technology Innovation in Internet of Things and Its Applications” and “Technology Innovation in Information, Modeling and Mobile Applications”.

In addition, we are really thankful for the contributions and for the valuable time spent in the review process by our Advisory Boards, Committee Members and Reviewers. Also, we appreciate our collaboration partners (Petra Christian

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On behalf of the editors Felix Pasila

Part II
Technology Innovation in Robotics Image Recognition and Computational Intelligence Applications

Image-based Distance Change Identification by Segment Correlation

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Abstract Image–based distance identification is an interesting topic in image processing. It can be classified into three methods. The parallax approaches, the method with marker and the method with a priori knowledge of an object's physical size. The above methods are not easily implemented in an embedded system. This paper reports the development of an efficient image-based algorithm to identify the change of distance between camera and the captured object by measuring the movement of objects in the image. The algorithm is designed to work on a single camera without the aid of image markers such as laser beams. The algorithm calculates the correlation of predefined segments in the image to detect object movements, and therefore identify the direction and magnitude of distance change. The algorithm was designed to be implemented in a quadcopter to identify its change of altitude. The performance of the algorithm was examined using a simulated environment, and is reported in this paper.

Keywords: Image processing, Distance measurement, Segment Correlation

Introduction

The research that is reported in this paper was conducted to develop image-based algorithm that is able to sense the change of distance between a camera and the captured object. The algorithm was developed to be applied in a quadcopter as a sensor to provide information about altitude change to its controller.

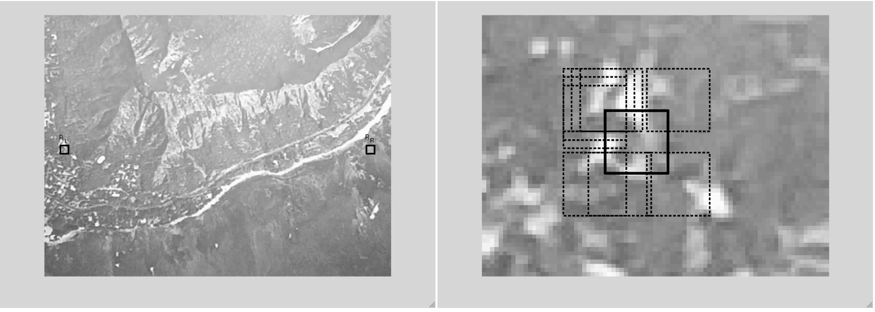
The algorithm of image-based distance measurement system can be grouped into three main methods. The parallax method [1-3] uses two cameras or a combination of mirrors to capture two or more images from different perspectives. The second method measures object distance with an aid of markers. Barreto [4] and Muljowidodo [5] developed distance measurement algorithm based on triangulation of a single laser beam, while Deng [6] and Lu [7] used two parallel laser beams projected to the object. The other methods [8-9] based their calculation on the knowledge of the physical size of objects in image. Such requirements are not easily implemented in a quadcopter due to its limitation in weight and computational capability. In [10], the author reported an algorithm to identify distance (altitude) change by observing the shift of gray level function in ten preselected rows in the image. The algorithm was able to identify distance change with an accuracy of more than *96%* but with a success rate of only *76%*.

This paper reports the development of another efficient image-based algorithm to identify the change of distance by calculating the correlation of predefined segments in the image to identify object's movement near the left and right edges of the image's frame. The current development of the algorithm reported in this paper shows a promising result. The algorithm can identify altitude change with an accuracy of above *97%*.

The Proposed Algorithm for Distance Change Identification

This section elaborates the proposed image-based algorithm to identify distance change between a camera and the captured object. The algorithm is based on image frames captured from a single facing down camera, mounted on the body of a quadcopter. The algorithm is designed to be simple and efficient in terms of computational complexity, computational time, and memory usage.

The fundamental principle of the algorithm is to detect the movement of objects in the captured frames. It is assumed that objects in the image move to the edge of the frame if the camera gets closer to the ground, and vice versa.



(a) (b)

Fig. 1. (a) The boxes, R_L and R_R, indicate the location of the referenced segments. (b) An Illustration of some neighboring segments, R'_L, in the comparing frame, $I'(x,y)$

2.1 Preprocessing

The algorithm calculates object's movement by comparing images of two consecutive frames, i.e. the reference frame, $I(x,y)$, and the comparing frame, $I'(x,y)$. The image frames are grayscale image captured from an 8-bit RGB camera (*460 x 640* pixels at *30* fps).

The algorithm only calculates the movement of objects inside two selected segments located near the left and right edges of the image frame, where object movements due to distance change are more observable. The segments, R_L and R_R, are sub-images of the reference frame, $I(x,y)$, with a size of *15* x *15* pixels, as illustrated in Fig. 1a.

$$R_L(m,n) = \{I(37+r,247+s) \mid -7 \leq r \leq 7 \text{ and } -7 \leq s \leq 7\} \quad (1)$$
$$R_R(m,n) = \{I(602+r,247+s) \mid -7 \leq r \leq 7 \text{ and } -7 \leq s \leq 7\} \quad (2)$$

2.2 Object Movement Identification

The direction and magnitude of object's movement is calculated by searching the relative location of R_L and R_R in the comparing image frame, $I'(x,y)$. The search is performed by calculating the correlation function between the reference segment (R_L or R_R) and its neighboring segments, R'_R or R'_L, in the comparing frame, $I'(x,y)$.

$$C_L(i,j) = \langle R_L, R'_{L\,i,j}\rangle \text{ and } C_R(i,j) = \langle R_R, R'_{R\,i,j}\rangle \quad (3)$$

The algorithm uses *400* neighboring segments on each side. The neighboring segments are the overlapping segments around the location of R_R or R_L with a size of *15* x *15* pixels (as shown in Fig. 1b). The segments are expressed with:

$$R'_L(m,n)_{i,j} = \{I'(x+i,y+j) \mid i = 20{:}40, \text{ and } j = 230{:}250\} \quad (4)$$
$$R'_R(m,n)_{i,j} = \{I'(x+i,y+j) \mid i = 585{:}605, \text{ and } j = 230{:}250\} \quad (5)$$

The movement vector is the vector from the centroid of R_R or R_L to the centroid of the local maxima in $C_L(i,j)$ or $C_R(i,j)$. By assuming that the centroid of R_R or R_L is at the origin, the movement vector is defined by:

$$\mathbf{v}_R = \arg\max_{i,j} C_R(i,j) \text{ and } \mathbf{v}_L = \arg\max_{i,j} C_L(i,j) \quad (6)$$

2.3 Distance Change Identification

The altitude change is identified by analyzing the two movement vectors, $\mathbf{v}_L$ and $\mathbf{v}_R$. The direction of the vectors may indicate four basic movements of the camera, as illustrated in Fig. 2.

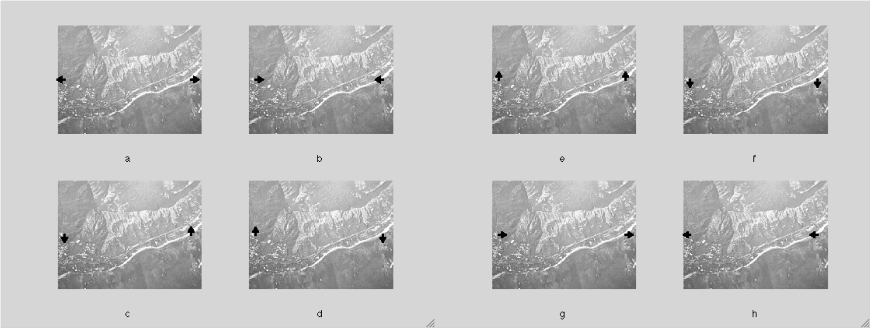


Fig. 2. The direction of the vectors $\boldsymbol{v}_L$ and $\boldsymbol{v}_R$ that indicates camera movement, i.e. (a) decrement of distance, (b) increment of distance, (c) clockwise rotation, (d) anti-clockwise rotation, (e) downward, (f) upward, (g) left, and (h) right.

To identify the direction and amount of distance change, the algorithm calculates only the projection of the vectors along the x-axis, $\boldsymbol{v}_{L\,x}$ and $\boldsymbol{v}_{R\,x}$. The distance increases if both vectors are pointing inward, vice versa. The amount of change, *d*, is proportional to the average of the two vectors. The distance change is considered to be absent if both vectors are pointing to the same direction, or having zero magnitude. The proportional coefficient, *k*, is determined by the initial altitude, *h*, and the horizontal size of the image frame (*640* pixels).

$$d = k\frac{v_{L\,x}+v_{R\,x}}{2} \qquad with \qquad k = \frac{2h}{640} \tag{7}$$

If the initial altitude, *h*, is unknown, the change of distance, *d*, is expressed as the proportion or percentage of *h*.

The algorithm is designed to be simple in terms of computational complexity, computational time, and memory usage. The complexity of the algorithm is due to the correlation function, $O(N^2)$. However, the algorithm consumes a relatively large memory space. In total, the algorithm needs almost 3 kbytes of memory space.

3. Experimental Results and Discussions

The algorithm was examined using a simulated environment as that in [10]. 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 was able to simulate some movements of the quadcopter. The simulated movements were the change of altitude (representing change of distance) along the z-axis, rotation of camera while maintaining its distance, 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.

3.1 Experiments with Various Change of Distance

In the first experiment, 20 frames were recorded from the camera at various different distances (z-axis) that represent distance changes from +/- *0.00* meters to +/- *0.04* meters. The frames were recorded while maintaining the camera rotation and translation. The first frame was recorded at an altitude of $h = 0.70$ meters. The experiment was conducted to investigate the ability of the algorithm to identify the change of distance. The results are shown in Fig. 3.

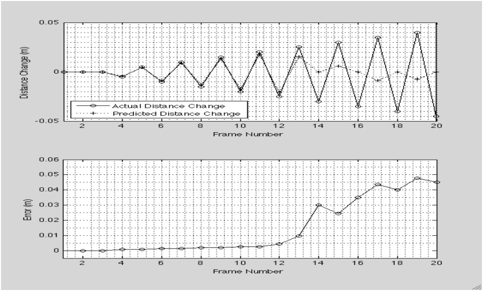


Fig. 3. The predicted distance change and error of experiment with variation of distance.

The results show that the algorithm could predict distance change accurately (with an error below *0.005* meters) from frame 1 to frame 11 when the distance change was below *0.02* meters. As the distance change was increased to a value above *0.02* meters, the algorithm failed to identify this change. The error increased to an unacceptable rate.

The limitation of the algorithm was caused by the distribution of the neighboring searching segments as explained in Section 2.2. The algorithm is only sensitive to a distance change of up to *0.0219* meters (equivalent to *3.12%* of its original distance).

3.2 Experiments with Translational Movement

The second experiment was conducted to investigate the algorithm's ability to compensate horizontal translation to both x-axis and y-axis. In the experiment, 25 frames were recorded from the camera at a constant altitude (z-axis) of *0.60* meters, while translated along the x-axis and y-axis as shown in Table 1. The results, shown in Fig. 4, confirm that the algorithm was able to compensate the translational movement with the maximum error of less than *0.01* meters (equivalent to *1.67%* of the initial distance). The error was due to the algorithm's misinterpretation of other objects as if it was the shift of the original object in R_R or R_L. The misinterpretation may occur if the captured images consist of flat, monotone, or periodic texture.

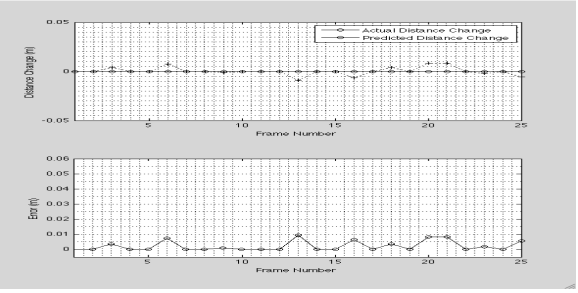


Fig. 4. The predicted distance change and error of experiment with translational movement.

Table 1. The x-axis and y-axis (in cm) translations of the frames in Fig. 5.

Frame	1	2	3	4	5	6	7	8	9	10	11	12	13
x-axis	0.0	0.0	0.5	1.0	1.5	2.0	2.0	1.5	1.0	0.5	0.0	-0.5	-1.0
y-axis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Frame	14	15	16	17	18	19	20	21	22	23	24	25
x-axis	-1.5	-2.0	-2.0	-1.5	-1.0	-0.5	0.0	0.0	0.0	0.0	0.0	0.0
y-axis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	0.0	-1.0	-2.0

3.3 Experiments with Rotational Movement

This experiment was conducted to investigate the algorithm's ability to compensate rotation movement. In this experiment, 9 frames were recorded from the camera at a constant altitude (z-axis) of *0.50* meters, while rotating around z-axis. The results, shown in Fig. 5, confirm that the algorithm was able to compensate the rotational movement with the maximum error of less than *0.015* meters (equivalent to *3%* of the initial distance). The error was also due to the algorithm's misinterpretation of other object as if it was the shift of the original object in R_R or R_L. As with the translational case, the misinterpretation may occur if the captured images consist of flat, monotone, or periodic texture.

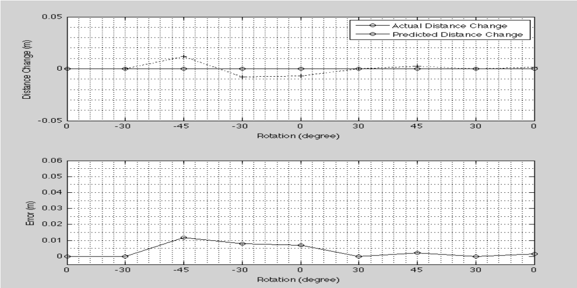


Fig. 5. The predicted distance change and error of experiment with rotational movement.

4. Conclusion

This paper presents an image-based algorithm to identify the change of distance based on correlation of reference segments. The algorithm was able to identify distance change of up to *3.12%* of its initial distance with an accuracy of more than *97%*, 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),the approach to reduce the number of needed memory, and the improvement of the algorithm accuracy.

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