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Adaptive Motion Detection Algorithm using Frame Differences and Dynamic Template Matching Method

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Abstract-There is many ways to detect the moving object. A common method is by comparing two or more image sequences. Comparing image by analysing all of image pixel is known as *frame differences* method.

Template matching is a technique that used to determine the reference image. Reference image that determined dynamically is known a dynamic template matching. This research proposes an algorithm to determine the reference image by using dynamic template matching adaptively. In the system, there are three ways to determine the reference image base on environment condition. This algorithm is implemented using web-based system and IP Camera as the capturing device. The algorithm provides detection accuracy of 95.5%.

Keywords- frame differences, dynamic template matching, web based motion detection

1. Introduction

Motion detection mechanism starts from the determination of a reference image. The reference image is considered as the normal condition of a room. Afterward, the subsequent image is compared with the reference one. The capturing process is carried out at regular intervals in accordance with the requirements of the system.

According to a study conducted by Mishra et al. [1], there are three methods commonly used to detect a motion. Those are background subtraction, optical flow and temporal differences. Background subtraction is performed by comparison of an image with the referenced one. This technique employs a static reference image [2][3][4].

Study in [5][6][7][8] used optical flow for motion detection. The application of optical flow requires additional hardware to support the performance and monitoring systems.

Method of temporal differences is also known by the name of the frame differences. This method is performed by comparison of captured image frames. Another study by Kenchannavar et al. [9] describes the algorithm of background subtraction and frame differences by applying the concept of Sum of Absolute Difference (SAD). SAD is used to determine whether there is a movement within an image pair.

Frame difference method uses specific technique to choose which reference image is used for motion detection. The technique is known as template matching. There are two methods of template matching: static template matching (background subtraction) and dynamic template matching (DTM).

This study uses a dynamic template matching method in determining the reference image. Furthermore, the dynamic template matching is enhanced to be adaptive to environmental changes. The new method is referred as the dynamic and adaptive template matching. In this study, the algorithms were implemented as web-based applications.

2. Related Works

Research by Yong et al. [10] was conducted using four methods of motion detection. These methods include methods of frame differences, background subtraction, pixelate filter, and blob counter. Image t at *t-1* is used as the reference one. The algorithm was implemented in C#.

Support Vector Machine (SVM) was also applied in the motion detection [4]. The study was not only performing motion detection, but also the segmentation of the objects. C++ and OpenCV were used for the implementation.

The study by Zheng [11] uses frame differences that are coupled with an adaptive threshold setting. Motion detection is also realized by using the method of statistical correlation method [12]. The correlation is used after the process of analysing the temporal differences in some of the image frame. The detection of motion was achieved by combining the frame differences technique with optical flow. This method was followed by a morphological filter technique [13].

Research conducted by Yokoyama et al. [14] also applied concept of vectors to movement detection. This method was performed by comparing multiple frames and marks the points of difference between the frames. This method yields information about the direction of movement of the object.

Zheng et al. [11] explains a method known as the Statistical Learning Algorithm [12]. Just like optical flow, the method requires complex calculation and large computational time.

Double differences technique is another method of motion detection [15]. Double differences are conducted by comparing the image with time *t* to image *t-1*, and then performed a second comparison between the image *t-1* with the image of *t-2*. In contrast to the method developed by Collins et al. [16], the comparisons were made between the image t with the image of *t-1*, and the image *t* with the image of *t-2*.

3. Algorithm

3.1 Frame Differences

This study uses frame differences method by comparing the average RGB components of each pixel. Equation 1 and equation 2 are used for the calibration step.

$$g_o(x,y) = \frac{g_R(x,y) + g_G(x,y) + g_B(x,y)}{3} \quad (1)$$

$$f_o(x,y) = \frac{f_R(x,y) + f_G(x,y) + f_B(x,y)}{3}$$

$$(g_o(x,y) - T) \le f_o(x,y) \le (g_o(x,y) + T) \quad (2)$$

Where: g_R, g_G, g_B are component of RGB images captured at time *t*, f_R, f_G, f_B the RGB components of the reference image. f_o and g_o the average value of the sum of the RGB colour components. *T* is the threshold or thresholds RGB value and then performed counting the percentage of pixels detected object. The detection is done using equation 3.

$$D = \frac{\sum f_i^R(x,y) + \sum f_i^G(x,y) + \sum f_i^B(x,y)}{\sum f_R + \sum f_G + \sum f_B} \times 100\% \quad (3)$$

Where *D* is the total percentage of differences were detected, whereas $\sum f_i^R(x,y), \sum f_i^G(x,y), \sum f_i^B(x,y)$ is the number of pixels that are detected by different RGB colour components. $\sum f_R, \sum f_G, \sum f_B$ are the total number of pixels an image taken from the three colour components.

3.2 Dynamic and Adaptive Template Matching

Reference image that used is a combination of reference at the time *t-1*, *t-n* and a new reference image if the scene (captured area of the camera) encounters significant change.

The changes could be: (1) changes in the brightness of the object, in this case it can occur if the room lights turned off, or the sun-lit room; (2) modification in captured area of the camera, this condition occurs when the camera field of view is changed; (3) changes in environmental conditions if there are objects come and then stand still. The flowchart of the algorithm can be seen in figure 1.

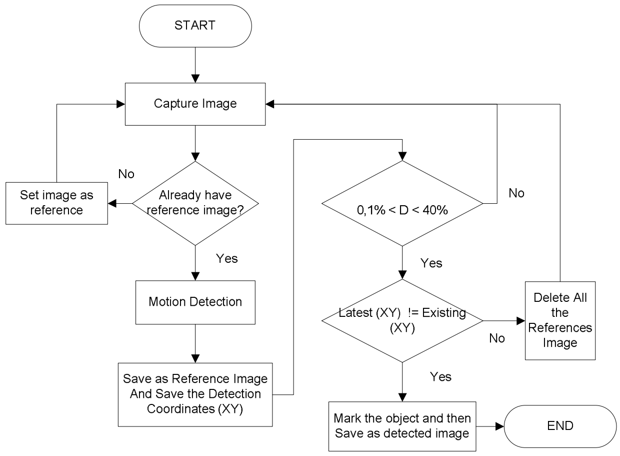

Fig. 1. Dynamic and Adaptive Template Matching (DATM) Method Flowchart

4. Motion Detection Analysis

4.1 DTM *t-1*, Static Template Matching and DATM Methods

A. Dynamic Template Matching t-1

Figure 2 and figure 3 show the identification of moving objects by DTM *t-1* method. Both images are sequentially captured with an IP Camera.

In Figure 2 (b) and 2 (c) motions have been detected. The moving object is identified as black colour (human motion). The weakness of this method can be seen in figure 3. Figure 3 shows the DTM *t-1* with moving object boundary characterized by the red mark. Figure 3 (c) marks the empty object that an object previously contained in figure 3 (b). This test shows the weakness of DTM *t-1* methods in detecting movement.

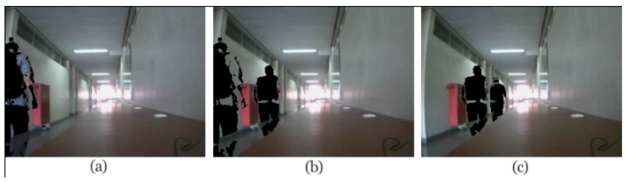

Fig. 2. Motion Detection *t-1* without marker in object boundary.

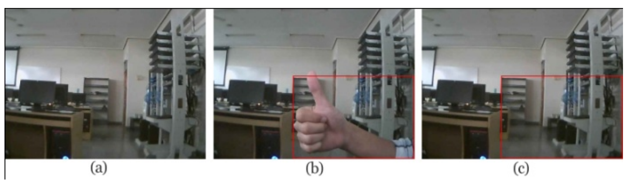

Fig. 3. Motion detection with reference *t-1*, with red marking shows object boundary

B. Static Template Matching

Testing is performed using a reference image that has been set by the system. This method is termed static template matching. The result can be seen in Figure 4.

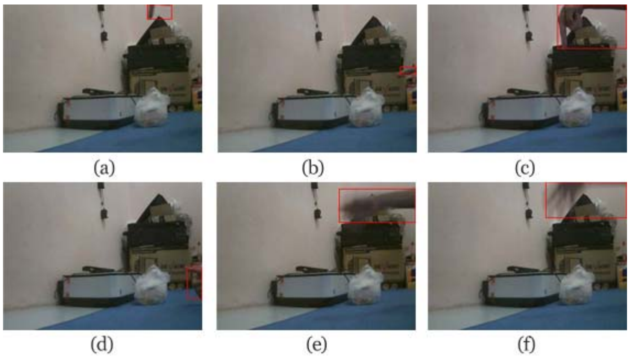

Fig. 4. Metode *Static Template Matching*

In figure 4, the system managed to overcome the weaknesses that occur in DTM *t-1* method. Each image in Figure 4 successfully detects moving objects and marks the object area.

However, this method still has a problem when an object comes and statically stays in the camera view (Figure5). An object (mouse) entered the field of view and correctly detected (figure 5 (b)). However, it was still detected as moving object in the next image (figure 5 (c), (d), (e)). It can be seen that the system is not adaptive to changes in the captured area.

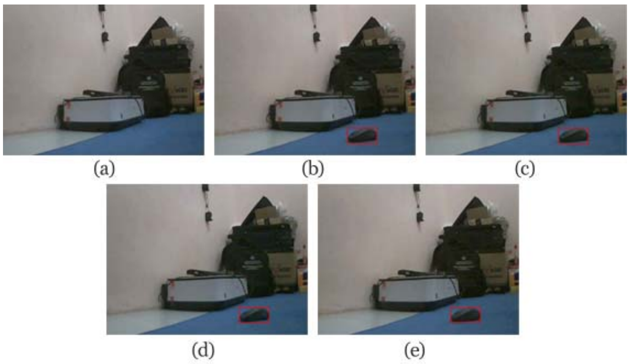

Figure 5. Error on motion detection with Static Template Matching Method

The design of new algorithm as shown on Figure 1 is to overcome the drawback of the previous methods. The DATM works by adjusting the reference image based on the condition of the captured area.

C. Dynamic and Adaptive Template Matching

In general, this system works by using three methods of determining the reference image. The method is dynamically changing and adaptive. The first method is the reference at the time *t-1*. This method is used for conditions when the system first captures the movement, then the reference *t-1* will have a role as a comparison to the detected image. If the next frame the system still detects movement, the references used are the images at *t-2*. If the next frame and detect the movement continues, then the reference image is used as *t-3*, and so on (*t-n*).

The third method works by re-determining the reference image if it detects motion at the same coordinate between frames. The test results using the DATM method can be seen in figure 6.

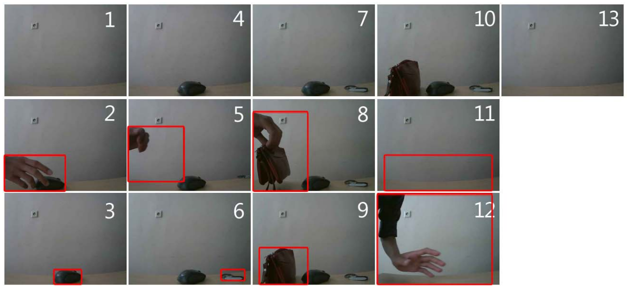

Fig. 6. Dynamic and Adaptive Template Matching Testing Results

Figure 6 is a sequence of image frames captured for DATM test. Image of 1, 4, 7, 10, and 13 are reference images, which are adaptively changed according to the condition of the captured area. New statics object are visible in a period of time in the catchment area. Thus the image of the new object is considered as a reference by the system.

Based on these tests, a DATM method capable of resolving a problem encountered when using the DTM*t-1* and Static Template Matching.

5. Experimental Result

Experiment was conducted to examine the accuracy of the *t-1*, DTM and DATM detection methods. Static template matching methods are not compared because the method is not adaptive to the environmental changing.

Testing and data collection conducted over three days. It was a 2 hours measurement for each day during office hours. Motion detection was done using IP Camera with PTZ (Pan Tilt Zoom) type (*Vivotek* brand). The camera was placed in the lobby of the Department of Electrical Engineering and Information Technology, Gadjah Mada University. The data was collected using DTM *t-1* and DATM simultaneously. The image was captured every second from the camera. The setting for both algorithms is the same, i.e.: the threshold value is 45, the range of percentage values that was detected (D) is from0.5% - 40%, the image resolution used is 256 ×192 pixels.

The results of the detection system are classified into two conditions, namely: True Positive and False Positive. True Positive means the system captures the image and correctly identified the moving objects. Whereas, False Positive is a condition in which the system captures the image, but mark the empty object or no identifiable objects as moving.

There are 1643 frames that were detected as motion when used *t-1* DTM method. Whereas 1278 frames of images were classified as motion with DATM method. The comparison can be seen in table 1.

Table 1. Accuracy comparison of DTM -1 and DATM

Comparison	***Metode***			
	DTM t-1		***DATM***	
True Positive	1474	89,8%	1221	95,5%
False Positive	169	10,2 %	57	4,5%

It can be seen that the accuracy of DATM is higher (95.5%) compared to the DTM *t-1* method (89.8%).

Table 2. Comparison of detection system result

Hasil Deteksi	Metode			
	DTM t-1		***DATM***	
Tight Marking	817	55,4%	713	58,3%
Over Marking	657	44,6%	508	41,7%

Table 2 shows the accuracy of detecting of boundary of moving object. Figure 6 with number 2 and 5 show examples of “Tight Marking” and “Over Marking” respectively.

6. Conclusion and Future Works

Dynamic and Adaptive Template Matching (DATM) is enhancement of DTM *t-1* and the static template matching. Based on the comparison of both methods, DATM method has detection accuracy rate 95.5%, Whereas, DTM *t-1*method has an accuracy of 89.8%.

Further research will be focused in the area of object segmentation. The aim is to identify the number of detected objects.

References

[1] Sumita Mishra, Prabhat Mishra, Naresh K Chaudhary, and Pallavi Asthana, "A Novel Comprehensive Method for Real Time Video Motion Detection Surveillance," *International Journal of Scientific & Engineering Research Volume 2, Issue 4*, 2011.

[2] P. Spagnolo, T. D'Orazio, M.Leo, and A.Distante, "Moving Object Segmentation by Background Subtraction and Temporal Analysis," *Image and Vision Computing*, vol. 24, pp. 411-423, May 2006.

[3] Zhen Tang and Zhenjiang Miao, "Fast Background Subtraction Using Improved GMM and Graph Cut," in *Congress on Image and Signal Processing, 2008. CISP '08.* , 2008, pp. 181 - 185.

[4] Hongyan Li and Hongyan Cao, "Detection and Segmentation of Moving Objects Based on Support Vector Machine," in *2010 Third International Symposium on Information Processing*, Shandong China, 2010, pp. 193-197.

[5] M. Allili, M.-F. Auclair-Fortier, P. Poulin, and D. Ziou, "A Computational Algebraic Topology Approach for Optical Flow," in *ICPR '02 Proceedings of the 16 th International Conference on Pattern Recognition (ICPR'02) Volume 1 - Volume 1* , Washington DC, USA, 2002.

[6] J Gallego, M. Pardas, and J.-L. Landabaso, "Segmentation and Tracking of Static and Moving Objects in Video Surveillance Scenarios," in *ICIP 2008. 15th IEEE International Conference on Image Processing*, 2008, pp. 2716 - 2719.

[7] Ho Gi Jung, Jae Kyu Suhr, Kwanghyuk Bae, and Jaihie Kim, "Free Parking Space Detection Using Optical Flow-based Euclidean 3D Reconstruction," in *Proceedings of the IAPR Conference on Machine Vision Applications (IAPR MVA 2007)*, Tokyo, Japan, 2007, pp. 16-18.

[8] Jens Klappstein, Tobi Vaudrey, Clemens Rabe, Andreas Wedel, and Reinhard Klette, "Moving Object Segmentation using Optical Flow and Depth Information," *Advances in Image and Video Technology*, 2009.

[9] H H Kenchannavar, Gaurang S Patkar, U P Kulkarni, and M M Math, "Simulink Model for *Frame* Difference and Background Subtraction comparision in Visual Sensor Network," in *2010 The 3rd International Conference on Machine Vision (ICMV 2010)*, Hongkong China, 2010.

[10] Yee Ching Yong, Rubita Sudirman, and Kim Mey Chew, "Motion Detection and Analysis with Four Different Detectors," in *2011 Third International Conference on Computational Intelligence, Modelling and Simulation*, Langkawi, 2011, pp. 46-50.

[11] Xiaoshi Zheng, Yanling Zhao, Na Li, and Huimin Wu, "An Automatic Moving Object Detection Algorithm for Video Surveillance Applications," in *2009 International Conference on Embedded Software and Systems*, Hangzhou China, 2009, pp. 541-543.

[12] S Murali and R Girisha, "Segmentation of Motion Objects from Surveillance Video Sequences using Temporal Differencing Combined with Multiple Correlation," in *2009 Sixth IEEE International Conference on Advanced Video and Signal Based Surveillance*, Genova, Italy , 2009, pp. 472-477.

[13] Li Fang, Zhang Meng, Claire Chen, and Qian Hui, "Smart Motion Detection Surveillance System," in *2009 International Conference on Education Technology and Computer*, Singapore, 2009, pp. 171-175.

[14] Takanori Yokoyama, Toshiki Iwasaki, and Toshinori Watanabe, "Motion Vector Based Moving Object Detection and Tracking in the MPEG Compressed Domain," in *2009 Seventh International Workshop on Content-Based Multimedia Indexing*, Chania, Crete, 2009, pp. 201-206.

[15] Y Kameda and M Minoh, "A Human Motion Estimation Method Using 3-Successive Viedo *Frames*," in *International Conference on Virtual Systems and Multimedia*, 1996, pp. 135–140.

[16] Robert T. Collins et al., "A System for Video Surveillance and Monitoring," 2000.