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Techniques for Background Updating under PTZ Camera Based Surveillance

Sunghoon Jung†, Minhwan Kim††

ABSTRACT

PTZ (Pan-Tilt-Zoom) camera based surveillance systems are enlarging their field of application due to their wide observable area. We aimed to detect both static and moving objects in automated working space by using a PTZ camera. For object detection we used background difference method because of the high quality segmentation. However, the method has a problem called 'hole' that is caused by non-continuous surveillance of the PTZ camera and its own characteristics. Moreover, the occlusion which occurs when the moving object overlaps with the static object should be solved for robust object detection. In this paper, we suggest a region-based technique for updating background images thereby overcoming the hole and occlusion problem. Through experiments with real scenes, it was verified that meaningful static and/or moving objects were detected very well.

Key words: Background updating, Hole problem, Occlusion problem, PTZ camera, Surveillance

1. INTRODUCTION

In these days, with increasing crimes and accidents, the need for surveillance system in public, crime-ridden and forbidden areas are also rapidly increasing. The surveillance system with CCTV (Closed Circuit Television) has many advantages as low cost, easy to install, and ability to collect the objective video data.

There are many previous researches about intelligent surveillance systems [1]. In this paper, we aimed to detect static and moving objects in wide space with small number of cameras. This objective is basically for detecting environmental change and alert in automated working space. In this application, both the static and moving object can be an obstacle which blocks the driving way of working vehicles.

We applied a PTZ (Pan-Tilt-Zoom) camera for reducing the number of cameras and used the background difference method for detecting both static and moving objects. In this case, background updating rises to an important issue for adapting background image to current status of the scene. While performing background updating, the characteristics of PTZ camera and the background difference method cause a problem. Assume that a movable object existed when the background image was grabbed and while the PTZ camera was observing other part of areas, the object left there. When the PTZ camera returns to the area where the object was, the previous region of the object will be detected as changed region. In this situation, the region where the object left is not an actual object but it is detected every time the camera observes there. We call the region as "hole" and will distinguish it from the actual objects.

※ Corresponding Author : Minhwan Kim, Address : (609-735) Department of Computer Engineering, Pusan National University, Busan, Korea, TEL : +82-51-510-2423, FAX : +82-51-518-5033, E-mail : mhkim@pusan.ac.kr

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† Dept. of Computer Engineering, Pusan National University (E-mail : shjung@pusan.ac.kr)
†† Dept. of Computer Engineering, Pusan National University

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After distinguishing, the hole region in background image is updated based on current input image. Thus we can detect only the actual objects.

Furthermore, nevertheless we adopted PTZ camera, static objects should be detected independent of the obscuring moving objects vice versa. For solving this occlusion situation, we keep point set for static objects. Static objects are registered to these point set during they are static and removed based on their region if they are detected as hole.

We can efficiently perform post-processing as recognition, discrimination, and localization on the segmented actual objects based on this approach. Also, we expect that this approach can be used for finding abandoned or stolen objects.

This paper is organized as follows. Section 2 introduces the previous works and compares them with what we want to do. Section 3 explains the technique we suggest. Section 4 shows the experimental results. Section 5 concludes our works.

2. PREVIOUS WORKS

Previous researches have their own goals to be intelligent. For example, some researchers worked on camera calibration for location measurement [2-5] while others worked on background making as image mosaic or statistical modeling for object detection [6-8]. Some researchers wanted to classify the objects into human or not [9,10] while others analyzed human's behavior [11,12].

In earlier days, the research target was on fixed cameras and diverse research results as object detection, recognition, analysis, and measurement, etc. are already reported. Nowadays, cameras with various functions have been produced representatively, PTZ and omni-directional camera. The researches about PTZ and omni-directional camera suffer from moving camera environment and severe distortion respectively but, it will be valuable to research about these cameras because, these provide wide surveillance area which is attended with expense reduction practically.

There were various researches which adopted various cameras for detecting objects in wide area. The researchers Video Surveillance and Monitoring (VSAM) project at Carnegie Mellon University [13] developed a system for providing continuous coverage by using multiple, cooperative video sensors. They developed various detection algorithms and integrated many kinds of cameras by networking.

Azzari, *et al.* [6], and Bevilacqua and Azzari [7] adopted PTZ cameras and proposed a method for background making using image mosaic to detect objects in the scene. Hu and Su [8] also adopted PTZ camera and proposed a method representing each scene captured by the camera using a spatial-temporal statistical model. Wang, *et al.* [14] adopted omni-directional camera and tried to perform motion detection, object tracking, and behavior analysis. Yao, *et al.* [15] combined omni-directional and PTZ cameras and used the geometrical relationship between them for detection and tracking.

Most of above researches are using the background difference method for detecting objects or changes in the scenes. When we make the background images by any methods, the probability that movable objects can be grabbed in the background image is very high and they can move out anytime. Especially, the problem becomes more serious when PTZ camera is adopted. Because PTZ camera doesn't observe fixed area continuously, if the movable objects moved out when the camera is observing other part of areas, the differenced region will be continuously detected as an object. Therefore a method for classifying it into a hole or an actual object is needed, to detect a meaningful object in the scene.

Luo and Bhandarkar [16] mentioned sleeping person problem which is similar with hole problem but, they used fixed camera and time-dependent parameter for preventing the object to be absorbed into background image. Kim, *et al.* [17] suggested a background updating method for fixed surveillance and used very similar method for classifying a move-in or move-out case. They created background model by pixel based operations and introduced short-term background by using layers for foreground detection. Also, they applied a color similarity test which is similar with edgeness comparison in this paper. However, when we use a PTZ camera, we should consider about its characteristic; non-continuous surveillance. Considering above researches, we suggest PTZ camera based surveillance system which can detect segmented actual objects by using background updating method.

3. BACKGROUND UPDATING UNDER NON-CONTINUOUS SURVEILLANCE

The biggest challenge to PTZ camera based surveillance system is that the camera rotates again and again. It means that we cannot assume continuous observing at a fixed view. For simplifying the problem, we limited the active views per fixed unit degree. After this, system acquires background images in each decided views. In this step, it is hard to remove all movable objects in the wide range where PTZ camera covers. For this reason, we need to treat about the hole problem for practical use of the system. Moreover, in this case both static and moving objects should be detected, the static objects should be detected until they move again or they are revealed as non-interest-object by the problem-dependent policy, without interfering with passing-over object detection.

Figure 1 is the flow of PTZ based surveillance system. The camera repeats rotation periodically and observes decided views in a given period. At the start of the observing period, the system finds changes in the background and watches new static objects. If the changed region is decided as a hole via hole detection method, it is reflected to background updating. If the changed region is decided as static object in a given period, the region is registered to a point set and merged in the background image until it moves again. The point set which has the static object can be partly or wholly cleared through the hole detection method and matching procedure.

3.1 Hole Detection

3.1.1 What is hole

A hole occurs when a movable object in background image moved out. If we don't take any action to the hole, the hole region is continuously detected as an object. When we use the background difference method, acquired background images are input image at a specific moment. Because we don't have any prior information, there is no criterion for classifying a differenced region in difference image into hole or object. In other words, we can't discriminate between hole and object by looking at only the differenced region. However, we found that if we utilize the differenced region and the surrounding region of it, there is a margin

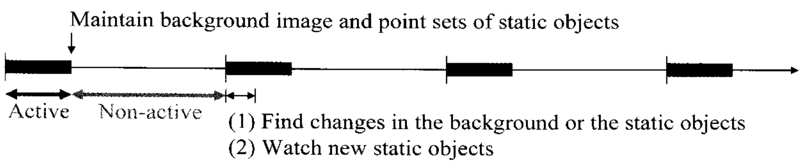

Fig. 1. The flow of PTZ based surveillance. The bold lines are active period at decided view. At the end of each period, system maintains the background image and point set of static objects in that view. At the start of next period, system finds changes in the background or the static objects and watches new static objects.

for distinguishing between hole and object. Figure 2 shows an example of hole occurrence.

Through the analysis of images captured by camera, we chose two criterions, histogram similarity and edgeness, to estimate the differenced region.

Histogram similarity first measures the similarity between the differenced region and the surrounding region of it in the background image. Second, it also measures the similarity between the differenced region and the surrounding region of it in the current input image. After that, the two similarities, in the background image and current input image, are compared for hole estimation.

Edgeness measures the number of edge-like points on the whole boundary of the differenced region in the background image and current input image. These two edgeness are also compared for hole estimation.

After measuring these four factors (two histogram similarities and two edgenesses), we combined these factors to determine the differenced region as hole or not. Each of these two criterions is the one of quality that can represent homogeneity or heterogeneity between the differenced region and the surrounding region of it.

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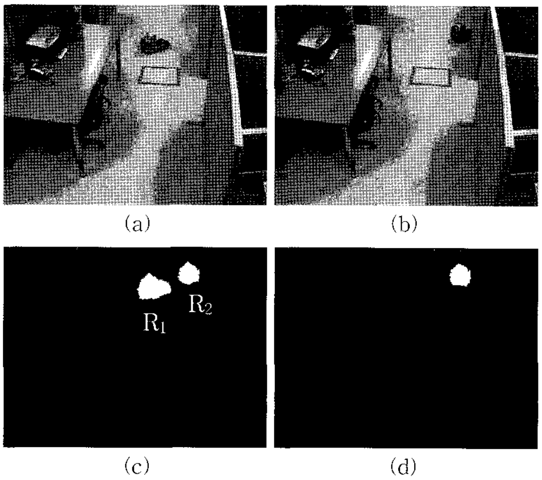


Fig. 2. An example of hole occurrence. (a) A background image. (b) An input image when the camera returns after observing other part of area. (c) A binarized difference image between (a) and (b). The region R_1 is hole but, R_2 is actual object. (d) A region of an actual object.

3.1.2 Histogram similarity estimation

The histogram similarity is estimated between the histogram of two regions; the differenced region and the surrounding region of it. In background image and current input image, the histogram similarities are estimated and normalized respectively. For simplicity, we assume that one differenced region consists of one connected component. The differenced component D is extracted by the background difference method and the surrounding region S is determined by morphological dilation using a structured element H followed by exclusion of D as shown in (Eq. 1) and Figure 3 shows each region in each image.

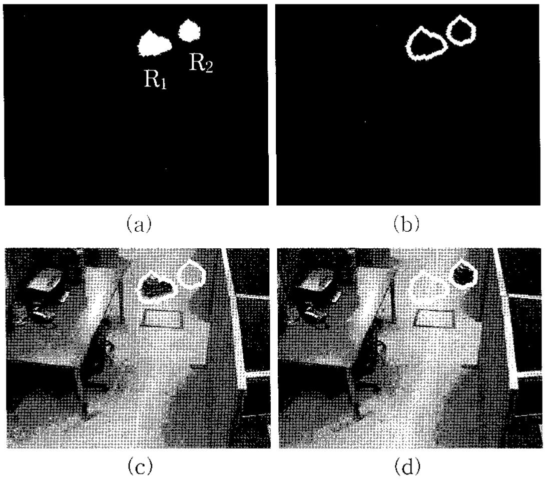


Fig. 3. An example of difference components and surrounding regions of them. (a) Difference components. (b) Surrounding regions. (c) Surrounding regions in background image. (d) Surrounding regions in current input image.

$$S=(D\oplus H)-D \qquad \text{(Eq. 1)}$$

Figure 4 shows the histogram of each region. We can see that the two histograms of differenced component R_1 and its surrounding in the background image show very different distribution. However, the two histograms of the same component and its surrounding in the current input image show similar distribution. On the contrary, the histograms related to component R_2 shows opposite characteristics.

In conclusion, we can infer that if the histogram similarity between differenced component and its surrounding region in background image is lower than in current input image, the differenced component has higher possibility as a hole. We used histogram intersection method for estimating similarity h_{IMG} in specific image between two normalized histograms NH as shown in (Eq. 2).

$$h_{IMG}=\sum_{l=0}^{255}\min(NH_D(l),NH_S(l)) \qquad \text{(Eq. 2)}$$

3.1.3 Edgeness comparison

One more criterion for hole detection is edgeness. It is similar with the color similarity test in [17], but edgeness comparison doesn't need a parameter for thresholding because, our method compares the edgenesses in background and current input image. We defined the edgeness as shown in (Eq. 3). According to the boundary, gradient in perpendicular direction is estimated and determines the point on the boundary as an edge or not.

$$Edgeness_{IMG}=\frac{\text{No. of Edge Points}}{\text{Length of Boundary}} \qquad \text{(Eq. 3)}$$

Figure 5 shows edge points of each differenced component. We can see that if the differenced component is hole, the edgeness in background image is high but low in current input image. On the contrary, the edgeness of actual object shows opposite characteristics.

In conclusion, we can infer that if the edgeness in background image is higher than in current input

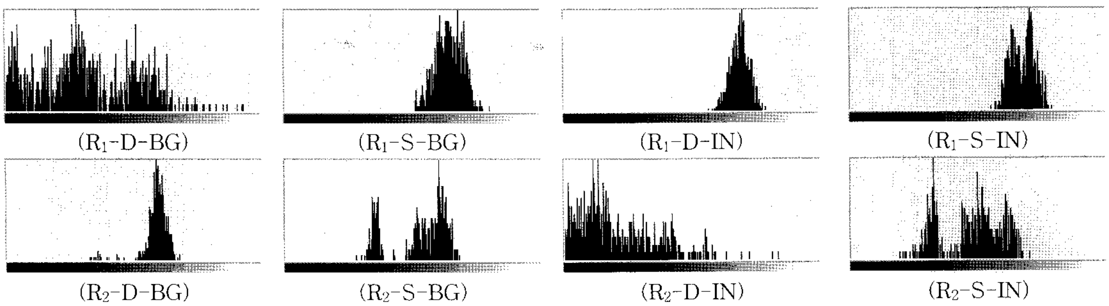


Fig. 4. Histograms related to difference components. The caption under each image means (component - region - image). For example R_1-D-BG means the differenced region of R_1 in the background image.

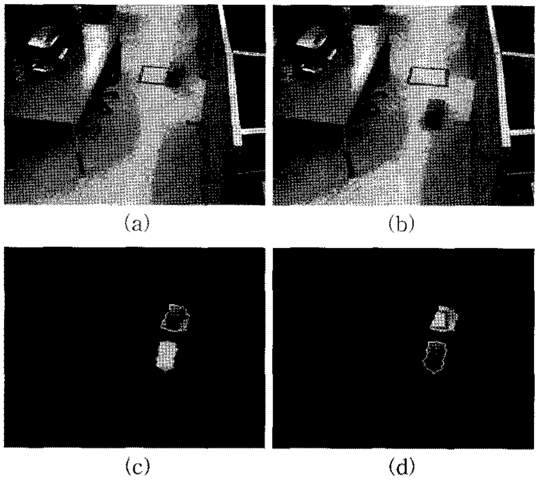


Fig. 5. An example of edgeness difference between hole and actual object. (a) A background image. (b) An input image when the camera returns after observing other part of area. (c) The edgeness in background image. Yellow points mean edge points while red points mean non-edge points. (d) The edgeness in current input image.

image, differenced component has higher possibility as a hole.

3.1.4 Hole decision

Finally, hole is decided through the estimated histogram similarities and edgenesses in background and input image. In this paper, we combined above two criterions as shown in (Eq. 4).

$$D=\begin{cases} \text{hole}, & \dfrac{h_{CUR}\times Edgeness_{BG}}{h_{BG}\times Edgeness_{CUR}}>1 \\ \text{object}, & \text{otherwise} \end{cases} \quad \text{(Eq. 4)}$$

3.2 Point Set for Static Objects

An actual object which is detected by the hole detection method can be classified into static object and moving object. Moving object is not the target for consideration because it does not interfere with the detection of other objects. However, static object can interfere with the detection of other objects passing over it because we can't know whether the differenced region is appeared by the static object or by the pass-over object.

For solving this problem, we keep point set for static objects. If the detected object stays for a given period, the points in the region of that object are registered in a point set. Each static object has its own point set individually. Figure 6 shows a registered static object and the points in the point set. For judging an object whether it is static or moving, we used the center location and orientation of the minimum bounding box which encloses the detected region. In temporal domain, if the center location and orientation maintain the value in given variation, it is considered as static object.

If a hole is detected, we find match in the point sets. We increase a count variable if a point in hole region is in point set otherwise, decrease. After that, the static object which has the highest including ratio in the hole region is determined as disappeared static object. On that static object, the hole region in the point set is cleared and the background image is updated. Figure 7 shows validity of this method from the possible cases of disappearing among the overlapped static objects.

As mentioned above, PTZ camera covers its range non-continuously thus at the moment the camera returns to a view, two or more object can be overlapped and stay. In that case, the objects are registered in one point set as one object is appeared. For this reason, we select the static object which has the highest including ratio and if the including ratio is under 90%, partly remove the

Fig. 6. An example of static object and its point set. (a) An object is considered as static if it stays in small variation. (b) The static object is registered in the point set.

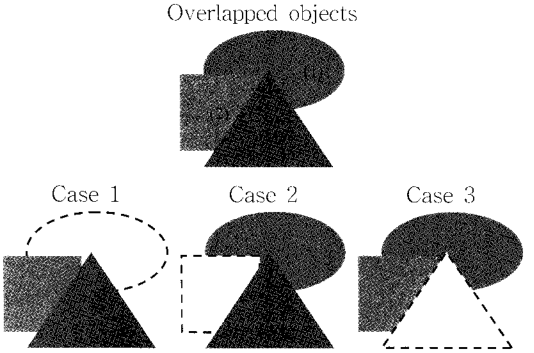


Fig. 7. An example of disappearing cases among the overlapped static object. The dotted line means difference region which is occurred by hole. (Case 1) The most behind object is disappeared. Only the object (1) has the including ratio. (Case 2) The middle object is disappeared. Object (1) and (2) have including ratio but, the ratio of object (1) is negative because excluded region is bigger than included. (Case 3) Similar with case 2.

region in point set. This technique is not a perfect solution because when a new static object is overlapped on the static object as above, we cannot acknowledge the change in occluded region. However, this technique can carve the static object region as much as possible when the object move out thus helping to solve the hole problem.

3.3 Background Update

A hole means a differenced component which is no more attractive to the surveillance system. Therefore, the differenced region in background image is updated by the corresponding region of the input image. If that region is matched with a registered static object, the related point set is partly or wholly cleared. After this background updating, the differenced component which is determined as hole disappears and doesn't extract in future.

Figure 8 shows the updated background by hole detection. In Figure 8, the differenced region R_1 in the background image is updated based on the current input image because it is the hole. However, the differenced region R_2 in the background image is maintaining its previous values and can continuously detect the object.

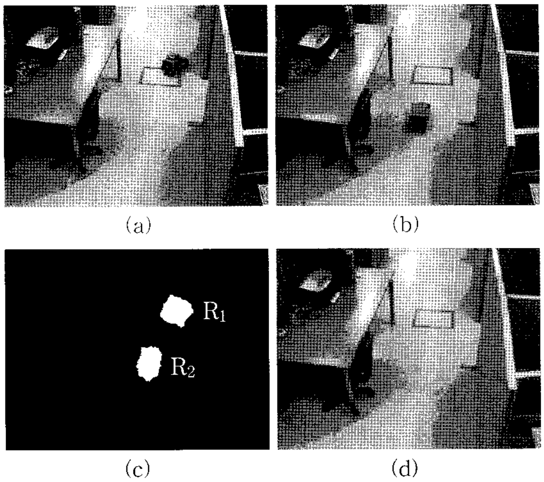


Fig. 8. Background update by hole detection. (a) Previous background image. (b) An input image when the camera returns after observing other part of area. (c) Difference components. (d) Updated background image.

For the pixels which are not included in differenced regions are updated by reflecting fixed proportion of the current input pixels. This enables background image to be robust on illumination variations.

4. EXPERIMENTAL RESULTS

For experiments on PTZ camera based surveillance and hole detection method, we used the AXIS 213 PTZ network camera and tested in both indoor and outdoor environments. After the camera is installed, background images are acquired over the defined positions. Figure 9 is an example of background images.

After background acquisition, system starts surveillance through pan and tilt. Figure 10 shows the result of hole and object detection at indoor environment.

In Figure 10, the first row is the initial background images after PTZ camera installed. We set

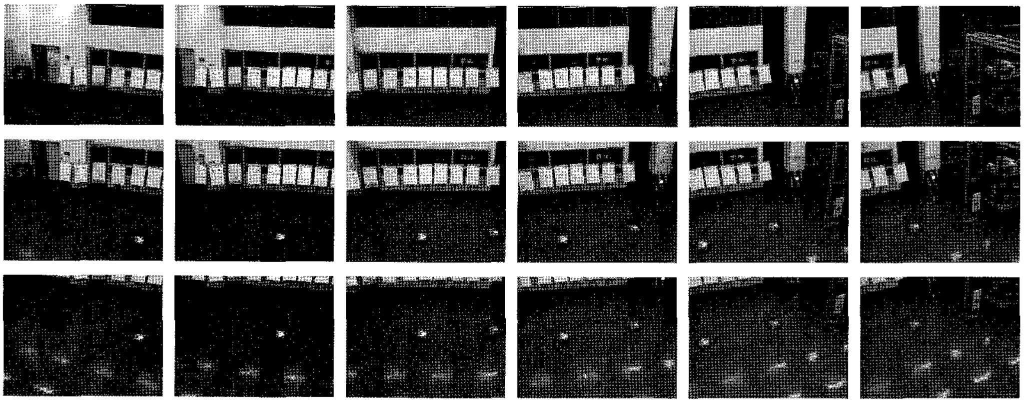
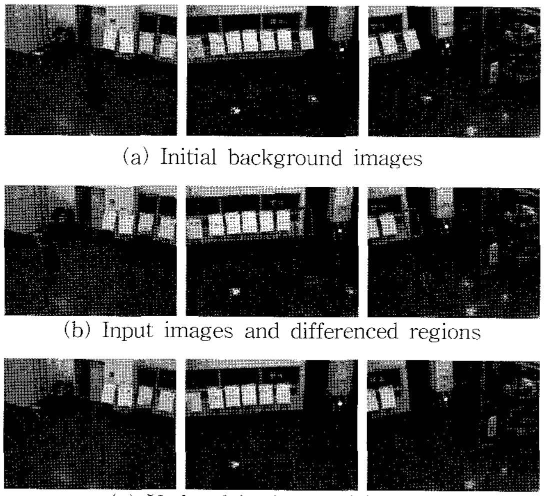


Fig. 9. An example of background images

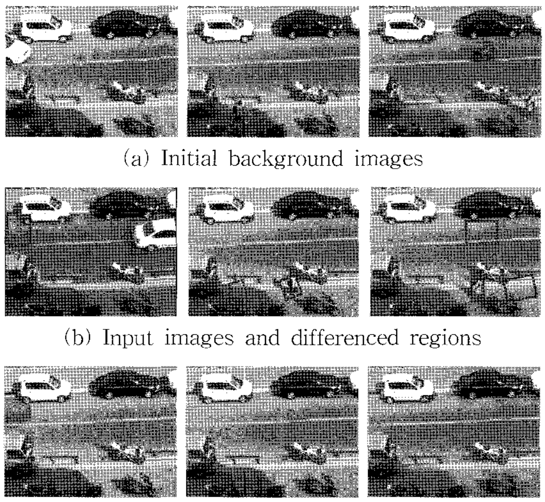


(a) Initial background images

(b) Input images and differenced regions

(c) Updated background images

Fig. 10. Test for background updating at indoor environment



(a) Initial background images

(b) Input images and differenced regions

(c) Updated background images

Fig. 11. Test for background updating at outdoor environment

several movable objects in the environment for hole detection test. While the camera is observing other part of the area, we removed some movable objects from the environment. Through the second row, the chair in the first background image and the box in the second and third background image were moved and the posting panel in the second and third background image was removed. In the third row, the differenced regions which are detected as hole were updated by substituting based on the current input images. Additionally, we tested our method at outdoor environment. Through Figure 11 we can confirm that proposed method can classify a hole or an object at outdoor as well as indoor.

Figure 12 is the result of experiment dealing with static objects. The scenario is as follows. We assume that each event happens at next active period in that view.

(1) Two objects appear and stay simultaneously.
(2) A new object is overlapped and stays.
(3) A moving object passes over the previous objects.
(4) One of the objects at (1) disappears.
(5) The remaining object at (4) disappears.

Through Figure 12 we can know that the static

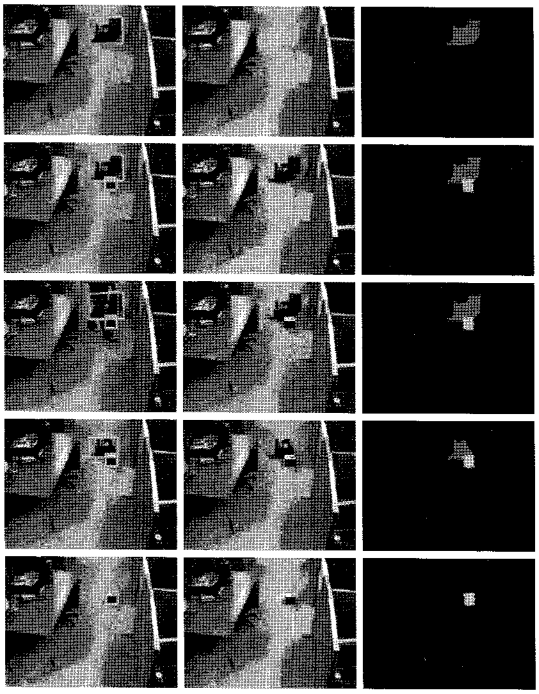


Fig. 12. Test for detecting static objects

object is well registered in the point set and does not interfere with detection of moving objects. Although the two objects which appear simultaneously can be bound in one point set, when one of the static object disappeared, the suggested method matched the hole region with static object and updated the background efficiently.

5. CONCLUSIONS

In this paper, we suggest a background updating method for PTZ camera based surveillance system. For detecting environmental change and alert in automated working space, we used background difference method and in this case, we should consider hole problem and occlusion problem. We proposed a method for classifying the differenced region into hole or actual object by using the histogram similarity and edgeness. Moreover, we proposed the point set method for maintaining the detected static objects and detecting the passing-over moving object on the static objects without interfering. We expect that this paper can be used for efficient post-processing on the segmented actual objects and finding abandoned or stolen objects as well as robust object detection.

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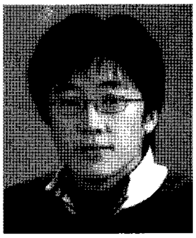
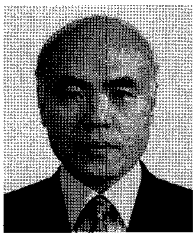


Sunghoon Jung

He received his B.S. and M.S. degrees from Pusan National University, Busan, Korea, in 2006 and 2008, respectively. He is currently a Ph.D. degree student of the Dept. of Computer Engineering in Pusan National University, Korea. His research interests include intelligent surveillance system and computer vision.



Minhwan Kim

He received his B.S., M.S., and Ph.D. degrees from Seoul National University, Seoul, Korea, in 1980, 1983, and 1988, respectively. He is currently a professor of the Dept. of Computer Engineering in Pusan National University, Korea. His research interests include intelligent surveillance system, multimedia information retrieval, color engineering, and computer vision.