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시각적 가려짐을 극복하는 강인한 유기물 탐지 기법

Robust Detection Technique for Abandoned Objects to Overcome Visual Occlusion

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요 약 오늘날은 사회 안전을 강화하기 위하여 공공장소에서 유기물을 자동으로 검출하는 지능적 비전 감시 시스템을 설계하는 것이 필요한 때이다. 그런데, 이미 인지된 유기물의 일부분 또는 전체는 주변사람들로 가려질 수가 있다. 필수 지표 중 하나인 PAT를 개선하기 위해서는 시스템이 이러한 가려짐 문제를 극복해야만 한다. 이 연구에서는 이러한 가려짐 문제를 고려하여 강인한 검출시스템을 구축하기 위해서 여러 단계로 구성된 새로운 설계 기법을 제안한다. 제안된 시스템의 유용성을 보이기 위하여 6개의 다양한 상황을 포함하는 이미지 스트림에 대해서 평가를 시행했고, 그 실험 결과는 침입과 유기 행위에 대해 각각 96%와 75%의 성능을 보인다. 마지막으로 다수의 사람에 의한 가림 현상에도 불구하고 제안된 시스템은 계속적으로 유기물을 인지하는 성능을 보이고 있다.

Abstract Nowadays it is required to design intelligent visual surveillance systems which automatically detect abandoned objects in public places to strengthen the social safety. Already recognized abandoned objects can be occluded partially or fully by surrounding people in public places after the first recognition. To improve an essential recognition performance index PAT, the system should overcome the occlusion problems. In this research, a design scheme is newly proposed to construct the robust detection system which is comprised of multiple stages considering the occlusion problem. To show the feasibilities of the proposed system, the evaluation was tried for the prepared image streams including 6 various situations and the experimental results show 96% and 75% in PAT performance for intrusion and abandoning events, respectively. Finally in spite of full occlusions by multiple persons, the proposed system shows the capability to continuously recognize the abandoned object after complex occlusions disappear.

Key Words : Visual surveillance, Occlusion, Abandoned object, Background extraction, PAT, PED.

Ⅰ. Introduction

Visual surveillance plays an important role in monitoring social securities of modern society. From CCTV systems which simply have functions of monitoring and storing to the intelligent systems with advanced behavior analysis, visual surveillance systems replace much of human works in social security nowadays. After the 911 terror in the United States, security authorities of many countries strengthen sterner measures to possible terrors. For this, terror organizations begin to change their tactics from direct attacks to indirect ones. One of indirect terror attacks is to abandon dangerous objects in public areas as illustrated in Fig. 1. It is easy to secretly abandon containers such as bags and sags which contain toxic or explosive materials in pubic places where a massive number of people flock. It is required

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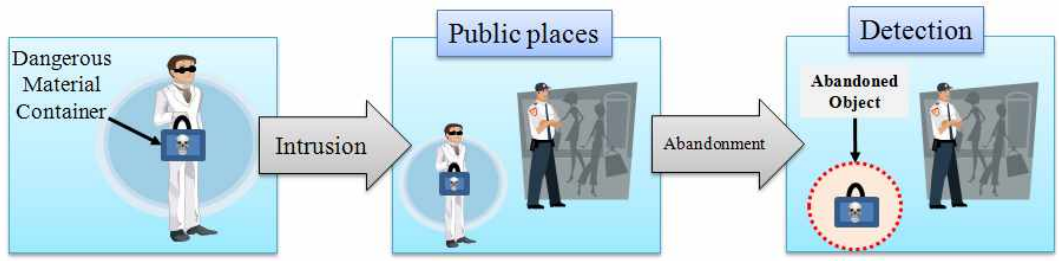

그림 1. 비전 감시 시스템에서 유기물의 자동 감지
Fig. 1. Automatic detection of abandoned objects in the visual surveillance system

그림 2. 비전 감시 시스템에서 가려짐 문제
Fig. 2. Occlusion problem in the visual surveillance system

to design visual surveillance systems which automatically detect abandoned objects in public places to strengthen the social safety and reduce the expenses in public security. There are a few researches to design visual surveillance systems to automatically detect abandoned objects as in [1]-[4]. Recently W. Kim designed an automatic detection system for dangerous abandoned objects based on vision technology in [5] and proposed an enhanced system which discriminates motionless people from abandoned objects by using the human recognition technique in [6].

The remainder of the paper is described as follows. The occlusion problem in the application to crowded public places is explained in Chapter Ⅱ. To overcome this problem, a robust detection system is newly proposed in Chapter Ⅲ. In Chapter Ⅳ experimental studies are described to show the feasibility of the proposed system and finally the research is concluded in Chapter Ⅴ.

Ⅱ. Problem Statement

If a visual surveillance system detects objects and successfully discriminates abandoned objects, it does not seem easy to steadily recognize the objects as abandoned ones in cluttered environments after the first recognition. As illustrated in Fig. 2, an object, which is already recognized as abandoned by a visual surveillance system, can be occluded partially or fully by surrounding people in public places. The problem is whether the visual surveillance system has the capability to still recognize the object as abandoned after the occlusions disappear because it is natural to understand that the system performances will be affected by occlusions which frequently happen in public areas.

As an important performance index, Percent Events Detected(PED) in [1] is evaluated for visual surveillance systems because it measures the sensitivity for real alarm events even though there may be false alarms in the results. Generally, PED is defined as follows :

$$PED = \frac{\#of\,Real\,Alrams\,Detected}{\#of\,Real\,Alrams}. \quad (1)$$

Meanwhile, as an accurate performance index,

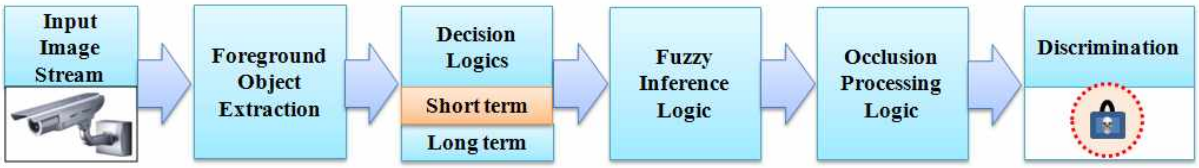

그림 3. 비전 감시 시스템의 구조
Fig. 3. Structure of the visual surveillance system

Percent Alarms True(PAT) should be evaluated according to the following equation,

$$PAT = \frac{\#of Real Alrams Detected}{\#of All Detected Alrams}. \quad (2)$$

As easily found in the previous equation, PAT depends on how to decrease false alarms in the entire detections. Because the occlusion problem is one of the major factors in false alarms to the entire detections, it is necessary to design a robust visual surveillance system which is insensitive to occlusion situations.

Ⅲ. Robust Detection System for Abandoned Objects

In this chapter, a design scheme is newly proposed to construct the robust detection system for abandoned objects as illustrated in Fig. 3. The system receives image streams as input information and finally generates the discriminated information on abandoned objects while occlusions happen. 4 stages are linked in cascade such as Foreground Object Extraction, Decision Logic, Fuzzy Inference and Occlusion Processing Logic. In the following sub-chapters, design schemes on these 4 stages will be described.

1. Foreground Object Extraction

Foreground objects are obtained by subtracting the background image from current importing image. Here the background image means the stationary pure background image without mobile objects such as people and moving things. Therefore, extracting the background image is the essential process to stably obtain foreground objects. One of the useful background extraction technique is Dynamic Background Extraction(DBE) method proposed by Kong et al.[7] and the concept is explained in Fig. 4. In the technique, each pixel is statistically analyzed and corresponding histograms are constructed in each R, G, B channel. Based on the histograms, the dominant R, G, B Bins are selected to represent the corresponding pixel, and these selection method is robust to temporary illumination changes in background. In the example of Figure 4, Bin2, Bin3 and Bin4 is selected in channel R, B and G as the intensity value, respectively because each Bin contains most of intensity information even though illumination changes happen locally. Actually the number of Bins may be chosen to 8 or 16 in this research.

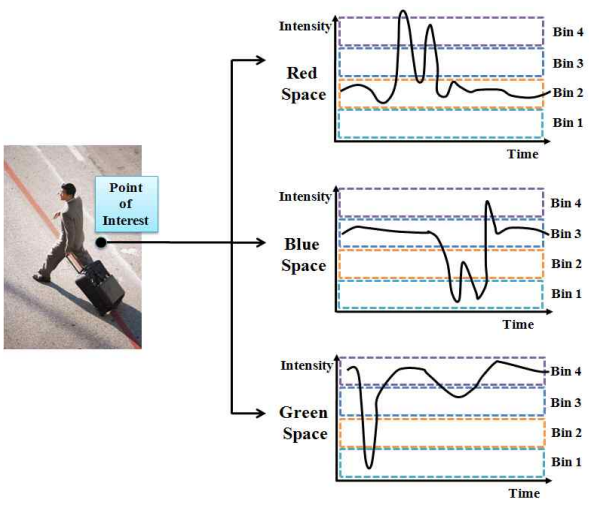

그림 4. 배경이미지 추출 기법
Fig. 4. Background extraction technique

After constructing the background image, foreground objects are easily obtained by subtracting this from the current importing image. After obtaining

foreground objects, it is necessary to discriminate human shapes to increase PED and PAT performances. Mohan et al. tried to detect humans with Harr wavelets and SVM(Support Vector Machine) classifier in [8]. In [9] Viola et al. used adaBoost classifier to detect pedestrians in streets and moreover Mikolajczyk st al. utilized adaBoost classifier to robustly detect human parts in [10]. In this approach, HOG(Histogram of Oriented Gradient) is applied to detect the human shapes in foreground objects based on the approach of Dalal and B. Triggs in [11].

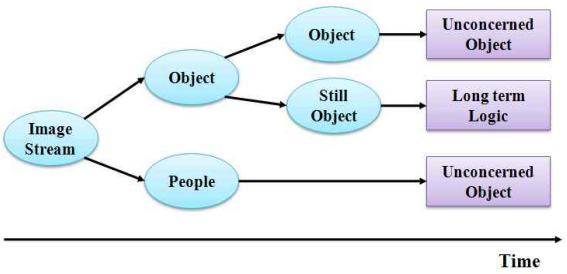

그림 5. 유기물에 대한 판단 로직
Fig. 5. Decision Logic for Abandoned Objects

2. Decision Logic for Abandoned Objects

Foreground objects obtained in the previous stage are analyzed in the Decision Logic stage as illustrated in Fig. 5. The objects can be grouped by two categories such as object and people. Objects in the people category is treated as unconcerned ones. In the short-term point of view, objects being analyzed will belong to "normal object" category, in which the objects are also treated as unconcerned one, or "still object" category, in which the objects exist alone and have no motion in a prescribed time. Because it is obvious that abandoned objects belong to this "still object" category, the still object should be analyzed in the long-term logic. Meanwhile, in the long-term logic two situations are considered as follows :

- o the situation in which objects are left alone over a certain time in the image stream, and
- o the situation in which objects and people exist for a certain time and after that the people disappear.

For the previous two situations, measures can be prepared to analyze objects according to the long-term logic truth table of Table 1.

표 1. 장기 판단 로직의 진리표
Table 1. Truth table of the long-term logic

Items		Still People		
		Change	No Change	None
Still Object	Change	Observation		
	No Change	Alert	Keep Attention or Alert	Alert

3. Fuzzy Inference Logic

In the previous stage, two situations are carefully considered to decide which are abandoned objects. The problem is how to choose "a certain time" which is shown in the two situations. Because the time depends on the degree of crowd for each public place, it is more adequate to represent the fuzzy variable for the time limit rather than the crisp type of number. Therefore a fuzzy logic system is utilized in this research as illustrated in Fig. 6. The system has a input which means the abandoning time and is fuzzified according to the input membership function of Fig. 7. The inference engine contains two simple fuzzy inference rules as follows :

- o If input is negative, then output is negative, and
- o If input is positive, then output is positive.

Resulting output is generated by the defuzzification of the mean of maxima method.

그림 6. 퍼지 로직 시스템
Fig. 6. Fuzzy logic system

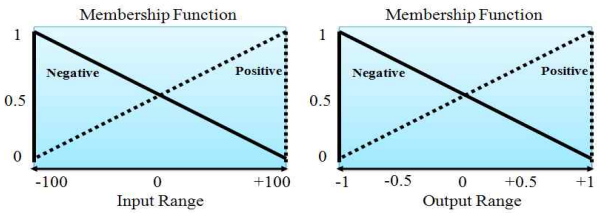

그림 7. 퍼지 멤버쉽 함수
Fig. 7. Fuzzy membership functions

4. Occlusion Processing Logic

Once an object is recognized as an abandoned object, its image information is stored and processed in certain memory spaces. If people going around occlude the abandoned object, at this moment the color values for the object are somewhat different from the original object and therefore the visual surveillance system redundantly detects this object as different abandoned one. However, since the system already has the region information for the first recognized abandoned object, the region comparison can be continuously tried between the original abandoned object image and another newly recognized abandoned object image which is actually the same as the original one. Finally if occlusions go away, the system still recognized the abandoned object without confusion in spite of temporary occlusions as illustrated in Fig. 8.

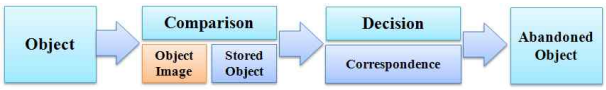

그림 8. 가려짐에 대한 처리 로직
Fig. 8. Processing logic for occlusion

Ⅳ. Experiments

The proposed design scheme in the previous chapter is implemented in a real software system which has the capability to have an IP camera input as in Fig. 9. In the figure, the image stream section shows original images from the IP camera and there are an object and a person. Background image section shows the background image constructed by the DBE technique. Binary image section shows abandoned object shape in the binary type expression. A red rectangle and a green one is drawn over to designate the object and human, respectively in the recognition section by the automatic recognition of the visual surveillance system.

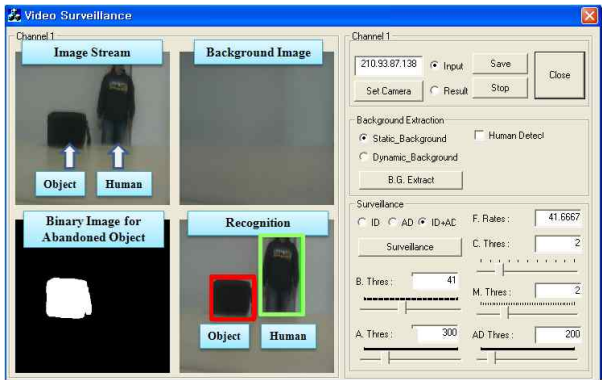

그림 9. 실험에서의 비전 감시 시스템
Fig. 9. The visual surveillance system in the experiment

To evaluate the proposed visual surveillance system, appropriate testing image stream should be prepared to include various situations. For this experiment, image streams for a meeting room was captured to include 5 essential situations which was used in the previous research of [6] and an occlusion situation in which multiple persons enter the meeting room and occlude an abandoned object on a table while going around it. The situations for the evaluation are summarized in Table 2. By applying the appropriate experimental procedures,

그림 10. 사람에 의한 가려짐에 대한 실험 결과
Fig. 10. Experimental result on the occlusions by people

corresponding experimental results are obtained and summarized in Table 3. For total 6 situations, 52 intrusion cases are successfully detected for all 54 intrusion events(PAT 96%). Meanwhile, as another important issue, the abandoned object detection result shows 18 successful detections for total 24 abandoning events(PAT 75%).

Fig. 10 shows the detection ability in image frames for the proposed surveillance system to a situation that multiple persons enter the meeting room and occlude an abandoned bag on a table while going around the table. In spite of full occlusions by multiple persons, the system still continues to recognize the abandoned object after occlusions go away.

표 2. 비전 감시 시스템 시험용 실험 상황
Table 2. Experimental situations to test the visual surveillance system

Situation	Image Content
Basic situations	5 essential situations tried in the experiment of [6]. · Simple situation · Complex situation · More complex situation · Situation on abandoned objects · Situation on motionless persons
Occlusion situation	Multiple persons enter a meeting room and occlude an abandoned object on a table while going around it.

표 3. 비전 감시 시스템의 PAT 시험 성능
Table 3. PAT performance of the visual surveillance system in the experiment

Item	Input for experiment	Detection rate
Detection performance for intrusion	· System : Intel QuadCore Q8200, RAM ; DDR2 4GB · IP Camera : AXIS 210A · 6 situations to test the visual surveillance system · Image stream obtained in a meeting room · Indoor environment test	· Detecting 52 cases for 54 intrusion events · Detection rate : 96%
Detection performance for abandoned object		· Detecting 18 cases for 24 abandoning events · Detection rate : 75%

Ⅴ. Conclusion

Nowadays it is required to design visual surveillance systems which automatically detect abandoned objects in public places to strengthen the social safety and reduce the expenses in public security. An already recognized abandoned object can be occluded partially or fully by surrounding people in public places after first recognition. To improve an essential performance index PAT, the system should overcome the occlusion problems. In this research, a design scheme is newly proposed to construct the robust detection system which is comprised of 4 stages such as Foreground Object Extraction, Decision Logic, Fuzzy Inference and Occlusion Processing Logic for abandoned objects. To show the feasibilities of the proposed system, the evaluation was tried for prepared image streams including 6 situations and the experimental results show 96% and 75% PAT performance for intrusion events and for abandoning events, respectively. Finally in spite of full occlusions by multiple persons, the system shows the capability to continuously recognize the abandoned object after complex occlusions go away.

In the further study, it is required to design the fuzzy system with multiple inputs and outputs to treat more complex occlusion situations.

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