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# Airport Monitoring System: Robust Airplane Extraction against Variable Environmental Conditions

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## Abstract

*We have developed an airport monitoring system which traces the movement of airplanes in the parking areas of airports. For this system, we have developed an image processing method that can detect moving objects and determine the sizes of the objects under illumination changes. Conventional methods adapted to changes in illumination are unable to correctly determine the size of objects because they can only detect the edges of the objects. We have therefore developed a two-stage background subtraction method which consists of local and global normalized subtraction. First, local normalized subtraction is applied to extract moving objects. Secondly, global normalized subtraction is applied to the area which encloses the detected objects to determine the size of the objects. With this method, airplanes can be detected in a stable manner amid changes in illumination.*

*We have evaluated this method by using 140 hours of video images which contain changes in illumination and confirmed 95% accuracy of airplane detection. This system is now in operation at the Kansai International Airport.*


## 1. Introduction

We have developed an airport monitoring system that monitors the parking area for airplanes called the "spot," where passengers plane and deplane (Figure 1). This system detects the movement of airplanes and records their arrival and departure times. Airport management companies are therefore able to obtain information about total use time for every spot and charge the airline companies the appropriate parking fee.

One possible method for airplane extraction is to measure the distance to the airplane with a laser range finder. However, acquiring the correct distance is difficult because all airplanes do not stop at exactly the same position. We have therefore selected an image processing method that can detect airplanes that are stopped in a variety of positions.

We encountered two problems in developing the system based on image processing techniques. One problem involved extracting airplanes amid changes in illumination and the other problem involved false detection due to boarding bridges. These two problems are described in detail below.

Fig. 1 A spot area in an airfield

**(1) To extract airplanes amid changes in illumination**

Background subtraction is generally used to extract moving objects. This method identifies objects as differentiated areas between the current image and the background image in terms of brightness. The advantage of this method is that the entire area of objects can be detected. However, because this method determines the presence of objects merely by changes in brightness, it is unable to distinguish objects from mere changes in illumination brought about by shadows formed by clouds and the like. In airports, there are numerous cloud shadows, so using this method will lead to numerous cases of false detection. Figure 3 (a) shows this method working in a case where cloud shadows are present. The white area indicates an area mistaken for moving objects due to changes in illumination caused by cloud shadows.

Some methods ([4]-[6]) have been proposed to extract only moving objects amid changes in illumination. These methods observe the local area to extract objects. This is because changes in illumination can be regarded as local constant changes in brightness. Moving objects change the local distribution in the brightness, and detecting local changes in the edges of objects via subtraction with the background enables moving objects to be extracted amid changes in illumination.

However, there are problems associated with these methods. These methods are unable to distinguish a large object with monotone coloring (such as an airplane) from small objects (such as vehicles) with a flat background. Figure 2 shows an example of such a case. Figures 2 (a) and (b) show a cross-sectional view of the brightness of a large object and two small objects, respectively. The x-axis indicates the position of the object(s) and the y-axis indicates the brightness. Figures 2 (c) and (d) show the range where movement can be detected by using these methods. The y-axis indicates whether detection takes place. The higher lines indicate the detection range and the lower lines indicate the nondetection range. For a large object, the methods are able to detect only the movements of the boundary of the object with edges. Meanwhile, for two small objects, the methods detect two entire objects because they are small and covered with edges. As a result, Figures 2 (c) and (d) are similar, and it is difficult to distinguish between a large object and two small objects. In the case of airport monitoring, these methods are unable to distinguish an airplane from other objects such as small vehicles.

We have solved this problem by using a two-stage normalized background subtraction method which combines both local and global area subtraction. Because it focuses on the local area, this method is very effective in accommodating changes in illumination. Because it also focuses on the global area, this method can also detect movements of entire objects.

**(2) False detection due to boarding bridges**

Boarding bridges for passenger planing and deplaning can easily be mistaken for an airplane because they are of a size comparable to that of airplanes. We have solved this problem by utilizing motion differences between airplanes and boarding bridges.

## 2. The two-stage normalized background subtraction method

Some methods for extracting only moving objects amid changes in illumination have been proposed. They identify objects as the area where local edges have undergone change compared with the background. This is because changes in illumination can be regarded as local constant changes in brightness while moving objects change the local distribution in the brightness.

However, a problem associated with these methods is their inability to distinguish an airplane from other objects such as small vehicles. This is because the changes in the edges detected by the methods for the two cases are very similar, as Figures 2 (c) and (d) illustrate.

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But as an airplane has an area that is much larger than that of other moving objects such as vehicles, airplanes can be distinguished in terms of area. To acquire the size of objects, background subtraction to global area is required. Figures 2 (e) and (f) illustrate the range to be detected via global area subtraction. This method is able to detect the entire area of objects because it compares entire objects to the background. Accordingly, Figures 2 (e) and (f) are easy to distinguish.

We have developed a two-stage normalized background subtraction method which combines local and global area subtraction. Local area subtraction makes this method very effective in accommodating changes in illumination. Conversely, global area subtraction enables object sizes to be acquired with this method.

In the first stage, local changes in edges are detected to extract objects against changes in illumination, via normalized block subtraction. In the second stage, global area subtraction is applied to detect the entire area of objects via normalized area subtraction. First, the method sets up a global area called the potential moving area. The potential moving area is then normalized to eliminate the effect of changes in illumination. Objects are then extracted as a result of subtraction with the background. The potential moving area should be large enough to contain entire objects to acquire object sizes. At the same time, to avoid the effect of changes in illumination in other areas, the area should not be too large. Accordingly, the potential moving area is dynamically defined as the enclosing area of the detected moving objects via normalized block subtraction.

The method is able to extract airplanes in a stable manner amid changes in illumination. The details of the method are described below.

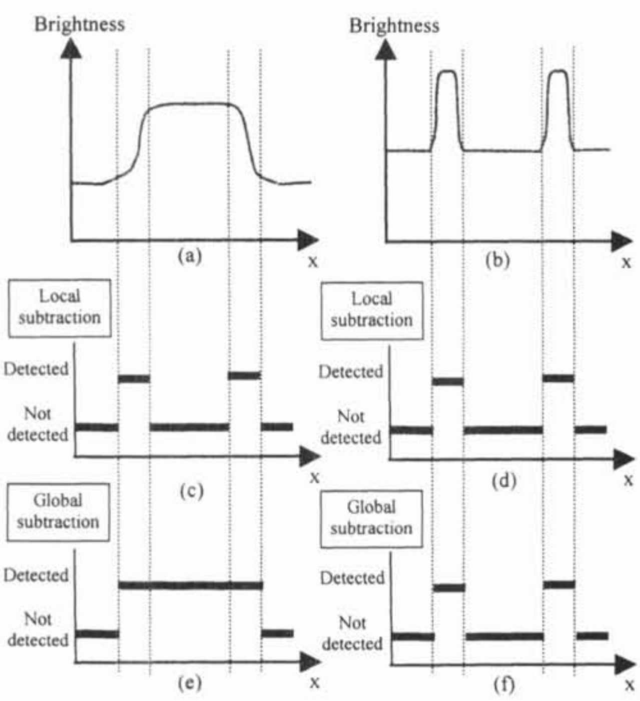



Fig. 2 Comparison of a large object and two small objects

## 2.1 Normalized block subtraction

The first stage of the two-stage method is normalized block subtraction. With normalized block subtraction, the screen is divided into small blocks and the brightness is normalized on each of the blocks to eliminate the effect of changes in illumination. If $p_i$ is the i-th pixel in a block containing N pixels, then the normalized pixel, $p_i'$, is obtained by

$$p_i' = p_i - \bar{p} \qquad (2)$$

Here,

$\bar{p}$ : the average of all of the brightness values in the block

The normalized background, $b_i'$, is obtained in the same manner. The movement is determined using the inter-block distance D defined as below.

$$D = \frac{\sum_{i=1}^{N} |p_i' - b_i'|}{N} \qquad (3)$$

The inter-block distance D represents the average distance between the corresponding elements of the vectors. Thus, the constant changes in brightness due to changes in illumination are eliminated via normalization and only moving objects are detected. The block with a large D value is defined as the moving block. And if there is a sufficient number of moving blocks, it is determined that some objects are moving. Figure 3 (b) shows how cloud shadows affect normalized block subtraction. The white blocks indicate the area where change is detected. Unlike the case in Figure 3(a), there are few such blocks.

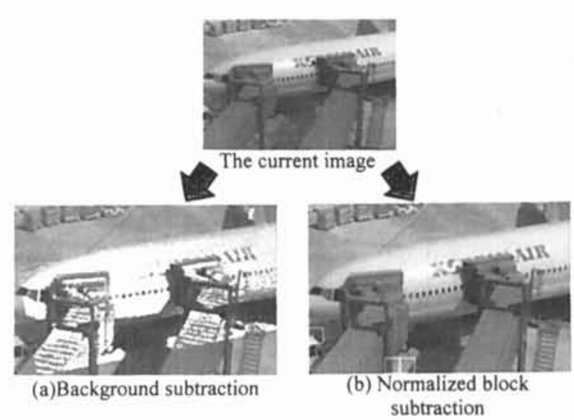



Fig. 3 Comparison of the effect of cloud shadows

## 2.2 Normalized area subtraction

Normalized block subtraction can detect only the edges of objects because it focuses on the local area. To solve this problem, normalized area background subtraction is applied as the second stage of the two-stage method. With normalized area subtraction, the entire distribution pattern of the objects is compared to the background. By comparing the entire distribution pattern, the method can extract entire objects.

First, a global area enclosing the detected moving block is defined as the potential moving area. Figure 4 shows how a potential moving area is defined. The white blocks in Figure 4 indicate the moving blocks detected via normalized block subtraction. The dotted lines are the border of the area where the moving blocks are detected. The dark area enclosed by the dotted lines is defined as the potential moving area.

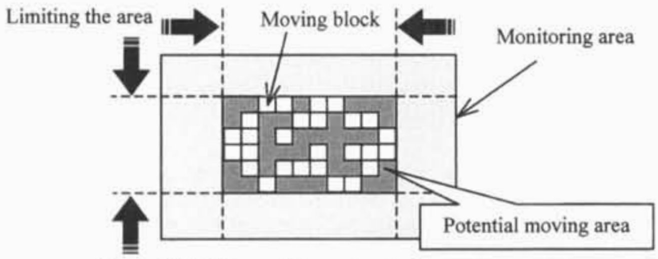



Fig. 4 Definition of the potential moving area

The pixels within the potential moving area are normalized to eliminate the effect of the changes in illumination. If $p_i$ is the i-th pixel in the area, then the normalized pixel, $p_i'$, is obtained by

$$p_i' = p_i - \bar{p} \tag{4}$$

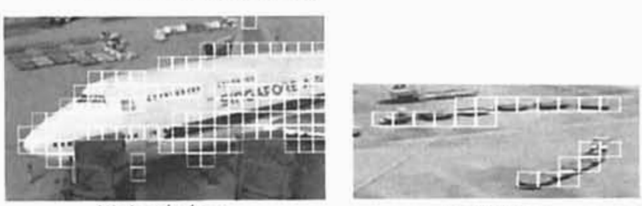
Here,

$\bar{p}$ : the average of all the brightness values in the potential moving area

The corresponding area in the background image is normalized in the same manner. The moving objects are obtained as a result of the subtraction between the normalized current image and the normalized background image.

Figures 5 (a) and (b) show the result of normalized block subtraction for an airplane and vehicles. The white block indicates the moving block. The moving block is not detected within the outline of the airplane. It is therefore difficult to distinguish the airplane from the vehicles by using the number of the moving blocks.

Figures 6 (a) and (b) show the result of normalized area subtraction for an airplane and vehicles. The white area indicates the detected moving objects. This method extracts entire objects because it compares entire objects to the background. As shown in Figure 6, the method can distinguish an airplane from vehicles.



(a) An airplane (b) Vehicles

Fig. 5 The result of the normalized block subtraction

(a) An airplane (b) Vehicles

Fig. 6 The result of the normalized area subtraction

## 3. False detection due to boarding bridges

There is a variety of moving objects in an airfield. Especially, boarding bridges are likely to cause any cases of false detection because they have as large size as an airplane.

A single boarding bridge is not large enough to cause false detection. However, two boarding bridges are generally used for a single airplane and, when moved simultaneously, will produce almost the same number of moving blocks as an airplane and cause cases of false detection to occur (Fig.7).

Fig. 7 Moving blocks caused by boarding bridges

We solved this problem by utilizing the differences in motion between an airplane and boarding bridges.

First, we investigated situations in which boarding bridges move. As a result, boarding bridges were found to move in three different situations as shown in Table 1 below.

Table 1 Classification of boarding bridge's movements

| Situation in which the boarding bridge(s) move | Spotting situations | Event to be detected |
|---|---|---|
| (a) Movement of boarding bridges alone | Empty | Spot-in |
| (b) Movement following spot-in | Parking | Spot-out |
| (c) Movement before spot-out | | |

Case (a) indicates the movement of boarding bridges where there is no airplane in the spot. Case (b) indicates the movement of boarding bridges to approach an airplane so that passengers can deplane following airplane spot-in. Case (c) indicates the movement of boarding bridges when they are separated from an airplane before the airplane starts to take off.

We solved the problem of false detection due to boarding bridges for each of the three cases given below.

### Case(a) Movement of boarding bridges alone

The event the airport monitoring system should detect is the spot-in of an airplane because the spot is empty. Therefore, distinguishing spot-in of an airplane from boarding bridges is required. We focused on the characteristic movement of airplane. As shown in (a) to (d) of Figure 8, an airplane appears from the right end and slowly proceeds to the left. Conversely, boarding bridges do not move in this manner.

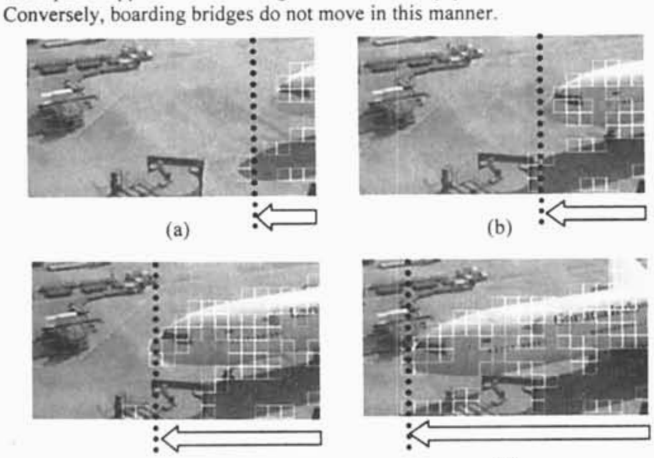
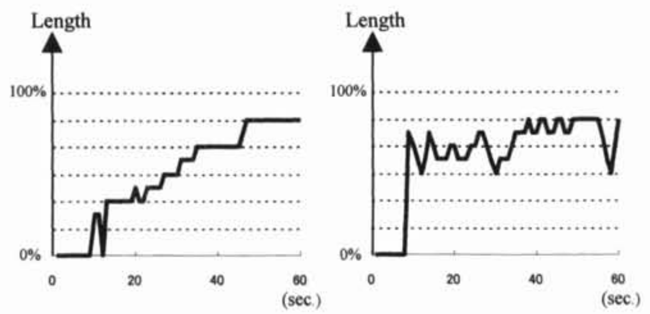



Fig. 8 Movement of an airplane at the spot-in

We utilized the differences used to distinguish an airplane from boarding bridges. First, we obtained the area in which a large number of moving blocks is detected. The dotted line in (a) to (d) of Figure 8 indicates the area boundary. Next, we measured the length of the area in the approaching direction. (Each arrow in (a) to (d) of Figure 8 shows the length.) The length indicates the front edge of the object. Figure 9 shows the length for an airplane and boarding bridges. The x-axis indicates the time and the y-axis indicates the length as a percentage of the length of the spot. The graph for the airplane shows an increase in one direction whereas the one for the boarding bridge shows random movement. Accordingly, airplanes can be distinguished and false detection can be avoided.




(a) The spot-in movement of an airplane

(b) The movement of a boarding bridges

Fig. 9 Comparison of movement of an airplane and boarding bridges

### Case (b) Movement following spot-in

The event the airport monitoring system should detect is the spot-out of an airplane. Therefore, distinguishing the spot-out of an airplane from the movement of boarding bridges is required. But unlike the case of spot-in, the direction of movement cannot be obtained by background subtraction in this case. Figure 10 illustrates the reason. When the airplane starts to move in the direction indicated by the arrow, the moving blocks emerge at the hatched area all at once. Therefore, the direction of movement cannot be determined with the moving blocks.

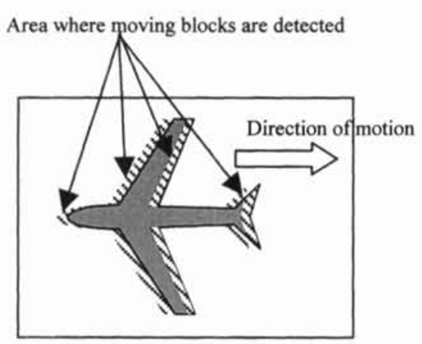



Fig. 10 Moving blocks at spot-out

Accordingly, we utilized the characteristic motion of boarding bridges. First of all, the boarding bridges always move after the spot-in of an airplane. Secondly, the boarding bridges move immediately after the spot-in of the airplane so that passengers may deplane. Therefore, large objects that move immediately after spot-in can be identified as a boarding bridge. By suspending detection for a certain period of time after an airplane spot-in, cases of false detection due to boarding bridges can be avoided.

### Case (c) Movement before the spot-out

The event the airport monitoring system should detect is an airplane spot-out. Therefore, distinguishing an airplane spot-out from the movement of boarding bridges is required. For the same reason cited for case (b), the direction of movement of airplane cannot be used. But in case (c), unlike case (b), two boarding bridges rarely move simultaneously. Boarding bridges separate from the airplane one by one. As mentioned earlier, a single boarding bridge will not cause any cases of false detection to occur, this problem should not occur with case (c).

## 4. Experiment

We have implemented the developed method and examined its performance. We used 140 hours of video images taken at the Kansai International Airport. They include scenes under a variety of conditions such as the presence of cloud shadows, the turning on and off of lights, night, during rainfall and so on. We also evaluated simple background subtraction for comparison purposes. Table 2 below shows the results.

Table 2 Results of the experiment

| | Number of detection errors | Frequency (No. of detection errors per hour) |
|---|---|---|
| Our method | 7 | 0.05 |
| Simple background subtraction | 81 | 0.59 |

When compared with simple background subtraction, our method makes less than one-tenth the detection errors. We also confirmed there were no cases of false detection due to boarding bridges. Note that most detection errors using simple background subtraction are caused by cloud shadows.

## 5. Conclusion

We have developed an airport monitoring system that is very effective in accommodating changes in illumination. The problem of false detection due to changes in illumination have been solved by using a two-stage method that combines normalized block subtraction and normalized area subtraction. Cases of false detection due to boarding bridges are solved by utilizing the differences in the motion of an airplane and boarding bridges such as the direction of movement.

We have evaluated the method with 140 hours of video images and confirmed an air detection accuracy rate of 95%. This system is now in operation at the Kansai International Airport.

## 6. References

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