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A Study on Sea Surveillance System with Flapping Reference Image

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Abstract

Our goal is to realize sea surveillance systems in which an image processor detects intruding objects such as boats in the sea. A difficulty of the sea surveillance systems is to detect moving objects such as boats inhibiting false detection caused by flapping, splashing and shiny surface of the sea. Firstly we pick up factors of false detection in sea surveillance. Secondly we propose a new surveillance system considering these factors. Our proposed system includes three methods for detecting boats of various speeds with inhibiting false detection in various condition of the sea such as heavy waves, splashing waves and shiny waves against a light. The three methods are detection of Differences between Surveillance images and a Reference image, abbreviated by **DSR**, and detection of Contours from Averaging images, abbreviated by **CA** and Silhouette Detection, abbreviated by **SD**. The proposed system detects boats of various speeds by DSR and CA under normal lighting conditions, while by SD under backlighting conditions. The proposed system decides the lighting conditions and select the three detecting method automatically. Lastly we discuss performances of our proposed system about actual sea images. Then we can show a successful performance of it about the actual sea.

1. Introduction

There are many TV cameras everywhere for security or safety systems. Camera systems have been used for a few decades of year in important public facilities such as roads, power plants, water supply plants and docks. Mostly system keepers are watching through monitors. Then automatic video surveillance systems are required for laborsaving. In this decade, automatic video surveillance systems become into common use by image processing software and hardware [1][2], though there are misdetection and false detection troubles. Misdetection is to fail to detect intruding objects while false detection is to work for no intruding object. They are inconsistent with each other, that is, they are apt to occur frequently when other is inhibited strongly. This is a serious problem we have to solve with automatic surveillance systems.

By the way there are many important facilities such as power plants and petrol tanks near the seaside. Therefore automatic surveillance systems have been strongly required, though they are prevented from practical use by false detection factors such as flapping, splashing and shiny surface of the sea. C. Stauffer et al. [3] have said that no rigid threshold can classify objects and background in flapping and shiny waves scene because of dynamic changes of brightness distribution in the scene.

We don't use an infrared camera in our surveillance system, however the infrared camera catches easily high temperature area such as running engines of boats on the water. Because a resolution of an infrared camera is lower than one of usual visual range camera. Furthermore all engines of drifting boats don't have high temperature. In addition, an infrared camera costs much higher than a usual camera. We built up a sea surveillance system using a visual range camera.

We discuss factors of false detection in sea surveillance firstly. We propose a new system to detect boats inhibiting false detection in the sea secondary. Then we applied our system to some scenes in which a boat is running at various speeds in the sea. Lastly, we show results of the experiments and discuss them.

2. Factors of false detection in sea surveillance

We shall encounter five problems in sea surveillance as follows. They are concerned with the weather and lighting conditions. They are

(1) Flapping waves in the sea,
(2) Splashing waves at cliffs,

(3) Shiny surface water,

(4) Continuing surf on shores and

(5) Reflected images of a farther shore.

They may cause false detection, and we show them in Figure 1. In heavy waves, flapping waves (1) and splashing waves (2) are especially serious problems because most of detection algorithms catch moving parts of the view whether there is intruding objects or not [4]. While reflected images (5) become serious in the calm of the sea. Moreover shiny surface water (3) becomes serious against lights. On the other hand continuing surf on shores (4) and white boats are similar each other because they move straightly with keeping their shapes. Now we admit that we cannot overcome the problems of continuing surf on shores (4) and reflected images (5) by image processing algorithms. We solved the reflected image problem by a polarizing filter. A polarizing filter cut reflected images effectively. While the continuing surf problem remains a problem that requires further discussions. Although it is a serious problem, it doesn't bother our sea surveillance system. Continuing surf doesn't occur in our sea surveillance system because the system surveys a deep-sea area. Continuing surf occurs in shallow water [5].

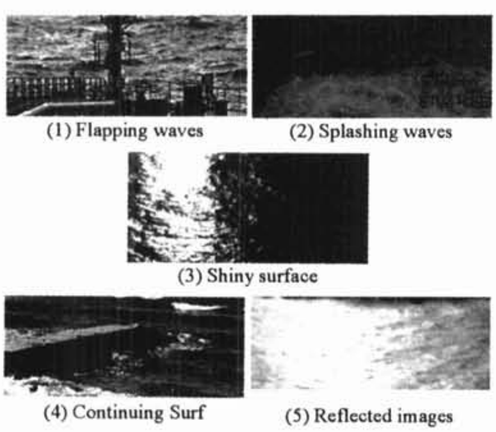


Figure 1. Factors of false detection

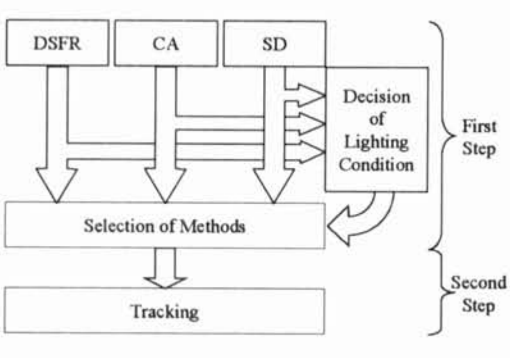


Figure 2. An overview of the proposed system

3. Our Proposed System

We show an overview of our proposed system to detect moving objects in Figure 2. The system is composed of two steps. Candidates of moving objects are detected in the first step. The candidates are tracked in the second step. When a candidate is tracked for a certain distance, it is considered as a moving object such as an intruding boat. Although the two-step system needs rather longer period to find boats of low speed, it depresses effectively false detection owing to flapping and splashing waves. Especially splashing waves (described at (2)) are eliminated effectively by the system.

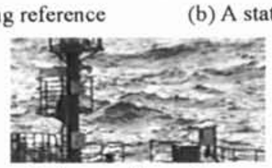
In the first step, the system includes three detecting methods. We call them DSFR, CA and SD. DSFR is a method of **D**ifferences between **S**urveillance images and a **F**lapping **R**eference image. CA is a method of **C**ontours from **A**veraging images. SD is a method of **S**ilhouette **D**etection. The former two methods work in parallel under the normal lighting, while the other works under backlighting. A block, **D**ecision of **L**ighting **C**ondition, (abbreviated by **DLC**) analyses surveillance images and decides lighting condition of the surveillance area. The lighting condition is normal lighting or backlighting. A block, Selection of Method, selects these three methods according to decision of DLC. In the first step, the system detects candidates of moving objects frame by frame of surveillance image sequences. A tracking block tracks the candidates in the surveillance image sequences. A track operation is correspondence problem among objects in deferent frames. There is a well-known algorithm of correspondence with the nearest object [6]. An algorithm of correspondence with a similar object by correlation is also known well [7]. The tracking algorithm [6] is sufficient in the sea surveillance use because a few intruding objects exist simultaneously.

4. A detecting method by DSFR

To detect some differences between surveillance images and a reference image for detecting objects is known well [4]. In the conventional detecting method, static images are used as a reference image. Then the method is apt to detect flapping waves as false detection. On the other hand, our DSFR inhibits to detect flapping waves well. Because surveillance images and the references have flapping waves in them, there are few differences caused by flapping waves. Figure 3 shows differences images between a surveillance image and references. Figure 3 (a) and (b) show a flapping reference and a static reference respectively. Figure 3 (c) shows a surveillance image at the same time as reference (a) and (b). There is no intruder object but flapping waves in the surveillance image. Then we obtain difference images (aa) and (bb). The image (aa) comes from DSFR, and the image (bb) comes from the conventional method. In these images, white area shows false detection. DSFR inhibits false detection at most of the area while the conventional method detects false objects at all the area.

(a) A flapping reference

(b) A static reference



(c) A surveillance image

(aa) A difference image by DSFR.

(bb) A difference image by the conventional method

Figure 3. Difference images by DSFR and the conventional method

DSFR often misses objects that are almost still such as drifting boats while it detects moving objects well. The flapping reference image includes a boat image when the boat moves slowly and causes brightness change smaller than one caused by flapping waves. Then DSFR cannot catch the boat. We use CA to prevent missing still boats. We explain a detecting method by CA in next section.

5. A detecting method by CA

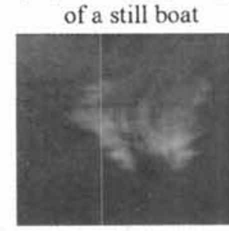
In general, we can detect contours of objects by spatial differential calculus because contours of objects are areas where brightness distributions change sharply. Some operators to make differential calculus are known well [8]. Contours of flapping waves are emphasized when we apply a differential operator to sea surveillance images. Therefore we make temporal averaging images of series of the sea surveillance images. Then we apply a differential operator to the temporal averaging images. There is no flapping wave but still boats in the temporal averaging images. Contours of still boats are clarified while ones of flapping waves are canceled by temporal averaging. So we can detect still boats in the temporal averaging images without the flapping waves' bothering.

Figure 4 shows two surveillance images and their averaging images. Figure 4 (a) shows a still boat image and (aa) shows its averaging image. Figure 4 (b) shows a high-speed boat image and (bb) shows its averaging image. Figure 4 (bb) shows blurry boat and splashing waves by averaging while figure 4 (aa) shows a boat clearly. Briefly, DSFR detects moving boats well while CA detects still boats well.

(a) A still boat

(aa) Averaging image of a still boat

(b) A boat of high speed



(bb) Averaging image of a high-speed boat

Figure 4. Boats of various speeds and its averaging images

6. A detecting method by SD

However a parallel system of DSFR and CA detects some boats of various speeds better than the conventional system inhibiting false detection caused by some waves, it sometimes makes false detection under backlighting. Some waves are brighter and have sharper contours than intruding objects under backlighting. Therefore we use a detecting method of Silhouette Detection, abbreviated by SD. Under backlighting, objects that they don't shine themselves become darker than shining surface of the sea. Figure 5 shows a boat silhouetted against shining surface of the water. In SD, our proposed system subtracts a surveillance image from the temporal averaging image made in CA. It neglects minus values to detect darker areas as silhouette. Then it considers moving dark areas as silhouetted intruder in SD. It doesn't make false detection under backlighting because it doesn't react against shiny areas. Therefore DSFR and CA are pausing, and Only SD works under backlighting in our proposed system. A DLC block decides the lighting condition.

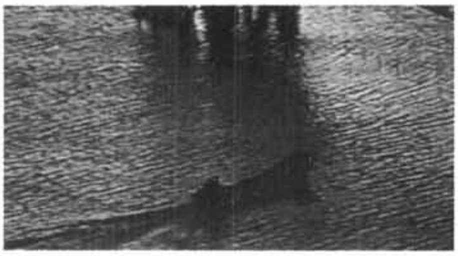


Figure 5. A silhouetted boat under backlighting

7. Experimental Results

7.1 Experimental Condition

We applied our proposed system to actual scene of sea surveillance. The scene comes from a TV camera set above 15 meters from the surface of the sea. The nearest point is 30 meters and the farthest point is 300 meters in the surveillance area from the TV camera. A target is a boat that is 5 meters long. Figure 6 shows a scene of the surveillance area.

Figure 6. A high-speed boat in the surveillance scene

7.2 Estimation

We used 120 minutes scene that includes flapping waves, splashing waves, reflection of the water, a high-speed boat and a still boat scenes for the estimation. We applied our proposed system and the conventional system to compare them. We compared their ability of inhibiting false detection after adjustment of their parameters to detect all boats in the scene. Both the systems survey the 120 minutes scene with system initializing every minute, which means that the 120 minutes scene was divided by 120 short periods. We estimated their ability of inhibiting false detection in each short period. We define a rate of inhibiting false detection as follows,

$$\begin{Bmatrix} Inhibition \\ Rate \end{Bmatrix} = \frac{Number\ of\ Inhibited\ periods}{120} \times 100. \quad \cdots\cdot (1)$$

7.3 Results

The conventional system inhibits false detection in three periods of the 120 periods. So its inhibition rate is 2.5 percent. On the other hand our proposed system inhibits false detection in 118 periods of the 120 periods, and an inhibition rate is 98.3 percent. Table 1 shows the results.

Table 1. The Inhibition Rate of false detection

	The Inhibition Rate (%)
The Proposed System	98.3
A Conventional System	2.5

8. Discussions & Conclusions

We have confirmed that our proposed system inhibits false detection against the flapping waves, splashing waves and reflecting surface of water effectively by the experimental results in Table 1. The system always detects boats of various speeds by the combination of DSFR, CA and SD. The proposed system made false detection at the edge of reflecting areas in two periods. DSFR's work under backlighting causes false detection. Because of the DLC block's decision is ambiguous at the edge of shiny surface.

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