Extraction of Moving Ships from Navigational Images

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ABSTRACT

Experiments to extract and track ships in the spatiotemporal images are performed aiming to provide useful supporting information for ship maneuvering instead of human eyes in the watching. Two computer vision techniques are applied to this purpose. The first is the template matching method and the second is optical flow method. These methods are applied complimentary and extracted information are integrated. The results for a set of sequential images on the sightseeing ship have been so far satisfactory.

1. Introduction

In maneuvering ship on the ocean, judging the surrounding situation properly is very important to secure the safety of the ship. To provide useful supporting information for ship maneuvering various systems such as ARPA system have been developed. However, to watch circumstances by operators is still important particularly under severe conditions such as navigation in passing narrow channel. It is desirable to provide new system in addition to the previously developed supporting systems of ship handling, because the confidence of the total system will be improved by plural different techniques. In this background, we make experiments to extract and track ships in the spatiotemporal images. There have been some researches to extract ships in the image. Typical approaches [1], [2] have been to extract a ship in a still image by vision technique. This means tracking of a ship is not accomplished. Our approach is to extract and track ships in the spatiotemporal images. Two computer vision techniques are applied to this purpose. The first is the template matching method and the second is optical flow method. These methods are applied complimentary and extracted information are integrated. In the following sections, outline of the experiments is described in section 2, template matching and tracking are described in sections 3. The optical flow method is described in section 4. Experimental results are shown in section 5. Section 6 concludes our approach.

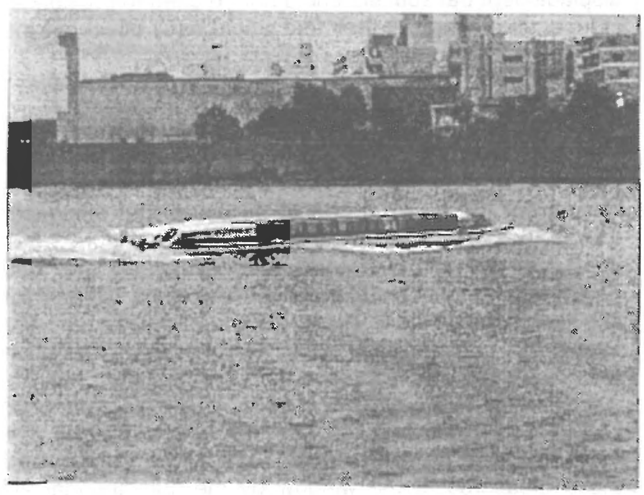

Figure 1: Image of a ship

2. Outline of the experiments

The problem to be solved here is to detect and track a moving ship in a field of view from a set of sequential images. The figure 1 shows one of our target scenes. To extract moving objects, some approaches are known in vision techniques. If an object shape (call it template) is known previously, it is able to extract it from each of sequential images [3]. A set of detected positions can provide tracking information. But, reliable extraction of a ship in an image is still an open problem if the situation is dynamically changing (typically apparent size will change). Also, the premise that the object shape is previously known is not realistic because to prepare the templates for a variety of various ships is a difficult problem. Though the difference operator adopted to a set of sequential images makes position information of moving objects, reliable tracking of a ship is still an open problem. The specific situation for detection of a moving ship is that it will cause a wake following to the ship image. The difference operator will detect the wake part in addition to the ship part. However the optical flow method [4][5] is computationally expensive, the problems in above mentioned methods are relatively easier to be solved. The extracted velocity vector for each pixel will be useful to obtain the movement of observer, to obtain relative depth map, and to reconstruct 3D information of the ship. In this paper we propose a scheme in which the optical flow method is used mainly and the modified template matching method is also used. It is intended to extract ship part from a set of (supposed to be) uniform velocity vectors calculated by the optical flow method. The template matching method is used to know macroscopic movement of a ship, whereas the optical flow provide microscopic movement of each pixel. The template used here is not previously prepared, but extracted from the image sequence. It is devised to classify the velocity vectors (detected by the optical flow method) into ones belonging to ship part and other part by using the macroscopic movement information obtained from the template. The computer programs we made and used are for extracting template, for tracking of a ship, and for calculating optical flow, and for extracting ship area. They are described in the following sections.

3. Template matching and tracking

It is a difficult problem to prepare the templates for a variety of various ships. The template we need here is just for tracking macroscopic movement of the ship. Therefore, we do not use the previously prepared template, but use ones extracted from the image sequence. The bow part of the ship is defined to be the template here. The difference operator is adopted to the n-th frame and (n+i)-th frame in the image sequence, followed by the thresholding operator. The obtained binary image is projected to the horizontal and vertical axes (see Figure 2). We decide that the one axis out of two axes is closer to the direction of ship movement (call the moving direction) if the projection width is wider. The horizontal axis is considered to be closer to the moving direction in figure 2. The width of the projection perpendicular to the axis mentioned above (α in figure 2) is used as a measure of bow part of the ship. The pixels within the rectangle defined by α and 2α are used for the template, where the start point of 2α is defined as a part where the cumulative sum of projection is growing. In figure 3, shows an example of a template. For each image in the sequence, the template is decided as described above. The n-th frame and (n+i)-th frame are compared and position in n+i th frame where the template in n-th frame mostly matches with one in n+i th frame. The following similarity measure is used:

$$g(x,y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} p(x-u, y-v) f(u,v)\,du\,dv$$

$$K = \sqrt{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} p^2(u,v)\,du\,dv \cdot \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f^2(u,v)\,du\,dv}$$

$$g'(x,y) = \frac{1}{K} g(x,y)$$

where
$f(x,y)$:image of a ship
$p(i,t)$:template
$g'(i,t)$:similarity measure
$|g'(i,t)| \leqq 1$.

A set of detected positions for bow of the ship provides tracking information of the ship movement.

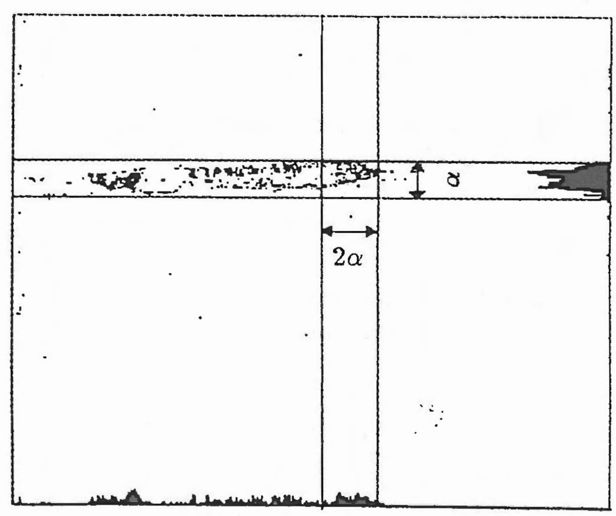

Figure 2: Extraction of a template

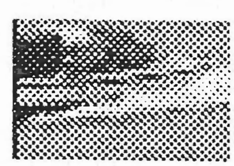

Figure 3: Extracted template

4. Optical flow

We assume a set of moving points whose brightness are kept constant within a small time dt. The following equation is formed if we assume that the point movement is dx, dy.

$$f(x,y,t) = f(x+dx, y+dy, t+dt)$$

, where $f(x,y,t)$ means the brightness of a point whose position and time is specified by x, y, and t. The Taylor expansion of $f(x,y,t)$ gives:

$$f(x+dx,y+dy,t+dt)=f(x,y,t)+\frac{\partial f}{\partial x}dx+\frac{\partial f}{\partial y}dy+\frac{\partial f}{\partial t}dt$$

, where the higher order terms are neglected. We obtain the following:

$$-\frac{\partial f}{\partial t} = \frac{\partial f}{\partial x}\frac{dx}{dt} + \frac{\partial f}{\partial y}\frac{dy}{dt}.$$

where $\frac{\partial f}{\partial t}, \frac{\partial f}{\partial x}, and \frac{\partial f}{\partial y}$ can be calculated from observed data. We want to obtain $\frac{dx}{dt}$ and $\frac{dy}{dt}$ (call u and v) in the following.

$$-\frac{\partial f}{\partial t} = \frac{\partial f}{\partial x}u + \frac{\partial f}{\partial y}v \tag{1}$$

This equation cannot be solved uniquely. Then we assume the velocity vectors to be smoothly changed and the following E^2 to be minimized.

$$E^2(x,y)=(\frac{\partial f}{\partial x}u+\frac{\partial f}{\partial y}v+\frac{\partial f}{\partial t})^2+\lambda(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}) \tag{2}$$

where λ is Lagrange's coefficient. This can be solved by successive approximation.

5. Experimental results

The image sequence we used consists of 30 frames / second, each frame (image) consists of 320x240 pixels. The television camera is fixed in the land, whereas the sightseeing ship moves on the canal is supposed to be a target for watching. The template extraction process (described in section 3) has been only necessary for every 5 frames, because the size of the ship in image is not change rapidly. Figure 4 shows the tracking result by the template matching method. Figure 5 shows velocity vectors obtained by the optical flow method. In figure 6, the vectors coherent with the tracking result of the ship are shown. The direction between the detected position of the template in n-th frame and one in (n+1)-th frame is the basis of the vectors. If a vector is close (within 5 degrees in our experiment) to the base direction, it is considered to be coherent. This scheme is effective to reject unreasonable elements detected by optical flow method. Major part of the ship is extracted by our experiment. But, some part within the ship without texture are difficult to be detected.

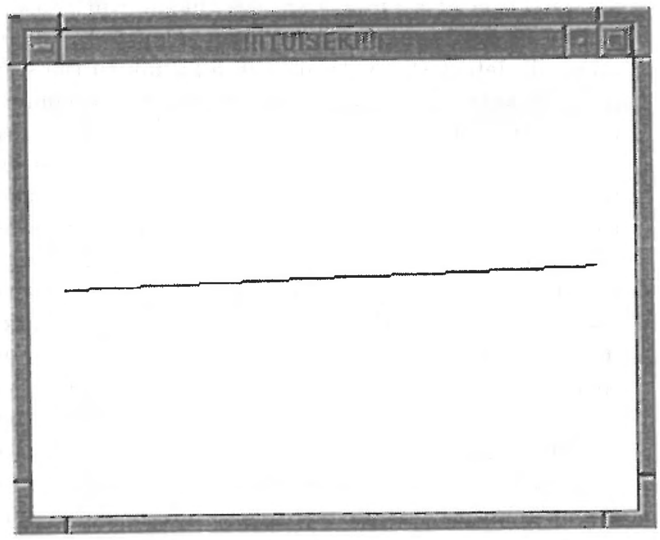

Figure 4: Tracking result

Figure 5: Optical flow

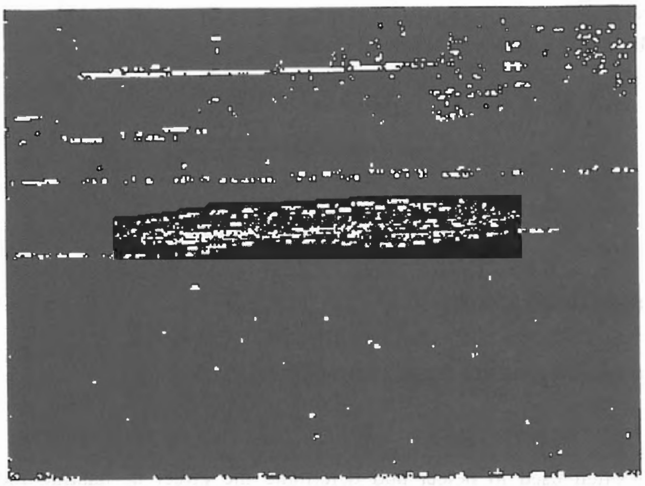

Figure 6: Integrated result of tracking and optical flow

6. Conclusion

Experiments to extract and track ships in the spatiotemporal images are performed. Two computer vision techniques are applied. The first is the template matching method and the second is optical flow method. These methods are applied complimentary and extracted information are integrated. The results show that flow vectors of the ship part can be extracted. Future works directed experiments in more realistic situations.

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