

DETECTION OF THE MOVEMENTS OF MEN FOR AUTONOMOUS VEHICLES

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This paper describes a method for detecting the movements of men walking on a passage using two consecutive TV images. The method consists of three steps: (1) finding a passage region and regions of objects in a TV image, (2) locating men in the region map, and (3) detecting the movements of men using their location in two consecutive region maps. High speed processing is to be achieved by employing a special hardware for image processing.

1. INTRODUCTION

This paper describes a method for detecting the movements of men walking on a passage using two consecutive TV images. Our final goal is to develop an autonomous vehicle with a TV camera, such as the one in a hospital for guiding the blind. Here, we deal with a simplified case where a TV camera is fixed and only men are on a passage.

There have been some works for detecting moving objects using cross-correlation [1]. But they are not effective for our purpose, because the size and the orientation of moving objects may change to a great extent and the numbers of objects are not always equal between the images.

The method in this paper finds the movements of men by locating them in each image. It consists of three steps as follows: (1) finding a passage region, (2) locating men, and (3) detecting the movements of men.

In order to catch up with the movements of men the processing for finding a path should be done very fast, say every 0.7 sec. We used a special hardware for the high speed processing.

2. FINDING A PASSAGE REGION

A passage is assumed to be illuminated sufficiently by many lamps on the ceiling and color of the surface of a passage is light enough. Under these conditions, vertical surfaces are much darker than horizontal ones, up to a certain height. The mean of brightness of men is smaller than that of the passage. However, some parts of men's clothes may be a little brighter than the passage due

to wrinkles. In this case, the variance of brightness of the parts is expected to be larger than that of the passage. Therefore, we use the mean and the variance of brightness of TV image to find a passage region.

Let $I(i,j)$ denote the light intensity of the pixel at (i,j) in a image. We use the following measures for the mean $M(i,j)$ and the variance $D(i,j)$ at the pixel at (i,j) ;

$$M(i,j) = \sum_{k=1}^3 I(i,j) \quad 2 \leq i,j \leq 255$$
$$D(i,j) = \left| \sum_{k=1}^3 [I(i,1) - I(i,3)] \right| + \left| \sum_{j=1}^3 [I(1,j) - I(3,j)] \right|$$

Each pixel is classified into a passage region or the other region by the following procedures.

- (1) If $M(i,j) > \theta_1$, then it is classified into a passage region.
- (2) If $M(i,j) < \theta_2$, then it is classified into the other region.
- (3) If $\theta_1 \leq M(i,j) \leq \theta_2$ and $D(i,j) < \theta_3$, then it is classified into a passage region.
- (4) Otherwise, the pixel is classified into the other region.

θ_1 , θ_2 and θ_3 are fixed based on the first TV image.

Here, we call the other regions the object regions on the passage. The small object regions are merged with a passage region. Since the width of the passage and the direction of the TV camera are known in advance, some erroneous parts such as wall regions, can be eliminated.

Fig.1 shows an example of a TV image and a passage region.

3. LOCATING MEN

We use the shapes of men and their size in order to find men in the object regions. We define an X-Y coordinate on a plane parallel to the passage plane of which the origin is at the location of TV camera and of which the Y axis coincides with the direction of the passage. Since the range information about points on passages can be obtained from the declination of the TV camera and its height, a passage region in a TV image can be transformed to the plane as shown in Fig.2. The area surrounded with broken lines in Fig.2 represents the maximum of a passage region and we call the area a region map.

The shapes of men on a region map can be classified into four types as shown in Fig.3 according to the position of feet. The type (d) represents the situation that one man overlaps another.

We shall explain the method for locating men on a region map using an example as shown in Fig.4. First, the region map is scanned from the bottom to the top to find the bottom point P1. Next, the curve is searched for a pair of P2 and P3 such that the width W of the curve is greater than the threshold θ_4 (0.3m) for the first time. If a pair of points P2(X2,Y2) and P3(X3,Y2) satisfies the condition, the man is located at the point P4((X2+X3)/2,Y1). Third, the detected man region is deleted from the region map. The lower part of the curve is deleted from the region map. The upper part of the curve is covered with a mask like a horn as shown in Fig.5(a). If the width W of the protruded part under the mask is greater than the threshold θ_5 (0.1m), we determine that another man is also included inside the curve. Then, the shape of the mask is changed into that of Fig.5(b), so that another man may be easily found later. This process repeats until no man is found.

4. DETECTING THE MOVEMENTS OF MEN

The movements of men are obtained by finding the correspondence of the positions of men

between two consecutive region maps. Suppose that the position of the k-th man in the first and in the second region maps are (X_{1k}, Y_{1k}) and (X_{2k}, Y_{2k}) , respectively, the distance between them is less than $V \cdot \Delta t$, where V is the maximum speed of men (assumed 1m/sec) and Δt is time interval (0.7sec). If the candidate position is only one under this condition, the correspondence is immediately determined. If there are n positions with more than one candidate, the correspondence of them is determined as follows.

Assuming that men are apt to move along the Y axis than the X axis. Now, we define a weighted distance for the k-th man as follows.

$$E_k = \sqrt{w \cdot (X_{1k} - X_{2k})^2 + (Y_{1k} - Y_{2k})^2} \quad w > 1$$

We determine the correspondence such that the following evaluation function may be minimized:

$$E = \sum_{k=1}^n E_k$$

Now, we consider the case where men come into or out of the region map and occlusion. A region map is divided into three zones (A, B and C zones) as shown in Fig.6. It is assumed that men always come into or go out of the region map through A or C zone.

First, the correspondence is found between men in B zone on the first map and those in the whole area on the second map. In this

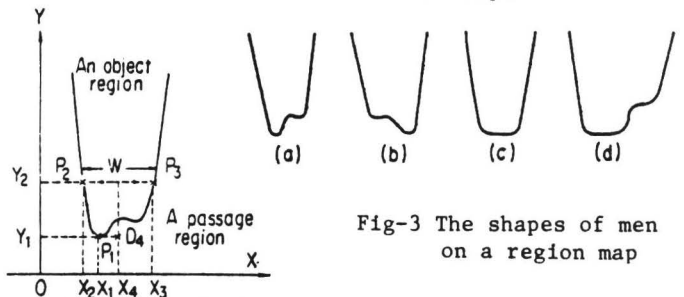
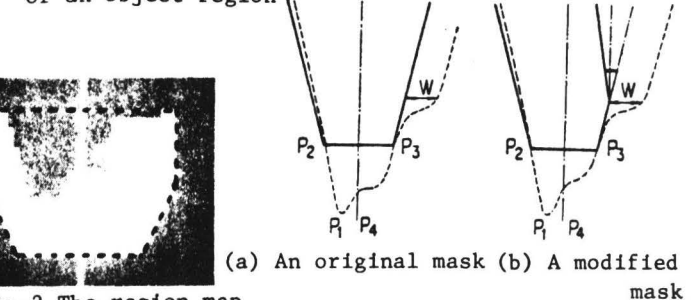


Fig-3 The shapes of men on a region map

Fig-4 A simplified example of an object region



(a) An original mask (b) A modified mask

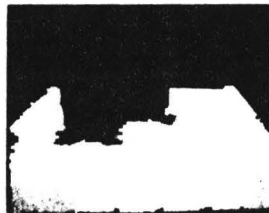
Fig-2 The region map

of the image of Fig-1 Fig-5 Example of mask

on a region map



(a) An input image



(b) A passage region of the image (a)

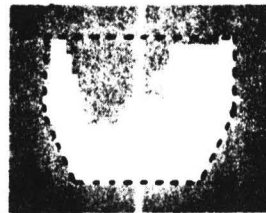


Fig-2 The region map

of the image of Fig-1 Fig-5 Example of mask

on a region map

Fig-1 An example of finding a passage region

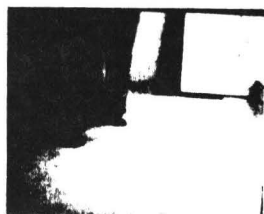
procedure some corresponding pairs are found. The remaining men in both maps are dealt with in the following way.

CASE 1 :there is no man in A and C zones on the first map.

In this case, men on the first map can not go out of the map. The remaining men on the first map are determined that they are behind some one on the second map. Conversely, the remaining men on the second map are determined to behind some one on the first map. The remaining men in A and C zones on thsecond map are determined that they have entered the map from the outside area.

CASE 2 :ther are some men in A or C zone on the first map.

The correspondence is found between men in A and C zones on the first map and the remainig men on the second map. If there still remain some men without correspondence, they are dealt with in the similar way as in CASE 1, except that the remaining men in A and c zones



(a) The 1-st scene



(b) The 2-nd scene



(c) The 3-rd scene



(d) The 4-th scene

Fig-7 Examples of four consecutive scenes

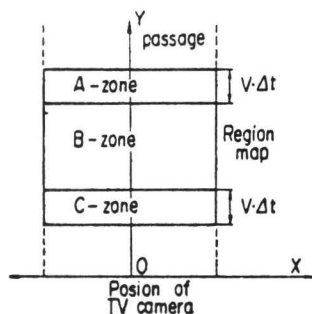


Fig-6 Three zones on a region map

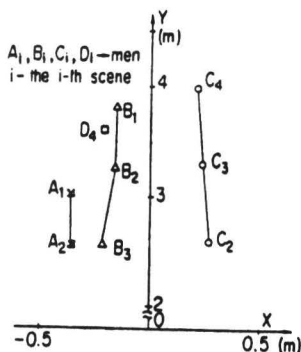


Fig-8 The locations of men of four scenes in Fig-7

on the first map are determined that they have gone out of the map.

5. EXPERIMENTAL RESULTS

We examine the metod in many cases. The four consecutive scenes as shown in Fig.7 are examples of input images. The men in these images are located on the map and the movements are detected as shown in Fig.8.

6. DISCUSSIONS

We used the Parallel Patten Processor (PPP) [2] for high speed processing. The PPP has several basic image proccssing function in hardware, memories for pictur data and a microprogrammed processor. We estimated the time needed for finding the region of a passage. The time was 580 msec as shown in Table 1. The total time for the processings including the location of men and the detection of the movement is larger than the time interval (0.7sec) at present. But the improvements of the hardware and the program will make the total time less than 0.7 sec.

In order to realize autonomous vehicles, we must consider the following problems: (1) a TV camera moves on a passage, (2) a passage is hook-shaped one, and (3) there are some objects on a passage, besides men.

OPERATION	NUMBER OF INSTRUCTIONS	EXECUTION TIME	FREQUENCY IN USE	CONSUMED TIME
MASK	3 step pixel	65 msec image	0.4	26 msec
MEAN OF BRIGHTNESS	5 or 6	130	0.36	47
VARIANCE OF BRIGHTNESS	12	195	0.24	47
2D-CONVOLUTION	by hardware	65	3	195
REGION LABELING	by hardware	200	1	200
DATA CONVERSION	by hardware	65	1	65

An instruction of the microprogram needs 250 nsec.
The memory cycle is 1 μ sec/pixel.
An image has 256x256 pixels.

Table-1 The detail of consumed time

ACKNOWLEDGEMENT

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REFERENCE

- [1] J.Z.butnicka, et al., "Automatic Movement Analysis and Classification of Moving Object", the 4-th IJCPR pp.750-752 1978.
- [2] K.Mori, et al., "Design of Local Parallel Pattern Processor for Image Processing", National Computer Conference, pp.1025-1031, 1978.