Motion Detection by Mathematical Morphology

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***Abstract*—Mathematical morphology is a frame work of non-linear signal processing analysis using geometric operators. We can extract the feature of motion in movie with this way. Motion detection in present way is processed in a unit of frame. We use three-dimensional morphological operator to process time-axis together for movie analysis.**

I. Introduction

In recent years, the video analysis photoed with the drive recorder is studied briskly. For example, movement quantity of the object is estimated by optical flow and the object in movie is tracked by the pattern match. The feature of the moving object is also detected by these way. These methods processed by unit of frame in movie. In this research, we use the movie considered as three-dimensional solid, and process to this with three-dimensional mathematical morphology. Mathematical morphology is the method that is able to detect the feature of shape. The feature of three-dimensional shape detected from movie is feature of motion because the solid of movie contain information of time. We verify weather the feature detected with morphology can be considerd as feature of movie.

In this paper, the principle of morphology is described in first, then the application of morphology to the dynamic scene is described, and the result of an experiment is shown at last.

II. Mathematical Morphological Operators

Mathematical Morphology is a framework of non-linear signal processing and analysis using geometric operators. Among morphological operators, the most basic ones are dilation and erosion. Any other operators such as opening and closing are composed of them. In this section, we give minimal requisites for this article. For a more detail description, we referred to [1].

To begin with, we describe dilation and erosion. Each of them uses two data called the object X and the structuring element B. The translation X_b of the object X by each element b of the structuring element B is given by the following expression. When the one that processing object X is obtained by doing the translation according to element b of structuring element B (assumed to be X_b), it is given by the following expressions.

$$X_b = \{x : x - b \in X\} \tag{1}$$

Then the dilation of X by B is defined as the union of X_b taken all over $b \in B$

$$\text{dilation} : X \oplus \check{B} = \bigcup_{b \in \check{B}} X_b \tag{2}$$

where $\check{B}$ is the reversed set of the structuring element B with respect to the origin. Similarly, the erosion of X by B is defined as the intersection in stead of union.

$$\text{erosion} : X \ominus \check{B} = \bigcap_{b \in \check{B}} X_b \tag{3}$$

We note that if dilation is performed, the object will expand, and if erosion is perfromed, the object will shrink.

Secondary,we describe opening and closing. They are composed as serial combinations of dilation and erosion. We denote by A_B and A^B suspectively the opening and the closing of A by B. They are defined by the followings.

$$\text{opening} : A^B = (A \ominus \check{B}) \oplus B \tag{4}$$

$$\text{closing} : A_B = (A \oplus \check{B}) \ominus B \tag{5}$$

Opening is performed by dilating the result of erosion by using a pair of mutually reversed structuring elements. The result of opening can be interpreted as follows. When the structuring element B is moved the fully inside of A, the area that can be the structuring element is result of opening.

On the contraly, closing is performed by eroding the result of dilation. Similarly to opening, a pair of rautually reversed structuring elements are used. When B is moved fully outside of A, it sweep the area that cannot be covered with the structuring element. Then the complement of the area is the result of closing . The conceptual drawings of morphological operators are shown in Fig.1.

Morphological operator can be applied not only for binary data but also for gray level data. Dare defined for object function $f(\boldsymbol{x})$ and structuring function $g(\boldsymbol{u})$ as follows.

$$\text{dilation} : [f \oplus \check{g}](\boldsymbol{x}) = \max_{\boldsymbol{x}+\boldsymbol{u} \in F, \boldsymbol{u} \in G} \{f(\boldsymbol{x}+\boldsymbol{u}) + g(\boldsymbol{u})\} \tag{6}$$

$$\text{erosion} : [f \ominus \check{g}](\boldsymbol{x}) = \min_{\boldsymbol{u} \in G} \{f(\boldsymbol{x}+\boldsymbol{u}) - g(\boldsymbol{u})\} \tag{7}$$

There are the maximum operator and minimum operator of the object function f by regarding the structuring function g as a weighted mask. When the structuring function g takes only the value 0 on its domain G, dilation and erosion become as follows.

$$\text{dilation} : [f \oplus \check{g}](\boldsymbol{x}) = \max_{\boldsymbol{x}+\boldsymbol{u} \in F, \boldsymbol{u} \in G} \{f(\boldsymbol{x}+\boldsymbol{u})\} \tag{8}$$

$$\text{erosion} : [f \ominus \check{g}](\boldsymbol{x}) = \min_{\boldsymbol{u} \in G} \{f(\boldsymbol{x}+\boldsymbol{u})\} \tag{9}$$

This means that to perform the maximum operator and minimum operator are only taken are the domain of a structuring function.

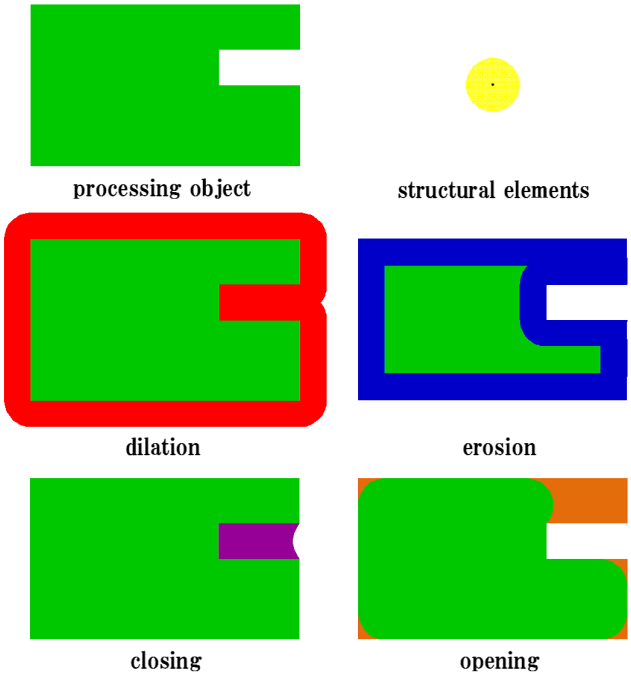

Fig. 1. Conceptual drawing of morphological operator. In dilation and closing, the part which color is red and purple shows expand. In erosion and opening, the part which color is blue and orange shows shrink.

III. Three-dimensional morphological operator for movie

In this section, we describe application of three-dimensional morphology for movie of binary data. All the morphological operators are processed in three-dimensional space. Therefore, the structural element also used the three-dimensional one. The line segment was used as a structural element this experiment. The reason is for taking out the translation portion of the move object in movie. The structural element of line segment is created by a form (10),

$$S = \bigcup_{i=0}^{i=n-1} i\boldsymbol{v} \quad (n > 1) \tag{10}$$

where $\boldsymbol{v}$ is a three-dimensional directional vector of the straight line, and n is the pixel size of structuring elements. However, the connection of line segment is not kept only by using this. In order to fulfill connectivity, a line segment is created by using this formula recursively and filling between. We define the distance of a time-axis as ”length”.

Morphological operator can be processed by considering this line segment to be a mask. Because dilation is equal to maximum value operation in the mask and erosion is equal to minimum value operation in the mask.

IV. Experiments and consideration

In this section, we show an experiment and its consideration. We conducted two kinds of experiments this time. First experient is the simulation to verify what is detected from movie by using mathematical morphology, and second is the experiment to verify that the feature of person’s movement can be detected from movie. We use the movie that circle or square move in it for simulation and we use the movie that person walk or run in it for second experiment. The movie used for the experiment is shown in Fig.2 - Fig.4. Fig.2 - Fig.4 show

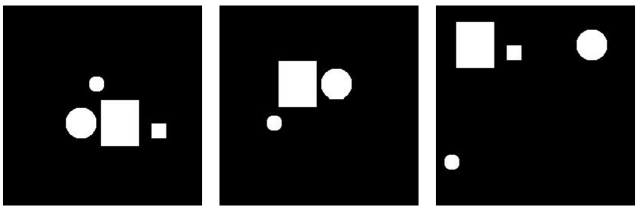

Fig. 2. Geometric figure movie

Fig. 3. Walking movie

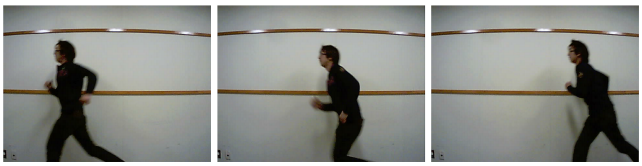

Fig. 4. Running movie

frames pick up from these movies. In these experiment, we use these movie binarized.

The details of the used movie are as follows.

TABLE I
DETAILS OF MOVIES

	frame size	number of frame
simulated movie	256x256 pixels	130 frames
walking movie	640x480 pixels	75 frames
running movie	640x480 pixels	43 frames

We use opening to detect the feature of movement from each movies in these experiments.

A. The experiment for simulated movies

The result of three-dimensional morphological operator for simulated movies is shown in Fig.2. Since the direction is beforehand known for this movie, it aims at the extraction of a square figure which passes from the upper left to the lower right (direction given by the vector (1, 1, 1)). The length of a structuring element is set to 10. Then the result when we set length of structural element 30 is shown in Fig.6 (the direction is same). It turnd out that the extraction is achieved given than the case for size 10.

Secondly, direction is changed (Fig.7). The length of a structuring element is set to 10 and a direction is set to (2, 2,

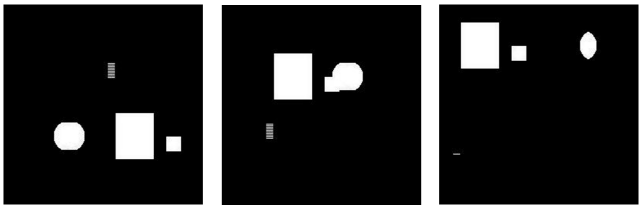

Fig. 5. As a result of opening（10 in length of a structure element）

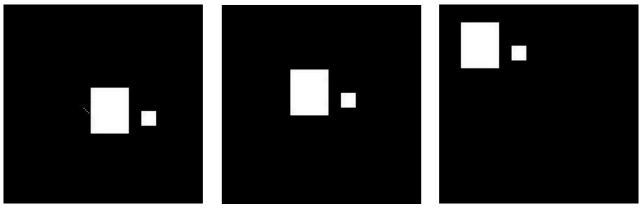

Fig. 6. As a result of opening (30 in length of a structure element)

1). If the direction of a structuring element is different from an actual direction of the movement, the extraction cannot be done completely as in shown.

What we know from these result is that morphological operator can extract moving object if we decide correct direction of structural element. If we use wrong structural element, we cannot extract moving object which we hope. The dicision of direction of structral element is important to detect feature from movie.

B. The experiment for actual movie

The result of the experiment that uses the walk or run movie is shown. We used the movie of binary data made from walking movie and running movie. We binarize the movies using the suitable threshold value for every movie. It is shown in Fig.8 and Fig.9. Since we used actual movie this time, we do not know what kind of direction of object in the movie before. Therefore, we use many kinds of structuring elements to extract the direction of object in the movie. In this experiment, a vertical - axis and a time-axis are fixed and horizontal-axis is changed. If a direction can be set up correctly, the translatoin portion should be outputted clealy.

First, the result using walking movie is shown in Fig.10 - Fig.12. The length of a structuring element is set to 30.
The result that set the direction to (-12, 0, 1) has taken out finely, but the other result cannot be taken out finely.

Fig. 7. As a result of opening (the direction is (2,2,1))

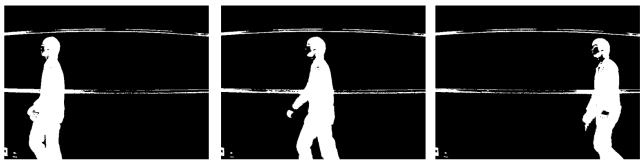

Fig. 8. walking movie (binary)

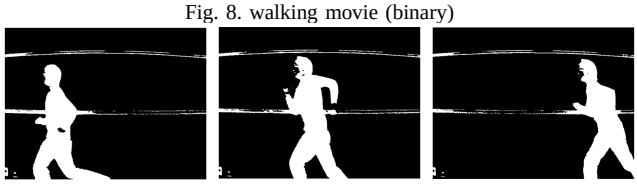

Fig. 9. running movie (binary)

Fig. 10. As a result of opening (the direction is (-7,0,1))

Fig. 11. As a result of opening (the direction is (-12,0,1))

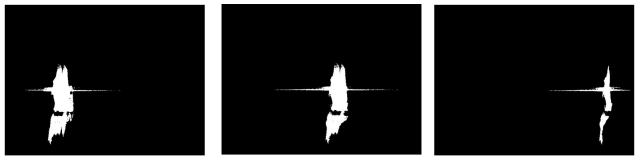

Fig. 12. As a result of opening (the direction is (-13,0,1))

Therefore, we decide the correct direction in this movie (-12, 0, 1). However, all the domains of the object cannot be taken out. It is thought that the movement up and down when person walks decreases the domain of the extraction. We can thought that this amount of the extraction shows the feature of the person's movement.

Secondly, the result of running movie is shown in Fig.13 - Fig.15. The length of a structuring element is set to 30. The result that set the direction to (-20, 0, 1) has taken out finely, but the other result cannot be taken out finely. Therefore, we decide the correct direction in this movie (-20, 0, 1). In addition, the extraction portion in walking movie is more than in running movie. The reason of this result is that running is more active than walking.

When we compared the above two experiments, it turns out that the direction of structuring element at running case is larger than the walking case. Moreover, since the difference of the feature of extraction between walking case and running

Fig. 13. As a result of opening (the direction is (-18,0,1))

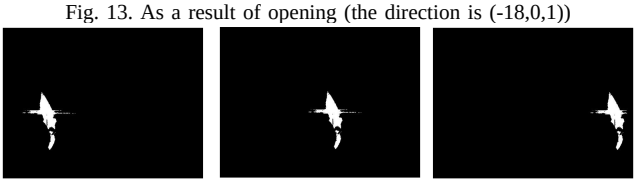

Fig. 14. As a result of opening (the direction is (-20,0,1))

Fig. 15. As a result of opening (the direction is (-21,0,1))

case is clear, the feature of extraction can be also thought as a feature of a moving object. If the movie is binarized clearly, the result of these experiment is more clear.

V. Summary

The feature of the motion of an object was able to be detect by using three-dimensional morphological operation for movie. In simulate experiment, we show that setting direction of structural element colectly is detect the object in movie clearly. In experiment using walking and running movie, we show that the feature of walking or running can detect with three-dimensional mathematical morphology.

We will verify about two things. One, we verify weather morphological pattern spectrum is able to detect feature more quantitative and practical. Another, we verify weather changing stractural element is able to detect many kinds of motion in movie.

References

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