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NEW RECOGNITION AND IDENTIFICATION METHOD FOR MICRO-ORGANISMS BY EXPERT SYSTEM DRIVEN IMAGE PROCESSING

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A **refined version** of automatic micro-organism recognition and identification method, 'O.I.S.M.2' is proposed in this paper , using image processing based on an expert system. This proposed method is based on the segmentation of the organism image, characterizing segment features, which are independent of individual size and length. Complicated shapes of organisms are divided into basic shape segments defined in this paper such as lines, circles, ovals etc. Organisms can then be expressed simply in a set of segments, regardless their individual differences.

1. INTRODUCTION

The conventional pattern matching method is hard to be applied for the automation of bio-technology. The reason is that, organisms, such as biological cells, have individual differences and transform their shape freely unlike industrial products. That is, it is almost impossible to make a unique image pattern of them.

In order to solve this problem, we propose a new image processing and reasoning expert system including the Organism Image Segmentation Method 2 (O.I.S.M.2). By using this method, the expert system can recognize and identify organisms avoiding their individual differences and shape transformation which results from their movement. Details of the image processing and reasoning processes of this Organism Image Segmentation Method 2 are shown in this paper.

The expert system has two special modes: (1)'Insufficient Data Supplement Mode' and (2) 'Discerning Mode', for irregularities which may occur during the process. In this refined version, we improved these two modes for more precise recognition or identification. Details of these two improved modes are also shown in this paper.

The effectiveness of this O.I.S.M.2 is proved with some experimental results. In the experiments, aqua-microbes and their two-dimensional black and white images are used.

2. ORGANISM IMAGE SEGMENTATION METHOD 2 (O.I.S.M.2)

2.1 Outline of the O.I.S.M.2

Image segmentation in this paper means that organism images, as defined before, are segmented according to their joints (see Fig.1).

In this paper, we made the following three fundamental assumptions to describe organisms by segments of basic shape to recognize and identify them. These assumptions are the same as O.I.S.M.1.

1. Organisms may transform their shape, segment length, segment area and basic shapes (defined below) remain unchanged.
2. The same species of organism has the same set of basic shape segments (defined below).
3. Between same species of organisms, corresponding proportions of segment length and segment area are almost the same.

These assumptions would also seem to be reasonable in the biological field.

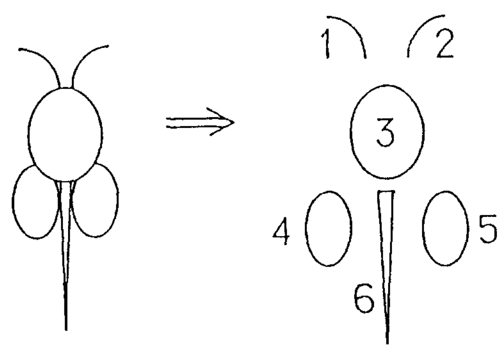


Fig.1 Organism image segmentation

2.2 Definition of Basic Shape

We defined "basic shape" as shown in Fig.2. These basic shapes are expressed by distances between points on the center-line and points on the outline (see Fig.3).

Therefore, a segment of an organism can always be expressed with the same set data even if they transform their shape (see Fig.4).

3. OUTLINE OF THE EXPERT SYSTEM FOR ORGANISM RECOGNITION AND IDENTIFICATION

3.1 Outline of the Expert System

The whole system is operated by an expert system written in Prolog using Fortran subroutines for numerical calculations. The system structure consisting of three main parts as follows (see Fig.5):

(1) Image Processing Part,
(2) Data Analysis and Calculation Part,
(3) Recognition and Identification Part.

Should matching fail, the system activates the "Insufficient Data Supplement Mode" or the "Discerning Mode" (described later).

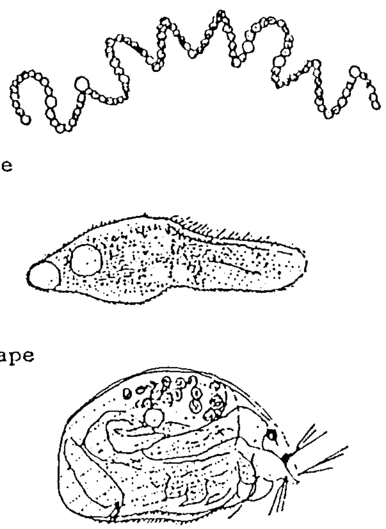


Fig.2 Example of basic shape

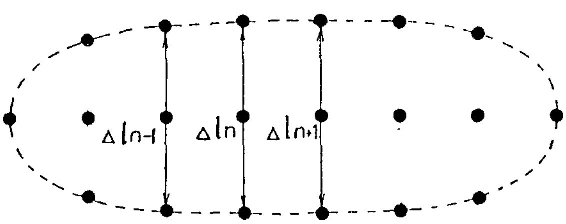
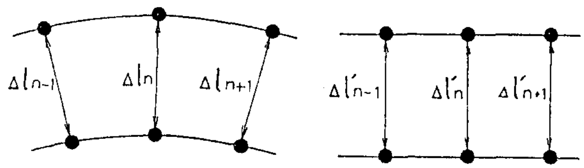


Fig.3 Expressions of basic shape



$$\Delta l_{n-1} \cong \Delta l'_{n-1}$$

$$\Delta l_n \cong \Delta l'_n$$

$$\Delta l_{n+1} \cong \Delta l'_{n+1}$$

Fig.4 Influence of organism movement to basic shape data

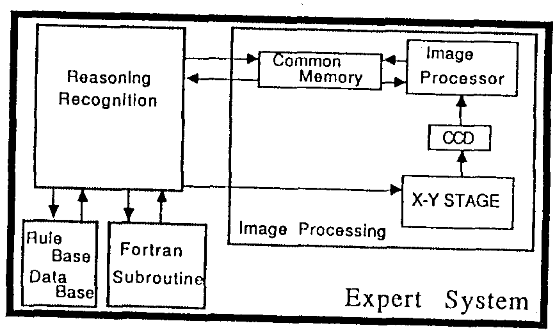


Fig.5 System structure

3.2 Data Base

The data base consists of frame units describing the organisms (see Fig.6), structured as follows:

[name of organism, number of segments, orderly relationship of segments, segment area,

segment length, structure of segments, segment shape, segment name]

4. OUTLINE OF ORGANISM RECOGNITION AND IDENTIFICATION

4.1 Outline of Organism Recognition and Identification Processes

This chapter describes the outline of whole processes for recognition and identification from the obtained image to the output result using a flowchart shown in Fig.7.

organism(organism's name)
(
Number-of-segments
Orderly-relationship-of-segments
Segment-length
Segment-area
Structure-of-segments
Segment-shape
Segment-name
)

Fig.6 Structure of data base

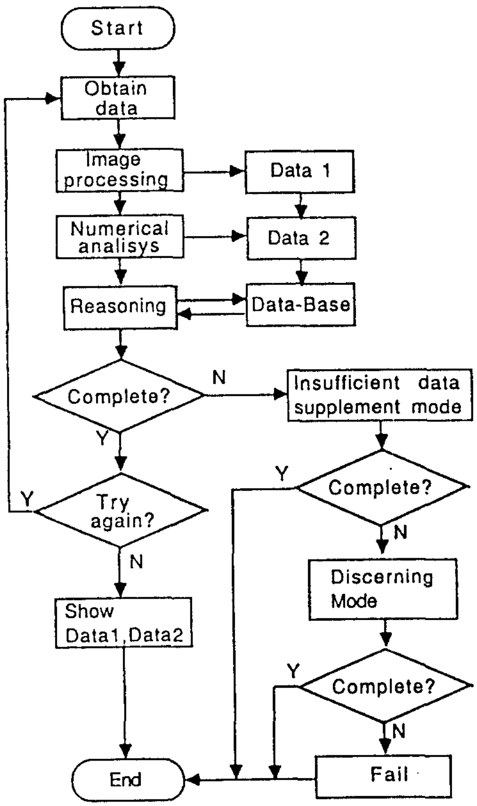


Fig.7 Flowchart

4.1.1 Processes in The Image Processing Part

(1.1) Obtaining a picture image,
(1.2) Setting of window around the object organism,
(1.3) Extraction of object organism,
(1.4) Obtaining center-lines of organism image,
(1.5) Extraction of characteristic points,
(1.6) Segmentation of object organism,
(1.7) Extraction of outline of object organism image

4.1.2 Processes in The Data Analysis and Calculation Part

(2.1) Splitting of center-line into dots,
(2.2) Calculation of segment width,
(2.3) Calculation of segment length and segment area

4.1.3 Processes in The Recognition and Identification Part

(3.1) Comparison of the segment length,
(3.2) Selection of candidate organisms from data base,
(3.3) Renumbering of segment number,
(3.4) Scale adjustment,
(3.5) Matching the segment length,
(3.6) Matching the segment area,
(3.7) Matching the basic shape of the segments,
(3.8) Output of the result,
(3.9) In the case of recognition and identification failure, one of the following three procedures is invoked depending on the type of error:

1. Should no candidate of the data base match in step 3.2, the "Insufficient Data Supplement Mode" is activated.
2. Should matching also fail in the Insufficient Data Supplement Mode, the "Discerning Mode" is activated.
3. Should these two additional modes both fail, the expert system cannot identify the object organism. The resulting message on the CRT is: "Fail of recognition and identification".

4.2 Improved Supplementing Insufficient Data

In the process of image processing, the input picture images are strongly affected by surrounding conditions, e.g. sometimes the image cannot be obtained completely. The most influential thing is the position and location of lights. However, the expert system, by supplementing data, can obtain the right result, even for variant light conditions.

In this case, data is supplemented to make the incomplete image sufficient for recognition and identification. Especially, the O.I.S.M.2 can reason and supply not only one insufficient segment data but also many insufficient segment data to the obtained data. Figure 8 shows an example of data supplement.

In the following, we explain how the expert system supplements data to the insufficient image of sample organism (P) in the figure 8.

(1) The system processes the obtained image to divide into segments.
(2) The system calculates length, area and basic shape of each segment.
(3) The system chooses the longest segment of P.
(4) The system makes a list of the orderly relationship of segment length.
(5) The system matches the data of orderly relationship of segment length with data in the data base.
(6) The system selects candidates for recognition (Q to S) (see Fig.9).
(7) The system matches the segment length, segment area and segment shape of organism P with those of Q.

(8) The system calculates matching rates of each candidate.
(9) The system selects one candidate (for example, Q) which has the highest matching rate.
(10)The system decides P and Q to be the same and supplements the insuf ficient data of P with data from Q.

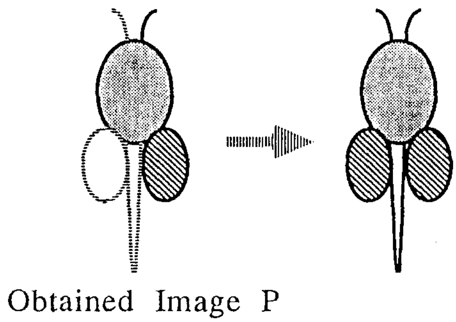


Fig.8 Example of supplementing insufficient data

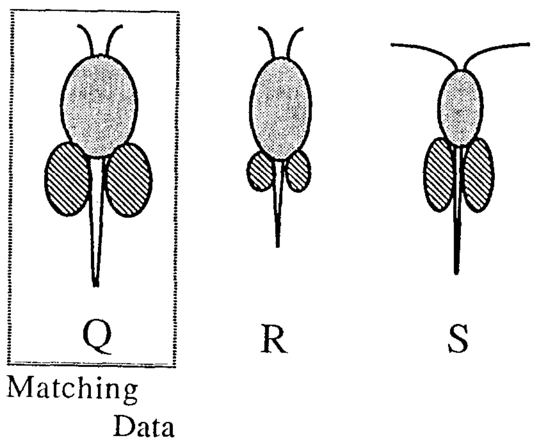


Fig.9 Selected candidates

4.3 Improved Discerning Mode

Owing to their movement, organisms sometimes crossed over. In such cases the system activates this discerning mode to distinguish how they are crossing-over.

For example, on obtained image in Fig.10, the expert system cannot distinguish how they are crossing-over. The Improved Discerning Mode obtains image #2 to #4 after image #1 and trace the edge dots, then reasons how organisms were crossed-over in the #1 image (see Fig.11).

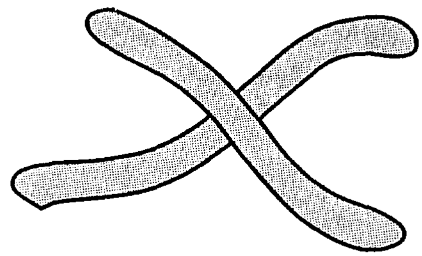


Fig.10 Example of cross-over of organism

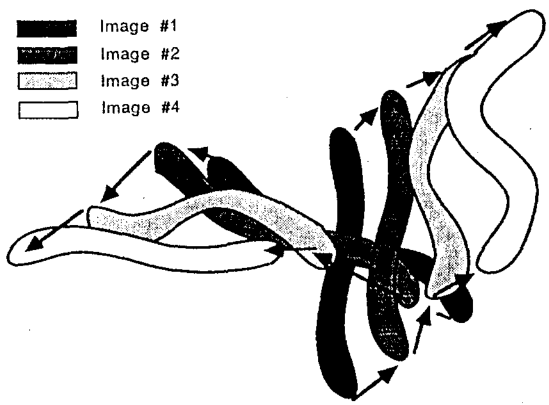


Fig.11 Improved discerning mode

5. EXPERIMENTAL RESULTS

To confirm the effectiveness of the method proposed in this paper, we did experiments using the equipment shown in Fig.12.

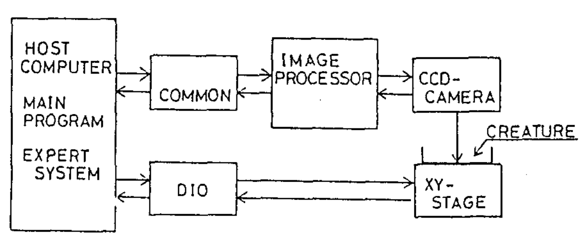


Fig.12 Experimental equipment

5.1 Recognition Experiment

The expert system obtains the image of organisms and then recognizes their species. In this experiment, six species of object organisms were used (see Fig.13):

1.Cyclops, 2.Diaptomus, 3.Nitzschia Fonticola, 4.Cedogonium Variaus, 5.Paramecium Caudatum, 6.Halla Parthenopeia.

These six organisms can be found easily in ponds or rivers. Except Halla Parthenopeia(#6), they are recognizable by microscope only.

The experimental result (see Table 1) shows that the expert system works effectively.

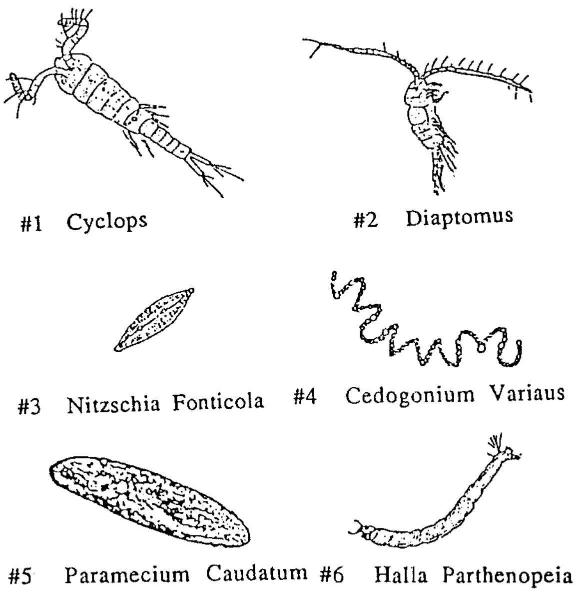


Fig. 13 Sample organism

Table1 Result of the recognition and identification

	Success(times)	Parcentage(%)
#1	13	65
#2	14	70
#3	19	95
#4	16	80
#5	17	85
#6	17	85

(20 times of Repetition)

5.2 Identification Experiment

The expert system obtains images of the same organisms at different times and then recognizes which organism in the former image corresponds to which organism in the latter image. Experiments were done with Halla Parthenopeia(#6) as object and sample images.

In detail, some organisms were put on the shale to obtain the first image then, after movement, the second image. The expert system recognizes which organism in the first image corresponds to which organism in the second image.

The experiment was done with 3,4 and 5 organisms and repeated 20 times. In the case of 3 organisms the identification success-rate was 90%, but with increasing number of organisms the success-rate decreases. However, the expert system can recognize and identify organisms even in cases where humans cannot.

5.3 Insufficient Data Supplement Experiment

This experiment was done to confirm the effectiveness of the Improved Insufficient Data Supplement Mode. In this experiment, incomplete organism images (where some segments are imperceptible) were entered into the expert system purposefully. As sample organism, Cyclops(#1) and Diaptomus(#2) were used.

The experiment was done 20 times and the results are shown in Table 2 and Table 3. Table 1 shows the result in cases where 1,2,3 or 4 segments were lacking. Table 2 shows the comparison the O.I.S.M.1 and O.I.S.M.2. In this case, only images lacking one segment were used.

From these results, we may conclude that the O.I.S.M.2 can reason and supply the insufficient data in cases where the number of segment lacking data is 2 or 3. However, we consider that the success-rate of the O.I.S.M.2 does in this case still not reach that of humans. We consider that this is because humans have macro constructive judgment ability, which the expert systems do not.

Table2 Results of the insufficient data supplement experiment

No. of lacking	Success(times)		Parcentage(%)	
	#1	#2	#1	#2
1	16	14	80	70
2	15	13	75	65
3	14	12	70	60
4	14	10	70	50

(20 times of Repetition)

5.4 Discerning Experiment

The effectiveness of the improved discerning mode was confirmed in this experiment for the following cases. As object organism, Halla Parthnopeia was used.(see Fig.14):

(1) Two Halla Parthenopeias in body-contact,
(2) Two Halla Parthenopeias overlapping each other.

After 20 trials, the success-rate was 70% for O.I.S.M.1 but 80% for O.I.S.M.2. However, the expert system discerning ability still differs considerably from humans who can obtain nearly a 100% success-rate.

We consider this is so because humans obtain much more information than the expert system, for example, using light-intensity the picture image becomes 3-dimensional. In this Discerning Mode, the expert system obtains two-dimensional black and white images, so it is difficult to extract much information from the image. This is the biggest difference between humans and the expert system. We consider this to be the reason for the difference in success-rates.

5.5 Discussions

From the experimental results, the O.I.S.M.2, proposed in this paper, was shown to work better than O.I.S.M.1 in recognition and identification. Especially, the O.I.S.M.2 is shown to be quite proficient in the insufficient data supplement experiment and the discerning experiment, which makes this method applicable for automation.

However, there is much to improve in the insufficient data supplement mode and discerning mode to make the performance of the expert system comparable to a human.

6. CONCLUSION

The refined version of an organism recognition and identification method (O.I.S.M.2) was proposed here different from the conventional pattern matching method. The effectiveness of this refined version method was confirmed by our experiments.

Comparing the O.I.S.M.2 with O.I.S.M.1, we consider the refined version can recognize and identify organisms more effectively.

Also, we consider this refined version can be applied more easily than the former one for automation purposes. However, the method cannot be applied for organisms which do not have a confirmed shape (basic shape), e.g. amoeba. This remains an open problem to be solved.

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Table3 Comparison of the O.I.S.M.1 and O.I.S.M.2

	Success(times)		Parcentage(%)	
	#1	#2	#1	#2
O.I.S.M.1	14	12	70	60
O.I.S.M.2	16	14	80	70

(20 times of Repetition)

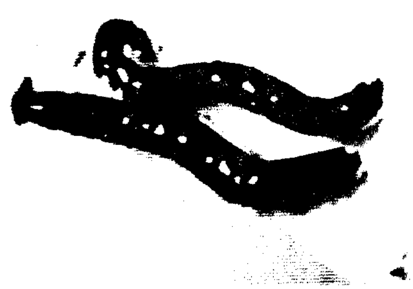

Fig.14 Halla Parthenoia