KNOWLEDGE ENGINEERING APPLICATION IN IMAGE PROCESSING

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ABSTRACT

This paper proposes, a method using knowledge engineering for image processing and discusses it's effectiveness.

To establish the logic and procedure for image processing, a specific software module must be selected from 350 software modules, named SPIDER in Japan, according to vague requirments and the original image. Highly specialized and experimental knowledge is required to select it.

By using the knowledge engineering method, the authors verified the selection and execution of these software modules. As a result, satisfactory processing has been made available to even nonexperts for use in image processing. In image processing execution, conventional language FORTRAN is used to obtain high speed image processing and AI language Prolog is used to infer a suitable software module. By applying AI language, a greater number of image processings, covering a wider range, are expected.

Key Words: Knowledge Engineering, Image Processing, Inference, Knowledge Representation, Expert System.

1. INTRODUCTION

Image processing technology application depends on image conditions (called the attribute in this paper) and the image processing specialist's know-how. It has not gained access to other fields easily.

From this standpoint, knowledge engineering has been applied to image processing in which specialist's know-how can be used. So, the authors called the established system "The image processing expert system."

Prior to the application of such knowledge engineering, the image processing engineer's knowledge was defined and, as a result, the image processing expert system, developed in the segmentation field, has been verified, making a reasonable part of it comprehensible to nonprofessional persons in image processing.

This paper describes "the aforementioned defined knowledge" and image processing knowledge representation, while putting forward a proposal for knowledge representation.

2. IMAGE PROCESSING KNOWLEDGE

Before presenting an analysis of image processing knowledge, the developmental background for the image processing expert system is described below.

2.1 Developmental Background

As far as pre-processing in two-dimensional image processes is concerned, basic approaches have been substantially established.

In Japan, The Electrotechnical Laboratory of the Agency of Industrial Science and Technology under The Ministry of International Trade and Industry (MITI) has developed and edited SPIDER (Subroutine Package for Image Data Enhancement and Recognition). SPIDER contains approximately 350 subroutine packages for each process field (orthogonal transform, enhancement & smoothing etc.), which is programmed by FORTRAN. The image processing engineers select suitable subroutines from the package group.
To select a suitable subroutine, the engineer should have special knowledge in regard to image processing.

Therefore, the authors have begun to study and develop an image processing expert system, in which these subroutine packages can be used, based on the image processing specialist's know-how.

2.2 Analysis of Knowledge Used in Image Processing

The knowledge base to image processing must be analyzed before the image processing expert system can be established.

The three most important issues are mentioned below : -- using a typical example of image processing, namely, a segmentation process -- :

(1) Specialist's processing procedures
(2) Specialist's knowledge classification
(3) Knowledge representation

2.2.1 Specialist's processing procedures

(1) Process example

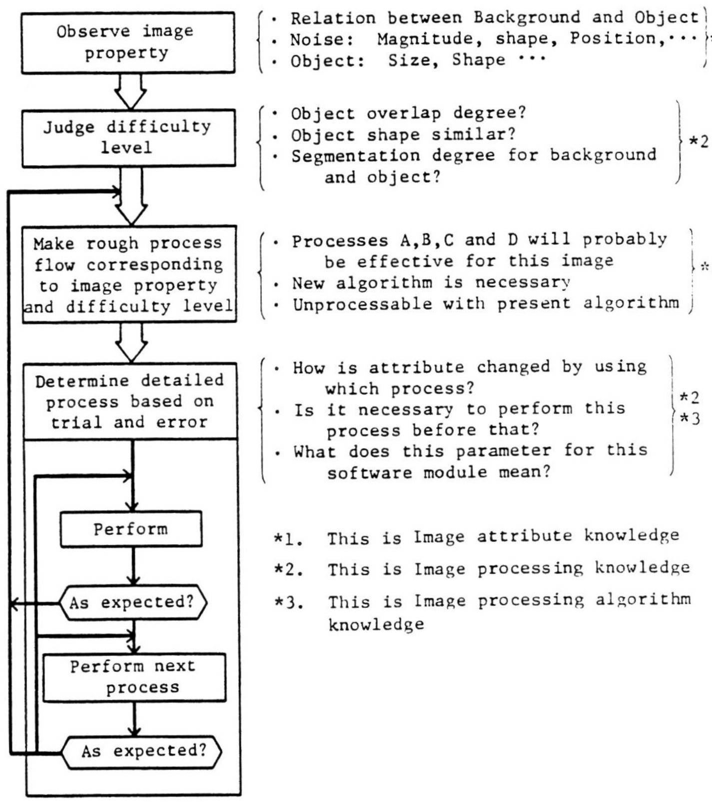
The image segmentation process must be studied prior to discussing the processing procedures.
The segmentation process can be widely used for material inspection etc.
The segmentation process procedure is shown in Fig. 1. The figure shows that the process contents considerably vary with different image attributes (brightness, noise, overlapping with the background, etc.). In other words, the processing procedures depend on the image condition.

(2) Approach procedure

The specialist's approach is expected to follow the procedures in Fig. 2, in consideration of (1). The specialist at this stage can be described as follows:

i) He fully understands the attributes of the objective image.
ii) He infers the conditions of the resulting image after processing.
iii) He understands the effects reaction of the target process.
iv) He is familiar with the algorithm.

Fig. 2 Specialist's Approach and Classification of Knowledge



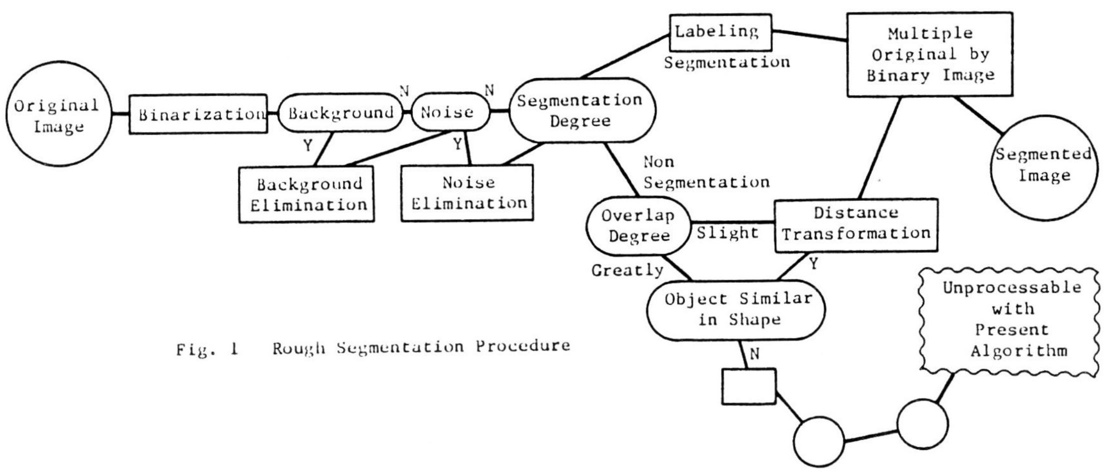


Fig. 1 Rough Segmentation Procedure

(3) Classification of specialist's knowledge

The knowledge used at each stage according to the approach in (2), is classified into the following three categories:

(a) Knowledge about image attributes
(b) Knowledge about image processing procedures
(c) Knowledge about image processing algorithm

The relevant knowledge is shown in Fig. 2 marked with *.

2.2.2 Knowledge about image attributes

The specialist, to whom the image to be processed is given, should understand:

i) Overall image
ii) Target condition
iii) Relationship with the background
iv) Noise, Strain, Diffusion

Examples of such knowledge about image attribute are as follow.

(General) knowledge about background)
- o Background is in an area other than the target area.
- o Background is often a larger area with the same features.
- o Background is often composed of two or more textures.

Image attributes and evaluation items are given in table 1

(2) Knowledge about image processing procedures

Knowledge about image processing procedures is broadly divided into the following two categories: knowledge about the basic process flow shown in Fig. 2; and knowledge -- so called specialist's know-how -- which regulates the processing in detail according to the correlation with the image attribute, or, simply put,

. Knowledge about basic processing procedures
. Knowledge about procedures which are defined as specialist's know- how.

Examples are given in Tables 2 and 3.

Table 2 Example of knowledge about basic processing procedures

(Binarization) o To an image over gray level 3, Set one or more threshold values. o Define sections outside of the two threshold values or the section between the theshold values as one (1), and define the others as zero (0). o Obtain an image comprising 0 and 1 only.

Table 1 Image Attribute Evaluation

Attribute		Evaluation Item							
Image	Overall image	Average gray level	Contrast (gray level variance)	Sharpness	Number of data bits				
	Objective area	Average gray level	Area	Shape	Number	Position	Overlap degree		
	Back-ground	Average gray level	Area		Number	Position			
Distur-bance	Noise	Average gray level	Area	Shape	Number	Position		Frequency	
	Strain		Area			Position	Direc-tivity	Frequency	Strain level
	Diffu-sion		Area			Position	Direc-tivity		Diffu-sion

Table 3 Example of knowledge about procedures defined as specialists' know-how

(Additional information on segmentation)
o If the objects overlap after binarization, binarize them again after calculating the overlap distance.
o If the objective image is low gray level, correct a gray level before binarization.
o If the objective image contains any noise, eliminate the noise before binarization or grey level correction.

(3) Knowledge about image process algorithms

It is expected that, in image processing, the specialist's know-how the attribute changes according to the process performed, which process routine should be used and how it should be applied. In other words, he has:

- o Knowledge about effects/ side-effects of image processing algorithms
- o Knowledge about how to use software modules.

Examples are given in Table 4.

Table 4 Knowledge about effects/ side-effects of image processing algorithms

(Binarization algorithm)
o When binarization is made, the grey level in other than the objective area equals 0.
o When binarization is made, the grey level in the objective area equals 1.

3. APPLIED KNOWLEDGE ENGINEERING

The specialist continues to perform image processing according to the knowledge mentioned in the preceding, and tries to apply the knowledge engineering to this process.

3.1 System Concept

To study the image processing knowledge application effectiveness, it is necessary to form the image process execution part characteristics (the knowledge effectiveness will be clarified only by execution of the image processing). The requirement is given by the user (for example, "Segmentation of the object from the original image"). The image processing expert system consists of the consultation section to infer the procedure, the execution parameter input section and the image processing execution section (Fig. 3).

3.2 Knowledge Representation

The structure suitable for inference is analyzed according to the knowledge analysis. Knowledge about the image processing procedure and knowledge about image attributes are described in detail below.

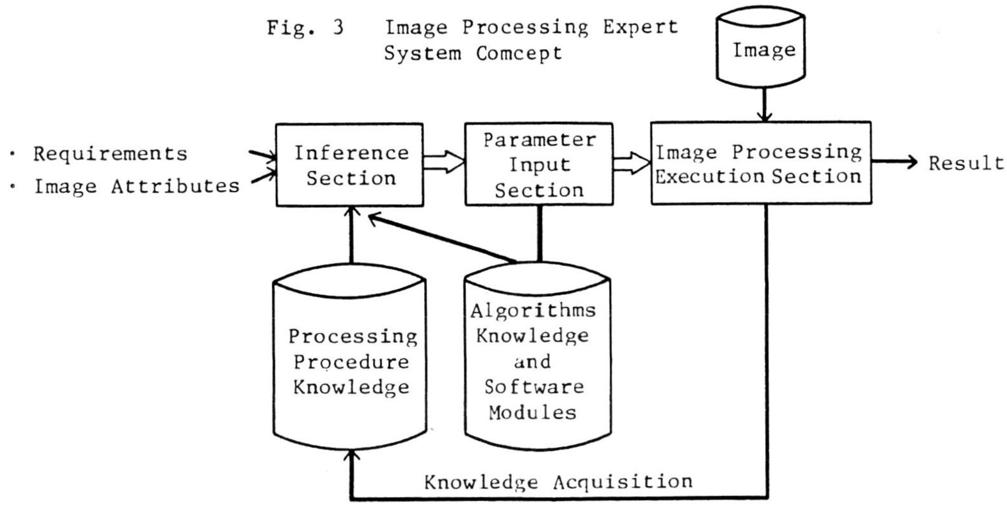
(1) Knowledge about image processing procedures

The knowledge structure is divided into the following categories:

(a) For process A, perform processes b, c, d, or e, f, g, --- . Meta-inference

(b) When the b_1 process is executed, the image attribute changes (greatly, moderately, or a little) and the

Fig. 3 Image Processing Expert System Comcept



attribute changes (greatly moderately, or a little).
Effects on the process image attribute (effects/side-effects)

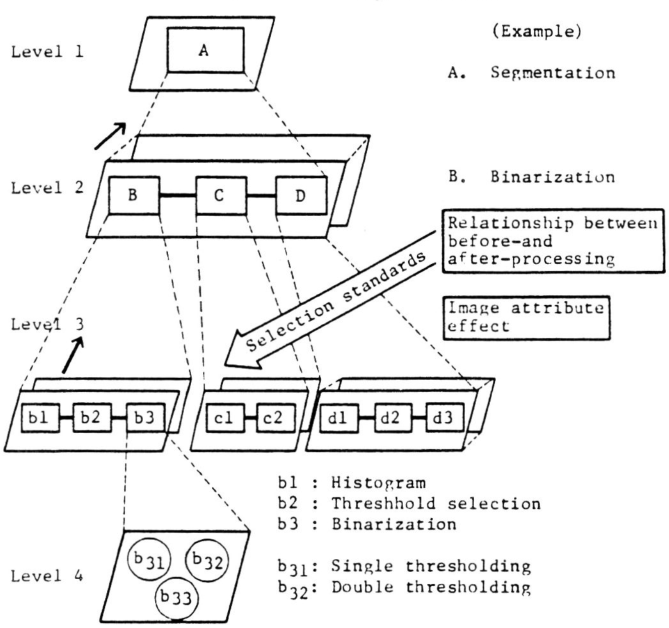
(c) Process B should be performed prior to process C.
Relationship between before and after processing

The knowledge structure can be described using the hierarchical structure shown in Fig. 4.

The relationship on level 3 in Fig. 4 is not strictly fixed, and an optimum processing combination is available depending on the image attribute. Knowledge about (b) and (c) affects this knowledge.

It seems that this knowledge is not systematic, it is stored in fragments, and may correspond with, be inferred from, or be related to the image attribute when the knowledge is used.

Fig. 4 Knowledge Structure



When the structure is clarified, knowledge engineering is a consideration.

i) Knowledge ambiguity
Because the image attribute criterion described later remains qualitative, the ambiguity is very high. However, it is not necessary to make the process procedure ambiguous because of necessary connections with the algorithm.

ii) Knowledge hierarchy
The knowledge has a hierarchy.

iii) Modularity
The knowledge on level 3 or below is fragmentary and modular.

iv) Relationship between fact and rule
The processing makes the image attribute change successively.

This shows that the image process needs rule base more than fact.

Based on the above, image processing procedure knowledge is listed below, using the production rule (Fig. 5).

In this system, knowledge data parts and inference engine parts are separeted individually. Thus, engine parts (programmed by PROLOG) interpret the rule below (Fig. 5).

Fig. 5 Image processing procedure knowledge example

Rule No.	:	rule 21
Process request part:		Binary image background elimination
Condition part	:	IF The gray level of the background and the object are similar, and the background is larger than the object
Execution part	:	THEN Perform labeling operations and then area-cutting operations
Effect part	:	The background disappears
Process result image:		Label image

(2) Image attribute knowledge

The structure and representation for the image attribute are given in Fig. 6. The image

Fig. 6 Representation example of image attribute

Noise frame
Features
- Shape : Circle, point, line and band
- Color : Monochrome
- Size : Minute and small
- Uniformity: Yes or no

Range
- Shape : Optional
- Color : Optional
- Size : Optional

Effects
- Visibility: Hard to see
- Supplement: If the density is high. this density will affect optional processing.

attribute and its evaluation are formed according to the frame. Each frame is generated at each process level according to the process execution. Necessary information is inherited from the high-level concept to the low-level concept between attributes.

3.3 Inference Structure

The inference mechanism to select the software module makes undeterministic inferences, employing a so-called forward inference method, in which the inference is made under an assumption that "if the given image attribute is a, b, c, ---, perform processes A, B, and C".

This mechanism is shown in Fig. 7.

Levels 2, 3 and 4 in Fig. 7 correspond to the processing procedure knowledge levels 2, 3 and 4 given in 3.2 (1), respectively.

B and C in Fig. 7 are metaknowledge. The inference is made by the optimum inference procedure image process fact list update, under unification of the fact list containing the current image attribute with the condition rule for the procedure knowledge.

image processing, about one hour is required to perform the steps from the introductory explanation to processing. On the other hand, achievement of a target image depends on the module functions and setting of optimal parameter values for module execution. Module functions are the subject of image processing technology, which should be further improved. For setting parameter values, since the application field is limited, the necessary values can be set at a very high probability.

As described preceding, at present, the operator's load in the derivation of image processing procedures is markedly decreased.

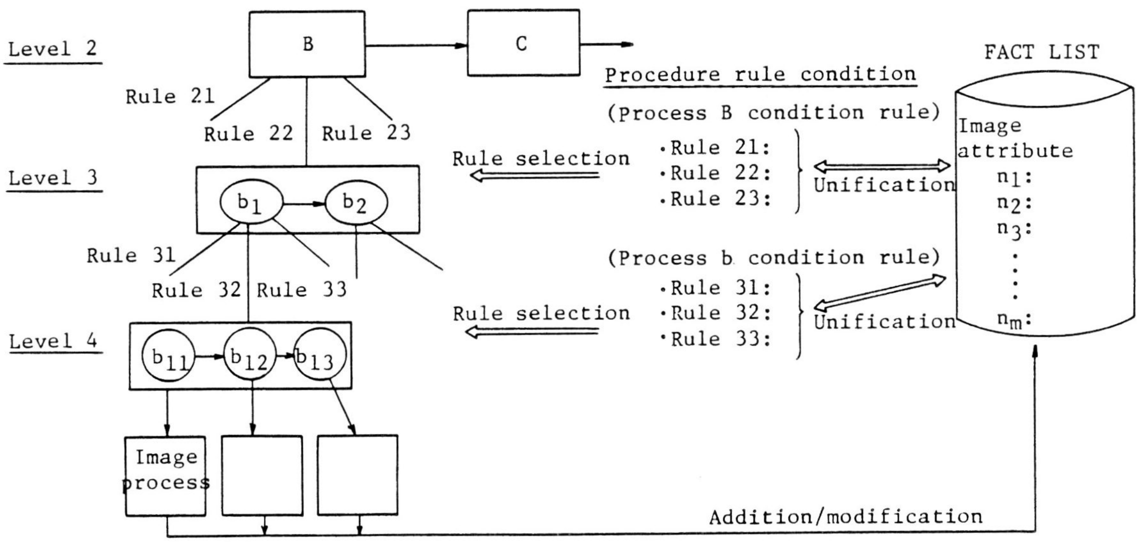
5. PROBLEMS TO BE SOLVED

The expert image processing system still has the following problems:

i) The system is not adapted for expression of an ambiguous image

ii) Action for objects, whose image processing technique has not been established, is difficult.

Fig. 7 Inference Process



4. EFFECTS

At present, the image processing expert system is considered a system whose application field is limited. To date, the system has been verified with approximately 300 rules and approximately 70 software modules. When processing is performed by a non-expert in

As described in 3.2 (2) concerning image attribute, definition problem (i) involves much ambiguity. As one image processing technique, an image quantitization technique, such as histogram analysis, profile analysis or label processing, can be used.

By quantitization using these techniques, it will become possible to reduce the portions left to the intuition of the user. Also to be studied is the Fuzzy theory in the expression method for information which is difficult to quantitize.

Though the system using the algorithm whose image processing technique has mostly been established is now being studied, it will be possible for expert researchers to develop a new algorithm on the basis of the existing algorithm.

When an unestablished algorithm is required, problem (ii) should be solved to assume and furnish conceptual processing for the user on the basis of the image attribute and procedure knowledge, thereby an assisting system for new algorithm development is required.

6. CONCLUSION

Up until now, when image processing technology has been applied to other fields, it has been necessary for the researcher in a particular field to start at the beginning, limiting technical application.

However, through research and development on the image processing expert system, the authors found a clue to the image processing technology application to a wider range of fields by applying knowledge engineering. Thus, it is considered that image processing technology can be made easier to use by applying knowledge engineering.

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REFERENCES

[1] Azriel Rosenfeld, Avinash C. Kak : Digital Picture Processing.

[2] Avron Barr, Edward A. Feigenbaum : The handbook of artificial intelligence.

[3] Nils J. Nilsson : Principles of Artificial Intelligence.

[4] W. F. Clocksin, C. S. Mellish : Programming in Prolog.

[5] Hideyuki Tamura and five others : SPIDER USER'S MANUAL.

[6] Hideyuki Nakashima : The Language and Interpreters Information Procesing Society of Japan VOL. 23, No. 11.

[7] Takashi Matsuyama : Knowledge Organization in Image Understanding, Information Processing Society of Japan VOL. 24, No. 12.

[8] Hideyuki Tamura, Katsuhiko Sakaue : Three Kinds of knowledge for Building Digital-Image-Analysis Expert System.

[9] Shigeoki Hirai : Knowledge-Based System Tool, The Society of Instrument and Control Engineers VOL. 22, NO. 9.

[10] Motoi Suwa : The Current State and Future Trend of Knowledge Engineering, The Society of Instrument and Control Engineers VOL. 22, NO. 9.

[11] Shinichi Honiden,. etal "One Method of prototyping for real-time system", submitted to trans of IPSJ (in Japan).

[12] Naomichi Sueda, etal "Prolog application in software reuse". Sumposium of the Role of Language in Problem Solving APL/Johns Hopkins University.