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A KNOWLEDGE-BASED SYSTEM FOR SELECTION OF SURFACE TEXTURE PARAMETERS: A PRELIMINARY INVESTIGATION

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Abstract

The use of microcomputers for processing surface profiles from stylus instruments has resulted in the availability of a great deal of information. However, a functional databank does not exist yet to assist the designer in the selection of proper surface finishes for different applications. The use of computers for analyzing surface profiles has also resulted in a number of methods for characterizing surface finish. As a result the user is faced with many options and has very little information to guide him in the analysis. This paper presents the results of a preliminary investigation aimed at simplifying surface texture analysis and selection using a knowledge-based system, a tool commonly used in artificial intelligence.

1 Introduction

The recent introduction of microcomputers into the processing of measured profiles of engineering surfaces has resulted in the availability of a great deal of information regarding the geometric characteristics of these profiles. Microcomputers have also contributed to the proliferation of parameters to specify surface texture. The number of these parameters is so large that the term "parameter rash" has been used to describe the present state of affairs.[1] This has resulted in a certain amount of confusion in the user's mind regarding the appropriate use of a parameter.[2] A related area in which there is very little information available is that of functional relationships of surface texture. Proper surface finish is critical to the operation and performance of a wide variety of equipment. Examples include moving parts in contact, stationary parts in contact, corrosion resistance, and adherence of paint or plating.[3] In many cases it is not practical to predict from fundamental principles what surface is required in order to achieve satisfactory performance in a particular application. The specification is based on experience and past data on performance.[3] In situations where the designer uses in-house proprietary information that relates past performance to surface texture, he may be faced with such questions as whether the application was similar, what process was used to achieve the finish, etc. The alternative is an experimental investigation, which may be lengthy and costly.

One approach to this problem is to develop a surface texture analysis and selection system. The selection of surface texture parameters could be based on past data, and the analysis of texture could be based on the requirements of the user (researcher, process engineer, quality control, job shop). The objectives mentioned above could be achieved by developing software in Pascal or some other structured language. However, the task could be performed efficiently by using the tools available in the area of artificial intelligence.

The objective of the project in progress is to develop a knowledge-based system for surface texture analysis and selection. The project is expected to be carried out in three phases. The first is a prototype phase that will demonstrate the use of a knowledge-based system for selection of surface finish parameters for different functional requirements. The second phase deals with the analysis of surface texture. The analysis depends on the requirements of the user. The profile obtained from a stylus instrument will be used for the analysis and, depending on the type of user, the system is expected to guide and perform the analysis. The third phase is the utilization and maintenance of the system and would focus on steps to expand and improve it to keep up with the technology and enhance that usefulness of the system.

This paper reports the results of the first phase: a knowledge-based system for selection of surface texture parameters to ensure proper functioning. The selection system has been developed on an IBM 4381 using an expert system shell, Expert System Development Environment (ESDE). This system was selected because it has built-in input/output capabilities and also has the ability to call external Pascal procedures to perform computation. The following section gives a brief introduction to expert systems and describes the prototype system developed for the selection of parameters.

2 Background on knowledge-based systems

The term "expert system", or "knowledge-based system", refers to an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. The knowledge of an expert system consists of facts and heuristics (rules). The facts constitute a body of information that is widely shared, publicly available, and generally agreed upon by experts in a field. The heuristics are mostly private, little-discussed rules of good judgement (rules of plausible reasoning, rules of good guessing) that characterize expert-level decision-making in the field. The performance level of an expert system is primarily a function of the size and quality of the knowledge base it possesses. The components of an expert system (Figure 1) can be distinguished as:

a knowledge base;
a reasoning or inference mechanism;
a user or client interface.

The most difficult task associated with the knowledge engineering function

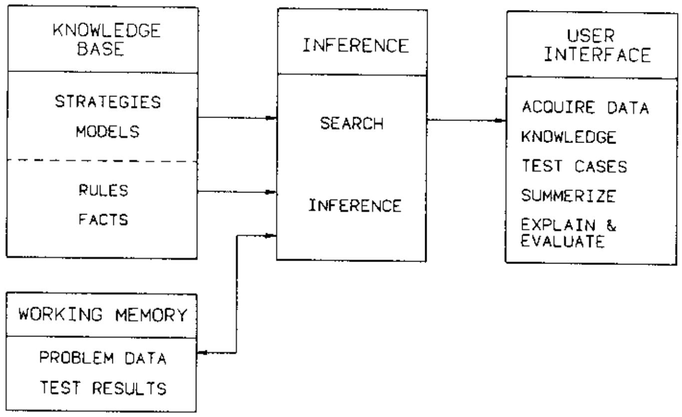

Figure 1 *Components of an expert system.*

is to determine an adequate structure for the knowledge base. The knowledge base is the main repository for domain-specific heuristics. It consists of the following information:

Domain facts
These are declarative representation of parameters, with both abstract clauses and concrete instances. Parameters are defined in ESDE as a variable of knowledge. A name and legal values are defined for the parameters. For example, the parameter "dynamic sealing" is defined thus:

PARAMETERS

PARAMETER: DYNAMIC SEALING

Constraint taken from('with_seal','without_seal')

Sourcing seq. Rule Consequent
User will input from terminal
Default will be taken

Prompt choose from the following operating conditions
(dynamic_sealing)

The legal values for this parameter are "with-seal" and "without seal".

Rules
The rules are developed on the basis of experimental investigation or are

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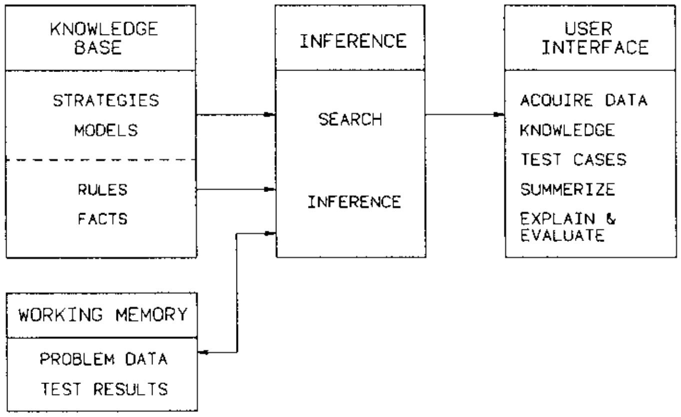

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Rules

The rules are developed on the basis of experimental investigation or are obtained from an expert. For example, the rule for selection of surface finish parameter in sealing applications is given below. Figure 2 shows an example of relationships among facts.

RULES

RULE: RULE0006

Rule text if surf_func is 'two_parts_incontact' and
two_parts_incontact is 'with_relative_displacement' and
with_rel_displ is 'dynamic_sealing' and
dynamic_sealing is 'with_seal' then
pri_para_to_be_spec is 'R and Wmax' and
sec_para_to_be_spec is 'Rmax,AR and AW' and
wavn_para_to_be_spec is ' < .6R' and
max_val_of_R is 'no_recommendations'

Owning FCBs ALL-Y:*FCB:GLOBAL

Rule type Inference

ESDE provides backward and forward chaining rule interpreters. The surface texture parameter selection system being developed makes use of a backward chaining interpreter. The operating conditions of the surface are defined and on the basis of this information the system provides a recommendation by invoking the appropriate rules.

Focus control block
This is the codified knowledge about how to perform problem-solving. It is a collection of interrelated rules, usually associated with a particular problem hypothesis or overall diagnostic conclusion. The focus control block for the present system is shown below:

Goals PARAMETER:PRI_PARA_TO_BE_SPEC
PARAMETER:SEC_PARA_TO_BE_SPEC
PARAMETER:WAVN_PARA_TO_BE_SPEC
PARAMETER:MAX_VAL_OF_R

Results PARAMETER:PRI_PARA_TO_BE_SPEC
PARAMETER:SEC_PARA_TO_BE_SPEC
PARAMETER:WAVN_PARA_TO_BE_SPEC
PARAMETER:MAX_VAL_OF_R

Control text
Determine Goals;
Display Results;

Announce This is an expert system that will assist in selection of surface texture parameter to satisfy different functional requirement.

An important primitive control function is the specification of inference technique. A block diagram of the inference procedure for finding the values of parameters is shown in Figure 3. ESDE provides two types of inference techniques:

backward chaining (DETERMINE);
forward chaining (DISCOVER).

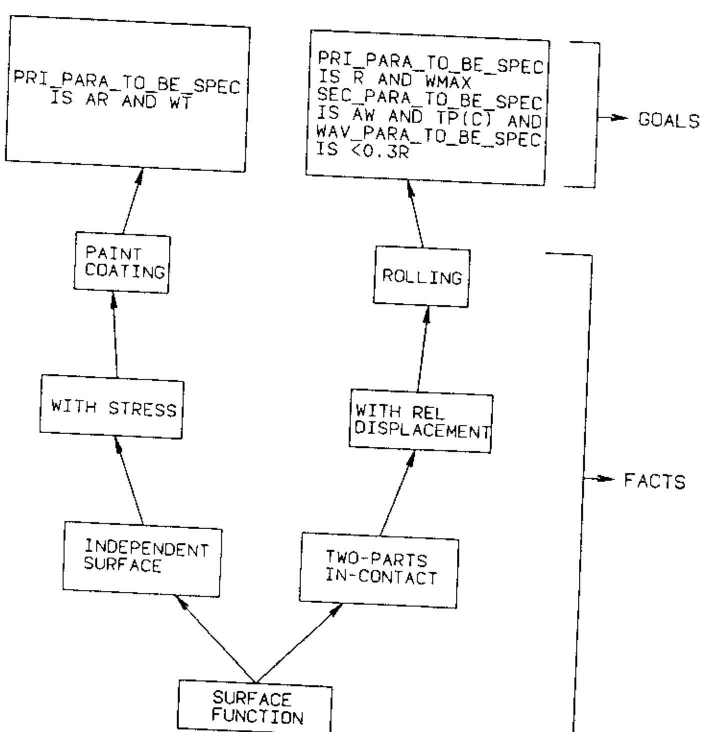

Figure 2 *A sample rule network.*

Table 1 *Classification of engineering surface functions, important surface parameters, and notations on documents. (After Vorburger et al.*[4]*)*

SURFACE FUNCTIONS				PARAMETERS								
				ROUGHNESS			WAVINESS				TOTAL PROFILE	
		DESIGNATIONS	SYMBOL	R	R_{MAX}	AR	W	W_{MAX}	W_t	AW	P_t	T_p (c)
TWO PARTS IN CONTACT	WITH RELATIVE DISPLACEMENT	SLIPPING (LUBRICATED)	FG	●			<.8R			○		●
		DRY FUNCTION	FS	●		○		●		○		
		ROLLING	FR	●			<.3R	●		○		○
		RESISTANCE TO HAMMERING	RM	○		○	○			○		●
		FLUID FRICTION	FF	●		○				○		
		DYNAMIC SEALING — WITH SEAL	ED	●	○	○	<.6R	●		○		
		DYNAMIC SEALING — WITHOUT SEAL	ED	○	●		<.6R					●
	WITHOUT DISPLACEMENT	STATIC SEALING — WITH GASKET	ES	○	●		< R		○	○		
		STATIC SEALING — WITHOUT GASKET	ES	○	●		< R		●			
		PRESS FIT	AC	○								●
		ADHERENCE (BONDING)	AD	●							○	
INDEPENDENT SURFACE	WITH STRESS	TOOLS (CUTTING SURFACE)	OC	○		○	●			●		
		FATIGUE STRENGTHS	EA	○	●	○						○
	WITHOUT STRESS	CORROSION RESISTANCE	RC	●	●							
		PAINT COATING	RE			○				○		
		ELECTROLYTIC COATING	DE	●	<2R	●						
		MEASURES	ME	●			< R					
		APPEARANCE (ASPECT)	AS	●		○	○			○		

● : MOST IMPORTANT PARAMETERS TO BE SPECIFIED

○ : SECONDARY PARAMETERS TO BE SPECIFIED DEPENDING ON FUNCTIONS

Table 2 *Tolerance classes and examples for three types of engineering functions. (After Vorburger et al.[4])*

PURPOSE	OPERATING CONDITIONS	MATERIAL	EXAMPLES	MAXIMUM VALUE OF R IN μm	SYMBOL
STATIC SEALING	VERY HEAVY	CAST IRON	VALVE AND SEAT	1	√ES
		ALUM	OIL PUMP COVER	1	
	HEAVY DUTY	STEEL	CYLINDER LINER LIP SEAL (NO GASKET)	6.3	
		ALUM	CYLINDER LINER LIP SEAL (WITH GASKET)	6.3	
	MODER-ATE	STEEL	FACE AND ID SUFACES OF MOTOR BLOCK	6.3	
		ALUM		10	
	LIGHT	CAST IRON		16	
		ALUM		20	
PRESS FITS	VERY HEAVY	CAST IRON	BALL BEARING SEAT MACHINE TOOL	0.63	√AC
		STEEL		0.63	
		ALUM		0.63	
	HEAVY DUTY	CAST IRON		2.5	
		STEEL		2.5	
		ALUM		2.5	
	MODER-ATE	CAST IRON	CONNECTING ROD BEARING *	6.3	
		STEEL		6.3	
		ALUM		6.3	
	LIGHT	CAST IRON		10	
		STEEL		10	
		ALUM		10	
ADHESIVE	ANY COND.	ANY MATER	POLYMER GLUE	20	√AD

* AFTER BORING, BEFORE HONING

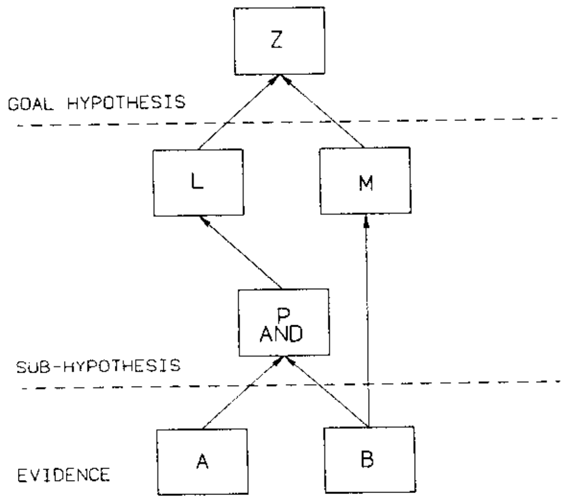

Figure 3 *A sample inference network.*

Client interface
The user or client interface provides a method for the system to request information from the users. The user provides information about a particular problem occurrence, and the system combines the information with recorded domain knowledge to help the user solve the problem. The client's responses control the path of the dialog until a conclusion is reached. During the consultation the user can ask questions such as "why" the system is asking for certain inputs, "how" the rules are being triggered etc., and thus makes it very convenient for the user.

3 Dialog example

The knowledge base for the surface finish parameter selection system is based on the French parameter selection system, Tables 1 and 2. This is obviously a limited knowledge base and more information can be included to make the system comprehensive. An example session for selection of surface texture parameter based on user-defined functions is given below.

```
*INTERACTION SURF_FUNC OF GLOBAL(1)
*NUMBER 1
*QUESTION
choose from the following the type of surface func
*SELECTION
```

```
two_parts_incontact
indep_surface
*PROMPT (Choose one of the following:)
*ANSWER two_parts_incontact
*INTERACTION TWO_PARTS_INCONTACT OF GLOBAL(1)
*NUMBER 2
*QUESTION
type of contact
*SELECTION
with_relative_displacement
without_displacement
*PROMPT (Choose one of the following:)
*ANSWER without_displacement
*INTERACTION WITHOUT_DISPL OF GLOBAL(1)
*NUMBER 3
*QUESTION
choose from the following
*SELECTION
static_sealing
press_fit
adherence
*PROMPT (Choose one of the following:)
*ANSWER static_sealing
*INTERACTION STATIC_SEALING OF GLOBAL(1)
*NUMBER 4
*QUESTION
is the static sealing
*SELECTION
with_gasket
without_gasket
*PROMPT (Choose one of the following:)
*ANSWER with_gasket
*INTERACTION OPERATING_CONDITIONS OF GLOBAL(1)
*NUMBER 5
*QUESTION
Operating conditions
*SELECTION
light
moderate
heavy_duty
very_heavy
*PROMPT (Choose one of the following:)
*ANSWER light
```

```
*INTERACTION MATERIAL OF GLOBAL(1)
*NUMBER 6
*QUESTION
choose the type of material that is being used. For
example in static sealing for heavy duty operating
conditions the material used is steel and alum.

*SELECTION
cast_iron and alum
steel and alum
cast_iron,steel and alum
*PROMPT (Choose one of the following:)
*ANSWER cast_iron and alum
```

Recommendation:
Pri. Para. to be Spec. is R_{max}
Sec. Para. to be Spec. is R, W_t, and AW
Wavn. Para. to be Spec. is < R
Maximum value of R, Cast-iron = 16 and Alum. = 20

This investigation was aimed at exploring the possibility of developing a knowledge-based system for surface texture analysis and selection, and determining the type of information required to develop a comprehensive system. Future work will be directed towards expanding the knowledge base and will also include analysis of surface texture.

References

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4 Vorburger, T., Bielle, J., Parsons, F. and Tabenkin, A.; *Creation of a Technical Data Bank for the Surfaces of Mechanical Parts.* NBS proposal, 1987.