The Structure of Surface Texture Knowledge

Wang Yan*, Paul J. Scott*+ and Xiangqian Jiang*

* Centre for Precision Technologies, University of Huddersfield Queensgate, Huddersfield HD1 3DH, United Kingdom

+ Taylor Hobson Ltd, 2 New Star Road, Leicester LE4 9JQ, United Kingdom

Email: y.wang2@hud.ac.uk

Abstract. This research aims to create an intelligent knowledge-based system for engineering and bio-medical engineering surface texture, which will provide expert knowledge of surface texture to link surface function, specification of micro- and nano-geometry through manufacture, and verification. The intelligent knowledge base should be capable of incorporating knowledge from multiple sources (standards, books, experts, etc), adding new knowledge from these sources and still remain a coherent reliable system. A new data model based on category theory will be adopted to construct this system.

1. Introduction

In order to optimise resources through the scientific and economic management of the variability of all production processes, the next generation GPS (Geometrical Product Specification and Verification) system [1&2] has been shown to be a revolutionary breakthrough. However its wide acceptance and application in industry has been a great problem. The next generations of GPS standards are considered to be too theoretical, abstract, complex and over-elaborate. It is proving to be very difficult for industry to understand and operate them effectively. This point is especially true for small and medium business’, where resources are not available to interpret and implement GPS correctly.

The three-year VirtualSurf project aims to advance considerably the current state-of-the-art by creating a virtual knowledge-based intelligent system to solve difficulties in surface texture specification and metrology that is a critical part of the next generation of GPS. The project will create a vehicle that will provide expert knowledge of surface texture to link surface function, specification of micro- and nano-geometry through manufacture, and verification. The intelligent knowledge base should be capable of incorporating knowledge from multiple sources (standards, books, experts, etc), adding new knowledge from these sources and still remain a coherent reliable system. The system should provide a universal platform for engineers in industry, making them easily to understand and use the latest surface texture knowledge.

2. Surface texture knowledge structures

Surface texture is important across a very wide spectrum of technical activities, from the design function to specification on a drawing, from the manufacturing process to verification. The whole structure of surface texture can be divided into four categories: function of surface, specification, manufacture and verification. Each is a category with different structure. For example, the structure of the function of a surface takes the form of a simple tree structure [3], the relationships are only
between the parent nodes to son nodes. While the specification (or callout), takes the form of a hierarchical structure, although it seems like the tree structure, it is more complicated, (see Figures 1-3), there are even more relations among the son nodes. Apart from the structure of each category, there are also the relationships between the four categories, for example the relationship between a specification and the measuring procedure to verify the specification.

3. Data models for surface texture knowledge structures

Database architecture comprises three levels: the external level, the conceptual level and the internal level. The conceptual model is a common, unconstrained view of the data, while the external view is the portion of data that will be of interest to particular users, and the internal model represents the actual storage representation of all the data in the database [4]. What the project creates is a general and formal framework for the conceptual data model of surface texture knowledge, users can then create or destroy different external views according to their specific requirements. In order to develop a widely used knowledge-based system, surface texture knowledge should come from multiple sources, for example: standards, books, experts, etc.

The dominant paradigm for databases is the “relational database” [5]. Although the relational database has good mathematical foundations, the knowledge must take the structure of a table, making it very inflexible. The other, increasingly popular, database paradigm is the “object – orientated database” [6]. This has the flexibility for knowledge to take any structure but unfortunately lacks a universal formal basis and mathematical foundations to ensure the database remains a coherent and reliable system as new knowledge is added.

The project will use a cutting edge paradigm for object-relationship model databases [7-9], based on Category theory [10-12] (general mathematical theory of structures and systems of structures), that generalises the relational and object orientated database models. Category theory provides a formal basis and abstracts from all representational aspects, and it has the ability to combine diagrammatic formalisms as in geometry with symbolic notation as in algebra [8]. This database model, which is a highly abstract model for databases, can bring together different data models and provide a common structure for describing data. It is thought to have both the flexibility of structures for entities and has good mathematical foundations that ensure the database remains a coherent and reliable system as new knowledge is added.

The fundamental constructs in category theory are objects and arrows between objects, which is similar to the entities and functions in the functional data model. The Functional data model has been proposed as a suitable formal and practical basis for object-oriented databases [13]. Now the most widely used functional model is DAPLEX [14], which provides the most natural query language. It is intended that the structure and manipulation language of category model can be developed based on DAPLEX.

![Figure 1: Surface texture callout symbol and brief explanation of symbols](image-url)
4. Example of a simple surface texture callout

Surface texture callouts are the symbols used on a drawing to define the surface texture design intent (see figure 1) and are defined in ISO 1302 [15]. The callout symbol takes the form of a hierarchical structure.

Figure 2 illustrates the functional structure of a simple surface texture callout using P/FDM [16]. P/FDM is an implementation of Shipman’s Functional Data Model and DAPLEX. Many of the symbols in the callout have default values. These are values to be used when the symbol does not define a particular value to use. For example, “Ra 3.3”, has the complete representation “0.008-2.5 / Ra516% 3.3”, where the missing values are given by the default values. Users, who are not familiar with the definitions, have to waste much time on looking up references in order to obtain the complete data information. The callout database is for users to easily retrieve necessary data information.

Figure 2: Functional Structure of Callout with defaults

Figure 3: Category Model of Basic Callout Structure without defaults
Based on the functional data model, the structure of a simple callout can be transferred to a category model, as figure 3 shows. Figure 3 is just a basic structure of the callout, without the default relations. In this model, relations among callout structures are represented by the category terms “pullback” and “product” which generalises the table structure in a relational database model.

5. Conclusions and Future work
The paper examines different structures of entities that occur in surface texture, and discusses different data models. Category theory is introduced, that generalizes the relational and object orientated database models to structure the surface texture knowledge. This data model has both the flexibility of structures for entities and has good mathematical foundations, which ensures the database remains a coherent and reliable system as new knowledge is added. Since the category model is similar to the functional model, and functional database models, such as DAPLEX, have their own query language, it is thought to be easier to develop the category database by transferring from the functional model.

The paper also provides an example, the surface texture callout, showing how to transfer the functional model to the category model. This category model for databases is still in infancy and needs further development, such as the manipulation languages. More work has to be done to realize the integrated intelligent surface texture knowledge-based system.

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