ASSISTING MOULD QUOTATION THROUGH RETRIEVAL OF SIMILAR DATA

Manuel Fonseca, Elsa Henriques, Alfredo Ferreira, Joaquim Jorge
Instituto Superior Técnico, Lisbon, Portugal;
mjf@inesc-id.pt; elsa.h@ist.utl.pt

Moulds are complex devices and their quotation is one of the most risky tasks in mould industry. In this paper a digital work environment based on a computer assisted mould quotation tool is proposed in which all the relevant information is quickly available to assist a robust and rapid quotation. The tool involves a new way to directly access past quotation, design and even manufacturing data based on the similarity of mould geometry and mould attributes. It applies new 2D/3D design concepts where sketches and text attributes are used to search for and access similar moulds. The main results from the analysis of mould quotation procedures and a preliminary tool prototype are presented.

1. INTRODUCTION

Quotation of complex moulds is one of the most difficult tasks in mould-making. Each mould is a unique device, where engineering solutions are implemented in accordance to the final part and moulding process requirements. It determines not only the efficiency of the mould manufacturing process but also the robustness and economy of the part moulding process (Wang, 2003). But, if each mould is unique, indeed the engineering solutions are frequently replicated in similar moulds. When facing a new project mould designers and mould quotation craftsmen start a reasoning process trying to remember a past similar mould. The idea is not to "re-invent the wheel" and not to star working on a "white piece of paper" but to work over validated past engineering solutions and cost data. In this reasoning process several problems arise. The first is that it is not clear what a similar mould is. The second can be expressed by the feeling "*I know I did something similar but I just can not remember neither what is it nor when was it*". The third is related to the fact that even if companies archive past data, those archives are frequently useless, due to the too long retrieval time and high probability of no succeeded search. This framework leads to:

- Long mould design process and long and ineffective quotation process due to inefficient past information use.
- Proliferation of design solutions some of them unproved and of poor quality.
- High dependence on knowledge "archived in the human vaults" and high risk of knowledge lost with their leaving.
- Necessity of qualified craftsmen for quotation. Mould-makers are SMEs and staff qualification is highly dependent on a slow learning process and practice on job, so qualified personnel is a scarce resource (Henriques, 2004).

In fact a new way to design and directly access past quotation, design, and even manufacturing data based on mould geometric and mould attributes similarity is required. This research work aims to develop a prototype tool based on digital technologies to support the mould quotation process. The tool applies new 2D/3D design concepts where sketches and text attributes are used to search for similar moulds and access relevant mould quotations. The idea is to develop a digital work environment in which all the relevant information is quickly available to assist the budgeter in robust but quick quotations. This paper presents the main results from the analysis of the quotation procedures and a preliminary prototype, aimed to explore and validate concepts and approaches.

2. TASK ANALYSIS AND USER REQUIREMENTS

To get an overview and collect information from the mould development process several companies were visited and qualified persons involved in the mould quotation and design processes were interviewed. Currently, a typical mould company performs several hundreds of mould quotations annually, but only 5% to 10% of them evolve to production. The quotations are made mainly by senior budgeters, as they require a large experience and know-how involving not only cost estimation, but also facets in mould design, production engineering and management, and even marketing intelligence. The problem mould industry is facing now is that senior budgeters (knowledge vaults) are frequently getting retired and junior staff or commercial staff does not have enough know-how to perform reliable cost estimations. In addition, the pressure over costs promoted by the global competition and by the purchasing departments of large and global clients, focused on short term financial results, are demanding quick quotations and do not allow profit margins where unreasonable quotations could be accommodated without significant damages in economical sustainability. In the industry survey different quotation methodologies were identified, based on two basic approaches:

1. Top-down approach – the quotation is built up based on the reasoning and accumulated experience (historic similar moulds "saved" as tacit knowledge). The focus is a synthesis competence only possible if a huge experience and tacit knowledge are present.
2. Bottom-up approach – the quotation is built up from a rough engineering solution upon which the aggregated cost and its parcels (materials, design, machining, trial-out,…) are identified. The focus is the analysis competen e and it requires the establishment of precise and formal procedures.

In both approaches some remarks were pointed out by budgeters: (1) they must deal with a constant trade-off between the speediness and the accuracy of the quotation; (2) formally (approach 2) or informally (approach 1), the mould design solutions are the basic reasoning to achieve the quotation; (3) formally or informally, the similarity to old moulds is a basic issue to support quotation decisions. Depending on the project dimension, on its economical and technological risk and even on the negotiation process, the two approaches are often sequential in time. It was noted that the requirement of speediness privilege the top-down approach. Nevertheless, its success (accuracy in a range of +- 10% of the real cost of the mould) strongly depends on a qualified budgeter integrating commercial, engineering, production competences.

2.1 Research Approaches and Quotation Commercial Systems

Some research has been developed in mould cost estimation. Most of the effort has been driven towards the part classification features and the effect of these features on the mould cost. (Chen, 1999; Rosen, 1992). Wang et al (2003) proposed a case-based reasoning to look for similar old moulds in a case library and carry on the case adaptations to achieve accurate estimations. Fagade et al (2000) developed a method to evaluate the part complexity at the early stages of design. He used a complexity metric defined by the number of dimensions that uniquely define the part geometry and applied multiple regression analyses with the mean mould quotes and mean lead-times as dependent variables and a systematic combination of mould attributes (part envelope volume, complexity dimension, number of actuators, tolerances, surface finishing) as independent variables. From a set of 30 moulds he concluded that these variables explain 91% of the mould cost and proposed multiple linear equations to estimate the mould final cost.

There are some commercial systems that support mould quotation process, such as ASAMould, Magics Tooling Expert, CalCard Pro Inject, CalcMaster. However, these systems are far from an extended dissemination in the industry. One of the reasons given by mould-makers is related to their complexity and difficult use, making any quotation a slow and complicated process. But, simultaneously companies refer the need for quotation tools easily adaptable to their business and their type of moulds. In fact two approaches have been developed in the quotation systems commercially available. One is what one can call automated mould engineering analysis. Starting from the part features effective engineering solutions are retrieved and used to elaborate the estimation. Nevertheless budgeters consider that is not possible to accept as adequate the solutions proposed because a lot of variables in the shop-floor and in the moulding process are not considered. The other approach is based on the fulfilment of an intricate list of parameters and so, to reach any simple estimation, an extensive effort is required. In general, this information is not sufficiently systematised and ready to be used. Moreover, frequently it is only possible to fulfil these parameters if a preliminary mould design is available. But when the percentage of quotations latter converted to orders is less than 10% the effort to do a preliminary mould design in a quotation is prohibitive. Companies refer that to work with current quotation systems high experience and qualified budgeters staff is needed. But if such staffs are available they can do more rapid and accurate quotations using simple calculation templates prepared by themselves. On the other hand, these systems are expensive and need a continuous maintenance performed by technicians with digital technologies competences. In SMEs these professionals are a scarce resource as it is very difficult to support them financially.

2.3 Proposed Approach

A new tool to assist mould makers in the elaboration of rapid and precise quotations, providing an environment where similar historical data is quickly accessed to speed up initial stages of product and mould concept discussions, and to facilitate and increase the robustness of the engineering decisions during the preliminary development is the main driver of this research work. Two methods to access (search/retrieval) information associated to past moulds are provided. The first method is based on mould attributes, such as, client name, dimensions, type of mould, part name, etc. (Figure 1). The second is based on geometric information of part drawings. Moulds always have associated part drawing (2D/3D), which can be used to index mould quotations in a database for later search and retrieval.

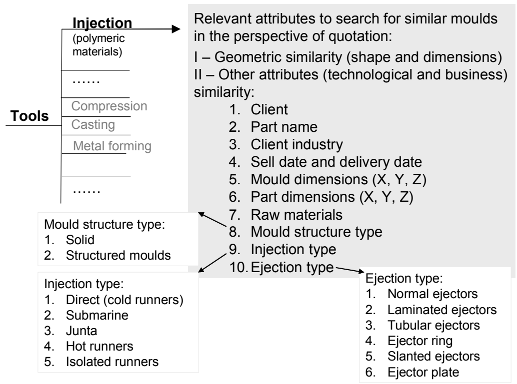

Figure 1- Overview of the searching attributes

This tool has the advantage of not modifying the current work methodologies. The idea is to develop a work environment for quotation, providing an effective access to morpho-dimensional and morpho-functional similar moulds produced in the company, to assist the budgeter in his decision making. Avoiding a strict framework, which has been the basic principle followed by other quotation tools develop for the sector, this approach can be viewed as a real human-centred quotation environment (Figure 2).

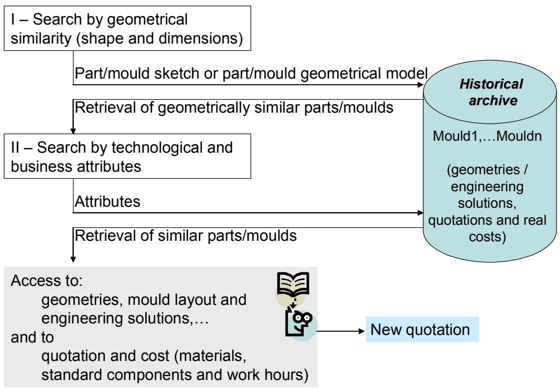

Figure 2 - Basic principles of the quotation assistance environment

3. TECHNOLOGICAL DESCRIPTION

While searching using attributes associated to moulds is not very hard, since it is only textual, searching using the geometric information is not trivial. To support this, the quotation tool provides mechanisms for users to specify queries using freehand sketches, which are then compared with the 2D or/and 3D drawings stored in the database. Moreover, techniques to simplify, index, search and retrieve complex 2D and 3D drawings were developed. It is important to notice that simple sketches drawn by users are compared with several complex CAD drawings. So, it is essential to use an efficient description mechanism to support this comparison. In summary, one can state that the main technological subject behind the quotation tool development is the retrieval of graphical information using sketches. In the remainder of this section the general architecture of the quotation tool is presented, followed by some research approaches related to 2D/3D drawing retrieval subject.

3.1 Prototype Architecture

The architecture of the quotation tool is divided in 2 parts. One where all the existent moulds related information is processed (classification) and the other where a query is submitted and a result is received (retrieval). The classification consists in collecting the information and storing it in a database for further access. There exist two kinds of data to process: textual, that specifies information related to a mould, and graphical, which comprehends parts and moulds drawings. The textual data is manually classified while drawings are automatically processed. Figure 3 presents the steps needed to process drawings and generate descriptions suitable for further comparison to sketches. Firstly a set of simplification algorithms are applied to eliminate useless elements, such as, small area polygons, small lines or very near lines. This simplification reduces the number of graphical elements, making the comparison between sketches and drawings easier, and reduces the complexity of the structure that describes the geometry and topology of drawings. After simplifications, drawings are analysed extracting from them topological (spatial arrangement) and geometric information of their graphical elements. Features extracted and the textual information associated to the mould are then stored in a database for further searching and retrieval.

The searching and retrieval (retrieval part) is done using either the textual information or a sketch. When using textual information, the system compares the properties specified by the user to those stored in the database and returns moulds with similar properties. The retrieval process is very different when the search is performed with sketches (Figure 3). In this case the sketches are processed to extract features that can be compared to those previously extracted from drawings. Afterwards, algorithms to compare user's sketches to drawings in the database are applied. The system returns a set of moulds with similar drawings. From this set of moulds, it is then possible to consult all the associated information: drawings (2D/3D), quotation, real costs, client, etc..

3.2 Research Work on Geometry Retrieval

Content-based retrieval is currently a trend in multimedia information processing. Rather than manually generate text-based descriptions, content-based retrieval matches the query against an automatically generated representation of the content of the element to retrieve. There are multiple types of visual entities that can be retrieved based on their content. Here we analyze some content-based retrieval systems for 2D and 3D.

Gross's Electronic Cocktail Napkin (Gross, 1996) addressed a visual retrieval scheme based on diagrams to index databases of architectural drawings. Users draw sketches, which are compared to stored annotations (diagrams), manually produced by users. This manual annotation makes it difficult to scale to large drawing sets. The S3 system (Berchtold, 1997) supports the retrieving of CAD models of parts, described by their geometry (2D contour) and thematic attributes. S3 relies exclusively on matching contours, ignoring spatial relations and shape information, making this method unsuitable for retrieving complex multi-shape drawings. Park et al (1999) described an approach to retrieve complex 2D drawings based on the dominant shape. Objects are described by recursively decomposing its shape into a dominant shape, auxiliary components and spatial relationships, which are used to create a complex structure of graphs. The small set of base geometric primitives and the not-so-efficient matching algorithm, based on the breadth-first tree matching, make it hard to handle large databases of drawings. Elad et al (2001) presented a technique to search for similar 3D objects in a database, using VRML. Authors addressed the subjective matter of similarity, providing an approach based not only on geometric similarity but also letting the user influence subsequent searches by marking some of the results as "good" or "bad". The algorithm uses statistical moments computed from 3D objects' surfaces as features to define object signatures. Chen et al (2003) proposed a system for retrieving 3D models based on the visual similarity, using 2D projections. Authors encode multiple orthogonal projections of a 3D object using both Zernike moments and Fourier descriptors. Although a scheme to speed up the retrieval process is used, the comparison between the query and each model in the database is not avoided. Bespalov et al (2003) presented a preliminary framework for shape matching through scale-space decomposition of 3D models. The algorithm is based on hierarchical decomposition of metric data using spectral properties. 3D objects are mapped into binary rooted trees, recasting the problem of finding a match between 3D models as a simpler technique of comparing rooted trees. Funkhouser et al (2003) described a method for retrieving 3D shapes using textual keywords and sketches (2D/3D) or a combination of both. Their 3D shape descriptor is based on descriptive spherical harmonics invariant to rotations. Recently Lou et al (2004) developed an approach to search for 3D shapes, incorporating multiple feature vectors, relevance feedback, query by example, browsing and multidimensional indexing structure. As the system extracts four feature vectors it requires a large space to store the descriptors. To improve effectiveness, authors also proposed a multi-step similarity search, combining moment invariants and geometric parameters.

The majority of existing drawing retrieval systems use small databases (less than 100 elements), simple elements not representing real mould drawings and complex matching schemes (graph matching), making difficult the adoption of efficient retrieval algorithms.

4. PROTOTYPE DESCRIPTION

After identifying mould-makers needs, defining requirements (with them), and agreeing in the proposed solution, we developed a prototype that allows searching for information about moulds using 2D sketches and drawings, and textual queries. The system for searching and retrieving moulds using 2D sketches is made of two prototypes, one to perform classification and another for retrieval. The prototype for classification processes automatically all drawings provided by the user, without any human intervention. The user only needs to give the location of drawings and the prototype does simplification, feature extraction and storage of logical information into the database.

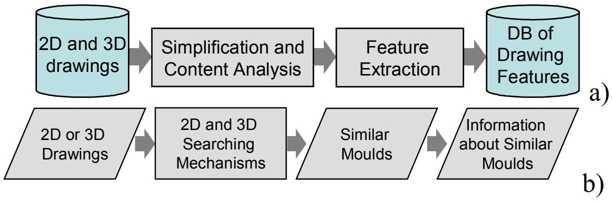

Figure 3- a) Collecting information b) Searching/retrieving

The prototype for retrieval, allows users to search and retrieve moulds, stored in the database by the classification prototype, using 2D sketches or an existent 2D drawing. It has a calligraphic interface divided in four main areas, one where users sketch an approximate drawing of what they want to find, another area with action buttons (right), an area for textual queries (left) and finally (on the bottom) the results area where similar drawings are presented to users (Figure 4).

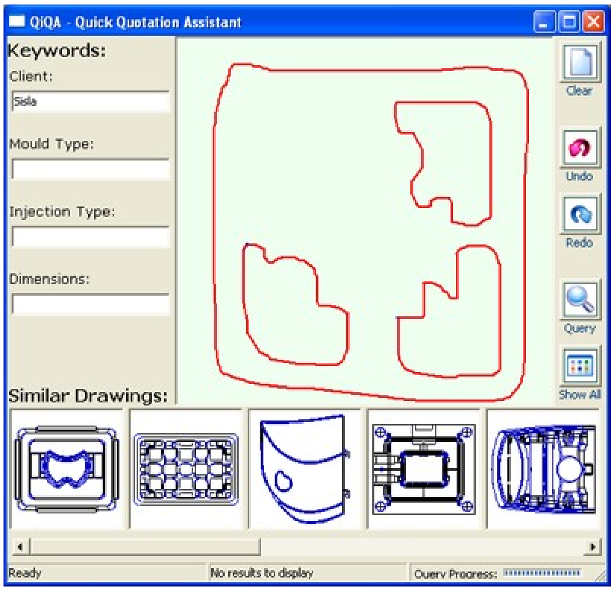

Figure 4- Searching and retrieval of mould information

Results are sorted by similarity, with the most similar on the left. To access all the information about a mould users only have to click on the desired result and the associated information is displayed. To search using an existent 2D drawing (from a CAD application), the user opens the file and then submit it as a query to the system. The rest of the process is similar to the use of sketches as queries. The prototype allows searching for a mould using only textual information, only geometric information (by sketches or CAD files) or a combination of both. Users can specify one or more textual attributes and then sketch a rough approximation of the desired mould. The system then combines the results from both types of information and presents the most similar results. Presently the system is completely operational in 2D. The development of the mechanisms to allow the classification, search and retrieval of 3D drawings has already started, being at present in a preliminary phase.

5. SUMMARY

This paper presents a research planned to develop a new tool to help mould makers in the quotation process. The solution provides an environment where mould budgeters can quickly access past similar moulds and consult them to support the decisions inherent to the cost estimation process. To that end, two retrieval mechanisms were combined based on drawing content and textual information. In this environment, mould-makers starting from the part (or mould) sketch (or CAD model) and from front end attributes can consult the historical data of the company and reuse engineering solutions achieved in the past, reducing the time needed to create a new quotation of a mould. In summary, the quick quotation tool, using cost and engineering solutions from similar projects, reduces the time needed to perform quick cost estimation, maintaining the accuracy and reducing the number of senior workers involved.

6. ACKNOWLEDGMENTS

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