Information interactions in data model driven design for manufacture

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Abstract

This paper presents a novel view of a software environment which has the potential to provide support to design for manufacture in line with the aims of global concurrent engineering. The arguments developed should have significant consequences for future CAE systems development and support the continuing globalisation in business development. The approach taken has at the centre of its philosophy the need to provide designers with high quality information on which to base their decisions. The concept of an information supported design for manufacture environment is not new, but a range of issues related to information interactions have yet to be resolved. This paper explores the use of information models to support functional and manufacturing interactions in design as well as the issues which are raised in attempting to support multiple views in design for manufacture. The design for manufacture of injection moulded products is used as the focus against which the ideas being explored in the paper are discussed

Keywords

information models, global manufacture, product range models, multi-viewpoint, design for manufacture

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1 INTRODUCTION

Concurrent Engineering is recognised as a major driver for business competitiveness where a successful implementation will achieve new product introductions which are 'better faster and cheaper'. As businesses become more and more global in their operation it is particularly important that computer aids for product design and manufacture are structured to provide appropriate support to global organisations.

This paper argues strongly in favour of information supported systems in design and manufacture as illustrated in figure 1. These can offer flexibility, data integrity, support throughout the product life cycle, as well as being of modular construction and independent of specific vendors (Ellis, 1995). This is achieved by separating the information content from the software applications which use and generate the information, hence making any specific application easy to replace as long as the underlying information model is maintained. These applications have been termed data model driven applications.

The development of information supported systems can be viewed as having three key aspects to be addressed. These being the structure of the information, the management of the information and the functionality of the applications programs which use the information. Although these three areas cannot be completely separated, this paper is principally concerned with the first of these, termed information modelling.

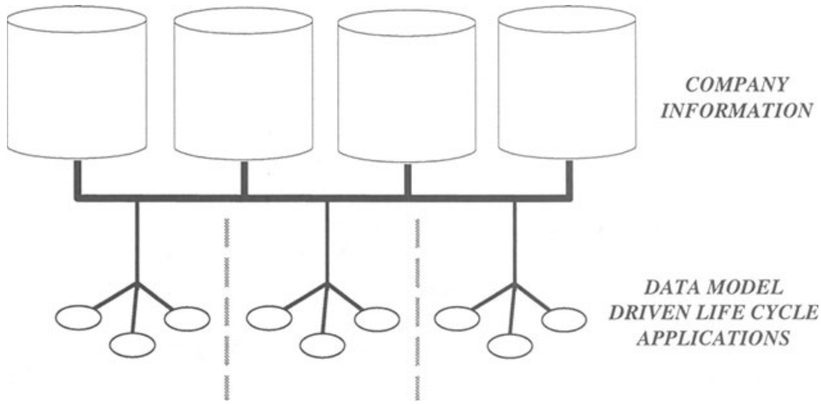

Figure 1 -The general information systems concept.

If information models are to be effective in future CAE systems to support design for manufacture in global manufacturing operations there are a number of key issues to be resolved. These can be listed as:

- How to capture multi-site manufacturing process information?
- How to deal with multiple manufacturing views of products?
- How to provide information structures which can support interactions between functional design and design for manufacture?

2 THE MULTIPLE DATA MODEL CONCEPT

While product models provide the core information in data model driven systems (Krause, 1993, Anderl, 1997), it is proposed that significant benefits can be achieved by utilising manufacturing models and product range models as illustrated in figure 2. There is a need for information concerning the manufacturing processes and resources which are available to make the products. The representation of such information has been termed a manufacturing model and in the case of injection moulded product design would offer information on moulding process capabilities, injection moulding machine capabilities, machining process capabilities as well as the range of manufacturing facilities available which provide these manufacturing processes (Al-Ashaab, 1995). The use of such models offers the potential of producing multiple manufacturing models, each of which can represent a different global manufacturing site.

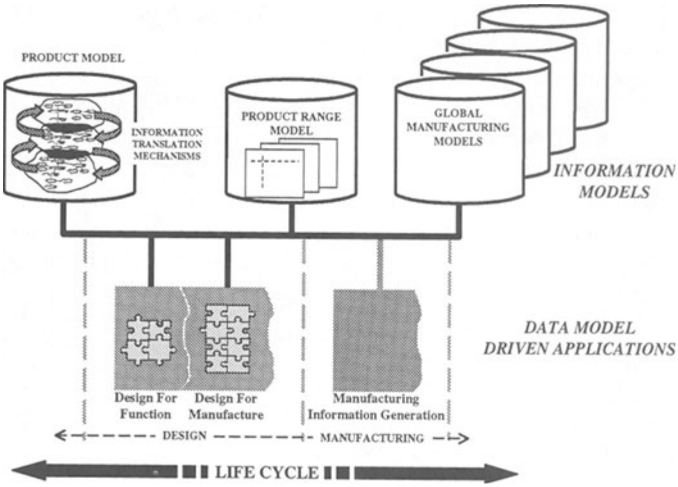

Figure 2 - Information models to support design for manufacture.

Product and manufacturing models provide the key sources of information to support design for manufacture applications. However, a critical issue which has not been resolved satisfactorily is how to link from a functional view of design to a manufacturing view of design (Young, 1996). A wide range of research has been pursued in feature recognition and design by features in attempts to make this link (Allada, 1995). However, design by features over constrains the designer from a functional point of view while feature recognition provides the designer with no manufacturing focus. Work has investigated functional features in injection moulding but has not successfully linked this to manufacture (Wood, 1996). The use of a product range model has the potential to overcome this problem and is applicable in variant design where there are common functional features; particularly pertinent examples can be found in the design for manufacture of high volume customised products. Recent work has investigated architectures for product families (Erens, 1997). A Product Range is considered to be any family of products where the family has a set of functional needs linked to a set of manufacturing systems which have the potential to meet these needs. A key issue has been to understand the scope and structure of such a model if it is to provide flexible support to designers while maintaining an adequate link to design for manufacture

3 MULTI-VIEWPOINT DESIGN FOR MANUFACTURE

Typically, design for manufacture software applications have been pursued from a single manufacturing viewpoint e.g. design for machining or design for assembly. Each view taken requires its own structure of product information which has largely been researched in the area of features technology. However, design for manufacture is typically not related to a single manufacturing process and future software systems must be able to provide multi-process support. This need for multiple views of a product has been one of the critical drawbacks with traditional feature based approaches.

Data model driven systems have the potential to provide multi-process design for manufacture support. Manufacturing information on each specific manufacturing process can be stored in the manufacturing model. There is therefore the need for mechanisms to translate product information into a form which will enable the appropriate manufacturing information to be drawn from the manufacturing model. This can be achieved by utilising product model structures which are supported by appropriate translation mechanisms, as illustrated in figure 3.

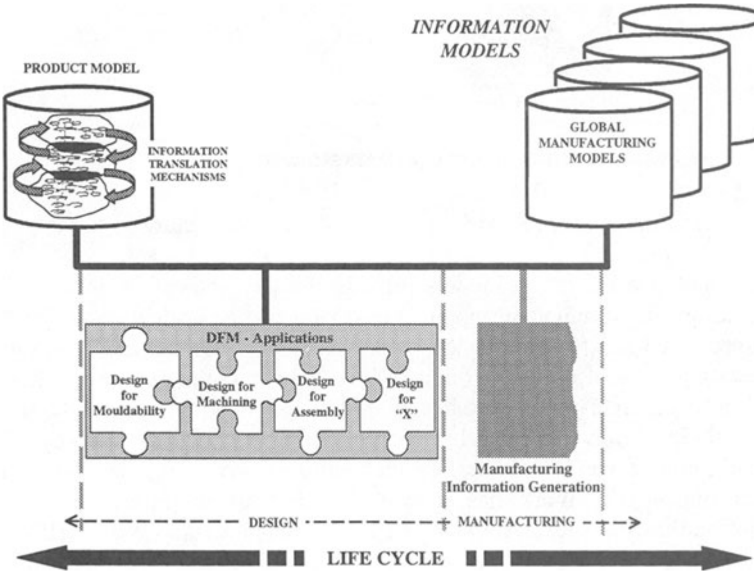

Figure 3 - Supporting multi-viewpoint design for manufacture.

The product model offers the ability to define a data model for each of the significant views of the product. Each of these is related, but different. In order to provide the links between these views it is necessary to define the domain translation mechanisms. These translation mechanisms hold knowledge about the relationships between the each significant pair of views, or domains, and therefore can act as a means of translating the information from within one domain into the appropriate form needed in another domain. Examples of domains related to the injection moulding are mouldability, the design of the mould e.g. the cavity design, and the manufacture of the mould including mchining, grinding, EDM and assembly.

4 FUNCTIONAL AND MANUFACTURING INTERPLAY

Although dealing with multiple views in design for manufacture is not straight forward, the views being considered are all related to specific manufacturing processes, which provides a context within which views can be compared. This is not the case when the interplay between design for function and design for manufacture is considered, as they are typically seen as two distinct phases of design with separate, more general, information requirements and with distinct software application tool sets. It is currently difficult to envisage how these information requirements could be brought together when totally new design concepts are being embodied. For example the information requirements of functions such as power transmission are so different from the manufacturing information requirements of machining.

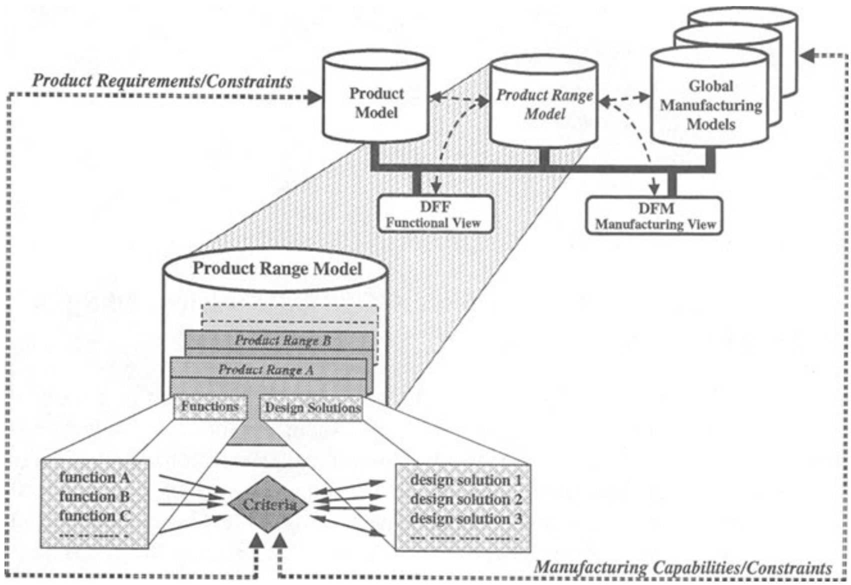

Figure 4 - Supporting functional and manufacturing interplay.

Functional and manufacturing interplay is more readily reconciled in the many cases of design where the new products being developed are variants on existing designs. The design of such products utilises the prior knowledge of earlier designs which can offer alternative known solutions to design problems, including general manufacturing methods. The Product Range Model work presented in this paper is exploring the structure of a data model which can capture these functional and manufacturing links within product ranges as illustrated in figure 4.

Each product range will have a number of functions to be fulfilled and each function is likely to have a number of known solutions which can be used to satisfy it. While any product within variant design should be supportable through this concept, injection mould tooling has been used as a particular product range to explore the detailed data structure work. An object oriented approach has been taken and the class structures defined are illustrated using the Booch Methodology.

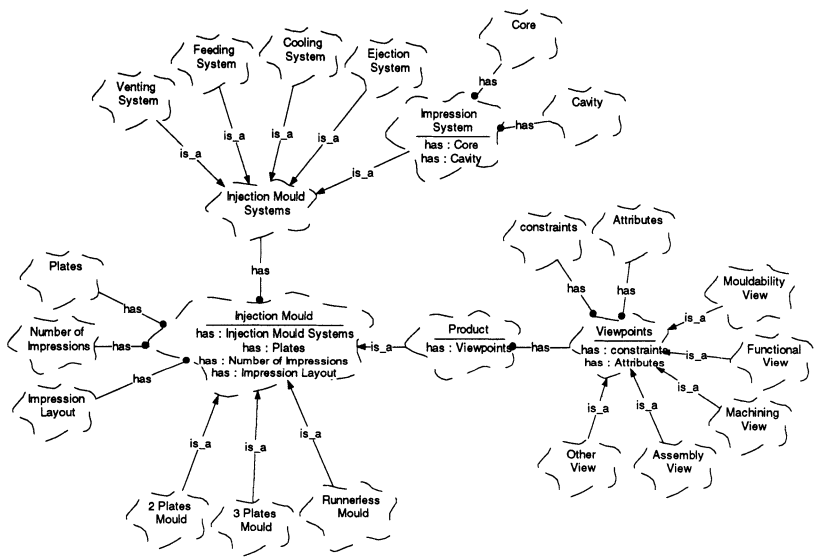

Figure 5 - Product model class structure for injection moulding.

5 DATA INTERACTIONS IN INJECTION MOULDING DESIGN FOR MANUFACTURE

This section uses injection moulding as a focus in order to explore the ideas of data interactions in design for manufacture and to define the information model structures necessary to support design for manufacture interactions in the design of this type of product. The mould itself is used as an instance of a product range while the interactions between the mould cavity design, the plastic product which is being moulded and the machining of the cavity are used as the focus for the detailed design for manufacture interactions.

5.1 The product model

It is assumed that the product model will be used to store all significant product related data and that in this case that this will include data concerning the mouldability of the plastic product, the mould to be used and the manufacture of the mould. The latter is restricted to machining the mould cavity. The mould to be used will be defined in general through interactions with the product range model whilst the more detailed definitions of the manufacturing views will be defined through interactions with design for manufacture applications which require information translations to enable their operation.

Figure 5 illustrates the product model class structure highlighting both the structure defined to support the mould definition and the ability to support multiple viewpoints; in particular mouldability and machining. The more detailed class structures used for mouldability and machining as well as cavity design are illustrated in figure 6. These provide the ability to support multiple design for manufacture views. Each of these could be considered to be typical of a feature data structure, specific to its own needs.

5.2 The product range model

The aim of the product range model is to provide a support to design decision making. Design decisions in injection moulding can be categorised into two main areas. The first of these being the initial selection of the type of mould e.g. two plate, three plate or runnerless, and the number of impressions to use. The second area is in considering the systems to be used in cooling, feeding, venting and ejecting the mould. It is in this second area where a range of alternative solutions can be defined to offer direct support to the functional needs of the design.

The product range model for injection moulding defines the relationships between moulding functions and their manufacturing solutions. The functions and sub-functions in the model allow the designer to search for potential manufacturing solutions. However, the suitability of each specific solution is influenced by decisions already made. These effects are illustrated in figure 7 which highlights interactions between initial design decisions and particular manufacturing solutions as well as interactions between the solutions to particular functions. For example, while the product range model should support all possible solutions, the choice of a particular cavity layout, may restrict the range of valid options subsequently available. Similarly the decision to use ejection pins through the core will limit the ease of cooling in the core.

This research has defined the main structure of a product range model for injection moulding as shown in figure 8. The association of attributes and constraints with each design solution should provide part of the solution to the narrowing of valid options as decisions are made. The relationships between this model, the product model and the manufacturing model is also being explored in order to provide improved support to design decision making.

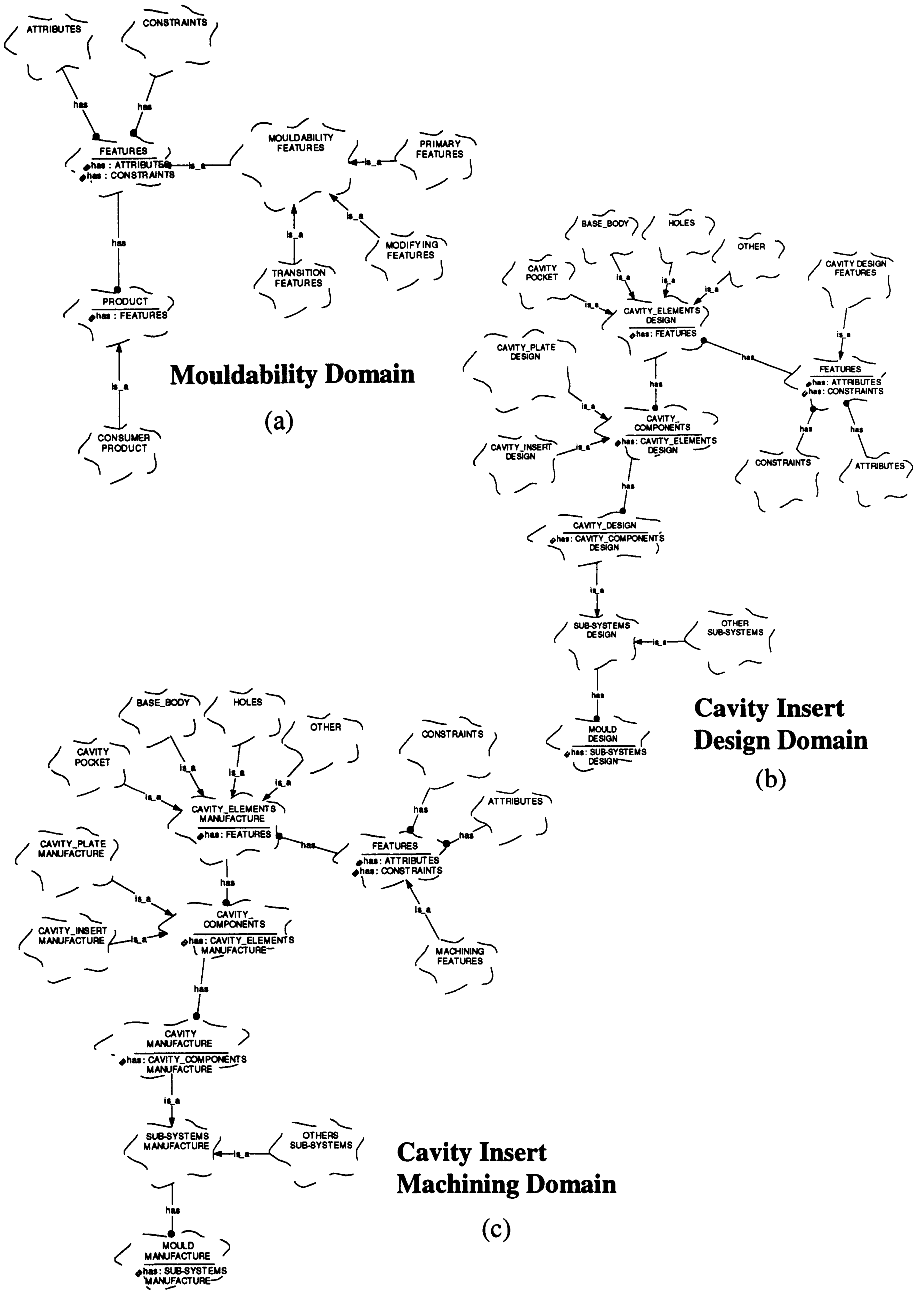

Figure 6 – (a) mouldability, (b) cavity and (c) machining class structure.

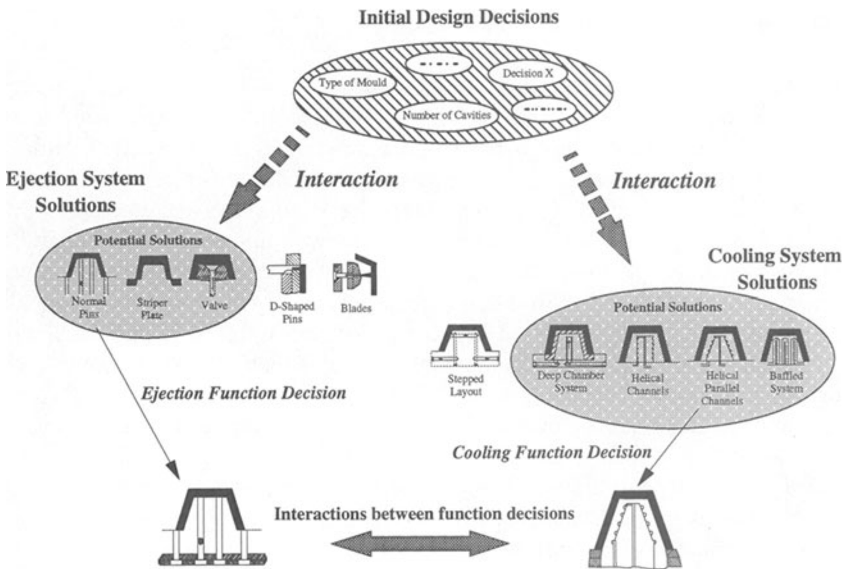

Figure 7 - The Effects of decisions on subsequent solution options.

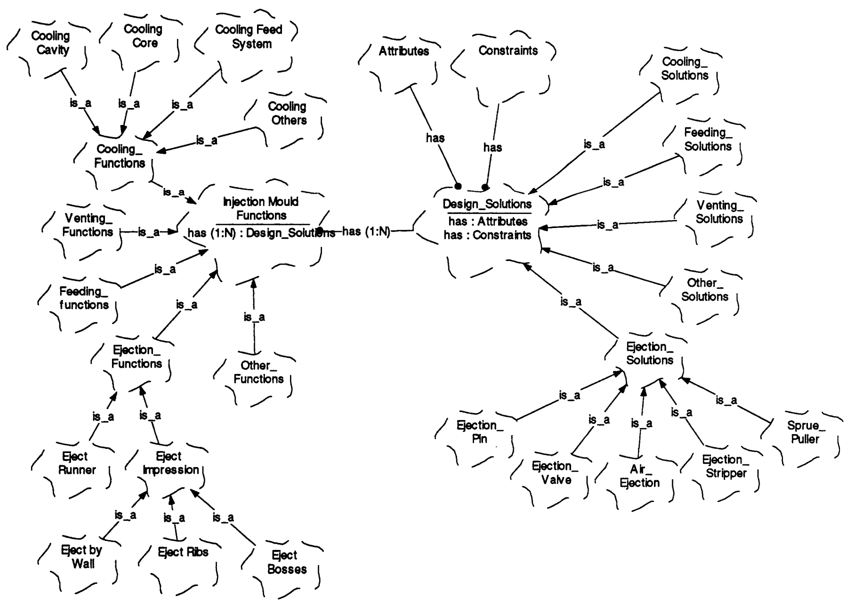

Figure 8 - The structure of an injection mould product range model

5.3 Information translation mechanisms

The product range model can provide general design solutions for each design function. However, for each specific design case, particular solutions need to be defined and the multiple design for manufacture views described in section 3 therefore need to be supported. The product data model structures illustrated in figure 6 have the potential to support the three design for manufacture views considered in this paper. However, before these views can be supported in parallel it is necessary to be able to translate between each of these data structures. This can be achieved through the use of translation mechanisms.

The translation mechanisms used here are illustrated in figure 9. The translation from mouldability to cavity design view takes the mouldability data in the product model, applies an understanding of the meaning of this data in terms of cavity design and produces an output view of the data appropriate to cavity design. Similarly the cavity design data is translated to a machining view by applying knowledge of cavity machining. These translation mechanisms effectively capture knowledge of the interrelationships between pairs of data views. Translation mechanisms can therefore only be effective when they are applied to particular known types of design.

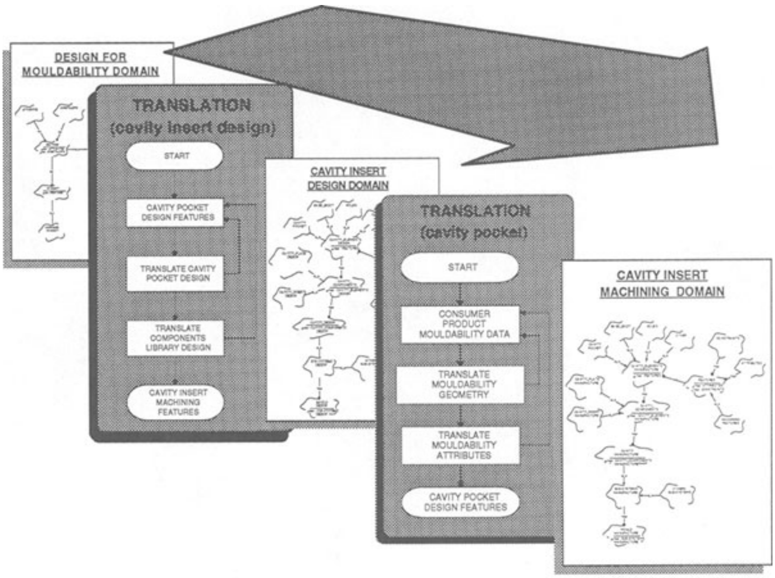

Figure 9 - Example translation procedures between views.

6 DISCUSSION AND CONCLUSIONS

It is important that future product design and manufacture systems take a data model driven approach if they are to provide appropriate information to support the design decisions of designers and manufacturing engineers. This paper has provided a novel view of how such systems can be enhanced to provide more useful support. It has argued that data models in the form of product and manufacturing models have the potential to provide the main product and manufacturing information to support global design decisions.

In particular it has argued that a link from design for function to design for manufacture can be achieved through the use of a product range model. Further it has argued that multiple manufacturing views of a design can be supported through the use of appropriate data model structures in a product model combined with translation mechanisms to enable movement of data from one viewpoint to another.

While this paper has proposed a concept based on 3 information models, it is important that communication of information between these models can be achieved. An essential aspect of this will be to maintain data compatibility between the models. There is also a need to develop a clearer understanding of the relationship between data produced through interaction with a product range model and the data generated through the use of translation mechanisms.

The investigation of translation mechanisms has found that for such mechanisms to be successful they must contain knowledge of the relationships between the 2 domains under consideration. A further issue, yet to be fully resolved, is the relationship between knowledge contained in the translation mechanisms and the knowledge within the supporting data driven applications.

The ideas presented in the paper have been explored and illustrated using injection moulding as a particular and appropriate case. The work is at the stage where the necessary data structures and translation mechanisms have been defined. An experimental object oriented system is now under development to explore the limitations of the approach. While the problems of information interactions are complex, it is believed that their solution can offer major advantages in the commercial exploitation of future information systems.

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9 BIOGRAPHY

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