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A multidisciplinary and collaborative problem solving architecture for high-level computer aided process planning in discrete manufacturing

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2007-02-22T13:09:47Z
http://hdl.handle.net/10539/2092

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E PART REPRESENTATION

Part representation evolved from wire modeling, to surface modeling, to solid modeling, and to feature modeling (Table E.1).

Wire frame models have been used by 90 percent of the companies because it was relatively inexpensive and it could be processed on more commonly cheaper machines (Jain and Kumar, 1998b), but manufacturing features such as threads and grooves were considered difficult to define (Sheu, 1998), and in general was difficult to say whether a point lies within the part or outside (Jain and Kumar, 1998b).

Surface models, such as Bezier, B-spline, NURBS, beta-spline, or Ferguson, were considered the best way to represent free-form surfaces (Kiritsis, 1995), but they were difficult to create (Jain and Kumar, 1998b), too complex to interpret for process planning purposes, and only suitable for parts which would be produced by one process, such as surface milling (Rozenfeld and Kerry, 1999).

Solid models seemed to be best suited for CAPP, but the part model was non-unique in nature (Jain and Kumar, 1998b), only useful for subtractive volumes to be cut out (Rozenfeld and Kerry, 1999), and expensive as powerful computers are required for the huge amount of data for feature recognition (Kiritsis, 1995).

Feature models used sets of information with functional meaning that allowed the association between shape and functionality (Martino et al., 1998). With all this, design features and manufacturing features were not always the same (Tseng, 1999); the features were not possible to be used to design a complete drawing, and in machining, they were represented by surfaces such as holes, or slots produced by known machining processes (Chep and Tricarico, 1999).

Table E.1 Models for part representation

CAD model	Part Representation
Wire models	Points, lines and curves
Surface models	Bounding faces, edges and vertices, with the surface patch represented by an n-degree polynomial parametric function
Solid models	Constructive Solid Geometry (CSG) and Boolean operations, where CSG were simple solids, called primitives, internally represented by B-rep with their bounding faces, edges and vertices.
Features	In design: an individual characteristic e.g. cylindrical surface, screw thread, slot or a profile (ISO TC184/SC4, 1993). In manufacturing: a portion of a part considered as a unit with manufacturing significance (Cay and Chassapis, 1997) and semantic meaning (Abdalla and Knight, 1994), frequently machined (Rho and Lee, 1996), and associated with a distinctive manufacturing process (Han and Requicha, 1998).

There were two main approaches for creating and using feature-based representations, namely design-by-features, and feature recognition.

In design-by-features, which was a top-down approach, the part was designed by directly inserting the features in the model, therefore associating the functional knowledge with the features used, and so, providing the designer with standards, user defined dictionaries (Martino et al., 1998), and an early access to manufacturing and material data (Feng et al., 1999.

In feature recognition, which was defined as a bottom-up search approach process (Cay and Chassapis, 1997), a pattern of entities in the CAD geometric model, their parameters, and interactions (Han and Requicha, 1998) were compared through geometric reasoning with the generic definitions of previously defined features (Kunigahalli et al., 1998). Also, the feature recognition systems made the assumption of a correct representation of the design, and that all the faces on a

component have to be machined (Xu and Hinduja 1997, Faraj 2003). In reality, for example, with the use of near-net shape manufacturing techniques in the production of cast and forged components, the number of faces which requires machining has been kept to a minimum (Xu and Hinduja, 1997).

Consequently, a number of models of CAD/CAPP environment (Figure E.1) and feature classifications (Figures E.2, E.3, E.4, and E.5) have been proposed.

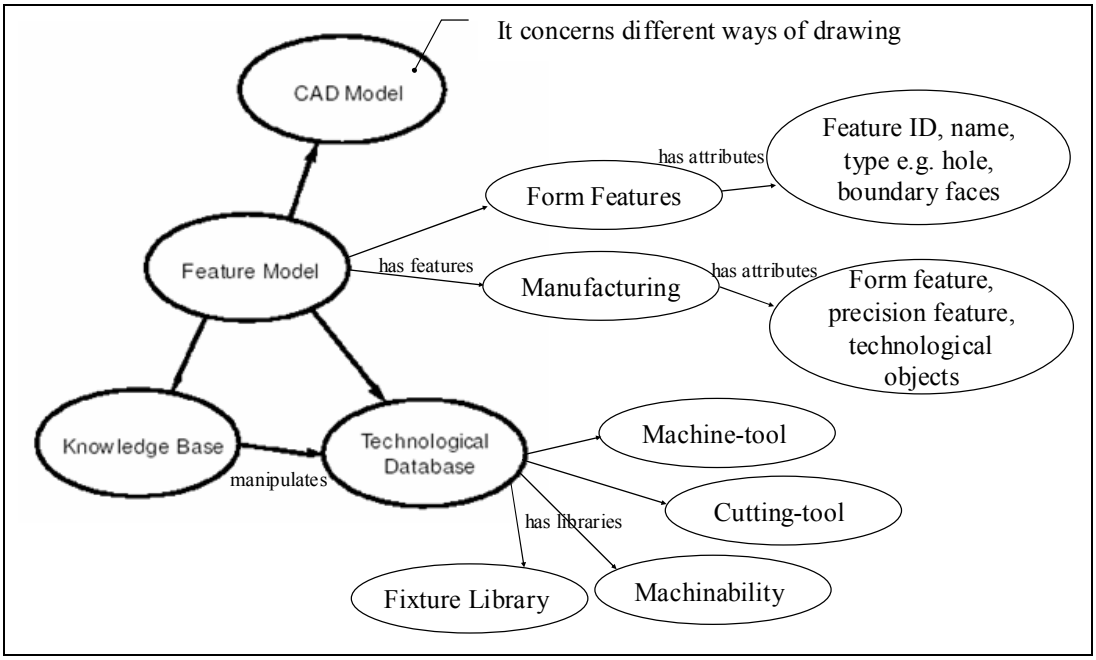


Figure E.1 System model of the CAD/CAPP environment which defines the centres of interest of the problem (Chep and Tricarico, 1999 - reorganised)

Finally, although the feature recognition has been regarded as a complex and infinite domain problem (Yuen et al., 2003), and features alone were not sufficient to describe a part (McMahon et al., 1997), few attempts have been made to integrate the design-by-features and feature recognition approaches (Martino et al., 1998), or incorporate the design-by-features into product modelling (Faraj, 2003),

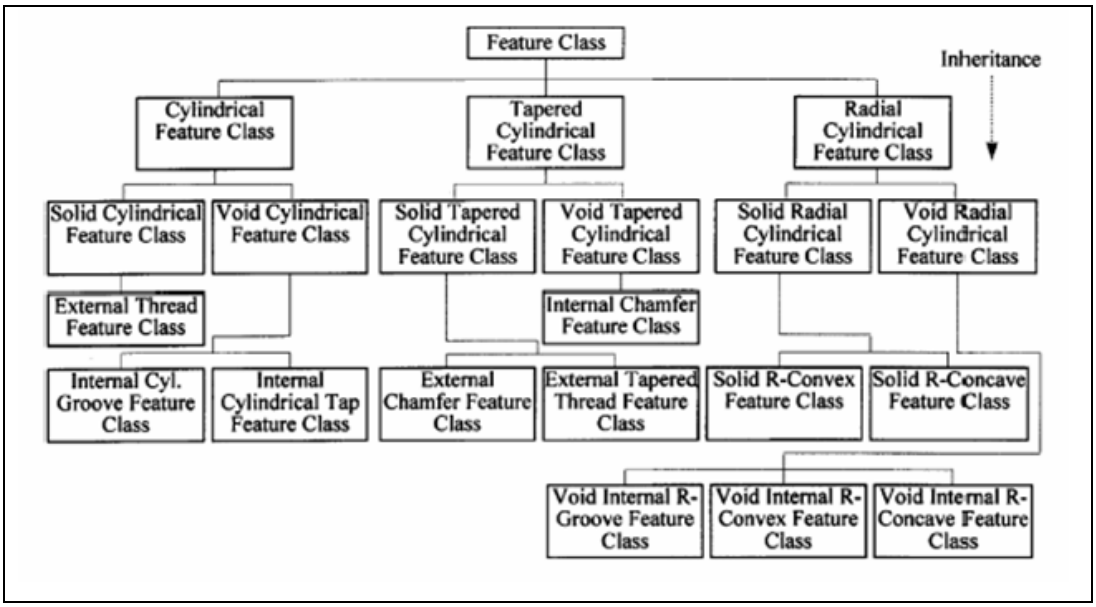


Figure E.2 The hierarchical class diagram of the object-oriented features (Chung and Peng, 2004)

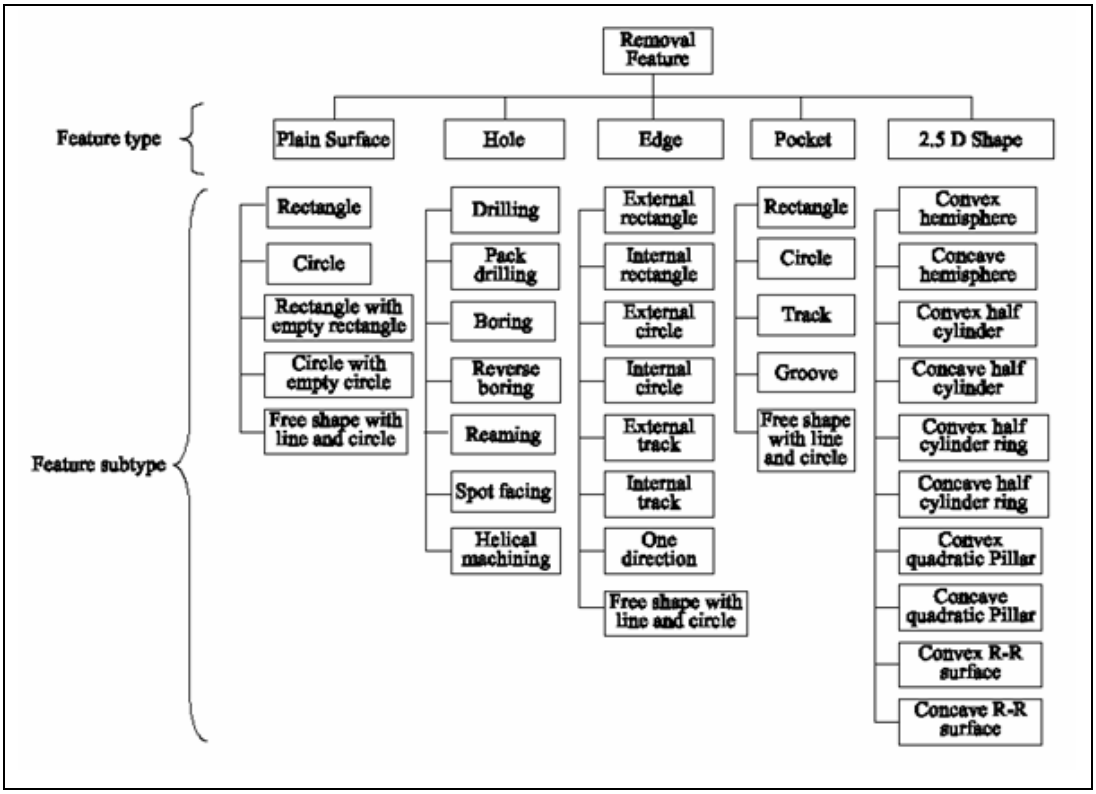


Figure E.3 Types of removal features (Jang et al., 2003)

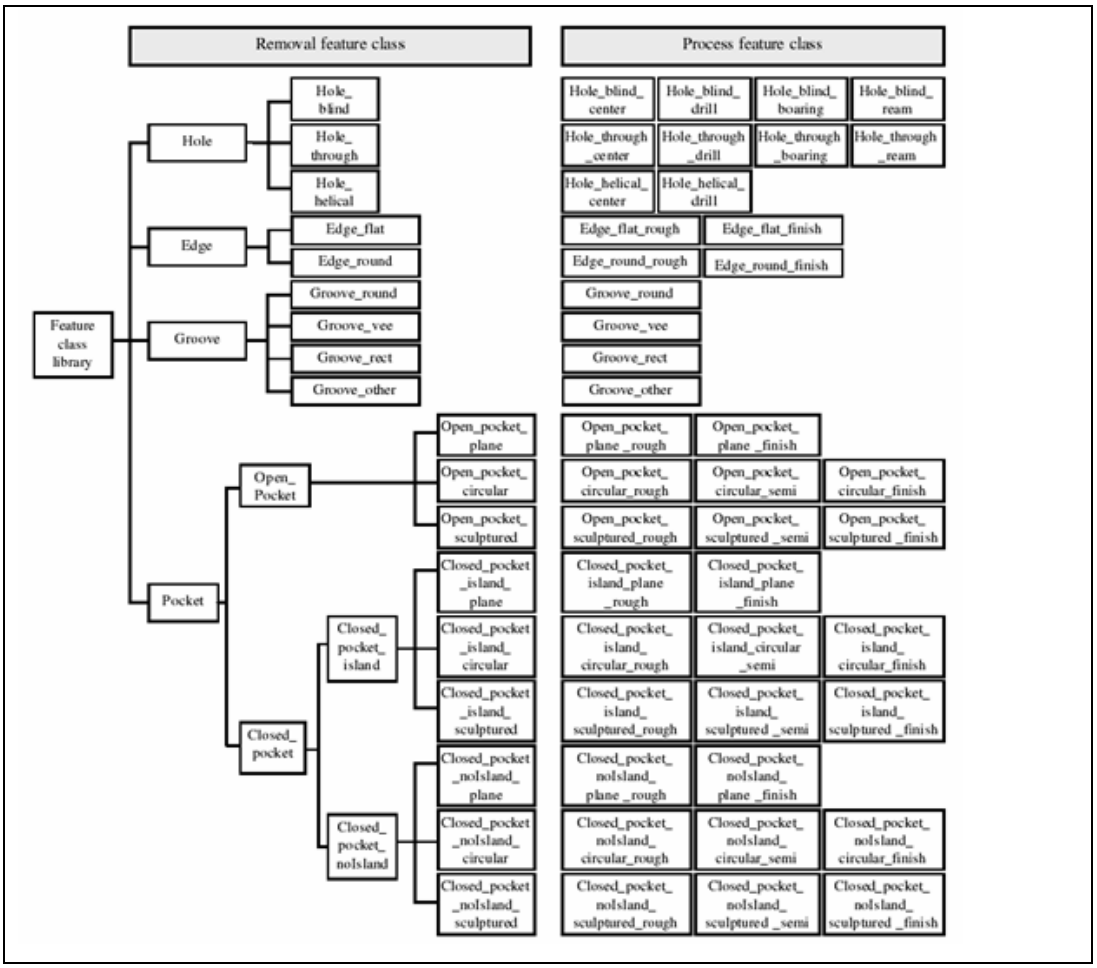


Figure E.4 Removal feature class library (Joo et al., 2001)

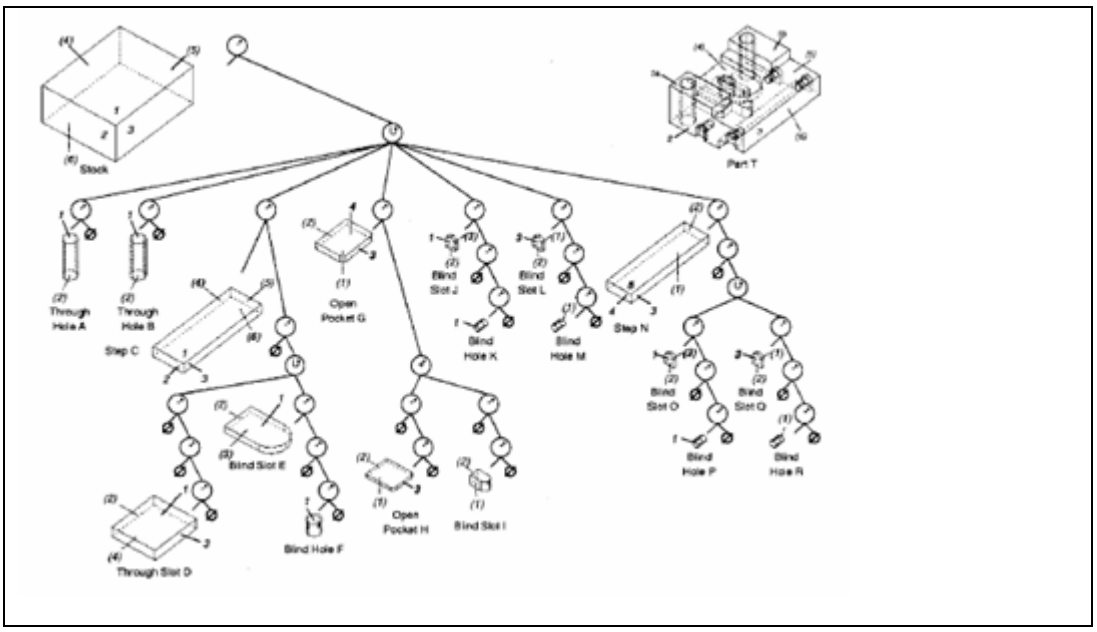


Figure E.5 Atomic feature decomposition of a part (Kim and Rho, 2001)