DSG: A CAM-ORIENTED SOLID MODELING INTERFACE

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ABSTRACT

As the trend away from computerized drafting and toward true computer-aided design continues, three-dimensional solid modeling CAD/CAM systems are being developed. Although these systems can provide complete, unambiguous, concise, and useful definitions of geometric objects, certain approaches seem deficient in two important areas: CAM integration and user interface. Thus, although a considerable amount of time in a production cycle is spent iterating between manufacturing and design so that functionally-correct parts are economically manufactured, many systems ignore facilities for aiding automation of manufacturing process planning. Similarly, some systems neglect human factors by not providing a model and model interface that permit a designer to express himself in terms natural to his design process.

We have attempted to address both of these shortcomings by introducing a new formalism, called DSG, and an interface for describing mechanical parts and assemblies through a sequence of operations resembling those in manufacturing. This orientation of CAD toward CAM avoids the "unbridgeable gap" between isolated CAD and CAM, while at the same time providing designers with powerful tools that very closely model their conceptualizations of design objects. This paper focuses primarily on DSG's interface with design engineers.

DSG — for Deforming Solid Geometry — defines the concept of a tool as a triple <N,F,P> which disjointly partitions Euclidean three-dimensional space into three regions, namely the volumes N and P and their separating surface F*; the void region of a tool is the union of N and F. Tools are applied to an abstract workpiece and "remove" the parts of the workpiece that fall into the void regions of the tools.

Suitable successive applications of valid tools to an initial workpiece permit construction of finite, arbitrarily-shaped raw stock. Further applications of valid tools by a designer "sculpt" such raw stock into final forms during the design process; the mathematical basis of DSG guarantees that no finite sequence of applications performed on finite raw stock can invalidate a workpiece (i.e., can create an unrealizable object). Valid tools can be further constrained to represent various shapes of raw stock (finite parametrized workpieces) and available actual tools.

Other operators make it possible to compose more complex tools out of simpler ones and can be viewed as abstractions of an extremely flexible machine tool which can be programmed to perform complex and lengthy sequences of simple operations and manufacturing processes.

The concepts of tools and workpieces make it possible to deal with one of the commonly-neglected issues in automated design, the handling of tolerances, from a perspective meaningful and natural to both designers and manufacturers. DSG views tolerances not as part definition parameters, but rather as deviations from the desired nominal description, caused by imprecision inherent in manufacturing processes, i.e., application of DSG tools.

Although a final manufacturing process plan need not literally follow the steps in a DSG definition of an object, we believe that an efficient process plan can be obtained more easily from a possible plan implicit in a DSG operation sequence than from the geometry of a part alone. DSG could be implemented from its current specifications as an input facility to various solid modelers such as IBM's GDP and the University of Rochester's PADL, or to any of several boundary representation schemes.

KEYWORDS: CAD/CAM, solid modeling, process planning

*F is a "patchwise smooth surface", i.e. an aggregate of smoothly-deformed planes.