A Concept of A Self-Learning Parametric CAD System

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Abstract

The paper introduces the concept of a self-learning parametric modeler intended for the computer-aided design. Mathematical model of the proposed parametric CAD system and a procedure of generating relations between the model's parameters are given.

Keywords: *CAD; design automation; parametric modeling; self-learning systems.*

1. INTRODUCTION

CAD systems have become common in industry even though they are still in the process of fast growth and development. We have observed many significant breakthroughs in this area including the transition from 2D to 3D modelers, using of parametric modeling etc. The present paper will suggest a further step in CAD development being application of the self-learning principle to parametric modeling.

2. PROBLEM STATEMENT

In many CAD packages, it is easier (or even required) to make a model from scratch rather than to modify an existing design. For example, in such a popular package as AutoCAD, it is next to impossible to change the diameter or the height of a 3D cylinder without erasing it and making a new model. If we consider Autodesk's Mechanical Desktop, or parallel packages such as SolidWorks, we see that although they feature fully parametric solids, and even assemblies, the process of design modification is often still a tricky matter and demands a concentrated effort to generate the required edits that may be desired.

A basic characteristic of the design of tools and manufacturing attachments, which are necessary to make a part or a product, is that their geometry does not evolve as a result of the designer's creativity. Actually, it is strictly defined by the parameters of the manufacturing equipment available. The obvious solution for computer-aided design of such objects seems to be parametric modeling.

3. PARAMETRIC MODELING: SOLUTIONS AND PROBLEMS

It is not a secret that 3D parametric modelers have a high learning curve that sometimes prevent industrial companies from readily accepting their implementation. In 2D parametric packages that are still widely used it is possible to create a design by entering a certain set of geometric parameters which will generate a model that is impossible to manufacture. However, in our opinion the major difficulty is that the designer is supposed to create equations that link the model's geometric parameters.

It is known that almost all parametric modelers feature customized relations between the model's dimensions expressed as mathematical expressions. Roughly speaking, if the designer knows that dimension *a* is always two times greater than dimension *b*, a formula *a=2*b* is entered. If such a relation is set then upon changing one of the parameters the second one is re-calculated automatically and the designer does not have to specify it.

The basic advantage of setting relations is that by modifying one or two dimensions we obtain the final design without labor-consuming specification of all parametric dimensions. Such advantages to the designer are obvious simply in regards to time. Indeed, it would be redundant to detail all the improvements for productivity and efficiency that are embedded within such a system.

4. SELF-LEARNING IN CAD

To solve the postulated problem we will introduce the concept of a “Self-Learning Parametric Modeler” (SLPM) [3] in which the generation of dimensional relations is performed by the system itself, not by the designer. A block diagram of SLPM is given in Figure 1.

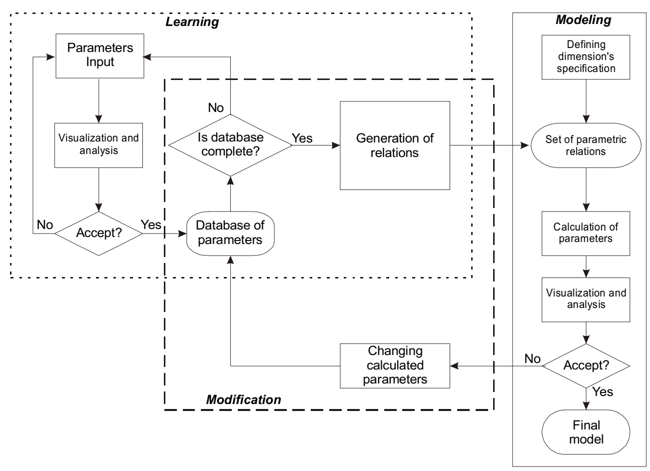

Figure 1. Block diagram of a self-learning parametric modeler.

The principal difference in this approach is the presence of two additional components: the database that stores sets of parameters, and the relations' generation and correction block. The system works in the following manner: At the learning stage the designer creates several design solutions. For each solution the set of its dimensional parameters is stored within the database. Within the database, the designer additionally specifies what we would term a “defining dimension”.

After the database is filled, a current version of the relations functional *R* is generated with the transformations described below. The functional is a set of functions r_i of the kind where DS is the

$$r_i = f(DS, S_i), \quad (1)$$

where DS is the defining dimension; defining dimension; S_i is the ith dimension.

Then, as the new design solution is developed after the defining dimension is specified by the designer, all the other dimensions S_i are calculated with the generated relations. Of course the designer may discard the proposed variant and change the parameters manually. Should this happen, the new design is stored in the database as well and the relations that have been regenerated. It is the essence of the system's permanent self-learning.

5. GENERATION OF ANALYTICAL RELATIONS BETWEEN PARAMETERS

The problem of obtaining parameters of an analytical relation from experimental data has been studied well [2, pp. 81-88] and there are many possible ways to solve it. In any event, we need an initial hypothesis concerning the relation under consideration, that is, whether it is linear, non-linear, or periodical. To consider this, we have studied relations between dimensions of manufacturing attachments available in the databases of several industrial companies situated in Tula, Russia.

The analysis included over 50 parts which included measuring gauges (calibers), and parts of a rotor transfer line (jaws, captures, receivers). Each part exists as a set of 20 to 60 versions with different dimensions. The data processing has been performed with *Statistica*. The relations obtained in this way are shown in Figs. 2 and 3 (all dimensions are given in millimeters).

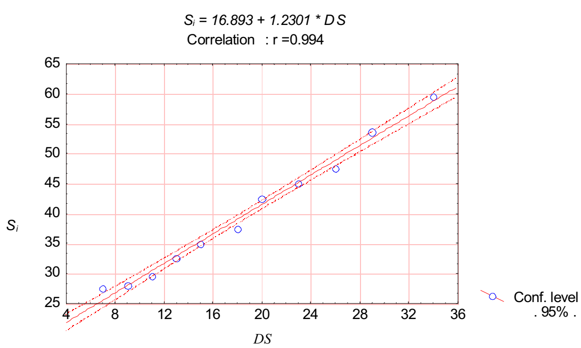

Figure 2. Correlation between the jaw's length and the diameter of the billet being captured.

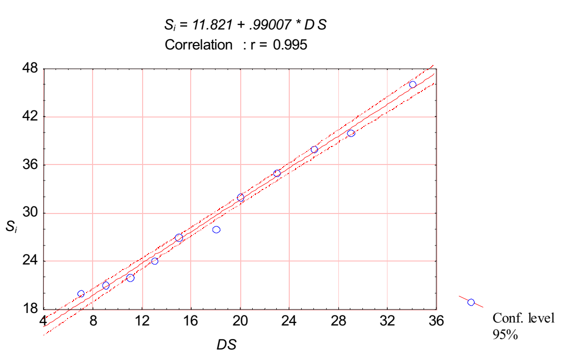

Figure 3. Correlation between the length of the jaw's straight segment and the diameter of the billet being captured.

Correlation analysis of the dimensional relations has revealed that they are linear of the *kx+b* kind, and deviations from linearity do not exceed 2%. So the conclusion is that we are dealing with a generation of linear relations of the *y=kx+b* kind.

6. GENERATION AND CORRECTION OF RELATION'S PARAMETERS

This procedure is rather simple due to the linear nature of relations. If we have *n* design solutions with the defining dimension x_i, and we want to find the *b* and *k* parameters of the relation between the defining dimension and a certain geometric parameter x_i, it can be done with the following system of equations:

$$\begin{cases} b \cdot n + k \cdot \sum_{i=1}^{n} x_i = \sum_{i=1}^{n} y_i \\ b \cdot \sum_{i=1}^{n} x_i + k \cdot \sum_{i=1}^{n} x_i^2 = \sum_{i=1}^{n} x_i \cdot y_i \end{cases} \quad (2)$$

The system (2) is solved every time a new design solution is completed to correct the values of *k* and *b*.

The results of calculating dimensions from such relations are, generally speaking, infinite non-periodical fractions that are unsuitable as real values of the part's dimensions. Several possible ways of implementing such a feature might include location of the closest standard value, or the manual choice between the two closest values from the series, etc. The proposed self-learning concept is equally fit for both 2D and 3D modeling.

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