A SYSTEM FOR THE SUPPORT TO THE REMOTE FEATURE-BASED DESIGN OF PRISMATIC PARTS THROUGH THE INTERNET

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Abstract. *Globalization has been causing a significant increase in the competition among companies, but it also allows the cooperation among companies, even if they are geographically distant from one another. A research area resulting from that virtual approximation is the remote manufacture of parts, which has the participation of the following actors: (i) a remote customer who inputs the orders; (ii) a modeling company responsible for the development and provision of software modules for the design of the parts and for the operations planning to be executed on the ordered parts; and (iii) a company where the manufacture will actually take place. It should be mentioned that these actors can be located anywhere in the world. In the present work a methodology will be described for the remote modeling of prismatic parts using the Internet, and the developed system is adherent to the ISO 10303 standard (STEP) part 224. The development of a graphic interface will be described, which is made available to the remote customers, without the need to install in their computers any commercial CAD software. The modeling of the parts is accomplished through a features library, which includes the following features in the present version: hole, step, slot and rectangular pocket. The obtained results show that the feature-based and STEP-based methodology is adequate for the implementation of the software, enabling an extension of the system regarding the modeling of other features, and its remote use through the Internet.*

Keywords*: Features; CAD; Manufacturability; Internet; Remote Customer*

1. INTRODUCTION

With the introduction of CNC machines in manufacturing about 50 years ago, there was the need of a computational representation of information about product design and manufacturing. The introduction of advanced production technologies such as flexible manufacturing systems (FMS), robots, automated storage systems, and part transportation systems increased the need for a complete and precise product information (Newman et al., 2008). At the same time, social and economical changes in the international markets have been changing significantly the way in which the manufacturing technologies have been used. Instead of factories organized predominantly according to a job shop layout, and disregarding the market, manufacturing systems have become more oriented to the product, seeking to reduce lead time, and to achieve greater efficiency and flexibility with the use of the manufacturing capacity. The term agile manufacturing comprises all those characteristics (Shah and Mäntylä, 1995).

Another characteristic of current manufacturing companies is that they have been working on a quite competitive environment, in which products with equal or better quality, with good prices have been launched by the competitors. At the same time, this competition caused by the globalization has been leading companies to seek for cooperation with other companies in order to remain competitive (Ferreira and Andriolli, 2005). The Internet is another factor that has been accelerating the globalization, and through the Internet the customers can buy or sell products without the need to leave their houses or workplaces, since the Internet enables the virtual approach between people or companies located geographically distant amongst them. Also, it can be used as a technology to allow the remote manufacture of parts. The advantage of this type of manufacture is that the customer does not need to have the pieces of equipment and accessories for producing the product. Another advantage is that both the customer and the manufacturing company can contact each other directly, and therefore the company can answer quickly the customers' requests.

In this context, it is important the development of research that seeks to provide the current manufacturing systems with characteristics such as interoperability, adaptability, agility, and reconfigurability, and that the companies are enabled to work in a globalized environment, using the Internet as a communication means.

This paper presents a framework for the development of a system for the design of prismatic parts, which uses the ISO 10303 standard (called "STEP"), part 224, and the system can be executed through the Internet. The parts are modeled through the instantiation of features, which are available through a library. In this system the data are stored in a structure of classes implemented in the Java language.

2. LITERATURE SURVEY

2.1. Evolution of the sharing of product information

Before the occurrence of the industrial revolution, the engineering task was associated with the physical model of a product to be manufactured. In order to manufacture a certain component, it was necessary to ensure that their dimensions corresponded to the model of the part through the use of calipers or gages. The manufacturing companies produced a specific type of product, and not generic components of many types. Then, the invention of the engineering drawings lead to more precise descriptions of the products. Many years later, with the development of the Computer-Aided Design (CAD) tools, the drawings created with these tools had a significant increase in productivity compared to the paper drawings, mainly due to their easy revision and storage.

The CAD tools opened new opportunities, such as the possibility of generating manufacturing instructions automatically, which can be executed directly from the drawing. However, since the CAD and CAM (Computer-Aided Manufacturing) tools became more complex in order to meet the several needs of engineering, the formats and each tool used to capture and store data were significantly different (NIST, 1999). This was and still is a problem for the companies, which need to share the product data among its different sectors, or among other companies that compose the supply chain.

According to Zeid (1991), two methods were used to solve this problem: (a) direct translation (fig. 1a), which implicates in the development of a pair of translators to exchange the data among each pair of systems, which implicates that each application needs a pair of translators, one to output to a certain format, and another to read from the same format, which is typically non-standard; (b) translation through a single file with a neutral format: such format is independent of the salesperson, and its structure is also independent of any existing system (fig. 1b).

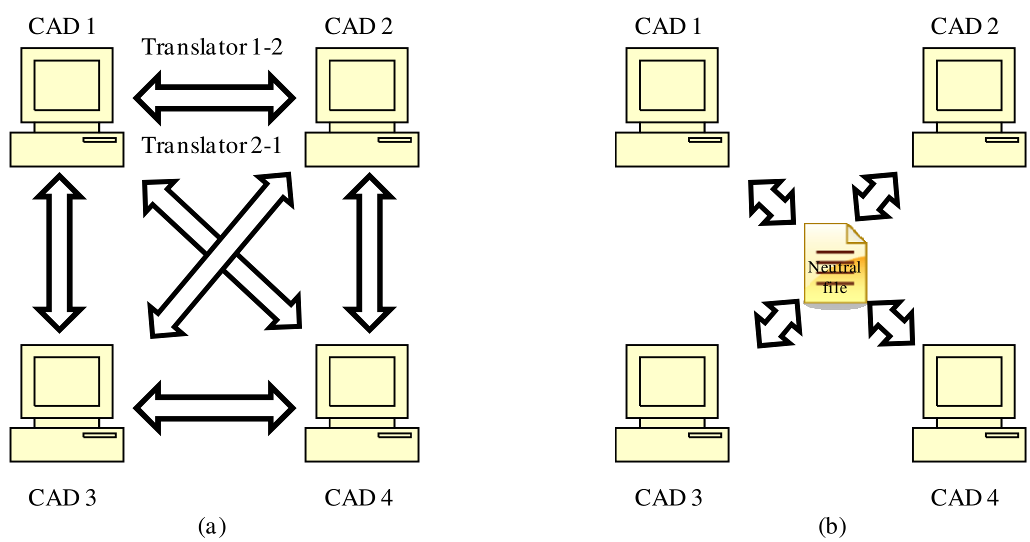

Figure 1. Information exchange (a) without neutral interface, and (b) with neutral interface (NIST, 1999).

It is noticed that, when the number of CAD systems involved increases (for instance, in companies that compose a supply chain), the number of necessary translators can be so high that this solution becomes very expensive.

Kern (1997) points out the following advantages of the use of a single neutral file: the use of only two translators for each involved system; the independence of the suppliers; the development cost tends to be smaller than the cost with direct translators, due to the relatively low amount of necessary programs when the number of CAD systems grows.

Different neutral formats were developed for the exchange of data among the different systems CAD, and some of those formats are: IGES (Initial Graphics Exchange Specification, 1988), SET (*Standart d'exchange et de Transfer*), VDS FS (*Verband der Deutchen Automobilindustrie Flächenchnittstelle*), and STEP (STandard for Exchange of Product data model).

The latter (STEP), corresponding to the ISO 10303 standard, supports not only the exchange of geometric data in files of CAD systems, but also the exchange of data regarding all the aspects in the product life cycle.

2.2. Design by Features

Features technology has been a research theme since the 1970's, and ever since there is a large amount of different uses and approaches of features presented in the literature. Several authors give different definitions for features, sucg as for instance Shah and Mäntylä (1994), who define features as entities that have higher semantic meaning than the pure geometric elements typically used in solid modeling (e.g. boxes and cylinders).

Sunil and Pande (2009) define a feature as a region of functional interest in a part. It is a group of connected faces having certain specific combination of topology and geometry, and that suggests some significant activity in the domain of design and manufacture.

In the ISO 10303-224 standard (2000), the entity *manufacturing_feature* is defined as: an entity that contains the necessary information to identify forms that represent material volumes that will be removed from a part through machining operations. Some examples of features are holes, steps, grooves, and rectangular pockets.

According to Shah and Mäntylä (1995), there are two approaches in feature-based design:

(a) Destruction by Machining Features, which begins with a model of the raw material that will be machined. The model of the part is created by subtracting from the raw material the features that correspond to the material removed by machining operations. In this approach, the user should remove geometric entities from a solid through machining of the raw material, in such a way that the manufacturing process of the part is incorporated inherently to the design. The advantage of this method is that the machining features are directly available in the part model, not being necessary the recognition of features;

(b) Synthesis of Design Features, in which the model can be built both by the addition and the subtraction of features, not being necessary to start with a model of raw material.

In the feature-based design approaches, the parts are created directly through the use of features and the geometric model is generated from the features model (fig. 2). This requires that the CAD system has generic definitions of features made available by the features library, allowing the instantiation of features through the specification of dimensions, locating parameters, the feature/face/edge on which the feature is located, and other attributes, constraints and relationships.

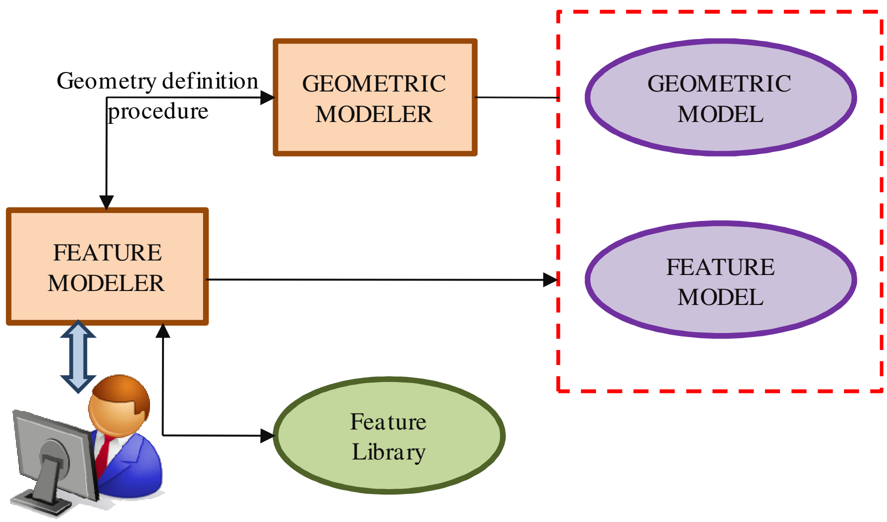

Figure 2. Creating parts through the design by features approach (Shah and Mäntylä, 1995).

3. FRAMEWORK OF THE PROPOSED SYSTEM FOR DESIGNING PRISMATIC PARTS

The proposed system is designed to be adherent to the ISO 10303 international standard, part 224 (Mechanical product definition for process plans using machining features), where support is given to the creation of parts through the instantiation of features, to allow the exchange of data among the different modules. In fig. 3 the CAD system is modeled in an IDEF0 diagram, where the input data are labeled with "I" (input), and the data that leaves the system are modeled with "O" (output), and the boxes represent the sub-activities. The sub-activities of this system are:

- To model the part through the use of the features library (fig. 2),
- To check whether the part is consistent from the point of view of manufacture;
- From the validated model, the neutral file should be generated according to the ISO 10303-224 standard;
- The visual representation of the part should be presented in the computer display.

With regard to the validation of the model, it concerns the application of procedures to aid the designer in creating a part that can be manufactured, and some validation rules that can be implemented are as follows:

- A feature that is not located within the limits of the face is not considered as being valid.
- The depth of a feature must not be greater than the maximum depth of the workpiece.
- It is not allowed the creation of features on faces that cannot be used for fixturing.

For the implementation of the structure of classes the Java language (http://java.sun.com/) was used, since it is an object-oriented language and software in this language can be executed at a distance through the Internet in several operating systems.

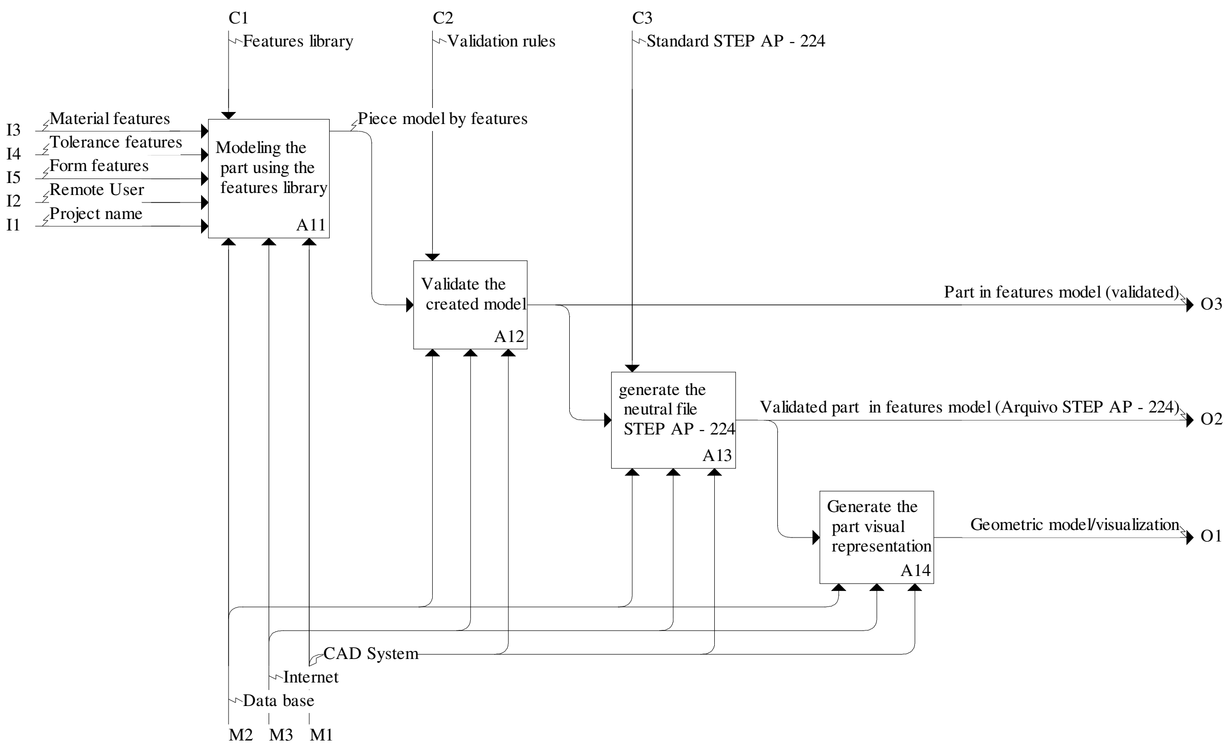

Figure 3. IDEF0 diagram of the CAD by features activity.

According to the ISO 10303 standard, part 224 (2000), the initial class, which should contain all the design data, is the class called Part. The data of a part can be divided into: administrative data; data of the part model; documentation of the control of the manufacturing process; measurement limits; properties of the part; requirements of materials, cutting tools, machines and fixturing elements. Fig. 4 presents the different data of a part, and all these data are modeled through the use of the modeling language defined in the ISO 10303 standard, part 11, called EXPRESS.

The EXPRESS language is object-oriented, and it was developed to provide a formal specification of the representation and exchange of product data. It also supplies the syntax and the semantics to represent the information in a uniform necessary and compact manner, describing the application model in an unequivocal way. The EXPRESS language can also be represented in a graphic way, through EXPRESS-G.

Therefore, since in the present work the Java programming language is used, the EXPRESS schemas and their corresponding entities should be mapped into equivalent classes. For such effect, the "SCHEMA feature_based_process_planning", defined in part 224 of the ISO 10303 standard should be modeled in UML (Unified Modeling Language), which is a useful tool in the design of object-oriented software systems. Fig. 5 presents a diagram of the entity Part in EXPRESS-G, where the entities are represented by rectangles, and in the case of rectangles with round edges, it contains the name of the entity only, and later in another diagram all its attributes are detailed. The attributes are represented by thin lines, and their names are above the line with small letters. Fig. 6 illustrates the equivalent diagram of the entity Part in UML.

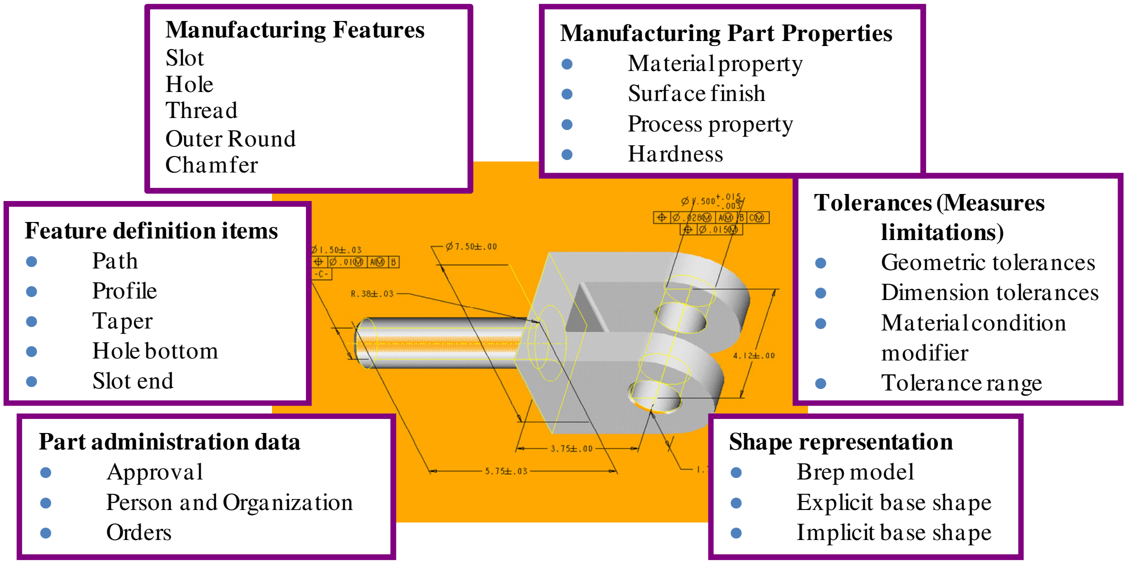

Figure 4. Different data that class Part should contain.

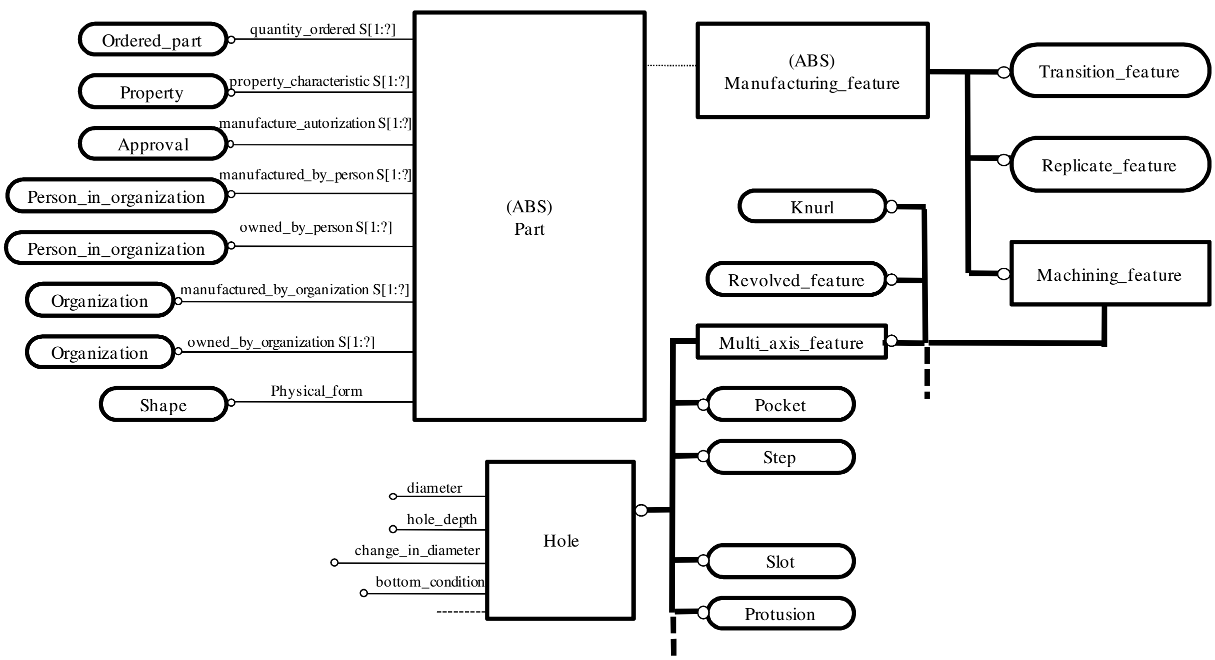

Figure 5. EXPRESS-G diagram of the entity Part and of some important entities that compose the library of features

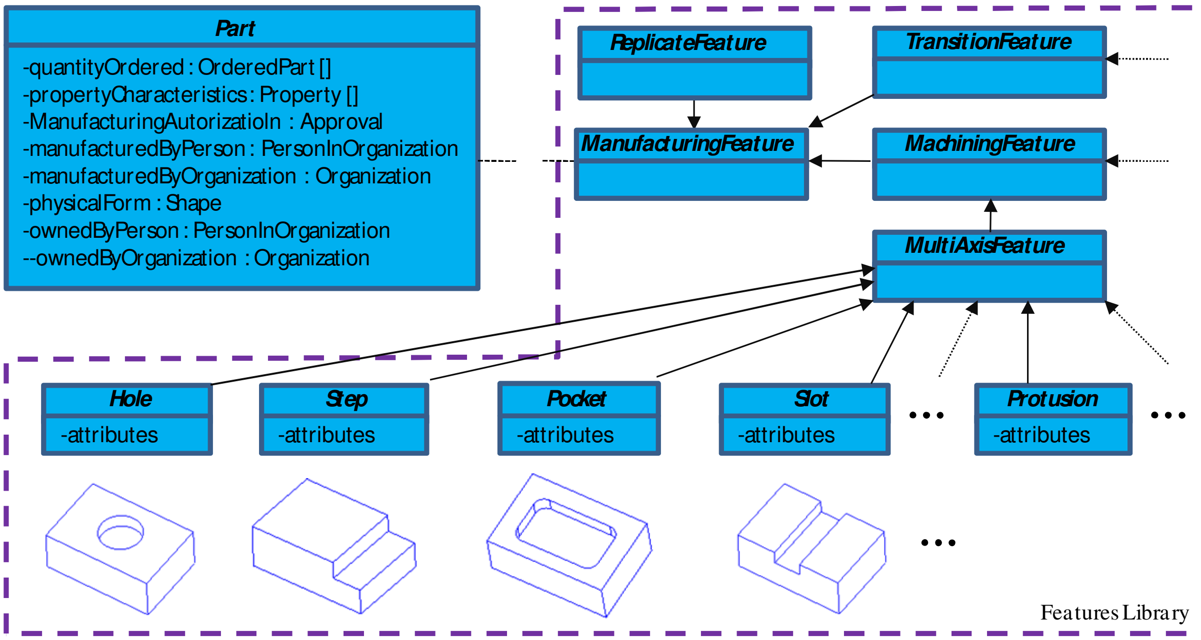

Figure 6. UML diagram of the class Part and of the features library.

3.1. Features library

The features library contains different manufacture features, in agreement with the ISO 10303-224 standard (2000), which become separated in the following types:

- transition features, which encompasses entities such as chamfer and fillet, among others,
- replicate features, where the creation of feature patterns is considered, and they can be copied in different angles and directions.
- machining features, with elements such as composed feature, revolution feature, thread, and feature of multiple axes. The multiple axes features comprise features such as holes, grooves, pockets, and steps, among others.

3.2. Graphical modeling

Among the approaches for constructing solids, the following two are among the most popular:

- Boundary Representation (B-rep), in which the solids are represented through topological elements (vertices, edges and faces) and geometric elements (surfaces, curves and points) (Congli and Tsuzuki, 2004);
- Constructive Solid Geometry (CSG), where the solid is formed through a tree in which each node represents a union operation (U), intersection (∩), or difference (-), and also primitive solids, as well as translation and rotation operations (Buchele and Crawford, 2004).

In the present work a hybrid approach is used, where the primitive solids (cylinders, boxes, spheres and cones) are represented by B-rep, while the creation of a part with its features is carried out through a CSG tree structure. The system is being developed, and the remote user can run the system in the following link: http://www.grima.ufsc.br/stepnc_project/. Fig. 7 shows a part modeled in this CAD system.

The graphic modeling of this system is made through the use of the Java 3D (Sun Microsystems, 2009) API (Application Programming Interface), which gives support to the creation of primitive solids (cylinders, boxes, spheres and cones), and from them other solids can be created through Boolean operations.

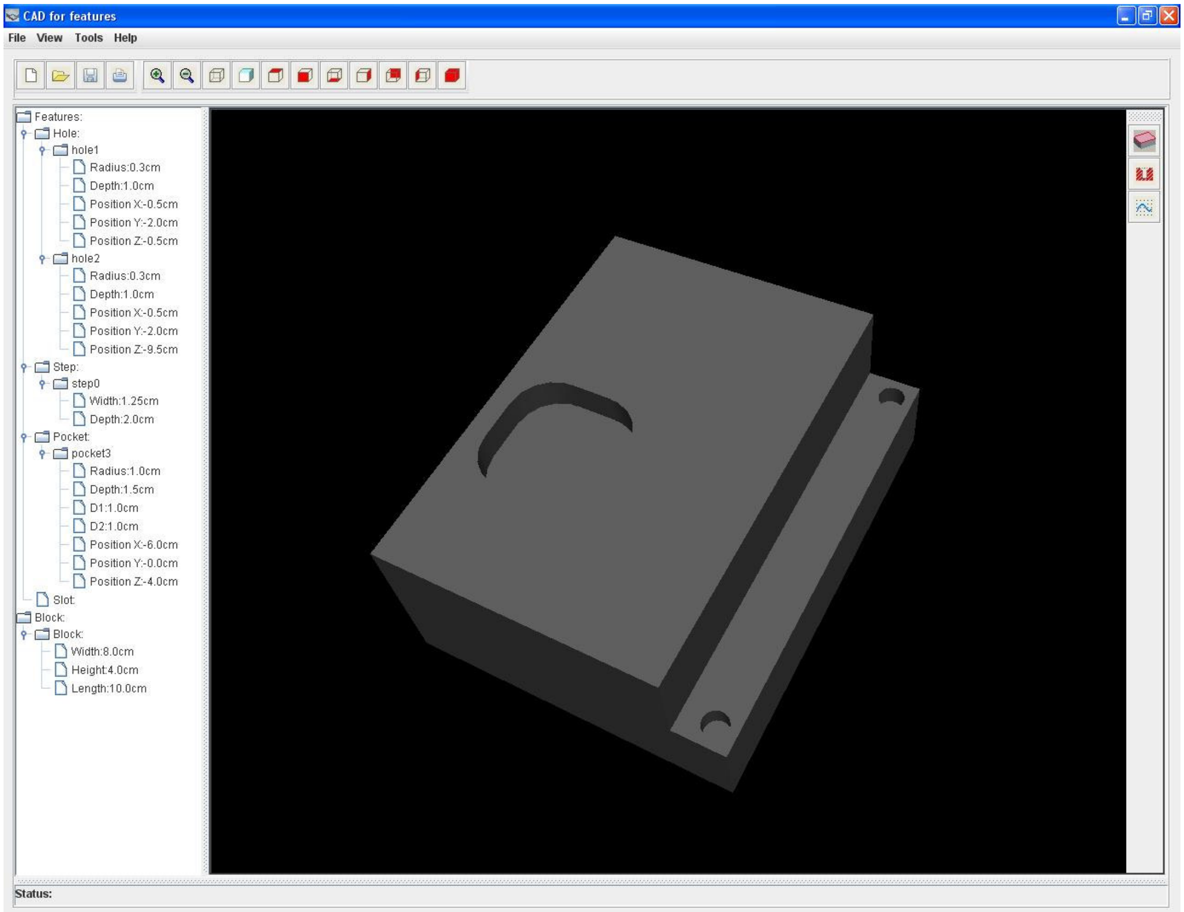

Figure 7. Graphical interface of the system for designing prismatic parts.

After the modeling of the part the CAD system, the user can generate the physical neutral file for the exchange of data, which corresponds to the part 21 in the STEP standard (ISO 10303-21, 1994). If it is the remote user's desire, this physical file can be exported to other CAD systems, as well as to CAM systems, which should be enabled to import files in this format. Fig. 8 presents portions of this file which contain the data regarding the hole1 feature shown in fig. 7.

```
ISO-10303-21;
HEADER;
FILE_NAME('Test_file');                               /*file name*/
FILE_SCHEMA (('FEATURE_BASED_PROCESS_PLANNING')); /*schema ISO 10303-224*/
ENDSEC;

DATA;
#11=HOLE_BOTTOM('','flat',#47,.F.);                 /*bottom condition: flat,
                                                       blind*/
...
#20=(                                                 /*diameter of hole1*/
LENGTH_MEASURE_WITH_UNIT()
MEASURE_REPRESENTATION_ITEM()
MEASURE_WITH_UNIT(LENGTH_MEASURE(0.3),#41)
REPRESENTATION_ITEM('diameter')
);
#21=(                                                 /*depth of hole1*/
LENGTH_MEASURE_WITH_UNIT()
MEASURE_REPRESENTATION_ITEM()
MEASURE_WITH_UNIT(LENGTH_MEASURE(1.),#41)
REPRESENTATION_ITEM('depth')
);
...
#26=CARTESIAN_POINT('',(-0.5,-2.,-0.5));            /*center of hole1*/
...
#54=APPLICATION_PROTOCOL_DEFINITION('international standard',
'feature_based_process_planning');
ENDSEC;
END-ISO-10303-21;
```

Figure 8. Physical file (part 21 of ISO 10303) related to the feature hole1 in the part modeled in fig. Figure 7.

4. CONCLUSIONS

Through the CAD system developed in this work, feature-based prismatic parts can be designed remotely through the Internet, and features are elements that facilitate the integration between the design activities and other activities, such as process planning and part manufacturing.

Also, this system uses the ISO 10303 standard, application protocol 224, which contains the necessary data to accomplish the tasks of computer-aided process planning and computer-aided manufacturing, and its availability through the Internet will result in its dissemination among the remote users.

As a future work, the authors intend to add other prismatic features to the library, such as protrusions and generic pockets. Besides, it is intended to provide the input in a friendly way dimensional and geometric tolerances, and roughness as well, which will confer the system CAD a high capacity for modeling parts found in the industry.

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7. RESPONSIBILITY NOTICE

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