Support of the CAD/CAM-Process Chain by Manufacturing Features

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Abstract

CAx-process chains can be operated more efficiently, if the information flow consists of semantically higher structured information [ANDERL-99]. A system-spreading feature technology combined with the methods of the product data technology based on a STEP offers the possibility to interpret process-spreading knowledge application-oriented and to improve thus the performance of the process chains.

Keywords

Feature-based Design, Feature-based Part Model, Manufacturing Features, Product Data Technology, Integration CAD/CAPP/CAM.

1 Introduction

Products and processes becoming more and more complex demand nowadays higher standards on the developers. The success factor time is more and more important in the development (time to market) as well in production (time to customer), therefore in the field of data processing the provision and analysis of information is still a most current topic, because it leads in the everyday life frequently to serious problems.

The meaning of information economy (information and communication) even for the development area, show executed investigations in research and development departments. Therefore up to 90% attained results are already available in other places, easily accessible and by a systematic search the own work would be needless [BULLINGER-90].

This basic problem is not limited to large-scale enterprises and companies, but also applicable to small and medium enterprises. Finally - independently of the business size - the fortune of humans for the information accommodation, processing and storage, is limited. The information economy, which is to support the human being at this point, moves thereby constantly in an area of conflict between threatening information flooding on the one hand and the requirement of a suitable compression of information on the other hand.

Against this background in the passed years a multiplicity of CAx tools was developed and used, in order to cover this need for information by a computer support in the different phases of the product life cycle. Usually these systems are specialized to support a certain application and are constructed frequently on their own, non-standardized information model, which represents again a special application view on the product. Therefore, application systems represent only isolated solutions and permit no joint use of product data, which are described in the information models [ANDERL-98].

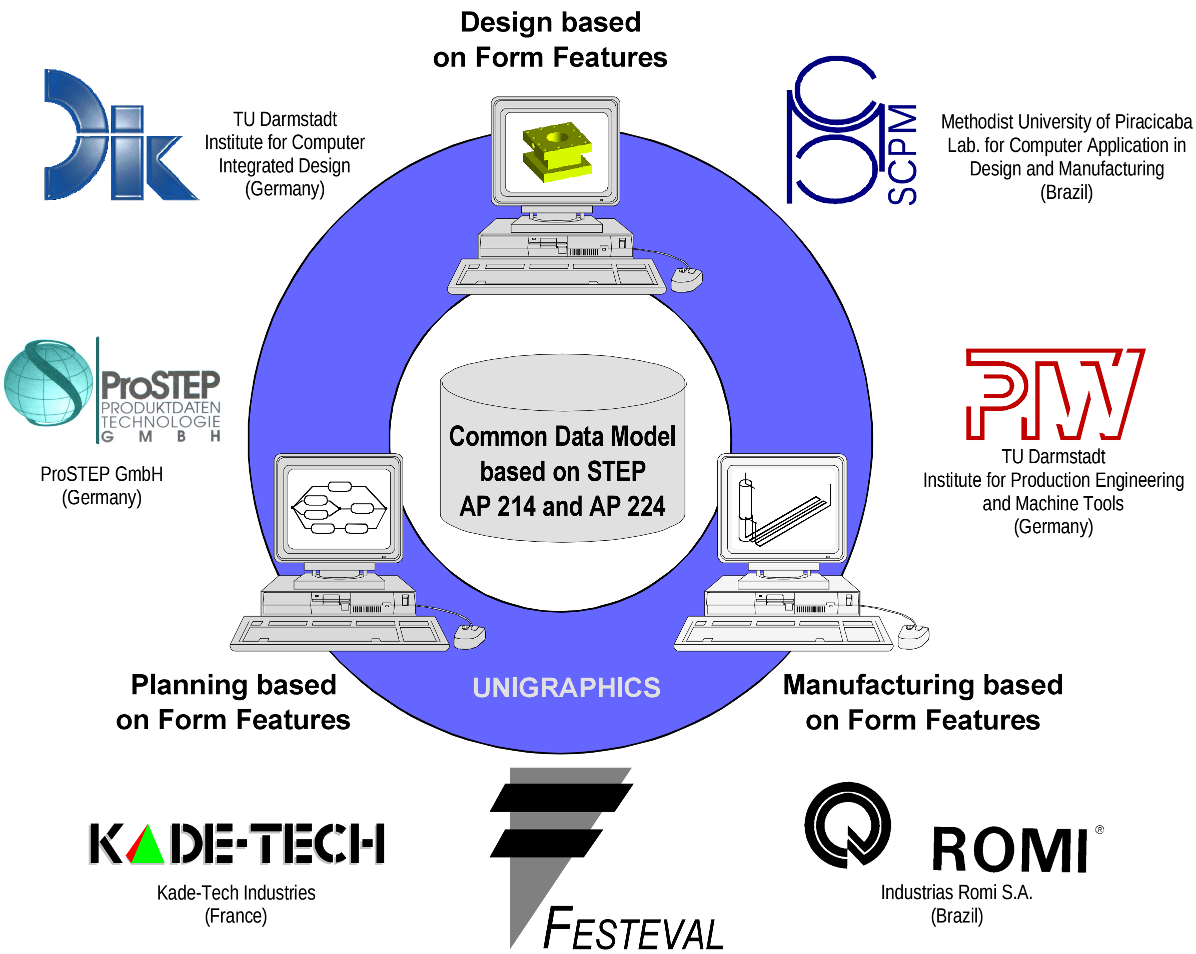

Figure 1: Festeval project partners

Thus for example engineers use CAD systems to create technical drawings for components and CAM systems support NC-programmers, machine users or manufacturing engineers during the creation of NC programs on the basis of these drawings. The making of drawings and the programming of NC programs on basis of these drawings was and is still a time-consuming affair, where frequently already available information is processed manually a second time and which is thereby frequently subject for errors. Therefore, in the last years the term “integration” and in particular the associated omission of the technical drawing as buffer between CAD and CAM plays an important role.

The Darmstadt University of Technology deals in connection with the Universidade Metodista de Piracicaba in the context of the Project INCO-DC #96-2161 - *FESTEVAL* with the implementation of an integrated CAD/CAM development environment based on an object-oriented approach with form features (Figure 1).

2 Request of an Integrated CAD/CAM Process Chain

What means CAD/CAM integration at all? Is it good? Do we need it? This depends primarily on the request to an integration. In order to understand the meaning of the term CAD/CAM integration, it is important to understand the functions, which must be integrated. The term CAD (Computer Aided Design) is common and describes each type of software, which enables a definition of a mechanical component by means of geometry, surfaces or bodies. CAM (Computer Aided Manufacturing) is basically a software for the development of NC programs.

Engineers used CAD/CAM systems for three different purposes:

- **Design Modelling:** A designer uses CAD systems for the modelling of components. The definition of a component can be called model, whereby the model can be represented in form of a technical drawing or a CAD file.
- **Manufacturing Modelling:** A manufacturing engineer or a NC programmer uses CAD software for a multiplicity of important tasks. Probably the furthest common function is the development of a computer model of a component, which was defined only by a drawing before. An other function is the check and repair of existing CAD data, to make this data useful for manufacturing. Manufacturing engineers derive sometimes also new component models from the original design, in order to permit the manufacturing by this way. This step covers for example an inserting of draft angle or the development of models for different manufacturing steps. Not to be forgotten the modelling of the clamping devices and tools which is an important part of the manufacturing.
- **NC Programming:** A manufacturing engineer or a NC programmer uses CAM software to select the tools, machines, cutting strategies, cutting parameters, etc. for the manufacturing of the models.

In a perfect world three different programs would be selected, everyone optimally adapted to one of these three areas and the software would co-operate perfectly. Unfortunately this not a perfect world! In order to co-operate with these different products, a large amount of integration is needed. For this demand three different types of the integration are available:

- **Data integration** is the ability to exchange component models on the basis of common files or a common data base.
- **Interface integration** is a common “look-and-feel” of the different software modules.
- **Program integration** means that different software modules co-operate for a user. This can be achieved by the fact that different functions are integrated physically in one computer program.

Who actually needs integration? Everyone needs integration! A shop floor manufactures the designs of other people, which were modelled with the CAD systems of other people. A shop floor needs no CAD system and has therefore also few use from an interface or a program integration with the CAD systems of the customers. Data integration with the customized CAD systems plays an important role because a workshop must deal with a large variety of data from different sources. The ability to import data from different sources has therefore a great importance.

For a small and medium size enterprise, with one person responsible for the conceptional modelling, the design, as well as the NC programming on an individual computer, the data integration plays apart from the program and interface integration a likewise important role.

A large production plant employs several persons for the conceptional modelling, design and the NC programming, whereby frequently these functions are separated in different departments. These enterprises vary between shop floor similar departments, which are forced to support a multiplicity of CAD formats and departments, which use the same CAD system as the design department, in order to ensure a maximum of integration.

In order to connect now the functions of the design modelling, manufacturing modelling and NC programming efficiently and fulfil the requests of an integrated CAD/CAM process chain *FESTEVAL* uses for the structuring of the geometry oriented data the advantages of the feature technology in connection with a modern 3D CAD System.

3 Feature Technology

Primary CAD systems are geometric oriented, but they also support increasingly function and technology oriented aspects or request of the other systems within the process chain. Newer CAD systems use the feature technology in this context. Features were introduced in the early 80's into the engineer surrounding field as items, which supply a language for the description of sections of a product. Features associate functional and semantic aspects with geometry and enable each application to have an dedicated view on the product by this way.

The beginning for research within the area of the feature technology originates from the desire to automate the NC path generation as far as possible. In addition an available component should be divided into items, which can be always directly processed. For these items the information could be stored, how they are to be processed, in particular with the defined cutting strategy, tools, machine tools, NC control, cutting parameters, etc.. In the meantime additional possibilities were detected to use the feature technology. Thus apart from geometry also information was assigned to the features e.g. to their function aspects.

Corresponding to the different usage the term “Feature” was described again and again in the course of research history. A feature is sometimes defined simply as “a region of interest in part model” [WILSON-88], sometimes it is defined as “a region which could be machined with one machine operation” [GRAYER-76]. Today a common description is:

“Feature = Form-Feature & Semantics” [KRAUSE-94].

What means this definition? And why is it so complicated? A form feature is a grouping of geometrical items, which are logically matching. They describe the geometrical shape of a feature. The shape of the feature can frequently be described by parameters and does not have to be explicitly indicated. A simple example for this is the “Hole”, which can be described by the parameters “Diameter”, “Depth” and “Tip Angle”. To complete the feature a reference plane and the exact positioning of the hole are necessary.

Semantics is frequently more difficult to describe, but this is special reason for the feature technology. Semantics stands for “Meaning”. Under this term fall the following points (see Figure 2):

- **Data attributes**, e.g. the above mentioned parameters for the description of geometry or a specification of tolerances.
- **Rules or methods**, which determine the behaviour of a feature. That means that, a feature can check with the help of its methods the fact if it fulfils the functions placed against it, also after a modification of its geometry. Further rules are available which define, how the feature geometry is to be processed.
- **Relations** for the regulation of connections between features. Hereby it is in particular defined, which aspects of a feature changes, if the view on the feature changes. The appropriate glossary word in this context is the word “feature mapping”, which is later to be explained.

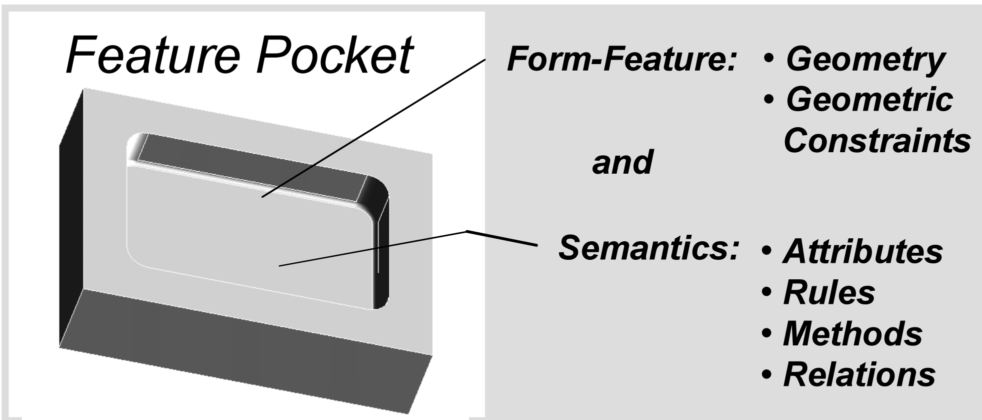

Figure 2: Feature definition

According to the application and to the different functions of the product development there are different semantics, which can be connected with geometry. Thus the designer essentially regards the function of a form feature at the component, while the manufacturing engineer is interested in how, with which tools and with which process he can manufacture the geometry. Accordingly there are thus design features, manufacturing features, quality features, etc..

Most feature types are well known in the engineer language. A possible classification is for example the following:

- **Volume Primitives:** Block, Cylinder, Cone, etc.
- **Design Features:** Hub-Shaft Union, Ball Bearing Sit, etc.
- **Manufacturing Features:** Pocket, Slot, Hole, etc.
- **Transition Features:** Chamfer, Round, etc.
- **Pattern Features:** Bore Rectangular Pattern, etc.

These are the standard features in the technology. In addition to the above mentioned definition there are also features, which do not have a geometrical representation. These are the function oriented types of features, for example the angle of rotation of a joint. A great help for the understanding is the comparison of the feature approach with the object-oriented approach in modern programming languages.

For the usage of the feature technology the way to get a feature-based description of the component is very important. At the beginning this technology was first used to describe a pure geometric model. For this model it was insignificant, in which way it had been defined. On this geometry frequently an interactive feature recognition was then executed. The recognition of the features takes place here through the user, who selects interactively at the screen surfaces of the component, defines them as matching and thus creates a feature. The advantage of this method is that it is independent of the geometric definition. A disadvantage is however that the correct description of the component depends on the correct interpretation of the user. Also his errors are serious, if the data are to be used for the generation of NC paths.

Another method for the production of this model is the automation of the recognition process, the so called feature recognition. Here the model is searched for areas, which correspond with feature types. These items are extracted from the data structure. The parameters of the feature becomes determined, e.g. the hole diameter. A disadvantage of these two procedures is that information, which were determined by the designer and which are beyond the pure geometric data are always lost [SCHÜTZER-95].

During the last years feature-based design systems were established. Designing with features solves the mentioned problem. In particular with Destructive Solid Geometry (DSG) systems the link to the process chain is easy to get. On the basis of a blank geometry, elements are taken off again and again, until only the desired surfaces remain. So you have a description of a blank and cutting objects, thus negatively minted. This is optimal from point of view of the NC path generation. Unfortunately such a description of a component does not support the view of the designer, who must essentially think about the functions, and only in second line about the manufacturing.

Therefore special design features were created, which support the view of the developer better, but one solved problem, creates however other problems. The design features must be transferred in manufacturing features, that means they must be mapped. The standard example is the rib, which a designer designates, in order to strengthen a structure of the part. If this rib is to be manufactured by cutting, then not the rib, but a pocket is milled left and right of the rib (see Figure 3). The semantics as well as the parameters of the feature will be changed by the mapping process: the thickness of the rib becomes the distance between two pockets.

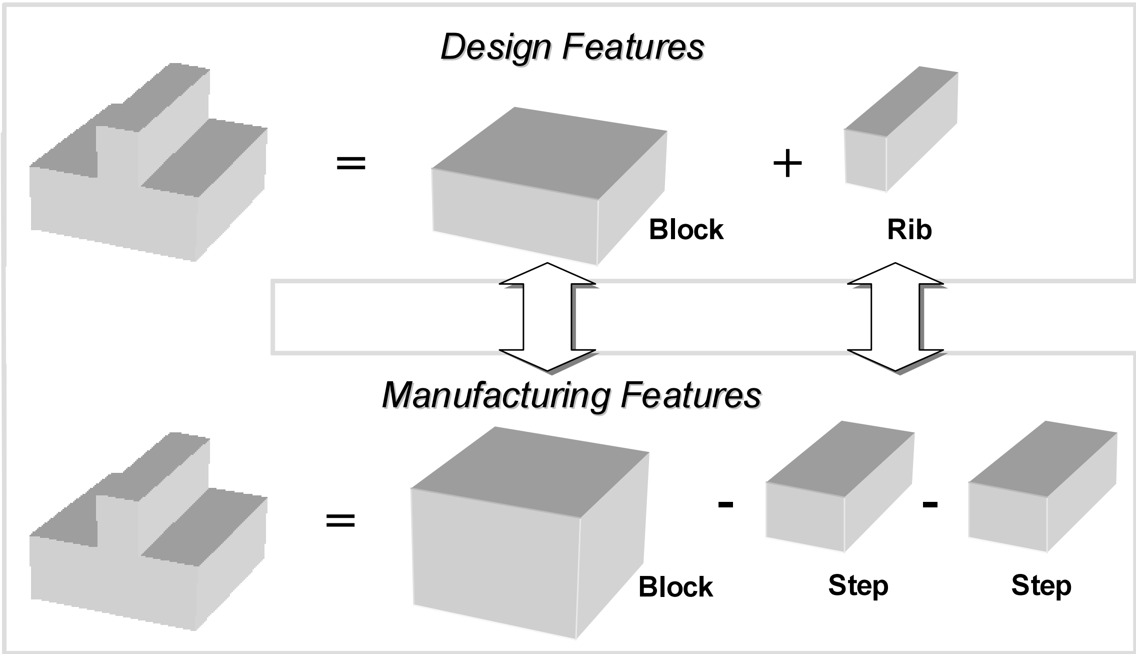

Figure 3: Design features versus manufacturing features

The European Project INCO-DC #96-2161 - *FESTEVAL* has its own feature definition (see Figure 4), which supports all the developments are being implement and part of them are presented in this paper.

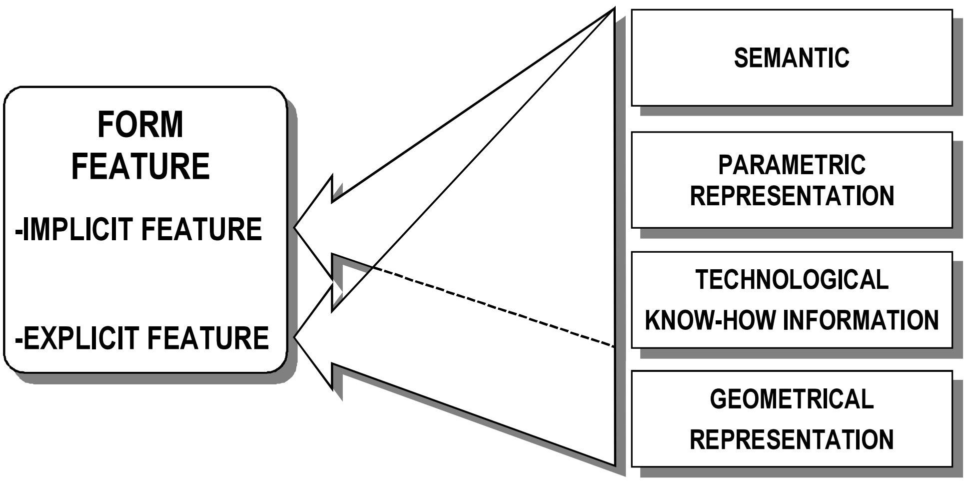

Figure 4: Feature definition applied in the FESTEVAL Project
[SCHÜTZER-95, SCHÜTZER-98]

FESTEVAL solves the problem of the semantics changed by the fact that *FESTEVAL* operates with manufacturing features. Thus there are no mapping problems, but this way is not yet completely free: modern feature-based CAD systems do not offer the possibility of operating with manufacturing features and to determine the interdependencies among them. The knowledge about these interdependences and the persistence of the manufacturing feature's semantic is in particular important for the further processing of the features and for the automatic NC path generation [SCHÜTZER-95]. For example, if a closed rectangular pocket will be milled, then it must be guaranteed that the feature possesses all characteristics of the type of that feature. A necessary investigation is, whether the pocket is placed completely in the part, or not. If for example two opposite sides of a pocket are not placed in the part, then it is not a valid pocket, but a slot, which must be manufactured in a completely different way than the pocket. This investigation is made in *FESTEVAL*.

The position of a feature can also influence the tool selection and afterwards the tool path. If all these investigations are executed, the necessary data are available in order to be able to continue the work after the design with other feature-based computer aided applications.

The feature technology can show here its full strength. The features do not only operate as geometric items, which can be processed together, they are like a type of container, in which all types of information can be stored. It is conceivable that a feature type admits to include their production costs. Skilled workers can store their experiences for the handling in certain features. These experiences will then be analysed and according to them decisions will be taken for a continuously improvement of the methods and the handling. During the quality assurance only elements of the feature geometry will be measured, which have to fulfil a certain function. These elements (surfaces, axis, edges, etc.) can be defined with the help of the feature technology. Altogether the possibilities of the feature technology are not yet exhausted, in particular the return flow of information and the handling of arbitrarily complex forms will employ the research in the future.

4 *FESTEVAL* Data Model

In order to be able to handle the large amount of data effectively and follow the demand after a data integration on the basis of common files, *FESTEVAL* implements a data model, which covers by its architecture all applications involved in the entire process chain.

The implementation of the data model is based on the specification of the existing application protocols AP214 and AP224, which are developed within ISO 10303 (STEP). The development of ISO 10303 "Standard for the Exchange of Product Model Data" (STEP) is at the moment executed by the standardisation committee ISO TC184 SC4 with the objective to create a mechanism for the description of product data throughout the entire product life cycle independently from special software systems. The approach is based on a standardized product data model and defines beyond that an architecture for the specification of product data as well as a methodology for their development. With this concept all functions of the product data technology, like

- data exchange,
- archiving,

- administration and
- transformation

of product data are to be supported. The working groups of the ISO TC184 SC4 consist of experts of different disciplines, which were supported by different projects regarding methodology and contents [SPECK-98].

Considering that the concept of such integrated design environment is available neither in the current CAx process chain, nor in the standards, the data model is derived from the mentioned application protocols and in accordance with the project will be requests modified or extended.

The data model supplies constructs for the definition and usage of features, for the allocation of technological information to a feature, for machine related dependencies among individual features and for the appropriate process planning information.

Special requests in this context to the data model are the following:

- The formal, unique and accurate description of the model.
- The expandability of the *FESTEVAL* data model, in order to be able to consider at any time new aspects. This request is in particular of great importance, since a continuous improvement of the CAx Systems to attend the technological progress is taking place.
- The robustness of the data model in relation to occurring modifications.
- The modular structure of the data model that permit a simple expandability of the data model and enables the implementation of software modules.
- The information model must illustrate all necessary information correctly.
- The information model is to consist of a minimum set of model structures.
- The information model must not indicate any redundancies.
- The information model must be compatible, i.e., incompatible information must not be contained in the model or be derivable from the model.

The implementation of the data model occurs with the methods, specified in ISO 10303. The specification of the data structures takes place in the formal language EXPRESS where the meaning of the specified data structures is verbal explained in English, or in EXPRESS-G as a graphical subset. The semantics of the described product data is obtained by the combination of both specifications.

Accordingly to ISO 10303-21, the storage of the data takes place on the basis of a physical file. On the other hand the data structure is held at run time in a central database. In order to arrange and regard the data model open for modifications and independent from certain applications, the database has a standardised interface, which permits the applications to get and modify all necessary instantiated objects. This interface corresponds to the ISO 10303-22.

For the modelling of the *FESTEVAL* data model there are two possible concepts:

- A detailed and concrete representation of the objects and attributes (see Figure 5). This leads to a clearly structured data model, which leaves no interpretation clearance to the user and offers a small flexibility. In order to keep such a data model with a high efficiency, a high degree of detail and a large amount of work are necessary.

- The use of generic constructs for the representation of the objects and attributes (see Figure 6). This permits a high flexibility together with a small modelling expenditure. The disadvantage of the generic constructs is that the rising degree of generics is linked with a high implementation expenditure and as a consequence the user friendly applicability sinks.

Therefore, during the modelling of the *FESTEVAL* data model an expressive and balanced combination of both methodologies was used.

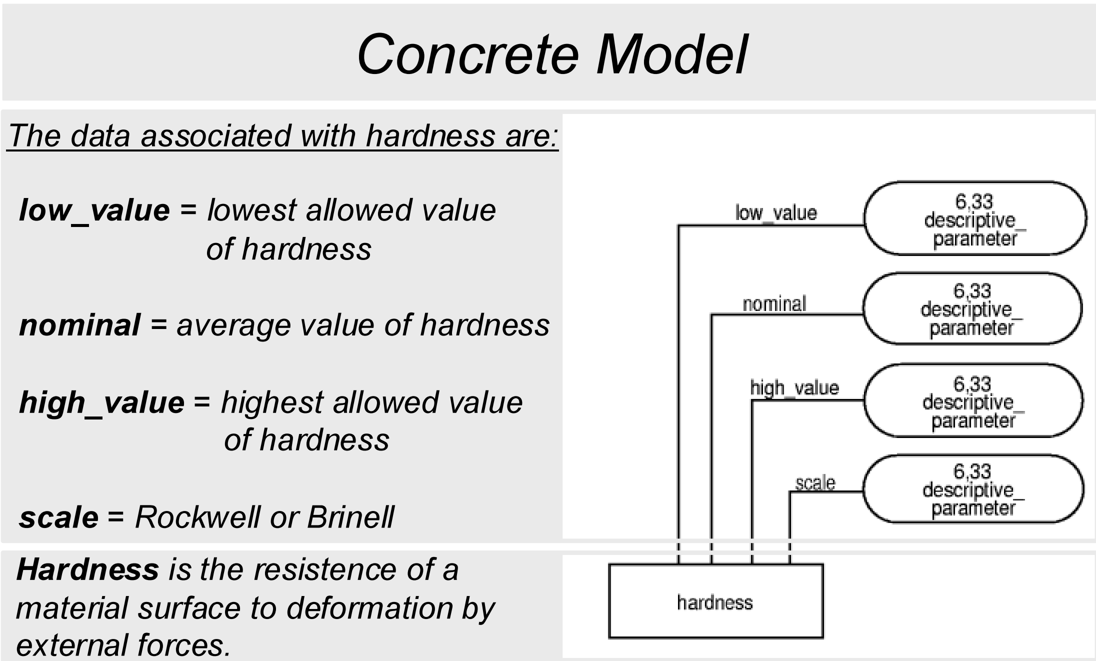

Figure 5: Part of a concrete data model

5 *FESTEVAL* Development Environment

5.1 Design Module

In the design module the modelling of a new workpiece begins with the definition or input of a blank followed by the construction of the workpiece with manufacturing features available in the library. Using manipulation functions the designer can place the instantiated manufacturing feature in the workpiece. Additionally the modification of the parameters and the transformation of the local coordinate systems of a feature are enabled (see Figure 7). Besides this the user has the possibility to delete a feature and to control, through an interdependence relationship, the modification of the dependent features.

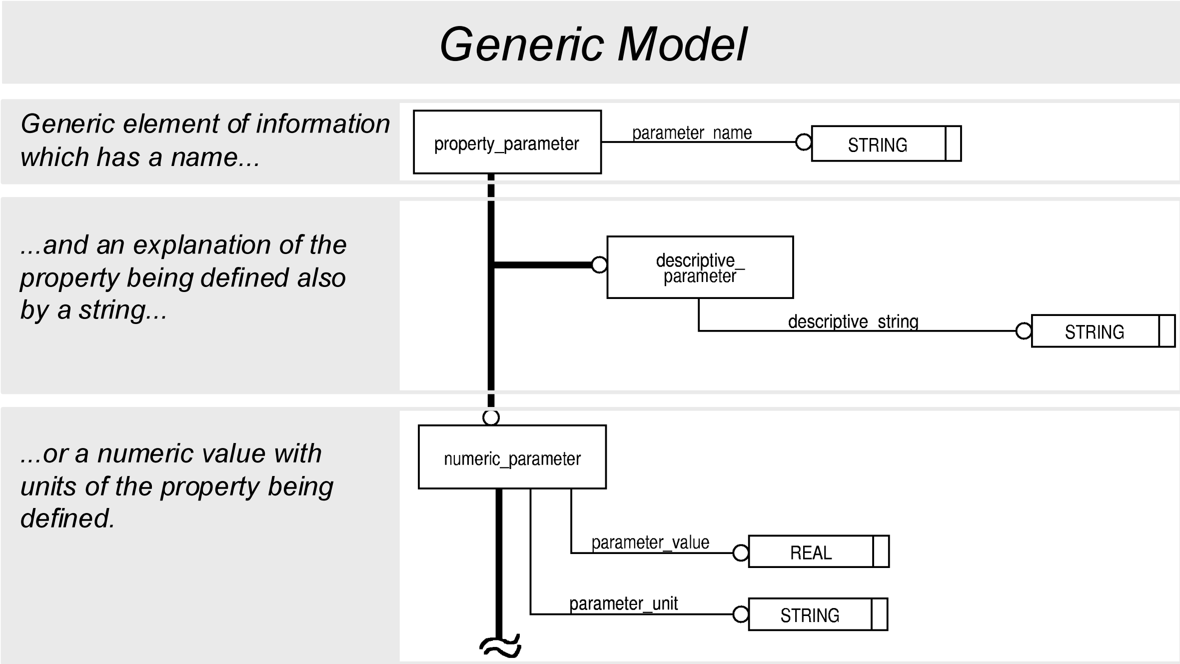

Figure 6: Part of a generic data model

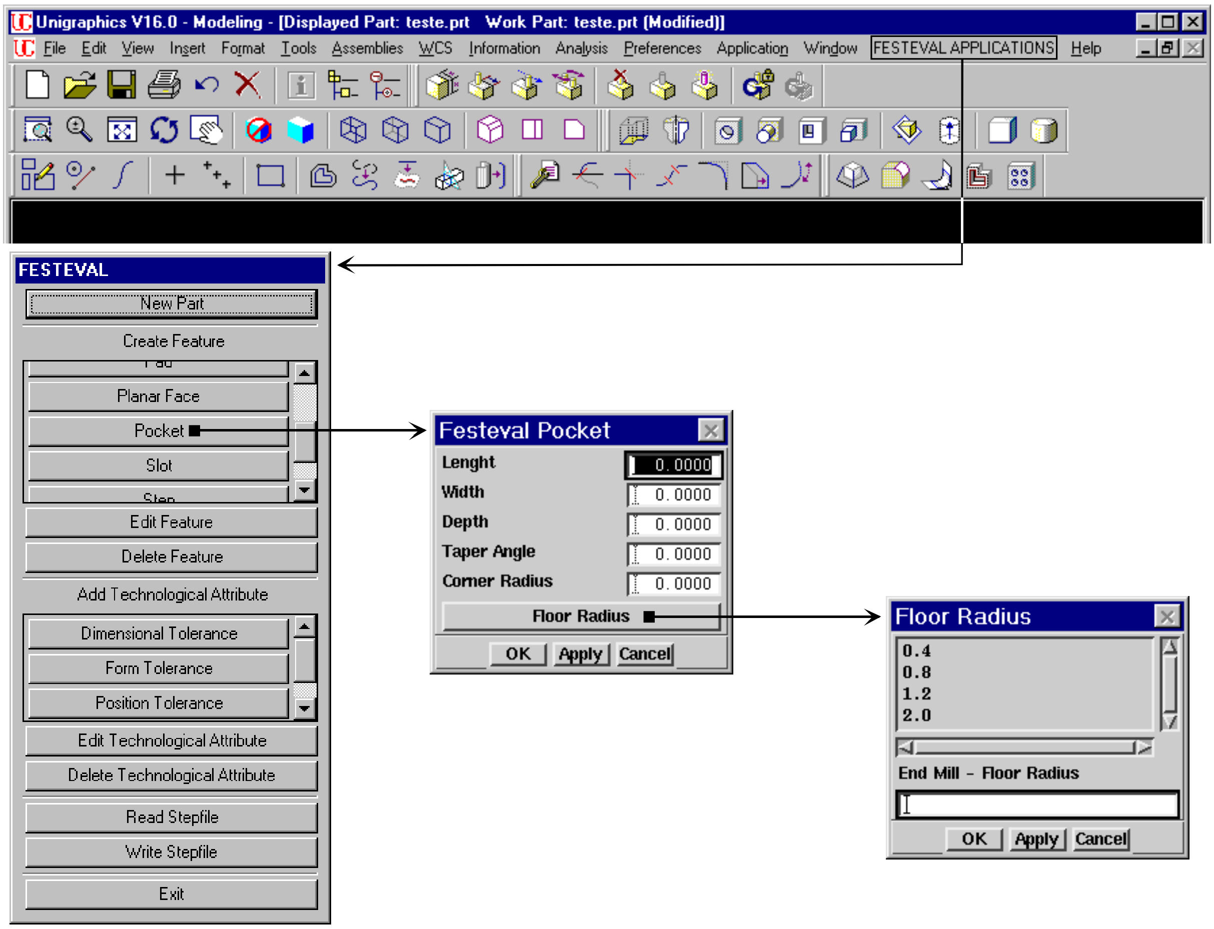

Figure 7: FESTEVAL - Integrated Design Environment

5.1.1 Persistence of the Manufacturing Feature's Semantic

After the creation and positioning methods, there exists the validation function for each manufacturing feature instantiated. It comprehends the semantic verification of the canonical volume of the feature and the persistence of the manufacturing feature's semantic along the design process. One of the first challenges for the researchers, was to determine exactly the characteristics of a persistent object, focusing on their geometric aspects. The first rule tested was to count primitive elements of these objects, verifying its persistence in terms of number of faces and/or edges. The faces are divided in material and virtual surfaces, and each group of faces is exposed to these rules (see Figure 8) [SCHÜTZER-95, SCHÜTZER-98].

Additionally each feature must be validated, to guarantee a problem free manufacturability of the feature in the further process chain. This examination and the recognition of the interdependencies are executed by internal functions of the design system. Only if this validation is successful, the feature is valid in the sense of *FESTEVAL* and may be used. The following characteristics are checked by a validation:

- Are appropriate tools available for production? (e.g. drill diameters, end mills, etc.)
- Are certain geometrical regulations kept? (e.g. minimum wall thickness, diameters, etc.)
- Is the semantical persistence of the feature kept (Figure 8)? (e.g. slot instead of pocket, etc.)

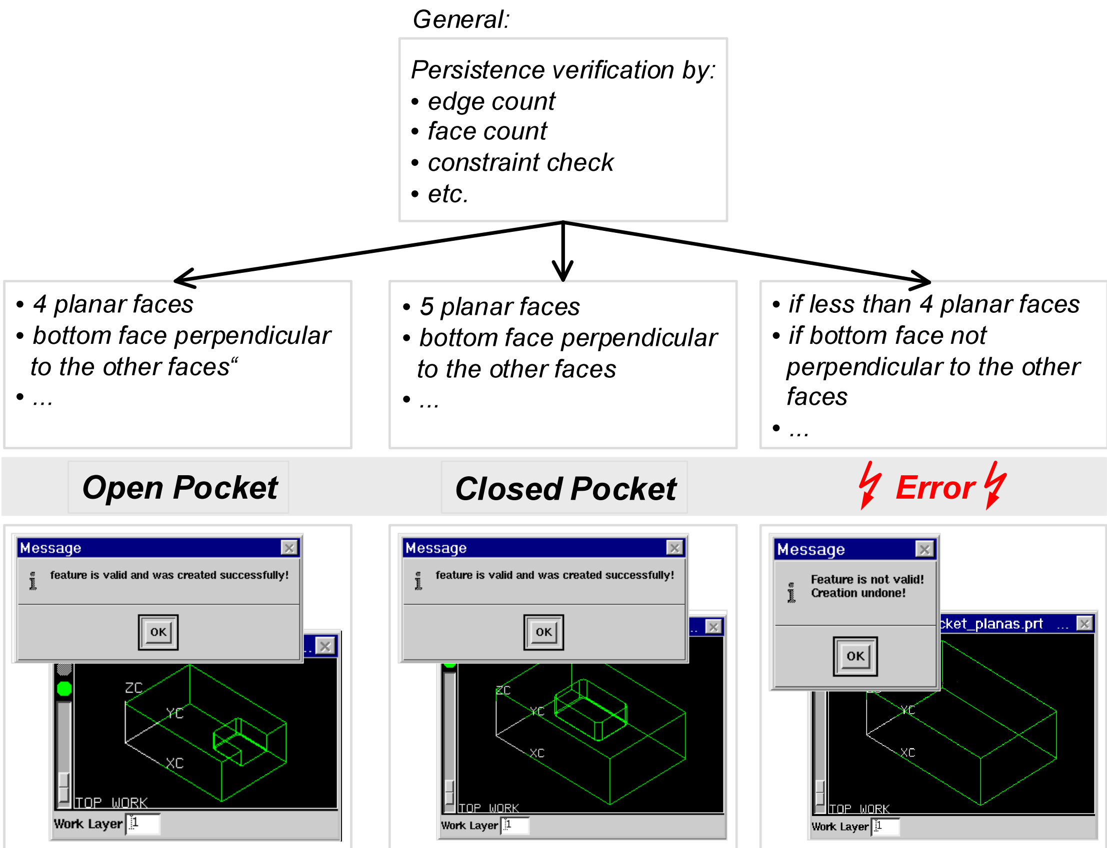

Figure 8: Validation of the feature pocket

The persistence is checked after the insertion or modification of any object, which has interdependence with a manufacturing feature. An output file is generated, in order to show to the final user, that the geometrical representation is maintained continuously coherent to its semantic, during the development of the design part.

5.1.2 Technological and Shape Interdependencies

In the traditional solid modelling systems, the part design is performed by general volumetric primitives, such as blocks and cylinders, and the typical operators are union and intersection. Feature-based design systems provide an intelligent language for expressing designs. Each feature has associated to itself, its form and functionality, but the actual CAD/CAM Systems are far from providing feature libraries, which permit digital integration of downstream CAx Systems.

Focusing on the deficiencies of these systems, it is known that they do not consider the manufacturability, and also the consequences of the interdependence among the manufacturing features in the part. In other words, the features are constructed separated, and there is no verification of the relationship between these objects and its influence on downstream CAx systems.

The construction of the manufacturing features follows the object engineering significance, thought and configured for the part's design-planning-manufacturing context. The sequencing of the machining operations is entirely related to the semantics of the these objects. Additionally, the start point for the tool approach depends on the interdependence between the manufacturing features.

Among the manufacturing features in a workpiece, shape and technological interdependencies of different types can exist. In the context of *FESTEVAL* volume and surface interactions are detected and stored. Information about these interdependencies are interpreted during the process planning and used to determine automatically a suitable process (e.g. the machining sequence, cutting strategies, composition of canonical volumes, etc.).

The interdependencies are classified in explicit and implicit. An explicit interdependence between features concerns two or several manufacturing features, which possess common surfaces or edges, or even an interaction of their canonical volume. On the other hand the implicit interdependence does not have a topological relationship. It forms however a technological interdependence among two or several features, which must be regarded during the production of the workpiece. Therefore the automatic recognition of implicit dependencies is in some cases complex and time consuming [SCHÜTZER-95].

Following the innovation concepts of *FESTEVAL* Integrated Design Module, the primitive elements of the form features are treated as objects, which are studied, in order to define interdependencies between these elements, supplying an engineering significance to the form features, which finally are implemented as manufacturing features.

After the verification of the persistence of the manufacturing feature's semantic, as already described, the manufacturing feature is immediately divided in faces, and these faces divided in edges. The code verifies for every edge, if it belongs to another feature in the part. If so, this information is saved - an identifier of the object is kept in a list - and the methodology of feature interdependencies is recalled for every object of the list. An output file is generated, which exposes the list of the interacting features. This list is defined by the identifiers of the objects, which can be features, faces, edges and others. The output file also expose to the user that the feature number "identifier" is valid or not valid after the construction (see Figure 9).

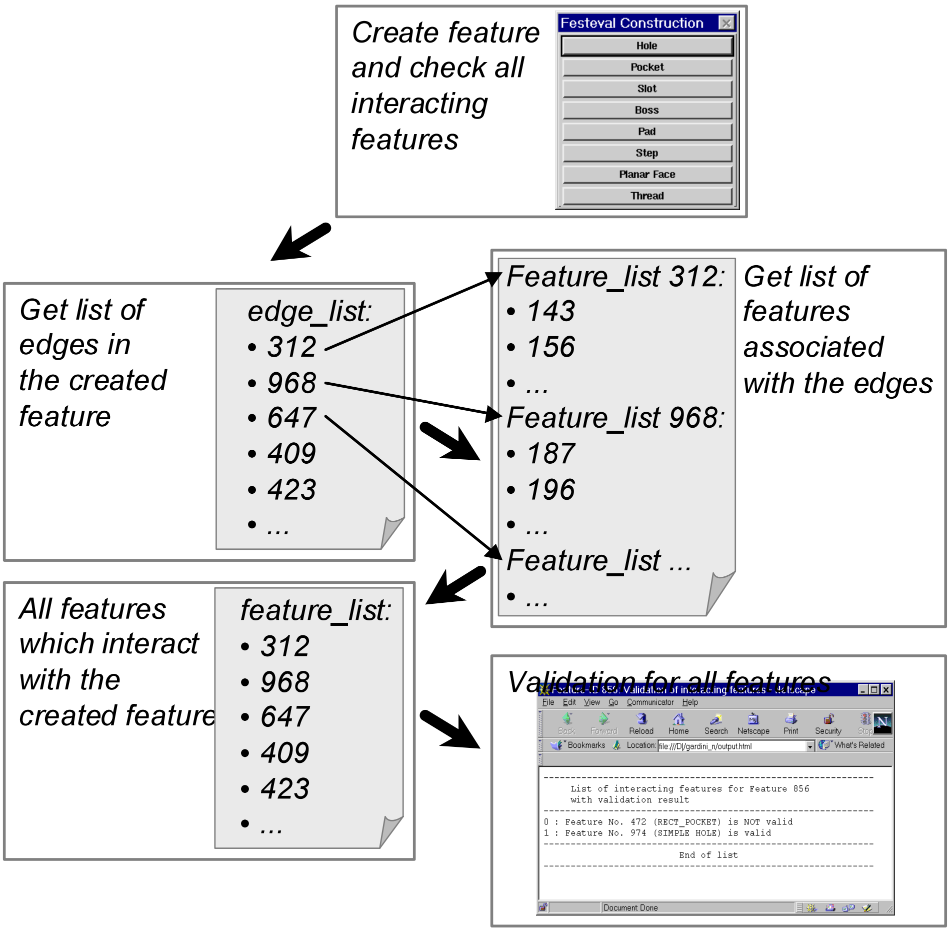

Figure 9: Identification of interdependencies between manufacturing features

The list of interacting features is always actualised, when a new manufacturing feature is instantiated, or when any of them are modified.

Sometimes, one feature, which was valid can have its semantic modified, after the instantiation of another feature. Following the concepts of persistence of the manufacturing feature's semantic, the system continually verifies and manages this persistence and informs the user about eventual alterations.

For the verification of these interdependencies, object oriented programming concepts and the Unigraphics' programming interface were used.

5.2 Planning Module

In the development process chain "design-planning-manufacturing" the Computer Aided Process Planning (CAPP) plays a central role. It is the connecting piece between design and manufacturing. The design department consults the planning department in the question of the manufacturability of new products. On the other hand there are a lot of requests from the planning department to the design department in the matter of design changes for manufacturing reasons.

In the context of *FESTEVAL* the emphasis of the functions for planning is situated in the definition of production, resources and the creation of the work plan. The examination of the manufacturability with available tools takes already place in the design.

5.2.1 Concept of the Planning

The CAPP of *FESTEVAL* consists of 3 main functional parts. The first part is built by the data base of the production means. By this, not only available tools and machine tools but also information of linked processes to these production means are represented. This includes maximum and minimum allowable speeds and torque as well as maximum sizes of the workpiece for the machine tools. Also the possible machining operation (e.g. turning, boring, 3 axis milling, 5 axis milling, etc.) are defined for the tools and machine tools.

The second main functional part contains the rule data base. This represents the actual planning knowledge. In the most simple case these are IF - THEN rules. In this way the selection of specific machining operations and appropriate tools are assigned to geometrical attributes of manufacturing features. An IF - THEN rule is built by a constraint part and an action part. The first one consists of one or several rules which are combined by a logical operator “AND”, “OR” or “NOT”. If the combination of all constraints are TRUE, the 1 to n actions described in the action part are assigned to the work plan (see Figure 10).

But the usage of IF - THEN rules can lead to contradictions that can not be solved, because several rules may exclude themselves mutually. This can be explained by the binary behaviour of these rules even if the rule is nearly fulfilled and may still be allowed. A connection of several rules can easily end up in the empty set of solutions. A much better system behaviour can be achieved by using fuzzy logic technology. In this case poor solutions are not completely excluded, but only weakly rated. So a poor solution is still possible as the worst case solution.

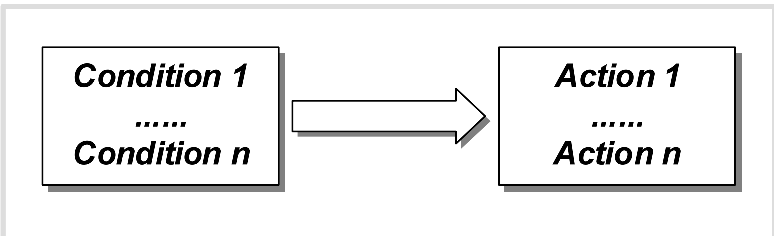

Figure 10: Model for rules

The third principle part is the optimisation tool itself. Its main tasks are the loading of all feature instances of the workpiece, which are created by the design department. Then valid machining operations and production means are associated to the manufacturing feature and the different solutions are evaluated. It results in an final order of the machining operation.

The criteria of the evaluation are either the number of tools, number of machine tools used, short travels between the features or an optimisation according to minimal costs.

The feature-based design environment of *FESTEVAL* forms the base for the inputs for the planning tool. This generates far more than only geometry, but supplies the semantics of individual areas by the use of manufacturing features. Beyond that, interdependencies are detected automatically between the features in the *FESTEVAL* design module. These can be used for the planning of the generation of the processing sequences. Due to the special procedure of the design in *FESTEVAL* the data are already completely prepared for the automated NC-path generation.

5.2.2 Generation of Setups

For the division of the machining operations into different setups, the relationship between features and the stock faces are used. All features referencing the same face of the stock are grouped together. Afterwards the minimum count of groups are sorted out by which all features can be machined.

The example shown in Figure 11 would create 2 groups. Group A (top face) referenced by the hole and slot, Group B (bottom face) referenced only by the hole. In this case one setup is enough (Group A - top face), in which all features can be machined.

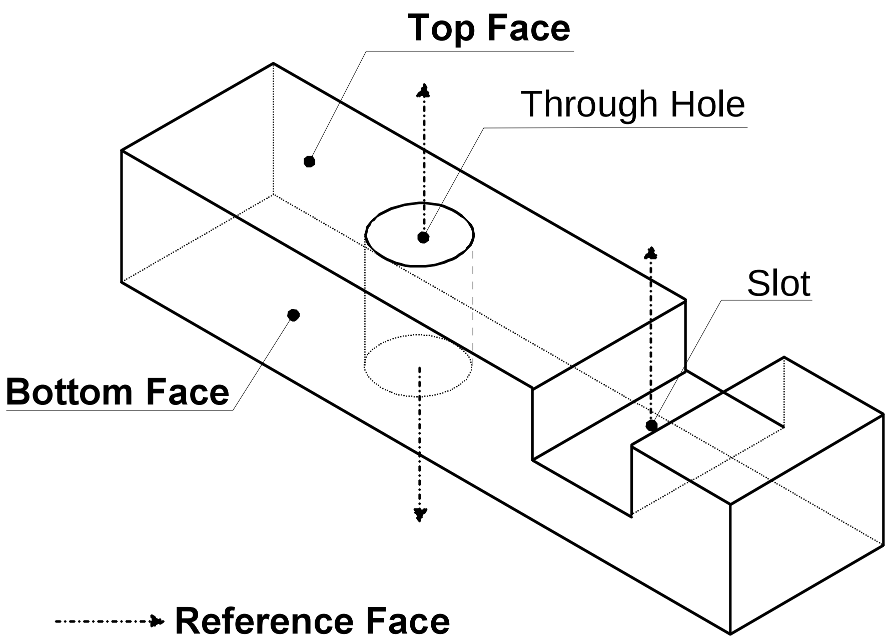

Figure 11: References of feature to blank faces by which they are accessible

5.2.3 Process Selection

The selection of the machining operation is done gradually by the evaluation of the manufacturing feature parameters and the rule data base. The semantical meaning of features, like “Bore” or “Thread” gives only a limited set of possible machining operations. Further on, the geometrical parameters are evaluated in order to reduce the number of machining operations. For one parameter set of a feature, several possible solutions may be defined. For instance a hole with a diameter of 30 mm may be processed by “centering rough boring and boring” but also by “circular milling”. Therefore the evaluation of the geometrical attributes does not necessarily lead to only one solution.

The rest of the varieties of machining operations are filtered by the reduction of the number of used tools. For instance the diameter of the bore for rough boring is not exactly determined. Therefore, it may be possible to use one bore for most of the rough boring operations. By the evaluation of the technological requirements of sizes the number of solutions and qualities are further reduced. In the example above the quality of the hole may be so high, that it is necessary not only to bore but also to ream the hole.

5.2.4 Definition of Production Means to Machining Operations

Already in the design system, feasible and available tools are assigned to machining operations. Since several tools can be used for the machining of one feature there is still a range of possible tool dimensions and different kinds of tools according to the chosen machining operation (see Figure 12).

The machine instances are associated to possible machining operations which can be performed on each machine. The selection of the machines are also dependent on the size and the weight of the workpiece. Also, the maximal allowable moments and speeds must be taken into account as well as the needed precision. These parameter are included as attributes in the description of features or machining operations.

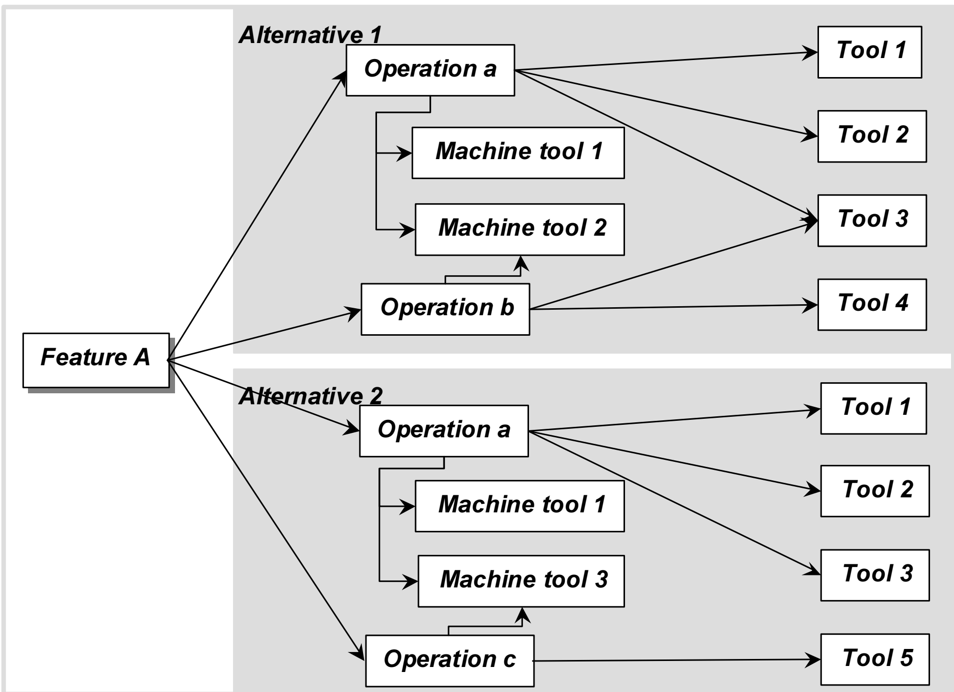

Figure 12: Selection of operations, machines and tools for a feature

The final decision, which machine will be used, is according to user defined criteria such as machining on cheapest machines or on High Speed Cutting machines. If the final decision can not be found by the algorithm the user has the possibility to interactively select the actual machine to be used.

The cutting parameters of the processes are dependent on the specific tools and are provided by the tools provider in tables. These are used for the determination of the technological data.

5.2.5 Combination of Feature Canonical Volumes

In the case of two features lying next to each other and bound with an virtual face, the cutting volume of the machining operations can be grouped together. This is of importance because the CAM System will calculate continuous travels and avoid unnecessary encounter and remove approaches. This leads finally to better results of the surface quality and a reduction in the manufacturing time.

The machining operations are grouped together in the partial machining model of the common data model. Acting on the supposition that the machining operations use the same tool and the same cutting strategy they can be machined as one continuous volume. This means: only these machining operations can be grouped together which fulfil this condition and on the other hand this condition leads to a cut down of the amount of machining varieties of the machining operations. [GLOCKNER-99].

5.2.6 Optimisation of the Operations' Sequence

The algorithm of the optimisation has to be able to minimise costs and process times. This includes the main and idle times like the change of machines. Especially the minimisation of the idle times are in the focus of the optimisation. But the user also supposes to have influence on the planning by locking specific machine tools or reordering the sequence after the optimisation manually. In the last case the planning system controls the consistency of the changes and identifies eventual contradictions of interdependencies.

The problem of optimisation is a combination of a selecting problem and a sequencing problem. Both are inter linked with each other. In order to reduce the number of combinations both problems are analysed separately.

As the problem of sequencing leads up to a reduction of the idle time (number of travels between cutting volumes, changes of tools, etc.), the selecting problem influences the main and idle time in a stronger way. If it is possible to reduce the number of machines and tools by selecting certain machining operations, the sequencing of these operations is less important. Therefore, the optimum machine operations are selected first and after that the sequencing is fulfilled. The solution proposed here in *FESTEVAL* is based on the results of the European Project Esprit III #6090 - FIRES and the PhD thesis of Hintz [HINTZ-96].

5.3 Software Architecture for the Planning Module

The Figure 13 presents the architecture of the planing module. The development system is used for the instantiation of rules and the input of the parametric description of machines and tools. Also the possible machining operations for available production means are defined. For the process planing data model, as well as for the common data model, the STEP standard was used. So the same access routines can be used for the common data model and the production means administration. In the prototype solution these instances are stored in a STEP physical file [ISO 10303-21].

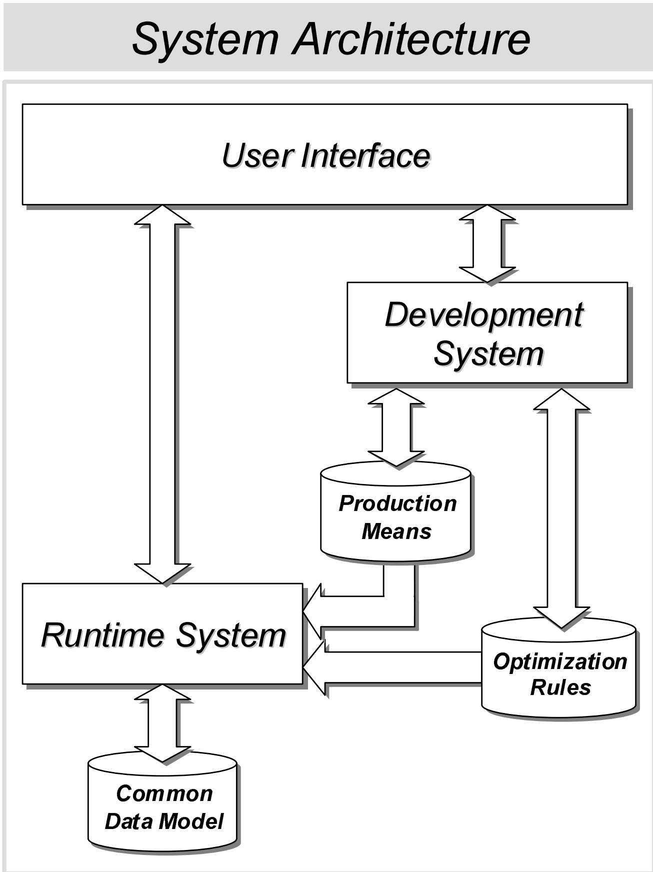

Figure 13: Software architecture

The run time system enables the determination of the appropriated machining strategies and the optimal operations' sequence. The feature instances and their parameters are read in from the common data model. In addition the STEP Class Library (SCL) of NIST is used [SAUDER-95].

The results of the optimisation are stored in the common data model and are therefore available for the production. The entire system is served by a user interface (see Figure 14), which is created with Visual C++ from Microsoft. For the generation of the dialogs the Microsoft Foundation Classes (MFC) are used.

The entire application is based on the multiple document interface concept of Microsoft. This designates that to each workpiece a document is created. This is represented in a MFC Windows standard. Through this concept the standard functionalities of the Windows applications are ensured. This has the advantage that the user gets faster the felling how to use the planing prototype.

The main menu is structured itself into the usual Windows functionality's like file handling, view handling and window handling, etc.. In addition there is the menu topic "Optimise" for the generation of the machining operation sequence and the topic "Rules" and "Prod. Means" for the definition of new rules and production means. This organisation represents however only a rough concept and is still in the course of the development.

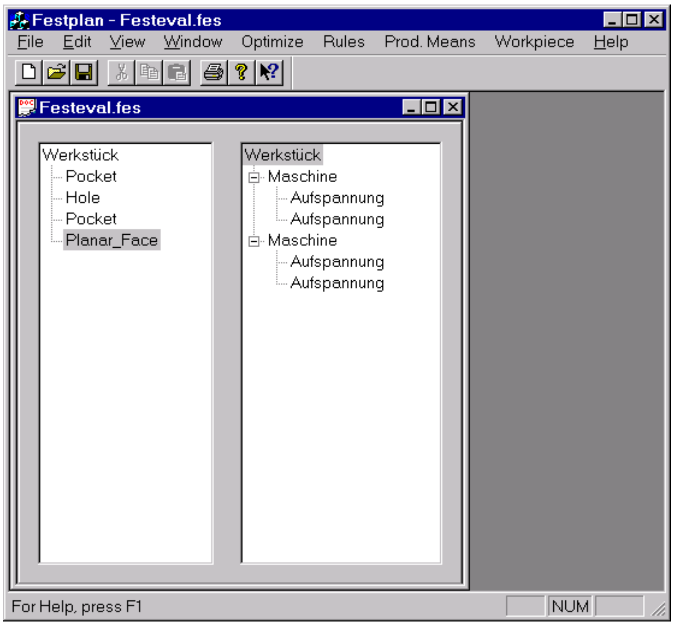

Figure 14: User interface

The topic "Workpiece" is active only until the design environment supplies the manufacturing feature instances. At the present it serves for the instantiation of features coupled with a possible processing.

Figure 15 represents a window for the input dialog for the definition of processing rules for features. The condition consists of a Boolean operator (connector) for the concatenation of several conditions, an attribute of the feature, a comparison operator and a characteristic value of the feature together. For the selection of the feature attributes the user uses a browser. In the lower part of the rule input dialog window the applied machining operations are determined, if the rules are valid.

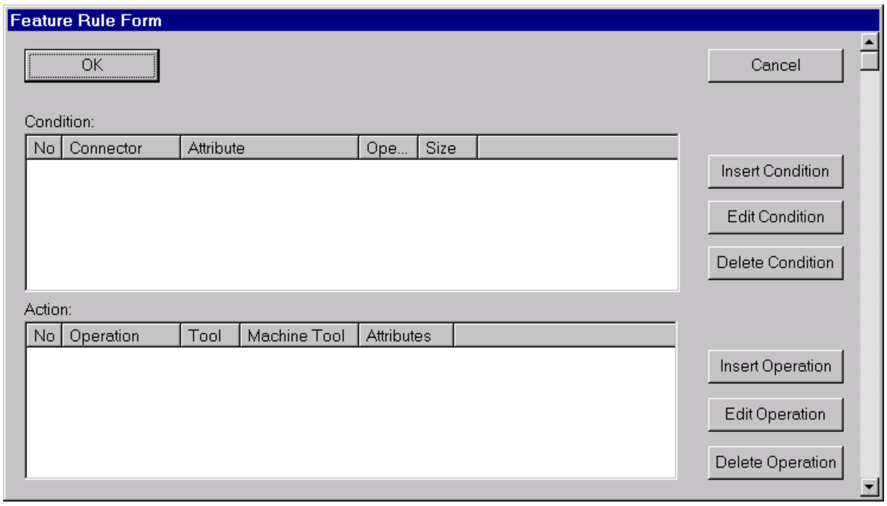

Figure 15: Input for rules

6 Conclusion

The development environment will support the designer actively by an automatic recognition, validation, representation as well as processing of the interdependencies among features. This has the consequence, that at a very early stage in product development chain the manufacturing of the workpiece can be already checked. The designer describes thereby not only the shape of the workpiece, but determines also different information (e.g. tolerances, surface quality, etc.), which are needed in the later process.

The usage of the feature concept in commercial systems is still at present very small. With exception of some companies, which are active as partners in research projects in this area, at the present there is no industries known that apply the features concept for the design and for the integration of CAD/CAPP/CAM systems. Nevertheless the current trend goes in the research and within the development of new CAx process chains to the use of features. Therefore the available concept and the *FESTEVAL* prototype should be a contribution.

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FESTEVAL

Support of the CAD/CAM Process Chain by Manufacturing Features

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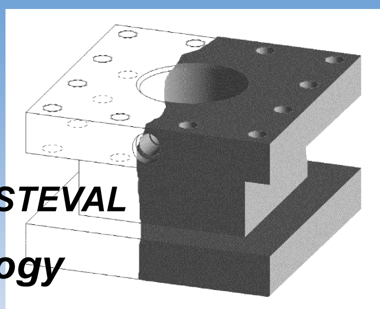
FESTEVAL



- ***Introduction***
- ***Objectives of FESTEVAL***
- ***Feature Technology***
- ***FESTEVAL Common Data Model***
- ***FESTEVAL Engineering Environment***
- ***Conclusions***

Overview

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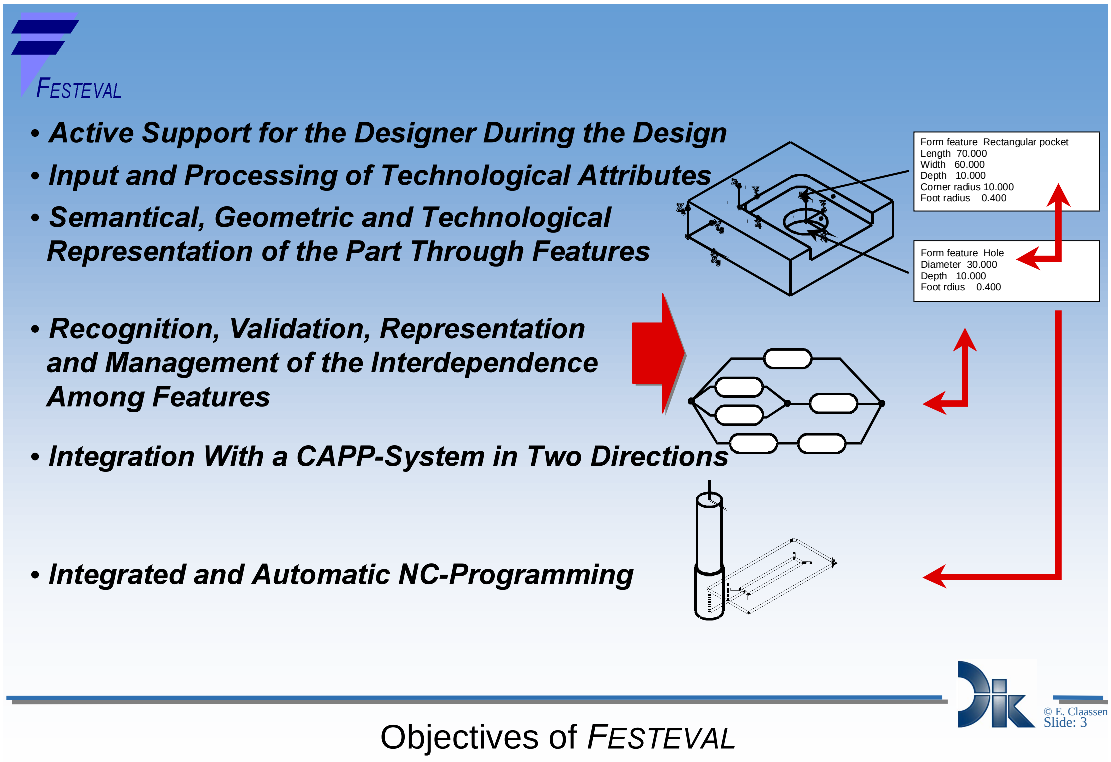
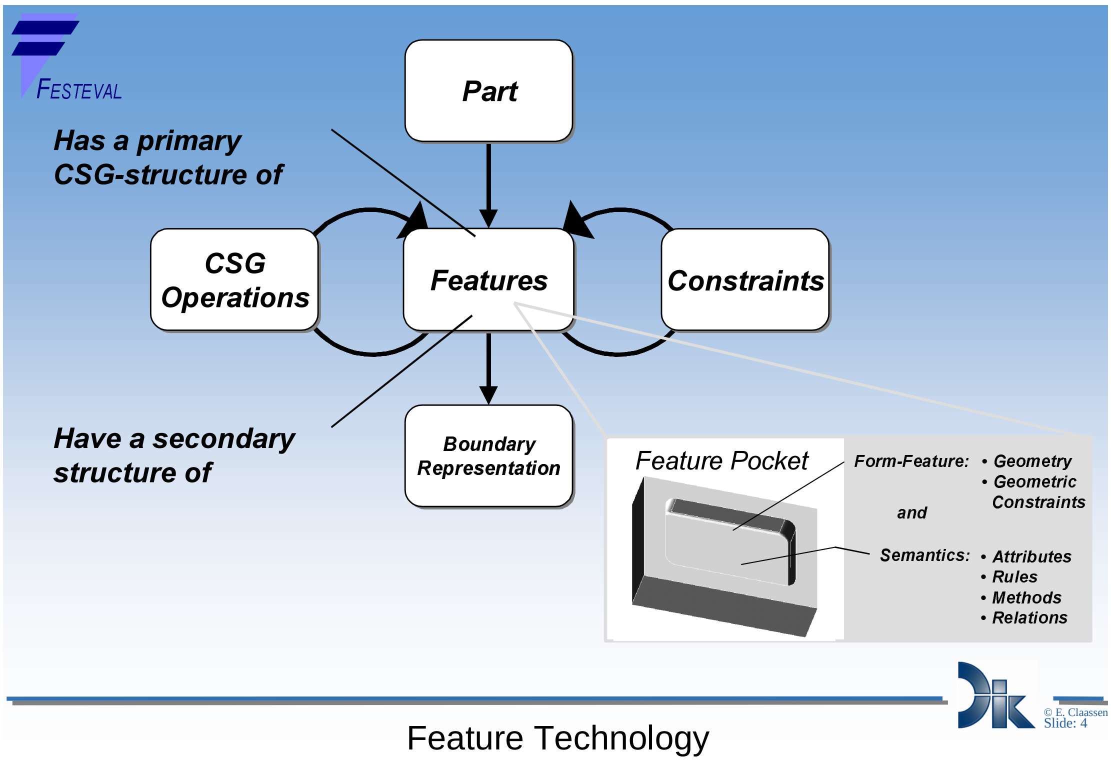

FESTEVAL
• Active Support for the Designer During the Design
• Input and Processing of Technological Attributes
• Semantical, Geometric and Technological Representation of the Part Through Features
• Recognition, Validation, Representation and Management of the Interdependence Among Features
• Integration With a CAPP-System in Two Directions
• Integrated and Automatic NC-Programming
Form feature Rectangular pocket
Length 70.000
Width 60.000
Depth 10.000
Corner radius 10.000
Foot radius 0.400
Form feature Hole
Diameter 30.000
Depth 10.000
Foot rdius 0.400
© E. Claassen
Slide: 3
Objectives of FESTEVAL


FESTEVAL
Part
Has a primary CSG-structure of
CSG Operations
Features
Constraints
Have a secondary structure of
Boundary Representation
Feature Pocket
Form-Feature:
• Geometry
• Geometric Constraints
and
Semantics:
• Attributes
• Rules
• Methods
• Relations
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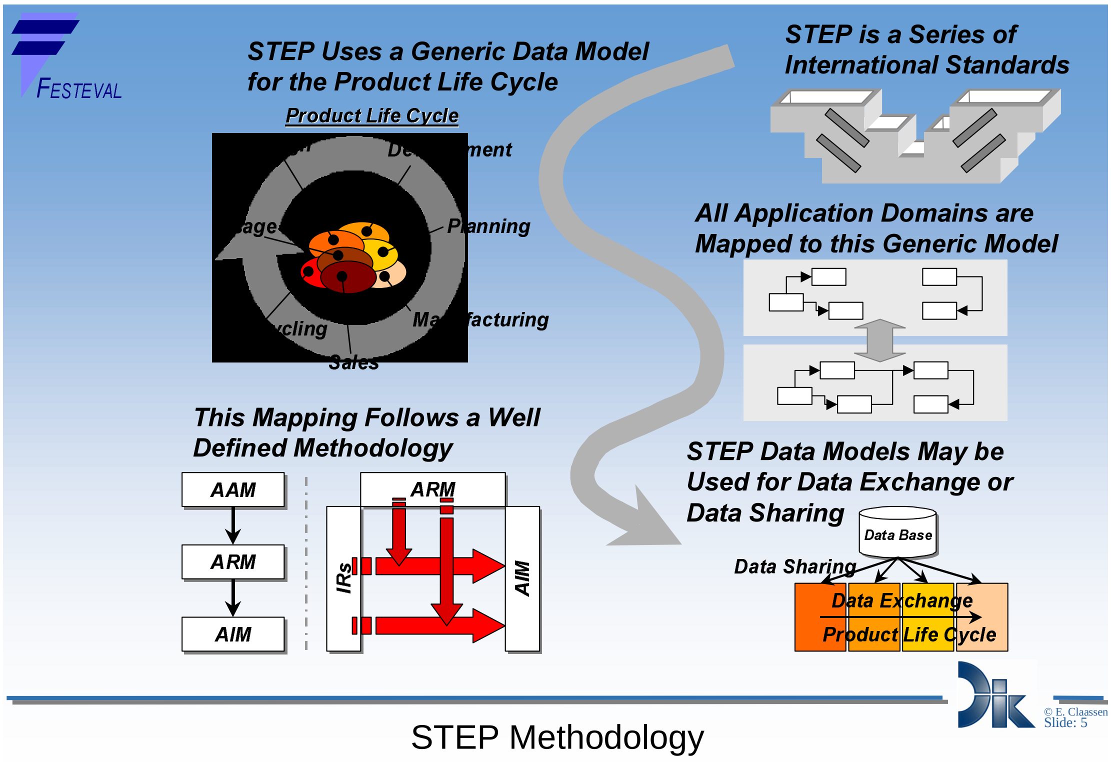
Slide: 4
Feature Technology


FESTEVAL
STEP Uses a Generic Data Model for the Product Life Cycle
Product Life Cycle
Planning
Manufacturing
Sales
STEP is a Series of International Standards
All Application Domains are Mapped to this Generic Model
This Mapping Follows a Well Defined Methodology
AAM
ARM
AIM
IRs
STEP Data Models May be Used for Data Exchange or Data Sharing
Data Base
Data Sharing
Data Exchange
Product Life Cycle
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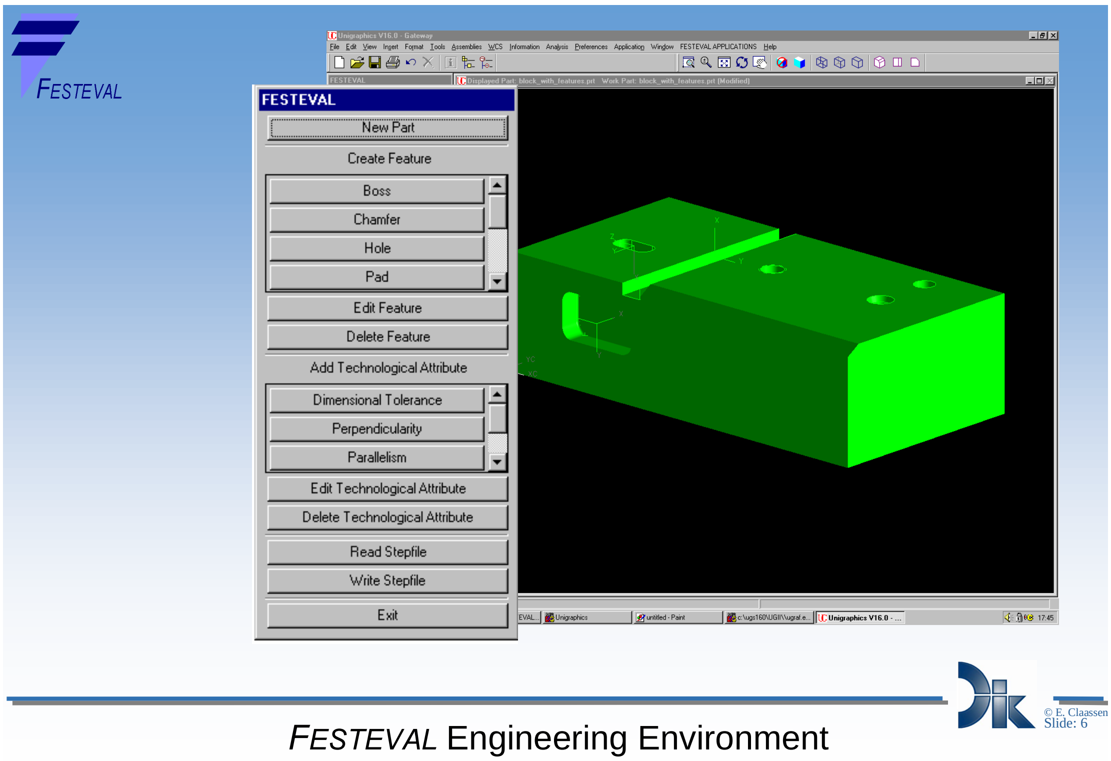
Slide: 5
STEP Methodology


FESTEVAL
FESTEVAL
New Part
Create Feature
Boss
Chamfer
Hole
Pad
Edit Feature
Delete Feature
Add Technological Attribute
Dimensional Tolerance
Perpendicularity
Parallelism
Edit Technological Attribute
Delete Technological Attribute
Read Stepfile
Write Stepfile
Exit
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Slide: 6
FESTEVAL Engineering Environment

FESTEVAL

Improvements of the Process Chain Based on Manufacturing Features

- ***Improved Design Activities Based on a Feature Semantic***
- ***Validity Check of Each Feature Instance***
- ***Recognition, Representation and Management of the Technological and Shape Interdependencies Relating the Manufacturing Features***
- ***Active Support During the Input of Technological Attributes***
- ***Automatic Generation of the NC Program***
- ***Full Information available in the Shop floor***
- ***Active Support During Optimisation at the Machine Control***

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Slide: 7

Conclusions