

An Overview of the CADCEUS System

1.0 Introduction

CADCEUS is an integrated CAD/CAM/CAE/CG system designed to totally support product development processes from conceptual design through manufacturing preparation for automobile, machinery, precision work, electric and electronics industries. The term CADCEUS(Computer Aided Design, manufacturing and engineering for Concurrent Engineering by Unisys System) is derived from the English word 'CADUCEUS' which means a stick with two entwined snakes and two wings, which God's messenger Hermes had. It is so named in the hope that it shall strongly support engineers who are engaged in mechanical design and manufacturing.

The manufacturing industries are strongly asked further improvement of product quality, reduction of development cost, and shortening of development time in order to meet wide variety of market needs. Drastic innovations in design and manufacturing are necessary for satisfying these requirements.

Key methodologies they are required to tackle are establishment of CIM environment in pursuit of efficient enterprise activities administration by unified information management, and establishment of collaborative and concurrent environment in pursuit of quality improvement and efficient design and manufacturing. CADCEUS is a next-generation integrated system which UNISYS has developed to meet above mentioned technical trends and requirements.

Chapter 2 of this paper describes the objectives of CADCEUS. Chapter 3 and 4 discuss its major characteristics and system configuration, respectively. Chapter 5 outlines major capabilities of CADCEUS.

2.0 Objectives of CADCEUS

The manufacturing industries have introduced CAD/CAM systems for the purpose of shortening lead time of product development. Advantages of conventional CAD/CAM systems, however, have been limited to the automation and rationalization of individual process. Substantial lead time reduction can not be expected under present circumstances. What are required are not only to improve CAD/CAM systems applied for individual process, but also to effectively combine islands of automation which resulted from the application of CAD/CAM systems to each process independently. Namely, it is necessary to achieve system integration and generation of necessary enough information transferred or shared among processes. If the information transferred from the preceding process is insufficient, it becomes inevitable to reconsider and re-input the information in the current process that has already been defined in the preceding process, which causes double efforts. If this situation is left unchanged, we can never expect productivity improvement, reduction of number of drawings, value shift from drawing to 3D model or realization of concurrent engineering by front loading each process. In the days before CAD/CAM systems were introduced, the intents of preceding process were transferred sufficiently by drawings, instruction manuals, or human-to-human communications. The conventional CAD/CAM systems can mainly transfer shape related information. They cannot transfer design intents under transferred shape, functional features, and various product attributes.

As far as shape representation is concerned, evolution from wireframe representation to surface representation, and then solid representation shows considerable progress for representing real object. But, these representations are limited to mathematical description of shape after design. Namely, design intents of shape are not modeled. This is the reason why drawings are necessitated as before. In order to resolve this situation, "Product Model" which incorporates every technical information of a product during its life cycle has been proposed and discussed among research fields and ISO TC184/SC4.

The primary objective of CADCEUS is to meet urgent needs for system integration, unified data management and advanced automation by implementing this “Product Model”. It also aims at innovation of the modeling environment, inheritance of design intents, promotion of automation, and incorporation of flexibility to design changes by combining new technologies such as parametrics and form feature.

3.0 Characteristics of CADCEUS

CADCEUS is an integrated CAD/CAM/CAE/CG system based on integrated database and integrated human interface. It supports all of the product development processes from conceptual design to manufacturing preparation and supports realization of Computer Integrated Manufacturing (CIM) and concurrent engineering environments.

This chapter briefly introduces product model concept implemented in CADCEUS.

3.1 Product Model

CADCEUS implements product model from the view points of “information integration” and “information completeness.”

3.1.1 Information Integration

CADCEUS product model realizes integrated data model of information necessary for all the product development processes for eliminating information loss between processes. It implies that direct use of designed part model becomes possible for the study of manufacturability. In conventional environments, there are cases that different systems are used for successive development processes. In that situation, data transformation between processes is inevitable, which causes loss or deterioration of data.

It becomes unnecessary to transform data between processes by using CADCEUS.

3.1.2 Information Completeness

Different from conventional systems, various information around product shape representing design intents may be included in CADCEUS product model, which make it easier to understand functional constituents of a product shape and their conditions. Use of these information improves common understanding of a product shape between designers and between processes, and makes it easier to change the product shape according to design changes. The product model with these characteristics in the center, design cycle and manufacturing cycle are performed as shown in Figure1.

Earlier manufacturability study by the use of each phase design model enables earlier incorporation of manufacturability requirements, which could lead to drastic reduction of pr

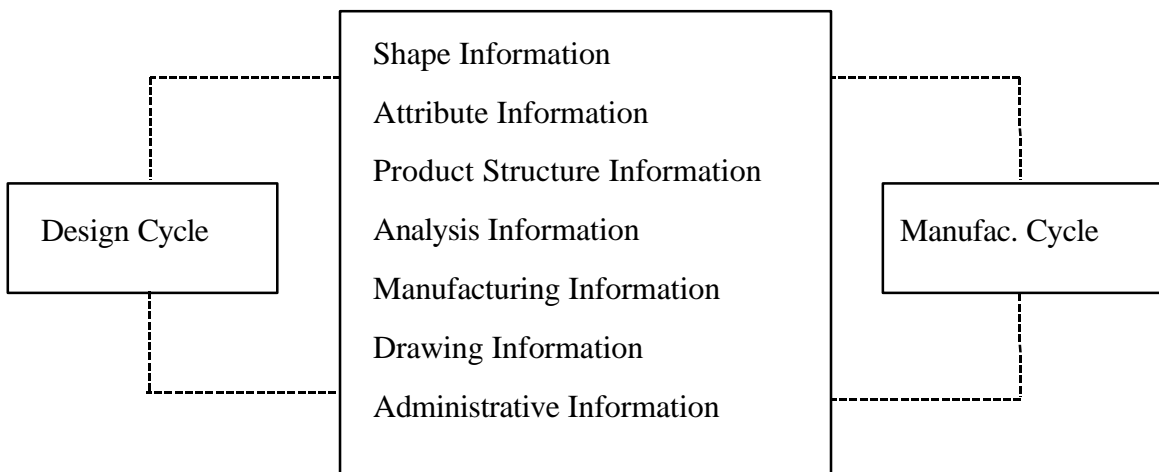


Figure 1. The Situation of the Product Model

3.2 Attributes of the Product Model

CADCEUS product model handles the following types of information:

(1) Shape information

Shape information consists of geometric information, topological

information,

constructive information, and geometric constraint information.

The constructive information and geometric constraint information are used for capture design intents.

Most conventional systems treat only final information about shape.

Therefore, it is difficult to efficiently change shape satisfying design intents.

Furthermore, final part shape is represented by a simple collection of geometry segments, which makes it impossible to understand or extract functional units. In order to overcome these deficiencies, CADCEUS stores constructive information which is the most useful information in CADCEUS modeling. The constructive information contains modeling operation history and modeling condition information associated to shape. These information in conjunction with geometric constraint information realize design intents representation and transfer.

CADCEUS shape model allows hybrid representation of wireframe, surface, and solid, which enables set operation between surfaces and solids. Non manifold representation is also allowed.

(2) Property information

The model can contain material, wall thickness, surface roughness as shape attributes.

(3) Assembly information

The model can contain information about hierarchical, positional, and connectivity relationships between parts.

(4) Drawing information

Drawing information is related to geometric information so as to realize automatic associativity between 3D model and its drawings.

(5) Analysis information

FEM or kinematic analysis models, analysis conditions, analysis results can be stored in the model.

(6) Machining information

The model can contain process planning information (machining method, machining conditions, etc.), cutter location information, and information about residuals.

3.3 Data Structure

The database of the CADCEUS system consists of two concepts for the categorization of design space and design object. They are “workspace” and “object”.

3.3.1 Workspace

The database of CADCEUS is segmented into blocks of appropriate design units. Each of these blocks is called a workspace. A designer may use two or more workspaces ,or two or more designers may use one workspace for realizing collaborative design.

The concept which corresponds to a product, or an assembly, or a subassembly, or a part, or a sheet, or a view of some sheet is “object”.

A workspace may contain arbitrary number of objects. An object should be closed in one workspace.

There are two ways of representing assembly. One is representing an assembly in a workspace relating objects contained in the workspace. The other is representing an assembly relating objects in two or more workspaces. The former is expected to be used in rather earlier design phases and the latter in detail design phase.

3.3.2 Object

As described above, “object” is a lower level notion of the workspace. Almost all technical data are contained in “object”.

Objects are classified into the following four types according to their properties and uses:

- (1) Part: corresponds to a single part.
- (2) Assembly: corresponds to an assembly or a subassembly.
- (3) Sheet: corresponds to a drawing sheet.
- (4) Projection: corresponds to a view(ex. front view) on a drawing.

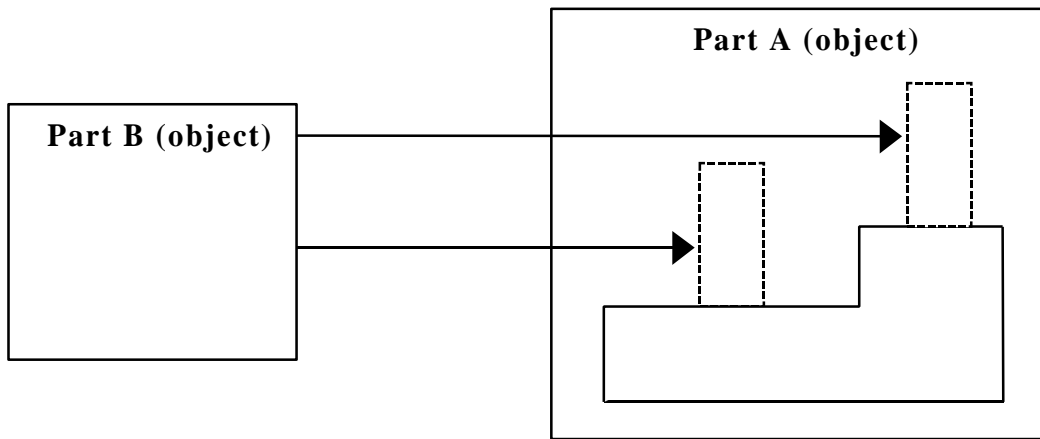


Figure2. Instantiation of Objects

One characteristics of the object is that it could be instantiated. Figure2 shows that object-B is instantiated twice on object-A. Since all the technical data such as shape are stored in the original object-B, any change of B could be immediately influenced on its instances on A. The other characteristics is that objects in a workspace could be geometrically related using hierarchical relationship or connectivity relationship. Use of the hierarchical relationship enables assembly hierarchical representation as shown in Figure3.

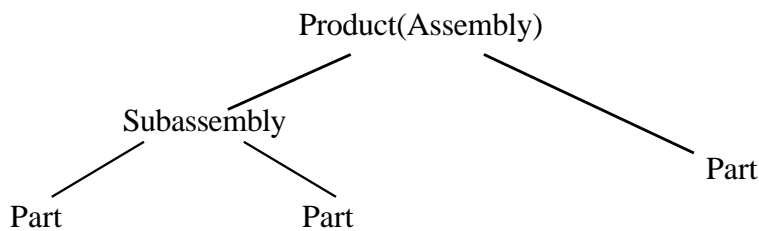


Figure4 shows mutual relationship of different object types, namely sheet, projection, and part objects. All of these objects are related by placement function. If the shape of a part is changed, the change is reflected on the drawings immediately and dimensions on the drawing are automatically changed accordingly.

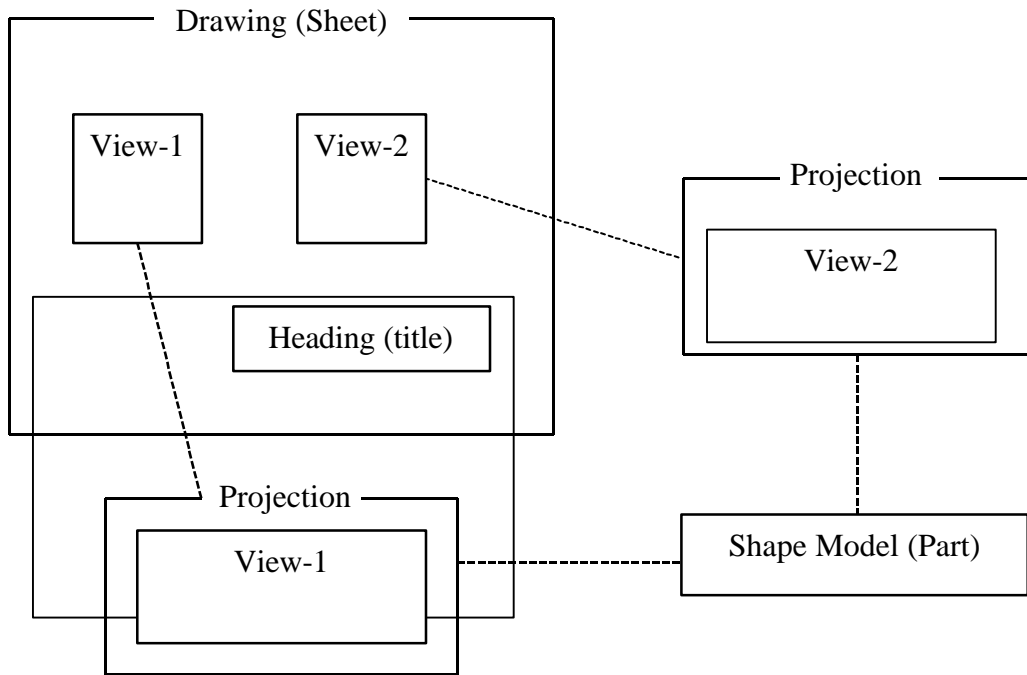


Figure4. Relationship between Drawing and 3D Model

There are mainly two grouping capabilities. One capability called “group” is used for grouping elements in an object. “group” is used for easy visual control or geometry manipulation. Though the group does not allow hierarchy, an element may belong to two or more groups.

The other grouping capability is “layer”. Different from the group, a layer may range to two or more objects. Major usage of the layer is a support of multiple viewing of elements and visual control.

3.4 Collaborative Design Environment

In order for realizing reduction of product development time, support of collaborative design work is quite important. CADCEUS supports collaborative design of a product by number of designers by switching private environment and shared environment ,and by maintaining integrity of data in shared environment. Figure5 shows the schematic diagram of the collaborative environment. The two environments are called private workspace and shared workspace respectively. Each designer performs his design in his private workspace without any intervention. He may check in, reference, update, save data to and from shared workspace. All the logical integrity on the latest status of data (object),relationship between objects are maintained in the shared workspace, thus realizing independence of each designers work and integrity management of all related data among

designers.

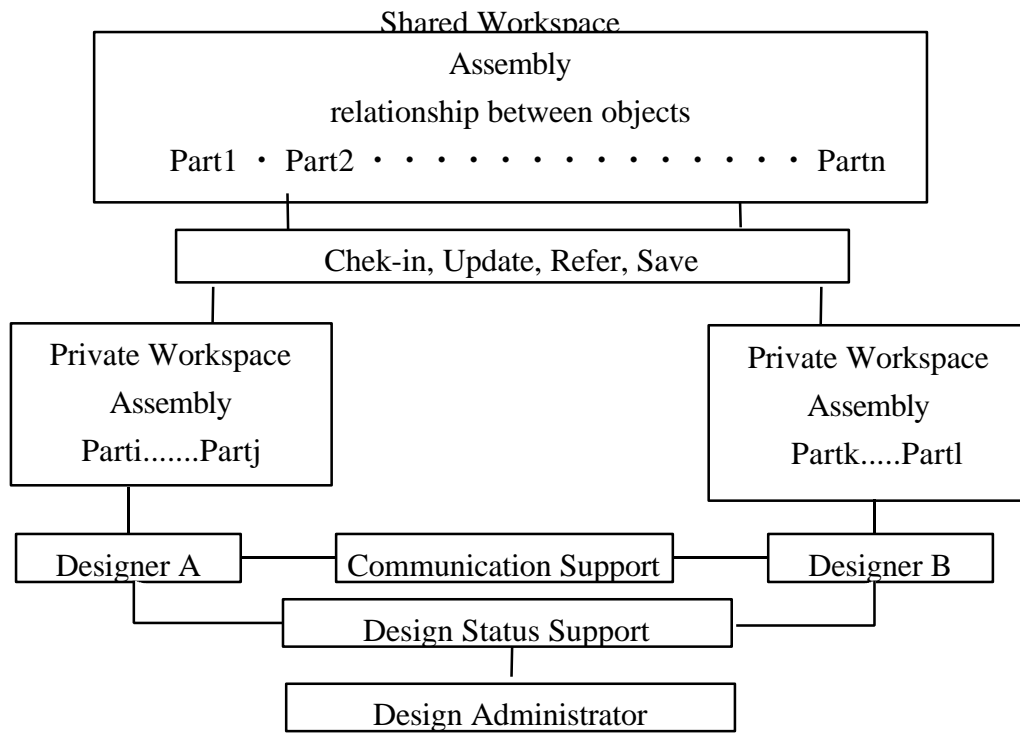


Figure5: Collaborative Design Support

4.0 System Configuration

CADCEUS is a distributed system that runs on graphic workstations and on personal computers. It realizes centralized data management through a network of host computer, servers, and workstations. The basic centralized/distributed hardware configuration for CADCEUS is shown in Figure6.

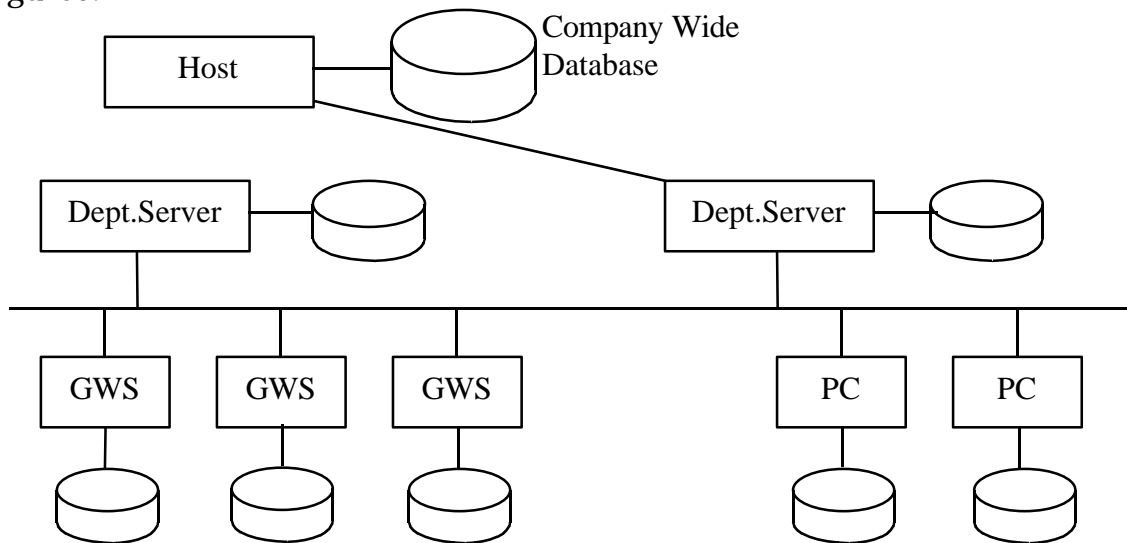


Figure6: Hardware Configuration

As for the software configuration, CADCEUS consists of variety of subsystems with the following characteristics where the product modeler plays a central role.

(see Figure7).

- (1) Drafting subsystem which has full associativity between shape model and its drawings, and has parametric drafting capability.
- (2) CAM subsystem which supports variety of machining methods and machining planning.
- (3) CAE subsystem which has variety of pre-processing and post-processing capabilities for FEM analysis and kinematic analysis.
- (4) CG subsystem which has various capabilities for the presentation.
- (5) Data Exchange subsystem for exchanging data with other CAD systems

In addition to these subsystems which directly support design and manufacturing activities, the followings are also provided.

- 1) Various utility functions for easing data administration and maintenance
- 2) Various customization tools for enabling user or activity oriented systems
- 3) Interface with PDM systems for the integrated management of product data and related documents such as drawings and various technical documents.

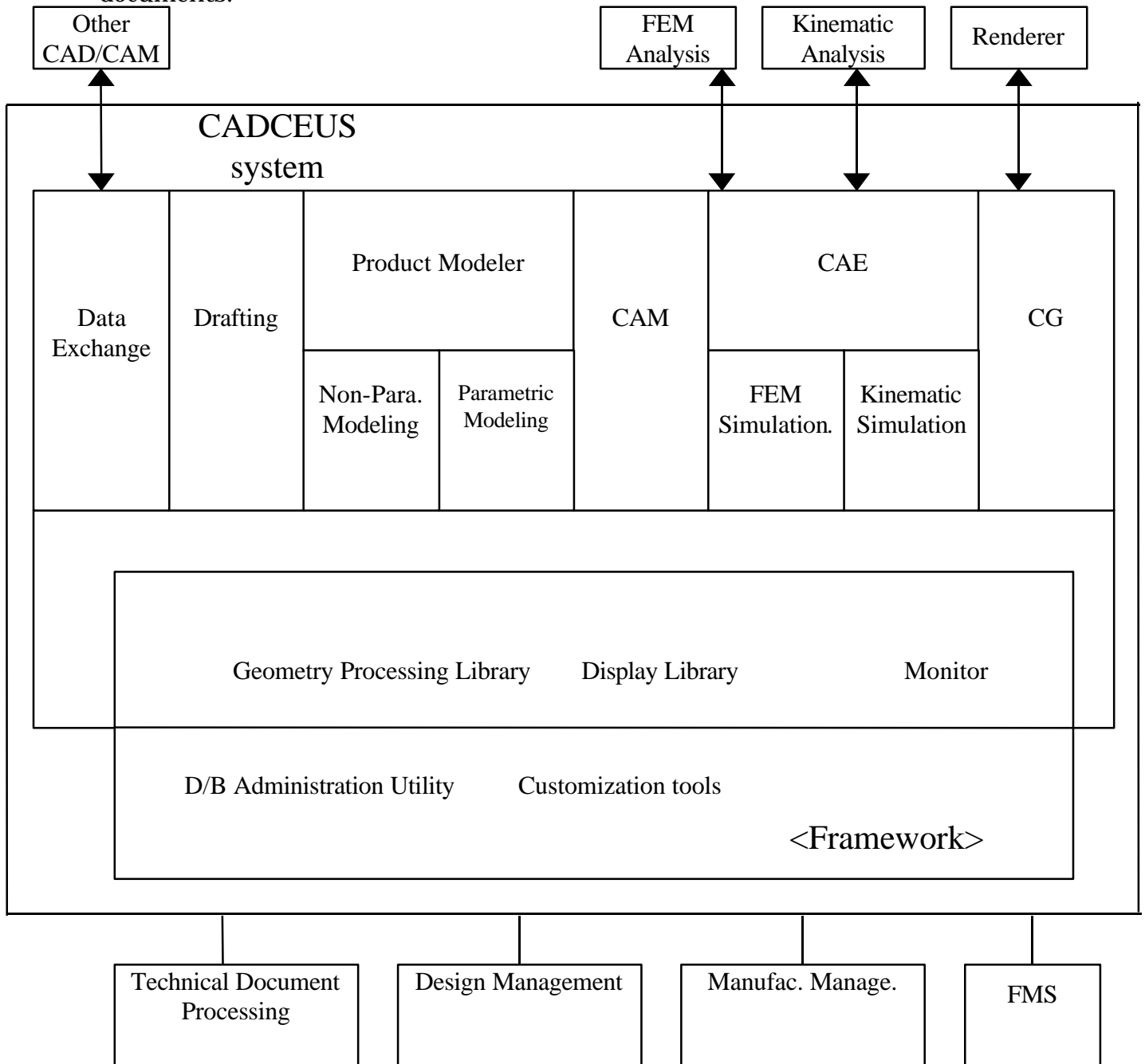


Figure7: Software Configuration

5.0 Functionality

CADCEUS provides various application functions to support product-model based product development processes. This chapter focuses on typical application functions of CADCEUS.

5.1 Modeling

Requirements of modeling functions varies depending on the nature of design activities in each process from early design to manufacturing preparation. Examples are design activity where determination of principal sections are crucial, design activity where object shape is designed by combining standard geometry, layout design of parts, detailed modeling of die faces, and so on. It is not realistic to satisfy variety of requirements by a single modeling approach. CADCEUS supports combination of the following modeling functions.

5.1.1 Geometric constraint modeling

Different from the conventional method of directly representing target shape as a collection of geometric elements, geometric constraint modeling is a method in which the system memorizes geometric constraints which the target shape must satisfy and variable parameters such as length and angle, and various relationships among parameters. When values are given to parameters, the system automatically generates shape satisfying all the prescribed constraints and the relationships among parameters. Constraint conditions include horizontal, vertical, parallel, perpendicular, length, and angle. CADCEUS is provided with a sketching function that facilitates the definition of geometrically constrained model. As an extension to geometrically constrained part model representation described above, parametric positioning between parts is also treated.

Compared with conventional modeling methods, geometric constraint modeling has strong advantage of being able to store design intents directly into the model. This capability is especially useful in those design activities where number of sectional geometry or fundamental shape should be studied with variety of conditions, design of slightly modified part shape, design

activities where registration and repeated use of standard shapes are dominant. Shape model generated by this method can be used as a profile of solid or surface primitive, or constituents of drawing. In combination with the procedural parametric modeling capability described in the next paragraph, automatic shape model generation is drastically improved.

5.1.2 Procedural parametric modeling(History based modeling)

In every product development processes, needs for modifying product shape frequently occur in order to meet the study of alternative design plans or to meet change of design. Procedural parametric modeling method strongly support these environments. In this method, the system memorizes shape modeling procedures and conditions.

When change of parameters, for example change of dimensions, or change of procedure itself occurs, the system automatically regenerates whole shape by re-executing memorized procedures with given conditions. This modeling method can be applied not only for solid modeling, but for surface modeling, wireframe modeling or their hybrids.

5.1.3 Form feature modeling

Form feature is a group of geometries which correspond to a functional unit that designers recognize. Typical features include protrusion, rib, fillet, and hole. Form feature modeling allows modeling operations not with conventional geometric segment level but with form feature level. In conjunction with procedural parametric modeling described above, shape modeling preserving form feature is made possible. Form features are application dependent by nature. It means that pre-defined form features are not sufficient for various applications. The user of CADCEUS can easily define own form feature by registering operation history for creating it.

5.1.4 Hybrids of conventional modeling and advanced modeling

It is understood that not all product shape is appropriately or efficiently modeled with the mixture of advanced modeling methods such as geometric

constraint modeling, procedural parametric modeling and form feature modeling. Based on this understanding, CADCEUS also supports conventional modeling with sophisticated capabilities such as automatic trimming of surfaces, set operation of surfaces with solids, advanced fillet generation, compound offset surfaces, wide variety of drafting capabilities etc.

5.2 Drafting

The features of the CADCEUS drafting capabilities are as follows.

5.2.1 Flexibility on various drafting standards

CADCEUS supports drafting in accordance with various drafting standards such as JIS, ISO, and ANSI.

5.2.2 Flexibility of units of measurement

CADCEUS allows dimensions presentation in various units of measurement in accordance with those used in shape representation.

5.2.3 Associativity between shape model and drawings

In the case of 3D shape model based drafting, CADCEUS handles each view of a sheet as a projection of the 3D shape model and memorizes the relationships between the 3D shape model and each projection. Manipulation of these relationships enables automatic reflection of shape model change on drawings. CADCEUS also allows independent visibility control of geometric elements in each view. Examples are change of line styles and visibility on/off control. It supports an automatic hidden line elimination function for solid models.

5.2.4 Parts list generation

CADCEUS allows the user to create a parts list by making use of table manipulation functions. The number of parts could be automatically

calculated from the hierarchical structure of the model.

5.2.5 Parametric drafting

CADCEUS allows the user to perform parametric drafting by combining geometric constraint modeling and conventional wireframe modeling functions. It means that dimension-driven parametric drafting where changes of the shape model on the drawing sheet satisfying all the prescribed constraints are automatically done in accordance of the dimension changes.

5.3 Computer Aided Manufacturing (CAM)

CADCEUS CAM subsystem supports various machining methods such as machining parts of complicated free form surfaces, drilling, and area machining of raw material and wire-cut machining, etc. The other features of this subsystem are as follows.

5.3.1 Machining planning

Capabilities for easing users definition of machining portion, machining range, machining methods and machining conditions are provided.

5.3.2 Cutter location calculation

This subsystem enables efficient machining for profile milling and character milling by automatically calculating cutter locations taking into account residuals of the previous machining process throughout the processes from rough milling to final finishing.

5.3.3 Treatment of machining knowhow

This subsystem allows the user to store various machining related technical information such as machining procedures and conditions. By the use of pre-registered information, the user can efficiently plan current machining.

5.4 Computer Aided Engineering (CAE)

One of the features of the CAE preprocessor is an effective use of form feature and parametric functions for easily obtaining idealized shape for FEM analysis.

Namely, very small holes or fillets which do not affect analysis results can be temporarily deleted by the use of above functions.

As for analysis model generation, automatic mesh generation capabilities for surface model and solid model, and adaptive mesh capability are provided.

As for analysis programs(solver), the user can select the most appropriate program for his application from among Unisys proprietary analysis programs MELTFLOW(resin flow analysis), CAST(resin solidification analysis), and METALFILL(metal flow analysis) or commercial analysis programs such as NASTRAN, MARC, ARGUS(nonlinear analysis of sheet metal), Applied Structure(sensitivity analysis, optimization analysis), and JOH-DYNA(shock analysis).

As for the post-processor, variety of animation functions in addition to the conventional output forms such as deformation diagrams, contour diagrams, arrow diagrams, and XY-graphs are provided.

5.5 Computer Graphics (CG)

CG subsystem mainly supports conceptual design by advanced rendering capabilities such as ray tracing or texture mapping, by painting functions such as image composition, and by various multi-media functions.

5.6 Data Exchange

The data exchange subsystem of CADCEUS consists of processors that provide interfaces listed below. They are organized around the intermediate file as shown in Figure 8.

- (1) STEP interface
- (2) IGES interface
- (3) JAMA-IS interface(JAMA: Japan Automobile Manufacturers Association)
- (4) Direct interfaces to major commercial CAD systems

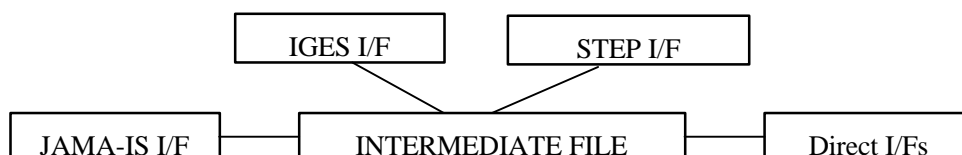


Figure8: Data Exchange Subsystem

5.7 Customization

CADCEUS is provided with customization capabilities which allow the user to establish his own operation environment, to add his own functions, and to promote automation. Major capabilities are;

- (1) Modify screen layout
- (2) Alter and reconstruct menu layout
- (3) Change messages
- (4) Add users own commands
- (5) Add users own subsystems

6.0 Conclusion

This paper briefly summarizes major characteristics and capabilities of CADCEUS which are expected to contribute drastic improvement of design environments ,and promotion of automation. The practical utilization of advanced modeling capabilities (such as parametric, geometric constraint, form feature) has just begun recently. Practical experiences of these capabilities will clarify real needs in actual design and manufacturing environments. We intend to sophisticate these capabilities based on real needs. We also feel it necessity to make positive efforts to extend CADCEUS for establishing world wide collaborative environments.

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