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Towards an Integrated Support Environment for CIC; Design to Construction of building assemblies.

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1. Current practice

Current building design practice is characterised by a disparate set of CAD systems for drafting, geometric modelling and visualization and an increasingly wide range of independent, application specific programs for design analysis (structural analysis, lighting, energy, cost estimation). Experiences with previously designed and executed building are not fully utilized. Further integration of design and construction in the building industry is indispensable to improve quality while lowering costs and reducing development time.

The elimination of unnecessary barriers in the sharing and exchange of data between computer applications would establish basic conditions for integrated product development. Further improvements in the processes of generating, modifying and sharing product information are required to increase the capability for building modelling and information management. Progressive intègration of information flows between computer applications should ultimately lead to an Integrated Support Environment for Design and Construction with extensions to Building management and Facility management.

2. Building representation

A product lifecycle approach, integrating object- and projectdata and the various processes over the entire lifecycle, provides a general framework for determining the information needs of building design and construction.
The conceptual building model has to fulfill multiple demands, in different stages of productdevelopment and usage, from various users and applications. The various partial representations nevertheless refer to one and the same building object; integration of the different "external views" is required.

The buiding model must allow the various participants in the building process to define their personal view, eliminating all unnecessary detail, and concurrently ensure over all users and applications a valid and consistent representation. General criteria to be fulfilled by the building representation and its underlying datamodel include: validity, completeness, consistency and non-redundancy. The extent to which these requirements can be met, in the conceptual model and its implementation, depends upon the expressive capabilities of datamodels to formalise semantic meaning and integrity constraints resp. the practical limitations of DMBS-technologies and knowledge representation techniques.

The model of the building-object as a final product evolves, in the course of the designproces, through a series of transformations. A structured set of functional specifications and budgettary constraints is first transformed into spatially structured functional areas and volumes. Concepts of form/shape and dimensions gradually materialise; the spatial and material structure of the building-object is further specified in conjunction with the representation of form and dimensions.

The iterative determination of form , dimensions and product-structure results in the specification of the final product, reflecting more detailed functional specifications, and estimates of costs and expected performance on a variety of design criteria. Continuous cost/quality trade-offs are involved. The "product-structure" consists of interdependent, spatial and physical, structures.

The physical realization of the building, during construction, involves the technological transformation of the physical productstructure (assemblies, components and materials) into scheduled operations ("in situ" manufacturing of parts and assembly operations). Procesplans for manufacturing and assembly describe operations, times and costs, include technology data as well as references to equipment and tools. Productionplanning and control of building operations incorporates material supply and handling, resource allocation (labour and equipment) and capacityplanning.

The building in progress constitutes the workspace for assembly and "in situ" manufacturing operations; the spatial structure of building determines the organisation in space for assembly operations and "in situ" manufacturing. Simulation of construction operations, including the aassociated equipment and workspace layout should be considered as an integral part of the design process in CIC.

The building, a composite spatial-physical object, is composed of spaces, assemblies of building elements and materials. As a

3-dimensional object, the building can be represented (in relative and world-coordinatesystems) as a combination of interrelated solids and voids with topological, geometrical and non-geometrical properties. The latter refer to functional, physical and economic properties of the various entities and relationships amongst them; the non-geometrical attributes may also include data on technology, operations and resource-requirements. The material productstructure of a building can generically be represented as an ordered set of assemblies of assemblies, each consisting of various componenttypes.

Abstraction hierarchies suitable for modelling building design data can be obtained through abstraction ("class"- or "type"- concept ; property inheritance) and aggregation (compound entity-classes). In addition to "part of"/"contains" and " connected to" relations used in modelling the spatial and physical structure of the building, relationtypes include:
-"delimits"/ "bounded by" (space-material associations);
-"precedes"/"succeeds" (structure of operations);
-"provides"/"utilizes resources" (supplier-resource relations).

The product-specification at the component-level is not limited to dimensions and materialproperties and tolerances, but may also include assembly- and manufacturing -"recipes" (activities and resources, times and costs) and maintenance-expectations.
The generic form of the productstructure can be represented by a semantic network, including both one-to-many and many-to-many relationships, with property inheritance.

3. Modelling products and processes.

Design to production includes functional modelling in close relation with productmodelling and productionmodelling (engineering, planning and control) within a famework of projectmanagement. Further extension of solid modellers into purpose productmodelling systems poses difficult problems in terms of data structures and efficiency requirements. The capability to deal with spatial and non-geometrical data simultaneously is fundamentally limited. A far higher degree of flexibility in combining spatial and non-spatial data is required than currently provided by geometric modelling systems and administrative DBMS.

Productdevelopment covers the entire trajectory from specification of functional requirements phase to physical realization: from the client's brief and initial design concepts to the finished product. Product modelling, in its broadest view, would include functional, spatial and technical modelling and incorporate the technological and administrative data to generate process plans for manufacturing and assembly.

A clear allocation of modelling functions is required. Functional analysis and modelling is primarily concerned with the specification of overall functional requirements, without prespecifying spatial/physical or technical realisation. In strong contrast with the predominant orientation of industrial CAD-CAM systems to the creation and analysis of physical objects and assemblies, architectural design has been primarily concerned with the support of architectural form generation and spatial layout design. The preliminary and detailed design of building assemblies constitutes the most direct and strategic linkage between design and construction. Productmodelling, to be implementable in practice, demands a sufficiently broad range of modelling functions, embedded in a integrated support environment.

The basic objective of a productmodel is to create and maintain a complete, consistent and non-redundant representation of the building being designed in different phases over the entire lifecycle. Applications generate and/or use product data. The major challenge is not only to structure and integrate data into a generic productmodel but to provide a support environment with a sufficiently wide range of modelling functions and powerful tools to create an appropriate model of a particular building. Transformation of a "generic" productmodel into a particular building product representation involves stepwise refinement by adding detail and auxiliary information. General productmodelling functions include : functional and technical specification, the determination of form and dimensions, determination of productstructure, cost and performance estimation and the transformation of productstructure into building operations.

4. Design to Construction of assemblies.

In spite of the immense diversity of products and processes and the uniqueness (at least in some respects) of each building project, a great deal of "commonality" exists at the level of assemblies, components and working methods. Productfamilies and group technologies can be identified.

Improved support of the design of physical assemblies in 3D space and their constituent components may be considered the most essential step in the adoption and futher development of productmodels and progressive integration of computer applications toward CIC.

An assembly is designed as a spatial-physical object in space with its inherent topology and geometry, within a framework of space-space relations and space-material associations
By parametrization a whole family of parts can be created by instantiation of a component type modification of parameters. Sets of (mathematical or trigonometrical) parametric relations can be used to define and control the geometry of the part and incorporate functional technical or manufacturing constraints and capture design intent.

A reference geometry (multiple coordinate systems, planar surfaces as datum planes, axes) allows integration into the design space. Standard components may include basic parts such as nuts and bolts, columns, walls, floors, stairways.
Form features and design elements may be used as basic building blocks in the creation of complex parts and assemblies.
The part serves as a base feature to build an more complex finished part by adding and refining form features, such as holes, slots and grooves or rounds.

The type-concept provides a conceptual basis for adaptive and parametric design. The aggregate-concept corresponds with assemblies involving combinatorial design of different component-types and their instances or occurrences.
Design integrity cannot be assured by static constraints on data integrity. Combinatorial and innovative design demand a sufficiently broad range of conceptual modelling capabilities to define the new components and/or assemblies as new entities.

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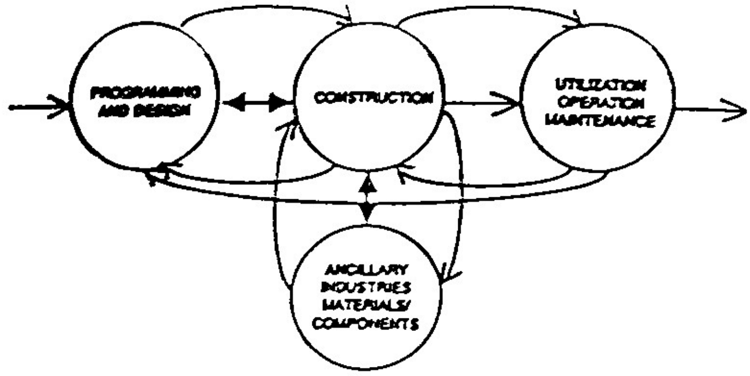
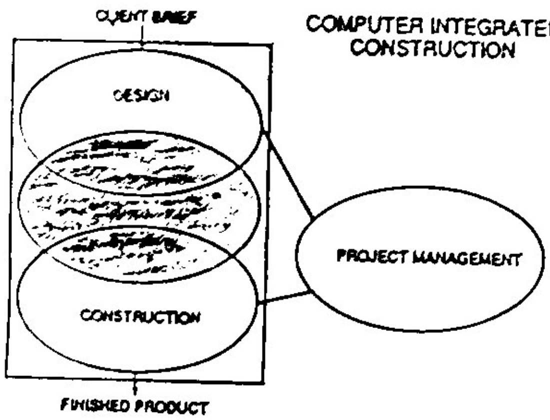
COMPUTER INTEGRATED CONSTRUCTION (CIC)



COMPUTER INTEGRATED CONSTRUCTION



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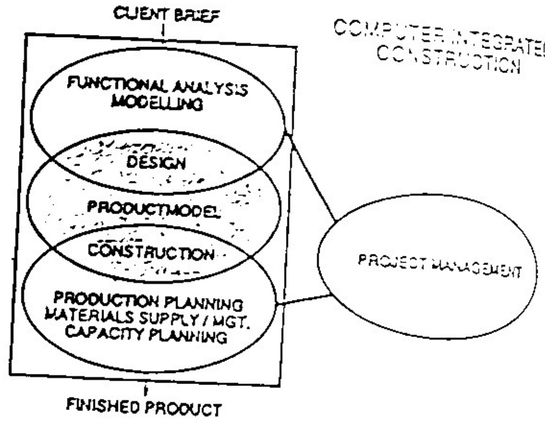
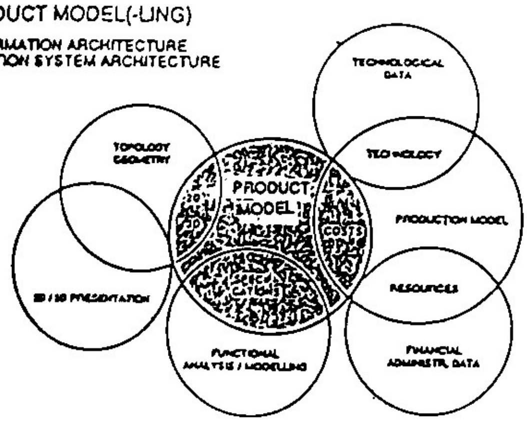
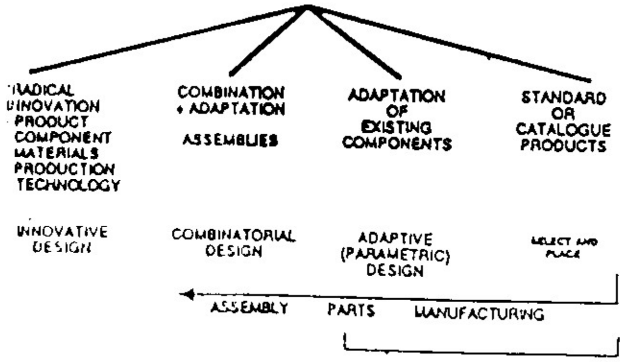


PRODUCT MODEL(-LING)

INFORMATION ARCHITECTURE
INFORMATION SYSTEM ARCHITECTURE



DESIGN TO PRODUCTION CIC



ASSEMBLY /, COMPONENTS VARIANTS IN PRODUCT-DEVELOPMENT

ASSEMBLY / COMPONENT	EXISTING (STANDARD)	ADAPTED (VARIANT) CUSTOM DESIGN	INNOVATIVE DESIGN
STANDARD PREVIOUS DESIGN	*	?	?
SPECIFIED TYPE "INSTANCE" PARAMETRISED	*	?	?
MODIFIED CUSTOM DESIGN	?	??	???
INNOVATIVE DESIGN	?	??	???