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COMPUTER INTEGRATED CONSTRUCTION

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ABSTRACT

The purpose of the automated, computer-integrated building realization process is to generate, automatically, all the information and the related documents for the design and the construction of a built facility. The paper reviews the concept of the computer controlled realization process and describes the knowledge base of the system employed for this purpose.

INTRODUCTION

The general concept of computer-integrated construction has been presented and discussed in many publications, e.g. [Sanvido 1992),)Teicholtz 1994), and others. The basic idea behind this concept was the employment of a common project model and knowledge base which could be shared by all actors to the design and the construction process - the developer, the designers and the constructors.

The central aspect of computer integrated construction - the product modelling of built facilities, has been extensively covered in the literature. An international standard - ISO 10303 - STEP - has been developed for computer representation and the exchange of product information. Many publications [Bjork 1992),[Sanvido 1992),[Gielingh 1988), [De La Garza 1992[, Pentilla (1990), Hartman (1991) and others, have delt with the development of a common model, within STEP or independent of it, for all AEC (Architectural, Engineering, Construction) applications. There are two main differences between the approach suggested here and those presented elsewhere:

a. The system presented here involves not only the representation of knowledge but also its generation for the various stages of the realization process.

b. It is specifically adapted to a specific type of buildings. This reflects the opinion of the authors that "generic" systems cannot effectively address the various issues of implementation.

The purpose of the automated, computer-integrated building realization process is to generate, automatically, all the information and the related documents for the design and the construction of a built facility. The realization process is computer-integrated in the sense that all the parties to the process have access, by appropriate application software, to a common computer-driven information base, which contains all the pertinent information about the facility at its various realization stages. The parties can therefore generate, modify, and share data on a real time or near real time basis. Even more importantly, the data at these stages is processed with the aid of a knowledge base, which in addition to all the pertinent information about the facility and its technological and business environment, also includes decision rules, algorithms and procedures, for processing this information in view of the user's objectives.

The process may be further extended to include the physical construction of the facility, off-site production of its components, and later its operation and maintenance. This implies employment of robots or other automata in construction.

The expected benefits from the process are as follows: saving of routine human work- in design and construction, improvement of the quality of building design and construction and effective coordination between the various parties to the construction process: all have access to common information about the process, and can follow time its transformation in real time.

THE NATURE OF THE AUTOMATED SYSTEM

The particular direction which has been pursued at the National Institute of Building Research in Israel (NBRI), has been described in [Warszawski 1990[. It involved a building of prefabricated components (columns, floor slabs, and exterior walls) manufactured off site, with the remaining finish works performed by a multipurpose interior construction robot.

Various stages of this project have been explored: a preliminary design [Wiezel 1991], detailed design [Retik 1994), performance analysis of the design [Becker 1993], schedule control [Retik 1994), general construction planning [Shaked 1994], (micro) planning of robotized work [Warszawski 1994], and robotized construction [Rosenfeld 1992]. However, each of these stages was developed separately with its own information modeling and application software.

The present paper reviews the elements of a computer-integrated building realization process and the approach to its development, dwelling mainly on the conceptual aspects of the development.

The main stages of the computer integrated process - defined by their output - can be enumerated as follows:

a. Statement of developer requirements from the facility.

b. Brief, which defines in specific (usually verbal) terms all the parameters of the facility, necessary to satisfy the requirements of the developer.

c. Preliminary design, which shows (in a graphical fashion) the layout and the elevations of the facility.

d. Detailed design (in terms of production details) of all the components of the facility.

e. Construction plan - the method of construction, and the allocation of resources to various activities, their organization, schedule, and budget.

f: Procurement plan of all the materials, components, and services necessary for the construction.

g. Microplanning of the robot work (for robotized construction).

h. Monitoring of the robot work (for robotized construction).

i. Construction control and contract administration.

j. Operation and maintenance of the facility during its useful life cycle.

These stages are depicted schematically in a process diagram, shown in fig. 1.

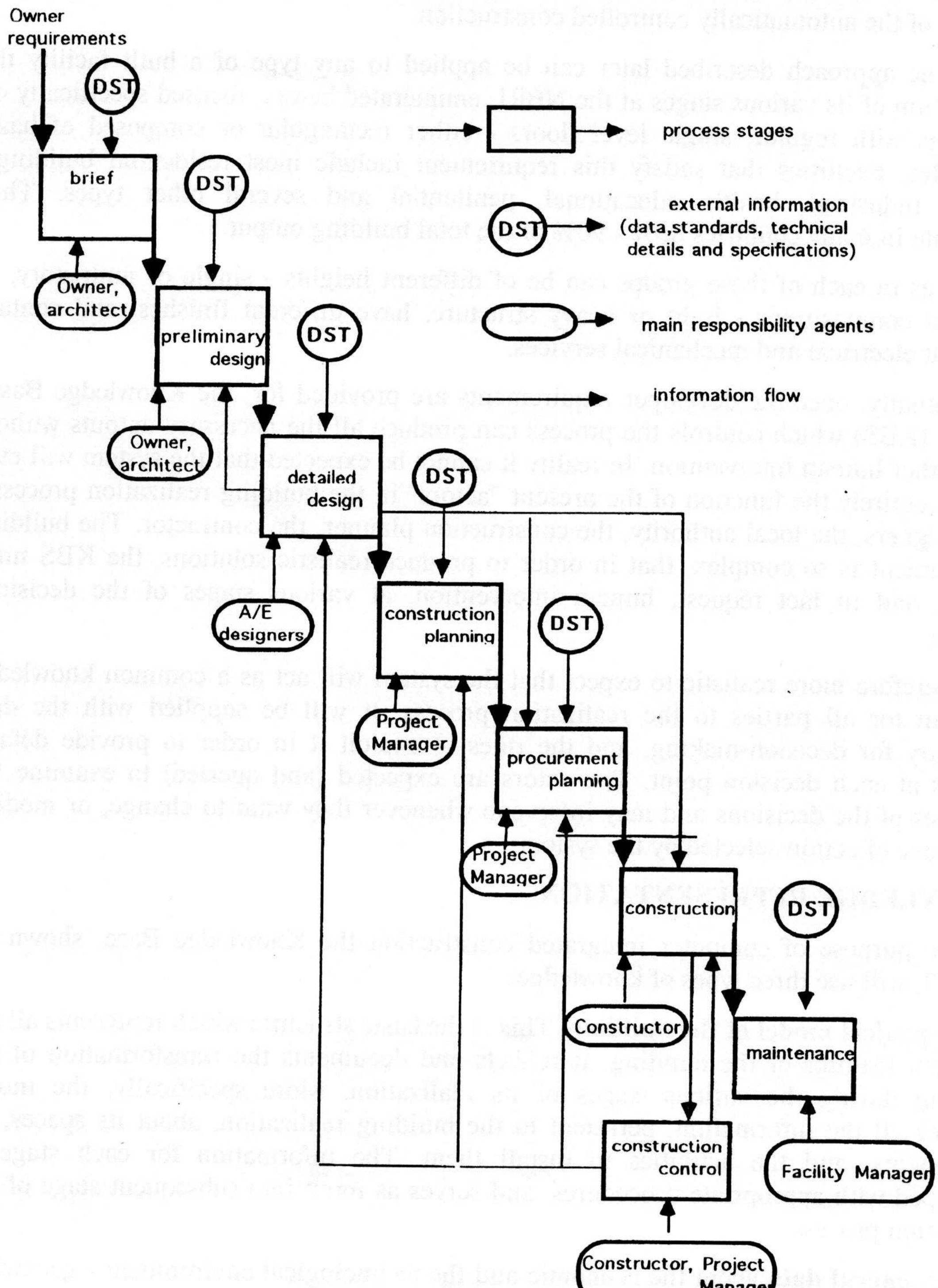

Figure 1- A schematic diagram of a computer integrated building realization process

This paper discusses the possibility of integrating the various stages - from generation of the brief to robotized construction - into one integrated sequence, with each stage receiving as an input the information generated in the previous stage, or stages. Another option of non- automated - manual or "traditional" construction, designed, planned, procured and monitored automatically can be considered as a special case of the general concept of the automatically controlled construction.

While the approach described later can be applied to any type of a built facility the exploration of its various stages at the NBRI, enumerated before, focused specifically on buildings with regular, single level floors - either rectangular or composed of basic rectangles. Facilities that satisfy this requirement include most residential buildings, offices, industrial, health, educational, penitential and several other types. They constitute in many countries 85% - 90% of the total building output.

Buildings in each of these groups can be of different heights - single or multistory, of different compositions - light or heavy structure, have different finishes, and contain different electrical and mechanical services.

Conceptually, once the developer requirements are provided for, the Knowledge Based System (KBS) which controls the process can produce all the necessary outputs without any further human intervention. In reality it cannot be expected that the system will ever obviate entirely the function of the present "actors" in the building realization process - the designers, the local authority, the construction planner, the contractor. The building environment is so complex, that in order to produce realistic solutions, the KBS must permit, and in fact request, human intervention, at various stages of the decision-making.

It is therefore more realistic to expect that the system will act as a common knowledge platform for all parties to the realization process. It will be supplied with the data necessary for decision-making, and the rules to exploit it in order to provide default options at each decision point. The actors are expected (and queried) to examine the premises of the decisions and may intervene whenever they want to change, or modify, the course of action selected by the system.

KNOWLEDGE REPRESENTATION

For the purpose of computer integrated construction the Knowledge Base, shown on figure 2, will use three types of knowledge:

a. **The project model of the building**. This is the basic structure which represents all the pertinent features of the building. It reflects and documents the transformation of the building during the various stages of its realization. More specifically, the model includes all the information, pertinent to the building realization, about its spaces, its components, and the activities to install them. The information for each stage is developed with appropriate procedures, and serves as input into subsequent stage of the realization process.

b. **The general data** about the economic and the technological environment - geometry, performance aspects, costs, input resources etc., of functional spaces, systems and components. The latter will be represented by "templates", i.e. parametric entities. The value of the parameters in the templates will be determined by application of procedures to the context data.

c. **The procedures** - rules, functions, algorithms, and queries from the user and the data base, which are necessary to advance the model from one stage to the next, with respect to all its objects. The procedures may be related to particular objects, or to hierarchies of objects.

The interface with the user serves for display of information, queries and interaction with the user.

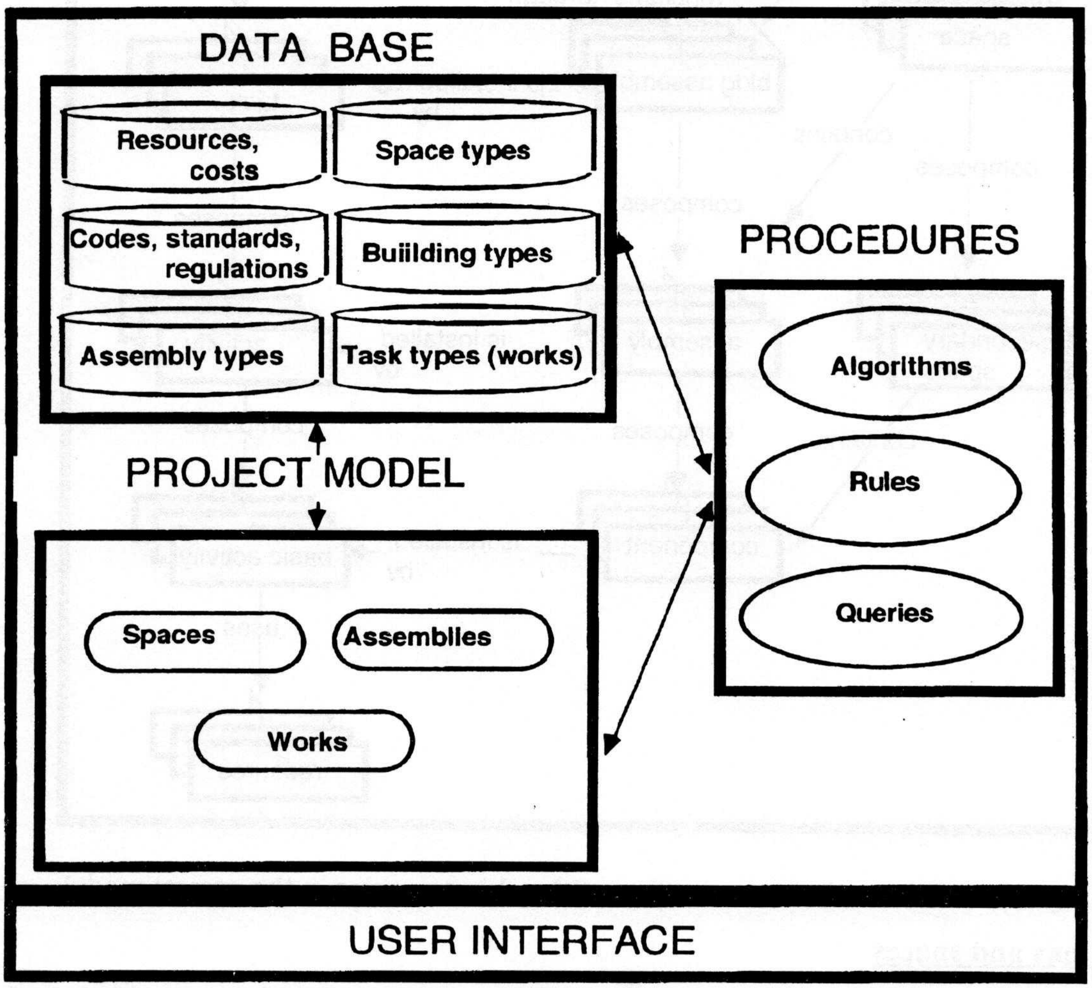

Figure 2 - The Knowledge Base of the system

THE PROJECT MODEL

The object oriented representation of the project model presented here uses three types of object hierarchies: for the representation of spaces, for the representation of functional systems, and for their installation. Each of the object entities has attributes which define it in terms of physical properties, performance or installation method. These attributes are added to the model at each stage of its development with the aid of the KBS procedures.

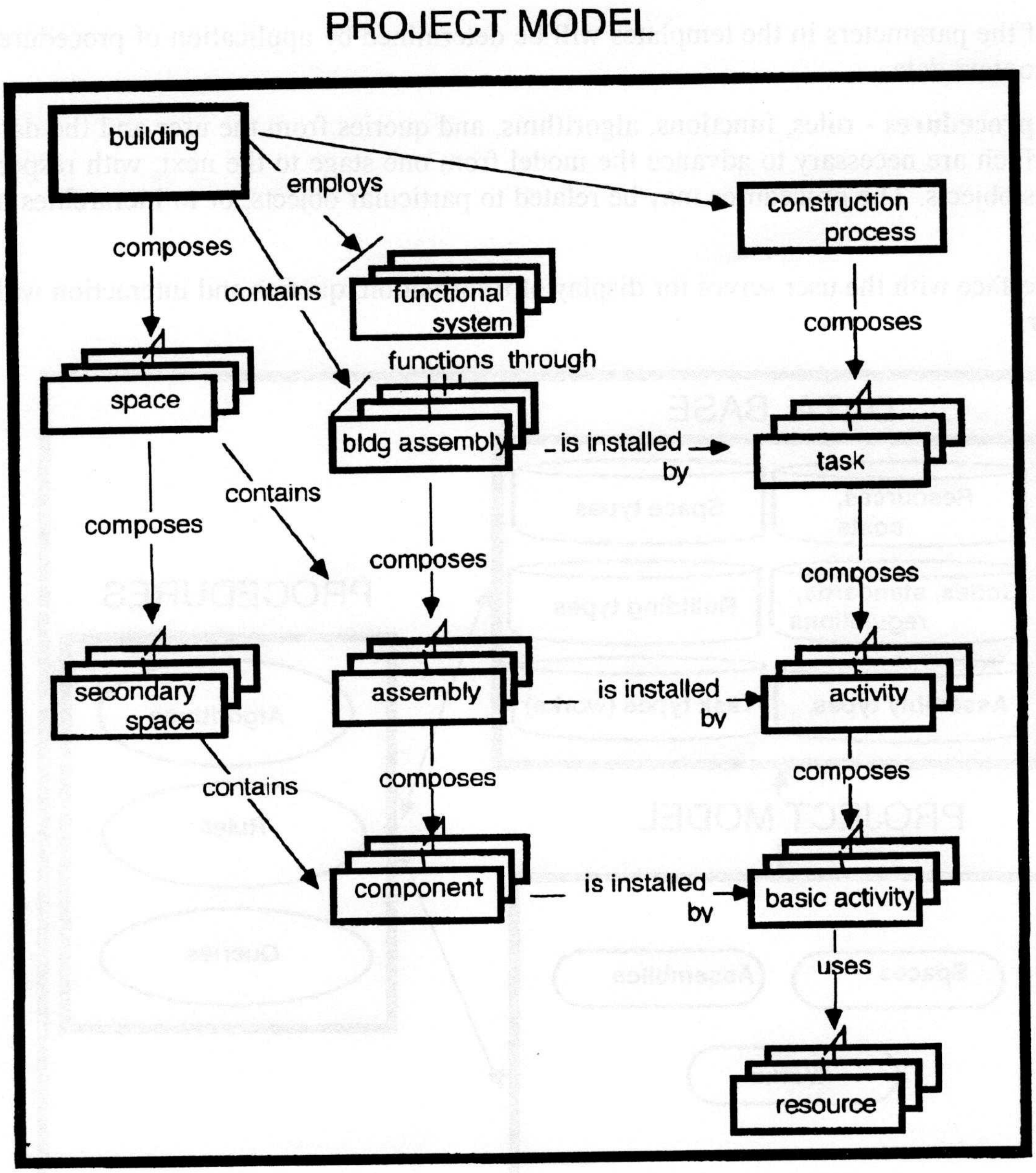

Figure 3 - Schematic representation of the object-entities in the project model

Functions and spaces

The basic purpose of any building is to provide a suitable shelter for general use or the uses required by the developer ("use" has the same meaning as "function", which will be reserved for the systems in the space). A general function may be residence, industrial activity, health care, commerce, administration, culture etc. To provide that shelter, the building is composed of three-dimensional bounded.spaces.

The spaces for the purpose of this presentation can be divided into primary and secondary ones. A primary space forms a distinct closed unit (at its 4 vertical faces or their substantial parts) with respect to the outside of the building or to other spaces of a different geometry. A secondary space is a fully or partially bounded part of a primary space.

Two types of primary spaces can be distinguished in the particular type of buildings examined here:

a. Floors - each floor with its own use e.g. office floor, residential floor, mechanical floor, laboratory etc. The floor may act as one undivided space, or it may be composed of secondary spaces - for example dwellings, rooms, toilets etc. Whether to subdivide it or not - depends on the context of the information needed at the particular stage of the building realization process.

b. Vertical shafts for staircases, elevators, or pipes, which connect the floors. These can be also divided, if needed into secondary spaces.

The spaces are generated with the aid of the data base as a feasible solution to the general requirements of the developer.

'The space (primary or secondary) - as an object - has these main attributes: use, location, geometry, and performance aspects - acoustics, illumination, capacity, loading etc. as well as the systems involved in these aspects.

Functional systems and assemblies

The building and each of its spaces performs its function with an array of functional systerms Examples of such systems are exterior enclosure, space dividers, structure (horizontal and vertical), lighting, plumbing, finishes, HVAC etc. The physical components of a functional system, using a particular technology can be grouped into *work assemblies.* These assemblies can operate on the total building level, on the primary space level or a secondary space level. For example, the concrete skeleton of all floors is a structural support assembly on a building level, which can be then subdivided into assemblies (e.g. floors and columns) on a space level.

The assemblies can be subdivided into individual components (e.g. columns on a particular floor) for the purpose of detailed design and the generation of production drawings.

The assembly is generated as a feasible solution to the performance requirements of the functional system and of the space it is going to serve. It has as its main attributes - the physical properties, specifications, dimensions, and the activities required for its installation.

Works, tasks, activities

A functional system can perform its specified function with alternative assemblies of physical components. These physical components can be classified according to the works - the methods, or technical solutions - with which they are produced and installed. For example, interior space dividers - a functional system - can be made with different worksmasonery of concrete blocks and mortar, gypsum boards on timber studs, etc. The attributes of work are: typical details, specification, dependence on other works, the nature of resources (materials, labor, and equipment) necessary for their execution, their possible combinations, and their quantities per unit of output in each combination.

Assemblies at the space level are installed by activities. . A group of activities installed by the same team of workers is referred to as a task.. The activities can be broken into basic activities for the installation of each individual component. The basic activities consume resources : labor, materials and equipment work.

Works conform to assemblies and include as their attributes the resource inputs necessary for their installment and its precedence relation to other works. Work performed in a particular space is an activitv. The attributes of an activity are the resources (inherited from its work) the relations with other activities and the time (early, late) of its execution.

THE DEVELOPMENT PHASES

The development of the system will be carried out in the following phases:

a. Development of the project model.

b. A complete representation of a specific building with the model.

c. Testing the system for a transfer form one realization stage to another : from preliminary design to detailed design (structural view).

d. Development of other realization stages.

CONCLUSIONS

An automated system is being developed for the realization of multistory rectangular buildings.

Automated building realization system receives as an input the developer requirements and generates, by application of AI procedures, the information necessary for realization of the various design and construction stages.

The system includes the object representation of the project, the data base with the generic information about spaces, functional systems and works, and the procedures for automated transformation of the model from one stage to the next.

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