AN OBJECT-ORIENTED PPROJECT MODEL APPROACH FOR INTEGRATED INFORMATION SYSTEM IN A/E/C INDUSTRY

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Abstract

As clients' requests are becoming more diverse and extensive than ever, it is necessary to concentrate company whole efforts and to fortify cooperation among different divisions in the A/E/C industry. In the past; development of information systems, was basicallyfocused on increasing efficiency of particular domain tasks, and was not enough to respond current problems. Therefore, a new method of developing collaborative and integrated information systems is required to synthesize resources in order to achieve total efficiency. However, it is difficult to generate, share and maintain project data during the various phases of the A/E/C project life cycle from planning to design, construction and management of the facility. The project data needs to be stored, retrieved, manipulated, and updated by many project participants, each with his/her own view of the information. In order to fully realize the model description of an A/E/C project, such a project model should support both product-based description and process-based description. Therefore, the author has been proposed an object-oriented project model (called PMAPM) supporting the multiple views that are required by various participants in A/E/C projects, which is very important for integration of the A/E/C industry.
The scope of this research is to establish an object-oriented project model supporting multiple views shared by various A/E/C project participants and provide several type of sub-product models for by computer-based systems using multiple views. The objective is the eventual development of an integrated system which includes activities from project planning through design, estimation, construction and facility management. The object-oriented project model is intended to link CAD systems, relational databases, knowledge-based expert systems and other conventional software. This paper describes the development, present status and future directions for PMAPM, an object-oriented project model designed to facilitate information sharing along the paths through which work flows between project stages or specialists.

1 INTRODUCTION

A number of computer-based systems, such as CAD, structure analysis, simulation software, knowledge-based expert system and so on, have been developing for the A/E/C industry. However many of these systems can only be utilized within narrow application domains. It means that these systems increased the productivity of each domains work but did not enough increased tottal productivity of project yet Because the project information, which will be needed for each domains, are only stored into the domain specific database or files for data exchange and the development of providing data transfer interface should be needed to realized a richer communication among applications of different domains. Therefore, project model that can properly describe a facility and is accessible by multiple participants of different disciplines is a very important ingredient for integration for A/E/C industry.
In building design, using databases for storing a large amount of independent but interrelated data about design elements and their relationships provide a benefit for us.

The objects observed in a building project are best modeled by an object-oriented model. Elements (such as columns and beams) can be defined as individual object types, and their properties (such as length and weight) are defined as attributes. Operations on the objects can be defined using methods. Many researchers have been attempting to develop a product model or a project model using object-oriented methodology. On the other side, some researchers have been attempting to realize a integrated system using a product model or a project model. [Penttila 89], [Sriram 89], [Sanvido 89, 90] and [Ito 90,911. However, there are few results to realize a global product or project model which is shared by the various participants or many applications of an A/E/C process.
Therefore, establishing of project model which support the multiple participants needs is a key issue for the computer integrated construction and this research result will provide the better environment for future integration.

2 PROJECT MODEL

In order to share the constructed facility information, an object-oriented product model approach is very useful to describes the building elements. Therefore, there are many researches on product model itself or system integration using a product model. However, many kind of information are refereed and created through the project life cycle, not only product information but also process related information such as project constraint. Moreover, each participant of an A/E/C project has own view of the information about a constructed facility. In general, for each project, there is one facility and the object representing the facility has only one physical value but many functional values depending on the various views of the information by the participants of different disciplines. It means that each participant has own viewpoint, own data requirement, own data format and own computer-based applications. Therefore, the product model which describes the constructed facility should provide both of product-related and process-related information to any participants.

2.1 PRODUCT MODEL

In the A/E/C industry, integrated information systems means the computer-based environment which provides both of product information and process information for any project participants at any time by any applications. Then for the integrated information system environment, information sharing mechanism for any participants is most important issue. This mechanism will be consisted by the product model which is not depend on the specific participants view. In this research, the definition of product model is to describe the building facility by:

- Define the building elements as a class object.
- Support not only physical elements but also non-physical elements.
- Define the actual element information as an instance object.
- Inherit the welldesigned attribute of the class object to the instance object.
- Define the relationships among the instance objects.
- Independent of any applications or domains.

On the other side, to realize a integrated information systems environment, not only the common product model but also a domain specific product model should be considered as a sub product model. Because, there are many conventional applications which have not the interface to access to the common product model. Then the process model which will be described below should provide required information as the sub product model for conventional applications from the common product model.

2.2 PROCESS MODEL

Through the project Life cycle, the project information needs to be stored, retrieved, manipulated, and updated by many participants of project by his/her own view point. For example, architect and structure engineer has own view point for columns or walls at the design stage. However, these columns or walls are physically same objects. Therefore, in the integrated information systems environment with common product model, the mechanism which will access to the common product model according to the participants needs are required. In this research, the definition of process model is to describe the A/E/C project process or participants work by:

- Define the organization or main tasks of process as a class object.
- Define the each participants work of project as a subclass or instance object.
- Define the detail tasks or applications as an attribute of instance object.
- Inherit the welldesigned attribute of the class object to the instance object.
- Store the process-related information as an instance object or attribute.
- Depend on the company organization.

Using this process model, each participants dose not need to know the structure of the product model, attributes of instances and interface systems for any database or applications, because participant behavior has been analyzed and embeded into the process model.

2.3 PMAPM

According to the above definition of process and product model, the author have been proposed the object-oriented project model called PMAPM (Object-Oriented Project Model for A/E/C Process with Multiple-Views) [Ito 90]. In PMAPM, there are many kinds of building elements defined as an object with properties and there are many kinds of view defined as an object which are according to the view points of each participants of project. (Figure-1 shows the top-level class objects of PMAPM and Figure-2 shows the some part of process model hierarchy of PMAPM.)

Moreover, the process model which is including several kind of methods in order to retrieve and update the project information from product model according to any participants requirements.

From the process point of view, an A/E/C project consists of many stages corresponding to the view definitions in PMAPM model, such as project management view, general view, project planning view, sales view, design view, estimation view, construction view, facility management view and so on. The project management view (for the project manager) and the general view (to store the general information about the project) provide the high level control and support of project information. The other views about a project follow the various phases of an A/E/C process. For each view object, we can further define object subclasses according to the participants work as sub-view. Therefore, the differences between process model description and product model description in PMAPM are follows:

- To define an object hierarchy describing the physical and non-physical building elements used in the design and construction of a facility as a product model and these objects have not only a graphical information but also their properties and its relationships with other objects.
- To define an object hierarchy describing the project work or participant's view point used through the project life cycle as process model and these view objects consist of not only the data but also many kinds of methods, functions and rules in order to extract or update the information according to each participant's need.

In PMAPM, using a combination of these separated models, multiple participants of a project are sharing the same information of the facility and they can extract or update

the information according to his/her own view by this object-oriented multiple-view approach.

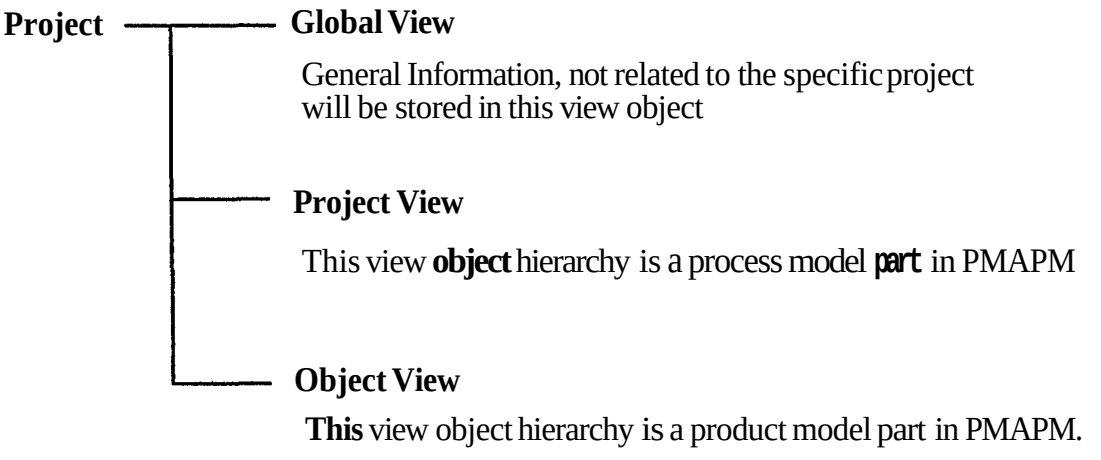

Figure-1 Top Level Class Definition of PMAPM

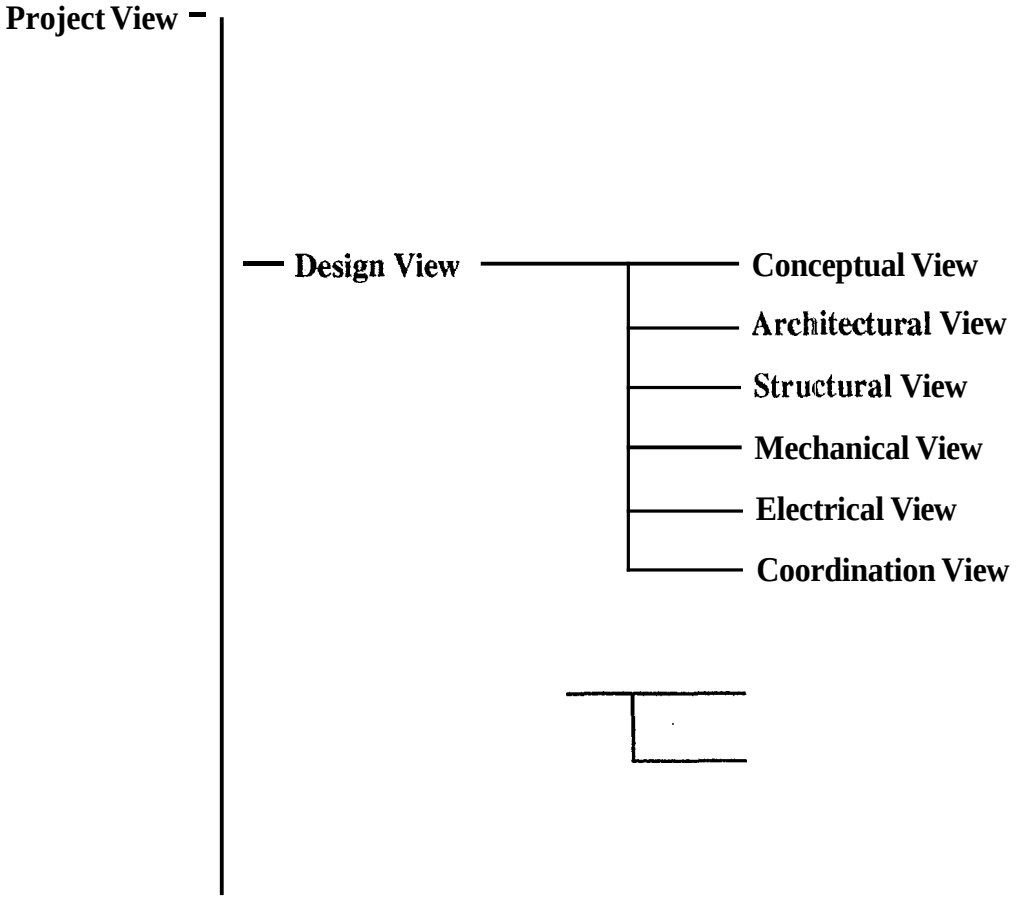

Figure-2 Example of Process Model Hierarchy in PMAPM

3 INTEGRATED INFORMATION SYSTEM

The basic concept of an integrated information system using PMAPM is schematically depicted as shown in Figure-3. In this section, I describes the main methods in process model of PMAPM in order to support the various participants. Also the example of related applications will introduce which PMAPM can provide the information as a sub-model of PMAPM.

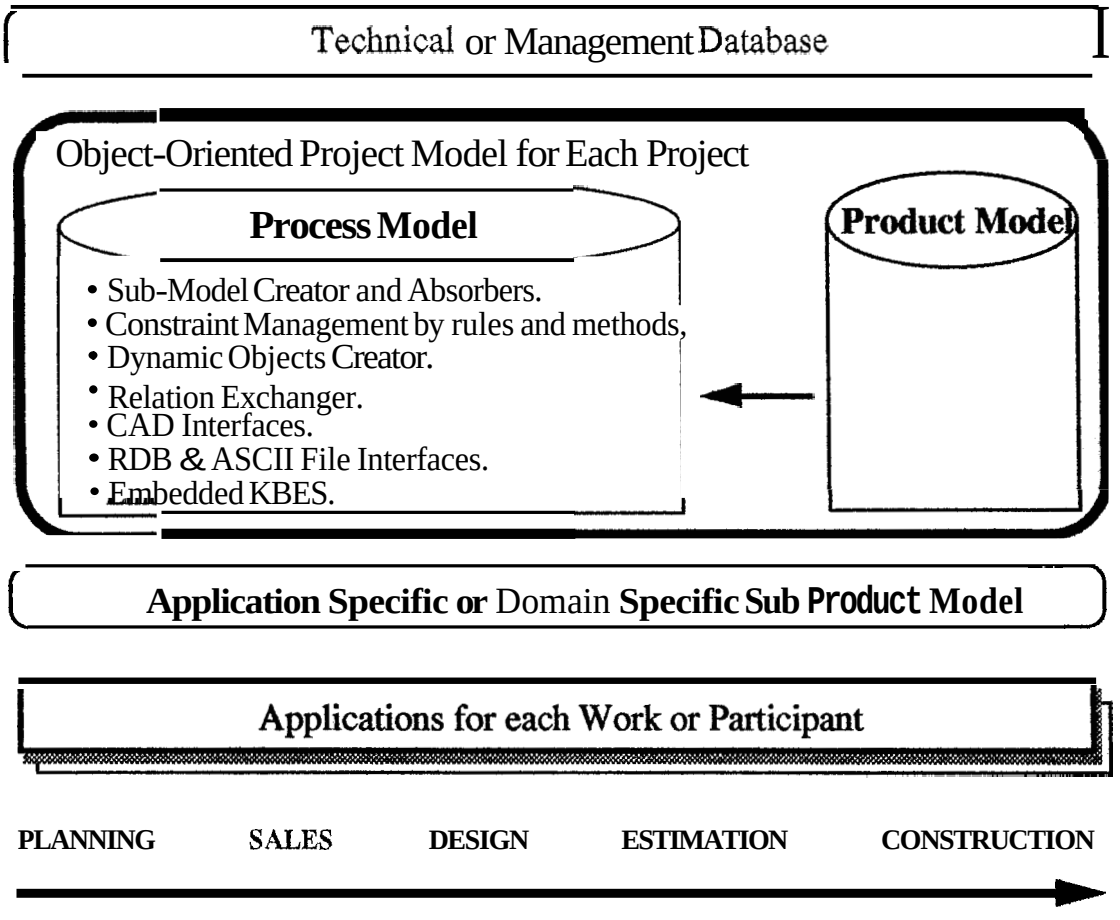

Figure-3 Integrated Information System Image using PMAPM

3.1 SUB-MODEL CREATOR AND SUB-MODEL ABSORBER

In order to provide or capture the domain specific or application specific information as a product model, the object-oriented process model in PMAPM provides the functions or methods which extract the data from the product model or store the data to the product model according to the participants needs. Then these functions or methods are interface systems between the common product model in PMAPM and the sub-product model which has domain specific or application specific object hierarchy or attributes. In general, such a functions or methods should support any type of product models which are described an object-oriented hierarchy. However, current PMAPM supports only some kind of sub-product model which created by PMAPM itself. Additionally, PMAPM can capture the building elements information from CIFECAD model which is created by CIFECAD.

3.2 CONSTRAINT MANAGER

Using PMAPM, multiple participants of a project can share the same information and it realize a richer communication among participants. However, it will occur many kind of conflicts among these participants. These conflicts are stored as constraints in views and propagated and resolved by the constraint management system named Constraint Manager in PMAPM. Currently, Constraint Manager creates, propagates, explains and evaluates constraints according to the participants needs through each view object functions or methods and send the alert message to the affected participant's view objects. Especially, Constraint Manager in PMAPM can control the non-physical constraint which will be created through the project life cycle. (Figure-4 shows the constraint management cycle of project)

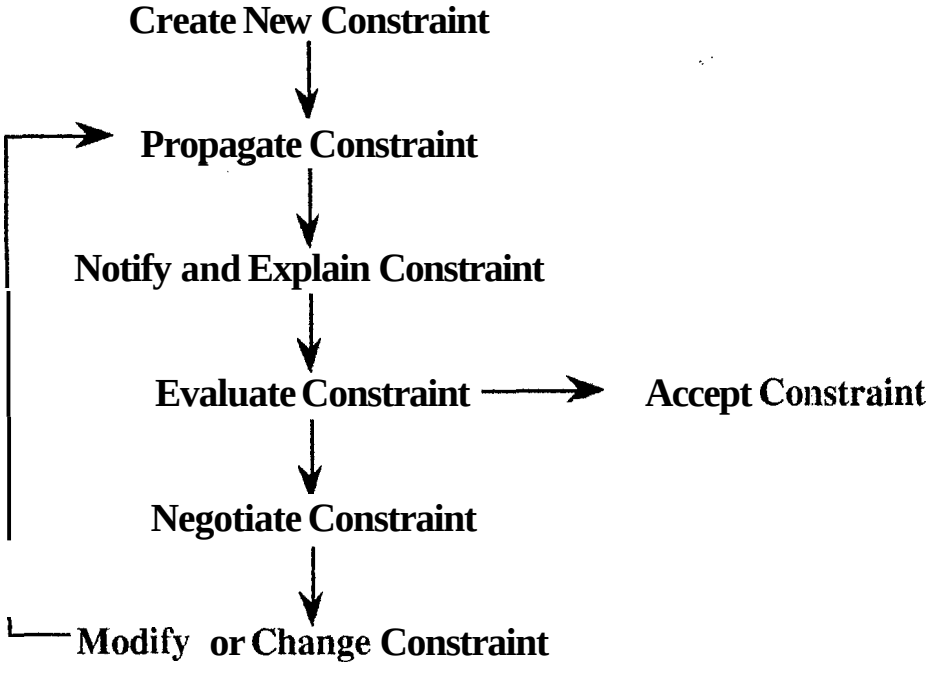

Figure-4 Constraint Management Cycle

3.3 RELATION CHANGER

In PMAPM, there are only four standard relationships which describe the relation between building elements, such as supported by, connected with, attached on and consisted by. However, in domain specific or application specific product model, there are many kind of relationships used according to each participant's needs, such as constructed after, comes before, calculate with and so on. Therefore, PMAPM provides the relation changing mechanism called Relation Changer. Relation Changer will change the relationships between elements according to user's needs through each view object.

3.4 CAD INTERFACE

In order to capture the building elements information, PMAPM has a CAD interface. Currently, PMAPM supports only ASCII formatted list-expression file, it is created by CIFECAD through Architectural-design-viewusing Sub-Model Absorber. However, it

is easy to support the another type of CAD file which is including not only graphical information but also non-graphical information about building elements.

3.5 RDB INTERFACE

Maintaining the common data for any project, such as unit cost, personnel information and so on, relational database is a very useful and should be connected to object-oriented project model in order to provide the any kind of information which is needed by the participants. In this prototype integrated system environment, unit finish cost, actual results data, personnel data and client data are stored into ORACLE and PMAPM has interface functions to ORACLE These functions retrieve the data from ORACLE according to the each view object's request, It is not so difficult to support the another database which *can* access by SQL command.

3.6 EMBEDDED KNOWLEDGE-BASED EXPERT SYSTEMS

- FINISHES [Ito 90]: FINISHES is a prototype knowledge-based counseling system which evaluates the finishing material based on the usage of the room and the grade of the facility. A user *can* use this system through architectural-space–view.
- FINISHCST [Ito 90]: FINISHCST is a prototype cost estimation system which calculates the preliminary finish cost using the unit cost information from the detail-cost-view using the RDB Interface to ORACLE. The information required by FINISHCST *can* be obtained via architectmil-cost-view or preliminary-estimation-view.
- DURATION [Ito 90]: DURATION is a prototype knowledge-based construction duration evaluation system. This system evaluate the construction duration from the total construction area, floor area, building structure, ground condition, etc.. A user *can* use DURATION through project-planning-view, architectural-building-view, structural-building-view or any other sub-view of construction-planning-view.

3.7 RELATED APPLICATION

- CIFECAD [Ito 90]: PMAPM has a high level graphic user interface, CIFECAD, for defining building elements and their attributes. CIFECAD is a customized AutoCAD system written in AutoLisp . With CIFECAD, a user *can* input the building elements with non-graphic information and obtain the drawing information not only in the DXF format for AutoCAD but also in ASCII formatied list-expression for other application programs. Moreover, the user does not need to worry about transferring design data from CIFECAD to the PMAPM because this process is automatically done by CAD interface between CIFECAD and PMAPM.
- OARPLAN [Darwiche 88]: OARPLAN is a prototype knowledge-based construction planning system and OARPLAN needs the design data in order to evaluate the construction project and to capture the activity in a project. PMAPM provides the sub-product model for OARPLAN through construction-planning-view using Sub-Model Creator with Relation Exchanger.
- COKE [Fischer 93]: COKE is a prototype expert system and COKE provides the feedback on the constructibility of the structural design of a reinforced concrete building structure.PMAPM provides the sub-model for COKE through structural-building-view and construction-methods-view using Sub-Model Creator. Moreover, CIFECAD has a interfacing module in order to create the ASCII formated list-expression file for COKE, too.

4 CONCLUSION

This paper described an object-oriented project model that supports multiple views for building projects and this model creates the many kind of sub-product model according to the user needs or application needs. Currently, PMAPM has been implemented the basic model hierarchy and integrated with various applications as described in this paper. Various interfaces to store and access information from PMAPM have also been developed and illustrated.

During the course of developing PMAPM, many benefits of using an object-oriented paradigm have been found to describe project model and to provide multiple views of the project model. Particularly, with the definition of multiple views, I can analyze and recognize the various requirements throughout the A/E/C process. Furthermore, this process-based approach is very useful to discover the information flow among the participants from different disciplines.

Finally, the purpose of this work is to realize the integrated system using an object-oriented project model to be referenced by multiple disciplines throughout the A/E/C process in the A/E/C industry. In order to achieve this purpose, continuing effort is needed to evaluate the requirements per each discipline and their needs to the PMAPM so that high level project model with multiple views can be established. Moreover, to implement this idea into the actual field is important.

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