AN ADVANCED OBJECT-ORIENTED ARCHITECTURE FOR INFORMATION EXCHANGE THROUGH SHARED OBJECTS

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Abstract

Despite the extensive use of computing technology within the Architecture, Engineering and Construction (AEC) industry during the past few years, the crucial issue of information sharing amongst AEC participants still remains to be addressed. This results in poor building project co-ordination and affects productivity and final outcome.

This paper presents the use of collaborative object databases for efficient data exchange between different AEC applications. Fundamental to this work is the development of an integrated product model that represents the information requirements for total project design and construction. The deployment of the Integrated Building Product Model (IBPM) as the basis for schema generation is also explained.

The system architecture demonstrates the ability to dynamically interchange objects between applications, which is being utilised as the means of automatic project plan generation from semantically enhanced CAD data. The system is aimed towards compliance to ISO-STEP for facilitating the exchange of information between dissimilar systems.

Keywords: *Object-oriented data base, intelligent CAD, CIC, dynamic exchange*

1 INTRODUCTION

It is common belief of many researchers in construction [3,4,5] that information exchange must reach higher levels of efficiency if demands to sustain competitiveness are to be met. The high fragmentation that exists in construction industry, due to the large number of disciplines involved throughout the life-cycle of a building project, poses a challenging task towards achieving integration. The newly emerged technologies in information technology (IT), and in particular object-orientation, can offer solutions in developing information systems capable of dealing with the vast complexity of building construction data and its transformation to support collaborative work.

The work presented in this paper is part of a major research project aimed at integrating design and construction. Fundamental to this work is the development of an integrated product model that represents the information requirements for total project design and construction. The deployment of the Integrated Building Product Model (IBPM) as the means of integrating different construction disciplines for information exchange and collaboration is presented. The generation and use of intelligent design objects for supporting multiple views of the design data is explained. The utilisation of an advanced architecture that allows dynamic exchange of construction objects in real-time is also illustrated. Compliance to ISO-STEP [7] for accessing data residing in distributed repositories is the way forward for Electronic Data Interchange (EDI).

2 BACKGROUND

There have been significant research initiatives directed towards information sharing for the construction industry. In this paper, three of these research efforts are briefly examined and looked from a system architecture point of view that relates to different strategies for supporting collaboration between different construction disciplines.

COMBINE [2] (Computer Models for the Building Industry in Europe) commenced in 1990 and is concentrated in the short term on developing a means for designers in different disciplines to exchange data between a set of building performance evaluation tools, each capable of assessing particular aspects of a building's performance. The focus in COMBINE is on energy-related data rather than design data which is the scope for this project. Although COMBINE fully adheres to ISO-STEP for data representation and exchange this was limited, in the first phase of the project, to off-line file exchange. However, the nearly completed second phase will support on-line data exchange.

In OOCAD (Object-Oriented CAD) [10] a formal generic product model on a conceptual level based on object-oriented concepts and the definition of a neutral file exchange format was developed. The use of the system was demonstrated by using three different software tools all of which communicate by using neutral (non-STEP) file formats. A CAD-package , a relational data base and an object-oriented programming tool were all part of the system architecture. The use of relational data bases however, in order to store object-oriented models in not believed to be an efficient solution and the use of object-oriented data base management systems (ODBMS) is recommended [6].

The ICON (Information/Integration for Construction) [1] project was concerned with the investigation of establishing a framework for integrated information systems in the construction industry by utilising knowledge elicitation, strategic management and information modelling. The system is structured around a central object-oriented data base and allows communication with CAD and project planning packages. However, data exchange does not occur on-line for all integrated applications since they are disparate across dissimilar platforms. In addition, the work carried out in ICON was independent of STEP.

3 INTEGRATED BUILDING PRODUCT MODEL (IBPM)

IBPM was initiated as an effort to develop a building product model capable of supporting multiple views of the construction data and be extendible so that more disciplines can be included when it is decided to widen the scope of the model. Primarily, it was concerned with integrating CAD and project planning and control applications. A framework that allows categorisation of data into different levels of abstraction was firstly established [6]. The Object Modelling Technique (OMT) [9] methodology was use to produce the diagrams. The model was structured around four building sub-systems: *Structural System, Space System, Separation System and Project Task System (Figure 1).*

3.1 Project Task System

The Project Task System is used to describe information about the construction and use of the three other spatial systems. The system is structured around the Task (activity) class which represents project planning activities. The Construction Project Plan class contains information about the start and finish of the project, distinguishing between scheduled and actual finish and start times. It describes total hours allocated to resources and project cost information. It also uses data from the Space system for tasks like furnishing, etc. A task is assigned to one or more resources represented as a resource group. It keeps information about duration, preceding and succeeding task and float time. One or more tasks may be needed to construct a structural or a separation member.

3.2 Space System

The Space System is concerned with describing all spaces in a building mainly from a functional point of view. A space is categorised as either a Room (kitchen, storeroom, office, etc.) or Circulation Space (corridor, lift well, etc.) but either types can be included to suit different applications. For each space, apart from description information, geometrical and topological information are also in scope. As is depicted in Figure 1, Space has a number of separation (enclosure) elements where a

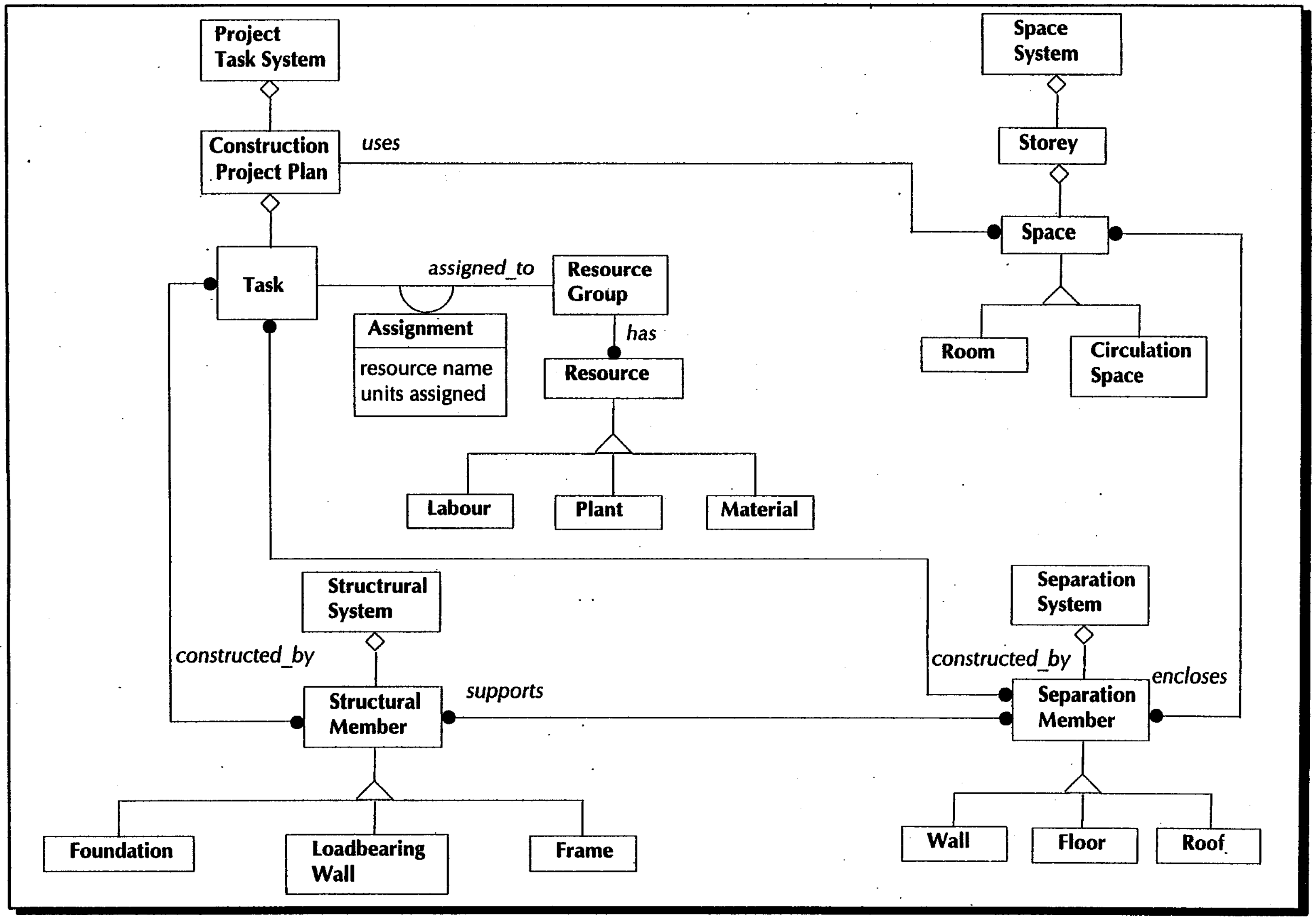

Figure 1. IBPM model

particular separation element can enclose more then one spaces (many-to-many relationship).

3.3 Separation System

The Separation System is concerned with building objects which are used as vertical (walls) or horizontal (floors, roofs) separators. The function of separation members is to bound spaces. The case of Load-bearing Wall is of special importance. If a wall carries weight then is part of the Structural System (see next section). However, it can also be used as an enclosure element for a particular space in a building and hence is also part of the Separation System. Clearly, the class object Load-bearing Wall must inherit properties from both system. This is resolved by using multiple inheritance.

3.4 Structural System

The main purpose of the Structural System is to describe data that are related to load distribution. Elements that are in scope include Foundation, Load-bearing Wall and building Frame. For each one of them, different sub-types are included (omitted in here). The Structural Members provide support for the Separation Member as is shown in Figure 1. The system can easily be extended by adding more sub-types to Structural Member class if needed in particular applications.

4 INTELLIGENT OBJECT CLASSES (IOCs)

An important issue that needs to be addressed within the framework of an integrated system for design and construction is how to facilitate collaboration amongst involved disciplines. A prerequisite towards the effort is to deploy mechanisms capable of retaining knowledge during the project's life-cycle. The utilisation of Intelligent Object Classes (IOCs) can serve this purpose. An IOC gathers information during the progression of the project and makes it available to the involved participants. Starting from design, IOCs accommodate additional data about, for example, "how to design" or "how to construct" a particular object. The structure of an IOC contains information about the following:

- generic attributes of common use (e.g. id, material)
- methods to support specialist tasks (e.g. calculate_volume)
- CAD representation information including geometry and topology
- inter-relationship dependencies to other objects

In Figure 2, the concept of a real-world wall entity is illustrated. A IOC describing the properties of a wall object is defined. Each specialist involved in the construction process has his own view on what a wall represents and utilises combined set of attributes and methods to perform individual tasks.

A structural engineer uses the object's geometry to calculate the load carrying capacity of a wall. An architect is mainly concerned about

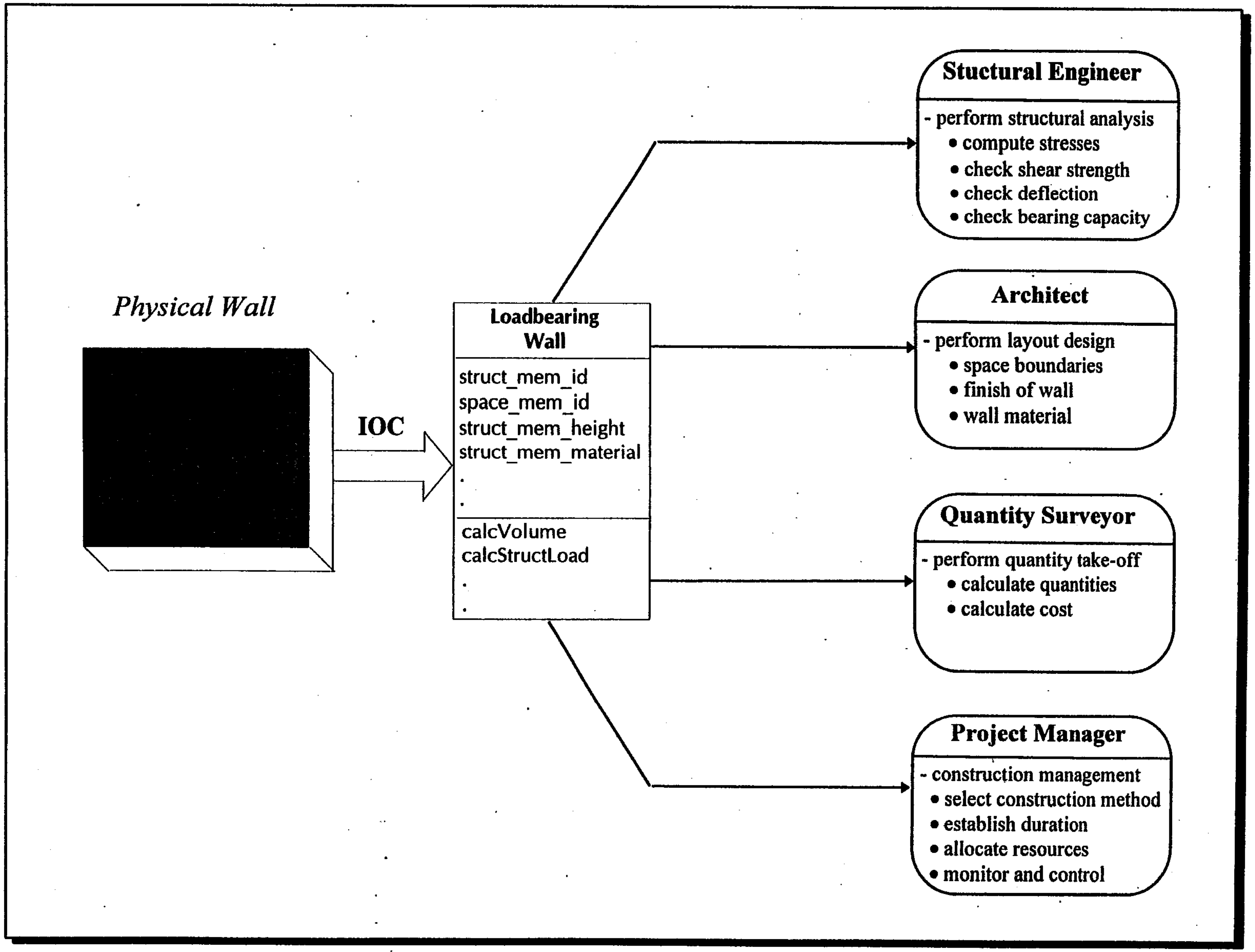

Figure 2. An Intelligent Object Class (IOC) can support collaborative engineering

space layout and wall appearance. A quantity surveyor can extract the total volume of the wall to produce a bill of materials. A project manager requires object dependency information to determine activity sequence and to choose appropriate construction methods and resources. The information contributed by each specialist is stored persistently and made available to others so collaborative construction is supported.

5 CO-CIS: COLLABORATIVE-CONSTRUCTION INTEGRATED SYSTEM

In Figure 3, the system architecture of CO-CIS is presented. The system is aimed at improving collaboration amongst construction disciplines and achieving greater integration of activities. IBPM, which is comprised of IOCs, is the back-bone of the system. The process of building application programming interfaces (APIs) is being enhanced by making the system compliant to STEP SDAI N350 [8]. CO-CIS constitutes three main modules: *IOCs generation from CAD, IBPM schema generation, and dynamic exchange of objects.*

5.1 IOCs Generation from CAD

This is the design module where a building drawing is produced by using a front-end add-on application which was developed as part of this project (MicroLink) [6]. The designer utilises cell (symbol) libraries to produce the drawing. The user has to his disposal the full MicroStation CAD functionality including 3D solid modelling, rendering, etc. During this process, "flat" CAD entities are semantically enriched [6] by using an integrated semantic modeller within MicroLink, thus generating instances of Intelligent Object Classes (IOCs) that populate the data base schemas.

5.2 IBPM Schema Generation

A CASE tool has been used to design the object diagrams that comprise IBPM (Figure 1). By using the code generation options, C++ classes were derived and hand-tailored to meet ObjectStore and SDAI requirements. The compiled schema was then persistently stored in ObjectStore ODBMS.

5.3 Dynamic Exchange of Objects

CO-CIS is designed so that data exchange can take place on-line in real-time. Dissimilar applications, ranging from project planning and control to cost estimating, can dynamically exchange IOC instances by utilising a client/server architecture approach.

6 CONCLUSIONS

The need for effective information sharing within the construction industry requires deployment of state-of-the-art tools and techniques. An advanced object-oriented system architecture, which is the cornerstone of a collaborative environment for

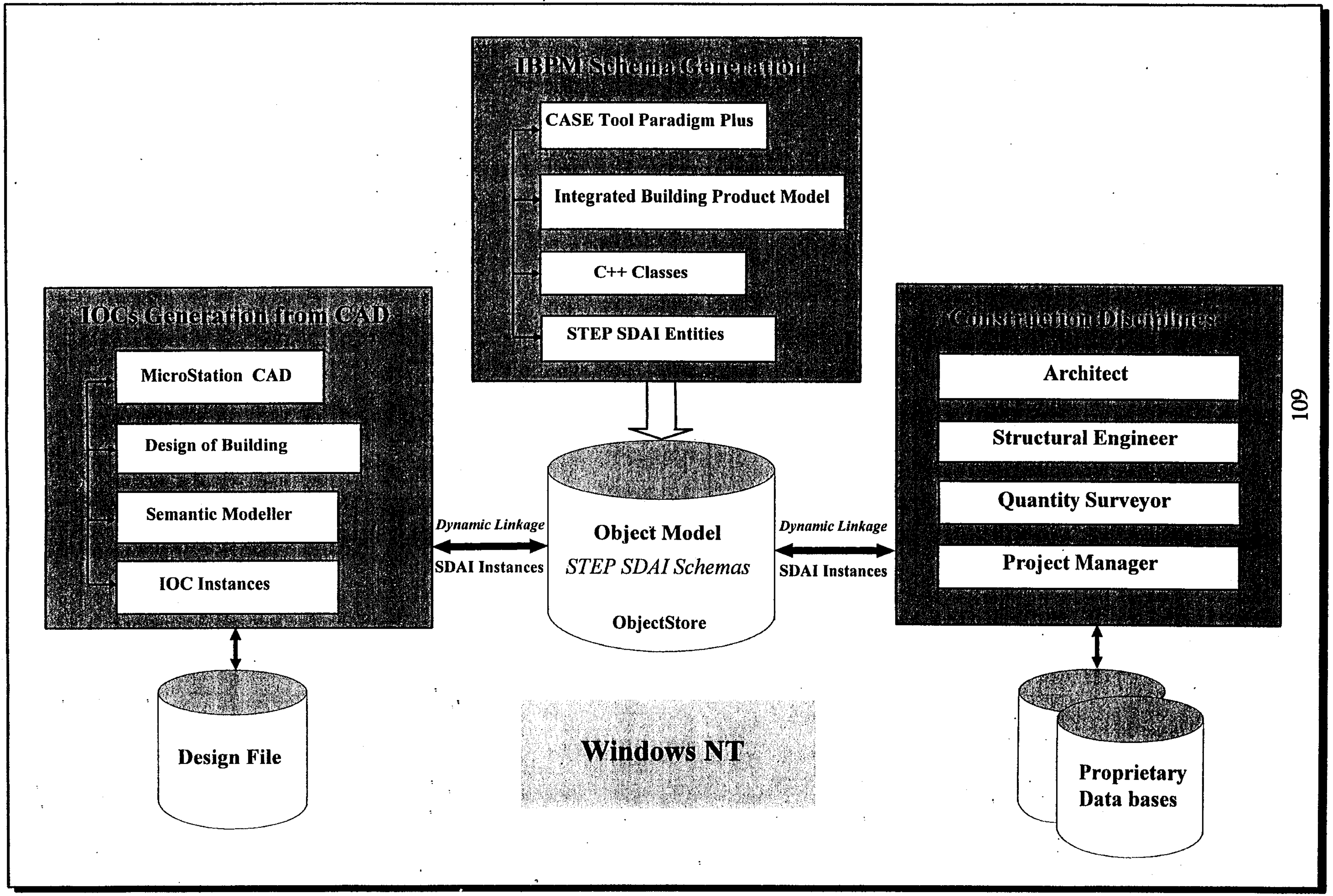

Figure 3. System architecture of CO-CIS (COllaborative Construction Integrated System)

construction disciplines (CO-CIS) was presented. The development of an object-oriented product model for design and construction (IBPM) was explained and was used as the basis of schema generation and persistent storage of building objects. The concept of Intelligent Object Classes (IOCs) and its use for acquiring knowledge and supporting multiple views during a project's life cycle was introduced. Finally, the usefulness of dynamically exchanging objects in real-time based on the client/server model was underlined.

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