INTEGRATING DESIGN AND CONSTRUCTION: A NEW APPROACH

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Abstract: This paper presents the issue of integrating design and construction in the context of Computer Integrated Construction (CIC). A new approach of a proposed strategic framework using the Modularised Approach is highlighted to overcome the complexity of integrating design and construction whereby such integrated environment need to share data via a central core. Such approach has been implemented by the AIC research group at the University of Salford, UK. A PC-based integrated environment prototype, SPACE has been developed which aims to integrate design and construction within the project's life cycle.

Keywords: Integration, Design, Construction, Modularised, Integrated Environment

1. INTRODUCTION

Construction industry by nature is a transient and highly fragmented industry and because of these two characteristics, co-ordination and proper communication have significantly effect on productivity and quality of construction project [1]. During project life cycle, the amount of information generated and exchanged is enormous even for a small-size construction project. The introduction of IT has brought a step forward towards enhancing the information processing and exchanging the information between the parties. Most of the project information are currently stored and processed on computers. Although the emergence of these technologies is to increase the productivity through computerization, the present of these technologies tend to solve specific problems and business needs only. Most of the packages are 'stand-alone' which resulted in 'island of automation' within the industry. Therefore, by integrating project participant's computer systems, the effectiveness of a project team will be greatly enhanced.

The integration of design and construction has also been proposed and considered to be the optimal approach to successfully reducing fragmentation and eliminating some of the major problems in the construction industry [2]. At the earlier stage of integration, the trend to integrate different computer systems was initiated by the need to manipulate and share information between a number of computer systems in a company [3]. As the number of computer technologies emerged, such as database management systems (DBMS), spreadsheets, computer-aided design (CAD) and knowledge-based systems (KBS), the development of the integrated computer systems also progressed through the combination of these technologies. Through the development of Computer Integrated Construction (CIC), integrated design and construction has been the main issue whereby such integrated environment need to share data via a central core. Great efforts therefore have been devoted towards the development of a flexible and comprehensive data structure for the single core. However, the development of such environment in isolation of any implementation attempt will lead to the development of theoretical models which could prove difficult to implement as implementation problems can be of a complete different nature.

2. APPROACH TO INTEGRATION

There are many aspects of integration that need to be addressed. One of the most important aspect is data exchange. Data can be exchanged in three ways, namely through a direct translator, a standard exchange format, and a product model. Each of these techniques for integrating design and construction although applicable, imposes its own limitations [3].

- *Direct translator approach* – the output data from one application program is directly translated into the format required for input to another application program as shown in Figure 1. The obvious disadvantage of this approach is the large number of translators that must be developed and maintained [4].

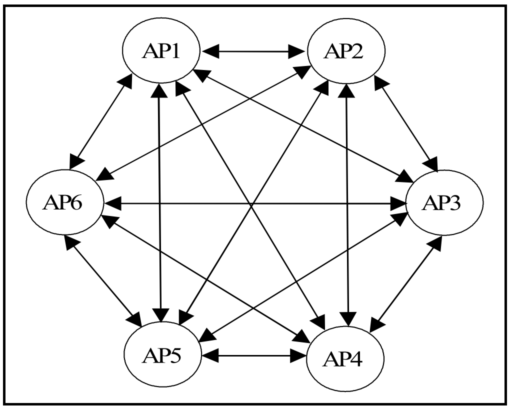


Figure 1. Direct translator approach

- *Standard exchange format approach* – all application programs read input and write output through a single file using a standard exchange format that is understood by all the application programs (Figure 2). This standard exchange format file is commonly known as neutral file and widely used as the need for communication between various CAD systems. The "industry standard" format of DXF and IGES was accepted as a *de facto* for exchanging geometric information [3]. The advantages of this approach such as uniformity to the system is introduced by using a single file and removing an existing application program will not effect the neutral file or other application program. However, using this approach a duplication of common data occurs whereby each application program only stores its own data which will results in consistency problems [4].

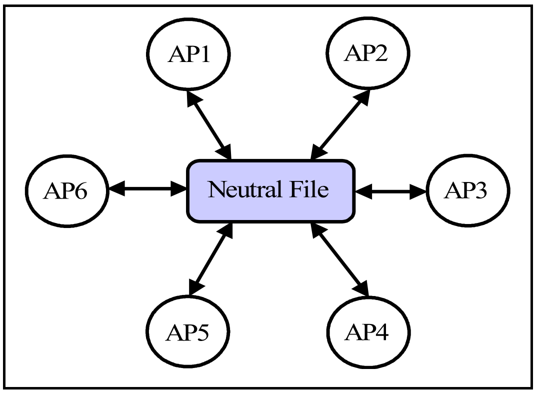
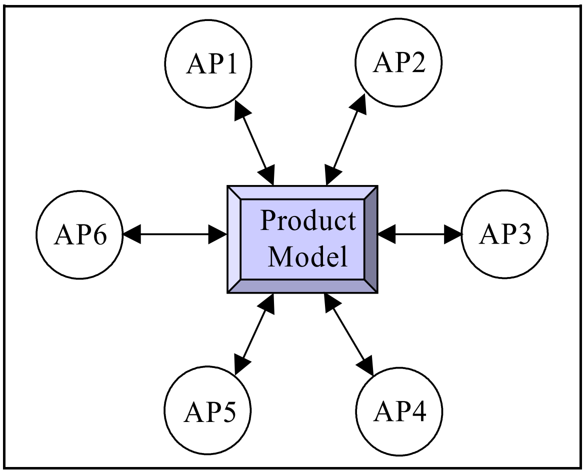


Figure 2. Standard exchange format approach

- *Product model approach* – This approach has been introduced to cater for all the problems mentioned above. For example, in the direct translator approach (traditional approach), large number of translators are needed as the number of applications increases. This will lead to data duplication, as each application requires its own representation of the product data. The standard exchange format was found to be inadequate to represent the project information since geometrical data alone such as line, circle, co-ordination, etc., cannot provide meaningful data in the form of an object which is important for other applications such as construction [5; 6; 7]. Therefore, the attempts to integrate additional applications into the environment are seen to be excessive and troublesome.

Figure 3. Product model approach



The use of a product model can reduce the problems stated above. It can reduce the required number of interfaces to integrate different construction applications and therefore facilitate information sharing (Figure 3). It eliminates the problem of multiple representations and transcription errors by having a single master model of the product [8]. Furthermore, the use of product model is seen as an enabling factor which, could provide richer representation of product data such as geometry, topology, relationship, etc. to completely define a component part or an assembly part for the purpose of design, analysis, construction, etc. [3].

3. A NEW APPROACH

Although the product model approach seems to provide more advantages compare with other common approaches, the information between the product data model and other data models may be overlapped. This will creates data redundancies where each data model might hold similar data/information. Therefore, the concept of data sharing must be applied where similar data should be shared between the various data models using the data sharing principles. This is an important issues, which has to be addressed when designing and implementing such models.

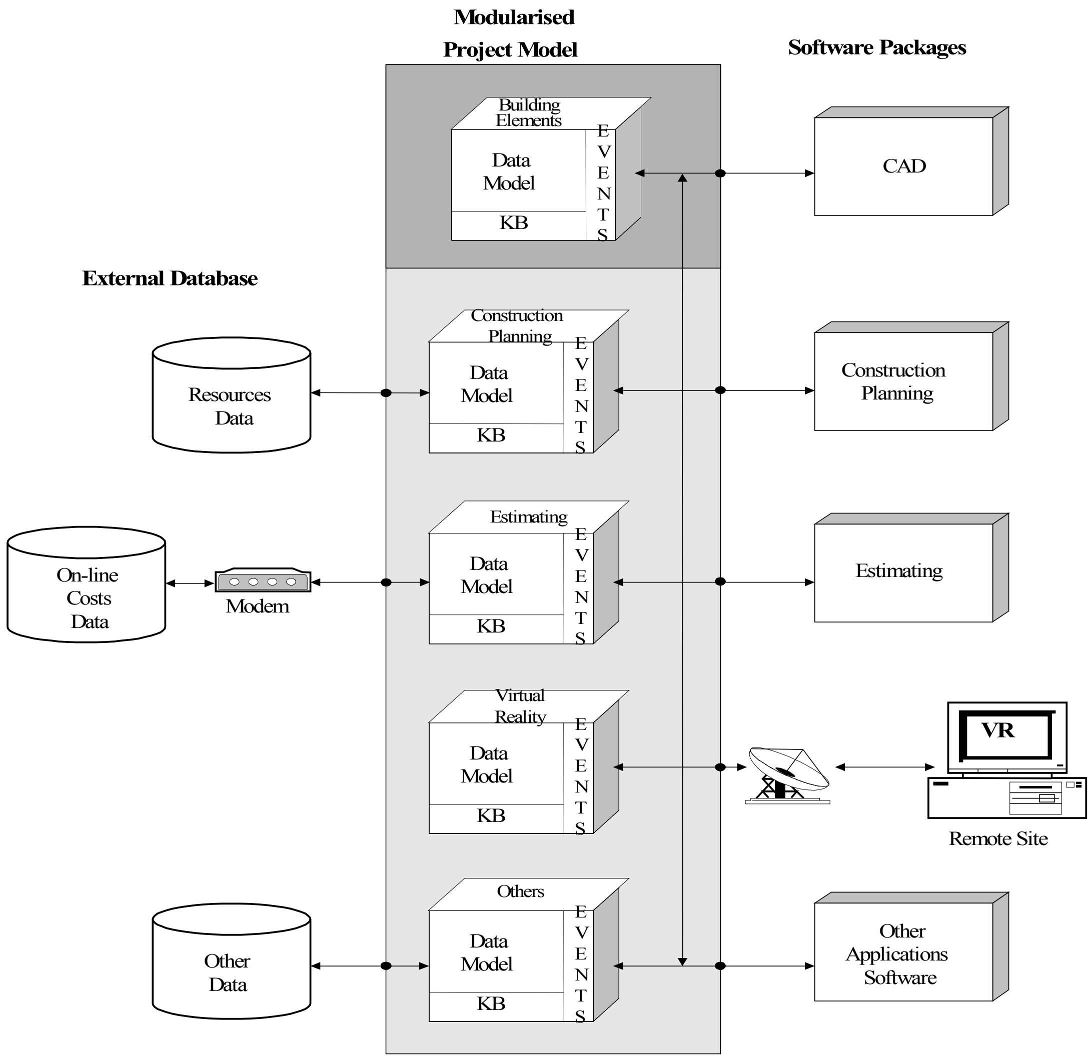


Figure 4. Conceptual representation of the ICE

The above concept has been proposed for the Integrated Construction Environment (ICE) with the aim of co-ordinating the integration process between the various construction applications. The implementation of this concept has led to the development of a modularised central core whereby each application has its own data model.

The proposed structure of the ICE is shown in Figure 4. It consists of three main parts, i.e. the project model, software packages including interfaces with the project model, and external databases. The project model which is the modularised central core, is a model that combines both product and process views [9]. Each module within the project model supports a particular application of the project life cycle and is supported by methods/events which are necessary to describe the module's behaviour and relationships with each other and with the external world, i.e. application software packages and external databases. Moreover, each module is underpinned by a knowledge base, which adds intelligence to its behaviour.

3.1 The project model

The project model comprises the building elements data module and other application data and process modules. The building elements data module mainly describe the building's components and their behaviours. The extent and structure of this module depend on the scope, the context, and the main objectives of the ICE, e.g. an environment for concrete framed buildings may have different building elements data structure of that of steel. Other application data modules, on the other hand, represent data required by other stages of the building life cycle such as specifications, estimating, construction planning, site layout planning, etc. Each of these modules must be developed to fulfil the need of a particular construction application. For example, a construction planning application requires an application data module to support the information required by the planning process, e.g. generic construction activities, resources available, construction methods, etc.

The modules should be designed to complement each other and to maintain and share data in the most efficient way. In this approach, data related to a particular stage of the project life cycle is maintained separately from other data, but makes use of other data modules as and when required. For example, construction planning data module contains generic information about construction activities, methods, resources, etc. When it is activated, it refers to the building data module, where building elements of the current project is stored, to generate the project's specific construction activities.

3.2 Software packages and external databases

The second part of the ICE represents the construction applications packages such as CAD, construction planning, estimating, virtual reality, etc. Such applications software packages can either be external, i.e. stand alone applications packages, or internal, i.e. developed within the environment of the ICE. In either case, each application has its own user interface to manipulate the information, and a specially developed two way communication channel to transfer information between the application and its related application data module at real time. In Figure 4, dark circles on the communication line represent the interface. These application packages are completely independent from the project model.

The third part of ICE environment is the external databases. The project model can retrieve external information from external databases as and when required by the various involved modules. This process can be carried out directly by the modules or shared by a number of applications modules, e.g. estimating and construction planning applications may need to share cost data which can be retrieved by any of these applications, say from on-line databases.

4. THE IMPLEMENTATION

The above concept of the ICE was implemented by the AIC (Automation and Integration in Construction) research group at the University of Salford. A PC based integrated environment prototype, SPACE (Simultaneous Prototyping in An integrated Construction Environment) has been developed which aims to integrate the "industry standard" software through one object-oriented knowledge-based system where project information is shared and transferred automatically and transparently as and when required by the software/construction packages.

SPACE takes an alternative view to the traditional design and construction practices. It considers the project life cycle stages as applications, which can be, accessed simultaneously i.e. construction applications can be triggered off at any time. This provides all users i.e. clients, design team, contractors, planners, etc. with the opportunity to access the relevant project information at any stage. For example, clients can visualise the project in 3D and/or can examine whether the design solution meets their requirements and/or budget, while designers can investigate the impact of their design on construction thus giving them the opportunity to improve on the constructability of their design. In such an environment, the cost of carrying out "what if" scenario is almost null.

SPACE provides users with a multi-disciplinary computer environment where project information can be shared between the various construction professionals. Project information is stored in the project model where all construction software applications such as design, estimating, construction planning, bill of quantities, virtual reality, etc. are attached to. Information is transferred to the software packages as and when required. For example, design information, as generated by a CAD package, is transferred to the project model and can be accessed by all the attached software applications. Moreover, each of the individual packages can access standard data from external databases, as shown in Figure 4. For example, contractor's resources or prices required for estimating can be accessed from in-house and/or on-line databases.

SPACE integrated environment is normally triggered off by feeding in project specific information through a design package, e.g. a CAD. As the design progresses, the design information is dynamically transferred to the building elements data module [10]. Once the data module is populated with the project specific information, users can run any other application package at any stage of the design. For example, the cost of the so far developed design can be dynamically determined by running the estimating application package. The estimating data module, in this instance, transfers the design elements along with their specifications and quantities to the estimating software package in order to produce either the total cost or cost break down of the current design. The generated costs can be altered at the estimating software package, if required. This alteration is then transferred back to the estimating data module where actions are triggered-off if the altered information is not feasible or does not comply with regulations, standards, in-house databases, etc.

Users can switch between various applications at any stage at any time. Software applications packages respond to requests from the project model with the output of these software packages, being limited to the amount of information supplied by the project model.

5. THE BENEFITS OF NEW APPROACH

The implementation of SPACE has several benefits. It is seen to be the tool that would overcome current problems. Such benefits are:-

- *Data Sharing* – sharing of information between different construction applications. Thus enabling the integration between all the project life cycle stages.
- *Integrated Project Database* - the development of several modules using modularised approach has proved to be an effective and efficient way for integrating different construction applications. Applications can be added as and when required without effecting the overall environment.
- *Maintenance* - the project model can be easily maintained or updated. Such processes can be carried out on the individual application modules as and when required by the applications without interrupting the other applications.
- *Visualisation* - the use of virtual reality as a front end for all the applications within the integrated environment provides new dimension to the construction applications. Project information can be easily assessed and/or evaluated through this graphical interface.

6. CONCLUSION

The complexity of design and construction applications and the vast amount of information involved in a project have hindered the development of an efficient integrated environment for design and construction. The lack of high level structure and a full understanding of such environment has led to the development of a number of small integrated design and construction applications where most of the developed systems have their own limitations especially when integrating many applications simultaneously.

A new approach of integrating design and construction was developed and integrated with the central project model. Applications were developed individually and independently from each other. The new approach had proven to be essential to such development of integrating design and construction as it gives an excellent view on how the various parts of the ICE were integrated.

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