Parametric Modelling Supporting Collaborative Design

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Abstract

In our paper, we will (1) discuss the primary motivations for the usage of parametric data in Collaborative Design. (2) Describe a project currently implemented using parametric modelling in Revit and Bentley. The final section of this paper, section (3), will investigate how the above mentioned libraries behave when they are transferred from one modelling program to another. The use of this type of design ideally should shorten the time span spent on detailed modelling of built artifacts. This section will describe the effort that is needed to ensure that the parameters are carried forward into the each program used by each entity. It will also briefly describe the fundamental difficulties of using various standard commercial packages in a collaborative design environment at the present time.

Keywords

Parametric modelling, collaborative design, Industry foundation classes

1 Introduction

In the construction and building management industry at the present time, a large amount of time is spent creating and editing 2D and 3D models. This paper focuses on the use of parametric modelling to support collaborative design and so save time and money for all parties in the construction industry.

Representation of all the information needed to describe buildings throughout the whole design; construction and management process has long been an objective for those applying information technologies in building [1].
As a result of this, Building Information Model (BIM) and parametric modelling are two hot topics in AEC (Architecture, Engineering and Construction) industry. BIM (Building Information Models) deals with representations of the buildings in design phase, and includes information for collaboration with external team members, production of high-quality construction documents, building performance, cost analysis and construction planning, etc. Parametric modelling defines rules and constraints, which define the relationships between building components. Creating and modifying these relationships will have an impact on the models, for example if a change is made, it will be automatically coordinated throughout the project, so the designs and documentation stay consistent and complete. There are several tools available which are designed to create parametric architectural models, including Revit Parametric Components (also known as families, running with Revit by Autodesk Systems), and Generative Components (Running within MicroStation by Bentley Systems). We do currently use these two tools for our research projects at University College Cork.

2 Building Information Model (BIM)

Building Information Modelling (BIM) technology transforms the paradigm of the construction industry from 2D-based drawing information systems into 3D object-based information system [2]. Typically a BIM contains all the data relating to the building’s performance – such as geometry, materials, energy systems and components, occupancy schedules, environmental conditions as well as operational data.

Building information modelling operates on digital databases. By storing and managing building information as databases, BIM systems can capture, manage, and present data in ways that are appropriate and customary for a particular designer, contractor, vendor or client. Such applications start with capturing and managing information about the building, and then present that information back as conventional drawings view or in any other appropriate way such as tables or perspective views, and make it available for use and reuse at every phase in the project (AutoDesk 2002).

It has been proposed previously that the BIM would be based on the IAI (Industry Alliance for Interoperability) Industry Foundation Class (IFC) data schema [3]. This will allow for the integration of all the building views (geometry, material, HVAC system etc), enabling interoperability among the various tools needed for performance-based assessment across the building life cycle, such as whole building energy simulation. However, this proposal is encountering difficulties in its realisation.
One major problem facing BIMs is the absence of the responsibility for modelling the construction product and material in a multidisciplinary cross industrial level of abstraction [4]. Architects don’t have the ability to model each of the thousands of elements that would be required to be modelled for each project. They would probably be paid for drawings and documents rather than models. Models may be project specific and cannot be used in product libraries. That approach would go beyond the investment employed. A solution to this is OIP, Object Information Packs, information model would be completed as part of construction project where each discipline carries out there own modelling.

The object-oriented tools to build such a model have now been available for some time, but the need to integrate the many people involved in the process, and the ways in which their information is organized, have been a limitation on the widespread use of building information models [5].

Constraints and parametric variation, which BIM CAD is built around, have been active areas of investigation in computer-aided architectural design for over fifteen years [6], and so we will now introduce comprehensively parametric modelling.

### 3 Parametric Modelling

Parametric design is, in a sense, a rather restricted term; it implies the use of parameters to define a form when what is actually in play is the use of relations [7].

Parametric Modelling is basically 3-D modelling with intelligence. It derives its name from the extensive use of parameters in creating parts and assemblies [8]. Currently parametric design has been adopted by most CAD software, which embeds parametric data into 3D objects, this includes parameters such as height, width, depth, thickness, materials, and other attributes related to the model, as in figure 1. Designers use a user interface to insert pre-drawn components from libraries (such as windows, doors, and stairs), which will be described in the following paragraphs.
One of the simplest ways of using a very rudimentary form of parametric design is to record a script of the commands and data values used to create an element. If this script is edited and the data values are changed, we will get a family of variants of the same type with different dimensions. We can refine this method by using a programme such as AutoLisp to write a macro, a routine or a little program that performs the suitable actions to model the element— the difference between these three terms can be assimilated to a difference in quantity, i.e., a few lines for a macro or a few pages for what might be called a simple program [7]. Macros are programs that are designed to help you save time, by automating repetitive tasks. Each macro performs a series of pre-defined steps to accomplish a particular task. The steps should be repeatable and the actions predictable. For example, you might define a macro to add a grid to your project, to rotate a selected object, or to collect information about the square footage of all the rooms in your structure. Other general examples include: Locating and extracting Revit content to external files, Tweaking geometry or parameters, creating many types of elements, Importing and exporting external file formats.

There are nine steps to creating a macro at the present version on Revit software. Add Revit VSTA, open / create a project, launch macro manager, view initial macro manager dialog, select template type, click new, name your macro, examine provided template and add implementation code, build your macro in Revit VSTA IDE. So with a basic knowledge of a programming language, one can create a project template using as many macros as one likes or requires.
4 Design Project Experience

In Bentley Architecture you can first construct a 3D model instead of a traditional 2D floor plan, the 2D elevations, sections and schedules and rendering are automatically generated in real time. The opposite is done by Autodesk Revit Architecture. The objective of such technology is to allow designers to share their libraries for team project, as well as reduce design cost and correction times.

In our research team we have successfully designed and implemented the Environmental Research Institute (ERI) building using the following software: Bentley Architecture, Revit Architecture. We used IFC to define building components such as walls, windows, and stairs, etc. Figure 1 shows the parametric elements which defined in IFC, the headline element defined as IFCWall, the height is 11:5 ¾, the weight is 0:11 ¾ and the material is brick red, the IFC schema are stored in EXPRESS language in accordance with ISO STEP (Standard for exchange of Product Data) which can be used as a mechanism for sharing semantically rich building information between CAD (computer-aided design) systems. Furthermore, the IFC model schema can be loaded into a step model server, providing the opportunity to hold the building model as an object database on a central shared computer and accessible across the Internet as a resource to support collaborative design.

Figure 2: Define building parameters using IFC (Bentley Architecture)
Revit was one of the first parametric building modellers designed for the AEC (Architecture Engineering Construction) industry. Revit Architecture building design software is purpose-built for Building Information Modelling (BIM). Make a change and it’s automatically coordinated throughout your project, so your designs and documentation stay consistent and complete. We create a set of instructions, including the rules and constraints of the design (as well as parameters defining certain aspects of the design), which can be used to build the model. We can use these instructions to always build a model from scratch, each time using the same parameters, or experimenting with different ones. The parameters can be numeric values, relationships, and can even include graphic parameters already existing in the model [9].

Figure 2 shows the 3D representation of ERI building in Revit architecture, all the parametric data are stored so called Revit families, which show your basic parameter value, including height, width and its context materials etc. We use Column as an example, which clearly describes how building rules can be defined in the ERI buildings.

- **Column numeric values**: Depth:600,Width:400,Material: Concrete - Cast In Situ
- **relationship**: column has to attach on floor/roof to form a joint, when the height of floor changed, the height of columns must be changed as well
- **Graphic parameter**: if any parameter of an object is changed, respective parameter of all associated objects will also change as well

![Fig.3: Define building parameters using Revit Parametric Components (Revit Architecture)](image-url)
5 Collaborative Design

The purpose of collaborative design is to allow conflicts and constraints to become visible immediately during design and so to allow correction of said discrepancies at the time when they become evident. Fortunately there are tools available at present which integrate parametric modelling with collaborative design. These tools enable the trained individuals to create models which abide by all the necessary constraints and which are practical in real world construction. From the late 1990s, globalization and keener competition have propelled more business changes. Wider collaboration across enterprise boundaries and industry spectrum are viewed as the catalyst for future business growth and profitability. To meet the requirement, R&D of collaborative engineering is towards supporting enterprise collaboration, with which collaborative activities are enabled not only among multidisciplinary product development teams within the same company, but also across the boundaries of companies with more active involvement of customers and different tiers of suppliers [10].

For the purpose of this paper, the finer details of collaborative design will be discussed first. These are the practical points which were experienced as part of a global collaborative design project. In collaborative design, the key action is to test all purposed design tools interoperability. Many tools boast export and import facilities from a variety of other tools, but the format of the export/import may not be to the necessary standard and this can result in extra work and loss of cohesion. For example some common problems when importing parametrically designed models are: Loss of properties (Revit to IES), Excess detail/ Loss of Detail (2D AutoCAD to Revit), Zero Coordinate point.

By testing the purposed software to be used for the collaborative design purpose, one can highlight possible problems which will be encountered and therefore evaluate whether it is advisable to use the software tool in question.

The next step is to set out the method of construction for the project, i.e. it is important to decide on the breakdown of the project before any design work is carried out. For example, when using the Revit design tools, one will create a number of levels. The structural tool will have levels created in order to design the structural members and the MEP tool will have levels for ducts, pipes, cables etc. In collaborative design it is essential to align these levels and ensure that the shell of the project integrates with these interior system levels. For example, interior walls which are not supporting loading may not be extending all the way to the above floor; they more than likely will only extend as
far as the plenum level. Points like this must be shared with the whole team before collaborative design begins.

The most important reason to use parametric modelling with collaborative design is due to the changing nature of all design products. It is very unlikely that a design project will maintain the same brief throughout its life span. In the process of product development, designers often have limited knowledge and information to accomplish product design tasks, while product requirements are sometimes nondeterministic. These changes often take place, and affect many parts and components of products due to the constraints among them. Furthermore, designers are usually geometrically distributed, letting the right designer get the necessary design change information at the right time may not be easy. Also software tools providing an effective and purposeful coordination support through analyzing dependencies among design tasks will definitely increase the coordination efficiency [11]. This referenced paper also outlines the four major types of collaborative design. They are as follows, in figure 4. For the context of this paper and due to the experience incurred; collaborative design at different places through the network will be focused on.

Figure 4: Four Types of Collaborative Design

Most collaborative design projects at present will use a specialized program to combine the different design tools work on a regular basis, weekly or twice weekly. There are a few tools available at present, such as Navisworks. This type of software allows the collaborative design team to carry out a number of processes. Autodesk® Navisworks® Manage software is a review solution used by design and construction
management. Navisworks Manage combines faultfinding analysis and interference management together with 4D project schedule simulation. Autodesk® Navisworks® Simulate software offers replication of design intent and modelling of 4D construction schedules, which enables pre-visualization of construction projects. Autodesk® Navisworks® Review software enables whole-project real-time visualization and review of various file formats regardless of file size. Together these software packages enable one to virtually experience in a visual context a project before physical work begins and so in fact enables a more complete evaluation and verification of the materials and textures appropriate to ones intended design.

6 Library Behaviour

In collaborative design it is very important for different parties to have the ability to adjust design details while at the same time maintaining the integrity of the design. By using parametric libraries it is possible to assign design rules to components and at the same time allow the components properties to vary as required without contradicting these rules.

Libraries are used in parametric modelling software whose main purpose is to design built artefacts. These libraries consist of groups of families which can be defined as a collection of objects, called types. A family groups elements with a common set of parameters, identical use, and similar graphical representation. Different types within a family may have different values of some or all parameters, but the set of parameters - their names and their meaning - are the same. Types are then defined as members of families. Each type has specific parameters that are constant for all instances of the type that exist in a model; these are Type Parameters. Types also have Instance Parameters, which may vary for each instance of a type in the model. There are many different pre defined families created in Revit. It is also possible to create your own family and types and therefore create individualized parametric details to the components [12].

These families can carry relationships not only with regard to their own properties but to their surroundings also. For example, if you create a desk in a room and it must have specific geometry that is related to the overall dimensions of the room, when the room is exported to another program and the room size is changed will the geometry of the desk also change? The use of this type of design ideally should shorten the time span spent on detailed modelling of built artefact.
7 Conclusions

Parametric modelling has the ability to support collaborative design in a way which will facilitate Building Information Modelling and so enable advancement in the area of ICT. Parametric modelling is and will continue to reduce the time and cost involved with constantly changing project descriptions.

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