BRIDGING THE GAP BETWEEN PHYSICAL AND DIGITAL MODELS IN ARCHITECTURAL DESIGN STUDIOS

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ABSTRACT:

The advance of technology in the areas of building, environmental control and computing, meant that architectural teaching processes needed to adapt to the increasing use of modern tools. However, in may schools of architecture, computer technology is not adequately integrated into the curriculum, because first, its introduction means that there is a need for an important change in the way architectural design is taught particularly in studios, and then, the learning outcomes of digital modelling are not known or understood. Not surprisingly, digital technology is allowing students and designers to explore new areas without restraining their imagination in order to produce buildable complex designs such as Frank Gehry's work. The process by which this is achieved relies primarily on the use of "hybrid" design techniques; i.e. the making of scaled physical models, followed by 3-Dimensional digitisation, and then 3D modelling. Traditionally, students produce very accurate scaled physical models as part of their design development, but struggle to recreate them digitally for further analysis and improvement. This paper presents a recent experience related to the introduction of a new course on 3D digitisation and modelling. This was done with the aim to bridge the gap between physical and digital models produced by students as part of their design development exercise. A preliminary research into scanning and digitisation methods including Photogrammetry was necessary in order to assess their suitability to the project requirements. This resulted in the production of a course unit addressing the different scanning and digitisation methods available. The objective of the course was to effectively use a tracking device (Microscribe 3D) to digitise complex physical models, and therefore create very accurate digital copies. Digital models were then improved to allow an understanding of the design - space, form, materials and light - through visualization and animation, especially during jury reviews and final presentations. The paper discusses the use of 3D digitisation and the digital modelling process, and assesses the benefit of this technology in terms of design freedom, and architectural qualities of the final projects compared to conventional design processes.

1. INTRODUCTION

A concern arising from the unfocused used of Computer Aided Design (CAD) in teaching within many schools of architecture including at the UAE University, has encouraged the author to apply for a course improvement grant in order to develop a new course. This course would use advanced CAD with the following aims: (a) to improve the design process, (b) to bridge the gap between physical and digital models, and (c) to enable students improve their design proposals. This paper summarises the process and outcomes of the new course that introduced the use of 3-Dimensional Digitisation in the design process. The paper first discusses current CAD applications within the architectural profession and educational institutions. It then, explains the architectural design process and introduces 3-dimensional digitisation. Finally, the educational challenges facing CAD applications and the viability of 3-dimensional digitisation in particular are reviewed.

2. THE CONTEXT

CAD made its appearance a few decades ago thanks to the aerospace and car industry. Within the last decade, there was a proliferation of CAD package providers, which made CAD systems widespread and easily accessible. Nowadays, digital technology is allowing designers to explore new architectural design processes given its fast development and availability.

There is no doubt that the introduction of digital tools in the design and construction of buildings has generated mixed feelings. In order to understand the reasons behind that there is a need to briefly overview CAD use within architectural practices and educational institutions.

2.1 Architectural Practice

According to Steele, J. (2001) "computers have revolutionized architecture", but at the same time they have created strong divisions amongst architects and scholars, primarily due to the fact that there is increasing concern that CAD is affecting

designers' identities and the expression of their creative work. Therefore, care should be taken when using this tool in architectural design. On the other hand, some designers have revolutionized the design process by letting the computers lead the way, particularly when it comes to resolving complicated geometries. CAD has been used primarily as a tool to enhance design by producing graphically defined concepts, and working drawings. At the same time, architects rely on free-hand sketches and physical cardboard models as important conventional tools that are combined with digital ones during their design process. (Szalapaj, & Chang, 1999)
Although many architectural design offices have used CAD as a drafting tool during much of the 1980's, this did not generate a new architectural language. In fact, it was during the 1990's that CAD finally started to become an important design tool thanks to architects such as Frank Gehry. He used CATIA computer program (developed by DASSAULT) for the first time in order to produce a smooth and well dimensioned steel structure part of his fish-shaped pavilion for Barcelona.

Peter Eisenman also used computer to design the Aronoff Centre for Design and Art by generating a series of tilted building forms. These two architects had opened the way to a new architecture that is born as a result of the interaction between the designer and the digital media. (Jencks, 2002:211; Van Bruggen, & Gehry, 1998)

Frank Gehry adapted CATIA mechanical design system to suit his needs not as a design tool but rather as a means to produce precise drawings, due to the complexity of his buildings. (Steele, 2001:122) He digitises large physical models using mechanical tracking devices, and feeds them into CATIA for analysis and production of working drawings. This is further illustrated by the fact that his physical models are constantly validated or altered by computer analysis. He does not just use them as a means that enables the design and manufacture of very complex building components.

In addition, CATIA allowed Gehry to produce detailed drawings that enabled the production of interior steel elements and limestone with minimum wastage. It also allowed the design team to carry out changes and evaluate them immediately in terms of feasibility and costing. The design and construction of the Guggenheim museum in Bilbao demonstrated that the use of CAD has created a new paradigm that "is credible at both the sensual and economic levels". (Jencks, 2002:251)

Generally CAD has allowed designers to mix heterogeneous building components in a smooth continuity by using powerful modifiers. Some architects claim that CAD packages influence the design outcome because of the way the software performs its mathematical calculations. Surely the software can influence form, however the crucial thing is that CAD can be customized and used efficiently to avoid the production of alien and repetitive architecture. (Jencks, 2002: 219)

More recently, computer designs show that CAD has allowed architects to use and manage complex building details, to the point of producing biomorphic architecture; architecture which deals with forms that are closer to nature and the human body.

2.2 Architectural Education

It is claimed that the use of computer applications in architectural education had a similar pattern to the one the industry has experienced. That is of being used either as a means to assist the design process, or as an integral part of this one. There is no doubt that most recent graduates are proficient in the use of CAD packages, therefore creating a serious gap between themselves and their predecessors. Having said that, architectural education has always failed to produce graduates that are capable of handling practical office matters or even construction problems in a conventional manner. (Steele, 2001:208)

It is widely understood that the aim of architectural education is to enable students understand the design process, its applications, and how to effectively use it in the making of the built environment. The process by which this is achieved and the applied design philosophy vary from one school to the other. However, the design process generally follows a methodological approach, and as a result, a variety of teaching means are normally used including model making and computer modelling. (Norman, 1998)

Many schools have adapted their curriculum to include CAD courses, Digital Design Studio and mandatory practical training or year out in practice such as in the United Kingdom and Ireland. At the United Arab Emirates University, Department of Architectural Engineering, a new course has been introduced that focuses on the introduction of 3-Dimensional Digitisation into the design process. This is a serious pedagogical challenge in studio teaching given that CAD has so far been used to complement conventionally produced design projects. In addition, the use of CAD is generally limited to 2-dimensional drawings, or incomplete 3-dimensional models. In fact, most physical models produced by students show more architectural qualities than the 3-dimensional computer models included in the final design submissions. This is due to the fact that CAD Applications courses do not effectively address the integration of CAD into design studios, or at least this is not shown in the product of design studio courses. (Kalisperis, 1998; Levine & Wake, 2000)

In most schools of architecture, students use physical models to express their design intentions, especially at the conceptual level. Furthermore, architecture students are encouraged to use CAD programs to study and present their work. The success of this endeavour varies greatly from one place to the other largely due to the availability of advanced CAD facilities, and faculty and students' interest in the field

3. THE PROCESS

Traditional computer modelling programs are unable to easily generate complex architecture, or for example architecture that contains organic geometry. One way of resolving this problem is to use 3-Dimensional Digitisation, a process that captures and edits the data with a 3D digitiser such as the mechanical tracking device called MicroScribe, created by Immersion Technologies. There is a wide variety of 3D digitisers that range from mechanical tracking devices to laser scanners.

A physical model at a given design stage can be digitised for further examination using a CAD application. There are many ways of digitising a physical model, but these generally fall into seven categories: mechanical tracking technology, laser scanners, magnetic tracking, ultrasonic scanning, Photogrammetry, Interferometry technology, and optical 3D scanners. For the purpose of the new CAD course, a number of digitisers have been reviewed with the aim to select an affordable and useful solution. The mechanical tracking device called MicroScribe was chosen, and later introduced to the studio teaching. (Fig. 1)

The main focus was to provide the students with an affordable tool that could easily 3D digitise conceptual physical models.

3.1 Mechanical Tracking technology

This uses a mechanical arm that is compact and easy to use. This device digitises contours of physical models using software such as Inscribe to process the data. The 3D computer model can then be transferred to a CAD application such as 3D Studio Max, Form Z or AutoCAD for further modelling.

Fig. 1: MicroScribe Digitisers from Immersion

Fig. 2: MicroScribe Digitiser, its accessories and the laptop

MicroScribe 3D is a tool to measure the location of points in 3-dimensions in space, or on the surface of an object. This equipment tracks the location of the hand-held probe tip. It is a precision mechanical arm with high-tech processor and censors. This equipment is connected to a host computer, and requires a software application interface such as Inscribe. (Fig. 2)

3.2 Three-dimensional digitisation

The design process emphasizes the importance of the use of free-hand drawings and efficient model making during the conceptual development and preliminary design phases. This normally starts as a free-hand drawing; then it is interpreted in a 3-dimensional fashion through the making of a physical model, and finally the model is transferred to a digital format, which allows further analysis and development.

Whilst some architects use the 3-dimensional digitisation as a last step to produce working drawings, it was intended here to use the digitisation process as a means to obtain accurate 3-dimensional digital models of preliminary physical models. These digital models can then be studied and improved so that accurate drawings are generated, and the final product as a whole is enhanced. The process of digitisation and 3D modelling followed seven stages:

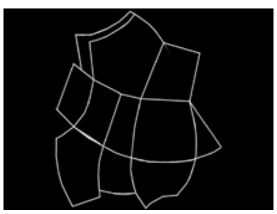
1. The integration of CAD into the design process was introduced and explained;
2. Completed physical models were digitised using MicroScribe 3D digitiser with AutoCAD;
3. Computer models were exported to a selected CAD application (3D Studio Max);
4. A shaded surface model was then produced, studied and improved;
5. Studies of the physical form and materials were carried out to improve the design;
6. Original physical models were improved and updated;
7. All drawings, plus rendering and animation of the model for final presentation were produced.

It should be noted that only students having designs involving complex shapes which otherwise are difficult to present in 3D or as plans, sections and elevations, were encouraged to digitise them. In order to illustrate here the approach used in 3D digitisation, a simple physical model made by a second year architectural students was used. This case was selected due to the design characteristics and the fact that the student was influenced by Gehry's architectural style, therefore producing irregular interlocking building shapes. In order to understand fully her design, she was required to produce a physical model that needed to be digitised. This is done in order to develop the design further and to produce accurate drawings for interim and final presentations.

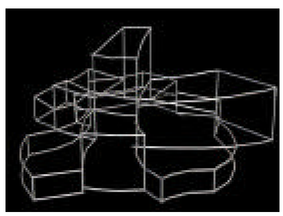
The digitisation of the full model took about an hour. AutoCAD and Inscribe were used as a data capture and drawing software.

Step 1: Set up & prepare Physical model

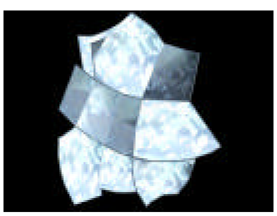
Step 2: Selection of points to be digitised



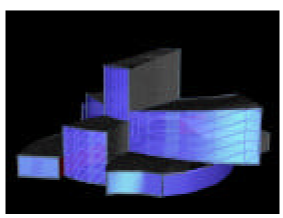
Step 3: An initial mesh is generated



Step 4: 3D view of the first mesh



Step 5: Surfaces are generated



Step 6: 3D view of model with basic materials

Fig. 3: The digitisation process

Before digitising the physical model, a grid or profile curves should be drawn onto the surface. This grid represents the mesh forming the surface of the physical model. This grid was used as a 3D reference for the digitisation process. As a result a mesh was generated, which later was turned into a shaded surface model. Additional profile curves can also be defined on the surface characteristics. (Fig. 3)

Digitising these profiles curves with the MicroScribe 3D is simple. The stylus tip is placed on the physical model and the foot pedal is clicked each time a point is desired. The object should be divided into clear sections that can be easily digitised. The grid should be accurate and following a logical pattern. Curved lines should have a dense grid to enable an accurate digitisation. Flat areas can be digitised using only their corners. (Fig. 3)

Once the digitisation process is complete a 3D model is produced which requires considerable editing. This is due to the fact that mechanical tracking device creates errors particularly if one digitises the same point more than once. These points need to be joined together in 3D space. In addition, planes should be smoothed out to match the levels shown on the physical model, particularly the horizontal and vertical lines. This process proved to be a tedious one that students were not able to successfully overcome due to their limited 3D modelling knowledge. In addition, software such as 3D Studio Max, Form Z or even AutoCAD are not capable of handling complex building design analysis and development in the way CATIA does. Having said that, CATIA has been customised by Gehry's technical team to suit his own design approach. (Steele, 2001:129)

Unfortunately, CATIA is still inaccessible to educational institutions due to its high price and expensive hardware requirements. Furthermore, there is the concern that CATIA's complexity may not make it an easy addition to a CAD curriculum. In addition, even with the help of CAD, students seem unaware about the complexity and character of their design problems and how they should be resolved. (Koutamanis, 1998)

4. THE CHALLENGE

Having presented the context of the project and the process involved when using 3D digitisation, there is now a need to discuss the challenges ahead for architectural students and lecturers.

Initially, the challenge was to introduce 3-dimensional digitisation in order:

1. To improve the design process;
2. To bridge the gap between physical models and digital models;
3. To enable students improve their design proposals.

4.1 To improve the Design Process

The course aim was to first allow students to expand the use of their acquired design skills through the combination of traditional model making techniques and computer 3D modelling. Students generally produce a physical model of their projects to convey a design message. In addition, projects sometimes contain 3D drawings produced by a digital media, usually AutoCAD or 3D Studio MAX. However, these drawings do not form a major part in the design process and, as a result, are time consuming add-ons that sometimes can discredit the efforts of the students.

With the new course, first, students are required to produce a series of sketches and models of the project. Once the tutors and the student are satisfied with the product, then a large and detailed physical model of the project is constructed. After this, the 3D digitisation of the physical model starts at Step 1 of the new CAD production process. The need for physical 3D sketch models in the early stages of conceptual design is critical.

4.2 To bridge the gap between physical models and digital models

Given that there is a widening gap between physical models and their digital counterparts, this new course aims at minimizing a noticeable shortcoming in the teaching of architectural design. It is an attempt to strengthen model-making techniques and to improve 3-dimensional computer modelling in design courses. A course in model-making techniques has also been developed to strengthen students' skills and abilities in making accurate models using a variety of materials and precision tools such as CNC cutters.

It can be said from this experience, that students should be able to produce complex buildings and easily display them using accurate physical models. Then, they can digitise them in order to develop the design further by producing a digital model. These digital models can later be used to build accurate final physical models using CNC cutters.

Students were encouraged to digitised their physical models in AutoCAD and then model them either using the same software or with other packages.

In order to do that, students were required to digitise their models using Microscribe 3D. First, faces of the models were divided into grids that will form 3D surfaces once they are digitised. Then, they proceeded with the digitising of points to produce a series of vertices on the computer screen, which together created a shape, which roughly resembles the faces of the physical model. The points are then manipulated, cleaned up and smoothed out.

The success of this step relied heavily on the 3D modelling expertise of students. This meant that 3D modelling was more problematic than the actual digitisation process. This is due to the fact that knowledge of CAD applications was up to the students and their interest in the field. Of course this created problems since some students were not able to successfully model their digitised p rojects. As a result, a considerable amount of time was spent improving students 3D modelling skills so that the outcome of 3D digitisation can be seen and used effectively.

4.3 To enable students improve their design proposals

There is no doubt that students' learning experience has been made much easier by the use of computers. Architecture students are able nowadays to produce sections, elevations, animations and virtual reality much faster, therefore providing efficient graphical information whether 2D or 3D.

That is why this course encouraged students to increasingly use techniques and the digital media to produce more elaborate designs and accurate drawings.

For instance, once a 3D model had been completed, students started their analytical studies, which consisted in generating a number of 3D views, application of materials and animations. They also were able to produce elevation views that were very useful in creating more detailed designs. Final elevations were edited in graphic software such as Adobe Photoshop or Illustrator.

Students were also able to generate detailed drawings in AutoCAD by exporting files from 3D modelling software. Sufficient knowledge in graphic editing using Photoshop, Illustrator or Corel Draw was required in order for students to obtain accurate and well-presented drawings. Alternatively, students produced their drawings in AutoCAD, plotted them and then applied free hand colouring. This adds to the belief amongst students that the production of photo-realistic images using CAD is more important than the design development. (Fig.4)

Fig. 4: AutoCAD drawing with free-hand colouring

A common complication associated with the use of CAD at this stage is that most of the time students were confronted with computer problems such as exporting and importing files between software, file size, image resolution, and plotter errors.

5. CONCLUSIONS

This paper presented a teaching experience related to the use of 3-Dimensional digitisation in architecture. The principal aim was to bridge the gap between physical and digital models. The reason behind this is that students generally produce accurate physical models, but are not able to recreate them digitally with the same precision in order to produce 2D and 3D drawings.

Knowing that the advantages of CAD applications in architecture vary from the production of technical drawings to Virtual Reality, their use and application have been diverse. While some architects use them to merely produce technical drawings, others rely heavily on their use in order to create buildings that are very difficult if not impossible to develop manually. At the same time, most architects use physical models in order to resolve design problems and to convey design ideas to clients and building contractors. Those who utilise them exclusively resort to 3-Dimensional digitisation in order to develop the design, resolve structural problems and produce working drawings.

Three-Dimensional Digitisation allows the production of accurate digital copies of physical models. In addition, 3D modelling has enabled an understanding of the capabilities and limitations of CAD.

The experience presented in this paper has shown that the digitisation process is simple and straightforward, but the next step, which is the 3D modelling, was troublesome. Students' deficiencies in 3D modelling knowledge and their misconceptions about CAD have created unnecessary burdens to the course development. Students were encouraged to explore complex building forms in the conventional way, and then create an accurate physical model half way through the design exercise that lasts about 12 weeks. This was followed by the digitisation process and the 3D modelling. Students had to use AutoCAD to digitise but were free to select any 3D modelling software for the next stage of their design work. Given that the curriculum offers later a course in advanced CAD applications, namely 3D Studio Max, students attending the design course were not skilled enough to handle complex 3D modelling. This meant that the result of the 3D modelling was limited to simple surface modelling and basic animations.

There is no doubt that 3D digitisation is a very useful tool that helps recreate complex physical models. However, the product of mechanical tracking requires considerable editing, which is time-consuming and necessitates expert knowledge in 3D modelling.

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