AN ANALYSIS OF A COURSE ON PARAMETRIC DESIGN

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ABSTRACT

This paper reviews the outline of an undergraduate elective course on graphic representations in (civil) engineering, focusing on the results of some experiments carried out during the course. The lectures cover a comprehensive review of fundamentals of computer-aided design. During the exercise, the students are asked to construct a parametric design system for a (civil) engineering project within a CAD system (e.g. AutoCAD, MicroStation or ArchiCAD). The subjects of these exercises include realising some user-friendly programs for the complete design of large halls, high-rise buildings, bridges, flood barriers and other (civil) engineering projects. The program written by the students must generate a complete 3D design of a desired project with a minimum number of parameters including the major dimensions, materials and typology of the building (including structural calculations, dimensioning, detailing and any other desired feature). In 2003, the individual project was replaced by an experiment allowing the integration of individual work of all students in a larger project that also involved the exercise supervisors. This paper is a description and analysis of this experiment.

Keywords: parametric design, design education, design exercise, design parameters

1 INTRODUCTION

Civil engineers are often involved in the design of large and complex construction projects such as halls, high-rise buildings, bridges, flood barriers and infrastructure projects (e.g. highways and railroads). Civil engineering students at the University of Technology in Delft, learn during their study some elementary design skills. Nowadays, many design support software are available such as CAD systems capable of capturing the design and presenting it in various ways such as realistic rendering, 2D and 3D representations. An important part of these software systems is the ability to process graphic information. In the Parametric Design course at the faculty of Civil Engineering, students learn the theoretical background for processing graphic information and learn practical details of parametric design systems. In this course, students take part in an exercise comprising of the design and implementation of a parametric design system. This paper gives an overview of this course and discusses the exercise carried out in 2003 where students collaboratively developed one parametric design system.

2 PARAMETRIC DESIGN COURSE

2.1 Overview of Related Courses

At the faculty of Civil Engineering and Geosciences, a section called Design and Construction Processes offers various courses on processes relevant to the Building and Construction sector but also some courses on the application of ICKT (Information, Communication and Knowledge Technology) for the BC industry. At present, the first year students are offered an introduction into the ICKT and different modelling techniques for solving problems in the BC industry such as Geographic Information Systems (GIS), CAD systems, numerical modelling, etc. During the course a wide range of ICKT issues are discussed that are relevant to several disciplines at the faculty such as building physics, material science, water management, coastal engineering, etcetera. During this first year course, students learn the fundamentals of writing a software program in Java and have to develop an application capable of solving a specific (civil engineering) problem taking advantage op modelling techniques using UML (Unified Modelling Language).

After this obligatory course, students can choose from several elective courses such as the Parametric Design, the Geographic Information System, or a mathematical modelling. The students with an interest in building and construction informatics are stimulated to follow courses offered during the MSc study such as BC Product Modelling, Knowledge Technology for the BC and Advanced Systems Design. Often these students prepare a MSc thesis on some advanced ICT applications for the BC industry such as eConstruction, feature recognition and intelligent buildings.

2.2 Theory of the Parametric Design

The Parametric Design course allows students to learn about the basic principles of computer graphics and in particular creating parametric design systems. The principles of computer graphics are presented during several lectures where the students learn the theories, methods and techniques for modelling graphic information such as vector formats, pixel formats, solid modelling, etc. A reasonable level of detail is applied for explaining the differences of graphic formats. Also the students learn about graphic transformations such as scaling, moving, copying, mirroring, Boolean operations, etc. In addition, some database concepts are explained such as relational databases and object databases. These database concepts form a bridge for the theory of product modelling for building design and construction. Students also learn about feature models and semantic product models. In this course the basic principles of product modelling is explained including object diagrams using Unified Modelling Language (UML). During the course, students create UML object diagrams of a building model as well as using a feature modeller.

2.3 The Parametric Design Exercise

A practical exercise forms a large portion of the course. The students build upon their previous knowledge of a CAD system and construct a solid model of an object (a building in this case). They are free to choose the object of their design they wish to create and are also free in the set-up of their design drawings.

The second part of the exercise is to construct a parametric design system by programming a CAD system (e.g. AutoCAD). The solid model they created in the first part of the exercise needs to be ‘parameterised’ and programmed using the ‘Visual Basic for Applications’ within the CAD program AutoCAD. Other CAD systems like

MicroStation or ArchiCAD can also be used when the students have working knowledge of these systems. The students have to define the parameters that are relevant for their design and have to discuss with the supervisors their plan for programming the system. The students have some skills in (procedural) computer programming as well as a working knowledge of schema techniques such as PSD and UML. Most students are not familiar with object-oriented programming or 'Visual Basic for Applications'. The students work one day a week on their exercise with the support of their supervisors.

3 PARAMETRIC DESIGN EXCERSISE

3.1 Set-up of a collaborative exercise

In the past, the exercise for the parametric design course comprised of several sub-tasks including the implementation of a parametric design system. First, the students had to draw a design in order to familiarise themselves with the working of a CAD software. During this exercise they gained insight into the set-up of such a drawing, keeping in mind that they have to implement a similar drawing parametrically.
During the next stage of the exercise, the students collaboratively created a parametric design system. This was in contrast with the previous years, when students had individual and unrelated assignments. The main idea was to integrate all parametric design systems into one larger system. This exercise had to be carefully planned by both the students and the supervisors. The latter planned a parametric design system for an urban development project containing residential housing, street layout, shopping malls, offices buildings, etc. Every student was then assigned the design of a part of this system, which must run autonomously but also can be integrated into the overall collaborative system.

3.2 The Exercise

Every student got an individual parametric design assignment that was part of an overall project. He or she had to decide which parameters to use, how to set up the design and how to implement such a system. The parametric design system was then created within the AutoCAD using 'Visual Basic for Applications' (VBA) as the development tool. The students had to learn how to program and implement their own parametric design system dealing with at least 4 parameters. The following exercises were assigned:

- Street and house plan (using abstract houses, shopping centres and office buildings)
- Houses (different types)
- Office buildings
- Shopping centre

The supervisors provided a structure for the collaboration because the students have little or no experience in developing software and hardly have any experience regarding collaboration in such projects.

3.3 Pre-structuring the Collaboration

To ensure the successful integration of individual parametric design systems into one larger system, the supervisors provided the integration structure for the collaboration. Amongst others, they prepared a software framework consisting of some basic

interfaces. As modules in 'Visual Basic contain software code, the framework resulted in pre-defined modules for each student.
Each student with its own part of the urban parametric design system could log in the network and access the 'Visual Basic' environment within the AutoCAD. Each project has its own module with several variables and (empty) routines. For example, the student with the exercise to develop a parametric design system for a house had a module with a similar name at his or her disposal in order to access to modules of other students. Pre-defining variables for the origin and 2D rotation of design including the routine 'draw' enabled students to use each other's work without dealing with their code. Each student has access to a copy of the individual modules but works only in his or her own module and interface. By using a predefined user interface, each individual interface of each student can be accessed (Figure 1).

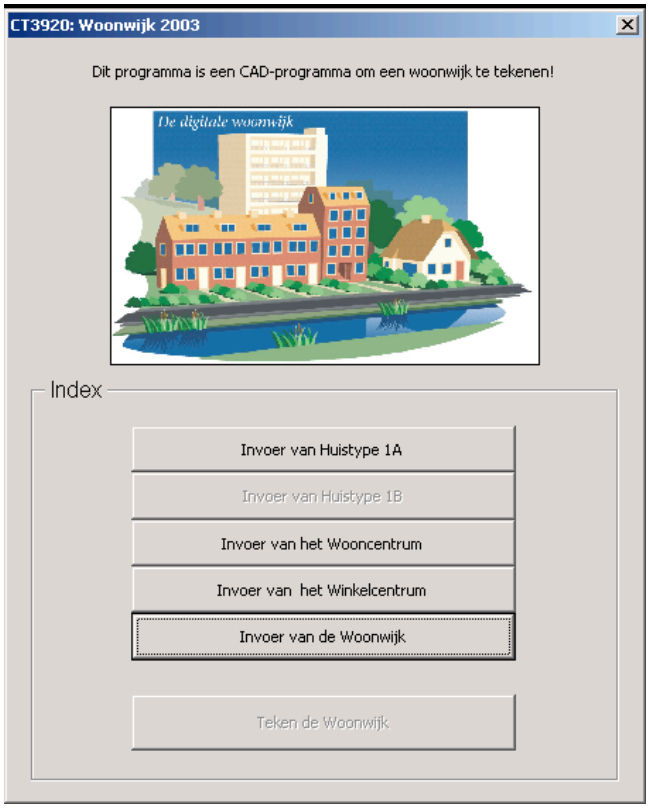

Figure 1 Each student developed its own user interface, which can be accessed through a predefined interface. Each button activates a student's user interfaces.

The idea was to use the whole parametric design system, which combined each individual parametric design system. The last parametric design system, 'Street and House plan', used the pre-defined routines and variables of the other systems. The parameters for the individual systems were private and therefore not accessible or visible to others.

4 THE RESULTS OF THE EXPERIMENT

4.1 Individual results

To ensure the success of the exercise when one student fails, the individual parametric design systems can run independently. Therefore, the supervisors were assured to have at least the individual components. During the oral examination, the students had to present their individual work. They were judged based on the architecture of the program, the choice of parameters and the result of the system. The following screenshots give an idea of the results of the students' works.

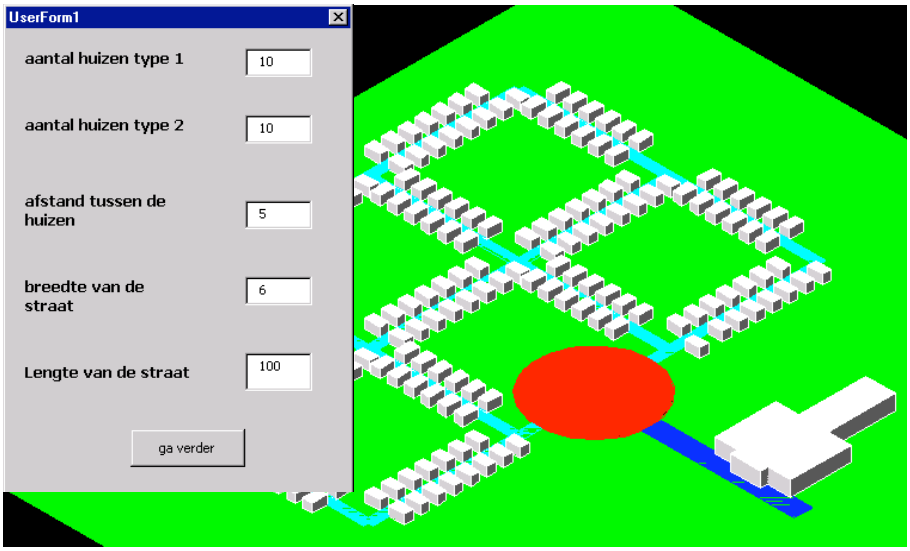

Figure 2 'Street and House plan' parametric design system, using parameters such as the number of houses of type 1, type 2, distance between the houses, length of the street, etc.

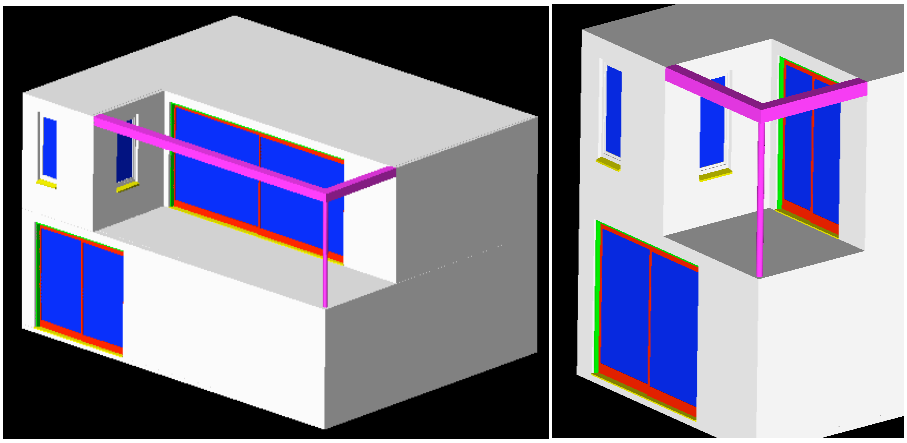

Figure 3 Parametric design system of a house (type 1) using parameters such as length and width of the house.

4.2 Collaboration

At the start of the project, the students negotiated and agreed on how to integrate all the individual systems using the predefined structure. Several aspects were not dealt with in the predefined structure such as the units to work with (meters or millimetres), the base point of the origin (middle of the object, left corner, etc).

In general, the students rushed into their own parametric design system without bothering too much about the integration. At the end and when the individual system became nearly complete, the supervisors stimulated the students to work on the integration. The integration was not without flaws. Besides problems related to the specifications of the interface several more technical issues manifested themselves. For example, several students used the 'copy' method quite roughly and copied 'all' their AutoCAD objects. Individually this worked well for them, but in the overall system, this method produced some problems. Furthermore, the width of the houses as private parameter gave problems related to the urban area system. The urban area system assumed a fixed width for the houses while this was not the case with the type of houses. However, after a full day of work on the integration, the students managed to get the individual components integrated into one system without too many errors and without any help from the supervisors.

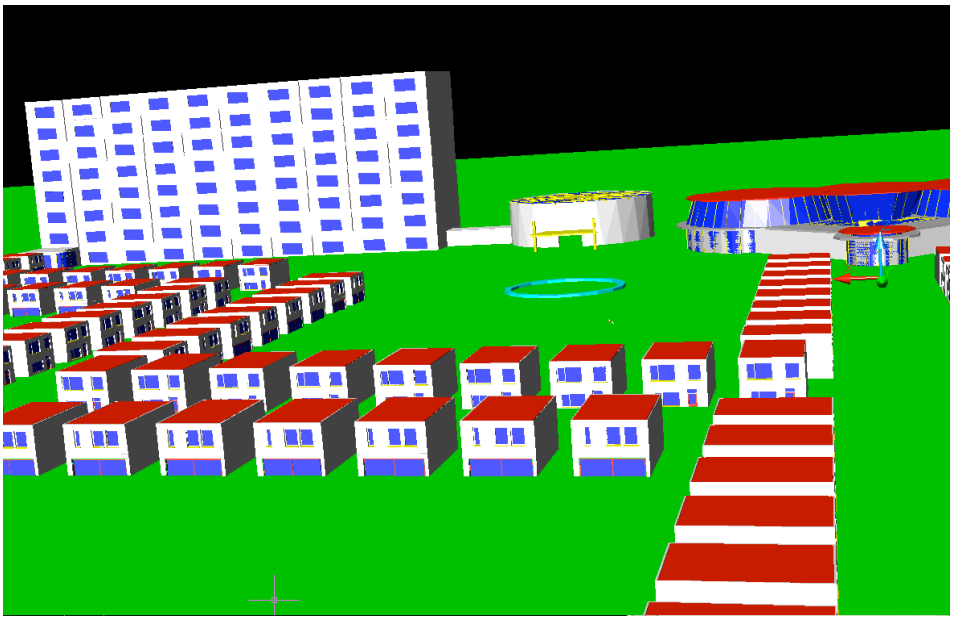

Figure 4 Screenshot of the collaborative parametric design system.

4.3 Conclusions of the collaboration exercise

The explanation on the pre-structuring and what was expected from the students was very time consuming. The individual exercise is quite clear and works reasonably. It is the tendency amongst the students to avoid any form of collaboration. Perhaps nobody wishes to feel responsible for the whole system or maybe it is difficult to oversee all aspects and consequences of project from the early stages of the project. During the

integration sessions, the students seem to grasp the idea more clearly. It seems only at that point they understand their own parametric design system and will realise the problems when they integrate the part.
The parametric design system of the 'Street and House Plan' seems however to be very crucial because it is the part of the system that facilitates the integration of the project and therefore manifests most of the problems.

5 CONCLUSIONS

Based on the successful completion of the collaboration exercise, the supervisors evaluated the process and assumed that the process was successful in reaching the goals and objectives set for the exercise. Nevertheless they agree that a more objective evaluation of the course must be based on the observation and evaluation of results of the course during some more years. However, they spent a great deal of time in guiding the students with this new exercise. Probably with a larger number of students involved in the project, this experiment may not have been as successful. Also, the first time running of the experiment also meant extra time for the realisation and evaluation of the process. The fact that the exercises could run independently ensured a safeguard against the eventual failure of the collaboration. The supervisors believe that the students have learned a lot about parametric design systems and about collaboration in design projects. It is interesting to observe that at the completion of the course, the students fully understood the goal of the exercise. The necessary guidance for the students is however very crucial and in the current situation at the faculty, it is very unlikely that the supervisors be able to continue with their experiment. This has something to do with less civil engineering students and the unfortunate schedule of the course within the curriculum.

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