A digital architectural design environment: Spatial awareness and the linkage of 2D- and 3D design content
Bos, P.; de Vries, B.

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1. Introduction

In Computer Aided Architectural Design, digital design is becoming an increasingly important process. The large number of recent articles about pure digital design cases (i.e., with only one CAD-package) is an indication of the demand for the utilisation of CAD-software advantages in the architectural design process. In most of these digital design cases, there is no proper design environment since only a single CAD-package is being used. Because of this, the CAD-package is the design environment, restricting design operations to only those of the CAD-software, and changing the course of the architectural design process. Traditionally, the 'pen and paper' design environment consisted of tools such as pen, paper and scale models. These tools, with accompanying freedom for design methodologies, are easily digitally represented, creating familiarity with custom design operations but benefiting from the potentials of a digital design environment. To properly translate the traditional architectural design process to a digital design process, the benefits and flaws of both digital as traditional design processes were evaluated after which a digital design environment was designed that combines both digital as traditional and benefits from the combination of both. This environment combines two-dimensional with three-dimensional data, placing the entire design process in a spatial context. The 2D-data is intelligently linked to the virtual 3D-model allowing for navigation through design data in 3D, and parallel design on different levels simultaneously. In this paper, a detailed description of the design environment is presented as well as report of the experiences regarding this environment in a design assignment.

2. Designing

The architectural design is an unpredictable process of reflection and generation, with a constant flow of ideas from the architects' mind to a certain medium. The choice of medium implicates certain design operations and decisions, defining the base of the input for the reflection and generation process. In this chapter, we discuss different media and the implications for the architectural design process.

2.1 The computer as a tool

With increasing complexity in architecture and the involvement of more people, designing becomes less transparent. More documents have to be handled resulting in the loss of overview. Computer Aided Architectural Design (CAAD) offers solutions for dealing with this complexity (Chougui, 2006).

CAD software is widely accepted in the architectural practice because of its speed, sharing properties and high adjustability of the design content. It is unthinkable that plans and sections are prepared without the use of the computer. CAD software is currently only applied in the final stage of the architectural design (i.e., the phase where the design is already finished). However, the CAD features (e.g., speed, adjustability and a wide range of other possibilities) are also useful in every other stage of the architectural design. This is what CAAD aims at. (de Vries et al., 2005)

2.2 Traditional 'pen and paper' design process

To create a digital design environment, we first take a close look at the traditional 'pen and paper' design process. In what we call 'pen and paper' design process, there are a few characteristics; high production of design schemes, design alternatives, design annotations, plans, sections, perspective drawings, and physical model building with different degrees of detail and scale. Sketching and model building as a way to visualize ideas is a proved way of designing, and plays a cru-
cial role in the architectural design phase. Hand drawings and sketches are produced to visualize the current state of the design, or to explore design alternatives. Every new alternative or idea requires a new drawing. Because of the high quantity, these individual drawings usually have a short life-span, resulting in possible loss of potentially valuable design material.

Another problem lies within the physical model building. A physical model is the only part of the traditional design process where the third dimension really comes into play. Although this 3D-visualization of the design is a vital part of the design process and the expression of form and space a necessary and real part of the creative process, physical model building is too comprehensive to be carried out whenever wanted or needed. The physical model is static in the sense that it will not evolve to adapt to future design decisions, hence the construction of new models. Of course this reconstruction of forms can lead to new insights (Cheng, 1995), but is also time-consuming which can lead to abandonment. Apart from being time-consuming, physical models are also made from material that has its own properties effecting the construction of a physical model. A physical model creates an entirely different image being made from concrete as from cardboard. A related issue is the problem of scale. Of course physical scale model building also takes place in a spacious context, but because of the constrain to model in an abstract scale mostly focuses on the exterior volumetric part of the model. Physical model building is usually performed at a scale of 1:100, 1:50, which brings the focus of the model to the exterior of the building. Analyzing interior qualities by doing lighting analysis and materialization studies are very complex at this scale.

Design communication is another interesting aspect of the design process to focus on when creating a digital design environment. To communicate a design, sections, plans, sketches, schemes and perhaps scale models are prepared. The exterior mass is covered by a physical scale model, but the interior is only represented by several plans and sections. This allows only for certain parts of the design to be discussed in detail. Plans and sections cannot represent the entire design, as these visualize the organization, and in lesser degree the aesthetic parts of the design. With the traditional 2D-media and physical scale models, there is not enough attention for the spatiality of the design.

Concluding there are three parts of the traditional design process that need attention. The first is the organization of the two-dimensional design materials; the second is the model building and the third is the possibility for spatial interaction with design material during meetings.

2.3 Virtual environments – virtual model building

Computers are becoming increasingly powerful allowing for realistic simulations and visualizations. This results in a shift of life towards the virtual. Our ability to move within, and understand this virtual world is increasing rapidly. The way we experience these virtual environments and what the implications are on the sense of space, is discussed by research papers on the nature of these virtual environments (Al-Attili, 2006; Chang et al., 2002; Huang et al., 2002). The extraction of information and the experience of spatiality in virtual environments is what makes the application for the architectural design practice interesting. This information can be extracted through the 2D-drawing, plans and sections, and that is what traditional media like hand drawings, plans and sections on paper are unable to express (Liu, 2001). This is a possible reason for the increasing popularity of these new digital media in architecture.

Virtual model building is less time-consuming than physical scale model building. This encourages designers to evaluate space more often in 3D during early schematic phases and perhaps more detailed. The more detailed these virtual models are, the more information we can derive. This is also helpful for design communication where more information can better support design meetings.

The actual modeling of 3D-models is a necessary and significant part of the creative process of the architectural design. By bringing this process to a virtual environment, the designer immerses into this simulated environment becoming a participant who can experience and influence instead of merely being a spectator.

3. Digital design and communication environment

After having discussed the different media and the implications for the architectural design process, we will continue by discussing an environment that combines the advantages of these media in a single architectural design environment.

3.1 Description of environment; working and aim

The proposed digital design environment responds to the need for an architectural design environment that organizes design data and provides room for visualizing ideas and experiencing this through spatial elements. Virtual model building using CAD is the core for making this possible. This 3D model has an ambiguous function. It is not merely a representation but the actual design and a visual outcome of all design decisions. The virtual 3D-model is besides being the design also a 3D-archive for both three dimensional design data as well as all two dimensional design data. By swapping between presets of the 3D-model that isolate certain parts of the design and have distinctive locations in the virtual model, an overview is presented of the entire design. This means that every custom preset part of the current state of the design can be isolated and studied in detail, but also every single 'rejected' design alternative can be viewed. To complete this 3D-archive, the 2D-archive has the same presets as the virtual 3D-model. These environments are linked together. When the user swaps between locations in the design (virtual 3D-model), for example from the exterior façade to the interior plan, the two dimensional environment changes from showing 2D-content regarding the building exterior, to showing 2D-content regarding the interior plan. These presets can be custom made, for example if you want to zoom in on a window frame, a preset for that specific window can be made with accompanying 2D wording space.

By using the virtual 3D-model as an archive for all 2D-design-content, navigating around the 3D-model is stimulated. This involves experiencing the design in three dimensions by just browsing through the design content. This literally adds a new dimension to content management and can be utilized for designing and design communication.

The setup of the environment consists of two parts, the 3D-part with the virtual 3D-model (3Ds-MAX) and the 2D-part with the sketching environment and the archive of 2D-content. The setup of this working space is similar to the current design environment with a physical desk containing 2D-design data and a computer screen where CAD software is running. In this environment the linkage of three-dimensional with two-dimensional data is implemented.

Figure 1 shows the 2D-part of the design environment. When changing locations in the virtual 3D-model this entire screen adapts to the indicated location in the design model. This means that the sketches (bottom part of the screen), the material that the user marked as important to the current state of the design (upper right part) and the archive for that specific part of the design (upper-left part) change to showing specific information regarding the new location in the virtual 3D-model. Figure 2, 3 and 4 illustrate this process giving three examples of the environment in three different loca-
The design environment consists of two screens. One shows 3D-studio MAX 8 and implements the three dimensional part of the design environment. The two dimensional part for file management is implemented by windows explorer. The bottom half of the screen is reserved for sketching and hand drawing and is implemented by Adobe Photoshop CS2. The upper half is divided into two file management windows (fig1). These two are different from each other as one (left) represents the archive by displaying a folder structure containing all 2D design material regarding that specific scene, and the other one (right) represents the physical desktop showing the currently ‘active’ design material. This is what, on a normal desk, would be on top of the pile of drawings, schemes, text documents, reference projects etcetera. The content of these files is visible, showing the user what needs closer attention or what the current status of the design is. All screens are interconnected which makes it possible to drag an image from one part to the other; from the archive to the drawing board, from the archive to the 3D-environment etc. The input device for the 2D environment is a graphic tablet (fig 6). This creates familiarity with the way sketches, hand drawings and design annotations are made in the ‘pen and paper’ design process.

The backbone of this environment is the ‘multiple desktop’ function that is hidden in Microsoft Windows. This multiple desktop operation is driven by Nvidia ‘Nview Desktop Manager’. This manager presets the entire setup so the entire environment can be loaded with one click (fig.5).

The design environment of the virtual 3D-model.
ing an overview of every past design alternative evaluated in 3D. The two-dimensional design content is being managed by categories defined by the presets in the 3D-model. The management per category is done manually. This makes version control and the definition of what is ‘old’ and what is ‘new’ too intensive for design history management. With the use of a proper content management system (Voigt et. Al., 2002) all 2D design material could be linked to the 3D design history or design alternatives. This enables the user to provide an overview of certain design decisions during the design phase or design process. It also allows for quick switching between design alternatives in the hierarchical design tree. During this test case, no prefabricated content-management system was available to support the user to experiment with the organization within this environment. The implemented scripts only allowed for switching between presets of the current design like exterior, city planning, interior dwelling, public square, staircase etc. in the 3D-environment. This means that when you want to see alternatives of the exterior façade, the 2D part of the environment will still show the current state of the design regarding the exterior façade.

4. Experimental Results

A design assignment was formulated to test the proposed design environment within the whole design process. The assignment aims to revalue the public domain of Amsterdam, linking working and living conditions and the public domain in a way that different archetypes have the ability to employ the building in their own way. This complex is situated near the extension of Amsterdam central station. Because this assignment is based on a complex program with interrelations between working, living and the public domain, it was important to design from the inside out; examining spatial relationships by the utilization of the program. It provided an excellent test-case for the proposed design environment.

4.1 Environment

When spatial context became important for the design, almost everything that could be placed in a spatial context was modeled and evaluated in 3D. This extensive 3D modeling lead to an enormous amount of 3D data which after a while became cluttered. To overcome this problem, a script module was designed to present the user with the option to switch between selection presets of 3D data (fig.7). These selection presets consisted of design alternatives or sub selections of the actual design. This allowed for isolating certain parts of the design to concentrate more detailed on problems or for example to switch between the exterior façade and the interior living space. To continue working in the spatial context of the surrounding program, the selection presets were extended with a selection sphere that included adjacent 3D models. This means that when selecting a dwelling, the pavement and backyard were visible too. These presets were presented in the form of buttons which were given meaningful names (fig. 2, 3 and 4).

4.2 design methodology

Following Breen’s quote that ‘the medium is the method’ (Breen, 2000) implies that the translation from the traditional paper medium to the virtual environment involves changes in the architectural design method. Given that the spatiality in the virtual 3D-model plays an important part of the design, and that the entire design phase takes place in a digital environment, it is within expectations that parts of the design method will differ. Also the possibility for parallel design on different levels simultaneously has implications for the design process. In this paragraph the differences with the conventional ‘pen and paper’ design methodology are discussed.

The architectural design phase started off non-different from the traditional ‘pen and paper’ design process, namely conceptual city-planning, diagrammatic and schematic research. This design phase’s two dimensional content was then translated into a four minute movie, orderly expressing an urban vision for Amsterdam in a way that wasn’t possible using static 2D-content only. This was after one month, and hereby deviating from the traditional ‘pen and paper’ design process for the first time. After this phase the three-dimensional working space was used extensively. Great deals of models were built with a selection sphere that included adjacent 3D models. This means that when selecting a dwelling, the pavement and backyard were visible too. These presets were presented in the form of buttons which were given meaningful names (fig. 2, 3 and 4).
time performing more abstract studies. The parallel working on different levels became more apparent as the design did not evolve as a single design model, but revealed as different cores (presets) merging together in a synergetic design. Although they evolve separately, this parallel working on different levels is possible because they still share the same space within the virtual environment. This led to, for example a volumetric mass study with one detailed dwelling to examine the spatial qualities from the inside out. This event is of course stimulated by the digital design environment, the definition of presets and the ability to rapidly switch between these different levels of the design.

4.3 Design communication

The communication of two-dimensional design data is placed in a three dimensional spatial context. Whether it is used for designing or design communication, there is always a spatial awareness of the relationships between the design content. This supports design meetings with more information than ‘traditional’ design meetings with hand-drawings, scale models, plans and sections. The influence of the design environment on these design meetings are discussed in this paragraph. Several discussions regarding the architectural design took place using this environment.

In the early stages of the design where city planning and the conceptual models were discussed, surprisingly not even once the virtual 3D-models were addressed to clarify certain aspects of the design. Apparently the generated 2D content was explicit enough to communicate the ideas. When spatiality became more important, and the complexity of the relations between functions started to increase, the virtual 3D models were used to gain insight in the spatiality of the building. A problem occurred with design communication when the swapping of presets implied large translations in space. For example when the environment swapped between the buildings exterior to a dwelling, the swapping resulted in a loss of orientation for the person who the design was being clarified to. To overcome this problem, the ‘un-hidden’ part of the 3D-model had to be increased to place the isolated part of the design back into a recognizable context. Another option was to temporarily unhide the entire design and walk around. For this purpose a script was generated to add an extra step to the switching between presets. This extra step was a slider that indicated the area around the focus point. This gives a range from zero to 40 meters providing the user with the option to decide how large unhidden surrounding should be to orientate between different presets.

Unfortunately there was not time for other users to gain acquaintance with the environment. Design communication sessions were operated by the main-architect only, which led to the debarring of other users from the 3D-environment. Little designing took place during design meetings. Some architects indicated that everything was going on in a spatial context, and the ability to express ideas in this spatial context was absent. This was actually true because the 3D-part of the environment was only operated by the designer himself, but it does indicate that the spatial awareness generated by this environment stimulates the generation of ideas in relation to this spatiality. The possibility of spatial expression of other users in this environment is what the environment lacks. Because the virtual 3D-model is the actual design, experimenting with ideas during design communication in the current state of the design environment would be undesirable because this would implicate altering the current design. The possibility to use the 3D-model as an under layer for 2D-content and thus sketching with accurate 3D-information was esteemed as unsatisfactory. This is interesting because apparently the means of the traditional 2D-media were seen as insufficient, and the need to express ideas in this spatial context was dominant.

5. Discussion and conclusion

We presented an environment for digital architectural design which links three-dimensional design data with two dimensional. By linking this material the user is offered a design environment in which searching for two-dimensional design content is unnecessary. Just by swapping to the aimed part of the design, the two dimensional working space changes to display only that design content regarding the specific part of the design.

This environment can be seen as a way to organize design data, but is actually more. By making 2D design data part of a 3D-model there is a very low threshold to examine spatial
relations in 3D. This results in a large number of 3D models, and since this generates the link to the 2D design content, exploring design content becomes a spatial experience of the actual design. That is where this design methodology stands out from the conventional methods. The crucial difference from the traditional ‘pen and paper’ design process is adding greatly to the constant spatial awareness in every phase of the architectural design and synergetic parallel design on different levels.

Designing in the proposed environment was very satisfactory because traditional operations like sketching and annotating were automatically combined with the benefits of the virtual 3D-environment. A feeling of experiencing the design throughout the entire design phase made the design very realistic, and design decisions well-founded. This places every design action in a spatial context opening numerous interesting spatial relationships.

The design communication sessions did not happen to full satisfaction. The environment apparently has trouble dealing with multiple users, which therefore degraded the level of interaction with the design data. Research about multiple user interaction with digital design data for design communication would be a great addition for this environment (see e.g. Han, 2005)

REFERENCES


