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GROUP FORMING: NEGOTIATING DESIGN VIA WEB-BASED INTERACTION AND COLLABORATION

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Abstract. This research project proposed to create spatial and communal qualities of Group Form architecture via a web-based user participation design method. The proposed method allows multiple users to simultaneously design houses on the same site, encouraging spatiotemporal negotiation as users interact and collaborate with one another. In order to assess the feasibility of this approach, a prototype of a web-based Group Form design tool was implemented using the Processing environment. An experiment using the web-based tool was conducted with the objective of exploring the actual user behaviour.

Keywords. User participation; group form; web-based tool; Processing; collaborative design.

1. Introduction

Online user participation in design is becoming more prevalent in today's world. Involving users in design can lead to a better fit between design and different user needs and can result in a sense of ownership over the design outcome. The Internet has become an invaluable tool to enable such user participation as users can interact via the web from any location over extended periods of time. Furthermore multiple users could be logged in at the same time, thereby creating opportunities for user-user interactions.

Collective Form, or Group Form (Maki, 1965) architecture can be found in medieval cities and traditional vernacular communities. They typically emerged over a long period of time, from spatial negotiation between neighbours as land was urbanized and as new buildings replaced the older ones. This process can be seen as a bottom-up planning approach where a micro single house unit is the generator of the macro village form.

Many architects today find the spatial relationship inherent in Group Forms as having desirable qualities. In some cases, they attempted to create these Group Form qualities in a top down manner though following certain spatial rules. For example, in Japanese architect Koji Tsutsui's Annular Orphanage in Uganda, Africa, clusters of housing facilities are formed by positioning rectangular units at a 45 degree angles to the adjacent units (Tsutsui, 2010). However, these attempts to create Group Form are missing certain key elements of how Group Form emerges in a bottom up manner.

This research project proposed to create spatial and communal qualities of Group Form architecture via a web-based user participation tool. The research begins with a precedence study of existing web-based tools available. Various types of user-design method are brainstormed and a prototype is created based on the proposed system. Also, the concept of user-to-user interaction via the web-based tool will be developed. Finally an experiment is carried out to test the approach and the outcome will be discussed.

2. Existing Web-Based Tool

Researchers have developed a wide range of web-based tools that allow end-users to design spaces and buildings. Three recent tools that allow end-users to customise residential designs will be briefly reviewed: WIDE Kingdom, Hinterland Koeln, and Bar_Code Housing System. Table 1 below gives an overview of key features of each of these tools.

Table 1. Comparison between three precedence studies.

	Stages	Instant Feedback	Direct manipulation of space	User-User Interaction
WIDE Kindom (2001)	Yes	Yes	No	No
Hinterland Koeln (2010)	Yes	Yes	Yes (Façade only)	No
Bar_Code Housing (2011)	Yes	Yes (2D only)	No	No
Proposed Web-based Tool	Yes	Yes	Yes	Yes

WIDE Kingdom (Chien and Shih, 2001) allows users to customise the design of their apartment units. It employs information filtering as the key mechanism for the customization of apartment units. Users can select the apartment unit, arrange the layout, try different interior finishes, and choose furniture via drop-down lists and text-field. While the manipulation of space is limited, the outcomes are rendered realistically in 3D for visualization.

Hinterland Koeln (2010) is a tool that allows citizens to build their houses within the courtyards of existing building plots. Users can outline their building plot on the map by drawings a shape using the mouse. Various parameters, including the elevation and floor height of the building, can be adjusted via sliders and the changes are reflected simultaneously. These features make the tool very intuitive for the laymen.

Bar_Code Housing System (2011) is a building system for the construction of affordable mass housing blocks with industrialized process. A tool has been created that generates a floor plan automatically based on a set of parameters input by the user, including the number of inhabitants and programmatic requirements to have the system. The tool is accompanied by a comprehensive web environment that facilitates communication and the collaboration amongst the stakeholders involved in the building project.

All three tools allow users to create customised designs via a web-based interface by specifying selections, parameters, and forms. However, it is noted that in all three cases the interaction is solely between the user and the tool. For a design method capable of generating Group Form, a tool would be required that supports user-to-user interaction. More specifically, one of the key elements of Group Form architecture is spatiotemporal negotiation between people with multiple conflicting goals. A Group Form design method is proposed that enables users to negotiate their design decisions via online interaction and collaboration.

3. Proposed Group Form Design Method

The proposed Group Form design method focuses on residential design, and involves both architects and end users in a structured process. The method consists of three distinct stages: *schema development*, *design development*, and *detailed design*.

- In the first stage, the architects would develop a set of spatial rules, referred to as the *design schema*. These rules would be encoded into a user-friendly web-based Group Form design tool that would allow non-experts to design their own residential units.
- In the second stage, end-users would use the Group Form design tool to develop their own designs. The design possibilities would be constrained by the architect's

spatial rules embedded within the tool. Multiple users would work on their designs at the same time within a single site over a specified limited period of time. Each participant would be able to see their neighbours design emerging over time, and various mechanisms would be implemented to allow multiple conflicting design decisions to be negotiated through online interaction and collaboration.

- In the third stage, the architect would take over the final negotiated design and develop it into a detailed design proposal.

4. Prototype Group Form Design Tool

A prototype Group Form design tools has been implemented as a web application written in the Processing language (Processing, 2010). The tool uses a client-server architecture, where the server hosts all design data, and clients are used to connect to the server and edit the designs.

The user works with the client application on their local computer, and over a period of time develops their design. Each time they make any changes to their design, the modifications will be sent to the server and the central model will be updated. If multiple users are logged in at the same time, any changes made to their design will be reflected on other users screen almost instantaneously. In addition, each user will have an avatar, and will see other user's avatars walking around and designing their housing units.

In order to explore the concept of spatial negotiation, it was decided to allow users to compete with one another in defining the spatial location of their house. Thus, rather than assigning each user to a predefined plot, they were allowed to claim any part of the site as their own. Conflicts could then be resolved either through consensus or through auction-style bidding. The former method involves users communicating with one another through online messaging. The latter method involves each user placing financial bids on the area of the site in question, with the highest bid wining. In addition, a complex spatial organisation was proposed, whereby individual housing units could be built on top of each and interlock in non-standard configurations. In order to ensure that no lifts were required, the height was limited to four floors.

4.1. SPATIAL RULES

In order to implement the tool, the first step was to define a set of spatial schema rules that allow designs to vary widely in terms of their overall organisation, but that also constrain them to be viable. These rules were then embedded in an easy to use software tool that would allow non-experts to create designs for their own housing units.

Initially, a range of alternative approaches were experimented with, including *free-hand drawing*, *component assembly*, and *cell selection*. Free-hand drawing has few constraints, and allows users to draw on a canvas. Component selection presents the user with a set of components that can be assembled in various ways to 'build' the housing unit. Cell selection discretises space into a set of regular cells, and allows the user to define the volume of their housing unit by selecting cells in 3d space.

A hybrid approach was finally selected that combined cell selection with a number of other techniques. In the first step, the volume of the site was discretised into a cellular grid and users define the volume of their house by selecting a set of cells. In the second step, the wall areas are divided into a smaller cellular grid, and doors and windows are inserted by specifying their insertion points.

The cellular grid was developed through a number of iterations. In the earlier iteration, various grid sizes were experimented with. However, the same grid has to be used to define all the spaces in the housing unit, which makes it difficult to select an appropriate cell size. On the one hand, if the cell size is too large, then the design moves became too coarse, with users being forced to add unnecessarily large cells. On the other hand, if the cell size is too small, then the design moves become too fine-grained, forcing the user to painstakingly select numerous cells to define their housing unit.

After exploring various options, a specialised technique was developed that allowed users to adjust both the position and size of the inhabited room volume in the cell. The inhabited room volume was set to be smaller than the size of the cell. The cell size was set to 8 x 8 meters, while the inhabited room volume was set to 6 x 6 meters. Once the user had selected a cell, they could then offset the inhabited room volume by pushing it into any of the four cell corners. In a second step, they could further tweak the dimensions of the inhabited room volume. The original 6 x 6 meter space could be resized in steps of 0.5 meters, with a maximum of three steps. Hence, in plan the area of each inhabited room volume could vary from 25 to 36 square meters. This allowed users to easily define their housing unit by selecting a small number of cells, while at the same time allowing users to have fine-grained control over the dimensions of each inhabited room volume. Figure 1 shows the

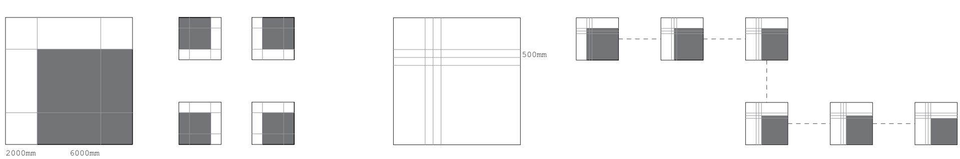

Figure 1. An inhabited room volume within a single cell offset to 4 positions (left) and changing size (right).

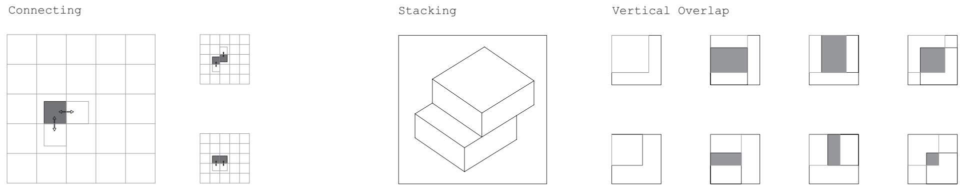

Figure 2. Connecting cells with enforced constraints.

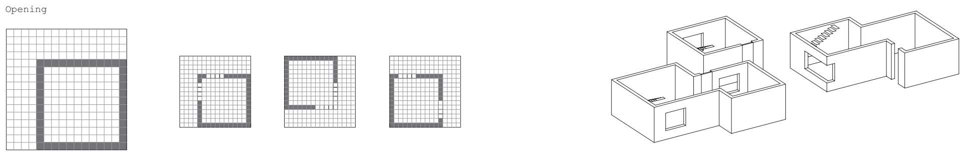

Figure 3. Adding windows.

inhabited room volume being offset within the grid cell to the four different positions and being resized to various different sizes.

In order to ensure that reasonable housing units are generated, three key of constraints are enforced: *gravity*, *connectivity* and *size*. The gravity constraint ensures that users are not able to select floating cells. They can only select cells that are positioned either on the ground or on top of other cells. The connectivity constraint ensures that users select cells that form one single connected habitable room volume. When selecting the first cell, any non-floating cell on the site can be selected. However, after that, they can only select cells adjacent to (including above and below) the already selected cells. The size constraint ensures that users cannot select beyond a certain limited number of cells. There is a maximum of four floors, and the user can select a maximum of four cells per floor.

Finally, once all the cells have been selected and the habitable room volumes defined, the user can then progress onto defining more detailed components of the design, including in particular the positions of the windows and doors. The walls are divided into square 'bricks' measuring 0.5 x 0.5 meters. Windows and doors can then be inserted into the walls by specifying the insertion point in this wall grid. Figure 3 shows the process of adding windows and doors to the walls.

In order to resolve conflicts of cell occupation, the tool allows users to compete for a cell by bidding money. Each user would offer bids for the cell and the user with the highest bid would eventually win the cell. Due to site conditions, certain areas might have higher demand such as those with better view. This approach

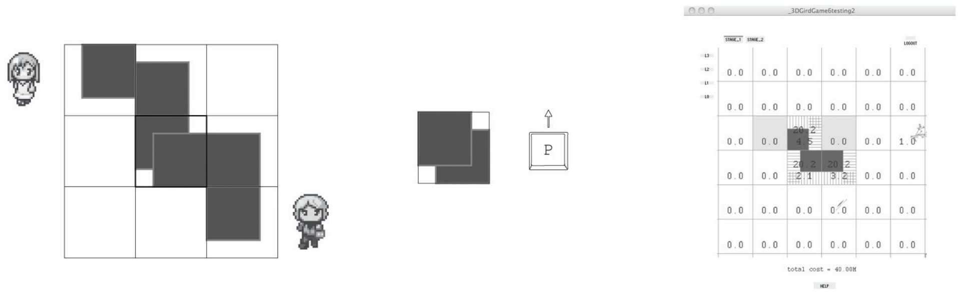

Figure 4. Resolving conflict with an auction style bidding system.

will therefore allow the financial cost of the space volume (and land) to emerge in a bottom-up manner through individual negotiations.

4.2. GROUP FORM TOOL

The final Group Form tool allows users to progress in a fluid and users-friendly manner through the two design steps of defining the habitable room volume by selecting cells, followed by inserting doors and windows.

Figure 5 shows screen shots of a user's interaction with the Group Form tool. For clarity, this scenario only contains a single user. The top three screen captures show step 1, in which grid cells are selected and habitable room volumes are defined. The bottom three screen captures show step 2, in which windows and doors are inserted.

Although an underlying grid is used, the resulting arrangement of units in plan and section do not suffer from monotony, as each user's customisation creates significant variability. Figure 6 shows an example of a plan generated using the schema rules described above.

4.3. GROUP FORM EXPERIMENT

In order to test the feasibility of the proposed Group Form design method, an experiment was conducted. The objective of the experiment is to explore actual user behaviour when using the tool as the feedback is invaluable for further improvement and implementation. The experiment was held in School of Design and Environment, National University of Singapore's computer lab.

Ten architecture students from fourth and fifth year participated. Participants were each given a character card with a role they had to assume. On the card, basic information such as name, age, gender, budget and occupation was stated. Some

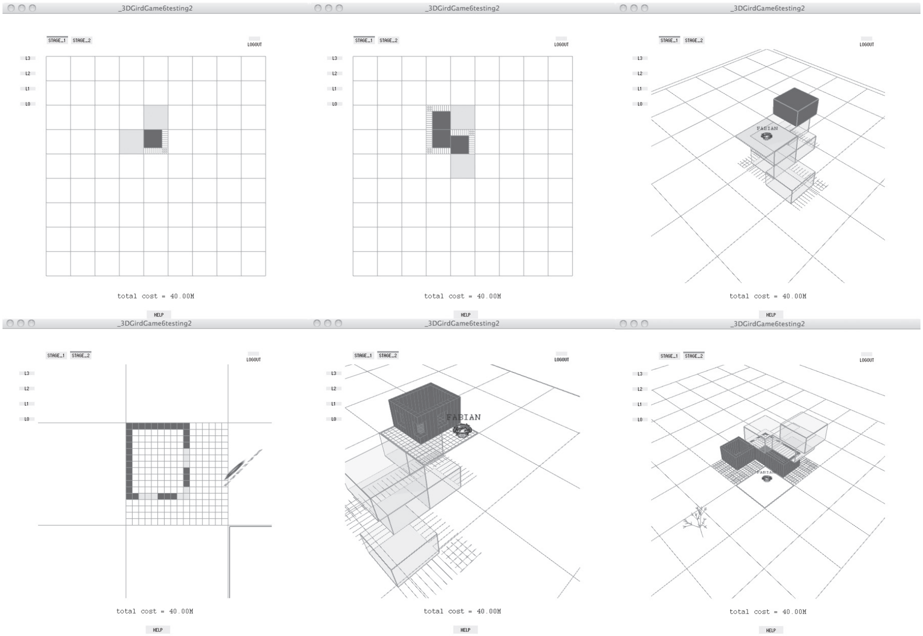

Figure 5. Screen captures of a single user working with the Group Form tool.

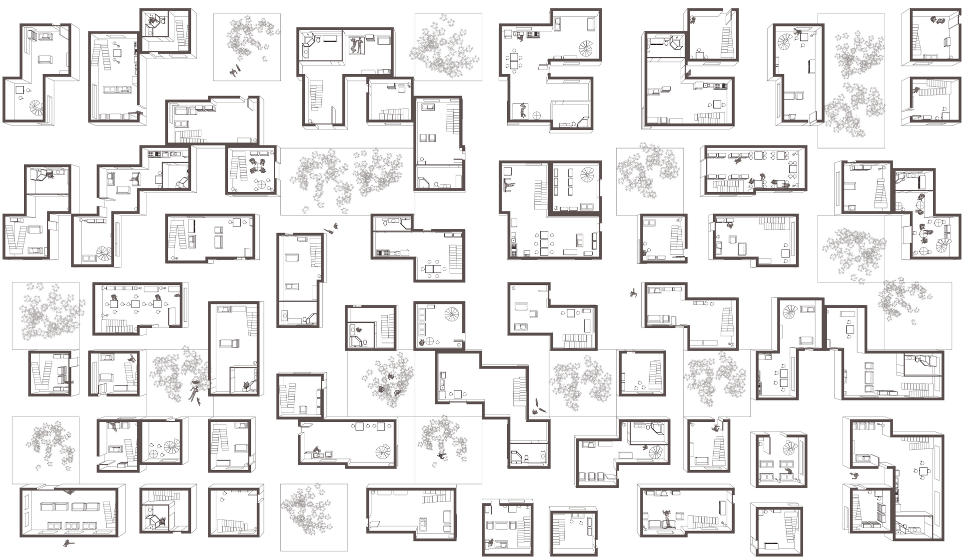

Figure 6. Floor plan generated using the spatial rules.

characters were related. In addition, some of the families were related to each other and therefore included preferences to live closer together. Participants were encouraged to consider the site condition (a square plot of land with forest, river, carpark or road on each side), the number of rooms required, their budget and land cost.

The experiment lasted for 40 minutes. After the experiment was complete, participants were asked to write down their aims, whether they have achieved their aims, and if they are satisfied with the outcome. They were then asked for more general feedback on the Group Form tool and how the prototype could be improved.

4.4. EXPERIMENT OUTCOME

The experiment resulted in a complex and spatially rich outcome. Users successfully developed designs for housing units that performed reasonably well from a functional point of view. From the point of view of developing a Group Form, the process of online interaction and collaboration was varied, and differed significantly from one user to the next. However, in general the feedback was positive as users could see the potential of such as design approach.

Based on the experiment, three key weaknesses were identified. First, better tools are required for user-to-user communication, such as support for private and group discussions and for the ability to annotate objects in space with comments. In addition, the resolution of conflicts through auction-style bidding required refinement.

Second, additional constraints can be added to disallow design moves that are clearly not desirable. For example, constraints could be added to disallow one user to place a window directly opposite and other users window, thereby avoiding privacy problems.

Third, additional feedback can be added. For example, in the current system, feedback on the land cost and construction cost are continuously display to the

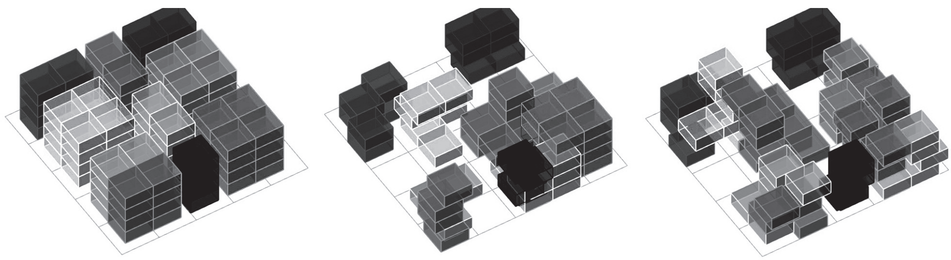

Figure 7. From left to right: Worst-case outcome, experiment outcome, expected outcome.

user. As these users are not expert designers, additional feedback such as predicted energy consumption and daylight levels could help improve the designs that are generated.

5. Conclusion

This research proposed a web-based design method for developing Group Form that supports spatiotemporal negotiation through online interaction and collaboration.

The method consists of three stages: in the first stage, architects encode a set of spatial rules within a design tool; in the second stage, non-expert end users use the tools to design their individual housing units; and in the final third stage, architects take over the negotiated design and develop it further into a detailed design proposal.

In order to demonstrate the feasibility of this method, a prototype of the web-based Group Form tool was implemented. This tool allowed users to design individual housing units within a shared virtual site, with real time feedback. The experiment highlighted the potential of the proposed method.

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