A Simple System for Complex Mass Housing Design Collaborations

A system development framework

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Through the lens of participatory mass housing the paper explores the conference theme of simplicity and complexity. A suitable home is a deep rooted desire in the heart of people, and everyone has their own vision of what is a suitable home. Yet the multi-faceted social needs of housing and how they are being designed and developed in mass housing buildings appear too complex and appear too costly that the process would involve direct user participations. The authors have developed a Computer Aided Participatory Housing Design System (CAPHDS) to allow end users (future occupants) become active stakeholders in the design process with the aid of computational design instruments. These tools allow end users to actively engage in the process. The paper describes how a mass housing design process can be broken down into a set of simple tasks that encourage the active engagement and joint development of end users and architects with the proposed design.

Keywords: Participatory design, housing design system, computer-aided, bottom-up

INTRODUCTION

'The idea of utopias not only courts criticism of being 'unrealistic' or 'idealised', it also has a whiff of revolutionary fervour.' - John Wood, 2007.

Individual needs cannot remain constant in our ever changing world. As each citizen plays their role in society, they build their unique version of 'life'. It becomes a significant challenge to provide equitably for all and allow, as Thomas More (1966) puts it in his definition of utopia, for each to lead a 'cheerful life, free of anxieties.' Yet, we believe that Wood's call for dreamers is necessary to elucidate possible ways to enhance the architect-user relationship and generate a built environment that matches the vision of the user.

Wood (2007) argues that one way to achieve 'micro-utopia' is to rely more on a 'distributed mode of action and responses,' to use a strategy of bottom-up, rather than top-down navigation. In the field of housing, this aligns with John Harbraken's concept of 'open housing' (1972). According to Harbraken's description to navigate from bottom-up, it is necessary to attract useful feedback through an 'Open Source' design that is transparent. The role of compu-
tional media is thus seen less as an instrument to increase the rate and quality of transactions, but rather as one enhancing the efficiency of communication and in turn generating an outcome that is closer to the user’s needs.

By envisaging user participation through efficient communication as the key to the achievement of a collaborative collective housing, we support Wood’s statement that ‘we have become experts at choosing and complaining but forgotten how to envisage what we really want’ (2007 pg. 12). In summary, this paper is making a daring proposition by proposing a possible solution within this complex context: a framework for a Computer Aided Participatory Housing Design System (CAPHDS) that provides a communicative and interactive platform for end users (future occupants) to envision and communicate their housing desires within their capabilities. By offering end users an instrument that enhances their communication and expression of their dreams, the possibility of user participatory mass housing is explored.

AN APPROACH TO DEVELOPING CAPHDS
Diving straight to the participatory context in computer aided design systems, the diverse and changing perceptions of the participants makes it increasingly difficult to determine if a design proposal of a mass housing building is capable of being generated from such systems. The primary challenge faced by this collaborative design system is shuffling between a simplification of the design parameters and details for end users with no architectural background and a complexity for the architects who need a rich set of profession specific details and data to ensure a buildable and successful project delivery. The idea of an ideal living space can be easier achieved if it is a standalone house, which don’t have to fulfill overall collective needs in a mass housing building that is characterised by a network of partly conflicting design parameters - without yet addressing individual needs or requirements. Although this paper sets out to propose a possible solution, a clear design structure and defined assumptions have to be set up to backup this theory. The participatory design development is broken down into three main stages; a) Formulation of the collaborative design workflow, b) Generation of the design collaboration and c) Evaluation of the design outcome. This paper is concerned with the third phase, the assessment of the outcome by applying design analysis criteria and benchmarking it against sustainable housing developments and Open Building Principles (OBP) as developed by Kendall et al. (2010). Emphasis is placed on providing a good level of communication flow and a system usability allowing laypersons to interact with the system and the proposed design intuitively.

The definition of John Wood’s micro-utopia is very similar to what CAPHDS is trying to achieve, the difference is the scale of the condition. To facilitate the development stages, close reference is also taken from John Wood’s (2007) five steps towards micro-utopia: i) breaking through participants’ psychological barrier, ii) providing a means for co-sharing, iii) determining the participants’ needs versus desires, iv) generate the outcome for visual observation and exchange, v) engaging the participants towards a practical outcome. From the steps, we can identify the challenges for a better communication system to encourage more collaborative and participation in the design process.

To demonstrate the possibilities of the proposed system, on based on the criteria of CAPHDS an instrument, called ModRule, has been developed by the author and is described in detail in Lo et al. (2015). ModRule is designed to enable end users of a mass housing building to communicate in the initial design phase their desires and wishes to each other as well as to the architects by setting rules and parameters that are crucial to end users. The design tool is able to work diversely to generate a wide variety of design options for every individual occupant as well as to negotiate conflicting interests and outcomes. Subsequently it is an instrument that allows architects to cooperate closely with potential inhabi-
tants of a mass housing building development and to react to users’ wishes and desires. The setup, therefore, is quite different from a typical design process. This paper will explain how ModRule as a system, provides the capability to address these points and what are the many challenges that remain to be resolved in the design process.

FORMULATION
The simplification of design starts from the beginning of the CAPHDS development process. As Gao (2012) describes the formulation of a collaborative design workflow can be initiated by breaking down mass housing design into five major components: spatial driver, structure frame, skin modules, inner partition system and utility system (Figure 1). This subdivisions allow for design flexibility to occur and for the architects to have control of every aspect of the design. Using a Building Information Modelling (BIM) methodology components are not separated and rather linked together to correlate and maintain information throughout the process. The five components offer the possibility to control information selectively which can be published as open source for others to use or contribute to the libraries of information.

Within these five components countless possibilities to develop meaningful design outcomes can be generated (Figure 1). The two components, skin modules and inner partition system, allow sufficient flexibility to design solutions that response to the design parameters as set by the end users. By opening up these two components for user participation, the architects will have to design the other three components specifically to accommodate the design variations. In other words, the architects have two critical operations; one, to construct the three components which include creating the basic building form, developing the structure frame accordingly and setting the public space and utilities. And two, to establish the variation schema of the other two components which include laying out a range of skin module and working out the arrangement of the inner partition system allowing types of input parameters such as daylight, sky-view factor, accessibility, thermal radiation, cost, etc. In this situation, a BIM model is necessary to manage the data and connecting the data of the dynamic open source model to the construction documents without consuming extra resources. The challenge for the architects is providing a BIM model that can respond to the wide spectrum of data that arrives from the various design options generated by the end users.

With the design workflow structured properly, ModRule facilitates the collaborative tasks of this stage of the design development (Lo et al. 2014). The basic design of the mass housing building is divided into grids of various sizes depending on the architects’ preferences, and every grid space can be assigned with parameters and variables. The architects first layout the building plan according to necessary elements such as building core, access- and exit routes, utilities, etc. (Figure 2). The grids have parameters attached to them such as space requirements, budget, orientation, daylight preference, etc. quantified and predefined by the architects. The end
users then are provided with their individual user profile that is created based on a profiling questionnaire that users complete prior to using ModRule. The user profiles quantify the various needs and desires of end users with respect to the set of parameters established by the architects. This acts as a guide for the end users while working with ModRule to design their desired way of living.

In principle the predefined grids in ModRule can be designed in any manner as the architects requires it. Taking reference of a Japanese tatami mat which is has a standard dimension. The layout of Japanese houses and apartments are based on the dimensions of one tatami, which acts a base unit of space. The architects set the dimensions of the base grid in ModRule (Figure 2) and users design their spaces based using the grids fields as units by selecting the grid-cells that are within the values sets of their user profiles.

After setting up the plan layout with its grid, the next step is to define the skin module and the inner partitions. The amount of variation can be controlled by the architects to keep the design economically and efficient. With these all defined and set up, the design is ready to be open up for end users to develop and generate the design of the mass housing collaboratively.

**GENERATION**

The generation of the design collaboration is the next stage to enhance the design participation further. Referring back to Wood’s steps, the first step is neither technological nor political but psychological. Yet, to break this psychological barrier, technology is necessary with the help of a strategy: Gamification.

Gamification functions both to promote participation and simplify the process of communication between various parties. Through the involvement of end users, the complexity of the design process is likely to increase especially in the context of mass housing. Recognition of a layperson’s interest in the conceptual design stage necessitates immediate communication with the architects and opens up the problem of dovetailing layperson demand, and maintenance of the professional architects’ quality control (Schnabel et al. 2014).

_SimCity_ and _Minecraft_ are two computer games frequently utilized in relation to architectural tasks (Sanchez 2015). Although they are open world games where the players are required to design everything from ‘tabula rasa’, the players are confined and limited by rules and logics such as working in a grid environment and using building elements provided by the system. In comparison, role-playing computer games (RPG) such as _Mass Effect_ and _Until Dawn_, which follow a particular story-line, require players to make decisions that change the course of the story resulting in individual and unique endings for each participant. The players simply need to make choices. They are not required to keep score or follow complex rules. The story, however, will be adjusted according to the choices made by the players resulting in different story endings. These tasks in the game are stored automatically in a ‘black box’ in the background freeing the player to focus on the game story.

Similarly, it is possible to simplify the CAPHDS design interface by shifting the complex computational processing into a black box so that end users participate in the design process with ease while architects export the required information from the black box.
to guide their production of the models. In doing so, the system could adjust the design outcomes according to the choices made by the end users resulting in design variation for each of them (Figure 3).

In ModRule, the design collaboration with the users starts with setting a goal system based on their personal profile. This goal system is like a checklist of targets that end users shall follow (Figure 4). This is taken in reference to 'objectives' in games where players try to achieve while playing the game. A 'goal bar' is available in ModRule interface that is interacting with the parameters and variables input in each grid. The goal bars fill up accordingly while choices are being made by the end users, indicating whether they are achieving what they declared they wanted.

The role of the goal bar is for every individual to manage their desires. This is to ensure that users are not designing a living space that is bigger than or overfunctioned of what they specified in their user profiles. The info of users' goal bars in available to every participant to encourage sharing, understanding, and social interaction. Ideally, the user transparency will encourage every participant to help others to achieve both, their personal and their common living space since all participants will finally be living together in their future building that they are jointly developing.

Depending on the project it is almost impossible to fulfill all personal goals because of the need to negotiate one’s goals with the other end users, yet the certainly aim and personal desire is to achieve as many as possible. There might be occasions where goals will have to be compromised to achieve others or a solution that fits the common interests. These situations will all be negotiated by the end users themselves offering every participant a better understanding of the overall process and a possible higher acceptance of the outcome.

Once everyone’s goals are more or less achieved up to a minimum threshold (i.e. above 80%), to a point where everyone has agreed on the outcome (Figure 4), the most important stage starts. This is where the individual living spaces are synthesised to generate a common overall architectural design. The 'ingredients' which were prepared at the earlier stage will be applied where users select and design their space with these ingredients. At this stage, the architects take the leading role. Although the aim is to achieve an overall design through a bottom-up, 'democratic' process, the top-down is not negligible especially in this context of mass housing. There are too many building and architectural issues that need the knowledge of professionals.

A CASE STUDY

To verify the proposed CAPHDS development stages, a case study was carried out. This case study was an initial test with ModRule. The main aim of this paper is to analyse the design outcomes and to provide an evaluation framework for the next development of the system.

A few designers were selected to use ModRule and set up the rules and parameters. After every designer has set his or her design framework and parameters, discussion and a trial 'plays' were carried out with each design to rate advantages and disadvantages in terms of flexibility and constraints of the set parameters. One design (Figure 5) was subse-
quently chosen for further development into a full mass housing building. This design provides clear parameters with sufficient restrictions to test a full end user participatory design process.

ModRule: SNOW FLAKE

PARAMETERS
1- Each block is 50 square metres.
2- Designed so that duplex and triplex are possible.
3- No person may own MORE THAN ONE block on any one floor.
4- Public space is not for sale.
5- Final unit to have no more than 35% of the wall space as windows.
6- Slab to slab height is 3500

FAMILY RULES
1- No children, maximum allowed space of 100 square metres.
2- 20% discount for a first child, 10% for every child thereafter. Max amount off is 40%.
3- Max of 200 square metres per any family.
4- Families with children must be within 1 floor of a public space area.
5- Elderly must be within 1 floor of public space.

Figure 5
Chosen design with set parameters.

Eight family profiles were developed to reflect a variety of end users’ profiles (Figure 6). The available parameters for the profiles were set up based on some key housing design parameters (Levitt 2009), such as daylight, privacy, sky-view, sound, wind, height, orientation, view, accessibility and needs for elderly. Kazue (2005) states in her research that it is very difficult for end users to answer what they want, yet it is much easier if they have to respond to questions about the qualities and problems they find in their current living spaces. In our case, the questions asked took reference to Kazue’s findings and the user profiles contained questions about the participants’ background characteristics such as their daily routines, habits, interests, likes and dislikes that are relevant for the design process. User profiles that do reflect the real situations of the participants are necessary to be taken into account from the beginning of the design phase. Placing families together without consideration of these characteristics has proved to create dissatisfaction among them (Kazue 2015).

These profiles are then converted into a goal system where ModRule will use to determine if the choices made are simple desires or needs. Also, when conflicts arise during the design collaboration process, the information can be used as a basis for negotiation. During this case study, there were minimal conflicts and everyone was working together to achieve a final design that best-fit everyone. The transparency of information appeared to contribute positively to the process.

As ModRule was still a prototype and not matured enough for a layperson to manipulate the space intuitively, each family had one representative designer to carry out the actual design according to the profile and instructions. For example, a family of four shall not be located beside a single family who opposes children, an elderly family is preferably located at the lower level and closer to the lift core to have better access to the ground level, etc. In order for every role to fulfill their desired living environment, multiple rounds of discussion and negotiation had to be performed. The parameters enhanced the negotiation with a clearer understanding of each other’s needs and criteria. The designers will then based on the finalised outcome (Figure 7), design the units in detail as a whole.

EVALUATION

With this case study, we can summarize CAPHDS to two main objectives: i) aiding end users to envision their housing needs and ii) provide a platform for sharing and communication between the architects and end users during the design process. This ontology would be used to ensure consistency in the evaluation of the design outcome. Since the system al-
Figure 6
Family profiles based on background characteristics and housing design parameters.

1. Retired Couple - PAUL
   - Budget - $300
   - Enjoy watching the sunsets
   - Spend large amounts of time outside walking
   - Have their children/grand children come and visit often.

2. Single middle aged man - RAYMOND
   - Budget - $650
   - Sky View - min 20
   - Spends most of his time at work
   - Somewhat reclusive
   - No interest in marriage or children
   - Is an avid astronomer.

3. Couple, 2 high school aged children - KEVIN
   - Budget - $450 + 30%
   - Both kids excel in sport
   - The father works away
   - The mother works part time.

4. Couple, 1 young child - YUENGEE
   - Budget - $170 + 20%
   - Day light - min 10
   - Planning on having more children
   - Father works while the mother stays at home
   - Father drives to work as opposed to taking the train.

5. Young couple, no children - GERALD
   - Budget - $320
   - Both work long hours
   - Enjoy spending their weekends away from home
   - No plans on having children yet.

6. Single mid-twenties lady - KELLY
   - Budget - $350
   - View - min 20
   - Likes to entertain guests
   - Works part time and spends the rest doing NGO work
   - Travels to exotic locations at every chance.

7. Two friends, mid-twenties - ARTHUR
   - Budget - $700
   - View - min 30
   - Both enjoy being outdoors and at the beach
   - Like to entertain guests
   - Both work long hours during the week.

8. Retired lady, widowed - TARYN
   - Budget - $450
   - View - min 40
   - Likes to watch the ocean and the sunset
   - Has grandchildren that visit often
   - Dislikes noise.

Although the designers show great interest and satisfaction from the design outcome, it is very hard to determine if the CAPHDS answers to the questions directly. This initial case study helps to determine a clearer evaluation framework that could be used for an extended study with an enhanced ModRule system. In addition, the above presented case study worked only with one model and one group of users which does not provide any basis for deeper observation and analysis.

**DISCUSSION**
The case study provided a list of components that are necessary ingredients for CAPHDS to be able for end users to envision their living spaces.

**Aiding end users:**
- Do potential buyers find it helpful to use a game system to investigate potential living spaces?
- Is their discovery of limitations to fantasised options because of achievability concerns likely to frustrate them and lead to withdrawal from the process?
- Does a colour scheme to inform users that choices are achievable improve the outcome?
- Does the design parameters act as a medium of negotiation between users to resolve conflicts?
- What actually determines user satisfaction with outcomes?

**Enhancing communication:**
- Do architects find the inclusion of client ideas possible using the system of parameters?
- What determine the effectiveness of the system in achieving the CAPHDS criteria?
- Does the provision of bonus points (dollar reductions?) encourage collaboration and bonding of the user community?
- Do they regard the process as useful and efficient in relation to cost and time?
The system has to be able to generate a design flexible enough for open participation and permit a layperson to engage in the design process intuitively. The components listed are based on OBP as they provide a clear discrimination of various building components, which dovetail with CAPHDS. The evaluation includes a way of assessing OBP criteria to determine the effectiveness of the system in achieving the aims. This list can then be later used for further development of ModRule:

- A clear understanding of responsibility in relation to community coherence and individual freedom
- Flexibility of customization options that maintain optimized efficiency in production
- Flexibility to adjust to variation in family types
- Clear distinction of decision-making levels with the aid of professional tools
- Interchangeability of building components
- Clear separation of different building subsystems
- Assurance that building performance can be considered and easily understood by end users
- Assurance of design responsivity to needs of end users after changes
- Responsivity of system operation to end users without need for technological assistance
- Supervision to minimise conflict during collaboration
- Setup of parameters to match end users profile

Taken from this list, the key towards a CAPHDS revolves around design parameters. ModRule is designed such that every grid space does not only have one but multiple parameters and at least one of the parameters is of negative nature. Going back to game logic, this is to ensure every player understands the conditions for their choices, considering them carefully, and not blindly choosing the 'best' spaces. This also shall prevent every player choosing the same grid space resulting in unnecessary conflicts. In ModRule, bonus points are given to end users when their choices benefit their surrounding neighbours. This would encourage end users to collaborate and foster a bond among the community.

Simple parameters could also limit the imaginations of end users to achievable options within the building structure. Because this information may be difficult for laypersons to grasp, the implementation of a simple colour scheme shall inform the end users whether their choices are practical.

If the parameters are set properly, they can provide more than just being design attributes. These parameters can also act as a medium of exchange between end users. This is very useful when conflicts occur between them during the participation process.

In general, there are two key challenges to the practicability of CAPHDS: i) The perceptions of the participants are diverse to begin with but also change in an interactive context, thus creating further complexity; and ii) A client-architect collaboration requires a structure that provides the simplification that laypersons need and the depth and complexity necessary for the architects. These two challenges can be addressed with ModRule that allows for dif-
different levels of negotiation and engagement.

Gamification is a key strategy in dealing with the challenges. Excluding the high-quality graphics and intense gameplay to captivate the interest of players, a game design also requires dealing with a broad range of players. By choosing the right group of target players, the game mechanics and parameters are set accordingly to allow constant or increasing engagement of the players. Although housing design does not involve any gameplay on the surface, the complex management and algorithm are being used to develop games such as SimCity. The intention is to use the same strategy by referring back to these games and determine how we can create a system to engage users in a real design context.

FURTHER DEVELOPMENT

Although there are clear research questions, the first case study only provides a groundwork for improvement of ModRule and the setting up of parameters. Subsequently a second study is planned to explore, observe and analysis the design outcome. This second study has to involve two entirely different models to provide comparison and reduce bias in reviewing the results.

The architects will develop a CAPHDS model (with ModRule) and a Fully Designed (FD) model (conventional 3-4 rooms types). A sample group of new first-year architecture students will be assigned the task of investigating a unit in a medium density housing project using the CAPHDS model. The reason for choosing this sample group is - besides the easy access to the pool of participants by the research team - that they can be regarded as layperson with minimum architecture knowledge. They are also a group of people who has a certain degree of desire to design their own living space. This provides the characteristics closest to the targeted end users that this research is ultimately looking for.

The students will then try out the system: share their ideas among themselves, collaborate with each other to achieve their desired outcomes, negotiate to reduce conflicts and develop the design results with the architects. With the CAPHDS model developed, similar groups of student will then be asked to compare their design result with the architects’ FD model. Two questionnaires will be given to each student and the architects, one for them to differentiate between

Table 1

<table>
<thead>
<tr>
<th>Parties Involved</th>
<th>Architects (involved)</th>
<th>End Users (involved)</th>
<th>General Public (outsiders)</th>
<th>Officials (outsiders)</th>
<th>Professionals (outsiders)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Steps</td>
<td>1) Architects design two models i) with CAPHDS ii) fully designed</td>
<td>2) Have the end users participate in the CAPHDS model</td>
<td>3) Compare between the finalised CAPHDS model with the 'fully designed' model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methods of Observation</td>
<td>Testing the two methods</td>
<td>Trying out the system</td>
<td>Compare the two final design</td>
<td>Compare the two final design</td>
<td>Compare the two final design</td>
</tr>
<tr>
<td>Methods of Evaluation</td>
<td>Questionnaire</td>
<td>Questionnaire</td>
<td>Popular Choice (voting)</td>
<td>Questionnaire</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Things to Evaluation</td>
<td>Design and System</td>
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<td>Design</td>
<td>Design</td>
<td>Design</td>
</tr>
<tr>
<td>Points of Consideration for Design</td>
<td>Design Duration Collaborativeness Engagement</td>
<td>Outlook Economical Fulfil needs</td>
<td>Outlook</td>
<td>Benefits Potentials User Satisfaction</td>
<td>Practicality Efficiency Sustainability Outlook</td>
</tr>
<tr>
<td>Points of Consideration for System</td>
<td>Structure Functions Maintenance Purpose</td>
<td>User-Friendliness Simplicity Fluency</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
the two models and the other to understand if the system provides them with the capabilities and satisfaction to generate the outcome.

To reduce biases, the two models will be opened up for the general public to vote and examine. The bias in this case mainly refers to the group of students. There is a possibility that the time and effort taken to develop the CAPHDS model is simply the factor that they prefer it to the FD model. By engaging the general public, this allows to counter the bias and to receive feedback which design appears to be more accepted, the CAPHDS or the FD model. This could just be achieved by a voting for the preferred design.

We developed a summary of the processes and considerations for the evaluations as presented in Table 1. There are five parties: the architects and end users who engaged with the CAPHDS and the general public, officials and professionals. They will evaluate the design and system accordingly. The questionnaires act as a checklist based on the CAPHDS criteria to evaluate whether design and system met its purpose. If these parties accept the outcome, a high degree of micro-utopia has been achieved due to the direct proportionality to the evaluation scale.

CONCLUSION
This paper presented CAPHDS as the next development for mass housing design. ModRule is designed based on CAPHDS to demonstrate the potential of using such a digital system for participatory process. A case study is presented to generate a detailed evaluation framework to determine if the system does provide the necessary means to aid end users to achieve their desired design. Although this paper tries to provide a simple tool for the users to design their space freely, a complex but well-structured system is definitely necessary to support the process. Since the target audiences are public users, few rounds of studies have to be carried out to fine tune the system performance and if the users are engaging the design collaboratively and not challenging each other. The simplicity of the output, in this case, is directly proportionate to the complexity of the logistic. However, with the help of computation, this could help allow architects to engage in participatory design processes of mass housing design whereby end users are active contributors of the design outcome.

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