DEFINING AND EVALUATING A GRAPHICAL USER INTERFACE FOR A HOUSING CO-DESIGN SYSTEM

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ABSTRACT

The inhabitants' participation in their houses' design process is critical for the customization of houses to their needs and aspirations and, thus, their satisfaction. The provision of mass-housing customization can be addressed using digital technologies, as they offer the generation of a wide range of solutions that can respond to the inhabitants' needs. However, computational systems must be easy-to-use by non-specialists. The available literature shows that, although there are some systems allowing house co-design, existing interfaces were not developed with a focus on the user experience nor tested with potential users. This paper reports ongoing Ph.D. work that aims to define and evaluate a graphical user interface of a co-design tool for mass-housing customization. Interviews with potential users were conducted, and user requirements were extracted. We defined a framework of co-design tasks and designed a graphical user interface for our system, which was then evaluated by a panel of end-users, with a low-fidelity prototype version. Results of the evaluation show that the participants were satisfied with the design. Participants proposed also various enhancements to our design.

KEYWORDS

Graphical User Interface, Co-Design of Houses, Usability, User-Centered Design, User Experience

1. INTRODUCTION

In the built environment, the end users' satisfaction depends on how the space suits their needs and desires. In mass-housing projects, addressing the specific requirements of all end users is a challenge, given their diversity. For houses to be built using a customized approach, end users must participate in the design process from the initial stages of making essential decisions. In architecture participatory processes, inhabitants are usually involved in the definition of requirements but not in the design phase. The usual lack of technical knowledge by inhabitants and the unavailability of tools to help them identify and give form to their wishes and needs, leads to difficulties in the communication between designers and inhabitants (Marschall, 1998).

To tackle this problem, we raise some research questions, namely, "How can we improve communication between designers and end-users?", and "How can we apply digital technologies to benefit the co-design process?". "Making" activities help non-designers externalize their ideas, and digital technologies may allow them to understand better the space representation and design possibilities (Brandt, Binder and Sanders, 2012; Stelzle and Noennig, 2019). Also, generative design methods, such as parametric design and shape grammars, can respond to the housing customization problem, as they can automatically generate a wide range of viable solutions that address the diversity of inhabitants' needs. Thus, we believe that a computational system based on generative design can improve co-design processes resulting in the inhabitants' satisfaction with their customized dwellings. However, for this system to be accessible to future residents, it is necessary to develop user-friendly, natural, and easy-to-use interfaces.

In the literature, we can find several computer systems which have been developed for the design of customized housing. Some are prototypes based on a generative design that responds to the introduction of requirements or parameters (e.g. *Barcode Housing System* (Madrazo *et al.*, 2010), *ModRule* (Lo, Schnabel and Gao, 2015) and *Architechtures* (SmartScapes Studio SL, 2019). There are also commercial solutions that allow users to design homes from scratch, with free-design features, according to their preferences and needs (e.g., *Sweet Home 3D* (ETeks, 2006) and *Roomsketcher* (RoomSketcherAS, no date). However, the gap we found is that their interfaces were not designed having user experience in mind, nor we could find in the literature, evidence of user evaluation studies.

Our goal is to define, prototype and evaluate a graphical user interface for a housing co-design system, focusing on the user experience. The contribution of this work lies in the fact that, adopting a user-centred design approach, the co-design tool is defined based on requirements extracted from direct contact with potential users, i.e., people involved in the past or currently engaged in building a house. This way, the interface will be able to better respond to the end users' needs.

In the next section, we explain the methodology used to gather information from potential end-users to aid in the system design. In section 3, we define the user requirements and introduce the design of a low-fidelity paper prototype (Rettig, 1994), illustrating the basic user interface and functionalities. In section 4, we present the results of a user test performed with the low-fidelity prototype. Finally, in section 5, we present the conclusions and suggest paths for future work.

2. METHODOLOGY

For the definition of a graphical user interface that allows inhabitants to co-design their homes, a five-step methodology was defined: (1) collection of the users' needs; (2) definition of user requirements; (3) definition of the system's features; (4) prototyping the user interface, (5) testing, and evaluating the user interface.

Collecting information from potential users (1) allows us to define the user requirements for the system (2). Based on these requirements, the system's functionalities are defined, as well as the graphical interface that users see and interact with (3). Once the tasks to be carried out by the users and the modes of visualization and interaction are defined, a prototype is created to be tested with potential users (4). In step 5 the prototype is tested with users to improve it according to their feedback regarding their satisfaction and the system's usability. Then, we return to step 4 to refine the interface and create a high-fidelity prototype to be tested again.

For step (1) thirty interviews were conducted with subjects divided in two groups: ten representatives of housing cooperatives and twenty inhabitants of these institutions. The general aim was to identify how participatory processes occurred and could occur and how digital tools could help these processes. Neither age nor gender of respondents were controlled. Men and women between 25 and 77 years old were interviewed. All respondents agreed to participate in the interviews, according to a consent form and user study protocol approved by Iscte’s ethics committee.

The interviews with housing cooperatives aimed to identify how these institutions work and whether inhabitants participated or expressed their willingness to participate in the design process of their homes. The interviews with inhabitants collected their perspectives on the process they were involved in, the way they participated, and how this could be improved. The questions focused on three phases: 1) the participation process they were involved in, 2) their satisfaction with the process and the outcome of the design, and 3) how a digital tool could help them to participate more actively in the design definition. This part of the interview intended to define aspects of the tool, such as functionalities, elements, and phases of the project in which they would like to participate, types of visualization, and interaction.

The results of the interviews with users (potential inhabitants) and architects (1) are reported in (Raposo et al, forthcoming) and upcoming work. Steps (2), (3) and (4) are explained in the next section. In section 4 we describe the results of the step (5).

3. SYSTEM DEFINITION

This section presents a first approach to defining the system, including the steps (2) user requirements, (3) features, and (4) graphical user interface defined in the previous section. User requirements are extracted from the interviews and are the basis for the system definition. In step 3 we define the system’s features which are the phases of the design process in which inhabitants can make decisions and describe the tasks. Finally, the graphical user interface defines how users interact with the design process via our system, including visualization and interaction modes.

The interviews conducted in step (1) showed that inhabitants are not usually involved in the design phase of participatory processes carried out by housing cooperatives. Despite this, when they were involved, they enjoyed having contact with the design and showed interest in participating more actively in the design definition. They would like to explore design possibilities by having a starting solution, that could help in making decisions which could be improved using digital technologies. Also, they showed no difficulties interpreting technical drawings when complemented with other less abstract ways of representing the project, such as perspectives of spaces. We concluded that a digital co-design tool must consider the following general user requirements: i) allow the user to make decisions about the housing, including the definition of the functional program, and the characteristics and relationship between spaces; ii) provide a simple interaction that does not require technical knowledge; iii) allow a 3D visualization for better understanding of the space and design possibilities; and iv) allow visualization and interaction on large screen devices with which people are used in their daily life, such as a computer.

Considering the outlined requirements, we defined a framework for the co-design of housing. We identified tasks carried out by three different players: the architect; the inhabitant; and the system itself.

The first task refers to the “definition of conditions”. In this task the architect defines all the general characteristics of the building, including the location and shape of the houses, as well as the conditions for the inhabitants to make decisions at a later stage (e.g., minimum, and maximum number of rooms per house).

In the “definition of household requirements” task, the inhabitant defines the functional program, deciding which spaces are needed and their overall area.

The housing layout configuration task, performed by means of a user experience involving the system and the inhabitant, encompasses four sub-tasks: a) layout generation; b) spatial layout arrangement; c) definition of permeabilities; d) room detailing.

The system performs the "layout generation” sub-task. The floor plan is automatically generated based on the requirements defined by the inhabitant and the conditions defined by the architect.

The inhabitant performs the remaining three sub-tasks. For example, in the “spatial layout arrangement” sub-task, the inhabitant chooses among the options presented by the system and can reorganize the rooms that were initially presented. In the “definition of permeabilities” sub-task, the inhabitant may accept or redefine the connections between rooms. In the “room detailing” sub-task, the system generates and presents a detailed plan with furniture symbolic representation for the inhabitant to understand the rooms’ size better. Furthermore, to assure a greater satisfaction upon bathrooms and kitchens (rooms which future changes can be very costly), the inhabitant can edit these elements from predefined options generated by the system.

In the “choice of finishes” task, the inhabitants choose the finishing materials for the different housing elements. As mentioned before, this research aims to develop a system interface centred on the user experience. Therefore, we focused our design in providing a user interface to the tasks performed by inhabitants, as opposed to designing a user interface for the architect. As a general requirement our tool must be easy to use, without the need of any technical knowledge from the user. For this reason, the system must assist the user throughout the process. Thus, we propose a system that automatically generates viable housing solutions based on user requirements and provides predefined options for users to choose and customize their house layouts. Also, the system needs to display warnings if the user performs actions that result in solutions that do not comply with regulations.

Our GUI (Graphical User Interface) contains three main areas: 1) a top toolbar with the design tasks and generic buttons (e.g., save, undo/redo, close); 2) the main workspace that is divided into two screens; and 3) a bottom horizontal space that corresponds to the library which displays the predefined options to choose.

For the user to be aware of the design phases, these are tracked in the top toolbar. In this toolbar the current phase being used is highlighted. In the bottom right corner of the interface, there are also buttons for the user to change to the next and previous tasks (see Figure 2). The interface provides instruction sentences to guide the user on what to do at each stage.

The main workspace is divided in two: on the left we have the interaction zone, and on the right, results of the choices are displayed. The interaction is made by clicking buttons and dragging icons from the library. In the “definition of the user requirements” task (Figure 1), the left screen is where the user chooses the rooms and their occupants. After choosing the option on the left screen, the user drags the icon corresponding to his/her option from the library to the right screen. In the remaining tasks, where there is already a housing layout to work on, the left screen displays the floorplan of the house layout, and the right screen displays a 3D representation (Figure 2). When the user changes the design, the system automatically refreshes both representations and the user sees the results of his/her options in real-time.

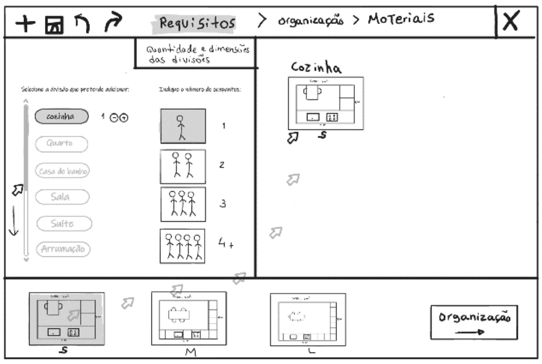

Figure 1. Low-fi interface of the definition of requirements phase, depicting the room characteristics chosen and the size option being dragged to the right screen of the main workspace

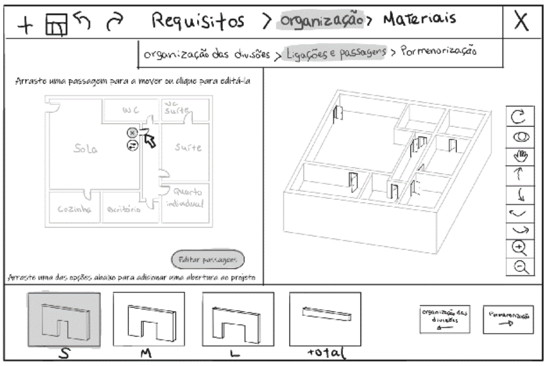

Figure 2. Low-fi interface of the spatial layout phase, showing the double visualization mode: 1) floorplan in the left screen and 2) 3D in the right screen

4. EVALUATION OF THE GRAPHICAL USER INTERFACE

Usability and task satisfaction tests were carried out to evaluate the first iteration of the tool development by means of a paper prototype. This evaluation aimed to identify problems and opportunities for improving the interface. Tasks were defined for participants to use the system, which then answer questionnaires to assess the usability of the system and their task satisfaction.

Formative tests were then made with five participants. Literature shows that this number of participants is enough to identify 85% of the problems in an interface (Gonçalves, Fonseca and Campos, 2017). Participants age ranged between 25 and 45 years old and gender was not controlled. The range of ages was identified during the interviews as potential users of such a design tool. Indeed, this is the age range that people join housing cooperatives and are more willing to take part of the definition process of their homes.

During and after the experience, the participants answered three questionnaires (regarding our dependent variables): SEQ (Single Ease Question), a single question that assesses the level of difficulty in performing a task (Sauro, 2018); SUS (System Usability Scale), to evaluate the usability of the system with 10 questions; and our own GUI (Graphical User Interface) scale, which assesses different aspects of the graphical interface with 10 questions too. The participants were satisfied with the experience and with the interface. In the SEQ questionnaire, all tasks were, on average, evaluated above 6 (scale from 1 to 7, from very difficult to very easy, respectively). The total score of the SUS questionnaire was 91.5. A score of 80.3 or higher is identified in literature as an excellent rating (Brooke, 1995). Regarding the GUI, questions phrased positively and negatively were asked alternately, to be evaluated on a scale of 1 to 5 (from "totally disagree" to "totally agree"). The results show that the negative questions obtained values with averages up to 2.2, and the positive ones obtained values above 4.5.

Participants were also asked to list what they felt were the best and worst aspects of the experience. According to the inhabitants, the system has the following strong points: i) several options to choose from; ii) ease of use; iii) diverse representation modes (plan view and 3D); iv) direct interaction with the house design; v) and seeing results in real-time. On the other hand, in addition to some minor adjustments, the negative aspects mentioned by the participants are related to the definition of permeabilities, i.e., connections between rooms. Accordingly, in the phase of defining the permeability, we observed more difficulty for participants in performing the tasks than in other phases of the process.

5. CONCLUSION

Digital technologies can improve the engagement of designers and end users in a co-design process as they provide non-specialists with a means to define and represent their wishes and needs. Unfortunately, the existing tools reported in the literature do not report the involvement of end users in their development and evaluation.

This research aims to define a digital tool that enables the inhabitants to collaborate with the architect to define their houses in a simple and informed way. For such a purpose we develop a system interface centred on the user experience, defining visualization and interaction modes that respect the requirements collected from the contact with potential end users. We define the user interface in accordance with the design tasks in which the inhabitants are involved. In every step, the interface provides instructions and graphical elements that assist the user in understanding the results of their choices. The participants of the evaluation tests performed with a low-fidelity paper prototype, considered the interface easy to use. They were satisfied that the system generated solutions they could choose from and improve on, as they were not design specialists. Also, the dual visualization mode, i.e., floor plan and 3D representation, was pointed as a strong aspect. On the other hand, the definition of permeabilities, i.e., connections between rooms, proved to be confusing for them.

In future work, we aim to improve the interface, especially the task of defining the connections between rooms. We will also create an improved high-fidelity prototype and test it again with a statistically significant number of participants. We intend to validate the framework developed showing that it enables to improve the engagement of end users in a co-design process, resulting in their satisfaction with their customized dwellings.

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