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Design Thinking for Computer-Aided Co-Design in Architecture and Urban Design

Shuva Chowdhury

Abstract

Bringing the designer's concept to the non-design expert's communicative level requires a significant understanding of the communication media. Primarily the design communication depends on the type of the tools used. Virtual tools with their pre-set operability limit the designer's ways of interaction with the artefacts. This article proposes a framework for designers to interact with non-design experts through an enhanced communicative media. The design framework indicates steps of design thinking to develop the interface by understanding both the virtual artefacts' perceptual affordance to the users and the design task. The paper discusses about projects tested in three different scenarios, urban design, architecture, and product design. It concludes with the arguments on designers' role as authors of the system design.

Keywords: design thinking, design participation, laypeople, interface, virtual artefacts

1. Introduction

Since the development of technology, the participation of end-users used to be an essential part in the design thinking phases. Design thinking with the users leads to deal complex aspects of design context, either in architecture or urban design, with the active participation of the stakeholders. The ever-changing development of virtual instruments and their current state of communicative power open new possibilities to engage non-expert stakeholders, primarily citizens, in the design decision making stages. However, mostly, the virtual instruments come with their pre-set operability, limiting the designerly ways of interactions with the virtual artefacts. Developing the design engagement instrument by understanding the need and interest of the end-users can bring conclusive results from the participation. Such instrument development phases follow the primary concept of design thinking. The process usually a journey of trial and errors. It is also necessary to identify goals and objectives of the design participation and ensure participants' feeling of control in the decision-making process. Thus, this study proposes a framework for designers like architects or urban designers to develop instruments by understanding the scope of interactions with the virtual artefacts and their perceptual representation in the virtual environment.

In the beginning, the article briefly discusses the current trend of shift in participatory design, the concept of tools, techniques and artefacts in design processes and the concept of design thinking in the instrument design. The brief literature review helps to understand the underlining concept of the proposed framework that had been tested with three interfaces. The article argues that the current trend in the computer-aided participatory design process requires developing the instruments with an empathised mindset on possible users' interactions with the interfaces.

2. A shift in participatory design

Participatory design, a broad term, generally means design processes whereby expert designers and people not trained in design work together can engage in collective creativity [1]. It is a collection of design approaches, methods, tools, and techniques shared between many disciplines [2]. Over the past decades, a significant shift has occurred in participatory design practice, where the end-users are involved in the decision-making process. Current covid scenario has also pushed that trend to find rapid, inclusive design solutions for safeguarding citizens' healthy well-being. To tackle this critical time, design professionals have accepted information technology-based intelligent and inclusive design techniques as mainstream line methods for design communication. Designers now design the instruments for end-users' participation to make the process legit and inclusive. In cases, they take advantages of computational tools to include users' feedback during the initial stage of the design phases. To do that, the designers need to identify the design problem and have empathy on the nature of possible interactions that can be obtained with the instruments. These steps are crucial and require experts' eye to identify the design problem and empathise with the users' likely behaviour while interacting with the instruments.

Participatory design process has seen its maximum success in community design practice. The result of such creative engagement depends on careful orchestration of the process keeping in mind the need and interest of the community. This design approach enables citizens to provide meaningful input into the projects through sharing diverse opinions and aspirations. However, to come into conclusive results in architecture and urban design, the participatory modes become pseudo, as the design facilitators cultivate the impression of openness of the participants but retain decision-making in their hand. Arguments are there to utilise such a variety of participatory design approaches where the design performance depends on the system, as they are mission-oriented, and the knowledge is reduced to its instrumental value. But the current disruption in the democratisation of technology shows us that instrumental values can meet social values. In that regard, the mission-oriented participatory design approach can produce design decisions on the demand of citizen needs.

Participatory design practices, which primarily focus on designing the technologies and services, are mainly informed by the user-oriented design approach. According to Bratteteig et al. [3] an approach can have six phases as an iterative design cycle (**Figure 1**). In the cycle, both the process and product are of equal importance. The process defines the usages, and the artefact (product or service) allows those usages to explore in different stages [4]. The importance of this process lies in the technology which mediates the users' behaviour. Involving future users as co-designers significantly increases the chance that the design outcomes have values and meanings to them. However, when there is a discrepancy between the design context and usage context, the process will not be strong enough to mediate the behaviour of the users in the way it was envisioned.

Figure 1.
Use-oriented design cycle [4].

3. Tools, techniques and artefacts

Participatory design instruments, including digital and physical games, mapping instruments, and visualisation systems, are used in participatory design activities to engage stakeholders in design thinking [5]. Participatory instruments support collaborative design enquiry and bring together a network of actors with different backgrounds, competencies and experiences [6]. Ehn [7] describes a design philosophy called ‘tool perspective’, which suggests that computer-based tools should be designed by considering the traditional practical understanding of tools and materials used within a given craft or profession. That means the design process must be carried by the common efforts of skilled, experienced users and design professionals. The users possess the needed practical understanding of the design but lack insight into the technical possibilities. The instrument designers must understand the specific decision process that uses the tool.

Traditionally drawings, product samples, models, and now virtual 3D models are used to mediate the journey of a building concept to the actual built form. These artefacts are often produced for different purposes and obviously for people with varying understanding of the design and construction process [8]. Luck [9] argues that design practice using physical artefacts at the early stages of building design is appropriate for design conversation, as it develops users’ understanding of the design. The design conversation builds the user’s confidence in the appearance of the design, rather than only through the ability of the artefacts to represent a future reality. The artefacts embody the current knowledge of the design in its present status and, during a conversation, prompt discussion on ideas. Here, the ‘act of interpretation’ is acting as a part of the design process. In this regards, Bucciarelli [10] stated earlier that design only exists in the collective sense and is realised through conversation and action. In the same note, Luck and McDonnell [11] observe that an architect has a range of prompts and conversational repertoires to elicit information from users when discussing a design.

The studies below primarily talk about the generation of virtual three-dimensional (3D) artefacts as elements for design conversation. The current nature of

technological interfaces enables anybody to manipulate virtual 3D artefacts by simple hand device movement in virtual environment (VE). The tested instruments below can produce instantaneous 3D artefacts with perceptual understanding particular to the instrument and the design tasks.

4. Design thinking in instrument design

Computer-based instrument design requires a design thinking mindset. Generally, design thinking is defined as an analytic and creative process to engage users in opportunities to experiment, create and prototype models, gather feedback, and redesign [12]. According to the Interaction Design Foundation group, there are five-stage in the design thinking model [13]. They are as follows: empathise, define (the problem), ideate, prototype, and test (**Figure 2**). The first stage is to gain an empathic understanding of the design problem. It includes consulting the experts to collect information more on the concerning issue through observing and engaging with the users. In the defining stage, the designer put together the gathered information. This is where the designer will analyse the observations and synthesise them to define the core problems. In this stage, the designer has to define the problem in a human-centred manner. In the third stage, the designer starts to generate ideas, as the users' initial understanding and need have been analysed in the earlier stages. A new innovative solution can be attained through “think outside the box” strategies with a solid background of expert designers. Then, the steps of prototyping, where the designer test the developed instrument by himself or within a team. This is an experimental phase, and the aim is to identify the best possible solution for each of the problems identified during the first three stages. This stage helps get a better idea of the constraints inherent with the instrument and gives a clever view of how real users would behave, think, and feel when interacting with the instrument. Finally, the designer rigorously tests the complete product using the best solutions identified during the prototyping phase. It is an iterative process. The results regenerated during the testing phases are often used to redefine the problems and inform the understanding of the users.

Figure 2.
Five-steps of design thinking [13].

5. The proposed framework

The proposed framework combines steps of initial data collection through a survey or other resources, instrument developments, design engagements and data collection (**Figure 3**). The initial step of the framework depends on the survey of the users' needs. It can be achieved through a questionnaire survey or by counting the brief of the clients. The second step is the instrument development steps. It comprises identifying the virtual instrument, defining the task by understanding the affordance of the instruments, and then finalising the design engagement interface. The instrument development stage is a non-linear loop-based iterative process. The instrument development steps itself is a reflective process where the design decision on instrument development depends on testing and self-evaluating approaches. Finally, the design engagement step, where the designer has to design the experiment setup to involve the non-experts in the design process and collect data from the engagement.

Figure 3.
The framework.

6. Interfaces for urban design

Here, two different scenarios have presented the immersive quality and the nature of communication. The instruments possess their specific quality of perceptual understandings of the artefacts in the virtual environment and, they also offer different ways of generating those artefacts. These differences instigate the needs to develop the design tasks along with the possible interaction with the users.

6.1 Immersive instrument

In 2019, an immersive virtual instrument developed to involve community people in the early stage of designing their neighbourhood [2, 14]. In the beginning, an initial preliminary survey conducted to identify the interest of the people. The research looked at a low-density suburb based in Wellington, New Zealand. The study looked at the local city council's charrette report to understand the design problem. The survey also helped to develop the design engagement tasks. These steps helped to understand the design engagement context. Then, in the instrument development stage, the designer had to select the right tool by empathising with users' possible interactions. This step was iterative. Several virtual software with different perceptual understandings 2D and 3D investigated to find a flexible tool for intuitive design generation of virtual artefacts. An immersive virtual instrument

had been chosen, where the virtual 3D artefacts generated with the movement of the hand devices. A design collaboration set-up developed for participants to design as a team (**Figure 4**). Finally, a protocol analysis conducted to investigate the type of design communication [15]. **Figure 5** shows some moments of the immersive environment of the users and the participants from the community. The result showed that the employed immersive iterative 3D artefacts provide predictive

Figure 4.
Design collaboration unit.

Figure 5.
Laypeople's participation in virtual co-urban design.

and explanatory power for understanding the interaction. The design discussion progressed when every designer's action produced visual information and initiated the next level of design action. It happened due to successful design communication media, which provided continuous visual feedback to the co-designer. The design task and the set-up of the experiment oriented designers to create building forms. Designers mutually construct conversation moment by moment as a form of interactivity through their use of verbal exchange and design action. The employed virtual environment (VE) design process reflected design actions and negotiations between designers. VE design communication happened due to the presence of design interactions. It resulted from human-computer interactions, where the computer produced 3D artefacts in the VE and eventually provided visual feedback to take design actions and initiated design discussion among designers.

If we see the instrument development stages, it can be seen that the success of the research depends on the type of software selected and the way design tasks was dealt. To do that, the designers had to empathise the possible ways of users' interaction. This step requires frequent testing with all other possible instruments. Developing the design task is another challenging part of such creative engagement. The task should have relevance to the design problem. The virtual representation of the urban environment also had the quality to deliver the resemblance of the 3D artefacts with the actual urban setting. Thus, the participants felt that they designed for their future neighbourhood.

6.2 Non-immersive instrument

In 2018, a non-immersive 2D interface was developed to generate the urban form based on parameters related to building height, plot ratio, land division, construction cost, and building width [16]. It scripted in 'Grasshopper3D', which is a visual programming platform in Rhino. The developed script relied on a set of rules and instructions that could generate the desired outcome. The interface offered various site-specific variables which could be modified in terms of number in the sliders (**Figure 6**). In one stage, the script had been extended for online collaboration. The development of the instrument started with understanding the design context. Same as the immersive one, it dealt with the same neighbourhood in Wellington. The initial survey helped to understand the design problem. Then, we had to identify the urban parameters translated into the visual programming platform in the instrument development stage. In this case, the parameters in the sliders were building height, plot ratio, land division, construction cost, and building width. The users could play with those parameters and could visual the generated urban forms in the interface. While developing the instrument, several self-evaluation steps explored. These steps required the empathising attitudes on possible users' interaction. The study did not get enough data to report on the users' performance. However, it shows a viable way to involve design experts to develop the computational interface for non-experts to be a part of the design generation.

There is some limitation of this kind of interface. Due to the non-immersive interaction, the design tasks are basically controlled by the given parameter of the interface. The users had to decide on the generated urban forms without knowing how one parameter affected the others. Mostly, the users choose by playing with the numbers in the sliders. As the changes happen by the system, it is hard to affiliate with the new scenario by the decision taken on the parameters. These lose the connection of design decisions. Besides, the relationship between the parameters building height, ratio, cost and land division controls the design outcome, which lacks the intuitive nature of design generation. However, this interface allows taking decision in urban planning scale, which is ineffective in the immersive instrument.

Figure 6.
Internet based 2D interface for urban form generation and collaboration.

7. Interface for product design

The interface developed for the product design is an online platform to generate parametric furniture. The interface developed in 'Grasshopper 3D' with its web-based extension 'Shapediver'. Similar with previous cases, defining the parameters for design interaction was one of the main tasks for the designer. The designer had to identify the parameters that could potentially modify geometry in relation to material cost (**Figure 7**). The users took their design decision based on negotiation between price and design. The instrument development started with empathising with the interface. As a part of testing, the survey conducted with seven participants. The task had been given to produce furniture which would cost less than 500 NZD. The online interface sent to the participants, and they generated the design by playing with the parameters and sent the model to the designer through the 'send the model' button. The users developed design options that were different to each other (**Figure 8**). The design variations show that the interface and its technological affordance can let first time users produce geometry on their choices. Though the perceptual understanding of the geometry is not in an immersive environment, the interface enables them to take relevant design decisions on the outcomes.

The study also explored in the remote collaboration environment. Designers continued their discussion through a text-based chat protocol. Designer A used

Figure 7.
The parametric furniture design interface.

Figure 8.
The generated design options.

the desktop-based 2D interface to generate the furniture while designer B saw the instant outcomes through a screen share and provided responses in a chatting system (**Figure 9**). The collaboration aspect in this scenario is not instantaneous but working in an internet-based communication protocol. The users who have access to design commands need to familiarise with the interface and its opportunities to take design decision following the suggestion from the other end users. The co-designers are not getting control over their decision as one person decides on the other side of the network. There is a lack of affiliation exist in the system. However, the design set-up seems to be efficient in any remote settings.

Figure 9.
The remote collaboration design unit.

8. Discussion and conclusion

Developing an instrument for end-users design interaction and participation requires experts' contribution to identifying the design problem, developing the task, and the instrument. These are evident in any design thinking approach. Experts play a significant role in determining the problem by empathising with evidence-based input through a survey or other recorded resources. They also need to synchronise the design task with the design problem of the context and the instrument. At the beginning of selecting the computational instrument, the experts rely on self-evaluative techniques to empathise with users' possible interaction. In cases, they test with participants to assess the system. Above, the three examples have not informed about those initial testing elaborately; however, the framework indicates the scope of possible ways of initial pre-testing before inviting the non-experts in the creative engagement. Besides, to develop any computer-aided design instrument, the experts also need to know how the computer system can deliver an interface for first-time users. Usually, finding the design problem is the designers' (both architects and urban designers) tasks; however, to deliver a computer-aided instrument, they need to understand the working process of a computer system. All the investigations show that, in this digital era, designers now need to understand the computer tools and their scope of communication to involve non-experts in the design process. The studies also demonstrate how virtual artefacts can influence users' perceptual understanding in the VE. Generally, the nature of design decisions depends on the interface types and their quality of visual communication with the users. The users decide on their design action against the instant visual feedback they get in the VE. If the interface is a 2D desktop, in that case, the interaction happens in a non-immersive environment, where the perceptual understanding of the 3D artefacts remains as scalar objects of the representation. In the immersive virtual environment, the users get a perceptual experience of the design content in full-scale. That means, whether the interface 2D or 3D, it is evident that interfaces offer easy manoeuvring systems to the non-experts. In addition, the collaborative design setup allows them to act as a design team to take decisions as co-designers. In conclusion, for all cases, the design thinking framework follows the steps of a defining problem with a participatory mindset, selecting a tool with relevance to the design task, testing the instrument and designing

the engagement pattern. These are the principles for any design thinking research, where the experts with computer-aided design generation in architecture and urban design would make the process inclusive and informed.

Disrupted digital technology is already changing the way architecture is designed and built. Now, the architecture of industrialization has replaced by the architecture of information. These profound changes are primarily centred on the foundations of architectural practices, such as representation, information management, and virtuality. Besides, the revival of social reformation encourages the inclusion of participatory design approach in the architectural design process. To continue a design process without creating repetition and to avoid homogeneity and recurrence of the same, one needs to reinvent the design continuity through the spontaneous participation of people. It means design iteration can be spontaneous if people are engaged in the design process. The recent advancement in the computing power of digital technology supports the continuity of design iteration, which possesses representation techniques for non-experts to involve in the design process. Such technology-driven design representation and iteration tools allow non-experts to participate actively in design ideation and generation stages. It reduces the power gap between non-experts and experts and changes the role of experts from designers to system designers.

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