6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the
Affiliated Conferences, AHFE 2015

An observational study of usability in collaborative tangible interfaces for complex planning systems

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Abstract

There has been an increasing interest in designing tangible user interface (TUI) systems in the context of urban planning. However, little has been done in studying the usability of such systems. In this paper, we present an observational study on a collaborative TUI system to examine the usability of the system in the urban planning process and to investigate its effect on stakeholders' engagement and decision-making. The study suggests that TUIs and physical objects encourage collaboration and communication among stakeholders, which lead to more informative decisions.

Keywords: HCI; Tangible User Interface (TUI); Urban planning; User experience; Complex systems

1. Introduction

In complex systems, stakeholders interact with each other for the planning and decision-making process. In the context of urban planning, stakeholders are involved from different backgrounds and with varying levels of subject matter expertise and domain knowledge. The complexity in the decision-making process for urban planning contexts is often coupled with inadequate understanding of interdependencies between decisions scenarios made by

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stakeholders from different sectors. Furthermore, the existing urban modeling and planning tools are often designed for specific professional audiences (e.g., architects) and are not accessible to a wider scope of users [1]. It is often difficult to anticipate usability problems from users with varied backgrounds and expertise. This is especially so for tangible interactive systems (e.g., urban modeling systems), where user interactions usually consist of sequences of actions on tangible objects and perception of the system feedback from the digital information embedded in the physical objects [2]. During the design of TUI systems, usability tests are usually conducted to examine the user experience. A collaborative interactive system would effectively facilitate stakeholder dialogues and interactions, and consequently help them make more informative decisions [3].

Technologies for supporting stakeholders in the decision-making process have evolved over the decades from sketching tools to interactive technologies such as web-based, augmented, and tangible interfaces. Intuitive interactive tools can create collaborative interaction spaces where users can efficiently work with each other, and see the result of their interaction immediately which makes the planning process more efficient. The objectives of this study are twofold, to examine user interactions with tangible user interfaces in the context of urban planning, and to investigate stakeholders' engagement and decision-making. In this study, we examined user engagement and decision-making in the context of regulation based, tangible planning tools, and investigated the utility of different usability approaches for assessing the user experience with tangible collaborative systems [4].

An observational study was conducted with the Changing Places group at Media Lab at Massachusetts Institute of Technology (MIT), where a representative sample of users from different backgrounds were invited to examine the usability of a collaborative tangible interface that has been developed by the Changing Places group for urban planning [5].

A comparative analysis of different approaches examined users' interaction and decision-making in TUI systems in the context urban planning. The sessions involved decision-making scenarios using artifacts that included paper-based visualizations of city plans as well as interactive tangible models of the urban area. A coding scheme was developed and considered for analyzing the video observations to examine the wide spectrum of actions, verbal cues, and non-verbal gestures, and quantify the occurrences of these interactions during the experiment [6].

This paper is structured as follows: The next section describes related work on studies of TUIs. Following that, we present the method used to conduct the observation study including participants, flow of activities, tasks, apparatus, and analysis of game sessions' recordings. We conclude with findings and insights gained from conducting this study.

2. Background

In recent years, collaborative TUIs proved to be more intuitive as it encourages collaboration and communication among stakeholders, which lead to better planning and decision-making [7]. Our research is based on the presumption that if we can examine user interactions with TUIs in the context of urban planning, and investigate effective ways for designing a strategic gaming session with collaborative tangible tools, we will be able to get insights about the design considerations and usability recommendations for the design of tangible interactive urban planning tools to ease the decision-making process.

Several observational studies have been conducted on TUIs. Brereton and McGarry [8] tested the usability of tangible objects and how TUI encourages engineers design thinking and communication. Fjeld and Sissel [9] test the usability of TUIs compared to alternative traditional 3D and 2D single user tools, by examining the learning effect and the overall user experience, which showed the 3D tools outperform the TUIs in terms of user satisfaction. Falcão and Price [10] focused on investigating collaborative activities in a tangible table-top environment to support how shared interfaces affect the way collaborative activities are structured, and examines the kinds of collaborative interactions that are productive for learning.

In our study we had the opportunity to compare two different urban planning methodologies, which allowed us to deeply understand the characteristics of an urban planning TUI system by supporting the collaborative decision-making from groups of stakeholders in a truly participatory manner.

3. Method

3.1. Participants

Ten participants from MIT community (students/staff/affiliates) were invited through an online form, email lists, and in-campus publication. The participants were divided into two groups; one group started with a paper-based model of city plans (Community Meeting session) then moved to the interactive tangible model of the urban area (PlayGround session); while the second group started with the PlayGround session to the Community Meeting session.

3.2. Procedure

The game was divided into two sessions: Community Meeting session that utilize the traditional urban planning process where participants were asked to sketch theirs plans of the area on papers and maps. The other session is the PlayGround, a platform for urban decision-making and community engagement. Using real-time feedback and analysis, PlayGround offers a common ground for discussion between municipalities, developers and the general public as shown in Fig. 1.

The whole experiment took an hour and 25 minutes. The game sessions required 60 minutes, 30 minutes for each session as shown in Fig. 2.
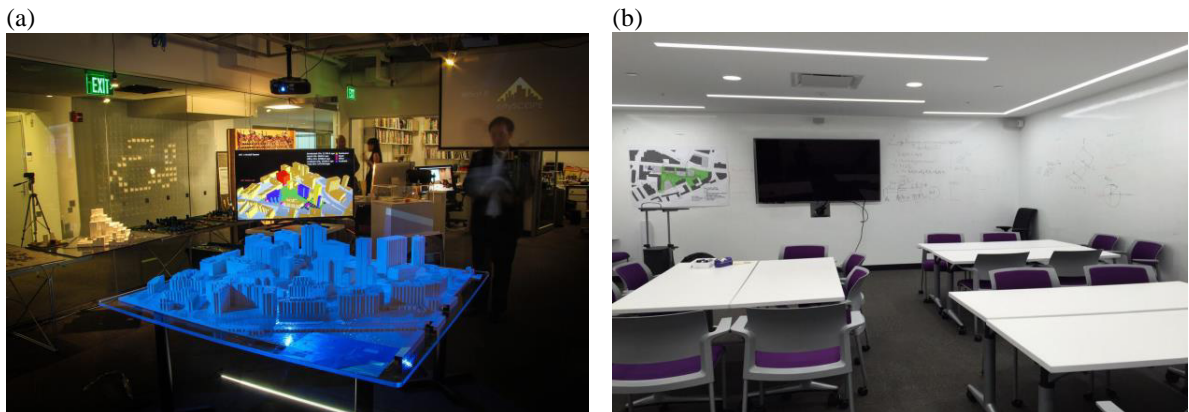
(a)   (b)

Fig. 1. (a) PlayGround; (b) Community Meeting.

Fig. 2. Flow of the Game Activities.

Fig. 3. (a) Plan of Kendall Square Area; (b) Sketching toolkit.

3.3. Task

In the experiment, the participants were asked to respond to real-life planning and design challenges. They were asked to rebuild and plan the Kendall Square area taking into account zoning restrictions by adding or changing residential, commercial buildings, parking lots, parks, …etc. as shown in Fig. 3(a).
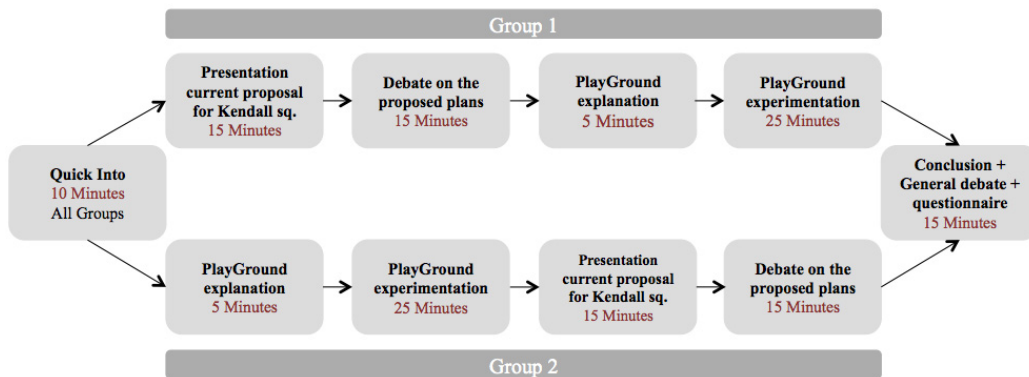
In the Community Meeting session, the participants were introduced to the previous plans of Kendall Square area, which have been conducted by the Cambridge community. Papers, maps, markers, and notes were handed to the participants to start sketching their renovation plan for the area as shown in Fig. 3(b). The session lasted for 30 minutes.

The PlayGround session utilizes an urban planning TUI system (MARK IV) where participant were asked to interact with the TUI that gives a real time feedback notifying the user whenever a violation of the zoning restrictions occurs through a 2D visualization platform.

3.4. Apparatus

3.4.1. TUI system (Mark IV)

Mark IV detects arbitrarily many uniquely tagged physical objects in real time as the user moves them. It performs real-time digital reconstruction of objects' configuration including form, position, ID, and any metadata. It also performs real-time analysis of the objects' configuration and real-time visualization of analysis via display screen and projection mapping of visual content onto objects.

The system includes a kit of tagged 3D objects (e.g. buildings), a table that constrains the placement of 3D objects into a scene, sensors for scanning the scene, computers, display screens, and projectors for projecting light patterns onto the scene. The projected light patterns, via projection mapping, augment the 3D physical scene with information and analytics unique to the user's configuration of the objects.

3.4.2. Usability Testing Software (Morae)

We used Morae [11], a usability testing tool to record, observe, and analyze the game sessions.

3.5. Analysis

In our study, we analyzed the video recordings of the game sessions using coding scheme. We considered three types of coding schemes, actions, verbal and non-verbal behaviors as described in DEVAN [12] and the coding schemes for verbal communication and gestures in collaborative architectural design in [13]. A list of codes adapted is shown in Table 1.

Table 1. List of Observational Codes.

Code	Description	Code	Description
EXP	Explore Function/Tool	EXT	Excitement
PUZ	Puzzled	SUR	Surprised
CLA	Clarification of Idea	ACT	Wrong Action
IDE	Introduction of Idea	FRT	Frustration
ACC	Acceptance of Idea	DIS	Discontinuous Action
EVA	Evaluation of Idea	REC	Recognition of Error or Misunderstanding
REF	Refinement of Idea	DBT	Doubt
HAN	Hand over	COR	Corrective Action
HES	Hesitation	FLO	Floor-Holding
DIF	Execution Difficulty	TAS	Give Task to Another User
EXE	Execution Problem	SCH	Search for Non-Existing Function

4. Findings

Applying coding schemes when analyzing video observations of users' interaction with the TUI, suggested methodological and design considerations.

The occurrences of certain codes in our video observations, as shown in Table 2, lead to some methodological consideration. For example, we noticed that most of the participants started by exploring the TUI system and searching its functionality as noted by the multiple occurrences of EXP and SCH codes. Therefore, giving users a clear demonstration of the system would make them less puzzled and more comfortable interacting with it. The occurrences of code IDE indicates that dealing with physical objects made participants more active and engaged in the planning and decision-making process. Due to the visualization platform, participants can share a common understanding of the proposed plan and accept other participants' ideas, and this was captured with the occurrences of ACC code. In agreement with [8], our observations of codes suggest that TUIs encourage collaboration and communication among participants.

Table 2. The occurrences of codes in video observations

Interaction Type	Code	Description	Group 1	Group 2
User to Object	EXE	Execution Problem	1	1
	DIS	Discontinues Action	-	2
	COR	Corrective Action	1	3
	GOAL	Wrong Goal	-	1
	PUZ	Puzzled	2	4
	SCH	Search for Non-existing Function	3	3
	DIF	Execution Difficulties	1	-
	REC	Recognition of Error/Misunderstanding	-	2
	HES	Hesitation	1	3
	EXT	Excitement	-	3
	SUR	Surprised	-	1
	EXP	Exploring	4	6
	FRT	Frustration	-	2
	DBT	Doubt	-	1
User to User	ACC	Acceptance of Idea	4	-
	HAN	Hand-over	1	-
	CLA	Clarification of Idea	4	7
	REF	Refinement of Idea	2	-
User to Many	IDE	Introduction of Idea	7	3
	EVA	Evaluation of Idea	1	1
	FLO	Floor holding	2	-

The incidents of other codes, proposed some design considerations as well. Unlike traditional sketching methods, where participants focused only on individual buildings without taking into consideration zoning restrictions and the effect of these changes on the surrounding area, the TUI system gives real time feedback whenever a violation occurs, which helps participants in the sense-making process as indicated in the multiple occurrences of CLA and EVA codes.

In terms of design considerations, the design of TUI systems can cause participants frustration and confusion, noted in codes FRT and PUZ, as when participants could not differentiate between removable and fixed physical objects, and when they indicated difficulties in identifying an object. These observations revealed opportunities for improving the visual perception of the TUI system.

5. Conclusion

Developing a collaborative TUI system for urban planning is challenging. To design a tangible interface system that supports collaboration and facilitates decision-making between stakeholders from different backgrounds, it is essential to test the usability of such system.

This paper analyzed the usability of a TUI system in the context of urban planning by applying a coding scheme on video observations of users' experience. Findings suggest that TUIs are superior to traditional urban planning methods in terms of rapid prototyping, collaboration, and decision-making process. Our coding analysis highlights methodological and design considerations when designing a TUI system. Future work would involve applying these coding schemes in larger study in the context of urban planning.

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