Human Factors Engineering in Interactive Urban Planning Decision Support Systems

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Abstract. This paper presents a systematic review of technologies designed and developed for urban and architectural planning. The usability and user experiences of urban planning systems designed with mixed reality, virtual reality, tangible interaction, and direct manipulation tabletop interfaces are examined. Emphasis in this review is on the design implications of different interaction modalities in supporting decision making in applied scenarios of urban planning. The human factors engineering process for urban planning decision support systems takes into account the perceptive space, comfort, and productivity of planners and decision makers. Tactile fusion of human perception and action is examined in urban planning decision support systems that are designed with virtual and tangible interaction. Case studies describing applied scenarios of urban planning are reviewed with a critique of navigation design, human perception, collaboration support, and visualization of decision scenarios. The human factors for designing systems that support clear representations of urban planning states across all sensory modalities are reported.

Keywords: Urban planning, Virtual reality, Mixed reality, Augmented Reality, Tangible User Interface, Decision support system.

1 Introduction

Urban planning is a complex process that involves a systematic conception of a rational order on the basis of available relevant knowledge of the city's infrastructure and its inhabitants. Diverse stakeholders such as urban planners, national planning officials, investors and the general public are part of this process. Stakeholders have multiple points of views and developing a shared understanding of complex computational data presents a major challenge in the planning process. Therefore, collaboration between actors is a must in the urban planning process. Decision support systems are ideally suited for supporting urban planning decision-making process as they have been developed to in order to enable the creation of a shared vision, support a broad understanding and acceptance of final planning decisions. In addition to saving costs, time

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and improving the quality of decision making process [1]. The Human Factors (HF) in the design of interactive urban planning systems involve the physical, cognitive and ergonomic design dimensions. Interaction in these DSS contexts needs to exploit spatiality (i.e. innate ability to interact with virtual and tangible objects) by facilitating intuitive spatial skills that humans have with the objects they use in urban planning DSS interfaces.

Following is an overview of the state of the art of visualization methods, decision support tools that are used in urban planning.

2 Technologies for Urban Planning

A proliferation in research for designing urban planning systems has examined interaction with different visualization methods including virtual reality (VR), augmented reality (AR) and mixed reality (MR). Recent studies in this urban planning context are listed in Table 1.

Table 1. Visualization methods for some urban planning systems

Visualization Method	Reference No.
Virtual Reality (VR)	[2] ,[3],[4],[5],[6]
Augmented Reality (AR)	[7], [8] ,[9], [10]
Mixed Reality (MR)	[11], [12], [13], [14]

Interaction technologies vary from traditional ones such as mouse and pointers to head mounted and tactile hand held controls. For example, in [2] Stereo display, hand-held devices (PDA, tablet PC), optical tracking systems, touch sensitive surfaces, and speech were used. When designing an interface for a system that incorporates different stakeholders it is important to understand what the purpose of each interaction method is and how it fits into the context-of-use in urban planning.

Different Input/ Output modalities provide flexibility in manipulating objects and viewing the results in different ways to support understandings. However, there exists a trade-off between the number of modalities and the complexity of the system. Complexities in operating the system present more human factor design challenges. More recent research has tended to focus on tangible interaction and tangible user interfaces (TUIs) (e.g. [15-18]). The term TUI was coined by Ishii and Ulmerr and is used to describe objects that "give physical form to digital information," which in the context of an urban planning DSS, often provide intuitive physical controls for complex computational data [21]. The strengths of TUIs lie within their ability to provide a linkage between digital information and physical objects. The essence of TUIs is the direct mapping of physical interaction and direct manipulation with the computational data embodied in the system [19].

3 Human Factors of TUIs in Urban Planning Decision Support Systems

In urban planning decision support systems, it is important that users interact with the system based on their background and their interests. From that point of view, [20] noted that both human factors and system factors should be considered when designing the interface of a DSS for urban planning. For the purpose of this review, human-related factors will be considered.

The minimum requirements for the implementation of high-fidelity interactive urban planning systems are meaningful coupling of physical interaction with human perception and cognitive abilities. Most of the urban planning systems include navigation functionalities such as scenario generation, simulation and provides multiple levels of details (LOD) such as in [2] and [8]. In addition, user friendliness, engagement and utility are key usability objectives that need to be considered in designing the TUIs. Prior research has shown that complexity in the design of physical artifacts to represent computational data in TUIs often impacts the user experience in interacting with a DSS because of inefficiency in using the 'physical handles' to control and manipulate the urban planning DSS.

Tangible interaction can be used to provide better support for ergonomic and collaborative design in the complex urban planning projects while keeping the interaction simple as in ColorTable [18]. ColorTable is a TUI that was developed in an iterative process of design-evaluation-feedback-redesign in successive workshops with users in the domain of real urban planning projects. Users of ColorTable can move colored tokens of different colors and shapes to share their ideas. The tokens allow users to set urban components such as building, streets, etc. Developers of ColorTable share its story design in an attempt to highlight some general design issues related to TUIs in collaborative urban planning. The study in [18] highlights that round shaped tables with the possibility of rotation were highly favorable to users' interaction. Moreover, color objects were perceived as easy to understand and were found to be usable by experts and non-experts.

In recent years, several case studies of urban planning systems have that shown the potential for TUIs to benefit users in urban planning contexts because they exploit the visual, tactile and sensory cues [17, 21]. One case study is the Venice Unfolding: a Tangible User Interface for exploring architectural projects in Venice [17]. This TUI is a prototype developed collaboratively by architects, urban planners and interaction designers. A formative user study was conducted for gathering feedback from users on their experience of action-perception coupling. Findings of that study suggested that using TUIs reduces the boundary between the physical world in urban planning and virtual data. Another pilot study using protocol analysis was conducted in [19] which examined how designers' perception of spatial cognition is improved when using TUIs.

4 Conclusion

This review has investigated some of the available technologies and visualization methods for urban planning decision support systems. It is the first step towards a more detailed review of design activities in TUIs. More research is underway for examining personalization methods and adaptation in designing the TUIs for urban planning systems.

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