Responsive Environments with Virtual Reality Experiments and Simulations

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Abstract

The safety and experience of the users of public infrastructure concern both them and the managers. Intelligent techniques such as virtual reality and computer simulations can enable environments to respond to users' needs. Such responsive environments can be designed to incorporate geographic information services based on pre-occupancy evaluations. For this workshop, I investigate the potential of responsive environments in several scenarios, including crowd disasters, social wayfinding, and fire evacuation. The methodology of this work combines behavioral science with computer science and engineering technologies. The results of this investigation show that intelligent interventions provide security, efficiency, and comfort for users within responsive environments. In general, this work combines the technical perspective of computer science with the behavioral perspective of cognitive science to define the next generation of responsive environments. This approach can help public space organizers and event planners to better understand the effect of design on the behavior of individuals. Furthermore, it can provide users with assistance and advice. These series of studies may also help behavioral scientists, computer scientists, and public space designers better understand smart environment design and collective intelligence.

1 Introduction

As technology has developed, humans' capacity to influence our behavior has far exceeded what the north wind and sun achieved in Aesop's fable. We have created buildings for shelter and air conditioning systems to protect ourselves from both heat and cold. Nevertheless, the creators of built environments have repeatedly found their users misusing their creations [Dalton, 2016], and the users often complain that the build environments are hard to understand and use [Carlson *et al.*, 2010]. There is certainly a gap between designers' initiatives and users' expectations. Designers of the public environment have suffered from such a disparity, the essential cause of which is the absence of users from the design process. After construction, the environments rarely incorporate feedback from their users' activities. They are not being *responding* to their users. Such important feedback is scarcely considered during the design process. The lack of feedback produces an environment that fails to actively answer the user's needs, thus leading to cumbersome scenarios. These scenarios have often failed to provide accessible information and/or have unintentionally created risky situations for users. Such failures have led to crowd disasters [Helbing and Mukerji, 2012; Pretorius *et al.*, 2015], ineffective emergency evacuations [Xie, 2011; Klippel *et al.*, 2006; Grosshandler *et al.*, 2005], and traffic accidents [Saulen, 2009]. These unfortunate events may also cause energy inefficiency [Pastore and Andersen, 2019], economic impact [Batey *et al.*, 1993], and more severe consequences such as casualties [Helbing and Mukerji, 2012; Brushlinsky *et al.*, 2016].

Recent developments in the research of the public environment have led to a renewed interest in integrating technologies into the design process. The rapid development of engineering technologies has enabled the environments to respond intelligently to their users through the evidence-based design. Conducting experiments in virtual reality enables the evaluations of the design even before the construction of the environments. Furthermore, computer simulations reveal the users' behavior patterns without massively collecting user' data in the real world thus violating privacy. Smart devices [Raento *et al.*, 2009] and sensor technologies [Hirtle and Raubal, 2013] are also used in the built environment in order to improve the perception of the entity and the experience of the users. In particular, these technologies allow the assessment of dangerous situations which are usually unethical if not impossible to study in the real world [Bode and Codling, 2013]. These prominent advantages of virtual experiments and computer simulations can help overcome a substantial proportion of such risks and inefficiency distribution of valuable resources. They provide pre-occupancy evaluations of the environment and help the designer to identify potential design flaws. With this assistance, environments that incorporate the user's behavior and feedback through empirical experiments and simulations can be referred as *responsive environments*. Such environments use information technologies to respond to their users' behaviors, thus avoiding some of the flaws generated by the traditional design procedure.

Despite its importance, a systematic understanding of what consists of a responsive environment and how to validate its effect are still missing. Much uncertainty still exists about the relationship between the responsive environments and the design flaws that can be addressed. This study will examine how to use virtual reality experiments and simulations to strengthen responsive environments.

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