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RESEARCH ARTICLE

A synchronous distributed cloud-based virtual reality meeting system for architectural and urban design

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Abstract
In the spatial design fields such as architectural design and urban design, a consensus-building process among a variety of stakeholders like project executors, architects, residents, users, and general citizens is required. New technological developments such as cloud computing and Virtual Design Studios (VDS) enable the creation of virtual meeting systems. This paper proposes an approach towards a synchronous distributed design meeting system. In this paper, in addition to sharing a 3D virtual space for a synchronous distributed type design meeting, we developed a prototype system that enables participants to sketch or make annotations and have discussions as well as add viewpoints to them. We applied these functions to evaluate an architectural design and urban landscape examination. In conclusion, the proposed method was evaluated as being effective and feasible. Yet, it shows a few shortcomings including the fact that simultaneous operation is limited to one client, and more arbitrary shapes should be supported in future versions of the application.

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1. Introduction

In the spatial design fields such as architectural design and urban design, a consensus-building process among a variety of stakeholders like project executors, architects, residents, users, and general citizens is required (Innes, 1996). Since it is oftentimes necessary to share three-dimensional (3D) images to study spatial design, 3D Computer Graphics (3DCG), Virtual Reality (VR) and Building Information Modelling (BIM) systems have been developed. Spatial design meetings using these systems have been traditionally held in a single room and at a certain scheduled time.

However in recent years, the mobility of people's activities and cloud computing technologies have advanced in the modern age of information and globalization. Therefore, Virtual Design Studios (VDS) have been constructed by numerous universities and institutions across the world exploiting new computing and communication technologies (Wojtowicz, 1994; Maher and Simoff, 1999; Kvan, 2000; Matsumoto et al., 2006). Mostly, VDS system developments and design trials of an asynchronous distributed type are used allowing stakeholders to participate in the design process at various places and at different times. This enables expansion of communication opportunities, without a participant needing to be concerned about restrictions of space and time.

VDS environments can accommodate a variety of platforms. The loose integration of design intensions and collaborative platforms causes considerable complications in the transition from individual to collaborative sessions. This results from the fact that most of the management of design representations, documentation and other information is done manually. To cope with these issues, virtual design environments include highly integrated applications for design, text and image processing, communication, scheduling, and information management. An essential shortcoming of these systems is the lack of synchronization between the views that different designers have and the context of their communication.

As a result from previous approaches, which are presented in Section 2, we defined the following research questions for our work:

(1) How annotation and discussion functions are effective in architecture or urban design using a synchronous distributed VR meeting?

This paper is structured as follows: Section 1 introduces the main focus on synchronous distributed VR meetings. Section 2 describes previous studies and the state of the art. Section 3 illustrates the VR system with a particular focus on the two main functions – annotation and discussion. Section 4 presents the validation of the prototype system by an empirical study. A new distributed meeting with an architect was held by applying the cloud-VR system. An initial design according to a project and the prototype system has been validated in the course of an architectural and urban design process. Finally, Section 5 lays out the conclusions and future work.

2. State of the art

In a synchronous distributed environment, different research efforts on design supporting a system for sharing 3D virtual space have been carried out, but show a number of shortcomings. First, there is a system which allows designers to be physically immersed in their sketches and physical models, literally inside life-size, real-time representations of these, while sharing them remotely with another system of the same sort (Dorta et al., 2011). However, sketches on digital whiteboards retain well-known scale problems from sketches on paper, and they do not permit several stakeholders participating in a meeting by using a standard PC. Safin and Leclercq (2009) evaluate the opportunities and constraints linked to the technological transfer of a sketch-based distant collaborative environment. This prototype required a large electronic table with projection system. Darses et al. (2008) describe a research project which aims at studying the value of a freehand design environment for architects. This sketch-based modelling software is implemented on a Tablet PC, which provides architects with the possibility to automatically generate 3D views from the freehand drawings. However, this study has poor drawn 3D external representations, which do not fit to the level of abstraction required for handling mental volumetric representations which are cognitively processed by the designers.

On one hand, Gu et al. (2009) and Shen and Kawakami (2010) developed a visualization tool on a multi-user platform to represent design alternatives and to supplement traditional presentation materials. These studies also pointed out that audio devices and web cameras are well-suited for online deliberation. Moreover, the data volume of the content of a design study is usually large. Therefore, when drawing 3D graphics using a client PC, a computer with a high-performance Graphics Processing Unit (GPU) is always required. Architect and urban design require the high-speed simulation and reconstruction in order to avoid an interruption during a synchronous distributed meeting (Al Maashri et al., 2009). A high-performance GPU had been initially used to accelerate the work of texture mapping and rendering polygons, later added units to accelerate geometric calculations to support computers in image processing, 3D reconstruction and large-scale modelling. However, high latency and cost are the major constraints to performance enhancement. Fukuda et al. (2012), on the other hand, present a first approach towards a distributed design meeting system. It allows stakeholders to participate in the design process at different places and at the same time while sharing a 3D virtual space. However, the user is not able to add sketches, figures or memos during a meeting.

In contrast to previous research efforts, this paper presents an approach towards a cloud-based VR system supporting synchronous distributed design meetings. Our approach is characterized by no necessity for a high-end GPU and by focusing on two main functional elements: the annotation function – allowing freehand sketching and textual inputs in a 3D virtual space and the discussion function – enabling stakeholders' real-time text-based discussion about a place in a 3D virtual space to facilitate studies of architectural or urban design.

3. Conceptual system design

This section lays out the conceptual system design decisions for the presented cloud-based VR approach. Section 3.1 contains general design decisions; Section 3.2 illustrates usability requirements in cloud VR systems, and Sections