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Visualization of Construction Activities in Outdoor Augmented Reality

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Introduction

The presented research investigates the application of outdoor Augmented Reality (AR) for 3D graphical simulation of construction activities. The objective of the research is an AR-based visualization platform that can be used with corresponding peripheral equipment (head-mounted display, GPS receiver, orientation tracker, and a portable computer) to generate both a mixed view of the real world (in background) and superimposed virtual construction graphics (e.g. CAD models) in an unprepared outdoor environment.

Background and Motivation

Visualization-based simulation has been the focus of interest for a number of previous works in this field. The main motive for such work has been the realization that by using visualization tools, all involved parties in a construction project can investigate and study the many potential issues and problems that may occur in the real project (such as resource utilization, physical constraints, operation conflicts, etc.) before committing real resources in the field.

As the basis for most of the above mentioned works (most of them in Virtual Reality), however, the CAD modeling approach requires that the entire project be modeled—including all the existing facilities, job site and temporary facilities, natural terrain, idle as well as operating equipments, etc. This, in fact, is a time-consuming, and in most of the cases impractical, method to animate and study a particular operation or portion of the whole project. By using the Augmented Reality (AR) approach, the real world can be conveniently used as the background; only virtual CAD models of those resources under study need to be created for being augmented over the real scenes of the surrounding environment.

There are a number of characteristics that distinguish the presented work from indoor AR applications. These include the extended use of advanced positioning tools (e.g. GPS); capability to produce real time output as the user moves around freely (i.e., by applying minimum constraints over the user’s position and orientation); and the ability to operate independently of environmental factors (e.g. lighting conditions and terrain variations). These are mainly the factors that make the designed platform a powerful tool for several outdoor AR applications.

Technical Approach

The head-mounted display models the behavior of the user’s eye where all the real objects in the surrounding space appear in a perspective view (i.e., the viewing area for the user consists of a truncated pyramid in which parallel lines coincide in the horizon). Using a set of C++ libraries called OpenGL, animated objects can be presented in a viewing frustum made by the platform with the user’s eye located at the center. Appropriate alignment of these two views in real time leads to a realistic mixed view of both real and virtual objects which is viewable for the user within either the computer or head-mounted display. Figure 1 shows the technical approach by which virtual models are superimposed on a scene from the real world.

Figure 1: Platform technical approach for superimposing virtual objects on the real world

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References


http://www.engin.umich.edu/dept/cee
In order to achieve this objective, a set of geometric transformation (translation and rotation) matrices are calculated at each instant during a simulation, and are applied to the current geometric state of the augmented virtual objects such that they are transformed to their correct location and pose appropriately relative to the user’s eye. By connecting an accurate GPS receiver and an inertial orientation tracker to a known point on the user (e.g. hard hat), the user’s global position and orientation (i.e. longitude, latitude, altitude, heading, pitch, and roll) are tracked continuously. These are used to compute relative translation and rotation matrices which are then applied to the augmented CAD objects in real time.

**Implementation and Validation**

To validate the results of the project, prototype software called UM-AR-GPS-ROVER has been developed and implemented. This software is capable of interactively placing three-dimensional CAD models at any desired location in an outdoor augmented space. The concept and the prototype have been tested successfully in several outdoor locations at the University of Michigan North Campus using various 3D construction models (such as buildings, frames, equipments). A Sony Camcorder was used to model the user’s eye input and a Delorme Earthmate GPS receiver together with an Intersense orientation tracker were the input devices for obtaining the user’s global position and head orientation. Figure 2 illustrates the peripheral equipments used in the field tests.

![Figure 2: Hardware setup for UM-AR-GPS-ROVER field tests](image)

Location: University of Michigan – North Campus “Yellow” parking lot

In order to test the prototype’s ability to augment dynamically changing graphical information in the user’s view, the concept of 4D-CAD has been introduced and integrated into the platform. As an example of this concept, scheduled construction activities for the erection of a structural steel frame (columns erection and girders/ beams connections) have been animated with the passage of simulated project time. In the animated example, “time” is introduced as an extra dimension for each augmented virtual object; in other words an object (e.g. steel beam or column) is not shown in the augmented space unless the simulation clock passes its scheduled completion time.

Figure 3 shows some snapshots of the field tests in which various construction models have been used as virtual objects. The first snapshot in this figure is indeed a dynamic (i.e. 4D-CAD) model in which every element of the virtual building has a time tag. The time tag defines the elapsed time since the beginning of the simulation when that element should appear on the screen. This, in fact, is the main point of departure in UM-AR-GPS-ROVER platform, where time is being introduced as an extra dimension beside the three main physical dimensions of any virtual object.

![Location: University of Michigan – North Campus “Yellow” parking lot](image)

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**Figure 3: Field test snapshots**
Professor James Barber Completes Breakthrough Theory on Elasticity

In a seminal paper to appear soon in the proceedings of the Royal Society of London, Professor James Barber will present the first three-dimensional solution for determining the elastic stresses in a prismatic bar under fairly general loading. Before the completion of the new theory, only an approximate solution could be found using beam theory; exact solutions were restricted to cases where only the ends of the bar are loaded. In his paper, Professor Barber extends these exact methods to treat the case of fairly general lateral loading, using a recursive algorithm.

The method provides an exact solution for a wide range of beam problems and has the advantage of generality in comparison with widely-used numerical methods. It also can be used to investigate the effect of three-dimensional loading on stress concentrating features such as holes and cracks.

As shown in Figure 1, a general solution is given to the three-dimensional linear elastic problem of a prismatic bar subjected to arbitrary tractions on its lateral surfaces—subject only to the restriction that they can be expanded as finite power series in the axial coordinate $z$. The solution is obtained by repeated differentiation of the tractions with respect to $z$, establishing a set of sub-problems. A recursive procedure is then developed for generating the solution that involves three steps: (1) integration of the stress and displacement fields with respect to $z$, using an appropriate Papkovich-Neuber representation; (2) solution of two-dimensional in-plane and antiplane corrective problems for the tractions that are independent of $z$; and (3) expression of these corrective solutions in P-N form.

The method can easily be extended to include body forces, provided that these can be described by a body-force potential.

The Class of 2025?

It's never too early to recruit a future CEE Engineer: 3-year-old Hugh Green pictured.

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