Augmented Reality for Viewing Articulated Structures

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Abstract

Scientists and engineers have a need to understand their data in context. Oftentimes, the data they are studying happened as a response to an external stimulus. Viewing just the data shows the effect, but what was the cause? This paper describes taking augmented reality into the field to provide such a context for data display. This project focuses on visualizing what is happening inside articulated structures. Articulated structures are used because examining their shape gives us the user location and head orientation to adequately create the AR synthetic views of the data. Future project directions are also discussed.

Keywords: Augmented Reality, Scientific Visualization, Knowledge Discovery, Mobile Computing

Introduction

Over the last 20 years, there have been significant advances in scientific visualization, to the point that it is an everyday part of doing science and engineering. But, one major limitation in scientific visualization has always been that, in order to truly take advantage of it, one must *bring the science to the visualization*. That is, scientific visualization usually takes place on the desktop or in a computer lab, which is not always where the data naturally lives. This is especially true for virtual and augmented reality[1]. These two technologies rely heavily on responsive 3D head-mounted graphics displays and on accurate and dynamic 3D tracking systems. There has been a significant body of work in these areas, but it has generally been focused on working in a computer lab, where tracking and communications can be better controlled [AZUMA99, BIMB00, BREEN96, KOL97, STATE96, SUM99, WHIT95]. Even where AR has been used in outdoor mobile systems, it has been used in very controlled, and limited, communications environments [FOXLIN98, HOLL99, YOU99].

But, we believe that a more widely applicable approach is to deliberately target less controlled and less technology-friendly outdoor environments. This project has focused on freeing augmented reality systems from the computer lab and instead moving them to where the data is. Specifically, we have been creating augmented reality solutions for visualizing data pertaining to articulated structures. There are two major reasons to want do this:

1. The digital display of the structure's data can be put *in context*. Rather than viewing the information in isolation, it can be placed in a *spatial context* and seen as a function of what else is going on around it.

2. The structure data can also be observed in a *temporal context*, that is, it can be more than just a snapshot in time. The data can be seen responding to time-changes in its environment.

We have deliberately focused our attention to the arena of *civil infrastructure*: the care and maintenance of society-critical bridges and buildings. Digital information through sensors is becoming more widespread throughout the environment in which we live. Buildings and bridges are just two such areas in which sensors are being deployed. Information provided by these sensors has proven useful in recent years but it has been difficult to

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[1] *Virtual reality*, as it is popularly defined, involves immersing the user in a synthetic 3D world and restricting their viewing of the real world through the use of enclosing helmets or rooms. *Augmented reality* involves a see-through helmet that superimposes synthetically generated graphics on top of the view of the real world

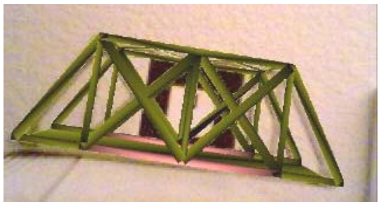
actually visualize this information in the context of where the data was gathered. For scientists, it may be more useful to be able to visualize such data out in the field rather than being constrained to a lab. This is where the appeal for mobile Augmented Reality comes in. Through the use of this emerging technology, a scientist would be able to go into an area of interest and have his/her vision "augmented" through a head-mounted display unit with useful data from the environment. This data would then be displayed using OpenGL 3D computer graphics that are then overlaid on top of the scientist's "live" view of the world (the image below demonstrates a nice example of this). Currently, this technology is being researched to help improve functionality in the real world. Once this technology becomes more available to scientists, it promises to not only aid scientists learn more about the data they analyzing but also will benefit many different aspects in people's lives by providing useful information about their local environment. These are applications that really push AR technology.

Head Tracking in the Field

In order to implement augmented reality outdoors, we must solve the 3D tracking problem. Global Positioning System (GPS) devices only get us part of the way. We are developing new computer methods to use the appearance of the articulated structures themselves as the 3D tracking device. This will give us very precise and reliable results. But, first we provide some project background.

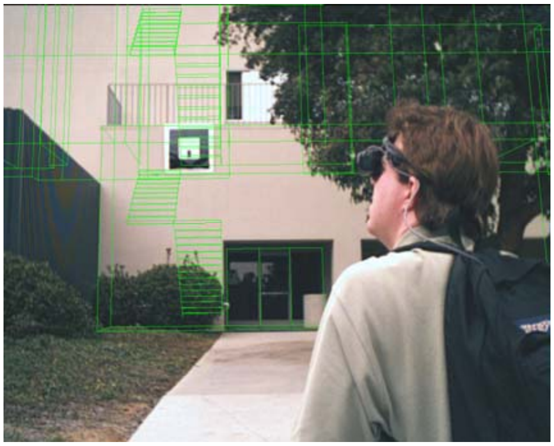
For the past three years, we have been experimenting with virtual and augmented reality as a way to assist in the understanding of civil infrastructure. This figure shows our first experiments in developing a low-end AR system. It consists of a Sony i-phone, an Ascension Flock of Birds 6 DOF electromagnetic tracking system, and a video camera. This worked well and allowed us to mock up and gain experience with a civil infrastructure setup in the lab.

This photo shows our first lab test setup with a model bridge that was outfitted with strain gages. When a weight was moved across the bridge, the strain gages recorded the stress distributions. Using information about the 3D geometry of the bridge (i.e., the bridge had been previously articulated), these stresses were turned into a color synthetic image that was then blended with the real 3D scene as viewed by the video camera. The combined results were sent to the viewer's head-mounted display system as shown below:



The first figure above shows just the model bridge with its tracking target. We used the target-tracking software from the **ARToolKit** [HIT01] to determine the viewer's location and orientation. The second figure shows the scene with the AR turned on, superimposing the stress distributions on the real model image. The stresses themselves were turned into colors that modulated the appearance of a 3D geometric model of the bridge. This colored geometric model is then what is actually superimposed on the real scene

Our next step was to extend the functionality of the ARToolKit so that it can be used outdoors. The outdoor headgear still has a video camera attached to it that creates a video stream of what the user is seeing. We generated a large tracking target on a plotter and hung it on a building. The program then determined that target's position in the video stream to determine the user's location and head orientation, just as we had done in the lab. This setup is shown below:



But, it is not practical to hang different targets on all buildings, so we decided to use each building's shape as its very own tracking target. The program in the mobile laptop examines the video stream and a database of building shapes to determine which building is in the view, and where it is being viewed from. To make this faster, we added a GPS unit to the system so that the program would have a rough idea where the user was standing so that most of the buildings in the database could be eliminated from consideration.

As shown below, we first high-pass filter the video image so that abrupt changes, such as edges and corners, are emphasized.

We use a Kanade-Lucas-Tomasi (KLT) image recognition algorithm in order to detect "feature points" from the environment and buildings. Typically, these feature points are prominent points of interest, usually corners. These feature points are used to determine the structure the thing we are looking at. Our Augmented Reality system then uses this structure information as a tracking target to determine the viewer's head location and orientation. These features are tracked over the live video stream. The orientation and position information is updated and used to create the proper 3D synthetic view of the overlaid information. This is then combined with the video and displayed into the head-mounted display unit.

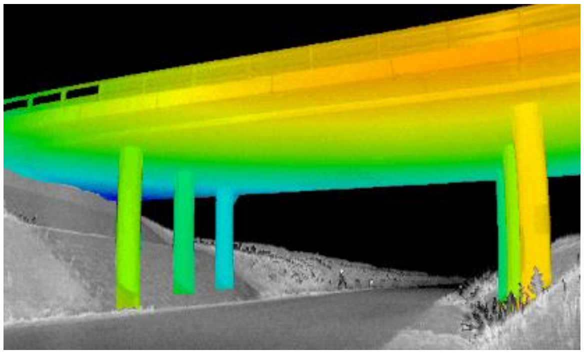
User Interface Issues

One of the early problems that we discovered was that the user interface is extremely difficult. By definition, an augmented reality user cannot go see the computer screen to see a user interface. Instead, we are working with a USB-based game controller as shown here. Using this type of controller is very intuitive, especially for those familiar with computer games. It has a joystick as well as buttons. Also, the new tilt-style game controllers have internal motion sensors inside them so that the entire controller can be used as a big joystick.

Future Work

One of our next uses of AR in the field will be bridge inspection. The photo above shows the understructure of the Byron Road Bridge, north of Oakland, CA, which is in very bad shape and is getting worse. Bridges like this one get inspected periodically to see if they are finally in bad enough shape to fix. Visual inspections do not tell the whole story, however. Fortunately, many bridges are being retrofit with networks of sensors. We will use AR to display the sensor information from the bridge, making it possible to really "see" what is happening inside. Also, using the temporal context aspects of this project, we will playback a time-animation of how the bridge has been evolving internally over time.

The figure below shows how we expect a structural engineer will use the AR technology. Wearing the AR helmet, the engineer will glance at the structure. Superimposed on it will be the metrics of interest (stress, strain, etc.), plotted as a continuous color display so that patterns in response to real-time events are obvious.



Conclusions

Augmented Reality will be at its very best when users can wear it as part of an outdoor mobile computing environment. As the world becomes more and more wired with network-based sensor networks, there will an abundance of data available on what is going on in the world around us. Outdoor mobile Augmented Reality will allow this data to be examined "in context". Scientists will be able to get a better sense of cause and effect when they can observe how the sensor data reacts to world stimuli.

Besides a way to assist scientific visualization, this will have many uses in civil infrastructure, such as in heads-up displays for cars and viewing what is happening in a building for firefighting.

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