AUGMENTED REALITY FOR THE VISUALIZATION OF MAPS

J.A.S. Centeno a, *, E.A. Mitishita a, R.T. Kishi b

a Federal University of Paraná, Geomatics Department, Curitiba, Brazil, (centeno, mitishita) @ufpr.br
b Federal University of Paraná, Hydraulics and Sanitary Engineering Department, Curitiba, Brazil, rtkishi.dhs@ufpr.br

Commission ICWG V/I

KEY WORDS: Augmented Reality, visualization, mapping

ABSTRACT:

In this paper we show the application of Augmented Reality to the visualization of 3-dimensional data. Augmented Reality is a branch of computer visualization that studies approaches to increase the visual perception of the real world merging additional information with the natural scene. In the described experiments, the fusion is performed in a video see-through visualization device. The orientation of the viewer is performed using techniques of pattern recognition. The system identifies a target in the images and estimates the relative position of the viewer based on the form and size of the visible target. So, a new virtual coordinates system is defined and this system is used for the inclusion of the virtual three-dimensional elements. The next step is the creation of the virtual object and its insertion in the image, which is displayed on a Head Mounted Display. The variation of the relief, when it is represented by a regular grid, can be represented using graphical primitives as rectangle or triangle. Objects, as buildings or trees, can also be modelled as three-dimensional elements combining graphical primitives or using triangular meshes. The amount of information is increased significantly by the inclusion of textures. The method is based on the ARToolKit and OpenGL libraries.

1. INTRODUCTION

Although the real world is three-dimensional, it is traditionally represented on a bi-dimensional surface, the printed map or the screen of a computer. The reading of the map, the success of the communication, does not depend only on its production, but it also depends on previous knowledge and experience of the reader. The user of a map has to be familiar with the representation standards and able to extract the three-dimensional information from it. However, some users experience problems because they might find difficulties to imagine the terrain from the contour lines, for example. The problem becomes more complicated when the user has to analyze temporal changes represented in maps.

Today, computer visualization tools are available at low cost and include tools of Virtual Reality. Recently, a new concept was introduced in the representation of the environment, the concept of Augmented Reality (AR). Behind the concept of Augmented Reality lies the idea that the perception of a viewer can be enriched using computer resources, avoiding the simulation of the whole world in the virtual environment. The concept of Augmented Reality can be applied to different areas, increasing human perception.

In this paper, we presented results of a project that aims at the application of Augmented Reality for the visualization of three-dimensional data. Examples that deal with an urban scene and digital terrain models are presented.

2. AUGMENTED REALITY

The availability of new options for the visualization of spatial data has changed the concept of map, which is no longer restricted to the printed map. For Gao (2001), two concepts are important in this context: the visible map and the invisible map. The visible map is the result of drawing objects on a sheet of paper or the screen of the computer. The invisible map can be a mental map (in the human brain) or digital (stored in a computer) and is the one that can be viewed, for example, with Virtual Reality.

According to Milgram and Kishino (1998), between the two environments, the real environment and the virtual environment, there is space for a continuum of representation possibilities, where the user combines both concepts in his perception process. Milgram and Kishino (1998) recognize two important points in this continuum: the Augmented Reality and the Augmented Virtuality. Figure 1 displays the Augmented Reality in relation to the Real Environment and the Virtual Reality.

The fusion of a real and a virtual environment demands the use of devices that help to produce a hybrid image. There are different options available, depending on the hardware. A classification is proposed in Azuma (1997):

- Optical See-Through: The visualization device is composed by transparent glasses, on which the virtual images are projected (Figure 2.a). Its advantage is the feasibility to
project the virtual elements directly on the real scene. An example of such systems is described in Leebmann (2006);

- Video See-Through: a video camera captures an image of the real world, which is displayed together with the virtual objects on the screen of an opaque head mounted display (HMD). Figure 2.b displays an example of an opaque head mounted display. An example is described in Bobrich and Otto (2002);
- Monitor-Based: These systems use conventional computer monitors. They are cheaper and easy to build, but offer less interactivity, as the system described by Drascic et al. (1993);
- Projector-Based: Virtual images or textures are projected on the surface of the real object. Reitmayr et al. (2005) describe an example of this option.

2.1 Reproduction fidelity

A key question in virtual representations was asked by Ogleby (1999) and is “how real is your reality?” The question is related to the quality and realism of the virtual information in terms of geometry and textures. It can vary from simple texts, lines or wireframes, to three-dimensional elements with realistic textures. Figure 3 displays two representations with different degrees of reproduction fidelity. In this example, the virtual model of a building is projected on the image of a real table. In the first case, (Figure 3.a) three-dimensional blocks are used and in the second one (Figure 3.b) the three-dimensional blocks are covered by textures obtained from real photos.

3. METHODOLOGY

For the three-dimensional representation of an object within an Augmented Reality environment it is necessary to compute the position and attitude of the viewer and later display the visible surface of the object together with the real scene. In this section, we describe the solutions that we adopted for each one of these steps. The methods are partially based on the previous experience of Bobrich and Otto (2002).

3.1 Position and attitude of the viewer

The estimate of the attitude and position of the viewer uses the ARToolkit library (Kato et al. 2002), widely used in the literature. It is based on the use of a digital camera to capture the image and the identification of artificial targets in this image. After detecting the target, the ARToolKit library computes the position and attitude of the camera in relation to this target, based on the its dimension and form in the image.

The computation of the position and attitude of the camera is based on the Collinearity equation, that project the three-dimensional space (object space) on the bi-dimensional image system. The Collinearity equation is a physical model representing the geometry between the projection centre of the camera, the ground coordinates of an object and the image coordinates. The exterior orientation must be re-computed every time the position of the viewer changes. Let the projection centre or the lens system be \( P_0(X_0, Y_0, Z_0) \), with rotation angles \( \omega, \varphi, \kappa \) around the X, Y and Z axis respectively (roll, pitch and yaw angles) given by the rotation matrix \( R \), the image coordinates be \( p(\varepsilon, \eta) \) and the ground coordinates be \( P(X,Y,Z) \). The Collinearity equation is given by Krauss (1997) as:

\[
e = e_0 + c(r_{13}(X-X_0) + r_{23}(Y-Y_0) + r_{33}(Z-Z_0))/A
\]

\[
\eta = \eta_0 + c(r_{12}(X-X_0) + r_{22}(Y-Y_0) + r_{32}(Z-Z_0))/A
\]

\[
A = r_{13}(X-X_0) + r_{23}(Y-Y_0) + r_{33}(Z-Z_0)
\]

Here:

\( r_{11}, r_{12}, \ldots, r_{33} \) stand for the elements of the 3x3 rotation matrix \( R \) and \( c \) stands for the focal length.

After orientating the camera, a relative coordinate system is created with the origin at the centre of the target, as illustrated in figure 4.
3.2 Modeling

The terrain, when represented by a regular grid, can be modeled using graphical primitives as rectangles or triangles. Objects located on the terrain, as buildings or trees, can be modeled combining the same graphic primitives or using triangular meshes. The information content is significantly increased by the inclusion of textures. However, the use of textures increases also the amount of data and processing time. According to Landes (1999), as displayed on Table 1, the realism increase is inversely proportional to the performance of the visualization.

<table>
<thead>
<tr>
<th>Representation</th>
<th>Realism</th>
<th>Performance of the visualization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bidimensional</td>
<td>– –</td>
<td>++</td>
</tr>
<tr>
<td>3D Blocks</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>3D Blocks, with textures</td>
<td>++</td>
<td>–</td>
</tr>
</tbody>
</table>

4. EXPERIMENTS

In the experiments, we built an Augmented Reality visualization device that uses opaque glasses, because of its lower cost. Its disadvantage is the need of accurate overlapping the virtual environment with the real world and the dependence of the spatial and temporal resolution of the imaging device.

In the first experiment, the aim was to enhance a map of a small city. The database was a map that includes blocks, parcels and buildings, but only the buildings and trees of some blocks of this map were selected for the experiment. The aim of the experiment is to evaluate the feasibility to visualize changes in the city.

Air photographs were used to identify the new buildings within the study area. In a new database, the position and orientation of each object (building/tree) was stored. The objects were classified in four classes: “existing building”, “new building”, “existing tree” and “new tree”.

A three-dimensional model for each class was built using graphic primitives of the OpenGL library. The objects were displayed as blocks with different colours, without textures. Special care was taken with the illumination of the model, to achieve more realism. The appearance of each surface is affected by the environmental light, considering reflection in terms of diffuse and specular reflection (Azevedo and Conci, 2003). The environmental reflection meets the surface with the same intensity, regardless of its orientation, avoiding the occurrence of completely dark surfaces. A point source, far from the model, was used for the specular illumination. The combination of these effects enables to give more realism to the artificial objects and enhances its volume.

In a second experiment, the system was used to visualize the terrain of a region. The contour lines of a topographic map were digitized and used to interpolate a digital terrain model in raster format. The model was displayed on the map, avoiding the need to imagine the relief. So, the user does not need to analyze the contour lines and can also see the map in the background. The digital terrain model was displayed using a triangular mesh, without texture. Only shadows were used to enhance the form of the terrain.

5. RESULTS

Using the Augmented reality system, the user can see the model from different angles, without using a keyboard or mouse, because his position and attitude are computed in real time when the target is completely visible. When the observer is too far from the target, or when the view angle is very low, the target cannot be positively recognized and the orientation is impossible. Although only the visual variable size was used to identify the new buildings, other visual variables, as “colour” or “texture”, can also be used for this purpose.

Figure 5 displays an example of the representation of the three-dimensional urban reduced model. The printed map can be seen in the background. The vertical dimension was exaggerated to easy the visualization of the virtual objects. The position of the model in the object space depends on the position of the target. The new buildings and trees were displayed higher as the existing objects, to show the changes in the city blocks.

Figure 6 displays the reduced model of a DTM (Digital Terrain Model) derived from the contour lines and displayed on the map. In this case, the user can interact with the model and change his point of view without the use of the mouse or keyboard. An interesting point, the position of a measurement station, is also included in the scene as a red ball.
6. CONCLUDING REMARKS

The use of Augmented Reality for visualization of three-dimensional data is viable and offers new possibilities for the visualization of spatial information, because it makes the interaction more intuitive and easy. It also simplifies the reading of the map, because the desired information can be more easily seen, reducing the mental work. In the experiments, changes within an urban region and a digital terrain model were displayed and the results show that Augmented Reality can help to improve the understanding of the information contained in a digital base.

The success of the methodology, based in the identification of targets in the images, depends on the identification of the targets. To cover larger areas, more targets can be used. One of the main problems is the delay in the representation of the virtual objects caused by the high volume of data. The advantage of using Augmented Reality for the visualization of reduced models within a closed environment is the independence of support devices for the determination of the position and attitude of the observer or interaction devices, like mouse and keyboard.

REFERENCES


