A MULTI-USER MOBILE SYSTEM TO VISUALIZE ENVIRONMENTAL PROCESSES

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Abstract

This paper presents a multi-user mobile system to visualize environmental processes. Two main modules define the system’s architecture, a geo-referenced model and an Augmented Reality (AR) composition module. The geo-referenced model is applied to the visualization of water quality, in rivers or lakes, but other models can be used allowing the visualization of different environmental processes. The AR composition module is the client side of this architecture, allowing users to visualize and interact with the geo-referenced model via two different views.

The first view, a 2D computer animation, enables the interaction with the geo-referenced model by adding or removing pollutant agents to the simulation. The second view, AR view, enables users to visualize the simulation over real images. Thus, it is possible to observe the evolution of the model in the vicinity of the users, superimposed over the view of the real environment.

Interacting with the model requires the knowledge of several distinct parameters. Therefore, several templates were defined to represent different agents. These templates are embedded with predefined values for an easier interaction with the model used in the simulation. In the client, these templates are viewed in the form of icons representing real agents. The model supports multiple users interacting with a unique simulation.

A GPS and an orientation tracker are used to track the users in the field of observation. The information obtained by these devices is sent to the server, so that the simulation model only sends data related to the environment in the vicinity of the user. Moreover, the information is sent to the client device tailored to its specifications, namely screen size.

INTRODUCTION

Environmental changes are a topic of interest for academics, managers and general public. Indeed, changes in the environment may affect everyone’s lives, and be a great point of concern. Simulation and visualization systems should provide realistic reproductions of the changes in the environment, for purposes as diverse as description, explanation, forecasting or planning.
In this work, a simulation model, simplified by ignoring certain details, is used to simulate observed environmental changes. The model allows complex systems to be understood and their behavior to be predicted within the scope of the model. In environmental management, the systems to be modeled are environmental processes, inherently spatial and temporal. The visualization of the simulations outputs can be made using different techniques, namely 2D Computer Animations, Virtual Reality (VR) and Augmented Reality (AR).

Computer animations, in 2D, can be considered as a support system to help a designer to outline the basic features of the environment and give all users a more general view of the system. VR enables immersion in a synthetic, computer generated 3D environment. Immersion can be accomplished by wearing a Head Mounted Display (HMD) and position trackers, which allow the computer to modify the output according to the user’s position and line of sight. However, most of the perception of the real world is blocked out when users are interacting with a traditional VR system.

AR generates a composite view for the user, combining both the real and virtual information generated by the computer, in real-time. AR enhances human perception supplying further information to the user not ordinarily detectable by human senses. Additionally, AR techniques improve efficiency, free the user from searching for additional cues in the scene and make the task more pleasant.

In fact, traditional AR systems are built with a huge set of devices, namely a Head-Mounted display (HMD), a laptop, and orientation and position trackers. These systems allow an easy and seamless interaction with real environments. Nonetheless, these setups are too cumbersome to provide a seamless and non-intrusive interaction for a roaming user.

Personal displays, namely personal digital assistants (PDAs), avoid burdening the user with heavy and cumbersome devices improving the AR experience. However, precisely due to its small size, a PDA-based AR system has technological limitations which can greatly degrade the user experience. Therefore the user interface is of extreme importance and should help to overcome these limitations, offering a pleasant experience. Furthermore, interaction between groups of people working on a project, often in different sites, is an important requirement in environmental management.

Considering these issues, the project Augmented Environments (ANTS) is developing a Mobile Augmented Reality System for environmental management providing geo-referenced information to the users, to be deployed in laptop computers and PDAs (Romão et al., 2002). This system allows a group of users to interact during the simulation of an environmental process, using geo-referenced information from each user.

In the next section, several projects that inspire our work will be discussed naming some of its potentialities. Subsequently, the system architecture of this mobile system is presented, firstly showing an overview of the complete system and finally discussing the server and client modules of the system. Lastly, project conclusions are shown and possible future work is presented.

**RELATED WORK**

Map-based visualization, VR and AR have been used for many purposes. Among these purposes are: specialized professionals training, entertainment industry, architecture and urban planning and, more recently, environmental visualization. These tools allow the
A multi-user mobile system to visualize environmental processes

simulation of different scenarios and the monitoring of people’s responses and behavior in real world situations. Each visualization system has its potentialities, which leads research to the usage of hybrid interfaces, taking advantage of the potentialities of each different visualization method.

Hedley et al. (2002) explored the use of hybrid user interfaces for collaborative geographic data visualization with two interfaces. The first interface combines AR, immersive VR and computer vision based hand and object tracking. Users wear a lightweight camera and display, so that they can look at a real map and see three-dimensional virtual terrain models overlaid in the map. In this case, users can fly and experience the model immersively, or use free hand gestures or physical markers to change the data representation. The second interface allows zooming the image, paddle interactions and pen annotations.

BITS (Browsing in Time and Space) interface was developed for the exploration of virtual ecosystems. It allows users to navigate and explore a complex virtual world, interact with surrounding objects and make annotations indexed in both time and space (Dias et al. 1995). Ghadirian and Bishop (2002) introduced a project to combine GIS-based environmental processes modeling with the use of AR technology to illustrate environmental changes in an immersive environment. The project is applied to weed modeling and simulation. A GPS and a camera are used to track users.

Despite research in mobile augmented reality systems is increasing, the technical challenges to develop these systems are still enormous: extremely high update rates, network communication gaps, low processing resources in the client side, image registration, match between camera field vision and model, technological limitations in the different sensors, namely GPS, magnetic trackers.

Accurately tracking users’ positions and viewpoint orientation is important to minimize image registration errors. An overview of tracking systems can be found in Rolland et al. (2001). Each tracking sensor has its advantages and disadvantages, namely vision-based trackers are computationally intensive, magnetic trackers have low accuracy and mechanical trackers are cumbersome.

Hybrid methods are then used to take advantage of each tracking method, also minimizing their problems (You et al., 1999; Azuma et al., 1999). Pasman et al. (1998) have described a mobile AR system. The system uses GPS and image capture to track users’ position. Orientation tracking is retrieved from object recognition and direct feedback from inertial tracker. Further research is needed to empower mobile devices with more accurate, lighter, cheaper and less power consuming devices. Furthermore, image registration errors should be avoided to maintain proper alignment of virtual information related to objects in the real scene.

SYSTEM ARCHITECTURE

Two main modules are the basis for this client-server architecture, namely a geo-referenced model and an AR composition module, as presented in Figure 1. The geo-referenced model is a central model in the system architecture. It is used to represent the physical environment being explored and track the user’s position.
The geo-referenced model is an HTTP server, receiving queries from the client applications. Each request must have a set of specified parameters, including the user’s position and orientation, in order to process and retrieve the supplementary information. The AR composition module is used to retrieve additional information from the geo-referenced model. The visualized data is the result of the query to the geo-referenced model, used in the simulation, and can be viewed using a computer animation, in 2D, or through AR.

To exemplify the use of this system, the ANTS project introduces an application for visualization and auralization of water quality in artificial lakes and natural water streams. In the next subsections, a description of the server and client architecture is presented.

**Server**

Targeted to mobile devices, the system architecture was designed to perform, in the server-side, the maximum operations needed to supply additional information to clients. Thus, server runs the simulation model, tracks users and performs additional transformations in the information, so that the client only has to use the information as it is, without the need for local adjustments. Namely, the server is able to adjust the information to client specific screen size.

The geo-referenced model is an HTTP Server, allowing a different set of devices to interact with the model. Thus, to query the model the client only has to set the needed parameters in the URL. Each client will interact with the same simulation, which allows testing different scenarios.

The Dispar (Discrete Particle distribution model) transport model is used in the geo-referenced model module of this application. Dispar is a mathematical formulation to solve advection-diffusion problems in aquatic systems. The Dispar transport model is a 2D model able to simulate several pollutant scenarios (Ferreira and Costa, 2002).

In our application, Dispar is applied to the Tejo estuary (Lisbon). Thus, it is possible to perform a previous calibration of the system and map latitude and longitude values gathered from the GPS to model coordinates. In addition, client orientation values are also mapped against the orientation of the module to supply correct information to the clients.

To interact with the server and be correctly identified in the model, the server stores an identifier (ID) linked with the information about the screen size of the client device. Thus, at bootstrap the client sends a request to the server with information about its position and orientation, view mode and screen size. In the reply, server sends a unique ID to the client.
The first client interacting with the geo-referenced model also has to send a request to the server to perform a new simulation, which is carried by the interface and hidden from the user. Afterwards, each client can request the model to add or remove agents acting in the simulation process (see Figure 2). Agents involved in the simulation can be pollutant sources, namely factories and swine farms, or waste water treatment plants.

Agents are templates embedded with predefined values, used to change parameters in the simulation and allowing for an easier interaction with the model. These templates allow common users to interact with the model and be able to visualize the impact in water quality when related agents are set near a water stream or artificial lake.

Environmental systems are spatial and temporal. Thus, all information retrieved from the geo-referenced model is generated dynamically, calculated in real time and controlled by the user. The user’s position and orientation is updated in each request to improve simulation view in the client application. The result will also be tailored according to the view mode in the client, whether in either computer animation view or AR view.

When the client is in computer animation view the geo-referenced model returns a map view of the model evolution in the user vicinity with an icon representing the user’s position and current orientation. Hence, the user can easily identify the environment in his or her vicinity. To allow users to control the view detail, a zoom facility was implemented enabling them to see a more detailed view of the nearby region or to see a more general view of a wider region.

When a position is selected in this view, agents can be linked to their related position in the geo-referenced model. Sewage pipes connect pollutant agents and a point in the water body to illustrate pollution release. If a pollutant agent is released within the range of a waste water treatment plant the wastes are conducted to it and pollutant discharge is reduced.
For visualization purposes, an AR view can also be selected. In this view the users cannot interact with the simulation. However, they are able to visualize the model evolution superimposed in the image of the real environment. In this view the degree of realism is increased, also improving environmental decision support.

A river surface is flat, so the image superimposed in the real environment is the pollution dispersion retrieved from the geo-referenced model tailored to the position and perspective of the users. Since each user is tracked within each request it is possible to tailor the image to each of them. Another advantage of this system is that some accuracy errors in image superimposition in water surface can be tolerated by the users, because there are no accurate visual references.

**Client**

Being a mobile device, the client has technological limitations. Thus, operations performed in the client-side are reduced, i.e. the operations are mainly to collect user position and orientation, to superimpose additional information and to deal with interactions from the users, whether in AR view or computer animation view, respectively.

In computer animation view, the client first requests a unique ID from the server sending it all parameters referred in the server architecture. After identifying the view mode used by the client, a map view of the server is sent to the client. Afterwards, in every time step a new image of model evolution is requested to the server and updated in the client.

By taping on the screen, the user can see a menu presenting the agents that can be added to the simulation in progress (see Figure 3). When an agent is selected, a request is sent to the server to add the related agent to the simulation. In that request, screen coordinates where the agent should be added, together with user position and orientation are sent to the server. With this information, a translation to model coordinates is performed in the server and the correspondent agent is added to the simulation. Removing an agent from the simulation is performed in the same way. After adding or removing an agent from the simulation, the changes will be reflected in all users.

![Figure 3: 2D Computer Animation.](image-url)
In AR view, a unique ID is also requested as in the computer animation view. Afterwards, an image of the model evolution is superimposed over the real image of the environment captured by a camera installed in the client device. The retrieved image is previously adjusted to client position and orientation in the geo-referenced model saving resources in the mobile client. The users will then be able to visualize the model evolution in their vicinity, superimposed over the real image.

While in the field of observation, the users are tracked via: GPS data, to grab the absolute position of the user; orientation tracker, to obtain the current orientation of the user’s head; and environment mapping, knowledge of the physical form and position of the entities on the environment that is being augmented.

For this project, two versions of the client are in development. First, a client is being developed for a PDA. The setup is formed with the following devices: HP iPAQ 5450 with Pocket PC 2002, Pretec CompactGPS, Lifeview FlyJacket i3800, Lifeview FlyJacket iCAM, Intersense Intertrax 2, Compaq iPAQ Serial Adapter Cable (3800/3900/5400 Series). In Figure 4, a picture of the PDA setup is shown without Pretec CompactGPS.

![Figure 4: PDA setup (without GPS).](image)

Finally, an additional client is in development for laptop computers. This setup is as follows: Laptop computer, Pretec CompactGPS, Phillips ToUCam Pro, Intersense Intertrax 2. In addition, to provide the necessary mobility to the roaming users, a wireless network is used to connect the client and server module. The described system doesn’t take into account gaps in the connection. A reliable connection is needed to perform updates in the client view.

**CONCLUSIONS AND FUTURE WORK**

The presented architecture was studied and tailored for environmental management, namely visualization of pollution dispersion in water streams and artificial lakes. With this architecture multiple users can interact with the geo-referenced model, enabling common users to interact with a pollution transport model. However, it can be applied in other domains adjusting the geo-referenced model for each situation.

The modularity of the present architecture facilitates the development of new modules for additional devices or different geo-referenced models. Different clients with different screen sizes can also be easily used with the geo-referenced model. Moreover, interaction with the model is improved with the usage of templates, also enabling common users to interact with a pollutant transport model and assess environmental impact of pollutant agents or waste water treatment plants.
The AR composition module supplies two different views to observe the model simulation. The first view, a computer animation, is suitable to interact with the model. The second view, supplies an additional degree of realism with pollution dispersion in the user’s vicinity superimposed over the real image. In the future, improvements in current modules should be made, namely the AR modules, either for PDA or laptop computers.

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