Visualizing Geo-referenced Data with the Eco Flight Simulator

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Introduction

As part of the Environmental Informatics and Visualization Laboratory at UMass Boston, we are creating the Eco Flight Simulator – a system for visualizing landscape patterns, ecosystem processes and biodiversity data. Many state and federal agencies are currently gathering large amounts of spatial data via aerial photographs and satellite imagery that can be used for seeing the landscape (distribution and location of habitats, size of habitat fragments, the relationships among political and ecosystem boundaries), analyzing ecosystem processes (water cycling, nutrient cycling, pollution movement) and investigating biodiversity issues (habitat types, populations of invasive species, species interactions, etc.). One of the major challenges facing society today is understand the consequences of the human alteration of natural systems (Cohen 1995, Daily 1998, Lubchenco 1998, NRC 2001). By improving visualization, we can open the access of existing data sets to a far broader community. This will result in enhanced understanding of complex, inter-related processes and more informed decision-making by affected communities.

Typically, these data are statically presented via maps with GIS software. To date, this GIS interface has not reached many non-specialist users. Flight simulator technologies, first developed for the military and now common in the entertainment industry, offer more compelling visualization - a user controlled bird's eye view of the landscape that can include the spatio-temporal complexity of the environment. Using commercial off-the-shelf hardware, open source software and public domain data, we are constructing a combination marine (Stellwagen Bank National Marine Sanctuary in the Gulf of Maine) and terrestrial flight simulator (Ipswich and Parker River Watersheds of Essex County, Massachusetts) as a demonstration of the concept.

Large and Complex Datasets Are Available

Local, state and federal agencies make decisions daily that drive land usage and environmental quality, and ultimately restructure underlying ecosystem processes. The amount of data available to influence these decisions is growing rapidly. Satellites and airplanes are creating very large datasets for terrestrial environments, and research vessels are starting to gather large datasets for marine environments. Furthermore, scientists have begun to gather historical datasets (Jackson et al. 2001, Foster et al. in development, also see Muir 2000). Although communities may have access to relevant data sets, they lack the software analysis tools and expertise to interpret the data. For the most part the public is unaware of the information that is available and when they are they do not have the expertise to use it. It might be said that we are drowning in a sea of data. If a broader community is to be part of the decision making process, they need reliable tools usable by non-experts. Current tools and technology are too specialized to be widely used

Eco Flyer Conception for Ease of Use

The Eco Flyer is being designed for users from the novice to the expert. Its primary interface is a friendly joystick. Rather than the pan and zoom 2D paradigm used on GIS systems, the Eco Flyer allows the user to become a pilot and explore a geographical region by flying over it. Instead of zooming in, the pilot simply flies lower. Instead of panning, the pilot turns their shuttlecraft. Habitat location or physical properties (such as temperature, wind speed, salinity, etc.) are displayed as color-coded translucent volumes. To load datasets or modify what is being displayed, the Eco Flyer has a Graphical User Interface (GUI). Through a collection of buttons and menus, the pilot can load data from a specific ship's cruise or launch a probe to collect specific weather data. We envision that a pilot can also engage "temporal drive". In this mode, moving the joystick allows the user to fly back in time. As a result, historical, ecological and physical data replaces the display of current values. Eventually, after the Eco Flyer can interface to predictive models, the user will be able to fly into the future and see the consequences of the decisions they make today.

The specifics of these sophisticated user interfaces will be developed in cooperation with representatives of user communities. Our goal is to display data and give the pilot control based on their background (Donovan et al. 1999).   This will allow meaningful use of the system by users of varying ages and educational background.

Technological Advancements Make Simulation Tools Widely Available

Historically, flight simulation and 3D visualization have required significant and expensive computer resources. While the needed computational resources do not decrease over time, the cost of these resources continues to decline. Partly fueled by the demand for more realistic 3D games, PC based simulation and graphics capabilities have dramatically increased while prices have continued to decline. Once 3D simulation and visualization required high end, expensive workstations. Now the average new home computer has sufficient power to turn the user into a pilot who can explore an ecosystem.

The Eco Flyer is an open source program. The program is free and can be redistributed at no cost. It will be release under the GPL and LGPL licenses (GNU). Since source code is included, anyone can modify the program to integrate a new data set, include educational material or simply fix a bug. Since it is written in Java, it is very platform independent and should run on the computer resources that are available.

Software and Database Approaches and Progress

The possible options for the Eco Flyer's technology base were discussed with representatives of Sun Microsystems during a visit to Sun headquarters in Santa Clara, CA. All of the currently available platform independent options (Java 3D, Java/OpenGL and Java/VRML) were examined. We agreed only the Java/OpenGL solution had demonstrated the ability to render images from a terrain database several hundred megabytes in size and hundreds of square miles in scope in real time. The Java/OpenGL approach is the most computationally efficient and therefore provides the best performance. OpenGL is a very lower level 3D graphical interface, which requires extensive application level support software. Fortunately, Jausoft (Goethel 2001) has developed an open source set of Java wrappers making it possible to make OpenGL calls directly from Java. Also, Sun Microsystems has created an open source Java/OpenGL example program named JCanyon (Russell 2001). JCanyon consists of over ten thousand lines of code and incorporates some of the latest 3D graphics research concepts into a terrain rendering engine and a flight simulator. It provides a minimal risk technology platform.

Java 3D (Java3D 2002) is a relatively new high level 3D API from Sun Microsystems to support 3D applications. While this API would require a smaller programming effort than OpenGL, Java 3D has not yet had time to mature. To date, we have seen no application built with it that can handle a terrain database that is several hundred megabytes. Until such a proof of concept exists, Java 3D poses an unacceptable risk.

It is not clear that a Java/VRML (VRML) solution provides sufficient flexibility. Typically, a standard VRML viewer is used to render a database and provides limited runtime hooks to modify a view or the elements in it. Since the actual 3D scene graph is not exposed, an application programmer has only limited control. For example, it is not clear how features such as “temporal drive” could be constructed in VRML.

Several significant datasets have been obtained as a result of two site visits. During a meeting at Woods Hole Oceanographic Institute we obtained an extensive elevation and imagery for a region of the Gulf of Maine. After we complete integration of the delivered data we will return to WHOI for additional data sets. A meeting at Monterey Bay Aquarium Research Institute (MBARI) yielded several datasets covering the area off the coast of southern California. Since the original meeting, we have also obtained data from a particular remotely operated vehicle (ROV) and visualized the data. It is worth noting that the data sets from the two research institutes were in very different formats.

To date, the Eco Flyer can be freely piloted over the sea floor of the Gulf of Maine or Monterey Bay. The user can hover, fly at most any given speed or direction and change altitude. The preferred interface is a joystick although a keyboard can also be used. Position data from an ROV can be loaded in and displayed. Virtual “water drops” can be fired from the Eco Flyer. These water drops flow downhill along the terrain and can be used to visualize the extent of a watershed or where polluted runoff goes. Standard GUI buttons are being added to select display modes and specify data to load. On a commodity Dell PC with a commodity graphics accelerator and a graphical window of 640x480, the frame rate remains above 30Hz. Using more efficient algorithms in several places could easily increase the frame rate.

Computer Engineering Challenges

Bringing fly-over 3-D visualization of environmental data to the desktop and to the desktop consumer is possible now but its widespread use for diverse datasets awaits further technological developments. In the body of this paper we discussed the central issue of visualization and the development of Java 3-D. A second issue is the design of flexible display strategies for user interfaces (Pancake 2001). After the first models are complete it will be possible to test interfaces with different user communities. Another challenge that 3-D visualization faces is data standardization and the integration of datasets as occurs in GIS community, where the development of metadata standards has been critical. Hopefully, increased standardization of data formats by scientific researchers will reduce the level of effort needed to incorporate new data sets. If 3-D visualization is to be used as part of a decision making tool, then ways to integrate modeling output into visualization tools are necessary. Emerging standards in ecological systems modeling will streamline this task (IMA project 1999).

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