1 Introduction

Public debates on science-based policy continue to grow in breadth and intensity. In the sector of land and water resource policy, substantial public uncertainty exists regarding such topics as the nature and management of global warming, forest fires, urban sprawl, and river systems. At the heart of the uncertainty is overwhelming complexity of interactions within systems, avalanches of data from many sources, and mediation of information within tight disciplinary boundaries.

We increasingly live in a digital world in which tremendous quantities of data are produced, and a wide range of computer simulations are used to design and test products and policies that affect public’s lives. Yet datasets and models about the world around us have accumulated far faster than the abilities of citizens to make sense of them. The tools for converting data into information still largely reside in the hands of professionals. Digital datasets provide unprecedented potential for individuals to engage in self-directed inquiry that can reveal interconnections and causal relationships not possible through any other kind of medium. People increasingly are digitally connected, however, they rarely engage in any kind of data inquiry and their digital experiences are largely mediated by intermediaries that convert data into information, just as has always been the case with books, newspapers, magazines, radio, and TV.

With support from the National Science Foundation, the Science Museum of Minnesota, Illinois State Museum, St. Louis Science Center, and the University of Illinois/National Center for Supercomputing Applications established the Mississippi RiverWeb Museum Consortium. The Consortium in turn conceived of and created the Digital River Basin (DRB) as a prototype for a novel, inquiry based learning experience. The DRB uses state-of-the-art computer-based modeling and visualization tools to promote experiential learning about the Mississippi River system through direct visitor interaction with real, scientific datasets.

The DRB includes a large format, interactive display that portrays the St. Louis stretch of the Mississippi River and three touchscreen consoles that allow visitors to construct and control their own digital explorations of the river. Using real datasets, the DRB presents a vivid and dynamic representation of the River and the processes that contribute to its behavior and characteristics. The content includes river ecology, hydraulics and management; and it introduces systemic principles for the visitor and allows visitors to emulate scientific research methods as they examine the forces shaping this portion of the Mississippi River Basin.
2 Display Environment

The Digital River Basin is composed of several interdependent display environments including a large format interactive display of an entire river reach with display insets of related information, and satellite touchscreen display modules portraying the river in both two and three-dimensional real-time rendering modes (Figure 1). Several factors drove the development of these display settings. First, due to cost constraints, the display and underlying technologies had to be assembled using stock commodity products. Second, while the exhibit is also about the role of scientific computing and visualization in science, traditional computer interfaces for many have failed to provide successful interaction between the visitor and the exhibit environment. Third, the exhibit must maintain high levels of interaction with both individual and small group user communities.

Figure 1: Digital River Basin (DRB) Configuration

Common Display

A digital display of an entire 30-40 mile river stretch is projected on a large (4x6 ft.) table (Figure 2). A particle visualization dynamically portrays the flow of the river, while a landcover background map provides locational context. Visitors individually or cooperatively query available data for the river stretch by moving simple instruments across the flat visual representation. The location and orientation of these instruments or “tools,” is tracked by pattern recognition software using an overhead infrared video camera.
and an image capture card on the computer. The display software renders site-specific information on selected river basin features such as place names, land cover, elevation, and flood risk, as well as dynamics, e.g., channel flow and erosion as the visitor chooses locations in the basin (Figure 3).

Figure 2: Common and Console Display Environment

![Figure 2: Common and Console Display Environment](image)

Figure 3: Common Display Tools

**Console Display**

Placed in proximity to the common display, console display visitors navigate through and explore a real-time 3D representation of the river basin (Figure 4). The 3D rendering uses the same data as that in the common display but creates a user-centric view. The touch screen consoles support two distinct but complementary modes of navigation. Visitors can “jump” from location to location by touching a flat index map corresponding to the river stretch depicted in the common display. Doing so takes them to the corresponding location.
in the 3d scene. Alternatively, visitors use physical controls to move directly within the 3d scene. A joystick supports rotation and forward and back motion, while a throttle-like lever controls elevation above or, when exploring the channel and other bodies of water, below the surface. Visitors can fly high above the floodplain, then descend to and explore around points of interest within the vicinity.

**Figure 4:** Console Display Interface

Other touch screen tools controls allow visitors to engage in activities such as taking guided tours, sampling fish species, investigating rainfall runoff, channel flow, flooding, or turbidity, and exploring local and system effects of human cultural features such as navigation dams and levees. Visitors can also pilot a tow barge up and down the river under different flow conditions with with different size tows (Figure 5).

**Figure 5:** River Pilot Simulator Activity
3 DRB Structure

The digital river basin is structured as a modular system of interacting components with the landscape acting as the organizing environment for free exploration of content. Conceptually, the system is organized around three layers. At the lowest level are databases of geographic data, model parameters, system status records, and configuration settings. The intermediate level contains models and computer code for visitor interaction, display management, database querying, and simulation modules. Activities and interactions are defined here as both generalized and specific functions. The top layer is represented by the visitors’ activities and experiences, which can be constructed in a dynamic manner through visitor selection by location, tool operation, etc. The combination of layers helps to ensure a rich and changing visitor experience but also permits extensibility to other data or contexts.

Figure 6: DRB Schematic Structure

3.1 Data

Data used in the project can be classified as geospatial, simulation, and interpretative/narrative. Data are used to construct the visualized environment of the river basin for context, as well as to provide content for observation and interpretation.

Geospatial Data

Digital elevation data forms the framework for the virtual world visualized in the DRB. DEMs were derived from standard USGS 7.5 minute data series. Bathymetric data for the main river channels was obtained from the U.S.A. Corps of Engineers who are responsible for maintaining the navigable portions of the riverways, and flood control structures such as levees and floodwalls (dams along the river system are used for maintaining navigation, not flood control). The DEM data were aggregated for use in surficial modelling tasks such as erosion and flood runoff, but performance issues required the data to be post processed.
using triangulation decimation and tiling of data fields. Decimation was based on gradient and other elevation derivatives to preserve important topological structures such as river bluffs and channels (Figure 7).

Figure 7: Underlying Geometric Structures

Landcover data were derived from a variety of sources. For the St. Louis and Illinois museum segments, USGS Gap Analysis Project data sets were used. For Minnesota, metropolitan and state databases were merged to create a regional landcover. As each state developed it’s own classification system, a joint landcover classification system was derived. Soils data were obtained from USDA STATSGO soils data, and are used primarily in erosion modelling tasks. Other data included river flow and stage gauge records, fish sampling stations, water quality observations, navigation features (locks, dams, buoy locations) and other relevant information (species abundance, range, cultural feature identification and location, etc). Rarely has such a mix of data been assembled into a single environment.

Simulation Data

Each simulation model resulted in data outputs to be used in visualization of landscape processes. In general, the models produced both scalar and vector data sets.

The hydrodynamic simulations produced scalar data such as water surface elevation flow depth and sediment concentrations. These data sets were visualized using both geometric models (water surface elevation) as well as color gradients, along with numerical reporting of values (via tools and display functions).

The hydrodynamic simulations also produced vector data in the form of velocity fields for channel and overland flows. Vector data were visualized using multiple representations including glyphs and particle simulations, as well as numerical reporting.
2D and 3D Models

In this first phase of development, 3d models were used primarily to render land use variations and also to provide local landmarks. Examples include the St. Louis Gateway Arch, bridges, and recognized buildings. Other 3d objects include the barge models used in the river pilot simulator, and simple building structures to represent urban areas. Other 2d objects were used as “scenic billboard” including trees and icons representing narrative points of information within the landscape (Figure 8).

Narrative Data

In addition to the 2 and 3 dimensional data, numerous datasets were created to provide a deeper layer of information at specific locations. A primary feature for navigating this narrative data included the use of icons within the landscape coordinated through the concept of a field guide. The field guide provides greater detail via text, images, and graphics including maps and animations (Figure 9). Animations were created to describe numerous processes occurring in the landscape at time scales beyond the real-time experience of the visitor. Panoramic images were georeferenced to provide a photographic image of specific locations within each museum’s stretch of the rivers. Visitors use the navigation controls to rotate themselves through the image (and the virtual space) so the image and orientation of the visitor in the DRB remain consistent. Narrative data were developed for ecosystem features, cultural features, and geomorphic processes occurring within the river basin.
conditions of flow (Figure 10). Thus numerous scenarios were run for each museum, including flow simulations under different weather conditions (low, average, and high flows), and under different management strategies (with and without dams, with levees added and removed) (Figure 11). Sediment transport in the rivers was modeled with the hydrodynamic flow simulations using sediment load data collected from observation stations within the river basin. Because of the size of the reaches (20-40 miles) and the need for high-resolution for visualization and the river pilot simulator, the model execution stretched the resources of the modeling software. Typical problem sizes for these simulations were 30-50,000 elements with up to 100,000 nodes. Simulation times ranged from minutes to hours, depending on model convergence properties, etc.

**Figure 10**: Scenario Management Example.

**Figure 11**: Output of 2d Finite Element Flow Simulation
Other simulations include erosion/deposition modelling using a stream-power based soil
detachment and deposition formulation (USPED, Mitasova, et al. 2000), sediment transport
in the river channel, and a tow simulation using basic free-body motion equations.

3.3 Visualization

Interaction with and visualization of the landscape, static and dynamic data forms the core
challenge of the experience. Balances between detail, level of realism, and modes of
navigation demanded considerable discussion and debate. With the landscape acting both
as the object of the visualization and the means of communication (a virtual gallery)
numerous issues emerge with respect to computational performance, visitor navigation and
orientation, and identification of information resources.

Performance objectives for the DRB included rendering near 15 frames per second for
smooth action and response to visitor actions at resolutions of 1024x1280 pixels. User
induced changes to the display environment required the ability to swap data sets in and out
of the graphics environment from random access memory and disk cache. The
visualization environment is built on SGI’s Performer graphics environment
(http://www.sgi.com) in addition to considerable amounts of custom C++ code, and is
readily ported to CAVE (immersive visualization, http://cave.ncsa.uiuc.edu) environments.
The museum exhibits, however, are not stereoscopic, and not photorealistic. Stereo
imagery was precluded from both cost and usability issues. With thousands of visitors,
wear and tear and public health concerns dictated that the user not be required to wear an
apparatus. The objective of group interaction and socialization also precluded personal
display equipment.

Features employed to achieve the performance goals include terrain mesh decimation,
liberal use of textures to enhance realism without increasing geometry, tiling and levels of
detail, far clipping planes and atmospheric effects as well as a recognition that high
resolution geometry or collision detection (except for the terrain surface), shadow casting
and other techniques were not necessary to convey the content of the data. For example, it
was decided not to use aerial photography as part of the exhibit because it was too realistic
and would distract users by having them search for familiar landmarks instead of exploring
other available content.

Research issues in visualization of 3 dimensional spaces include loss of orientation,
difficulty in spatial judgment, and other factors (Ellis and Johnston, 1999) and influenced
design considerations. Previous experience (Johnston, 1998) indicated the desirability of
maintaining exo-centric perspectives while navigating in the 3d space, thus an index map
with the user’s location and direction is provided on the console display. In addition, the
location of each console user is presented on the common display to reinforce orientation
and visitor interaction. Other issues in interaction include selection of objects in 3d space.
The DRB provides several modes for selection. One mode consists of a “sphere of
influence”, that is, a feature becomes active when the visitor approaches it (or its
iconographic representation). Most narrative features are activated in this manner.
Alternatively, visitors may touch icons in the landscape to invoke actions. A 3d selection
algorithm is employed to enable visitors to select both near and distant objects. Finally,
objects can be pre-selected via a “tour”. Selected features are displayed both in the 3d
display and on the 2d index map. The visitor may touch the index map to jump to and activate the feature, or can navigate to the feature and activate it as described previously.

4 Results

Embedded in the Digital River Basin is a comprehensive set of data, experiences, and interactions. It serves as a prototype for a naturalistic experience of virtual environments blending familiar concepts of mapping, and gaming technologies to create an intuitive means for exploring a landscape unconstrained by physical bounds of space and time.

As a museum exhibit, the Digital River Basin has proven to be very successful, both in formal and informal evaluation settings. Exhibit evaluators have observed unprecedented levels of engagement both in terms of attention time and social interaction within and even between visitor groups. While the learning objects for the exhibit are being met to varying degrees, indications are that the direction of learning is correct and that further refinement of visualizations and interactions will enhance these further. At present, the depth and breadth of information available is somewhat daunting to casual visitors.

5 Conclusions & Outlook

While created for a museum visitor experience, the DRB is designed to be generalized as a data visualization and interaction environment for a wide range of landscape-scale problem domains. An overriding goal for the DRB was that it follow a modular, hierarchical object design that can be adapted to defined stretches of the river, and which can also be extensible to accommodate further data and computer simulation modules at a later stage. As such, the DRB environment is able to incorporate mixed datasets, more detailed data and visualizations, and novel interfaces through which visitors can query the data via combinations of physical and “virtual” tools and navigate seamlessly from over or on the floodplain to the river’s surface and beneath. In achieving increased robustness and generalization, the DRB will be well positioned to serve as a medium for professional and public discovery and discussion of landscape issues.

6 References

Mitasova, H., Mitas, L., Brown, W. M., Johnston, D., 2000, Terrain modeling and Soil Erosion Simulation: applications for evaluation and design of conservation strategies Report for USA CERL. University of Illinois, Urbana-Champaign, IL