Visualization of Water Resource Data

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Abstract

We have developed an interactive tool for the visualization of water flow and storage in a river-reservoir system. Meaningful parameters from a multi-dimensional parameter space are used in the tool to represent the main characteristics of the water flow. We have adopted rendering techniques from information visualization, such as 3D glyphs, to visualize the important characteristics.

The visualization is embedded in a geographical layout, thus bridging the areas of information and scientific visualization. For case-study purposes, we applied our visualization tool to major elements of the water network in the Sacramento and San Joaquin river basins in Northern California and used it to study the temporal changes in the water flow and the water levels in the reservoirs over several years. The functionality of our toolkit includes static visualization of a water system for a single day as well as dynamic visualization of changes in water flow and levels over time.

Introduction

The river system of Northern California forms a well-knit network of inlet streams, reservoirs and highly regulated river channels that flow into the Sacramento-San Joaquin Delta and the San Fransisco Bay. Large pumping plants operated by federal, state and local water supply agencies export water from the Delta via aqueducts to destinations as distant as Southern California. The entire water system supports many beneficial uses including agricultural, municipal and industrial water supply, hydroelectric power generation, waste water and waste heat assimilation, fish and wildlife production and recreation. The developed water is stored in reservoirs and conveyed via river channels, the Delta and the aqueducts. Hence, the term *functional tank* is used for reservoirs and *functional pipe* used for rivers, aqueducts or the Delta. Of particular interests are the water flow change in the pipes and the water level change in the tanks.

Several characteristic parameters of water resources are measured, thus, leading to a multi-dimensional parameter space. Typical parameters are water volume, water depth, cross-sectional area, and amount of water flowing in and out, namely, *influx* and *outflux*, respectively. These values are measured at the center of the tanks and at the gauging stations of the pipes, with a time step of a day, over a period of several years. Our tool can also be used for editing the rendering of the water system. It has various features providing flexibility in adding and deleting selected features.

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For visualization purposes, we project the multi-dimensional parameter space to a lower-dimensional space by extracting specific parameters. We treat the functional tanks and the functional pipes differently, as, typically, water depth, water volume, and cross-sectional area of tanks are of interest for the tanks; and flux values for the pipes. We use 3D glyphs for visualization purposes, which is an information visualization approach. We bridge the areas of information visualization and scientific visualization [1] in a geographic context [2], by embedding a representation of abstract data in the physical geographical layout of the water system. Using visual *metaphors* to represent abstract information is one of the most widely used information visualization techniques [3][4].

This work was inspired by a specific application concerned with understanding temporal changes in the flow of water in the water network in Northern California. It helps in learning various physical and natural phenomena, like changes in the volume of water in the functional pipes and tanks show certain seasonal characteristics of the flow in the system. Similar work has been done by Cox et al. [2] for representing the time-oriented geographical networks using 3D glyphs to represent the nodes. They used *dynamic parameter adjusting* for minimizing cluttering of glyphs. Kolojejchick et al. [5] have described techniques to create a coordinated suite of basic tools and specialized information appliances by combining basic analysis and reporting tools into an integrated information workspace. Our work is the abstract representation using a combination of 3D glyphs and 2D textures placed appropriately on a map texture to show time-varying water flow and the use of editing tool to make changes in the layout.

Rendering

Our abstract rendering of the functional tanks and pipes is as shown in Figure 1. The functional tanks, rendered as cylinders, are categorized into small, medium, and large tanks, based on their respective maximum cross-sectional area. This categorization is done in order to keep the tank radius fixed for each category. Direct correlation, observed between the maximum surface area and the maximum volume in each of the tanks, is exploited in this case. When no time-varying data is available for a displayed tank, we use a static transparent rendering corresponding to a single time step. Different from other information visualization work, we depict actual changes in two dimensions in a single dimension in our abstract representation.

Natural functional pipes are rendered as curved ribbons, and man-made ones (like the aqueduct) are rendered as straight ribbons. The effect of flow in a river is brought out in a visualization by the use of a moving texture for flowing water. The tributaries and distributaries of the pipes are called *sub-pipes*, which act as independent pipes, but share the same gauging station with the main pipe. For instance, the different tributaries of the lower Sacramento-American river system are rendered as sub-pipes. The pipe is divided into segments of user-specified lengths, which are rendered at user-specified angles at each other. This flexibility allows us to better represent rivers following a meandering course better. The Delta basin is also categorized as a functional pipe as it connect rivers to the Pacific Ocean or the Bay. It is rendered as a triangle with its apex pointing in the direction of the net flow of water. The pipes are rendered using an animated water texture. The rate of moving the texture is directly proportional to the outflux measured at the gauging station.

The height of the tanks is determined by a normalized value of the volume of the tank, and the flow rate of the texture in the pipes is determined by a normalized value of the outflux. Normalization is done by using the maximum of the respective parameters. The tanks and pipes are placed in the image on a textured relief map of California, in the correct longitude-latitude geographical locations provided in the datasets of the tank centers and the pipe gauging stations, respectively.

Height variation of tanks and flows in the pipes can be animated using the playback widgets provided in the interface. The state of the water bodies can be frozen at a particular time step, or an animation can be performed for all time steps. The time step can be incremented by a day or by a week to effectively compare the states of the system at consecutive time steps.

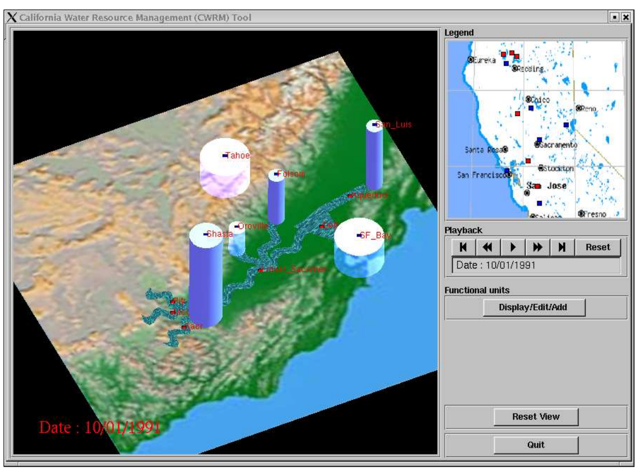

Figure 1: Visualization snapshot. This visualization shows the river system of Northern California, with functional tanks shown as cylinders and functional pipes shown with a moving texture for water. On the right are a reference political map, animation playback widgets and an editing widget.

Editing

The primary functionality of our tool is to visualize flow patterns over time in the water network. Since the number of water bodies contained in this system is very large and making available measurements for all the units may be difficult, the toolkit should have features to allow a user to render functional units that one may add later. Hence, our tool includes an editing functionality too.

Though the editing features provide a user with the flexibility of rendering the water body, its location is fixed by its reference coordinates. In the case of functional tanks, one can vary the radii of the small, medium, and large tanks; however it is constrained by the increasing order of their radii. The functional pipes are constructed based on the virtue of being natural or man-made or the virtue of being a pipe or the Delta. A user can orient the functional pipe according to the connectivity information of the system. When rendering a pipe, a user can specify parameters like segment lengths, angles between segments, orientation of a pipe, and relative position of a gauging station with respect to the length of the pipe or its segment. The editing features of the tool support changing data values for each water body by changing the respective input file.

Results

Our visualization tool can be applied to the water bodies in Northern California. It allows a user to study changes in the flow pattern in a specific part of the river system, or to analyze the characteristics of these changes, for instance, periodicity, cause-and-effect, etc. The animation capability helps to infer much information about the seasonal changes in the water system. For instance, a strong correlation can be observed between the rapid increase in height of Shasta Lake and in the flow of the lower Sacramento-American river system in the months of January and February, in all five years. Similarly, the increase in height of Lake Shasta can be attributed to the increased flux in the Pit, McCloud and Sacramento rivers that drain into Shasta Lake.

Its editing capabilities enable a user to add water bodies to the system effectively. One can also change values for the existing water bodies. Moreover, the tool is a useful educational system due to its user-friendly characteristics.

Future Work

As the number of water bodies is very large and visual clutter can result, we plan to add a multi-resolution data structure component to the tool. This capability will enable a user to view the data at adaptive levels of resolution/detail, depending on area of interest or amount of available screen space.

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