Visualization of Scientific Data

GRADUATE PROJECT REPORT

Submitted to the Faculty of
The Department of Computing Sciences
Texas A & M University- Corpus Christi
Corpus Christi, Texas

In Partial Fulfillment of the Requirements for the Degree of
Master of Science in Computer Science

by

Ram Kumar Vangala
Fall 2008

Committee Members

Dr. Scott King
Committee Chairperson

Dr. Ajay Katangur
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Dr. Diane Denny
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ABSTRACT

A picture is worth a thousand words. Visualization of scientific data makes the task of reading large volumes of data, finding the changes that happen in real time and understanding them much easier compared to number representation.

This paper talks about a tool designed to periodically monitor a given parameter in the bay. The tool collects the data pertaining to the parameter from the stations in the bay in real time and interpolates the values of the entire bay and then converts these values into images in real time.

This tool can be further used to explore attributes such as water depth, water speed, Wind Direction, Salinity, etc by retrieving the information from the stations and using it to show the visualization of the data.
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1. BACKGROUND AND RATIONALE

Water bodies such as bays support much wildlife such as fish, shrimp, blue crabs, and endangered whooping cranes. For these animals to survive, the Salinity levels contained in the water must be within the tolerance. In the Nueces Bay there is much fluctuation in the Salinity. The fresh water inflow reduces the Salinity of the water. There is a need for a fresh water inflow monitoring system.

The Choke Canyon Reservoir built in 1985 on the Nueces River changed the equilibrium of Nueces Bay. The reservoir reduced the freshwater inflow into the Nueces Bay to such an extent that an external water Salinity monitoring was essential to control the fresh water inflow into the Nueces Bay [DNR 2007].

The City of Corpus Christi along with the Texas Parks and Wildlife Department (TPWD), the Texas Natural Resources Conservation Commission (TNRCC) and the Texas Water Development Board (TWDB) started studying the problem and came up with the water flow management system from the City of Corpus Christi and the Division of Nearshore Research (DNR). The DNR has been monitoring the Salinity level in the Nueces bay since November 1991 [DNR 2007].

1.1. Nueces Estuary

The area covered by Nueces estuary is approximately 500 square km with an average depth of 2.4 m [Orlando 1991]. The Nueces estuary is divided into a number of channels like Corpus Christi channel, La Quinta channel and the Encinal Peninsula channel. Corpus Christi bay and Nueces bay are the two largest bays in the Nueces Estuary while Redfish Bay and Oso Bay are the next largest bays. Figure 1.1 illustrates the Nueces Estuary layout.
Figure 1.1: Nueces Estuary [Orlando 1991]

The estuary has three, northern, southern and outer, boundaries. These three boundaries together establish a low level dam at Calallen. This dam represents the head of tide on the Nueces River to the terminus at Aransas Pass. The northern boundary joins the Mission Aransas estuary at Redfish Bay. The southern boundary separates the Corpus Christi Bay with the upper Laguna Madre. This southern boundary is located at the JFK Causeway. The outer boundary is located at Mustang Island that separates the estuary from the Gulf of Mexico [Orlando 1991].

Due to the unfavorable conditions caused by both natural and man made obstructions, the flow of freshwater and saltwater within the Nueces Estuary is lowered than what it was earlier. The main source of the fresh water inflow is from the Nueces River which enumerates about 99 percent of estimated inflow. There is another source of freshwater which is from the Oso Creek which has less than one percentage of the
estimated flow. Isolated freshwater pulses, rather than seasonal fluctuations of freshwater inflow, are attributable to the most significant changes in bay-wide Salinity distribution [Orlando 1991].

1.2. Nueces Bay

The Nueces Bay has a surface area of approximately 74.5 square km and depths ranging up to 1.2 meters [Jacksony 1995]. This bay serves as nursing grounds to numerous species such as brown and white shrimp, bay anchovy, spotted sea trout, and striped mullet. An important factor which decides the outer look of the Nueces Bay is Salinity, which is the number of grams of dissolved salts present in 1,000 grams of water, and is usually expressed in parts per thousand (ppt) [CB 2005]. The Salinity of the Nueces Bay ranges from 15-30 ppt [Jacksony 1995], and without the proper balance of salt and freshwater inflow into the Bay, countless aquatic species would be unable to survive.

1.3. What is Visualization?

Visualization is the process of presenting data in a form that allows rapid understanding of relationships and findings that are not readily evident from raw data. This process assists humans in visualizing the data.

1.4. Data Visualization

Data represented in visual form aims at effectively transferring the information using the human visual system. Reading through large chunks of data is a tedious task and narrowing the key elements in the data is even more difficult. Data can be presented in a number of ways such as graphs, maps, animations, and simulations, which aids in the communication of vital information. Humans can grasp complex information easier when presented in the form of images or graphs as compared to numeric representation. The
important role of graphs is to help scientists interpret the data [Egger 2005].

1.5. Current Nueces Bay Data Visualization

The DNR stores various data collected from the bay and preserves them for future use. The DNR holds data from the past ten years in its database that can be accessed via the Internet at, http://lighthouse.tamucc.edu/Main/HomePage. Currently, data is collected every thirty minutes, and stored in its database. This data is retrieved from the website in numerous ways, one of which is via two-dimensional graphs as shown in Figure 1.2 however; the graph often does not allow the viewer to see the correlations between all aspects of the data.

![Figure 1.2: Mapping of the Salinity in Nueces Bay during 2006-2007. [DNR 2007]](image-url)
1.6. Related Research

Most data representation tools use universal software systems such as MatLab, Matematica, DPGraph, SPSS, etc. [Kolodnytsky 2001]. These specialized tools are very powerful and should be integrated with some other software system. Mathematical modeling software like MatLab have built in tools for data visualization. To use this kind of software, the user has to learn some domain specific languages of these software tools [Kolodnytsky 2001]. However a good data visualization system lets the scientists interactively explore the parameters [Kwan 2000]. The present day visualization software packages contain controls such as control panel for controlling the scene with buttons, menus, slider bars, and key-in boxes. Some of the software packages allow users to define each task-oriented visualization pipeline such as data-flow network, etc. But no mechanism exists for visualizing the iterative process of parameter selection [Kwan 2000].

Interactive Structured Time-varying Visualizer

This particular research was on visualization of ocean flow. Chupa and Moorehead present a tool which can simultaneously visualize several datasets with varying temporal and spatial resolutions in a single view volume [Chupa 1999]. The tool provided a visualization technique for two dimensional mapping with hue-saturation value color wheel. The color wheel gives the users an insight of ocean eddy structure.

The Interactive Structured Time-varying Visualizer (ISTV) tool contained datasets which were logical four dimensional grids (three for dimension and one for time). This particular grid structure allows storing values at each and every grid location.
These values can also be saved to file for later purposes and read by the software according to the need.

The ISTV tool would also capture the 3-D space animation and save it to disk for later replaying. As an attempt to simplify the visualization task for the end user, the ISTV tool loads the Logical Grid Files (LGFs). These files contain all the necessary information for the visualization to start and thus providing an abstraction for transparent access to data on disk.

Text labels are inserted to provide users a clear understanding of current machine state. The text labels include time stamp, station location, etc. These text labels are defined in 3D space of model so that if the user navigates in the view window, the text labels also move relatively with the scene.

The ISTV tool can load multiple data files. This allows adding different parameter values into the animation without the need to modify the datasets and recompiling the program [Chupa 1999].

**A User centered look at Glyph based Security Visualization**

This particular research was done on glyph based security visualization. A glyph is a vector with direction and magnitude. Anita Komlodi and Penny Rheingans describe a tool for an intrusion detection system [Komlodi 2005]. The Intrusion Detection (ID) tool is based on the common approach of capturing the network topology in a graph with systems as nodes and connections as edges. The system generates glyphs which represent nodes. Each glyph is colored using a lookup table and based on the corresponding data variable at that particular location. The tool is designed to vary the opacity of the glyph in accordance with the value of the corresponding data variable.
The tool uses labels to notify the user of the properties of the glyphs. The tool allows users to make two decisions during labeling the glyphs:

- what to label each glyph with and
- when to label the glyph

If two or more glyphs have equal or similar values then they are overlapped to avoid redundancy.
2. NARRATIVE

The primary goal of scientific data visualization is to provide users the ability to visualize data. This helps them in studying the pattern. By using visualization, they can combine different data to see the effects. It also helps the users in decision making.

This project deals with visualizing the data presented to the software tool. The software will generate images of the data over time and present them to the user.

The tool provides the flexibility to the user to select various parameters for the visualization. The user has a choice for selecting a parameter for coloring, such as Water Temperature, Salinity, wind speed, etc. If the user wants to add additional information into the image, they can add more parameters and visualize those using different colors or glyphs.

2.1 Nueces Bay Visualization

A mesh frame is created for the Nueces bay. The first mesh makes up the shoreline and bathymetry (depth) data for the bay. The second mesh lies on top of the first layer. This layer consists of the environmental data, such as Salinity, Water Temperature, water pressure, water level, maximum wave depth, etc. The two superimpose on each other and can not be displayed separately.

Additional information about the land can be added into the image to make the images look realistic. This requires extra computation as the elevation of land differs from location to location and displaying it would be costly.
The Nueces bay has five stations monitoring the water in the bay. Each station collects data regarding various parameters. These values are used to calculate the remaining values in the bay. This produces an animation over time.

The model for calculating values for the bay can be changed according to the user’s choice. Different math techniques can be used to find values surrounding each station in the bay. For instance, linear interpolation (discussed in section 3.2) can be used for calculating the Salinity all over the bay using the values at the stations, while barycentric method can be used for the water depth. Currently the tool uses linear interpolation to calculate the values surrounding each station.
2.2. **Software Tools Used in the Research**

The software used to build the tool is OpenGL, Qt and Wget. The tool is designed to work on Linux machine. OpenGL stands for Open Graphics Library. OpenGL is an API for displaying the 2D/3D graphics [OpenGL 2007]. This particular API is free to download. Qt is a cross-platform application development framework widely used for GUI development and non-GUI programs such as console tools and servers. This particular software is prominently used in various applications like Opera, Google Earth, Qtopia, Skype [Qt 2007]. Wget is free software which is used to get (retrieve) files using HTTP, HTTPS and FTP in a simpler way. Wget stands for World Wide Web and get [Wget 2007]. This particular software is robust and converts links for offline viewing of HTML content.

2.3. **Tool developed as part of research**

The tool provides features such as single parameter visualization using colors, double parameter visualization using color and height, more than two parameters using glyphs and colors, animation over time, color statistics (legend) and data gathering. The tool can be used to alter the speed of the animation. The user has a choice of color palettes to be used for each of the parameter visualization. The tool can capture still images of the animation.

2.3.1 **Data Gathering**

The data fed to the tool comes from the lighthouse.tamu.edu Website. The tool incorporates the data collection feature. When the user selects a parameter for a period of time, the tool checks for the local availability of the data. If the data is not available on the local machine, it collects the data for that period of time. The users will be allowed to collect at least one type of data at a time. All the data collected will be saved onto the
local disk and will be used by the tool for visualization. The reason for storing the data locally is that the overhead of collecting data for each time slot can be reduced and this overhead is dependant on the available network speed.

The lighthouse Website is equipped to create the query for getting the data from their database based on the selection of fields (parameters). Similarly, the tool would provide the parameter selection and based on the selected parameters and the date range, the data will be downloaded onto the local system. After successful completion of the data download, the tool will use the downloaded data for the animation.

2.3.2 Types of Data Visualization

- 2-D Visualization
- 3-D Visualization
- Glyphs Visualization
- Animation

2.3.2.1 2-D Visualization

Using this method, only a single parameter can be visualized at any given time. The color scale can be selected from the color palette (discussed in section 2.3.3) for the parameter selected.

2.3.2.2 3-D Visualization

In this method of visualization two different parameters can be visualized at any given time. Of the two parameters, one of the parameter will be used for color and the other parameter will be used for the height in the visualization.
2.3.2.3 **Glyphs Visualization**

More than two different parameters can be visualized using glyphs. Glyphs are vector having both magnitude and direction. Glyphs can be used to represent a vector flow field [Glyphs 2007]. Placing a glyph at every data location and aligning it to the direction of flow will show the direction of the flow across the entire space. Further, by scaling the size of the glyph by the magnitude of the flow at that point, the user can quickly locate areas of high-velocity flow by finding the larger glyphs. Glyphs range from simple lines to more complex shapes such as Arrows or Cones.

2.3.2.4 **Animation**

The tool can produce pictures of the bay with different colors, each color representing a specific value on the given scale. The user has to specify at least one parameter for the animation to run. The tool checks whether the selected parameter data is available offline on the local machine before starting the animation. If the selected parameter data is not available, the tool will display a message asking permission to get the data. A slider bar will be attached to the tool to indicate the present time frame of data being displayed. This helps the users to take a note of time frame.

2.3.3 **Control to explore data**

User interaction is an important aspect for exploring data. Various controls that are used in visualization are rotation, tool palettes, animation speed control, iteration controls, window resizing, color palettes, etc. The controls that the software tool provides are animation speed control, color choosing, changing the view, legend.

2.3.3.1 **Animation Speed Control**

The tool has a VCR like interface where in the user can control the animation speed according to their requirement. In addition to controlling the speed of animation,
the user will be able to pause the animation, resume the animation, etc. This interface is created using the Qt software.

2.3.3.2 Color palettes

The tool has a set of color palettes. Color palettes constitute a band of colors predefined with the intensities. The user can edit these colors and specify the value which corresponds to the color. They basically define the red, green and blue color component for each value. The user can pick one of these colors for particular parameter visualization. Each color value will be associated to a particular value. Based on the data value at the location, the color is indexed.

2.3.3.3 Change the View

In 3D visualization, proper visualization of all the aspects can be done using rotation. The software tool to be produced provides the flexibility for the user to rotate the visualization in one direction at a given time. Mouse events are used to capture the users’ moves for rotation. The software tool also provides a reset button to restore the settings to initial settings. This feature helps the user in situations where in the user made some changes and does not want to save them.

2.3.3.4 Choose what and how

The software tool allows the user to choose the parameters according to the need. It also provides the flexibility of how that particular parameter has to be visualized; i.e. after selecting a parameter, the user can choose how the parameter is to be shown. For example, if the user wants to visualize water depth, then the water depth parameter must be selected and then the user must decide which visualization technique (color, height, glyphs) should be used for the water depth.
3. SYSTEM DESIGN

The visualization project collects the data from the stations and uses these values to color the region. The project involves various tasks to be performed before the visualization can happen. The tasks can be divided into three steps.

- Data collection
- Math Model
- Displaying

The monitoring stations are located in the bay. These stations can furnish different series values at only those particular locations. In order to color the entire region, values pertaining to the entire region are required. The mathematical model is used to fill in the remaining values in the bay.

3.1 Source Data

There are five different stations within the Nueces Bay. They are named as Salt01, Salt03, Salt04, Salt05, and Salt08. Each of these stations monitor various parameters like Salinity(sal), Primary Water Level (pwl), Air Temperature (atp), Water Temperature (wtp), Wind Speed (wsd), Wind Gusts (wgt), Wind Direction (wdr), Barometric Pressure (bpr), pH (ph), Dissolved Oxygen (do), Saturation (sat), Water Depth (dth), Monthly Mean High Water (mmhw), Monthly Mean Tide Level (mmtl), Monthly Mean Sea Level (mmsl), Monthly Mean Low Water (mmlw), Monthly Mean Lower Low Water (mmllw), Monthly Great Diurnal Range (mgt), Monthly Mean Tide Range (mtn), etc.

Figure 3.1 shows the layout of Nueces bay and the location of the monitoring stations in the bay.
Figure 3.1: Nueces Bay monitoring stations [DNR 2007]

The data pertaining to each station is saved to the lighthouse Website at regular intervals of time with the station name and the time [DNR 2007].

The data values of each parameter are downloaded from the lighthouse Website. Figure 3.2 shows the data collected for station Salt01 for Water Depth parameter. These parameter values are given as inputs to the mathematical model to fill in the remaining values in the Bay. If the data is not present in the Website database; then the value at that particular instance will be ‘NA’ value (Not Available). These 'NA' values are interpreted to be the value contained in ERROR_VALUE variable by the program. The error value can be set to the required value by changing an entry in “constants.h” file. The tool saves the downloaded data as a text file with the file name as station name.
3.2 Math Model

The mathematical model decides how the values surrounding a station are calculated. For testing purpose, the tool uses linear interpolation method for finding the values in between the stations in the bay. A more complex math model can be used for the purpose [Sierra 2004]. Linear interpolation is a simple interpolation technique to find a value at a point, given two values. For any given point $X$ in the bay, the values at the two nearest stations are used to find the value at $X$. The percentage of the stations distance from the point $X$ multiplied by the value at the nearest stations gives the value at $X$.

$$X = X_1 \cdot \frac{d}{L} + (X_2) \cdot (1-\frac{d}{L})$$  \hspace{1cm} (3.2)

Where $X$, $X_1$, $X_2$ are the values

- $d$ is the distance from point $P$ to first nearest station
- $L$ is the distance of station $A$ to station $B$

Using formula 3.2, the value at point $P$ ($X$) can be found providing the values at $P_1$ ($X_1$) and $P_2$ ($X_2$) respectively.
3.3 Display

The data value at a particular time instance is read from each of the station files and fed to the mathematical module. The mathematical module fills the remaining values in the bay. The obtained values are used to color the bay. The colors are chosen from the color pattern chosen by the user.

During the animation, the data from each station file is read at time $t_0$ and fed to the mathematical module. The values obtained from mathematical module are used to color the bay. This process of reading values and obtaining the values at the surrounding and using these to color continues. This kind of displaying gives pictures at every frame. This makes up the animation. When the reading process reaches the last time slot, it is re-initialized to the beginning, so that the animation runs continuously.

![Control Flow diagram]

**Figure 3.3:** Control Flow diagram

The animation tool provides flexibility to change the setting on the fly without the need to recompile the project. These features include:

- Configuration File
- Control setting
- Information display
- Moving light source
- Screen capturing
- Rotating the Scene

3.3.1 Configuration File:

The tool is equipped with a configuration file, “test.config” to keep track of the latest successful setting made. During the start of the tool, the configuration file is read and loads the previous run settings into its variables. If this configuration file is missing, a new file with the default configuration is created. Figure 3.4 depicts the configuration file.

![Figure 3.4: test.config snapshot](image)
Once a setting is made and is successful, it is written to the configuration file with the date and time these settings are made.

### 3.3.2 Control setting:

The setting button is used to set or alter the existing settings of the tool. A new window called “setting” pops up with controls to set series, date range, color settings, glyph grid size, glyphs color setting and image capture. The glyphs color setting button is active when both the glyph direction and magnitude has a series to display. Figure 3.5 depicts the setting window.

![Setting window](image)

**Figure 3.5**: Setting panel

The changes made in the settings window only apply when the "set" button is pressed. After successfully applying the settings, the settings window disappears. See appendix for more information on how to make changes in the settings window.

The animation tool can animate a minimum of one series per frame and a maximum of four series per frame. The tool uses colors, glyphs and Z display as three different displaying techniques to present the data. Glyphs are vectors with direction and magnitude. To use glyphs both the direction and magnitude quantities have to be set to some parameter. Z display adds a depth field to the animation image making it 3D. The Z display will need a color series in parallel. The user is free to select any combination of the display techniques (color, glyphs and Z) depending on the number of series being selected. Figure 3.6 illustrates the selection feature.
Figure 3.6: Settings panel

User can select a series from the list of series in a drop-down box. These series list are created from “series.txt” file. The manual has complete description about how to add or remove a series from the list. Figure 3.7 illustrates the series selection feature.

Figure 3.7: Series selection from drop-down menu

3.3.3 Information display:

The animation window displays various information on the screen which include time stamp of the current frame, animation duration and legend information. A slider on top of the window helps to skip some time stamps and select the required date and time stamps. The animation slider time interval shrinks or expands based on the start and end dates of the current animation.

A VCR interface attached to the tool helps users pause, play, and increase or decrease the animation speed. During the pause mode, a message stating “PAUSE” will
be displayed on the screen. Figure 3.8 illustrates the VCR interface on the animation window.

![Figure 3.8: VCR interface](image)

**Animation duration:**

The start and the end dates of the animation are displayed on the left hand side of the animation window. This information helps the user pick the dates he/she is interested in. Figure 3.9 illustrates the animation duration display on the animation window.

![Figure 3.9: Animation duration](image)

The animation window displays what’s being displayed and how it is being displayed. A pictorial view of how the series is displayed with the series name adjacent to it is shown on the screen. The pictorial view is unique for each kind of display.

**Legend Information:**

The pictorial view for color series is a band of colors with the minimum and maximum value on top of the color band. The color band helps users to know the color used to represent a series value. A tick is marked from the minimum value to the
maximum value. Small ticks are marked every 5 units while bigger ticks are drawn every 10 units.

To the right hand side of the color band is the name of the series which is being displayed using these band of colors. Figure 3.10 shows a snapshot of Salinity series selected for color visualization.

![Salinity Color Band]

**Figure 3.10:** Series information display

The minimum and maximum values differ from series to series. These values are taken from a data file called “series_range.txt”. See appendix for more information.

The pictorial view for glyphs information is a vertical bar and next to it, is the name of the series used for glyph magnitude. The direction is indicated by an arrow head pointing in upward direction followed by the name of the series. The color of the glyphs magnitude and direction indicator will be the same color used for actual indication. Figure 3.11 demonstrates the glyphs information indicator where glyphs magnitude represents wind speed series and glyphs direction represents Wind Direction series.

![Glyph Information Display]

**Figure 3.11:** Glyph information display
The Z component information consists of a two headed arrow with bars on each side of the arrow. The series name using this feature is displayed next to the arrows.

During the animation, only selected features with the series which represent them are displayed in the information area. Figure 3.12 illustrates the feature with Salinity selected for color and Water Depth selected for Z.

![Figure 3.12: Color and Z info display](image)

### 3.3.4 Moving the Light source:

The light source can be moved to the desired location within the window using the mouse. To initiate the light moving, key in ‘M’ key and move the mouse to the desired location and by pressing any of the mouse buttons saves it to the new location. This feature helps in visualizing the deformations and bumps in the animation. Figure 3.13 illustrates this feature.
When displaying multiple attributes at one time using the depth value, it is necessary to use lighting for the user to gather information about the shape of the attribute. However, lighting will also change the color of the main attribute. Lighting is turned on and off with the “L” key. The land will not be visible when the light is turned off.

3.3.5 Screen Capturing:

The tool provides a feature of capturing screenshots and saving them dynamically. The captured screenshots are labeled as “imageX.jpg” where X stands for a number from 000000001 to 999999999. Zeros are appended before the number to sort the images as they are created.

Figure 3.13: Moving light source using mouse
3.3.6 Rotating the Scene:

The entire scene can be tilted or rotated by using the mouse left and right buttons. To rotate the scene in X and Z axis, use mouse left button and for rotating in Y and Z axis, use mouse right button. Any slight rotation of the scene, removes the land from the scene as the land will overlap the bay blocking some part of the scene.
4. RESULTS

First time the tool is run on the machine, it creates a folder named "images" to store the captured images. Figure 4.1 shows the image folder creation.

![Image folder creation](image1.jpg)

**Figure 4.1:** Image folder creation

Similarly a series when selected for the first time on the local machine a folder with the shorthand name of the series is created, to save all the data files pertaining to the series for each station.

![Series folder creation](image2.jpg)

**Figure 4.2:** Series folder creation

Not all stations have data at all the intervals. Data downloads for these times will have a “NA” (not available) entry in the data file. To indicate the missing data at the
stations, a yellow square is drawn on the respective station. Figure 4.3 depicts the missing data indication.

![Figure 4.3: Missing data indication](image)

The missing data indicator uses the value contained in “ERROR_VALUE” variable substituting the existing “NA” value record in the data file. The ERROR_VALUE can be changed by changing the entry in “constants.h” file.

**4.1. Color visualization:**

A single series can be visualized using color. The color value at the location represents the series value at the respective point. Series selection for color visualization can be made in the setting panel. A dropdown-box lists all the available series for the bay. The required series has to be selected and the date and time period needs to be set. Figure 4.4 illustrates the series selection for color visualization.
Figure 4.4: Color Series selection drop-down box

The animation of Nueces bay for Salinity series form April 26 2006 to July 31 2008 is illustrated in figure 4.5

Figure 4.5: Salinity visualizing using color

The color scheme can be changed without changing any of the existing settings giving a different coloring effect to the same set of values. The tool also provides a
feature to change only the color for the same value or change the color to a different value.

Figure 4.6 illustrates color visualization with Salinity set as color series with different color scheme.

**Figure 4.6:** Salinity visualization using color with different color scheme

Water Temperature series visualized using color for April 26 2006 to July 31 2008 duration is illustrated in Figure 4.7.
Figure 4.7: Water Temperature series visualization using color

The yellow squares at the stations indicate missing data at that particular time. These missing values are interpreted to be an error value.

Air Temperature visualized using color over the period April 26 2006 to July 31 2008 is illustrated in figure 4.8.
4.2 Glyphs Visualization:

Glyphs visualization requires two series, one for direction and one for magnitude of the glyph. The direction series should have units in degrees from north. For the Nueces bay, the only series which has direction is Wind Direction. Hence only the Wind Direction is listed on the list of series to be picked for the glyph direction.

Figure 4.9 illustrates the glyphs selection for Water Temperature and Wind Direction series from April 26 2006 to July 31 2008 time period.

Figure 4.9: Glyph selection drop-down box.
The number of glyphs on the scene can be altered in both x and y direction independently. Figure 4.10 illustrates the glyphs selection for Temperature and Wind Direction selected for glyph magnitude and glyph direction respectively.

![Glyph visualization with Water Temperature and Wind Direction](image)

**Figure 4.10:** Glyph visualization with Water Temperature and Wind Direction

Figure 4.11 illustrates glyphs with Water Temperature and Wind Direction selected for glyph magnitude and glyph direction respectively with reduced glyphs grid size to 10x10.
Figure 4.11: Glyph visualization with Water Temperature and Wind Direction grid size (10x10)

4.3 Color and Glyphs Visualization:

Using color and glyphs visualization, users can visualize three series at a time. Figure 4.12 illustrates animation scene with series; Salinity selected for color, Water Temperature for glyph magnitude and Wind Direction for glyph direction.
Figure 4.12: Color and Glyphs visualization with Salinity selected for color, Water Temperature for glyph magnitude and Wind Direction for glyph direction

4.4 Color and Z visualization:

Using color and Z depth, two series can be visualized at a time. The Z series plugged in creates a 3D view which will be visible with the lighting turned on. The lighting highlights the areas which have higher value that the rest of the bay. Figure 4.13 illustrates the color and Z visualization with Salinity chosen for color and water depth chosen for Z.
Figure 4.13: Color and Z visualization with Salinity chosen for color and water depth chosen for Z.

The animation scene can be rotated/tilted along any of the given two axis at a time. The rotation shows how high or shallow a region on the bay is from the rest. The rotation can be achieved by using the mouse button and moving it. The left mouse button rotates in Y and Z axis while the right mouse button rotates in X and Z axis. Figure 4.14 illustrates the scene rotated about X and Z axis.
Figure 4.14: Color and Z visualization with Salinity chosen for color and water depth chosen for Z and scene rotated on x and z axis

The color, glyphs and Z add more details into the animation scene and each having a series to display will create animation scene with four series displayed in each frame.

Figure 4.15 illustrates the animation with Salinity series selected for color, water depth series selected for Z, Water Temperature for glyph’s direction and Wind Direction for glyph’s direction.
Figure 4.15: Color, Glyph’s and Z visualization with Salinity series selected for color, water depth series selected for Z, Water Temperature for glyph direction and Wind Direction for glyph direction.

Turning the lights off removes the high lights on the land and on the bay making land look like a green plane. The land will be visible only when there is no rotation about any axis. Figure 4.16 illustrates the animation with light turn off.
Frame rate is the number of frames displayed per second. The top right hand corner of the animation window displays the frame rate of the current animation. The animation tool calculates the value at each point within the bay using linear interpolation and then displays it. This is a continuous process. Due to this the frame rate will be lower for the animation scene which has Z display selected.

In the case of glyphs, the number of glyphs displayed [glyphs grid size] is inversely proportional to the frame rate.

4.5 Animation Capture:

The tool provides a flexible feature of capturing the animation to an image file (jpeg). The tool provides two ways of capturing the animation.

**Figure 4.16:** Color, Glyph’s and Z visualization with Salinity series selected for color, water depth series selected for Z, Water Temperature for glyph direction and Wind Direction for glyph direction and lighting turned off.
- Single Screenshot
- Continuous Screenshot

4.5.1 Single Screenshot:

A single screenshot of the animation window will be captured and saved to the images folder with ascending file names. A double click of the left mouse button does the single screenshot capture.

4.5.2 Continuous Screenshot:

All the frames generated and displayed get saved into image files. To enable this feature click “setting” button on the animation window this opens the settings panel. A checkbox on the settings panel which reads “Capture each frame” needs to be checked. Figure 4.17 illustrates enabling the continuous screenshot capturing feature.

![Settings window panel with capture each frame set](image)

**Figure 4.17:** Settings window panel with capture each frame set

To disable this feature, uncheck the checkbox in the settings panel. The animation speed will go down when the screen shot capturing is taking place.
5. FUTURE WORK

The Scientific data visualization project will be a continuous ongoing research project that will expand and evolve over time. The visualizations created will provide users with an enhanced way of looking at various details of data at a given instance and find the relation between the various data displayed over time. The software tool presents data in a manner simple enough for the users to understand and interpret the relation between different parameters (series).

Future developments of the project include making a visualization model to perform future predictions of the bay’s reaction to an ever-changing environment, by incorporating neural networks for predictions; develop different mathematical models to interpolate data between the stations, which can be used for visualizing data for any bay/inlet. Future study could be done to see if it is possible to let the interpolation and extrapolation of the math modeling be computed within graphics hardware using shaders.

The future work would provide researchers an enhanced way of looking at data that is crucial to better understanding our environment. This would also give a new way to present data in a manner that is simplistic enough for the layman to understand, at the same time detailed enough for a researcher to draw new hypotheses.
BIBLIOGRAPHY AND REFERENCES


[Jessica 2005] Jessica, M. D. Visualization of Environmental Data in the Nueces Bay. Texas A & M University Corpus Christi


MANUAL

1. Files Needed

The layout of the bay with the shoreline and bathymetry (depth of the ocean) data has to be present in the file named “Overlay_Rev.txt” file. For all the points falling in the bay, the value of the elevation must be zero and for the remaining elevations the value is the elevation at that particular point. The file needs to be saved in the format of a grid (rows and columns). The number of columns and rows of the grid should match with the value contained in “constants.h” file.

All the series names that are of interest or the series which have values are to be listed in the file named “series.txt”. The tool will list out only the series that are present in this file for data visualization and data collection. The format of the file content is as follows.

Series Name (Short hand form of series). Figure 1.1 depicts the list of series available at Nueces bay.

<table>
<thead>
<tr>
<th>Series Name (Short hand form of series)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Water Level (pwl)</td>
</tr>
<tr>
<td>Backup Water Level (bwl)</td>
</tr>
<tr>
<td>Harmonic Predicted Water Level (harmw)</td>
</tr>
<tr>
<td>Storm Surge (surge)</td>
</tr>
<tr>
<td>Water Level Std Dev (sig)</td>
</tr>
<tr>
<td>Water Level Outliers (out)</td>
</tr>
<tr>
<td>Stage Height (sth)</td>
</tr>
<tr>
<td>Air Temperature (atp)</td>
</tr>
<tr>
<td>Water Temperature (wtp)</td>
</tr>
<tr>
<td>Wind Speed (wsd)</td>
</tr>
<tr>
<td>Wind Gusts (wgt)</td>
</tr>
<tr>
<td>Barometric Pressure (bpr)</td>
</tr>
<tr>
<td>Cumulative Rain Fall (crf)</td>
</tr>
<tr>
<td>Redundant Wind Speed (wsd2)</td>
</tr>
<tr>
<td>Redundant Wind Gusts (wgt2)</td>
</tr>
<tr>
<td>Redundant Wind Direction (wdr2)</td>
</tr>
<tr>
<td>Significant Wave Height (swh)</td>
</tr>
<tr>
<td>Peak Wave Period (pwp)</td>
</tr>
<tr>
<td>RDI Significant Wave Height (rswh)</td>
</tr>
<tr>
<td>RDI Peak Wave Period (rpwp)</td>
</tr>
<tr>
<td>RDI Water Depth (rdth)</td>
</tr>
<tr>
<td>RDI Wave Direction (wvdr)</td>
</tr>
<tr>
<td>RDI Maximum Wave Height (mxwh)</td>
</tr>
<tr>
<td>RDI Mean Wave Period (mnwp)</td>
</tr>
<tr>
<td>Pressure (prs)</td>
</tr>
</tbody>
</table>

Figure 1.1: Series Listing file
Each series has its minimum and maximum values. These values can be used to find the average value and in accordance to this value coloring will be done. For this purpose, a file named as “series_range.txt” has to be created with the range values in it. The file structure is as follows.

SeriesName  Min Max StandardDeviation 5*SD. Figure 1.2 depicts the range of each series available at Nueces Bay

<table>
<thead>
<tr>
<th>Series</th>
<th>Min</th>
<th>Max</th>
<th>StandardDeviation</th>
<th>5*SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>sal</td>
<td>0</td>
<td>50.1</td>
<td>12.023</td>
<td>60.1187</td>
</tr>
<tr>
<td>spcon</td>
<td>0</td>
<td>73.12</td>
<td>18.025</td>
<td>90.126</td>
</tr>
<tr>
<td>ph</td>
<td>0</td>
<td>10.23</td>
<td>0.284</td>
<td>1.4217</td>
</tr>
<tr>
<td>do</td>
<td>0</td>
<td>18.01</td>
<td>2.4602</td>
<td>12.301</td>
</tr>
<tr>
<td>sat</td>
<td>0</td>
<td>199.6</td>
<td>26.585</td>
<td>132.925</td>
</tr>
<tr>
<td>dth</td>
<td>-5.22</td>
<td>9.9</td>
<td>0.527</td>
<td>2.636</td>
</tr>
</tbody>
</table>

Figure 1.2: Series Range file

If a series is not listed in the series_range file, its values are assumed to be default. The order of series listed in the series.txt and series_range.txt file need not be the same.

The tool will find the exact match and then read associated with the field. Colors used by the tool are a set of predefined colors in the format of RGB color component. A set of these colors form a color scheme. The tool uses theses color scheme for coloring the display. Some of these color schemes are the work of Cynthia Brewer, Mark Harrower, and The Pennsylvania State University [Brewer 2002]. The user can customize or create a color scheme and can even save it for later use. Figure 1.3 depicts a format of the color scheme file and its content.
2. Changing Settings

The tool provides different features to explore the data. Once the data is fed to the tool, it starts displaying them in one of the three different ways. This depends on the number of series that are to be displayed at a given instance. For displaying only one series at a given instance, 2D display should be used. If the user needs to display two
series at an instance, then the user can switch to 2D with the Z display. The Z display is height added to the 2D display. The user can make a choice on which series is to be used for 2D and which series for the Z display. For displaying three series, the user can switch to glyphs (a directional arrow) along with 2D. For displaying four series, the user has to make use of 3D and glyphs. For each of the feature, the user can select a desired color for displaying. Figure 2 shows the setting panel window.

![Setting Window](image)

**Figure 2:** Setting Window

### 2.1 Series Selection:

The tool provides a list of series for the user to pick one form them. This list of series comes from “series.txt” file. An entry made into the series file shows up on the widget automatically. All the series are sorted alphabetically before they are displayed. Figure 2.1 shows a closer look at the selection of a series.

![Series selection drop-down box](image)

**Figure 2.1:** Series selection drop-down box
2.2 Date Selection:

The tool has a date selection widget, which lets the user set the beginning and ending date for the animation. The date has a format of month day year. A shorthand notation of month is used. The maximum end date can be is the current system date. Figure 2.2 shows a closer look at the date selection on the settings panel.

![Date Selection](image)

**Figure 2.2:** Date Selection

2.3 Time Intervals:

A time interval drop down box lets the user select the time gap between each data gathering. The maximum gap can be 24 hrs and the minimum is ½ hr. By default ½ hr will be selected and the user is free to set the interval to any of the value in the list. Figure 2.3 shows a closer look at the time interval selection on the settings panel.

![Time Interval Selection](image)

**Figure 2.3:** Time Interval selection for data gathering
2.4 Glyphs Grid Size:

The tool provides the flexibility to resize the grid size of glyphs. Two separate dropdown boxes allow the user to resize the number of rows and columns for the grid. The maximum allowable number of rows or columns is 100 and the minimum is 10. During the display if the glyphs are crowded then by adjusting the size of the grid to a lower number this problem can be resolved. Figure 2.4 illustrates the glyphs grid size altering feature available on settings panel with a closer look.

![Figure 2.4: Glyphs grid size selection](image)

2.5 Z Factor:

This feature is useful when 3D display is used for the animation. The depth of the display can be controlled by this value. At times, for certain series selected, the calculated height value might be less in this circumstance, and it is difficult to find the fluctuation in the height. In order to increase the fluctuation, the height value is multiplied with the Z factor value. A text box takes the integer values in the range of 0 through 100. As the user types in the value, validations are applied. Figure 2.5 depicts the Z Factor textbox present on the settings panel with closer look on Z factor.
Figure 2.5: Z Factor setting

2.6 Capture Each Frame:

The tool provides the feature to capture all the frames as they are generated and save them as JPEG files. To facilitate this feature, a check box is provided which when checked, a folder with the current date and time is created within images folder to hold all these images. The numbering of the images starts from 000000001 to 999999999. Figure 2.6 shows the check box which when selected captures the entire animation.

Figure 2.6: Capture each frame checkbox on settings panel.

2.7 Color Setting

The tool provides a set of color schemes to select one from. Color palettes or color schemes constitute a band of colors predefined with the intensities. Some of these color schemes were developed by Cynthia Brewer, Mark Harrower [Brewer 2002]. Color Scheme (color palette) defines the red, green and blue color component and associates this to a particular value.
The user can pick any one of these colors for particular parameter visualization. The drop down box lists the entire available color scheme. Once a color scheme is selected, all the colors in the color palette are displayed. Figure 2.7 shows a snapshot of the color palette selector.

![Color Scheme Selector](image1)

**Figure 2.7:** Color Palette selection panel

After the color palette is loaded, the user is free to customize these colors and save them with a different name for later use. The customizing includes adding a color at a particular value, changing the colors, moving the color to different value, deleting a color at a particular value. Figure 2.8 depicts the color scheme editor panel.

![Color Scheme editor](image2)

**Figure 2.8:** Color Scheme editor panel.

A small square is marked at places where there is a color associated with it. These values can be selected by either clicking on the square or entering the value in the center textbox. Once the required value is selected, the user is free to change the color at the respective place. Figure 2.9 shows a snapshot of color scheme editor panel after selecting color at value 29.
A new color can be added at a particular value by selecting the value and clicking the add color button. This opens a new window of color picking. The default color selected by this window will be the color present at the value. Figure 2.10 illustrates adding of a color at value 38.
The selected colors can be moved to another value by dragging it to a new value and releasing. Figure 2.11 illustrates the moving of color at value 29 to 44.

Selected color can be deleted by pressing the delete button. Figure 2.12 illustrates the deletion of color at value 44.
Figure 2.12: Color Scheme editor with deletion of color at value 44.
Compiling and Running the project

$qmake -project

[This command will create a .pro file containing all the files that are required for the compilation and executing]

$qmake

[This command will create a MakeFile based on the .pro file created by the previous command]

$make

[This command will compile all the dependant files and create an executable]

$. /PROJECT_NAME

[PROJECT_NAME will be the name of the director currently in]

$make clean

[This command cleans all the previous object files, core files and backup file(ending in ~)]

Trouble Shooting

During the compilation process, if you receive a long list of errors; this might be due to wrong version of Qt being used.

To trouble shoot this, at the command prompt,

$ which qmake

[This reveals the qmake used by default. if the above command displays "/usr/bin/qmake", then the Qt 4.1 might not be installed or paths might not be set properly.]

Checking for Qt4.1

$ find /usr -name Qt-4.1*
[If Qt 4.1 is installed, it shows the installation path. Point the Path system variable to this path.]

**Adding the Qt path to system PATH variable.**

```bash
$ vi .bash_profile
```

[This opens the user profile file. Edit the line containing PATH=:]

Edit the below line

```bash
PATH=:SHOME/bin:$PATH
```

The final PATH should look something similar to the below

```bash
PATH=/usr/local/Trolltech/Qt-4.1.1/bin:$HOME/bin:$PATH
```

save and exit

For the changes to make effect, logout and then login again.

After logging-in, check if the PATH variable got updated.

```bash
$ printenv PATH
```

[This command prints the content of the variable PATH]

Edit the qmake.conf file to add the OpenGL libraries.

```bash
$ find /usr -name qmake.conf
```

Look for the qmake.conf contained in `/usr/local/Trolltech/Qt-4.1.1/mkspecs/linux-g++/`

Make a backup copy of the original config file.

```bash
$ cd /usr/local/Trolltech/Qt-4.1.1/mkspecs/linux-g++
$ cp qmake.conf qmake_backup.conf
```

Now edit the qmake.conf file to include OpenGL libraries.

```bash
$ cd /usr/local/Trolltech/Qt-4.1.1/mkspecs/linux-g++
$ vi qmake.conf
```

Look for
QMAKE_INCDIR =

and edit it to

QMAKE_INCDIR += -I/usr/include -I/usr/local/Trolltech/Qt-4.1.1/include -I/usr/local/Trolltech/Qt-4.1.1/include/QtOpenGL

Look for

QMAKE_LIBS =

and edit it to

QMAKE_LIBS += -L/usr/local/Trolltech/Qt-4.1.1/lib -lQtOpenGL -lQtCore -lglut

save and exit

[Now logout and login for changes to take effect. After logging-in first clean all project binary files]

$ make clean

Go through the compilation and running project process