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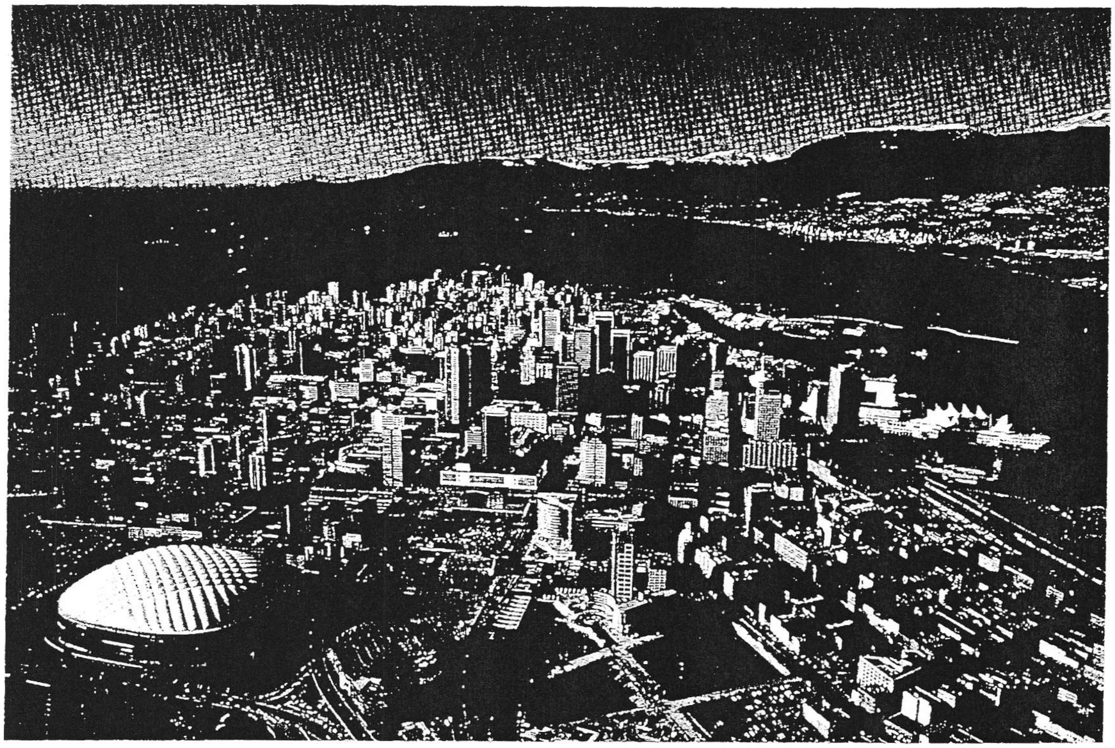

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THE CREATION OF A SYSTEM FOR 3D SATELLITE AND TERRAIN IMAGERY*

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ABSTRACT

Satellite and terrain imagery is an important tool that has numerous applications. It can be used for environmental, commercial and educational purposes. Although satellite and other terrain images are useful, they are two-dimensional representations of three-dimensional objects and areas. This paper will describe the design and implementation of a 3D imaging system that will use a Semantic Database system as the main engine for the storage and retrieval of substantive data including Landsat TM satellite imagery, Digital Aerial Photography and standard U.S.G.S. Digital Elevation Model (DEM) data. The system will include the databases, an easy to use graphical user interface and a main core to handle requests from users and the database. As this is a relatively new area of work and research at the HPDRC, we are in the beginning phases of the project. This system is being designed to be sophisticated enough for the professional while being simple enough for the casual user.

1.0 INTRODUCTION

The availability and use of remotely sensed data has increased dramatically in the past several years. It is used not only by geologists and environmentalists, but by industries such as urban planners, oil companies and other commercial enterprises. The amount and varied types of information that can be extracted from remotely sensed data is vast and complicated. Although this is advantageous in terms of the availability of needed information, the extraction of this information it is often difficult and time consuming.

The spatial data sets that are currently available come from numerous sources and are in many different formats. This can make it difficult when a user requires information that is found in two or more different data sets. Data sets that are in different formats often require separate programs to view and extract the data. Problems are further increased when the amount of data is considered. Spatial data sets are inherently extremely large. Storage and retrieval of spatial data, even when the desired information is of a uniform format, is often cumbersome at best.

Due to the immense value of spatial data, it is inescapable that researchers and other potential users need a simpler and more convenient method of accessing this data. More specifically, integrating different types of data into one, easy to use and comprehensive package is needed to fully take advantage of its value. Further, by integrating specific types of data sets such as DEM and Landsat data, it is possible to render 3D terrain images that are more visually appealing and useful for data classification and enhancement.

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To reach this objective, we have employed the semantic/object oriented modeling approach to the design and implementation of a spatial database and combined it with a multimedia interface and capabilities to produce TerraFly. TerraFly is a multimedia spatial database and its user interface which acts as an interactive vehicle for flying over the earth and exploring spatial data of interest. Its enhancements include an integration of spatial, textual and multimedia data along with the capability to store and display both 2D and 3D images.

The rest of the paper is organized as follows. Section 2 describes TerraFly's components and the types of data used in TerraFly. Section 3 provides an overview of the semantic/object oriented modeling approach. Section 4 describes the implementation of TerraFly. Section 5 summarizes our conclusions.

2.0 TERRAFLY'S COMPONENTS

2.1 BASIC COMPONENTS

The development of a multimedia spatial database and its user interface requires careful selection of its components. The types of components selected have a major effect on the development and performance of the system. In addition, a tight integration of its major components, the database, software and hardware, is of the utmost importance (Alvarez, 1998). The components of TerraFly are as follows:

- Database: A multimedia spatial database which stores textual, spatial and multimedia data was used. The database was implemented using the Sem-ODB Management System, developed at HPDRC.
- Software: Macromedia Director 6 was used as the Multimedia Authoring Tool for the introductory sequence of the user interface. The programming languages C++ and Lingo were also used to construct the user interface.
- Hardware: A Windows based system which includes a video card, sound card, microphone, speakers, digital camera, scanner and other components.

2.2 MULTIMEDIA SPATIAL DATABASES

2.2.1 Landsat Database

This database stores textual, multimedia and spatial data (i.e., Landsat TM data deployed by NASA's Goddard Space Flight Center). The textual data consists of information about the Landsat data such as date, satellite, path, row, sensor number, latitude and longitude. The multimedia data includes sound data, voice data and pictures. The spatial data is stored by dividing it into 160 x 312 byte tiles and then compressing these tiles using g-zip algorithms prior to being stored in the database.

2.2.2 Aerial Photography Database

As with the Landsat Database, the aerial photography database stores textual, multimedia and spatial data (i.e., Digital Aerial Photography, DOQ, acquired from the USGS). The textual data consists of information regarding the DOQ data such as date, rows, columns, latitude and longitude. The multimedia data includes sound data, voice data and topography data.

2.2.3 3D Landsat Database

This database contains ground elevation data which is primarily acquired from Digital Elevation Model (DEM) data from the USGS (or related contour data if DEM data at the desired resolution is not available). DEMs are topographic map data stored as 16-bit gray-scale raster image files that contain ground elevation data. 7.5-minute DEM data (i.e., 30-meter resolution) is primarily used and correspond to the USGS 7.5-minute topographic quadrangle map series. It is from elevation data, combined with that from the

Landsat database, that 3D images are rendered and placed in the database for TerraFly. We are currently in the process of integrating this database into the TerraFly system.

2.2.4 GNIS and Address Range Database

This database primarily stores textual data which is later integrated and displayed with the spatial data by TerraFly. It contains Geographic Names Information System (GNIS) data obtained from the USGS. GNIS data contains information such as the names of physical and cultural features (e.g., hospitals, parks, airports, schools, etc.), feature type, state, county, latitude and longitude. The database also stores information obtained from the US Census Bureau regarding street names, address ranges, latitude and longitude of street segments and the names and set of geographic coordinates which correspond to boundaries of specific areas such as cities and townships.

3.0 SEMANTIC/OBJECT ORIENTED APPROACH TO DATABASE DESIGN

The databases used for TerraFly hold a great deal of non-conventional data (i.e., spatial data, images, etc.). As a result of this, TerraFly's multimedia spatial databases are created using the semantic/object oriented approach. By using this approach, the varied types of data can be stored in the same database in a logical manner. Most DBMS are unable to do this and must store different types of data in separate databases (Waugh, 1987). This is inefficient and can be difficult to use and understand (Rishe, 1994).

To circumvent these and other problems (see Rishe, 1992) (Rishe, 1994), the HPDRC has developed a high performance Semantic/Object Oriented Database Management System (Sem-ODB) under NASA sponsorship. The Sem-ODB was used to implement all of the databases used by TerraFly. This approach has been found to be more efficient and easier to understand than traditional relational approaches for the storage of large amounts of data (Rishe, 1998a).

Semantic database models are designed in such a way that the logic underlying the database is easy to understand. One reason for this is that the representation of the data is invisible to the user, who discerns the objects in the database as real world entities. This more intuitive approach to database design is able to capture not only the data contained in the database, but the meaning behind the data.

When looking at the organization of the data in the database, it is easy to see the logic behind the design. Information is represented by a set of categories, relations and attributes. Categories are sets of objects that are grouped together based upon common properties. Objects are information regarding real world entities that we wish to store in the database. These objects can be tangible, such as a person, or intangible, such as an event. Relations are logical associations between categories and attributes are relations between a category and a data type. It is through the relations that the meaning behind the data is captured (Rishe, 1992).

An additional benefit of the use of the semantic database model is that it addresses the issue of storage size. Spatial data and 3D imagery is inherently large and relational models require a great deal of overhead in terms of space allocation due to its use of tables and indices. The use of a semantic database eliminate the need for tables and indices, thus reducing the space allocation required (Rishe, 1998b).

4.0 TERRAFLY IMPLEMENTATION

The TerraFly system is an interactive, fly-over vehicle for viewing spatial data and related information. The data currently used by TerraFly primarily covers the area corresponding to the Miami-Dade County region of Florida. However, TerraFly is designed to be portable and independent from the data sets it uses. Thus, it can easily be used with data sets from other areas of the world. To access the data in the databases, TerraFly employs an easy to use graphical user interface (GUI). The GUI consists of two major parts, an introductory multimedia sequence created using Macromedia Director 6 and the main fly-over interface developed using Visual C++.

4.1 INTRODUCTORY SEQUENCE

As was stated previously, the introduction was created using Macromedia Director 6, a Multimedia Authoring Tool. The sequence begins by flying over the Earth's surface to the Miami-Dade County region in South Florida. An aerial view of the flight continues until the user arrives at the Florida International University (FIU) University Park campus. This is where the High Performance Database Research Center (HPDRC), associated with the School of Computer Science, is located. After this brief introduction, users can elect to link to external Internet Web pages to peruse more detailed information about the HPDRC, FIU, and our sponsor, NASA. Alternately, the user may elect to review documentation about Thematic Mapper (TM) data from the Landsat 5 series of satellites or take a flight by launching the interactive flying application (Alvarez, 1998).

4.2 INTERACTIVE, FLY-OVER INTERFACE

When a user elects to take a flight, the main fly-over interface is launched. This is a separate GUI, written in C++, which displays both spatial data and information regarding that data. It includes a main flying window in which spatial data is displayed, a series of text-boxes which display information related to the data, sensor band controls, RGB intensity controls and other functions. Figure 1 shows the fly-over interface.

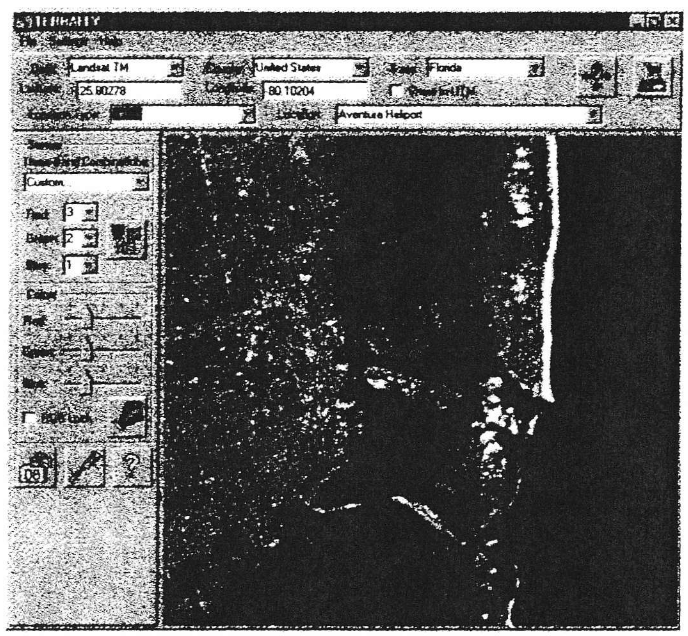

Figure 1. Fly-Over Interface

4.2.1 Features And Options

The options and features currently available for the data sets are found below:

- *Main Flight Window*: The main flight window displays the spatial data image and allows users to fly over the available images through use of the mouse. The direction of flight is determined by the position of the mouse in the window.
- *Data*: This is a textbox from which the user may select the desired data set that is currently available. There are three spatial data sets that may be chosen: Landsat, Aerial Photography and 3D Landsat (currently being implemented).
- *Country* and *State*: From these two textboxes, the user can choose the country and state of interest. Because TerraFly is independent of the data, the countries and states are available can vary. Currently, however, only data for Florida in available.
- *Latitude* and *Longitude*: These two textboxes display the latitude and longitude of the center point of the current image. These continuously change while the user is flying is engaged in flying.
- *Go-To button* ***: Pressing this button will open a new window from which the user can specify the latitude and longitude to which he or she wishes to travel. This currently loads the desired location directly. Future versions, however, will allow the user to fly using the auto-pilot to the desired location.
- *Location Type*: This is a combination textbox/drop-down menu[**] from which the type of place a person is interested in finding can be chosen. The choice made in this menu is intricately tied to the choices available in *Location* (see below) in that the type of location that is chosen here determines the available choices found in *Location*.
- *Location*: This is a combination textbox/drop-down menu[**] from which the actual place a person is interested in finding can be chosen. This currently loads the desired location directly. Future versions, however, will allow the user to fly using the auto-pilot to the desired location.
- *Sensor Band Controls*: These controls allow the user to manipulate the sensor band combinations of Landsat TM data to view false color images. This provides greater flexibility and availability of information. For the Landsat data, users are able to select from a list of 7 possible sensors for each color band. When a band combination is selected, the set of bands is retrieved from the database, the associated false color image is computed and the resulting image is displayed in the main flying window. TerraFly provides 2 ways of doing this:
  - *Pre-defined Three-Band Combinations*: This is a drop-down menu which provides predefined sensor combinations. These are commonly used combinations that provide interesting data for basic users as well as short-cuts for the more scientific users.
  - *Advanced Three-Band Combinations*: This is a series of three drop down menus (*Red*, *Green* and *Blue*) in which the more scientific user may choose any desired three-band combination they wish to study or analyze. A query button, ***, is pressed once the user has finished choosing the desired band combination.
- *RGB Intensity Control*: These three sliding selectors allow the user to increase or decrease the intensity of the color bands. After a selection is made, its query button, ***, is pressed to process the request.

[**] The combination textbox/drop-down menu functions as follows. The user may scroll through the list and make a choice as one would with any drop-down menu. Alternately, however, the user may begin to type the desired entry. As each letter is typed, the entry closest to the typed entry will be highlighted. For example, typing the letters 'fi' will highlight the first entry which starts with those letters. This provides a quick and easy way to find a desired entry when the list in the drop-down menu is extensive.

The options and features currently being implemented are found below:

- *Street Name*: This is being implemented as a combination textbox/drop-down menu** from which a street a person is interested in finding can be chosen. The choice made in this menu is intricately tied to the choices available in *Address Range* (see below) in that the street that is chosen here determines the available choices found in *Address Range*.
- *Address Range*: This is being implemented as a combination textbox/drop-down menu** from which the address range on a specified street (see *Street Name*) a person is interested in finding can be chosen. Once implemented, the user will have the option of either loading the desired location directly or flying to it using the auto-pilot.
- *Auto-Pilot*: This option will allow users to fly to a specific area from the one they are currently at automatically. At this time, in order to fly, the user must point the mouse in the desire direction and continuously hold down the left mouse button.
- *Elevation*: This is being implemented as a textbox that will display the ground elevation of the center point of the current image. As with the *Latitude* and *Longitude*, as the user flies from one area to another, any changes in elevation will automatically be reflected in this textbox.
- *Zoom In/Zoom Out*: Zooming capabilities are currently being added to TerraFly. This will allow users to view the data at varying resolutions.
- *Speech Synthesis*: Speech capabilities such as audio descriptions of the data on the screen are under development.

4.2.2 Display Process and Analysis

The TerraFly system involves both static and dynamic display processes. During the static display process, three blocks of data, one for each band, are retrieved from the database. The data is then decompressed and the false color composite image is created. Once the process is complete, the data is in BIP format and displayed on the screen.

The dynamic display process is more involved. Additional computation and data access is required, and high efficiency algorithms are run to contend with the immense amount of data the system requires to produce smooth flight (Alvarez, 1998). Originally, a circular buffer was implemented in an attempt to produce smooth and seamless flight. Unfortunately, this solution was not sufficient.

Instead, a two buffer system has been implemented. The key to this system is found in the construction of the two buffers. Each buffer can be visualized as a series of smaller buffers combined to create a large buffer, where the smaller buffers are each the size of one tile. The size of each of the larger buffers are two tile sizes wider and two tile sizes longer than the display size. There are two buffer pointers, which we'll call bp1 and bp2. Bp1 will always point to the buffer which contains the display window. Bp2 will always point to the buffer to which new data is loaded.

The buffer pointed to by bp1 is filled as described above. Within this buffer, there is a predetermined boundary. When the user is flying, the predetermined boundary will eventually be crossed by the display window. When this occurs, new data must be retrieved from the database. The process is then as follows:

1. Which tiles need to be retrieved are determined by the direction of the flight.
2. The tiles are retrieved and loaded into the correct position in the second buffer (i.e., bp2).
3. The pointers from bp1 are copied to pb2 in the appropriate position relative to the new tiles. The pointers to the tiles closest to the new tiles are copied first (the tiles at the opposite end of bp1 are no longer needed and will not be copied, keeping the sizes of the two buffers the same).
4. The buffer pointers are then swapped. Thus, bp1 is now pointing to what was bp2. The window is still in the same relative position in terms of the tiles, but is shifted in terms of its placement in the buffer.

4.3 APPLICATION DATA

As was stated previously, TerraFly combines spatial data with information about that data. Related semantic, spatial and multimedia data are all stored in the same database. This subsection briefly discusses the data that is used by TerraFly.

The spatial data used in TerraFly (see Section 2.2) is primarily stored in a raster format (Muffin, 1987). Corresponding textual data, such as latitude, longitude, path, and so forth, is stored along with this data. The actual data currently used includes:

- One quad of Landsat TM data. This data covers an area of 2850 square miles of the Miami-Dade county region. It has a resolution of 30 meters.
- 72 quads of Digital Aerial Photography (DOQ). This data covers and area of 1400 square miles of the Miami-Dade county region. It has a resolution of 1 meter and dates from 1994 and 1995. Since each quad is 150 MB, there are a total of 12 GB of data. Due to this large amount of data, JPG compression was used to compress the data (see below).
- GNIS and US Census data. This is primarily textual data that covers the Miami-Dade county region. It includes information such as the names of physical and cultural features found in the county, feature types, street names, address ranges and area boundaries, as well as corresponding latitude and longitude coordinates.

The data used in the 3D Landsat database will also cover the Miami-Dade county region and is currently under development. Due to the processing needed to render the 3D images, rendering of the data is performed prior to being put into the database. In short, standard DEM or contour data file is combined with corresponding satellite or aerial photography data through the use of raytracing, depth-buffer or similar algorithms. The resulting images must then be mosaiced, cut into tiles and then placed into the database.

Although sound and image data has already been loaded into the databases, additional multimedia data and techniques are currently under development. We are in the investigating the possibility of integrating a text-to-speech engine with TerraFly and adding voice/text data files that contain further descriptions of the spatial data on the screen.

As was mentioned above, this system uses a large amount of spatial data (over 12 GB). This is in addition to the textual and multimedia data used by the system. Two methods, JPG and g-zip, were used to compress the spatial data prior to it being put in the database. The g-zip programs, based on the Lempel-Ziv algorithm (Ziv, 1997), were altered slightly to allow the program to write the output to memory instead of to a file, thus allowing memory to memory compression. In doing so, this allows us to be able to store the spatial data compressed and decompress this data on-the-fly as needed (Alvarez, 1998).

5.0 Conclusions

Although TerraFly is still under development, it has already shown that by integrating various types of remotely sensed data, it is an important and valuable tool. This system facilitates the storage, manipulation and analysis of spatial and digital data. Further, it provides an interesting and informative vehicle by which casual users can learn about the data available, while still being flexible and detailed enough for scientists.

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