A System for Geographical and Spatial Data Exploration on the Internet

Celyn S. L. Chan, Tony K. Y. Chan and Edmond C. Prakash

School of Computer Engineering
Nanyang Technological University
Nanyang Avenue
Singapore-639798

`ASprakash@ntu.edu.sg`

Abstract

Developing a detailed 3D conceptual spatial data model and incorporating it for visualization, is a promising method of Spatial Data Exploration for a variety of applications especially in the display, analysis and interpretation of useful and timely meteorological and geographical information. Spatial Data Exploration is quite complex due to the following factors:

    i)   the spatial nature of data that is being processed

    ii)   time-variant nature of data.

In this paper we present a new system that can use VR techniques for spatial data exploration. We also present the implementation and some results that validate our architecture.

1. Introduction

1.1 Introduction to spatial technologies

Spatial technologies include GIS, GPS, remote-sensing and scientific visualisation[1,2,3]. The similarity between these technologies is that they all produce and/or manipulate data with spatial coordinates. Ultimately, this data can be any features on the earth's surface or any surface. This includes roads, streams, buildings, county boundaries, power lines, sewer lines, recorded locations of eagle nests, past forest fires, future reservoirs - to name just a few examples. It also includes photos or images of the earth's surface, as well as three-dimensional representation of phenomena such as geologic structures within the earth's surface or ice-flow within a glacier.

As the web gradually developed into a 2D-graphical tool through graphical HTML browsers, there is also need for sharing and display of 3D web-content. No standards were implemented initially. Research groups mushroomed and worked independently on different standards. The web

then was 'dynamic'. This phrase is repeated a lot when it comes to developing tools that use whatever the latest technology is on the Web. An unfortunate side effect is that by the time a research group has built something on the tool, the tool may be superseded by something newer. This is precisely what has been happening with 3D graphics and programming models for the Web[4,5,6].

1.2 Contributions

The following work has been done as part of this research:

    i)   The areas explored in this project include visualization, mapping, 3D object modeling and layering of different types of information.

    ii)   The aim is to design and build a prototype system, similar to a GIS where several types of data are integrated into one form that is easy for the user to navigate. An additional requirement is portability, as this system is designed for distribution through the Internet.

    iii)   Implementation is done in VRML, and the functionality of this modeling language is exploited to the fullest. The usage of this tool is designed to be as intuitive as possible that the average Internet user can navigate through this easily and effectively.

2. The spatial data exploration system

The overall architecture of the spatial data exploration system is shown in Fig. 1. This project has lots of potential applications. Through this tool, an user can interactively view natural phenomenon, learn more about a country from the layered information, navigate to related URLs linked to some layers, and take a virtual tour or flight across the world to far off areas from the comfort of his home, through the Internet. That shows the system can have input data as static, archived, dynamic or of real-time nature.

The design described is portable and has been implemented and tested on Netscape and Internet Explorer on Unix (SGI) workstations and Windows PCs. A simple Earth model has been done with different types of information layered onto it; further developments can

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append more types of information, achieve automatic update of the information for interactive visualization from online repositories using scripting and database techniques.

The simulated 3D world is akin to viewing the globe in space. The Earth starts off as a faraway viewpoint in front of the user(see Fig. 2).

Figure 1. Architecture of the spatial data exploration system.
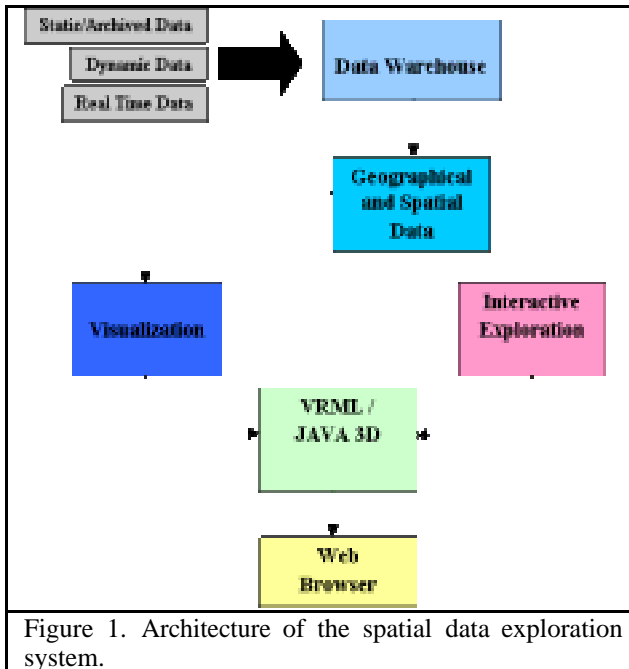
2.1 Development of the spherical earth

2.1.1 Important considerations

The layer of cloud must be surrounding the Earth. As clouds normally do not cover the whole Earth, there are some parts where the layer of cloud must show the Earth. Transparency of the cloud layer must thus be achieved. The background is then preferably set to 'transparent'. For images that support transparency, only the GIF format could be used in VRML. To allow the projection of a layer of clouds 'over' the Earth, another geometric Sphere shape is used. However, this sphere must be of a larger radius than the Earth's sphere and have the same coordinate system and center of origin. The shape then must be set to have a transparency value of 1.0(fully transparent) from its material field node. Animating the layer of clouds may be possible. This is because the texture used to map the larger transparent sphere can be changed dynamically as the world is running. Cloud movement can then be shown.
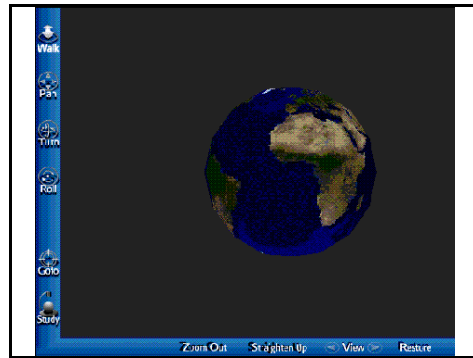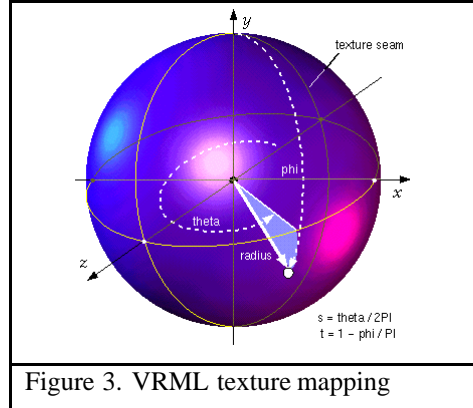

Figure 2. Earth on sphere

Figure 3. VRML texture mapping

2.1.2 Cloud imagery collection

The cloud images are taken by satellites that orbit in sync with the earth. Such satellites that are always hovering above the same region are known as *geo-stationary satellites*. Due to the fact that the satellites simply capture the image of the Earth as viewed from their locations in outer space, all the satellite images contains terrain within them also. MSS then processes the satellite images received in two ways. First they are printed on special paper and properly archived, and the raw data is sent for processing using supercomputers. Scaled down versions of the large original images are then posted on the MSS homepage for dissemination. Satellite pictures of the cloud conditions used in this project are obtained through the Meteorological Service Singapore (MSS) official homepage at http://www.gov.sg/metsin. Images are posted onto the homepage on an hourly basis. There are 24 images per day.

The satellite pictures obtained by the MSS are from the Geo-stationary Meteorological Satellite (GMS) belonging to the Japan Meteorological Agency (JMA). Since the satellite is orbiting together with the earth at the same speed around the sun, the region over where the cloud images is taken stays constant. Below is an example of a satellite image taken from the Geo-stationary Meteorological Satellite (GMS) that belongs to Japan Meteorology Agency (JMA), taken on August 29, 18.30 UTC (2.30am on August 30, Singapore time). During image processing, each image is duplicated two times and

individually scaled, resulting in a total of three images with three different resolutions. They are: the Full Infra-Red, Asean Infra-Red, and the Sing Infra-Red, known as FIR, AIR and SIR respectively. SIR images are currently not available from the MSS. A FIR image, after processing is shown below.
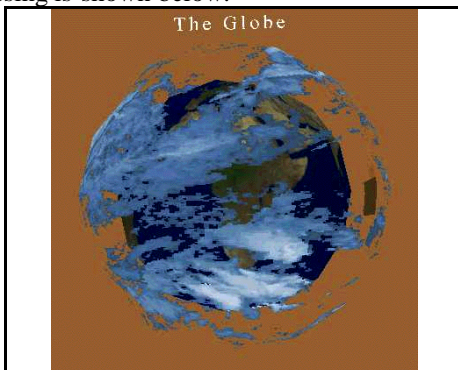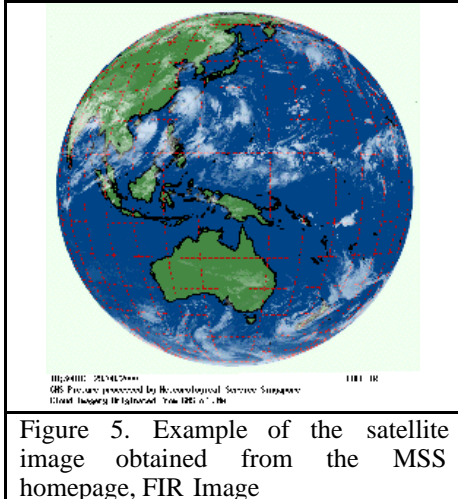

Figure 4. Earth with the clouds layer

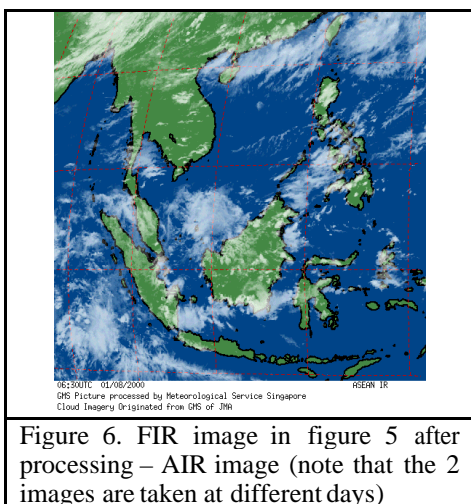Figure 5. Example of the satellite image obtained from the MSS homepage, FIR Image

Figure 6. FIR image in figure 5 after processing – AIR image (note that the 2 images are taken at different days)
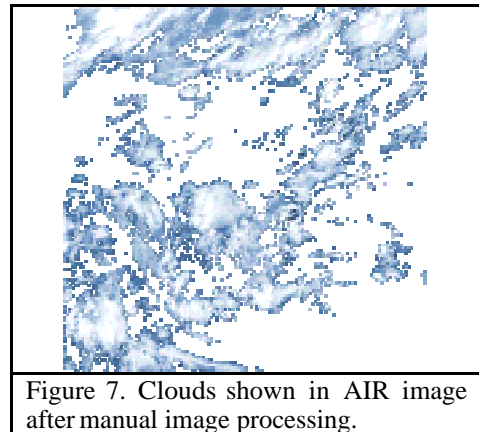

Figure 7. Clouds shown in AIR image after manual image processing.

2.1.3 Image processing to extract only the clouds

Most of satellite images obtained contain some terrain information, and not only the cloud conditions alone. So, the images must be processed again using image processing application software to remove the unwanted terrain part with only the cloud imagery left for use. This is done using Paint Shop Pro version 6.0, distributed as a 30-day trial version. Only clouds are shown after manual image processing is done to remove the terrain and gridlines information. Colors that belong to terrain (green, brown, black) and gridlines are shown as red. Coastlines of land were shown as black. These individual unwanted pixels were 'erased' off the image using the 'Color Replacer' tool and replaces with a color that is nearest to the average colors surrounding it. This had to be done by the author painstakingly and each image takes about half an hour to process on average.

2.1.4 Animating the cloud layer

Simulation of a layer of clouds over the globe of the earth enables the visualization of the movement of and change in cloud cover for the regions of terrain. In VRML, it is possible to change the textures that are mapped onto the sphere layer covering the globe using the Script node together with TimeSensor node. The TimeSensor node creates a clock that can be used to control animation. The frequency of the changing of the image textures mapped onto the sphere is determined and the TimeSensor node is used to implement a virtual clock for the world created. This clock is used to control the changing of cloud layer images. If this change is done fast enough, a moving cloud animation can be perceived. Transparency of the cloud layer and Terrain segments on the globe are partly visible.

The current animation consists of 24 images, each taken one hour apart. A script written in JavaScript is included in a VRML Script node. The images are labeled consecutively using numbers. The script's function is to list the correct the image to be sent to the Sphere node for texture mapping. On the other hand, the TimeSensor node

coordinates and controls the time to invoke the Script node. Events are the main 'messengers conveying the new image to be displayed to the Cloud Sphere shape(see Fig. 8).
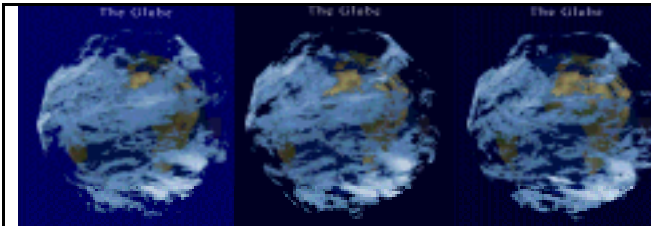

Figure 8. Changing of cloud layer

2.2 Layering individual country maps

The globe constructed consists of many countries and continents. Additional information is available for some countries, mainly those in Southeast Asia. To access this additional information, the user has to click on a translucent layer that is 'covered' over the country on the globe.

These countries have specially defined viewpoints in the viewpoint list to facilitate easier navigation by the user. Using these viewpoints to arrive at these countries, the user can then click on the layers, and be transported to another VRML world, where the country's map is shown in higher resolution(see Fig. 9, 10 and 11).

2.2.1 How layering is done

Each layer is linked to another VRML world through Anchor nodes. The Anchor grouping node retrieves the content of a URL when the user activates (e.g., clicks) some geometry contained within the Anchor node's children. If the URL points to a valid VRML file, that world replaces the previous world of which the Anchor node is a part. If non-VRML data is retrieved, such as a web link, the browser shall determine how to handle that data; typically, it will be passed to an appropriate non-VRML browser. Links to related web-sites can be included to the Anchor node besides VRML files.

Layers of sphere connect to other worlds through the Anchor node. They are included in the main VRML Globe file through Inline nodes. This way of structuring the software development separates the different kind of data layered (clouds, satellite image of hot spots, maps) and makes for easier debugging. Each layer leads to more VRML world files. This structure is inclined towards a tree-structure nesting methodology where each layer is an individual layer integrated together in the Globe view (root node).

To implement a transparent layer over the globe with additional available data, world tiling is used. The surface of the sphere is split into sections, which spans over several countries. A section over the Earth that has further data available will be created as an Anchor to link to the data, and traced over the corresponding land region.
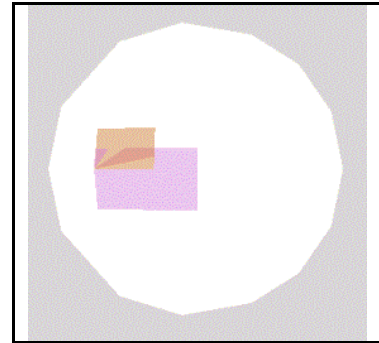

Figure 9 .Layers over a sphere

2.2.2 Singapore layer

The Singapore map is the main focus of the VRML world linked to the Singapore layer. As the original map in detail is quite large, and loading time is a major concern, 3 versions of the map is created of different sizes, and different level of details. As more detailed files are added to a scene, the browser takes longer to build and load the scene, and it seems less interactive also.

One way to control the world detail is to note that shapes farther away in the world from the user need not be drawn in such details and to load a less detailed world scene if the user is 'far away'. The **LOD** node, short-form for *Level of Detail*, allows for different versions of the same scene to be enclosed in a LOD group. Ranges are then provided to allow the browser to switch between the VRML scenes as the user navigates the world.

Other kinds of information displaying on the Singapore map include weather symbols, text labels, links to major Singapore sites pertaining to government and weather. Several viewpoints are used to provide a tour of the map for the user to click on.

Figure 10. Singapore layer view

2.2.3 Indonesia Layer

Fire is traditionally used by the shifting cultivators and small-scale farmers as a tool for clearing land in the Southeast Asian region. In recent years, fire has increasingly been used by large plantations to clear land and for conversion of forest into plantations and agricultural land. In time of drought, the fires may go out of control, resulting in severe damage to the forest and the

surrounding region. These forest fires occur in Indonesia every year during the hot and dry season from April to July. Such events often bring about large plumes of smoke that affect areas kilometers away. The most serious fires occur regularly in the regions of Kalimantan and Sumatra. An ability to detect the specific regions of fire enable meteorologists and firefighters to make timely prediction of haze magnitude and area(see Fig. 11, 12, 13 and 14).

The Indonesia map is loaded in one version. There are no other versions as the file size is considerably reasonable to load. Anchor nodes are added to access other world where satellite imagery of hot spots in Sumatra and Kalimantan are added. Several viewpoints are added for easier user navigation. One of the viewpoints is shown below. The NOAA satellite takes the imagery and transmits the information to MSS. The images are also available from the MSS homepage. However, some image processing needs to be done to truncate the size and change the resolution to a suitable format for use in the VRML world. Further description of the both Kalimantan and Sumatra hotspots identification are presented below.

Whenever hotspots are detected from the AVHRR infrared channel 3 of the NOAA12/14 satellite, the hotspot map will show their approximate positions, as indicated by red dots. Grey shaded areas indicate regions of significant cloud. A hotspot is a satellite pixel that exhibits high temperatures. A large fire could cause a number of adjacent pixels to be identified as hotspots. Hence the number of fires could be less than the number of hotspots. The satellite identification and date/time of the satellite pass are given in the header at the top of the map.

Daylight pictures are composites from infrared and visible satellite imageries. Colors are added to help identify and highlight various features. Generally, smoke haze shows up in shades of yellow which may appear in streaks fanning out from a small source or as large fuzzy patches. "Hot spots" can be identified as red dots. As the imageries are taken from satellites, overlying clouds if present will invariably obscure areas with smoke haze and hot spots. Strong reflection of sunlight can also give rise to reddish shades over sea areas. These are *not related* to hot spots. Night time pictures are composites from infrared satellite imageries. They display only the hot spots (if present), but not the smoke haze.

Kalimantan: There are five viewpoints defined for the Kalimantan satellite image. Four of these five viewpoints together covered the entire view over the whole Kalimantan. A transparent image of Kalimantan hotspot map with the identified hotspots is hovering over the satellite image. This draping of the hotspot chart over satellite imagery can be used for analysis and correlation of the relation between smoke haze and hotspot regions.

Sumatra: There are seven viewpoints defined for the Sumatra satellite image. Five of the viewpoints together give an entire view over the whole Sumatra. Similar to the Kalimantan terrain hotspots visualization, a

transparent image of Sumatra hotspot map with the identified hotspots is draped over the satellite image.

Figure 11. Indonesia map with anchors to Sumatra and Kalimantan hot spots.
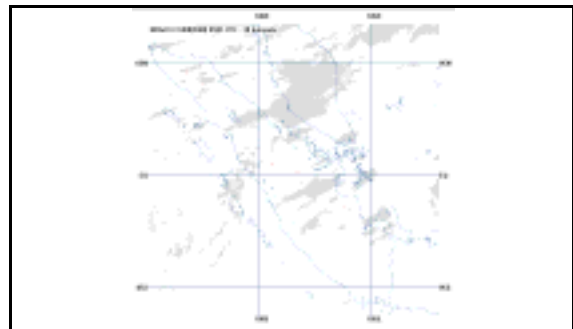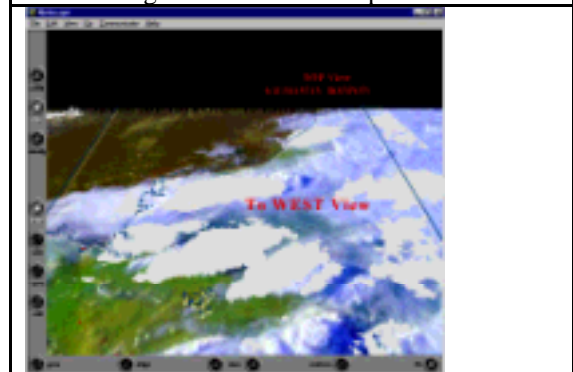

Figure 12. NOAA hotspot chart

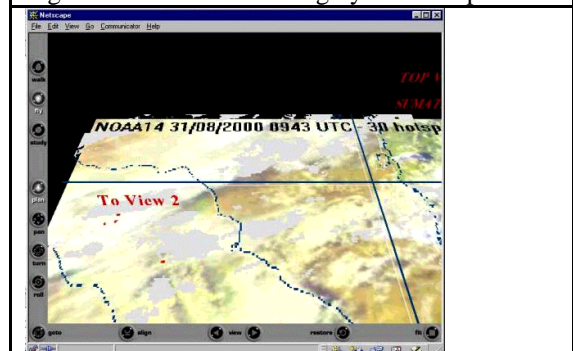Figure 13. Kalimantan imagery and viewpoints
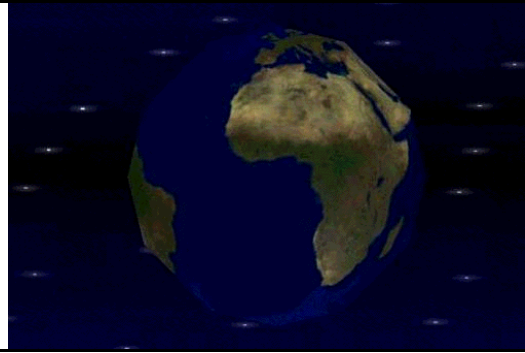
Figure 14. Sumatra imagery and viewpoints

Figure 15. Layers over a sphere

2.3 Animated Light – Daylight

Besides simulating the cloud layer, the environment lighting of the sky is also simulated. 24 hr a day. This can be done by varying the color and the brightness of the 'light' over time. By default, the VRML browser creates only a single light in a world. This is the headlight that is attached to the current viewpoint that moves as the viewer moves. The light is white and always points straight ahead into the world. The environment lighting effect can be achieved using another TimeSensor node and the ColorInterpolator node. The ColorInterpolator node uses a list of key fractional time and key colors in its **key** and **keyValue** fields. When driven by the fractional time output of the TimeSensor node, the ColorInterpolator node uses linear interpolation to compute intermediate colors values (RGB) used to light the environment (see Fig. 15).

2.4 Useful Links or URL's

In the world created, there are translucent layers whereby the user can click on to go to a specific nation's map. Built onto the maps are several Anchor nodes that provide more information about the items incorporated. The decision criteria for the types of links to be provided are based on several factors. They include:

- Usefulness of data to the general public as they are the targeted users.
- Amount of detail provided to the 'world' where information is to be supplied
- Extent of relativity between the linked information to the world in focus.

The main reason for using the Anchors to link to other details is because the world provided cannot include all kinds of information that is available for several reasons. It may be due to copyrights on the information base, or the inability of the browser to support such huge amount of details. Thus, these Anchor nodes link to web sites containing further data that the user may be interested in. For example, to find out more about the forest fire conditions, besides looking at the Hotspot chart draped over the satellite imagery, analysis results and recent updates are also provided by the Meteorological Service Singapore. This information can be obtained by the user navigating the current 'world' by linking the home-page address of MSS to the labels provided in the map (see Fig. 16).

In the Singapore map, links to the Singapore Tourism Board is provided for tourists that may be interested to come to Singapore, as well as the Singapore Changi Airport. The Online Singapore Street Directory Guide is another useful link if the user need a map of higher resolution and details that cannot be provided by the world. Some Anchor nodes are also children of Billboard nodes

2.5 Text inclusion

There are many examples of text inclusion in the worlds developed. Such inclusion is to reinforce the graphical aspects provided. Different kinds of users may perceive the same piece of graphical image differently. This usage of text is to minimize the wrong conceptions that may arise. The uses of text included for identification of places, direction and also to differentiate between places that are of strong resemblance. They can be provided as User Interfacing objects. Some of the text labels can also start animations (Anchor) as in the case of two animations showing Moon Phase about Earth, and the Earth's rotation (see Fig. 16).

Billboard Text nodes: The Billboard group node extends the basic grouping abilities of the Group node by creating a special purpose billboard coordinate system. The billboard coordinate system is automatically rotated a programmer-defined axis so that the shapes in the group, as a unit, always turn to face the viewer, even as the viewer moves around the group. Billboarding can be used for a wide variety of effects in the VRML world, like displaying signs for countries and help messages.

2.6 Selected viewpoints and animations

Viewpoints are points of interest that are specified by the author that the user steer to through the browser user-interface tool buttons or text labels. They are distributed throughout each VRML world files. Some of these combined to form a flyby of a world. If a user is lost inside any worlds, the list of viewpoints serves as a means for him/her to quickly get back on track.

For educational purposes, two animations demonstrating the orbit of the moon around Earth showing the Lunar phase and the revolution of the Earth that causes the seasons are included in the software. Through these animations, the user can see immediately how these natural phenomenon occur. Virtual tours or flybys are created out of the viewpoints to allow the user

a bird's eye view of some worlds created that may be too large to navigate properly. Significant points in the world are covered during such flybys.

3. Conclusion

We have shown that spatial data exploration on the web is feasible. From simple sphere texture mapping of the earth, we extend the system to support clouds, provide environmental hot spots, hierarchical links for navigation, sub-region selection, dynamic cloud selection, illumination and text information with hyperlinks. These techniques provide the users on the internet to do an exploration of data that is related to geographical and spatial information.
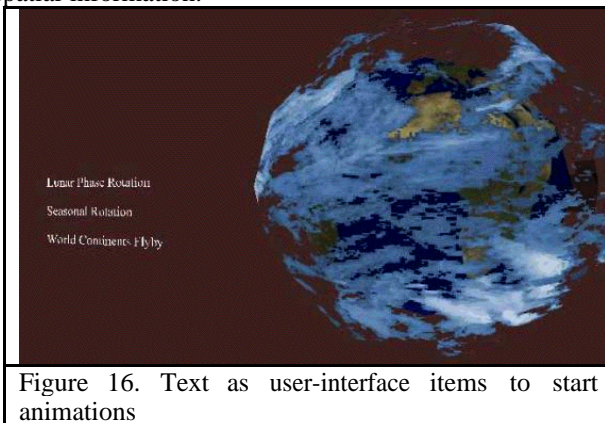

Figure 16. Text as user-interface items to start animations

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