Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 11 (18): 3247-3257, 2011
ISSN 1812-5654 / DOI: 10.3923/jas.2011.3247.3257

Online 3D Terrain Visualization: Implementation and Testing

C.M. Ruzinoor, A.R.M. Shariff, A.R. Mahmud and B. Pradhan
Institute of Advanced Technology, Universiti Putra Malaysia, 43400 Serdang, Malaysia

Abstract: Geographical Information Systems (GIS) and three dimensional (3D) World Wide Web (WWW) applications usage are on the rise. The demand for online 3D terrain visualization has increased not just for cartographers, geographers, geologists and psychologists but also popular among the ordinary people. The aim of study was to determine that how online 3D terrain visualization could be employed using the most appropriate GIS software by finding the applicable web server to launch the system. The Virtual Reality Markup Language (VRML) was used as the file format for visualizing 3D terrain in online environments. For that purpose, two experiments were conducted in these studies. First experiment involved the comparison of VRML output from four different GIS software in terms of terrain visualization quality (bad, acceptable, better) and data file size (VRML original, VRML compress and image). The technique of 3D terrain draped with satellite imageries was involved in these experiments. The Arc GIS 9.2 software was found to be the best GIS software which produced promising results with high quality of terrain visualization. Second experiment involved on finding the best web servers by comparing four selected web servers at different locations for launching the system online. The Spatial Research Group web server which is located close to the testing environment found to be the best. This is because it has the best value and fastest time for most of the tests being done. Therefore, these findings are useful in guiding the developers to choose the most suitable GIS software for developing online 3D terrain visualization. It is also could assists the developers to choose the applicable web server for the development of online 3D terrain visualization.

Key words: 3D terrain visualization, web server, GIS software, VRML, online, satellite image

INTRODUCTION

Recently, the new ways of visualizing terrain information especially in 3D environments are moving forward to web based system. This is due to the emergence of new generation of geo-browsers such as Google Earth, Microsoft Virtual Earth and NASA's World Wind (Sipes, 2007). Many people currently depend on these geo-browsers for their daily work and also for decision making purpose. For this reason, the number of internet users and its technology has also been increased dramatically. Terrain visualization is an important component of geo-browser application which makes the world visualized in 3D environments that's allow the users to see, explore and understand the spatial features of the Earth Surface (Patterson, 2001). Other than that, for representing and analyzing 3D world more enhanced and advanced tools is need as the number of applications is increased (Zlatanova *et al*., 2002). That is why the research on online 3D terrain visualization has drawn interests by many researchers. Many researchers utilized Virtual Reality Markup Language (VRML) as their file format for implementing online 3D terrain visualization (Basic and Nuantawee, 2004; Beard, 2006; Honjo and Lim, 2001; Huirong *et al*., 2009; Zhou *et al*., 2006). VRML is fundamentally a 3D interchange format which is designed for visualizing 3D objects in web based environments (Carey and Bell, 1997). It is also a tools which has been proven to be useful for reality modeling, producing 3D animations and interactive mapping (Basic and Nuantawee, 2004). This is the reason why VRML has used in this study for the output format. O'Hagan *et al*. (2008) reported Arc Scene software has capability on exporting their output into 3D with VRML/X3D format but the results of 3D models show a very large file. This is the reason why this study investigates on terrain visualization quality of the VRML files and file size (VRML and image) for terrain model developed from GIS software. Some of the research on reducing the size of terrain data by using compression technique has been conducted by Pradhan *et al*. (2006a, b, 2007a, b) for offline environments. Besides that, one of the demands for online 3D terrain visualization was real time capability of the system. By utilizing the VRML, the techniques such as level of details, tiles technique, progressive technique and selective visualization was

Corresponding Author: Abdul Rashid Mohamed Shariff, Institute of Advanced Technology, Universiti Putra Malaysia, 43400 Serdang, Malaysia Tel: +603-89467543 Fax: +603-89468470

introduced by researchers to achieve real-time visualization (Araya *et al*., 2002; Beard, 2006; Huirong *et al*., 2009; Zhu *et al*., 2003). Other than that, VRML format also can be used as an effective stimulus for landscape assessment (included terrain data) (Lim *et al*., 2006). In terms of terrain visualization, VRML is still viable for creation of terrain visualization (Martinez *et al*., 2010). This means that VRML still a valid environments for implementing 3D visualization especially for terrain visualization. Therefore, until now, many researches use VRML as their tools for 3D visualization due to its high performance language. However, there is still limited researches conducted to measure the capability of VRML in web based environment especially in different web servers. The 3D information like 3D terrain can be easily transferred through internet by using VRML (Honjo and Lim, 2001).

This study is categorized in Geographical Information Systems (GIS) and Remote Sensing (RS). Many researchers have utilized both technologies in many applications (Al-Mashreki *et al*., 2010; Al-Dakheel *et al*., 2009; Albaji *et al*., 2008; Reddy *et al*., 2008; El-Nahry and Khashaba, 2006; Dhaimat and Shawabkeh, 2006; Bolca *et al*., 2005). GIS can be defined as a set of tools or technology which is using for storing, collecting, retrieving and transforming spatial data (Moghaddam *et al*., 2007). Initially this study used Digital Elevation Models (DEM) for the terrain data. DEM is a digital representation of terrain topography of the earth surface and it is actually forming by several points defined in 3D Cartesian space (x, y, z) (Dinesh, 2008; Tagil and Jenness, 2008). This study also involved image draping technique over GIS layer (terrain) with attribute information using GIS Software (Limp, 2000). This technique was first introduced by Brodlie (1992) and being applied by many researchers for implementing online 3D terrain, visualization. For example, Ruzinoor *et al*. (2009a, b, 2008a, b, 2010a, b) have applied this technique for extensive study on online 3D terrain visualization. While, Gruen and Roditakis (2003) had modeled and visualize the Mount Everest using VRML format. They are using aerial image data and Digital Terrain Model overlaid together. Several visualization software such as Cosmoplayer, Virtual GIS 8.4, TerrainView, Skyline and Maya 2.5 had been tested to visualize the data. It was found that not all software could be used to visualize such a huge amount of data. For example Cosmoplayer cannot perform walk through of the data. Martinez *et al*. (2010) used orthophotograph overlaid with Digital Terrain Elevation Model (DTEM) to produce online 3D terrain visualization using VRML and graphic engine. Appleton *et al*. (2002) used image draping technique to overlay Landsat image with 3D representation of terrain Digital Elevation Model (DEM). Three selected software Landscape Explorer 2000, VirtualGIS v8.4 and 3D analyst has been used to perform the technique. The assessment of image drape software capabilities are made based on ease of data import, terrain surface, navigation, drape image quality, 3D objects and sky. These assessments were made based on the output from the software but not in VRML format. This is different from the study undertaken in this study, where the main aim of this study is to investigate the best GIS software on producing VRML outputs and the best web servers for implementing online 3D terrain visualization.

ONLINE 3D TERRAIN VISUALIZATION

This study involved two experiments which were conducted separately. The first experiment involves only one web server and the second experiment involves four different web servers. The details on how the experiments were conducted are explained in the next section. Both experiments involve 3D terrain visualization in online environment. The technique used for developing online 3D terrain visualization involved image draping technique and utilizing VRML for creating the file which can be rendered online by launching into the web servers. The data involved in this study was the contour data and satellite data of Universiti Putra Malaysia (UPM). The contour data was provided by the Department of Survey and Mapping Malaysia (JUPEM) and the satellite data was provided by Taman Pertanian Universiti UPM. Other than that, both of the experiments involved the VRML file compression. The Chisel software developed by Trapezium development LLC and additions by Michael N. Louka was used for this purpose (HRVC, 2008). The user needs to make sure that the file is not larger than 100 MB in order to be compressed by this software. This software can compress the file up to 80% from the original VRML file size. The basic model to implement the online system is shown in Fig. 1.

The method of online 3D terrain visualization started with identifying the areas that need to be visualized. In this stage, users need to identify the location of their data that they want to visualize. Next stage is preparing contour and imaging data from geographical indication means. At this stage, the users should already have the contour data and satellite image data for preparing the data according to the area of interest. Then the data is processed to produce data layers. In this stage, the contour data is converted into appropriate format of 3D terrain such as Digital Elevation Model (DEM) (grid) or

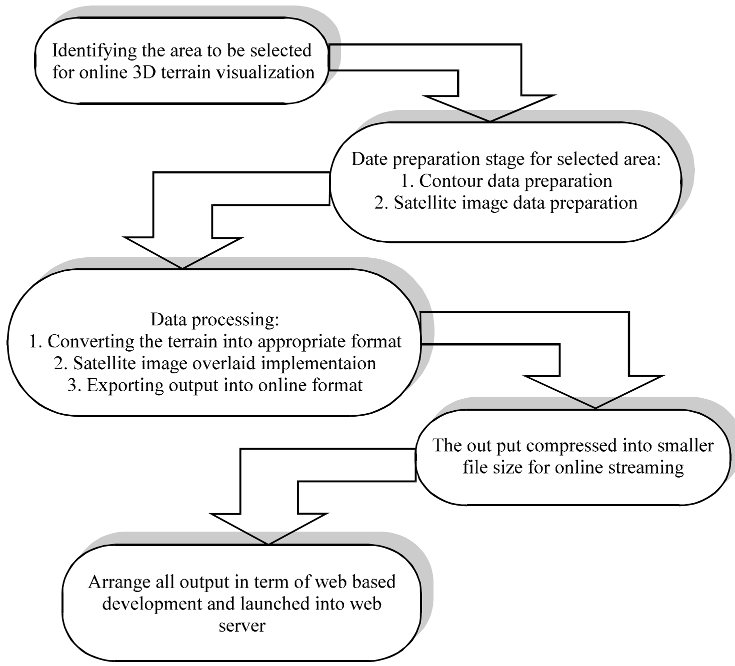

Fig. 1: Basic model of online 3D terrain visualization

Triangulated Irregular Network (TIN). This data is then overlaid with satellite image and exported into online format (such as VRML). Lastly, the data layers (VRML) are compressed and organized properly to be presented in a web environment. Based on these basic models, online 3D terrain visualization is performed for conducting the two experiments mentioned before.

Experiment 1: Comparison of different types of GIS software for online 3D terrain visualization: In this experiment, four selected GIS software were chosen which are R2V, ERDAS, Arc GIS 9.2 and ENVI. The reason of selecting of all these software is due to their popularity in GIS market. Most of the GIS users use the all these software in their work. The scope of the experiment is only based on 3D terrain draped with satellite imageries. In order to apply this technique, each of software has its own method but basically still followed the basic models that explained before. Two types of terrain format used in this study are DEM and TIN. This 3D terrain data was overlaid with high resolution satellite image (QUICKBIRD). The output of this data (VRML) was used for experiments. The elements of comparison are based on terrain visualization quality and file size data file size (VRML original, VRML compress and image). The software which has lower file size with high quality of terrain visualization is selected as the best software for implementing online 3D terrain visualization. For example Appleton *et al.* (2002) measured the image drape quality into two categories which is good and excellent. However, in this study, the quality of terrain visualization measured into three major categories which are better, acceptable and bad. Better means that the quality of visualization image is excellent. This includes all of the objects inside the visualization image can be recognized easily, no blurring image, could run on more than two VRML viewers and smooth terrain data. Acceptable means that the quality of visualization image is good where some of the objects inside the visualization image can be recognized, some blurring image and the terrain data is relatively smooth. Lastly, bad means that the quality of visualization image is bad where almost all objects inside the visualization image cannot be recognized, blurring image, and the terrain data not smooth.

Data preparation: The data used in this experiment consist of contour data and satellite image data of UPM. The interval between each contour line is 5 m. The projection used in this data was the Rectified Skew Orthomorphic (RSO) Peninsular Malaysia. The contour line of UPM was in a DXF file. The R2V software can easily read this data and convert it directly into DEM or grid. But for Arc GIS 9.2, this data needs to be converted into SHP files first before it can be read. R2V software is used to convert the DXF data into SHP files for further processing. The satellite imagery used in this experiment was the QUICKBIRD (0.6 m resolution). The projection used for this satellite image data is the same as contour line data, which is in RSO format. In order to fit with the contour line data, this satellite image data need to be clipped so that it covers the same area as the contour line data. But before it can be clipped, this data needs to be converted into Geo TIFF format. The Global Mapper software was used for this purpose. Then PCI Geomatica V 9.1 is used to clip the data into the same area as the contour line data. The coordinates for UPM are measured first from the contour line data and then this information was used in PCI Geomatica software for clipping the data. Finally, the data was saved in TIFF format.

Implementation on different GIS software: The first implementation started with R2V software. The data from the preparation stage was in 3D DEM grid format. This data was then draped with satellite images. Lastly, the data was exported into the VRML file. The process of draping image started with opening the 3D file in DEM format by using the pull down menu. The satellite image data was then opened in TIFF format. These satellite images are then draped over 3D DEM surface by using the Image Drape functions. The output of this process was the block of 3D terrain visualization. This output is then converted into a VRML file using the Export functions tools. This VRML data is now ready to be used in online 3D terrain visualization.

The second implementation continued with ERDAS software. The data is in SHP file format after it completing the data preparation stage. Using Arc GIS, this data was then converted into raster TIN (GRID format). To create the VRML file, first need to open the VirtualGIS Viewer. Then, the raster TIN file was opened as GRD format. The next step is by opening the satellite image (TIFF format) as Raster Layer. The Raster options will automatically check the Raster overlay. After that, the satellite images were draped automatically over the 3D terrain surface. The data is then converted into VRML file using the export functions tools. This VRML data is now ready to be use in online 3D terrain visualization.

The third implementation continued with Arc GIS 9.2 software. The processes began with opening the SHP file of the terrain data and then converted it into TIN format. Now the terrain data is in 3D format and can be viewed in 3D. At this stage, some of the 3D analyst functions can be performed to this data, such as shading the different heights with different colours. The next step was adding the satellite image (TIFF format) to the project. To overlaid the Terrain data (TIN) with satellite images, the properties of the satellite image layer were opened. The base heights were obtained from the TIN surface created earlier. Now the user can view the 3D terrain overlaid with satellite image on their screen. The data is then converted into VRML file using the Export Scene functions tools. This VRML data is now ready to be used in the online system.

The fourth implementation continued with ENVI software. The process begins by opening the satellite image and then continued with loading the RGB data from the available band list. This was done by selecting the topographic and then 3D SurfaceView. After that, the input bands were selected; either R or G or B and proceeded with 3D SurfaceView Input Parameters. Any DEM resolution can be chosen from 64 to 512. The Vertical Exaggeration was set to be 1.0 and lastly proceeded with loading the 3D SurfaceView. Now the user can view the 3D terrain draped with satellite image in their screen. The data is then converted into VRML file. This VRML data is now ready to be used in online system.

Results of experiment 1: The results from this experiment were obtained by comparing the quality of terrain visualization produced by the four different GIS software in terms of the VRML files. Four VRML file has been launched into Spatial Research Group Web server to make it available for public to give their comments about output of VRML data. Figure 2 a-d show the results from four experiments being conducted. The output of first experiment for R2V can be found at address: “http://spatial.upm.edu.my/webupm/r2v3d.wrl”. Figure 2a shows the image of this experiment. It shows that the quality of terrain visualization is bad. This is because almost all objects inside the visualization image cannot be recognized at all. It produced blurring image and also has distortions image almost everywhere inside the visualization image. The terrain data produced from this software is smooth but with unbelievable height where some of the height is not right. The good thing is that the terrain visualization was in solid block (3D) as compared to other VRML outputs from other GIS software which only produced pseudo 3D (2.5D view). In term of file size, the software produced highest of original VRML file which is 11,588 kb embed together with image compared to others GIS software. When it was compressed, the VRML file size reduced to 536 kb (Table 1). Therefore, based on these criteria, it is found that R2V software is not suitable for producing VRML file in online 3D terrain visualization.

The output of second experiment for ERDAS software can be accessed from the address: “http://spatial.upm.edu.my/webupm/erdas.wrl”. Figure 2b shows the result of the experiment. In this case, the quality of terrain visualization is also bad. This is because almost all objects inside the visualization image cannot be

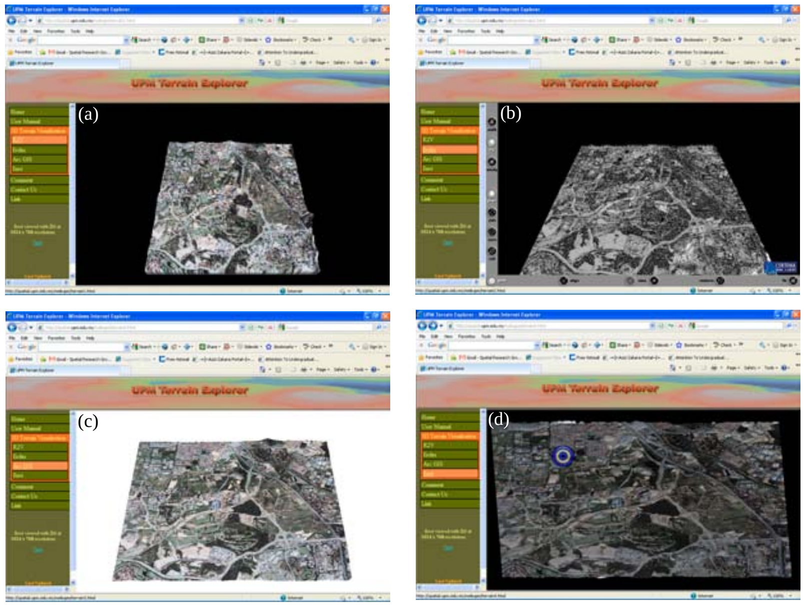

Fig. 2(a-d): Image of online 3D terrain visualization generated from 4. Image generated from, (a) R2V Software, (b) ERDAS Software, (c) Arc GIS 9.2 Software and (d) ENVI Software

Table 1: Comparison of different GIS software for online 3D terrain visualization

	GIS software			
Criteria	R2V	ERDAS	Arc GIS 9.2	ENVI
Original VRML file size	11,588 kb	4,703 kb	10,325 kb	11,150 kb
VRML file size after compress	536 kb	1,073 kb	648 kb	4,083 kb
Image file size	None	624 kb	488 kb	None
Terrain visualization quality	Bad	Bad	Better	Acceptable

recognized at all. It produced blurring image almost everywhere inside the visualization image and also the image is not coloured event the raster layers set as true Color. But if the raster layers set as pseudo color, the outputs are better inside the ERDAS software but when exported into VRML formats the images could not be exported. Only terrain data was exported into VRML file. The terrain data produced from this software also not smooth. In terms of file size, the software produced lowest of original VRML file which is 4,703 kb with 624 kb image file as compared to others GIS software. When it was compressed, only 26% of the file size was reduced to 1,073 kb. This value is higher compared to other VRML file produced from other GIS software (Table 1). Based on these criteria it was found that ERDAS software was not suitable for producing VRML file to be used in online 3D terrain visualization.

The output of third experiment for Arc GIS 9.2 can be accessed from the address: "http://spatial.upm.edu.my/webupm/arcgis3d.wrl". Figure 2c shows the result of the experiment. It shows that the quality of terrain visualization is better. This is because almost all objects inside the visualization image can be recognized easily. Most of the region in the study area can be seen clearly. When the camera zooms closely to the objects, the objects still can be identified by the users and not blur. The terrain data produced from this software is smooth showing the correct height information. In terms of file size, the software produced the original VRML file with 10,325 kb and the image file size was 488 kb (Table 1). When it was compressed, the VRML file size reduced to 648 kb. Based on these criteria, it is quite obvious that Arc GIS 9.2 software is the most suitable software for producing VRML file to be used in online 3D terrain visualization. Even after compression, the VRML file produced from R2V software is still less than 1 Mb with excellent quality of terrain visualization. This file size is the lowest when it is compared with VRML file produced from ERDAS and ENVI. With smaller VRML file size, the time taken for rendering the scene in online environment is lower and faster. The interaction with the terrain also will be easier and faster.

The output of fourth experiment for ENVI can be accessed from the address: "http://spatial.upm.edu.my/webupm/envi3d.wrl". Figure 2d shows the result of the experiment. It shows that the quality of terrain visualization is acceptable. This is because some of the objects inside the visualization image can be recognized and some cannot be recognized. Other than that, the visualization image is very difficult to interpret. For example the road inside the image displayed as a long bumper and some areas within the image which are supposed to be flat are seen as covered by hilly areas. The image also blurred in some area. The terrain data produced from this software is relatively smooth where some of the area showing as hilly area even it's not hilly. In terms of file size, the software produced the original VRML file with 11,150 kb and embedded together with the image. This is not good because this will slow the rendering time. When it was compressed, the VRML file size reduced to 4,083 kb. This is the biggest file size as compared to VRML compressed file produced from other GIS software (Table 1). Based on all these criteria, ENVI software was not suitable software for producing VRML file to be used in online 3D terrain visualization. This is because the VRML file after compression is still larger than 1 Mb. Therefore, the time taken for rendering the scene in online environment is longer and slower. Table 1 shows the comparison of different output produced from four GIS software based on the quality of terrain visualization and file size (VRML and image) before and after compression.

Furthermore, the experiments on comparing different types of VRML viewers for viewing the outputs from each of the GIS software output was performed. The reason is that there are many free VRML viewers available in the market. For these experiments, five VRML viewers Cortona, Flux Player, Cosmo World, Demotride and Bit Management are being chosen for testing. Each of VRML viewers has its own advantage and disadvantages. The aim of these experiments was only to investigate which VRML viewers could run the output obtained from GIS software. The criteria for the best VRML viewer were the viewer which could run the outputs from all GIS software. Based on the testing being done, it was found that not all VRML outputs from GIS software could be run in VRML viewers. Table 2 shows the result of the testing. For example the VRML outputs produced by ERDAS only could be run on Cortona but the others VRML viewer could not produce any outputs from the VRML data. The best VRML viewer among five was Cortona. This viewer produced outputs from all GIS software R2V, Arc GIS, ERDAS and also ENVI. This result could help the users on finding the best VRML viewer which could run the outputs from any GIS software.

In summary online 3D terrain visualization can be deployed by using any GIS software. The reason is that almost all GIS software test in this study has a capability on exporting their output into VRML file. But not all GIS will produce high quality of terrain visualization and also smaller VRML file size. The file size is smaller because some of the software produced separate file of VRML and

Table 2: Comparison of different VRML viewer for viewing the output of online 3D terrain visualization

	GIS software			
VRML viewer	R2V	ERDAS	Arc GIS 9.2	ENVI
Cortona	Run	Run	Run	Run
Bit management	Run	No ouput	Run	Run
Flux player	Run	No ouput	Run	No ouput
Cosmo player	Run	No ouput	No ouput	No ouput
Demotride	No ouput	No ouput	No ouput	No ouput

image file like Arc GIS and ERDAS. Some software produced embeds file where both of VRML file and image embed together like R2V and ENVI software. The lower file size make the rendering time faster in online environment. In this experiment, from all four GIS software tested, the Arc GIS 9.2 was found to be the best because it produced better quality of terrain visualization as compared to others. The terrain is also smooth and most of the objects in the 3D surface can be recognized easily. This software also produces separate file (VRML and image) with smaller file size. The output from Arc GIS 9.2 will be used in the next experiment. It also can be concluded that not all VRML file produced from GIS software can be run in any VRML viewer and not all VRML viewer can run the VRML output from any GIS software.

Experiment 2: Comparison of different types of web servers for online 3D terrain visualization: The most important criteria for implementing online 3D terrain visualization were the web servers used. The most important source of information and services in this new era was web servers. Most of the web servers are expected to serve millions of transactions request per day. Due to this, it will affect on its performance for different levels of loading (Lu and Gokhale, 2006). For that reason, in the second experiment we tried to seek investigation on finding the best performance of web servers for implementing online 3D terrain visualization. The web servers were used to upload the VRML file and also launching the online system. The basic criteria on measuring the performance of web server was loading time, CPU usage and frame rate per second (fps). The best web servers should have the high speed during the data loading and also lower CPU usage and higher frame rate per second (fps) during online rendering. All of these basic criteria were used in this experiment to measure the performance of web servers with different number of users accessing the web servers synchronously. In this experiment, four selected web servers were chosen which were Spatial Research Group Server in UPM, Universiti Utara Malaysia (UUM) web server, ruzinoor.my web server and Fortunecity free web server. The distance of each web server from the testing place was different.

The data used in this experiment is similar with the first experiment. It consisted of contour data and satellite data of UPM. Arc Map was used to crop the contour data from the original Sri Kembangan data and R2V software was used for editing the height value of the data. This data was saved in SHP files. The satellite imagery in this experiment was also QUICKBIRD (0.6 m resolution). PCI Geomatica V 9.1 was used to clip the satellite data to be the same area as the contour line data. Lastly, the data was saved in TIFF format. This process continued with draping satellite images over 3D terrain data. Finally the data was saved in VRML files and compressed by chisel software. Based on the feedbacks from the first experiment, it was found that the VRML outputs produced from Arc GIS 9.2 was the best to be used in online 3D terrain visualization. This data is ready to be uploaded and launched into web servers.

Implementation on different web servers: Four web servers were employed in this study which were Spatial Research Group Web Server in UPM, ruzinoor.my Web Server in Petaling Jaya, UUM Webcube Web Server and Fortunecity web server. The location of Spatial Research Group Web Server was inside the testing environment. The second web server Ruzinoor.my was located 20 km from the location of testing and then the third web servers UUM webcube web server located 496 km from the testing location. The fourth web servers Fortunecity web server was located far away from testing location which is in New York, United States. The VRML data need to be uploaded and launched into these four web servers for conducting this experiment. The specification of these four web servers are shown in Table 3.

The VRML data for first web server was launched into address "http://spatial.upm.edu.my/ruzinoor/webupm/arcgis3d.wrl". The VRML data for the second web server was launched into address "http://www.ruzinoor.my/webupm-/arcgis3d.wrl". The VRML data for the third web server was launched into address "http://staf.uum.edu.my/ruzinoor/webupm/arcgis3d.wrl". The VRML data for the fourth web server was launched into address "http://rchemat.fortunecity.com/-arcgis3d.wrl".

The testing was done by accessing the performance of web server based on loading time, CPU usage and fps. The first testing involves measuring loading time in four different web servers in one Laptop computer during office hours and after the office hours. The second testing was conducted by allowing different number of users accessing the data from each web servers synchronously. The testing was handled by allowing 2 users accessing the data in one web servers and continued with 4 users, 6 users and end with 8 users. Each user performed the same action which is walk through into the surface of 3D terrain in online environment. The specifications of the Laptop computer used for the experiments are Intel Core Duo Processor with 1.66 GHz, 2 Gb DDR2 memory, 60 Gb hard disk and Intel Graphics Media Accelerator 950.

Table 3: Specifications of spatial research group web server

Spatial research group	Web server
Domain	http://spatial.upm.edu.my
Location	Spatial Lab UPM
Provider	UPM
Type	Windows Server (XAMP)

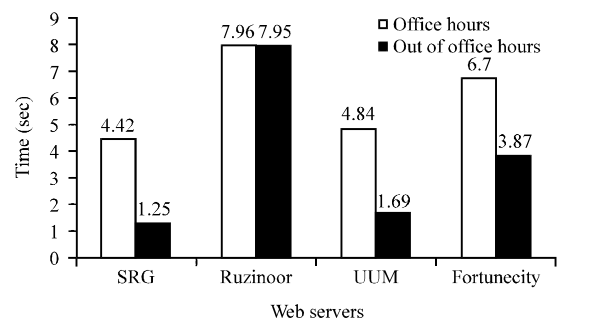

Fig. 3: Loading time in different web servers

Results of experiment 2: The results of this study were divided into two parts. The first part was measuring the loading time in four different web servers running on one Laptop computer. The measurement was performed by using stop watch and the results were produced into two decimal points. The results of this experiment are shown in Fig. 3.

The result shows that the best web server was Spatial Research Group Web Server which has the fastest loading time during office hours (4.42 sec) and after the office hours (1.25 sec). The worst web servers were ruzinoor.my which took more than 7 sec to load the file during office hours and also after the office hours. But overall the four web servers had taken less than 8 sec for loading the file which is not bad for accessing the system.

The second experiment was performed by testing the loading time, CPU usage and frame per second (fps) by different number of users accessing the web server synchronously. The number of users started with 2 users, and then increased into 4, 6 and 8 users, respectively. The results of this experiment are shown in Fig. 4a-c.

The result for loading time in Fig. 4a shows that when the number of users increases, the loading time becomes much slower. This may due to the time for loading the same file by many users synchronously will slows the file accessibility from the same web server. Overall, the UUM web server had the best loading time (4.45 sec) for the whole number of users as compared to other web servers.

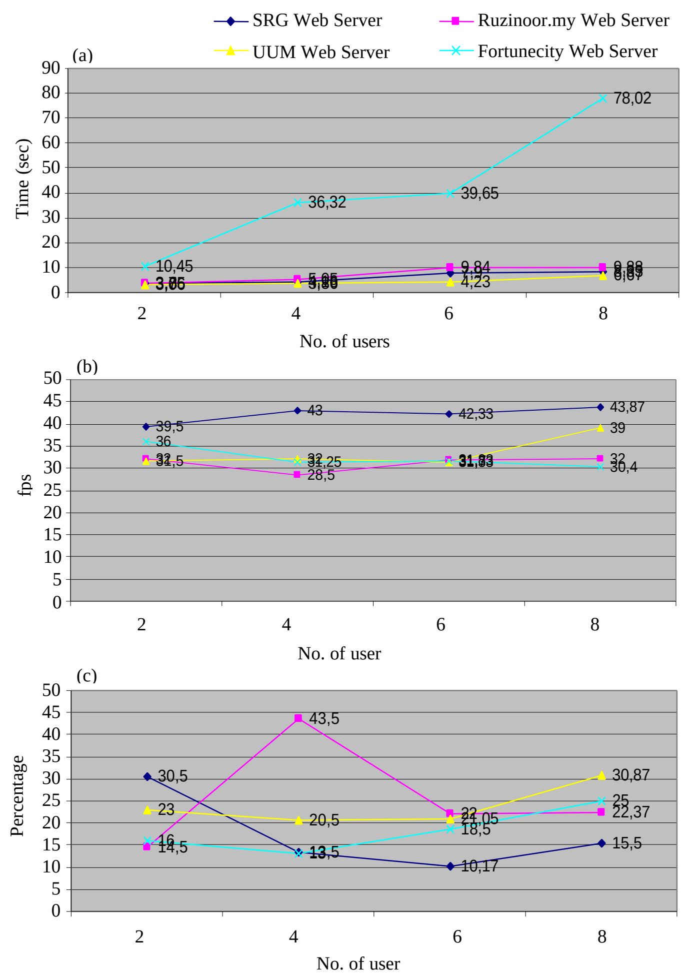

Fig. 4(a-c): The results of the experiment from different number of users. (a) Loading time, (b) Frames per second and (c) CPU usage

This should not have occurred if the comparison is based on the location of the web server alone. The nearest web server to the users should produce the fastest time to load the file and the longest distance to the users should slow the loading time. If this condition was considered, the Spatial Research Group web server was the best. This may due to the network bandwidth and queuing process (read and write) for this web server at the best situation during the time was tested. That is why this web server stated the fastest loading time as compared to others. Beside that the Fortunecity recorded the longest time for loading the data (41.11 sec). It means that the UUM web server had the fastest time on loading the data and the Fortunecity web server had the slowest time on loading the data among four web servers.

The result for fps value in Fig. 4b shows inconsistency of four different web servers. In normal situation, when the number of users increases, the fps value should be lower. However, the experiment results produced an opposite fps value. When the number of users became eight, the fps value was the highest in most web servers. This may be due to the network bandwidth and queuing process (read and write) during the time of testing. Eight users are in the optimum situation which allows the fps value to be the highest. Only Fortunecity web server recorded the best value for fps; when the number of user increased, the fps value becomes slower. On average, the Spatial Research Group web server recorded the fastest fps value for accessing the file online for the whole number of users. It means that this web server was the best among the other web servers in terms of fps value.

The results for CPU usage in Fig. 4c produced more inconsistent values for the web servers. In normal situation when the number of users increases the CPU usage should also increase. But in this situation most of the web server produced the opposite results. This may due to the value of network bandwidth and queuing process (read and write) during the time for accessing the file. This was inconsistent, sometimes, it recorded the lowest value and at other times, it recorded the highest value. That is why most of the web servers gave inconsistent values for the CPU usage. The most inconsistent value for CPU usage was ruzinoor my web server whereby, with the two users, it recorded the lowest value and with four users it recorded the highest value. This is different with Fortunecity web server which followed the rules, whereby when the number of users increased the CPU usage also increased its percentage. On average, the Spatial Research Group web server recorded the lowest CPU usage for accessing the file online for the whole number of users. It means that this server was the best among the other web servers in terms of CPU usage value.

In summary, the most basic criteria for evaluating the performance of web servers have among the four chosen web servers are loading time, CPU usage and fps value. It was found that the Spatial Research Group Server had the best value on all these criteria being tested. So based on this study the most suitable web server to be used in online 3D terrain visualization was these web server. Besides that, this study has also successfully demonstrated on the effect of number of users on accessing the similar data from the same web servers. The results produced inconsistent value for CPU usage and fps value while loading time value was consistent. This is may be due to the network bandwidth and queuing process (read and write) during the testing time.

CONCLUSION

In this study, various GIS software and web servers were utilized and tested to generate the best solution for developing online 3D terrain visualization. It was found that these two issues were important to consider by the developers in order to design the online system. The measurement on the quality of 3D terrain visualization has been successfully tested on four selected GIS software. This measurement specifically applied into VRML outputs generated from GIS software. The quality measured derived from the suggested criteria which is bad, acceptable and better. The assessment indicates that not all VRML file generated from GIS software were good in quality. Each of GIS software has its own strength and weakness. From the experiments, two GIS software produced bad quality, one produced an acceptable quality, and the other one produced better quality whereby the terrain was smoothly rendered with high quality image draped. At the same time, the observation on the file size also had been collected during the experiments. This is important because the file size will effect on rendering time during the online streaming. If the file size is large, the rendering time will be slower and inversely increase the speed of rendering if it is small. This observation indicates that two of GIS software (Arc GIS and ERDAS) had generated separate file of VRML and textured while the other two GIS software (R2V and ENVI) embed both of file together. The separate files were generated with smaller VRML file, whereas the embed file were generated with bigger VRML file. For that reason, it is necessary to select the GIS software which has the capability to generate VRML file with a good quality of visualization image and a separate file (VRML and image).

On the second issue, the measurement on evaluating the performance of web server were successfully utilized and tested in order to find the best web servers for developing online 3D terrain visualization. The performance of web server are measured based on three basic criteria suggested i.e., loading time, CPU usage and fps. The good performance of web server indicates by speed during loading the data, lower CPU usage and highest fps value during the rendering time with user interaction. This assessment indicates that the location of the web servers link directly to the performance of web servers. The Spatial Research Group web server which is located in the similar room with testing area was found to be the best server with faster loading time, lower CPU usage and highest fps value. Moreover, this experiment also successfully demonstrated on the effect of number of users accessing the similar data from the same web servers. The assessment indicates that the results has produced inconsistent value for CPU usage and fps value. However, the result for loading time value was consistent. This may due to the stability of the network bandwidth and queuing processes (read and write). It can be highlighted that the stability of the network bandwidth and queuing process (read and write) linked directly with the performance of the web server. Overall, this study has been proven to be useful for the GIS developers in guiding them on choosing the most suitable GIS software and applicable web server on developing online 3D terrain visualization.

ACKNOWLEDGMENTS

The authors would like to express their sincere appreciation to Taman Pertanian Universiti (TPU), UPM for providing the satellite image of UPM area. The most sincere thanks to Department of Survey and Mapping Malaysia (JUPEM) for providing the contour data for UPM area.

REFERENCES

Al-Dakheel, Y.Y., A.H.A. Hussein, A.S. El-Mahmoudi and M.A. Massoud, 2009. Soil, water chemistry and sedimentological studies of Al Asfar evaporation Lake and its Inland Sabkha, Al Hassa Area, Saudi Arabia. Asian J. Earth Sci., 2: 1-21.

Al-Mashreki, M.H., J.B.M. Akhir, S. Abd Rahim, K.M. Desa and Z.A. Rahman, 2010. Remote sensing and GIS application for assessment of land suitability potential for agriculture in the IBB governorate, the Republic of Yemen. Pak. J. Biol. Sci., 132: 1116-1128.

Albaji, M., S.B. Nasab, H.A. Kashkuli, A.A. Naseri, G. Sayyad and S. Jafari, 2008. Comparison of different irrigation methods based on the parametric evaluation approach in north molasani plain, Iran. J. Agron., 7: 187-191.

Appleton, K., A. Lovett, G. Sunnenberg and T. Dockerty, 2002. Rural landscape visualisation from GIS databases: A comparison of approaches, options and problems. Comp. Envir. Urban Sys., 26: 141-162.

Araya, S., J. Hyunsuk and R. Araya, 2002. An effective terrain model for web-based 3D geographic information systems. Elect. Commun. Japan, 85: 43-52.

Basic, F. and M. Nuantawee, 2004. Generating a VRML world from database contents: Illustrated by application to flood risk communication. J. Spatial Sci., 49: 37-47.

Beard, D.J., 2006. Using VRML to share large volumes of complex 3D geoscientific information via the web. Paper presented at the Web3D 2006 11th International Conference on 3D Web Technology, April 18-21, Columbia, Maryland.

Bolca, M., U. Altinbas, Y. Kurucu and M.T. Esetlili, 2005. Determination of change detection of lanscape of the kucuk menderes delta using GIS and the remote sensing techniques. J. Applied Sci., 5: 659-665.

Brodlie, K.W., 1992. Scientific Visualisation : Techniques and Applications. Springer-Verlag, Berlin, ISBN-13: 9783540545651, pp: 284.

Carey, R. and G. Bell, 1997. The Annotated VRML 2.0 Reference Manual. Addison Wesley Developers Press, University of Michigan, U.S., ISBN-13: 9780201419740, pp: 501.

Dhaimat, O. and T. Shawabkeh, 2006. Monitoring of Madaba city growth by RS and GIS technique. J. Applied Sci., 6: 2231-2237.

Dinesh, S., 2008. Extraction of hydrological features from digital elevation models using morphological thinning. Asian J. Scientific Res., 1: 310-323.

El-Nahry, A.H. and H.E. Khashaba, 2006. Land suitability modeling of natural vegetation using integrated remote sensing and GIS techniques: A case study. J. Applied Sci., 6: 51-56.

Gruen, A. and A. Roditakis, 2003. Visualization and animation of Mount Everest. Paper presented at the International Workshop on Visualization and Animation of Reality-based 3D Models (ISPRS), Switzerland. http://academic.research.microsoft.com/Publication/5019460/visualization-and-animation-of-mount-everest

HRVC, 2008. Chisel 2.1.3 (HRVC Edition) VRML Optimisation Tool. http://www2.hrp.no/vr/tools/chisel/install.htm

Honjo, T. and E.-M. Lim, 2001. Visualization of landscape by VRML system. Land. Urban Plann., 55: 175-183.

Huirong, C., P. Rencan, L. Shujun and Y. Caixia, 2009. The visualization of 3D Terrain Based on VRML. Proceedings of the 2009 International Forum on Information Technology and Applications (IFITA '09), IEEE Computer Society Washington, DC., pp: 116-118.

Lim, E.M., T. Honjo and K. Umeki, 2006. The validity of VRML images as a stimulus for landscape assessment. Lands. Urban Plann., 77: 80-93.

Limp, W.F., 2000. Put the fizz into data viz. GeoWorld, 13: 40-45.

Lu, J. and S.S. Gokhale, 2006. Web server performance analysis. Proceedings of the 6th International Conference on Web Engineering, (ICWE '06), ACM New York, pp: 111-112.

Martinez, E., E. Jimenez, F. Sanz, M. Perez, J. Blanco and J. Santamaria, 2010. Virtual representation of terrain through the web with VRML-Web3D and graphic libraries. Int. J. Interac. Desi. Manufact., 4: 125-136.

Moghaddam, M.H.R., M. Khayyam, M. Ahmadi and M. Farajzadeh, 2007. Mapping susceptibility landslide by using the weight-of-evidence model: A case study in merek valley, Iran. J. Applied Sci., 7: 3342-3355.

O'Hagan, R.G., B. Robinson, G. Swan and D. Finny, 2008. Web-based visualisation of water information: An overview. CSIRO: Water for a Healthy Country National Research Flagship. http://academic.research. microsoft.com/ Publication/6389359/web-based-visualisation-of-water-information-an-overview

Patterson, T., 2001. DEM manipulation and 3D terrain visualization: Techniques used by the U.S. National Park Service. J. Can. Cartogr. Assoc., 38: 89-101.

Pradhan, B., S. Kumar, S. Mansor, A.R. Ramli and A.R.B.M. Shariff, 2006a. A fast processing algorithm for lidar data compression using second generation wavelets. Korean J. Remote Sensing, 22: 49-61.

Pradhan, B., S. Kumar, S. Mansor, A.R. Ramli and A.R.B.M. Shariff, 2006b. Spatial data compression and denoising via wavelet transformation. Appl. GIS, 2: 1-16.

Pradhan, B., S. Kumar, S. Mansor, A.R. Ramli and A.R.B.M. Shariff, 2007a. GIS terrain data compression using Lifting Scheme- a new direction. Int. J. Comp. Internet Manag., 15: 9-19.

Pradhan, B., S. Kumar, S. Mansor, A.R. Ramli and A.R.M. Shariff, 2007b. Second generation wavelet based GIS data compression using Delaunay triangulation. Engin. Comput., 24: 200-213.

Reddy, C.S., S. Babar, K. Sudha and V.S. Raju, 2008. Vegetation cover mapping and landscape level disturbance gradient analysis in warangal district, Andhra Pradesh, India using satellite remote sensing and GIS. Space Res. J., 1: 29-38.

Ruzinoor, C.M., M.S. Abdul Rashid, M. Ahmad Rodzi and P. Biswajeet, 2008a. Development of 3D web based terrain visualizer. Paper presented at the International Symposium and Exhibition on Geoinformation 2008 (ISG2008), Kuala Lumpur, Malaysia.

Ruzinoor, C.M., M.S. Abdul Rashid, M. Ahmad Rodzi and P. Biswajeet, 2008b. Online 3D real time terrain rendering algorithm for GIS data: A Conceptual Idea. Paper presented at the 3rd International Workshop on 3D Geoinformation 2008, Seoul, South Korea.

Ruzinoor, C.M., M.S. Abdul Rashid and M. Ahmad Rodzi, 2009a. Effective visualization of online terrain draped with satellite imageries. Paper presented at the Workshop on Interactive Digital Media 200, Johor Bahru, Johor.

Ruzinoor, C.M., M.S. Abdul Rashid, M. Ahmad Rodzi and P. Biswajeet, 2009b. 3D terrain visualization for GIS: A comparison of different technique. Paper presented at the International Conference on 3D Maps, Dresden, Germany.

Ruzinoor, C.M., M.S. Abdul Rashid, M. Ahmad Rodzi, P. Biswajeet and M.R. Mohd Shafry, 2010a. 3D terrain visualization: A comparison of different contour intervals for terrain data draped with aerial photograph. Paper presented at the MRSS 6th Remote Sensing and GIS Conference and Exhibition (MRSS 2010), Kuala Lumpur, Malaysia.

Ruzinoor, C.M., M.S. Abdul Rashid, M. Ahmad Rodzi, P. Biswajeet and M.R. Mohd Shafry, 2010b. Development of online 3D terrain for oil palm plantation. Paper presented at the World Engineering Congress (WEC 2010), Kuching Sarawak, Malaysia.

Sipes, J.L., 2007. 3D photorealistic modeling using geobrowsers (Spatial Tech column). http://gis.cadalyst.com/gis/GIS/3D- Photorealistic-Modeling-Using-Geobrowsers-Spati/ArticleStandard/Article/detail/424087

Tagil, S. and J. Jenness, 2008. GIS-based automated landform classification and topographic, landcover and geologic attributes of landforms around the yazoren polje, Turkey. J. Applied Sci., 8: 910-921.

Zhou, G., Z. Tan, M. Cen and C. Li, 2006. Customizing visualization in three-dimensional urban GIS via web-based interaction. J. Urban Plann. Devel., 132: 97-103.

Zhu, C., E.C. Tan and K.Y. Chan, 2003. 3D Terrain visualization for Web GIS. Paper presented at the Map Asia 2003, Kuala Lumpur, Malaysia. http://academic.research.microsoft.com/Publication/12865983/3d-terrain-visualization-for-web-gis

Zlatanova, S., A. Abdul-Rahman and M. Pilouk, 2002. 3D GIS: Current status and perspective. Paper presented at the Symposium on Gespatial Theory, Processing and Applications, Ottawa.