# AN RDBMS-SUPPORTED, WEB-BASED, 3D GIS, VISUALISATION AND ANALYSIS TOOL

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## ABSTRACT

The increasingly widespread availability of spatial data through formal infrastructures (governmental SDI, national clearinghouses, geoportals) and less formal sources (corporate intranets, websites …) has heightened awareness of the importance of and possibilities in spatial data mining. Successful spatial data mining requires highly functional visualisation tools for representation and analysis. The flowline from spatial database, through browsing, querying and searching, to access, delivery and final visualisation must be examined to ensure its efficiency. This paper describes a tool which brings 3D GIS functionality to a standard web browser, without the need for specific plug-ins.

We present an online visualisation tool, GeoDOVE (Geospatial Database Online Visualisation Environment), which is a 3D visualisation environment for viewing and analysing spatial information using an internet browser. GeoDOVE is integrated with a database server and web browsing software, and offers significant 3D spatial data display capability. GeoDOVE connects to candidate data files, their layers and metadata. Querying can be undertaken by visual examination of data file properties and spatial extent. GeoDOVE obtains data from an Open DataBase Connectivity-(ODBC-) compliant online-RDBMS, such as MySQL™ or MS SQL SERVER™, database server via the internet (or offline-RDBMS such as Microsoft™ Access). As a free piece of software MySQL™ is of particular interest due to its widespread use. GIS data files are uploaded onto the database server over the web, directly via an ODBC bridge. GeoDOVE uses Java DBC to access the data from the server without the need for middleware to communicate with the database. The system can handle data in commonly used file formats such as ESRI Shapefiles, worldfiles, Geography Markup Language, VRML etc.

The commitment to free open-source technologies is maintained in the development of visualisation capabilities using Java 2™ and Java 3D™ (available free of charge from java.sun.com). With particular concentration on handling 3D data, GeoDOVE allows for draping of images over terrain surfaces, feature extrusion for urban area representation, real-time 'fly-throughs' and dynamic data rendering. The real-time linkage of the visualisation tool with the database over the web allows for standard querying of the database by position and by attribute. In addition, linkage to multiple database servers (for example, using ArcSDE) is possible, as is database integration and conflation. The architecture of the GeoDOVE system is described, along with examples of its use with a range of spatial databases served in different ways and integrated to allow for visualisation and 'added value'.

## 1.0 INTRODUCTION

The growth of web-based Geographic Information Systems (WebGIS) and three-dimensional (3D) computer graphics technologies has resulted in the introduction of a number of 3D WebGIS tools. Some of these tools have been developed for hydrological (Huang 2003), urban (Batty et al. 1998) and geological modelling (Gong et al. 2004). The development of these tools has been fuelled by the development of rapid 3D data collection technologies such as Global Positioning System (GPS), LIght Detection And Ranging (LIDAR) and satellite-based remote sensing; and also the global initiative to make spatial data accessible through spatial data clearinghouses. By definition a spatial data clearinghouse is an electronic facility for searching, viewing, transferring, ordering, advertising and/or disseminating spatial data from numerous sources via the Internet and, as appropriate, providing complementary services (Crompvoets et al. 2004): thus WebGIS plays an important role in enabling users to access and use the data.

Advances in web-based 3D computer graphics, geospatial data interoperability and remote database technology have led to new possibilities for 3D WebGIS. Some of these advances include the introduction of the Geography Markup Language (GML), development of function-rich spatial database servers such as PostGIS and the open-sourcing of the Java3D Applications Programmers Interface (API). Through the integration of these technologies, functionality previously found only on standalone GIS is now possible on web-based GIS. This paper will illustrate some of this functionality by introducing a web-based GIS system for visualising and analysing 3D geospatial data, called the Geospatial Database Online Visualisation Environment (GeoDOVE).

## 2.0 RELATED PREVIOUS WORK

One of the earliest studies in web-based geospatial visualisation was undertaken by Brown (1999). His paper proposed a framework for integrating Java External Authoring Interface (EAI) and Virtual Reality Modeling Language (VRML) to produce a Graphical User Interface (GUI) for Geographic Information Retrieval (GIR). VRML is a file format for creating 3D virtual worlds; it thus relies on a browser created using other graphics technologies for rendering. The Java EAI was particularly unstable, as each producer vendor implemented their own Java classes (Moore et al. 1997). Brown observed that using the Java Database Connectivity (JDBC) Applications Programmers' Interface (API) with VRML was slow and inefficient (Brown 1999). A 3D WebGIS using the Java EAI/VRML approach is GeoV&A by Huang et al. (2001). GeoV&A is an application for 3D visualisation and analysis: however, by virtue of using VRML files for creating 3D scenes, it is dependent on the level of interactivity offered by the VRML browser in addition to being subject to the JDBC limitations identified by Brown (1999).

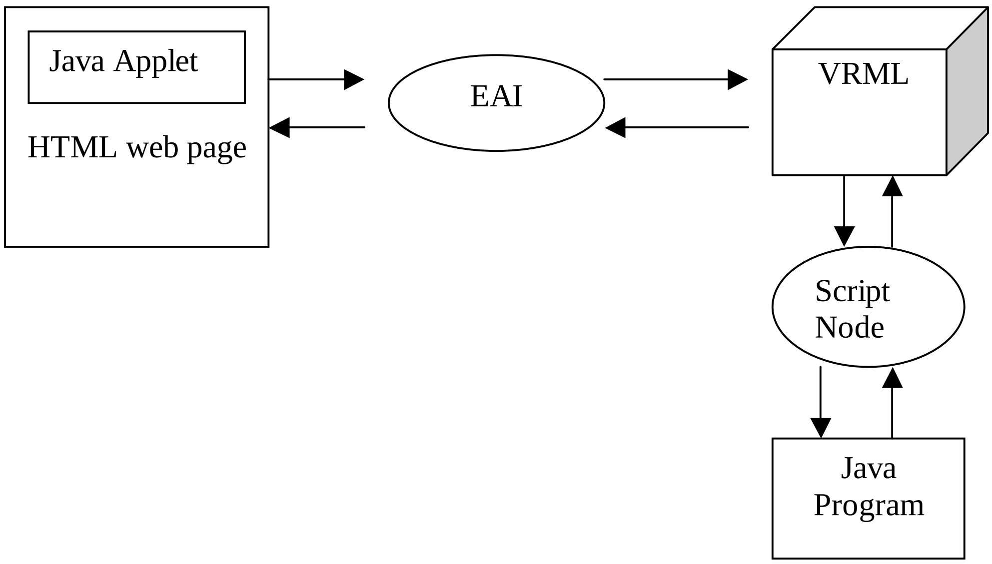

Figure 1. Integrating Java EAI and VRML to derive 3D content. (Brown 1999)

Whereas the Java EAI/VRML approach was mainly a thin-client approach, Huang (2003) proposes a hybrid client-server model for web-based 3D hydrological visualisation using the Java3D API. He demonstrates that Java3D can be successfully used to implement a web-based environmental visualisation tool by creating an application that computes a hydrological model, called TOPMODEL, and presents the results in a 3D virtual world. In our study, we attempt to further this research by showing that generic 3D GIS functions can be incorporated into 3D WebGIS. To demonstrate this, a prototype 3D WebGIS was developed to run completely from a Java Runtime Environment (JRE).

## 3.0 GEODOVE SYSTEM ARCHITECTURE

Generically, GeoDOVE adopts a thick client approach. However, the 'thickness' of the client depends on which database server is providing the data. For example, the applet can read in a GML stream from a web server then all subsequent functions are carried out on the client. On the other hand, the applet can also read in data from a function-rich spatial database server such as PostGIS and have most subsequent functions occurring on the server. To further illustrate this 'hybrid' architecture, figure 2 shows the architecture adopted for implementing GeoDOVE. Differences between the Java EAI/VRML and the Java3D/GeoDOVE architectures are shown by figure 1 and figure 2. In figure 1, there is the EAI layer between the server-side database and the client-side viewer whereas on figure 2 there is no intermediary between the database and the viewer. This direct connectivity improves execution speed and the viewer's scalability, as it is not dependent on intermediary technologies.

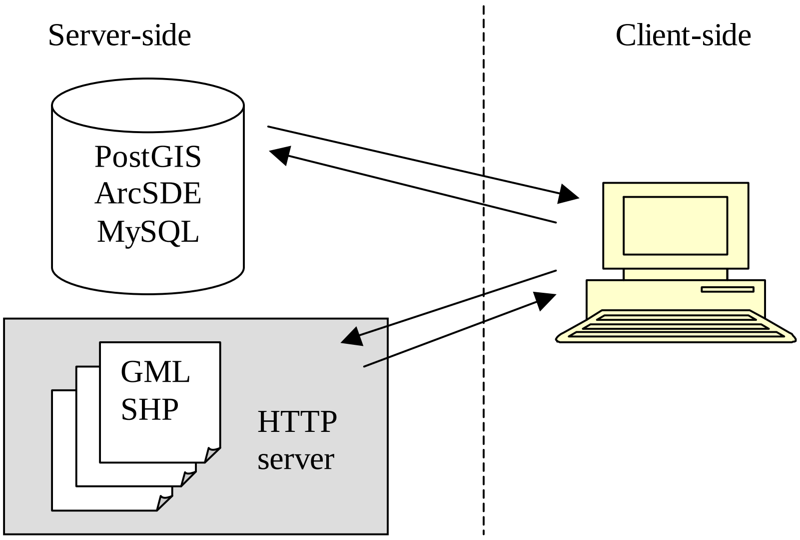


Figure 2. The architecture adopted for the GeoDOVE system

**3.1 Graphics Technology**
A number of graphics technologies were investigated for this study; namely OpenGL, DirectX, Java3D, VRML and OpenGL Performer. OpenGL and DirectX are low-level technologies providing an interface to the hardware (Walsh and Gehringer 2002). They both offer a function-driven API where the scene is developed from top-to-bottom, making code re-usability difficult. Java3D on the other hand offers a scene graph model which allows uses objects to be re-used or shared in different parts of the virtual world. Furthermore, DirectX is only available for the Microsoft Windows platform and is thus not platform-independent. Different platforms offer OpenGL bindings specific to their platforms. This means that even though OpenGL and OpenGL Performer are platform-independent they still require platform-specific API's to access their libraries. In contrast, Java3D programs run in any JRE and are therefore platform independent. The difference in platforms is resolved by the JRE and is thus transparent to Java3D.

In comparison to higher level technologies such as VRML or other 3D modelling file formats, Java3D offers greater flexibility in modifying the virtual world during runtime. Since Java3D is part of the Java language, one has a full programming environment available which provides more power than VRML at the expense of greater effort in scene development (Burrows and England 2002). This is evidenced by the fact that Java3D allows the user to merge 3D models from different file formats, including VRML, into a single virtual world. As VRML is a file format it does not import other 3D file formats into its own. For these reasons, Java3D was chosen for implementing GeoDOVE.

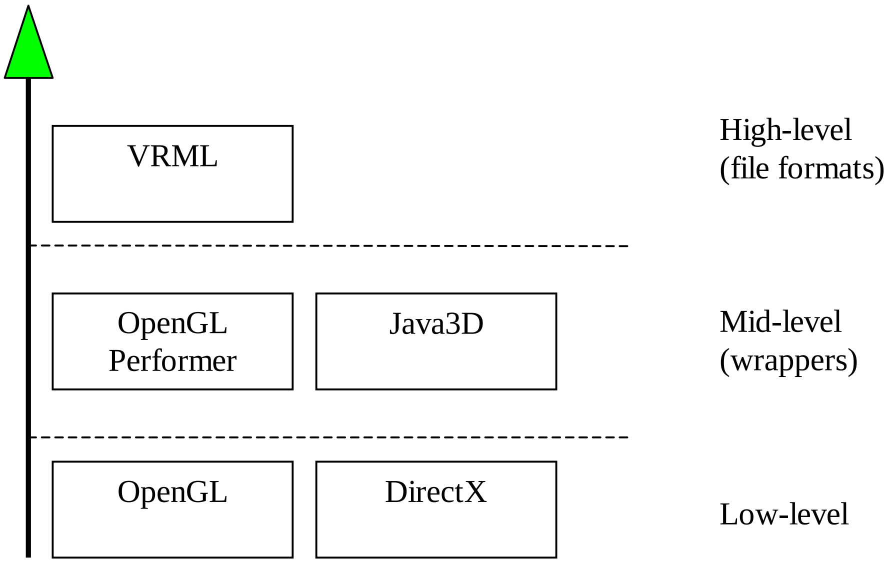

Figure 3.Comparison of high and low level graphics technologies.

### 3.2 Database Connectivity

GeoDOVE has been enabled to access data on two open source database servers; Postgres/PostGIS and MySQL. In their study Moreno-Sanchez and Anderson (2003) conclude that open source software (OSS) is ideal for organizations that wish to server their geospatial data on the World Wide Web. This is because OSS (a) requires no software costs, (b) is easy to learn by personnel with general IT background (c) offers a small software footprint (d) ensures no need to commit to a proprietary web-GIS (e) gives a possibility to extend with custom-made geo-processing functions (Moreno-Sanchez and Anderson 2003). PostGIS is the spatial extension of the open-source PostgreSQL database server. Through its open source interface, developers can extend the system by adding their own data types, functions, operators, aggregate functions, index methods and procedural languages (PostgreSQL.org 2005). PostGIS offers Open Geospatial Consortium (OGC) Simple Features data types and access to some commonly used vector spatial functions such as buffering, convex hull, area computations and so on. Both PostGIS and MySQL input and output vector spatial data in Well Known Text (WKT) statements. WKT is an open and human readable file format.

Despite offering advanced vector data handling, PostGIS does not currently offer advanced raster data capabilities. Similarly, MySQL's own spatial extension currently does not offer support for raster data handling, nor does it offer support for 3D vector coordinates. It was because of this that for storage in MySQL our study developed a platform-independent approach to vector and raster data storage. Furthermore by virtue of being platform independent the same raster handling functionality could be incorporated into PostGIS at a later stage. Through the standalone GeoDOVE Administrator tool, which uses the Java Advanced Imaging API, a raster image or ASCII file is read in. The georeferencing information is then stored in a relational table, called *Grid_Coverages*, that acts as the catalogue of all raster datasets held in the Relational Database Management System (RDBMS). Each band of the image or ASCII grid file is then stored in a table record as a stream of little-endian ordered bytes taking the form shown on figure 4. This raster storage structure allows each stored dataset to have any number of bands as each band is stored in a relational table record. This structure would be capable of holding hyper-spectral remote sensing imagery.

| **BandID** | **Pixels** |
|---|---|
| 1 | 041,056,246,053,042,165,034,216,043,256,053,042,063,045,246,125,043,061,243 |
| 2 | 246,125,143,061,243,043,256,043,263,052,046,053,042,63,045,246,125,043,061 |
| 3 | 154,156,241,156,246,253,042,165,034,216,243,256,043,263,252,046,053,042,063 |
| 4 | [Column1 pixels][Column 2 pixels][Column 3 pixels]……[Column n pixels] |

Figure 4. Raster storage in an RDBMS

The client-side application is a Java applet. Java applets are Java programs that are embedded in a webpage also run from a web browser. They are different to Java Webstart applications as the latter programs are invoked from a webpage but run externally to the web browser. Both Java applets and Webstart applications are subject to ‘sandbox’ security features. The sandbox allows distributed applications to have access only to files from the path or Uniform Resource Locator the application was downloaded from. In client-server architecture this means that an applet operating in a sandbox would have access only to files on the server. To overcome this, the GeoDOVE application has been signed to enable it to offer the user the choice to access files on the client system and to connect on remote database servers at different web domains.

## 4 FUNCTIONALITY

As GeoDOVE reads in data in generic geospatial data structures, it is important to allow the user to manipulate the displayed content to represent real world objects such as buildings, walls or trees. Furthermore, it was necessary to allow the user to specify what type of textures the surfaces should adopt. A function was thus developed for extruding polygonal features and applying textures to the extruded edges as shown on figure 5. The figure also shows the ability to list attributes of all features within the visible layer and to subsequently highlight the attributes of a selected feature. This demonstrates that objects within the virtual world are able to change appearance as a result of user interaction. Such functionality could be used to allow users to specify their own stylesheets or colour schemes. This flexibility in presentation is not available in 3D file formats such as VRML or its geospatial extension, GeoVRML. It is, however, very important to allow users to change the colour schemes as they are likely to have their own corporate legend templates or they may wish to conflate data from a number of different sources.

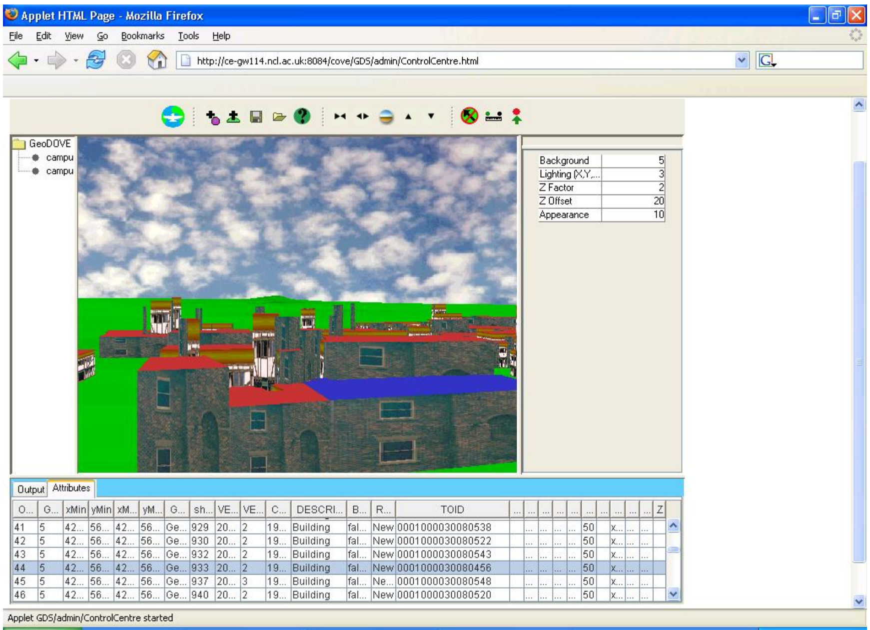

Figure 5. DTM with extruded polygons as buildings.

The virtual world is also modifiable as a result of the values of attributes in the geospatial database. For example, figure 6 shows a Digital Elevation Model (DEM) that has been automatically coloured according to the elevation value. A legend shown on the graphical user interface indicates the classifications of elevation with their corresponding colours. Additional functionality includes computation of 3D distance, using the view’s position in virtual space as the pointer. As with most 3D graphics environments applying images to planes as textures reduces the rendering speed of the application. To overcome this limitation, Level-Of-Detail (LOD) is applied. LOD is an approach in 3D modelling for switching the visibility of objects in a scene on or off depending on their distance from the viewing ‘camera’.

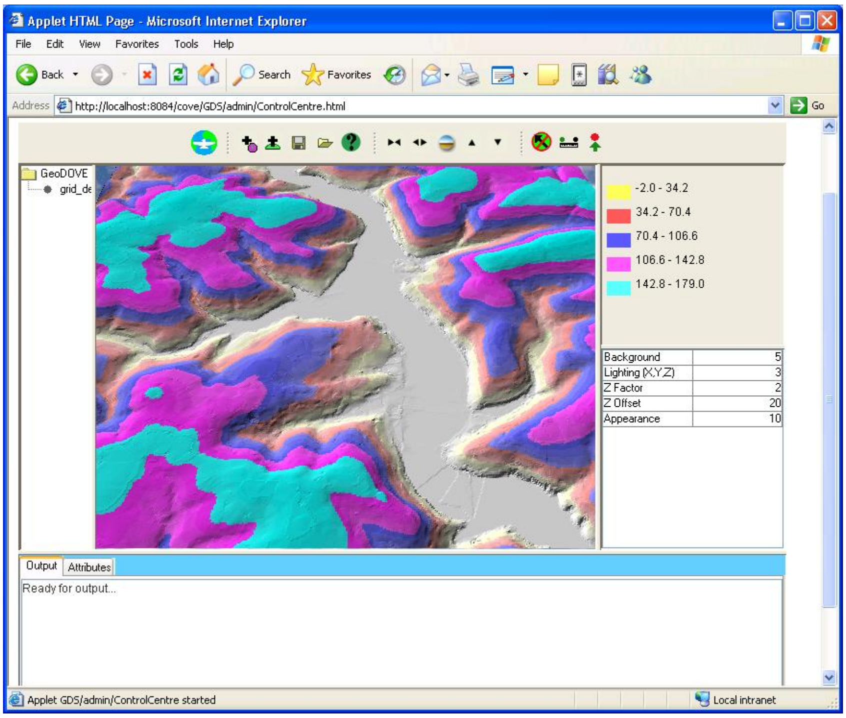


Figure 6. DEM modelling with colouring

## 5 CONCLUSION

This study has attempted to highlight how a combination of Java3D and open source database technology can enable the development of 3D WebGIS. It has provided a critical comparison of Java3D and other 3D graphics technologies, in particular VRML, and concluded that Java3D offers greater flexibility and allows for reading data directly from OGC Simple Features geometries for example WKT. This capability eliminates 3D file formats such as VRML from the data flowline and therefore makes data transfer more efficient. An approach to enabling RDBMS to store multi-band raster datasets has also been presented in this paper. The approach is platform independent and can be used in any relational database.

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## REFERENCES

Anderson, G. and R. Moreno-Sanchez (2003). Building Web-Based Spatial Information Solutions around Open Specifications and Open Source Software to support land-use planning in Mexico. 11th annual GIS Research UK conference, London, pp154-157.…

Batty, M., M. Dodge, S. Doyle and A. Smith (1998). Modelling Virtual Urban Environments. London, Centre for Advanced Spatial Analysis Working Paper 1.

Brown, I. (1999). "Developing a Virtual Reality User Interface (VRUI) for Geographic Information Retrieval on the Internet." Transactions in GIS **3**(3): 207-220.

Burrows, A. L. and D. England (2002). "Java 3D, 3D graphical environments and behaviour." Software Practice & Experience **32**(4): 359-376.

Crompvoets, J., A. Rajabifard, A. Bregt and I. Williamson. (2004). "Assessing the worldwide developments of national spatial data clearinghouses." International Journal of Geographical Information Science **18**(7): 1-25.

Gong, J., P. Cheng and Y. Wang (2004). "Three-dimensional modeling and application in geological exploration engineering." Computer & Geosciences: 391-404.

Huang, B., B. Jiang and H. Lin (2001) "An integration of GIS, virtual reality and the Internet for visualization, analysis and exploration of spatial data" International Journal of GIS: 15 (5) 439-456

Huang, B. (2003). "Web-based dynamic and interactive environmental visualization." Computers, Environment and Urban Systems **27**(6): 62-636.

Moore, K., J. Dykes and J. Wood (2000) "Using Java to interact with geo-referenced VRML within a Virtual Field Course", Computers and Geosciences 25, 1125-1136.

www.PostgreSQL.org (accessed 2005). PostgreSQL Documentation.

Walsh, A. E. and D. Gehringer (2002). Java3D API Jump-Start, Sun Microsystems Press, 272pp.

## BIOGRAPHY

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