Beyond FOSS 3D GIS Technologies:
A Chance for Developing Countries

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Abstract

The growing success enjoyed in recent years by 3D consumer geobrowsers such as Google Earth, Virtual Earth or WorldWind, has opened up the geospatial field, traditionally limited to domain experts, to the wider public, giving birth to the field referred to as "Neogeography" (Tuner, 2006). The usability and interactive nature that characterise these applications make them ideal candidates for applications that expose geographical services to the community. Nonetheless as most of these applications have been mostly designed for non-expert use the interoperability between these applications and existing Spatial Data Infrastructures (SDI) through ISO, OGC® or CEN (Comité Européen de Normalisation) standards is rather limited, usually restricted to WMS (Web Map Service) support. As highlighted by Zipf (2008) the recent corpus of new specifications and protocol defined by OGC® pave the way to services specifically developed for 3D applications.

Concurrently Internet bandwidth consumption as well as number of broadband subscribers in developing countries is increasing at very fast rate (The World Bank, 2008). To this extent the adoption of 3D GIS FOSS technologies, in place of standard 2D web-GIS applications, can help developing countries fill the technological gap in the domain of Geographical Information between so-called developed and developing countries in a similar way to what has already happened in other IT-related domains where more recent technologies have been deployed despite the unavailability of pre-existing infrastructure. A typical example is the diffusion of mobile phone technology despite the scarce availability of traditional communication infrastructures.

The work described in this paper illustrates the results of an ongoing project which is bringing to the development of a FOSS 3D client that can be used by operators and citizens to access and author information present within a regional SDI through a number of OGC® web services.

The infrastructure is totally based on FOSS, both in terms of GeoDB (PostGIS), middleware (JEE – Java Enterprise Edition), application server (JBoss) and 3D client (NASA WorldWindJava) and therefore it is particularly suited to be used within the context of developing countries.

At the service level the architecture implemented is based on a multi-level middleware structure, implemented through Enterprise Java Beans (EJB), implemented on top of GeoTools libraries that expose a number of OGC® services. The 3D client allows user to consume those services

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accordingly to the privileges assigned to each user. Standard users can only view data within the 3D environment which is being sent by selected repositories via WMS or WFS. Data available can be interactively filtered through an innovative interface based on graphs directly rendered on top of the 3D scene. A specific set of server components has been implemented to maximise system performances through a specifically developed caching system at the server level.

Additionally, authorised users can author the content available within the infrastructure directly from the 3D environment, through a specifically developed interface which is integrated within the 3D scene. Operators in fact can upload new content, define its visibility, arrange its logical structure in layer as well as their mapping style from within the 3D scene through the use of a visual user-friendly interface. The styling is automatically encoded as SLD (Styled Layer Descriptor) and stored centrally within the repository and used to render the relevant data to all users.

1. Outlook and Related Works

The long lasting debate on the importance to provide developing countries with access to geographical information has fuelled the scientific, technical and political communities. The international debate has been traditionally dominated by two parties, those predicting a widespread adoption of geospatial technologies as key tools to better support the governance of developing countries and those claiming that unsustainable costs and technological barriers would lead to a wider gap between so-called developed and developing countries. An example of the latter was provided by United Nations Human Settlements Programme (Habitat 1990) who predicted that integrated GIS infrastructure would play no more than a marginal role within less developed countries due to the lack of proper education as well as to high costs. Coversely a very large number of studies (Jackson et al. 2007) have advocated the role of GIS technologies within developing countries as instruments to manage health care accessibility or to deploy planning activities (Hall 1997). As reported in (Yii et al 2008) the adoption of FOSS GIS technology has proved a viable solution for department with limited budget to create IT systems to access data on public health.

Several experiences show the positive results of the adoption of 3D Geobrowsers as Decision Support Systems (DSS). 3D Geobrowsers are being widely used as DSS in the context of public health and fight to diseases within developing countries. An example is provided by Lozano-Fuentes et al (2007) who report how information on the urban layout of Mexican towns were defined in Google Earth by manually creating colour-coded polygons according to the abundance of dengue cases. A similar goal is shared by the Malaria Atlas Project (Wellcome Trust, U.K, 2008) which has promoted use of Google Earth to view distribution of maps of the spread of the disease.

3D Geobrowsers' key role for environmental protection (Mendea et al. 2007) (Ssegane et al, 2007) and disaster prevention spans beyond developed countries (Kwan et al. 2005). Their user friendliness is in fact essential to facilitate exchange and dissemination of spatial information among stakeholders and government agencies (Grasso et al. 2006 and 2008). Several international agencies are promoting use of 3D Geobrowsers as DSS. An example of this is FAO GeoNetwork, which provides interactive access to specific indicators, related to food production worldwide. A

similar move is being taken by the United Nations Environment Programme, which is proposing the use of 3D geobrowsers as gateway to Global Environmental Alert Service (Grasso et al. 2006 and 2008). In line with this National Oceanic and Atmospheric Administration (NOAA, 2007) has made available through Google Earth information on 3,000 free-drifting profiling floats.

A further example of this trend is SERVIR (Coughlin, 2008), a project promoted to disseminate environmental data coming from Earth observation in the widest possible way to decision makers and people alike within 8 Mesoamerican countries. The project has been developed as customisation of NASA WorldWind. SERVIR is used to provide experts, administrators and the public, with 3D visualisation capabilities using near real-time satellite images and maps. The system provides access via WMS to GEOSS data which can be animated and overlaid on top of the 3D surface of the territory. This is particularly useful to monitor phenomena such as landslides by overlaying rain forecast terrain slope etc. Its importance was demonstrated in 2006 in Panama when it was used to assess potential flooding in the region due to heavy rainfall.

The use of 3D technologies is essential to emergency response (Laituri et al. 2008) especially to help non technical people locate areas of intervention (Enemark, 2008). These can be used to support online disaster-response community (ODRC) (Laituri et al. 2008) integrating both emergency information services and social networks on the event. If the importance and extent of this approach can be valuable within developed countries, as demonstrated in the aftermath of Hurricane Katrina, this can be vital in the context of developing countries. The importance of the adoption of Geobrowser to support post-event rescue operations has been proved essential in the event of the Indian Ocean tsunami (Laituri et al. 2008) and after the earthquake in Pakistan during 2005 (Nourbakhsh, 2006) when Google Earth was used by The Citizens Foundation a disaster relief agency, to plan rescue operations.

The increasing number of open interoperable technologies can be essential to support environmental protection and disaster mitigation including 3D-based services (Zipf, 2008), (OKGIS, 2008). As underlined by (Laituri et al. 2008) the importance of being able to integrate and distribute data in interoperable form is essential to provide effective solutions in terms of response and preparation to disasters. The importance of interoperability was evident during the post-event rescue operation following the earthquake in Pakistan in 2005 when the lack of interoperability delayed the availability, through Google Earth, of high resolution images to support rescue workers.

2. The Architecture Developed

The work presented in this paper has been initiated in answer to the needs of a typical public administration willing to provide access to a wide range of geospatial data of environmental interest, ranging from raster and vector information to live sensor data. The requirements were to maximise interoperability and ease of use in order to support a wide community of users ranging from experts to users with little or no formal training in geospatial disciplines including administrators and common people. As highlighted in the previous section this makes the proposed solution particularly suitable to the requirements of developing countries with specific regards to its adoption within scenarios related to environmental and emergency management.

The overall architecture has been entirely developed through FOSS, as Java and JEE (Java Enterprise Edition) software components. This follows a typical multi-tier approach where all server-side components, deployed within an open-source application server (JBoss), have been developed following an SDI perspective. The data level is provided by Postgres/PostGIS which is being accessed by a JEE middleware which in turn exposes a number of services to 3D client applications developed on top of the open source WorldWindJava libraries developed by NASA. At the middleware level each component has been developed as EJB 3.0 (Enterprise Java Bean), either stateful or stateless depending on their use. The EJB provides all the necessary business logics. Its functions can be invoked in various ways, specifically via ESB (Enterprise Service Bus), through JMS (Java Message Service) with the use of MDB (Message Driven Bean), as well as via standard RMI (Remote Method Invocation) calls. Each EJB is coupled to a Java servlet, deployed through the Tomcat servlet container made available by JBoss. Each servlet is used to expose to the client applications the EJB functionalities as Web Service (WS). This approach ensures, wherever possible, support for a number of OWS (OCG® Web Service) such as WMS (Web Map Service), WFS (Web Feature Service) or WPS (Web Processing Service). With respect to this each EJB makes use of a number of different libraries such as GeoTools, to ensure support of WMS, WFS as well as the API by 52°North Initiative (52°North, 2008) to expose WPS (Web Processing Service).

At the client level a 3D Geobrowser allows full access to all services exposed by the middleware in a very user friendly way. Users can activate complex functionalities, such as those available for processing made available as WPS, with a simple sequence of mouse clicks. The client entirely written in Java, it can be started as standalone application, as standard Java Applet or as Java WebStart application. The 3D client, which can be run on a variety of different platforms, has been developed on top of WorldWindJava libraries developed by NASA, and it makes use of additional libraries to support more advanced Graphical User Interfaces (GUI). The extension of the standard FengGUI library, developed to create OpenGL-based Graphical User Interfaces (GUI), it allows the implementation of standard GUI components such as menus, icons, and buttons within an OpenGL context. As visible from Figure 2 all the elements of the interface are "immersed" within the virtual scene without the need for external graphical components outside the 3D window.

The GUI is rendered over the virtual scene through partially transparent graphical widget. This ensures that the user does not lose focus with the main scene thus allowing constant reference with the virtual scene behind. Furthermore, as a consequence of this choice, the look and feel of the application does not vary when different platforms are adopted as the GUI components are rendered by OpenGL rather than through AWT, Swing or SWT. As a result of the project several components, not provided by the original FengGUI distribution have been developed and made available to the FOSS community. The client makes also use of graph-based interfaces to provide alternative access to data structures such as layer structure or user hierarchy. This representation has shown its main advantages when dealing with a complex provincial plan whose main thematic maps where composed of more than 180 layers, cross-referenced by a number of different themes. A standard tree-based TOC (Table of Content) approach would clearly be inadequate to interact with such a long list of layers. A 2D representation based on graph it has allowed an easier representation

of layers highlighting connections between layers and themes. Additionally multiple views of the same dataset allow further hierarchy-based perspectives, for instance to show the connections and dependencies between the different departments responsible for creating and editing each layers.

All the functionalities are made available in a very user friendly way through a very simple ring menu, directly located on top of the scene in overlay to the virtual scene. The great attention paid to usability has resulted in an extremely user-friendly application, which can be made available through the web to allow non expert users to enable access to standard OWS with little training.

3. Example of Use

Within a typical scenario the user starts the 3D client as WebStart Application by clicking on a web link with a standard browser. If required they log in the system by simply selecting their profile through the graph-based interface and typing their password. Functionalities are made available according to their profile through the ring menu. Following the successful authentication the interface of the 3D client will show, to each user, their specific list of layers, grouped either within a traditional TOC or made available through a graph-based interface. The interface, which makes use of partially transparent components, is shown in overlay to the scene thus ensuring constant reference between actions performed at the interface level and the virtual scene. As soon as the user selects from the graph one of the node this automatically opens up showing all its children.

When a layer is activated the corresponding set of WMS requests, referring to the region observed by the user, is automatically sent to the server. Here a servlet receives the request and, via RMI, it invokes the appropriate EJB that checks if the corresponding information is present within a high performance cache specifically developed for this task. If the information has been previously requested, and therefore it is already present within the server-side cache, this is immediately retrieved from the DB and it is passed to the servlet which in turns uses it to answer to the WMS request. Conversely if the information is not available within the cache, the EJB invokes a further Java Bean responsible for the mapping. The requested image is rendered and returned to the servlet which responds to the client. Additionally the image is added to the cache through the relevant EJB.

As highlighted in previous sections, it is widely acknowledged (Laituri et al. 2008) (Nourbakhsh, 2006) that being able to update and share geographical data in an interoperable way is essential, in the context of developing countries, during environmental control and disaster management

For this reason the 3D Geobrowser lets authorised users update and share the information present at the data level within the GeoDB(s). Authorised users can both change the layer structure, by creating, deleting or renaming a layer, as well as update information onto the central repository. The graph-based interface can be further invoked to define group-based visibility of a specific dataset.
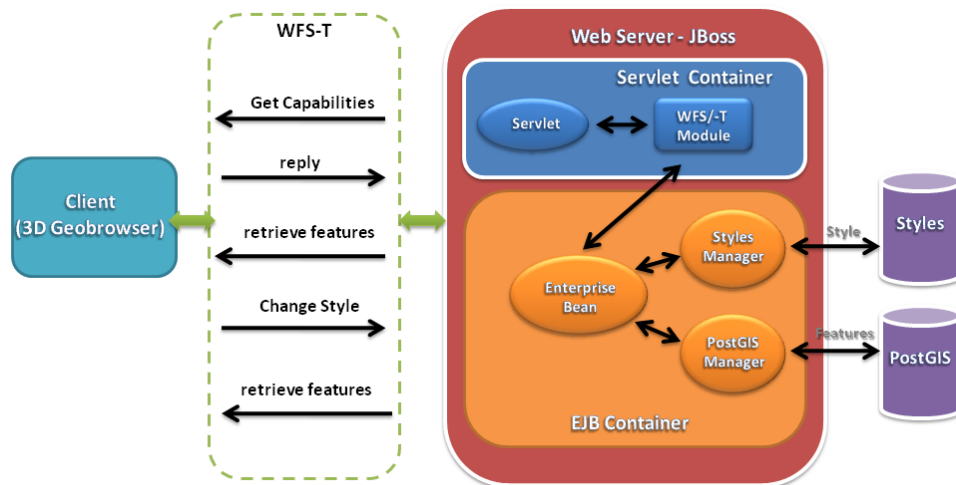
Figure 1. The Overall Authoring Process

A GUI component allows the user to simply select the relevant file on their file system and to specify the appropriate EPSG code or projection details. The file is sent to the central repository to an EJB which receives it and it automatically invokes a re-projection service made available by a further EJB. After this operation, which is completely transparent to the user, the data is finally stored, it is sent to the EJBs responsible for mapping and it finally becomes visible to the client. At the client side the image, which is received via WMS, becomes immediately visible behind the GUI, while at the server side this is passed to the component responsible for server-side caching.

Figure 2. The Simplified (left) and Advanced (right) Style Editor Interface

Authorised users can also select features by clicking over the 3D scene to change their appearance. This can be done in two different ways according to the level of competence of the user profile. As visible in Figure 2 operators can make use of a simple interface to change basic attributes such as line colour, thickness or layer transparency. This information is coded by the system as SLD (Styled Layer Descriptor), which is stored within a DB, to be used by the EJB responsible for mapping. Specifically, as described in Figure 1 the request from the geobrowser is received by a Servlet/EJB couple responsible to deal with WFS requests. The servlet, which is responsible to handle the client requests in turns invokes the relevant EJB specifically developed to encode SLD information. Operators can also access complex processing functionalities, provided as WPS (Web Processing Service), within the 3D Geobrowser in a very user friendly way. An example of this is the developed service for the calculation of a profile of a terrain available as

DTM created from a LIDAR dataset. This makes it possible to process large dataset without the need for large data exchange between server and client. The user in fact interactively selects within the 3D scene the profile of the section they want to calculate through a simple sequence of left-clicks on the terrain. As soon as the path is complete the user confirms the profile, the WPS request is sent to the relevant server which calculates the profile from a high resolution LIDAR dataset. The result, which is returned in quasi-real-time, is entirely calculated at the server and therefore it does not impose any restriction, in terms of computational resources, to the client which therefore is always a very lightweight application. This approach in fact allows benefiting from computational resources which can be made available in an interoperable form through the network for processing functionalities. As soon as the result arrives to the client this is rendered in overlay and the user can then interactively obtain information on the height of the specific point.

4. Conclusions

The work presented in this paper shows how technology is now mature for widespread use of 3D Geobrowsers. These can provide an effective answer to a wide range of requirement set by developing countries in that they can ensure the user friendliness necessary for a wide adoption among non expert users. The application presented can be used both by laypeople and by expert operators alike as it allows data authoring and it provide access to complex functionalities via WPS. The architecture adopted allows benefitting from interoperable Spatial Data Infrastructures to capable to provide harmonised access to GI through standard OWS.

Additionally, as illustrated in the previous section the 3D client developed can be used by authorised operators to easily update and share geographical data. As underlined by several authors (Laituri et al. 2008) (Nourbakhsh, 2006) the approach proposed can bring large benefit to developing countries to deliver an improved control over the environmental resources as well as to ensure better response and preparation to disasters. As highlighted by a number of authors (Nourbakhsh, 2006) the importance of allowing authenticated users to update and share geographical data in an interoperable manner provides, in the context of developing countries, key added value in that it enables easy updating of existing data which may not be entirely reliable. As testified by a number of experiences (Laituri et al. 2008) (Nourbakhsh, 2006) (Coughlin, 2008) the system developed can provide essential support environmental protection and disaster mitigation.

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