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Developing JSG Framework and Applications in COMGIS Project

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***Abstract*: Geographic Information System (GIS) is emerging as new trends in research due to its applications cover many important aspects of societies such as natural resource management, civil construction, hazard prediction, 3D city simulation, economic policies decision, etc. Recently, these have been some studies about three dimensional GIS systems in WWW environment [1], [21]-[23], [25] in which making these kinds of systems, spatial analysis and 2D GIS data mining are considered the main focuses in the following years. In this paper, we continue these themes and our early works [22], [26] by developing a framework namely JSG for 3D WebGIS applications. In the other words, a know-how process of creating 3D WebGIS systems from GIS data conversion, terrain splitting to application deployment will be presented. An application of this framework in COMGIS project of Bolzano province, Italy will show its efficiency in real situations.**

***Keywords*:** GIS, 3D WebGIS, JSG, COMGIS, Splitting algorithms, mapping algorithms**.**

I. Introduction

It is obvious that applications of GIS on Web or WebGIS are increasing concerns not only in researches but also in industries and services. Providing map interfaces and internal geographic information transmission and calculation, they support our works efficiently. Moreover, the flexible and easy-to-use characteristics of WebGISs are some major factors that can explain why they are widely used nowadays. A lot examples of WebGIS can be found in simulation [8], line management [6], pipe network [46], city information system [44], tourism [2], [4], agriculture [19], natural resource management [24], and many other fields [13], [16], [20], [36], [43], [47].

However, it is said that GIS is being evolved in a new form which closely relates to realistic objects when integrated with Virtual Reality. Obviously, it is what we want to mention in this paper: the 3D GIS. To think simple, the world we live is 3D. All objects we touch and see everyday are also in 3D forms. Therefore, to make GIS applications become more realistic, we need to integrate them to Virtual Reality technology. As mentioned before, this future GIS application should be run in WWW environment for the sake of free use, access and flexibility. In [1] and [21], the authors have pointed out some new trends and prospects on the development of three dimensional WebGIS systems in which making this kind of systems, spatial analysis and 2D GIS data mining are the main focuses in the following years. For instance, Le Hoang Son [22] has shown a method to build WebGIS-3D systems namely SGIS-3D through the combination of *Digital Elevation Model (DEM)*, GeoVRML standard and Spatial Analysis operations. Later, another study from Le Hoang Son [23] providing more spatial analysis operations for this system has reconfirmed the above consideration.

The SGIS-3D system is described in [22] as the best 3D WebGIS system in comparison with some other ones in terms of analysis operations and terrain displaying. However, in fact, it still remains some disadvantages. First, the GeoVRML standard [28] uses Cortona player as a plugin to display on Web. This plugin runs with Internet Explorer browser only. Moreover, these are some conflicts between different versions of this plugin. Therefore, it is hard to display terrains in all web browsers with GeoVRML standard. Second, it takes a lot of time to display terrains having large sizes. Although, it is proved to be able to display the terrain containing the size up to 897 x 793 in *x* and *z* axes, the displayed time is really long. In practical applications, the size of inputted DEM terrain is often large depending on its resolution. In fact, this figure can be hundreds or thousands gigabytes and hence is a major obstacle when putting terrains on Web which requires processing in short time. Finally, the DEM itself contains topographic spatial data only and no other attribute information is provided. Thus, a very important characteristic of common GIS and WebGIS systems that is querying attribute information, exploiting and mining on them is not utilized. In SGIS-3D [22], the author implemented point query in terrains by using ray crossing algorithm [10], [15], [27], [30]. However, it is not suitable if the number of tested points is large, hence the processing time is increased as a result. These problems should be overcome in order to make a 'truly' 3D WebGISs in equivalent to what have been represented in 2D GISs and WebGISs.

To deal with these difficulties, our main idea is to make a survey of some current striking 3D WebGIS standards and choose the most suitable one. For second and third problem, a schema of terrain splitting algorithm is presented. Therefore, in this paper, we will present a framework so called JSG which can remedy some disadvantages above by combining these techniques. In the other word, a hybrid solution between 2D and 3D WebGIS is invoked to utilize both advantages. As such, a process of how to create 3D WebGIS systems from GIS data conversion, terrain splitting to application deployment is presented. Thence, we will try to apply our method to the COMGIS project in Bolzano, Italy.

The rest of this paper is organized as follows. Section 2 takes a brief overview about the state-of-the-art SGIS-3D system. Some striking 3D WebGIS standards will be presented in Section 3. We will describe in detail the JSG framework in Section 4. Section 5 mentions some related researches and their comparison. An application of JSG framework in COMGIS project will be presented in Section 6. Finally, we will make conclusion and future works in the last section.

II. The SGIS-3D system

The SGIS-3D system which was proposed in [22] aimed to support: (1) Some basic GIS functions such as: Zoom in, Zoom out, Spatial and Attribute Queries, (2) 3D functions: Display terrains, explore and rotate objects, show Level of Details, (3) Some advance functions such as: automatically installed plugins to view GIS-3D and Spatial analysis tools. Additionally, this system also has a tool to generate terrains and new spatial analysis operations. One of the most interesting functions of this system is the capability to share spatial analysis operations through network environment. This means wherever you are in the world, if you have some ideas about Spatial analysis operations and you want to check them, you only have to access to the homepage of SGIS-3D and provide some lines of processing scripts in JavaScript format and GeoVRML node definitions. SGIS-3D automatically interprets these codes and links them to given terrains. The final result is a user-defined spatial analysis operation and we can test it by interacting with 3D maps. This function is very useful for users in all over the world to share ideas about spatial analysis operations among people in WebGIS-3D platform. The architectural model for SGIS-3D system is described in Figure 1. Main activities of this model are:

- Web Clients send request to connect to SGIS-3D Server with purpose to display 3D terrains and query GIS-3D data. Then, Server automatically installs 3D plugins for Web Clients in case of first time visitor.

- According to clients' requests, Server locates and loads terrains in Map3D- a set of basic terrains having structures defined as GeoVRML terrains plus an attribute database name in conjunction with RDBMS.

- After loading terrains, Server executes a query to RDBMS based on database name in Map3D and clicked point in 3D maps (Id).

- If Clients want to use spatial analysis operations then Server will call some functions in SA (Spatial Analysis). It contains a set of pre-defined spatial analysis operations having structures: scripts and GeoVRML nodes. The extension of these files is .sa.

- Eventually, Server puts all terrains, node definitions and scripts into a GeoVRML file. The return result to Web Clients is a 3D map as well as Spatial Queries information in computers' screens. The connection to Server is terminated.

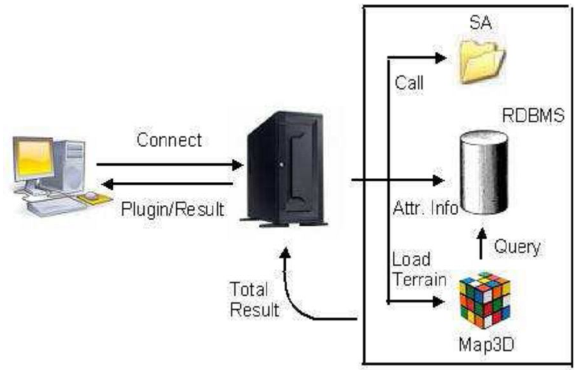

Figure 1. SGIS-3D Architecture model

Specifically, we consider 2 special cases: When the 3D map and chosen spatial analysis operations are displayed in client's side and when we need to add more spatial analysis operations (for sharing). These cases are exemplified by Figure 2 and 3.

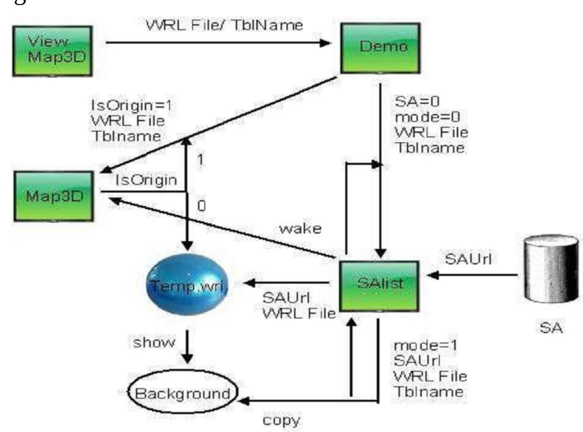

Figure 2. Display 3D maps, Spatial Analysis operations

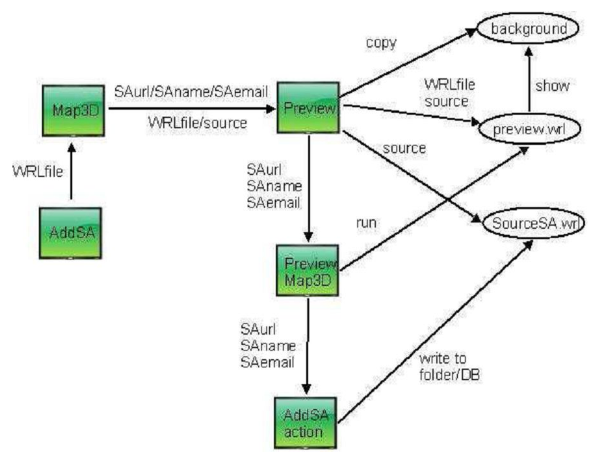

Figure 3. Add SA operations data flow

Details of the mechanisms in these cases can be referenced in [22]. Since then, we have already had a brief outlook on how SGIS-3D system could support making, displaying and sharing spatial analysis operations. Therefore, it is considered the best system in terms of analysis operations and terrain displaying. However, as mentioned in previous section, GeoVRML is very selective about browsers to display. Consequently, we need to look for other 3D WebGIS standards to replace GeoVRML.

III. Some 3D WebGIS standards

A. X3D

Extensible 3D- *X3D* [9] is the ISO standard XML-based file format for representing 3D computer graphics, the successor to the Virtual Reality Modeling Language (VRML). X3D uses GeoSpatial nodes to represent geographical data. The GeoSpatial nodes in X3D is derived from GeoVRML such as: GeoCoordinate, GeoLocation, GeoMetadata, GeoViewpoint, etc. X3D players are Flux, Blaxxun Contact, etc.

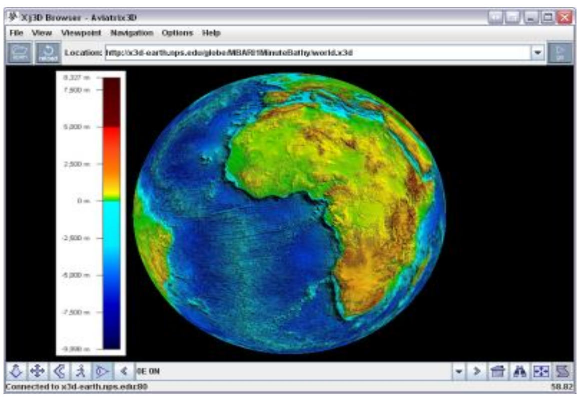

Figure 4. A X3D model of Earth Terrain

B. KML

KML (Keyhole Markup Language) is a file format based on XML enabling to visual geographic system through Internet. It has been developed by Google for use with the Google Earth application since 2004. KML is a XML grammar to orient for online visualizing geographic objects. It becomes a specification of the OGC (Open GIS Consortium). Base on documentation of OGC for KML, details are in 07-147r2 OGC [31]. It is used to encrypt and transfer geographic data to visualize in geographic browsers such as: Google Earth, ArcGIS Explorer, etc.

KML files include a set of features (place marks, images, polygons, 3D models, textual descriptions, etc) to visual in the Google Earth, maps and mobiles, or any Earth browsers supporting KML. Other data like tilt, heading, altitude which together define a "camera view" provide users more details. KML is usually stored in KMZ files which are zipped files with a .kmz extension. In order to view KML file on web, you need to install the Google Earth plugin.

C. GML

Geography Markup Language (GML) [37] is a XML grammar defined by the Open Geospatial Consortium (OGC) in order to express geographical features. Born on October 1999, up to now the latest version of GML has been GML3. GML serves as a modeling language for geographic systems, enables to create an open format for geographic transactions on the Internet. Note that the concept of feature in GML is very general and includes not only conventional "vector" or discrete objects, but also coverages and sensor data. The ability to integrate all of the geographic data is a key of GML.

CityGML is also a XML grammar used in 3D geographic system. Based on GML 3 (Geographical Markup Language 3), CityGML provides more special features for 3D city simulation. The latest version of CityGML is 4.0 and is designed as an open data model to define relations and classes for almost geographic objects in cities. CityGML focuses on geographic features, projections, visual attributes. It is intended to become an open standard and therefore can be used free of charge. Authors [18] supposed that CityGML meant for exchanging rich 3D urban objects in XML, or through a file or served through WFS (Web Feature Server). WFS is an essential method to generate CityGML output. The semantic information contained in the model can be used in the styling process which generates graphics and represented as a KML/COLLADA or X3D files. GML player is Java Applet or 3DGISCityvu.

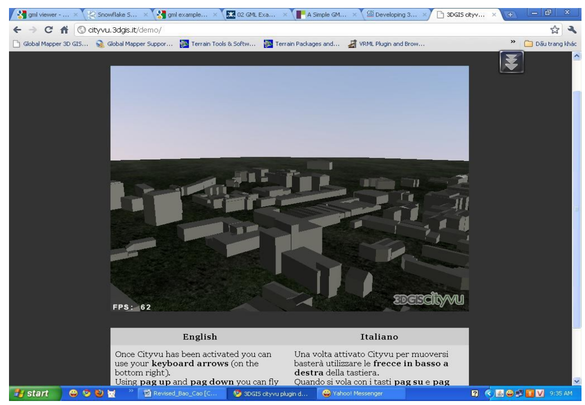

Figure 5. Example of GML

D. COLLADA

Collada (COLLAborative Design Activity) is a format in applications of 3D simulation. Collada has been developed by non-profit consortium Khronos Group since January 2006. However, Collada was original from Sony Computer Entertainment and was proposed by Rémi Arnaud and Mark C. Barnes. Currently, Sony Computer Entertainment shares the copyright of Collada with Khronos Group.

Collada defines a standard open source XML framework that enables to exchange digital data between geographic applications. Collada file usually has a .dae (digital asset exchange) extension. It focuses on compilation tools and exchanges data for appropriate applications. Collada is mainly targeted on Game industry [39]. In order to view Collada file (.dae) on web, Collada web viewer software is used. Recently, Google Corporation has proposed O3D [34] - an open source JavaScript API for creating interactive 3D graphics applications that run in a browser window: games, 3D model viewers, product demos, virtual worlds (Figure 6). It provides a sample COLLADA Converter, which can be used to import files in the COLLADA format, an open standard for 3D assets that is supported by popular content creation applications such as Sketch Up, 3ds Max, and Maya.

The main advantage of O3D has over alternative desktop or console based 3D rendering engines is that O3D may load, render, and transform models and their respective textures dynamically, using AJAX and/or COMET in real-time.

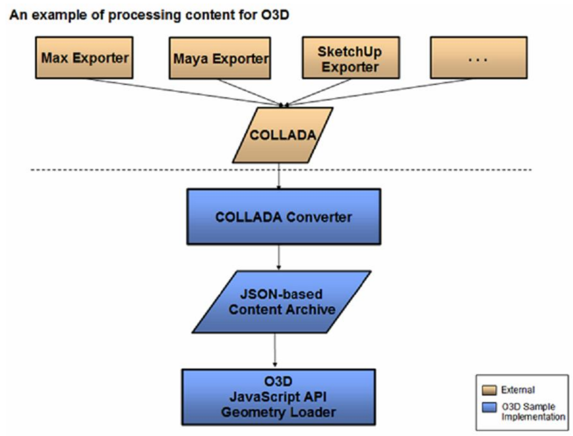

Figure 6. *O3D*

IV. A Framework based on JME, Splitting mechanism and GML

From details of some striking 3D WebGIS standards in previous section, we recognize that there are not as much standards that satisfy the free-use and browsers compatibilities conditions as wanted.

File formats	Advantages	Disadvantages
Geo VRML	High precision. GeoVRML supports conversion from geospatial coordinates to GeoVRML's cartesian coordinates.	GeoVRML does not address issues of time. Cortona3D Viewer plugin supports only Internet Explorer browser.
X3D	Easy to use because X3D is an ISO standard XML-based file format. X3D supports conversion from X3D geospatial coordinates to X3D's cartesian coordinates.	If X3D file has geospatial components, it work only with Xj3D browser.
GML	GML is a flexible format that other ones are able to convert to GML without losing information. There are a lot of softwares to view GML file.	Most GML files are too large to transfer geographic data.
KML	Easy to use. Especially, you can add some 3D objects on the map by using KML file.	Base on the Earth terrain given by Google.
Collada	Collada is a flexible format for storing almost geographic data. Other formats can convert to Collada easily.	There are less plugin to view Collada file on web. Colladawebviewer even does not have geographic extensions so that it is difficult to view terrain data.

Figure 7. 3D WebGIS standards comparison

For example, X3D works with Internet Explorer and Xj3D browsers only while in Collada standard, there are less plugin to view it on the web. In contrast, KML which are supported by Google Corporation can be viewed by many browsers. However, it is based on the Earth terrain given by Google and users can not add their own terrains. The last one, GML, is the most suitable standard for our research. Because it only requires Java applet to be installed in Internet browsers, indeed its advantages can be utilized. Therefore, *GML* is chosen to be the standard in our researches (Figure 7).

For the second and third problem, providing that we have a DEM terrain in conjunction with some *2D Polygonal Vector Data (2PVD)* in ERSI Shape standard, an idea of *splitting mechanism* is invoked. Basically, a Digital Elevation Model (DEM) [29], also sometimes called a digital terrain model (DTM), generally refers to a representation of the Earth's surface while a digital surface model (DSM) on the other hand includes buildings, vegetation, and roads, as well as natural terrain features. The structure of DEM ASCII file consists of the following lines.

ncols	*nrows*
xllcorner	*yllcorner*
cellsize	*NODATA_value*
<height_values_array>	

The two numbers *ncols* and *nrows* are terrain's size. The coordinates of center are given by *xllcorner* and *yllcorner*. The size in each cell is described in *cellsize* parameter and a collection of elevation values is also depicted as an array. Please note that all places that do not exist are marked by NODATA values. However, as stated in Section 1, the size of our inputted data is too large. Thus, it is hard to display them in Web browsers which require processing in a short time. Our idea is to split a DEM terrain into small ones and convert them to GML for displaying in Web with the condition that every small DEMs should have specific meanings. Because we have 2PVD, the division can be performed in this way. As we know, an ERSI Shape [17], [41] is a digital vector storage format for storing geometric location and associated attribute information. In specific, each Shape file can be in Polygon, Line or Point type. For maximal reduction of DEM/ DSM as possible, Polygon Shape file is chosen. This file consists of a single fixed length header followed by one or more variable length records. Each of the variable length records includes a record header component and a record contents component. In fact, the main file header is fixed at 100 bytes in length and contains 17 fields; nine 4-byte (32-bit signed integer or int32) integer fields followed by eight 8-byte (double) signed floating point fields.

From these, we generate the *terrain splitting and mapping schema* to divide the DEM terrain following by Polygon Shape files in 2PVD.

Step 1: Input DEM and 2PVD and number of processors.

Step 2: Divide Polygon Shape files in 2PVD into small polygons.

Step 3: Get coordinates of major points of polygons.

Step 4: Transform these coordinates following by projections in Polygon Shape files.

Step 5: Split the original DEM into some small ones following by continuous areas in Polygon Shape files and the number of processors in the system.

Step 6: For each processor, scan coordinates in small DEM which are equal to the coordinates of polygons belonging to it.

Step 7: Separate height values in DEM related to each coordinates

Step 8: Fill out blank values to form a new DEM file

Step 9: Output DEMs

This schema is a generalization of our early work [26]. In that literature, we proposed three algorithms namely *CBA*, *2OPS* and *SESA* for *Terrain Splitting and Mapping (TSM)* problem and performed a lot of experiments to check them in different conditions. Therefore, these algorithms are very suitable in our context.

However, sometimes the number of areas in each Polygon Shape file is too large. Plus, there is a possibility of clear difference between areas. Indeed, we must add some areas in a polygon into a part. Here is a modified version of the schema above for this situation.

Step 1: Input DEM and Polygon Shape file.

Step 2: Divide Shape files into some rectangular parts as follows.

- Create a grid whose number of cells is equal to a square number.

- Find out coordinates of grid nodes.

Step 3: Transform these coordinates following by projections in Shape file

Step 4: Scan coordinates in DEM which are belong to grid cells

While (i, j) in DEM and ($i <= a_1$) *and* ($j <= b_1$)

Get (i, j)

Step 5: Separate height values in DEM related to each coordinates

Step 6: Fill out blank values to form a new DEM file

Step 7: Output DEMs

After having small DEMs, we convert these data to the GML standard. Because it contains a rich set of primitives which are used to build geographic application specific schemas, for example: Feature, Coverage, Direction, etc; the conversion is more convenient. In specific, c*oordinates* in GML are represented by *geometry objects* and can be specified by any of the following GML elements: *<gml: coordinates>*, *<gml: pos>* and *<gml: posList>*. There figures are located in a *Coordinate Reference System* (CRS) which determines the geometry of each geometry element in a GML document. Unlike KML or GeoRSS, GML does not default to a coordinate system when none is provided. Instead, the desired coordinate system must be specified explicitly with a Coordinate Reference System (CRS) or Spatial Reference System (SRS). After we put all points in a CRS, thence a Polygon type should be defined as follows.

```
<gml:Polygon
gml:id="UUID_2046ae85-f8f1-4588-ae2d-bd2ca8586057">
    <gml:exterior>
    <gml:LinearRing gml:id="UUID_2046ae85">
    <gml:posList srsDimension="3">
       442062.515734 111702.025744 29.323486
       442062.515734 111744.025744 13.585449
        … (height values)
     </gml:posList>
    </gml:LinearRing>
    </gml:exterior>
</gml:Polygon>
```

The center of coordinate system is specified by *<gml: lowerCorner>* and *<gml: upperCorner>*.

```
<gml:boundedBy>
   <gml:Envelope  srsDimension="3"
         srsName="urn:ogc:def:crs:EPSG::7405">
          <gml:lowerCorner>
                 442085.337512 110929.09899 3.436534
          </gml:lowerCorner>
          <gml:upperCorner>
                442107.035163 110939.47181 14.952245
          </gml:upperCorner>
    </gml:Envelope>
</gml:boundedBy>
```

From all above, the necessary GML data are prepared to be displayed. What we should do more is to establish a 3D WebGIS system for holding this task. In this study, *JMonkey* [11] is chosen to be that one. Originally, JMonkey Engine (JME) is a high-performance 3D game engine, written entirely in Java. OpenGL is supported via LWJGL, with JOGL. For sound, OpenAL is supported. Additionally, JME is a community-driven open source project released under the new BSD license. Started from 2003 by Mark Powell as a side project to see if a fully featured graphics API could be written in Java, nowadays, it is currently being used by several commercial game studios as well as by university game classes. While the project will continue to support and develop its most popular 2.0 branch for years still to come, a 3.0 branch is quickly emerging in response to higher standards of the next generation in performance and hardware.

To develop JME to be a 3D WebGIS system, a lot of efforts have been done. First, two tools which allow creating 3D terrains from DEM and GML data in a CRS were set up. Second, we attached basic GIS functions such as spatial queries by points and polygons which displaying attribute information after dragging a rectangular area in the terrain. In this phase, we also attached an associative function which links attribute query results to 3D terrain. Third, some advance GIS functions such as 3D spatial analysis, Overlay, etc were installed to 3D WebGIS system. Finally, we created a 3D making box which allows building 3D buildings, trees and many other 3D objects in the terrain. These new objects are stored as GML objects.

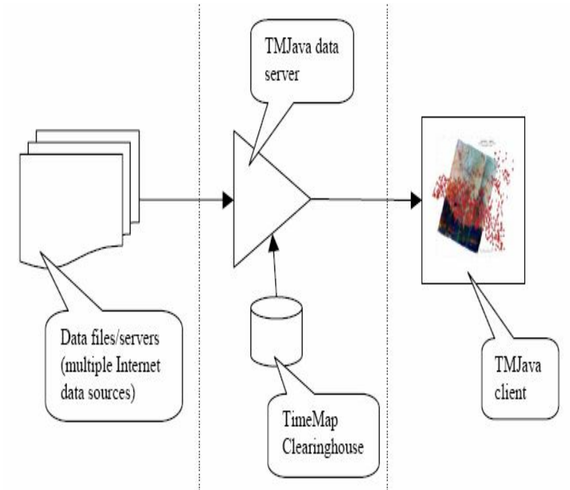

Figure 8. Alov Map mechanism

To associate 2PVD with DEM terrains, a 2D WebGIS system based on ALOV Map [14] is established. Created by Ian Johnson in 2003, the purpose of this open-source web mapping library is to display users' maps and exploit information on them without installing any tools on clients. Hence, GIS users can use some advance queries functions for their own tasks without prior knowledge of WebGIS setting up and administration (Figure 8). In this study, we have created a simple 2D WebGIS based on this library and added some more advance functions to it. Therefore, a link between 2D GIS data and 3D terrains is formed. Therefore, a visual look throughout the terrain will provide a significant use to users.

The whole framework based on JME, Splitting Mechanism and GML (JSG) is depicted in Figure 9 and Figure 10. Some main activities of JSG framework in Figure 9 can be summarized as follows.

- Original DEM terrain is passed through splitting and mapping algorithms. Since then, some small terrains have been created.
- A 2D WebGIS based on Alov Map library is used to view 2D Polygonal Vector Data in ERSI Shape standards. When users query an area in this map, then a link to its 3D representation is established.
- A conversion toolbox is created in JSG to convert DEM terrain to other 3D WebGIS standards, for example: GML and Collada. It is useful to integrate with other web mappings which work with those standards.
- Outputted terrains in one of two standards: DEM and GML are transferred to some components of JSG to process.
- Hence, in contrast with SGIS-3D where only two components are installed namely spatial analysis and query, a lot of processing components in JSG such as Overlay, Display Terrain, Spatial Analysis, Query, 3D Visualization and Modification are formed in JSG. For example, Overlay Component can overlay more terrains into one to form a historic map. All analysis operations' algorithms in Spatial Analysis Component are similar to our early work in [22]. In Query Component, these are two options: Spatial and Attribute Query. All kind of queries connect directly to PostgreSQL database. The 3D Visualization Component provides not only 3D functions in SGIS-3D but also a 3D object attach function. Thus, it is very useful to build users' terrains. Finally, the outputted terrain can be printed or exported to PDF for later uses.

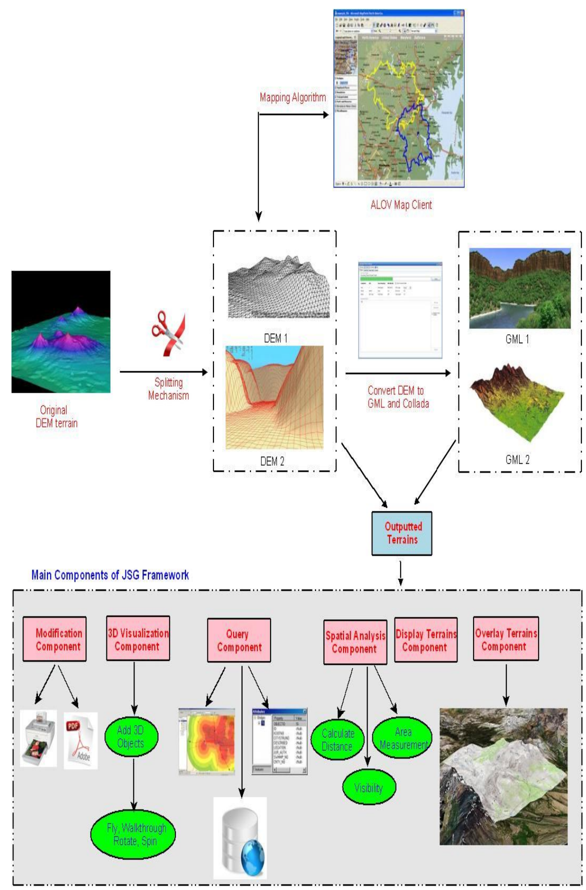

Figure 9. The JSG Framework

In Figure 10, we describe in details the Display Terrain Component. This engine starts with some terrains in users' folder. After opening them, users can choose loading other terrains from the central database. If possible, these terrains have to be decompressed to correct formats. Then, the Overlay Component is called to overlay these terrains together. Otherwise, a user terrain will be displayed instead. Finally, these terrains can be saved to the central database for reference. To reduce their size, a spatial compression technique is used. Then, memory for storing the central database will be saved.

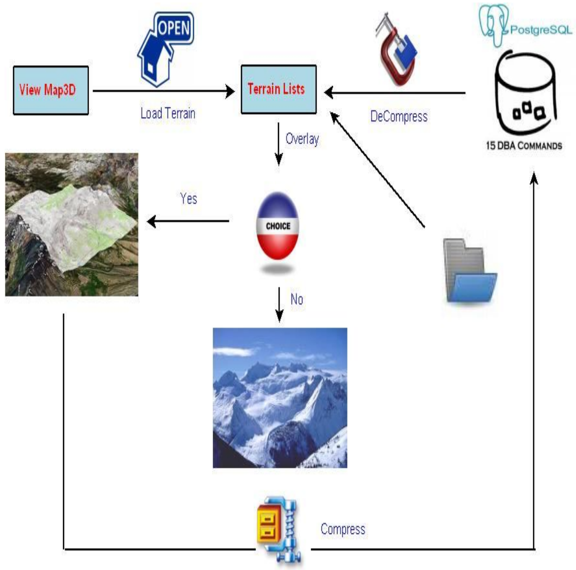

Figure 10. View terrains

Until now, we have already seen the JSG framework totally.

V. Related Researches

Authors [5] proposed GOOVI3D system which was a medium client-server where most of the functionalities were provided at the server side but some were also kept at the client side. The components of the system were VRML, HTML, Java and warehouse. The system however was a bit dependent on the file organization in the warehouse (i.e. mixture between files and DBMS storage). The major disadvantage is that the extended protocol IIOP was used (not available overall). SALIX [42] was a typical example of a thick client. The system was intended for interactive landscape planning, i.e. planning trees and bushes and simulating their growing. The GUI was based on the Cortona environment, using VRML and java to provide all the functionality. DBMS was used only to store the objects of interest. The significant aspect of this system is the extended functionality in terms of interaction and manipulation. There are still more improvements necessary toward making real use of functionality available at DBMS. In [7], the authors proposed a prototype of WebGIS-3D on the basis of 3D terrain visualization. The implementation of this prototype, Singapore Terrain Explorer (STE) successfully integrated the advantages of both 2D and 3D interfaces and achieved dynamic links between various interface components. However, it was quite simple and based essentially on VRML which requires a big supplement to geographic nodes. One more approach to develop 3D WebGIS systems was [40]. In this study, the X3D functionality was integrated into a 3D WebGIS prototype system. The prototype system was tested for terrain visualization using medium resolution DEM for parts of Japan. Authors [12] continued this approach by developing Open 3D GIS. It intended to enable a geographic database to be viewed in a 3D visualization on the web, using a web browser. The user could choose between two options: export 3D features directly to this through the cgi_o3dg.py script loading them from an already opened MapServer rendering window using HTML query methods, or load tridi-mentional meshes directly from PostgreSQL. One hybrid approach between VRML and X3D was also studied by Ming in [45]. In this study, a new solution was implemented using various open standards that enable 3D visualization of geospatial data as VRML or X3D model. The system offered a "browser only" solution, wherein not only the existing data from distributed Web Feature Service (WFS) and Web Coverage Service (WCS) could be visualized but also dynamic results offered through WPS could be accessed. However, the lack of this system is the browser compatibility when it works only with Xj3D browser. A recent study can be found from SGIS-3D system [22]. As being said before, this system has some limitations. Finally, in practical, Google Earth [38] is the most famous 3D GIS software in the world. Although KML defined by Google is the standard which exchanges GIS data in the Web, Google Earth still runs on Desktop environment and it lacks of some basic and all advance GIS functions as being mentioned in our prototype. This table below shows the comparison of some 3D WebGIS systems.

Table 1. Comparison of some prototypes

Proto -type	Geo Supports	Browser Compati -bility	Handle large terrain	Advance GIS functions
GOOVI	No	Yes	No	No
SALIX	No	Yes	No	No
STE	Little	Yes	No	No
Ninsaw at	No	No	Yes	No
Open 3D GIS	Yes	Yes	No	No
Ming	Yes	No	No	No
SGIS 3D	Yes	No	No	Yes
Google Earth	Yes	No	Yes	No
JSG	Yes	Yes	Yes	Yes

VI. An application in COMGIS project

This project is in the collaboration between Bolzano-Bolzen province (Italy), the Politecnico di Milano University (Italy) and Vietnam National University (VNU). Started from April, 2010, still in progress, the big aim of COMGIS is to construct a 3D WebGIS system based on collected 3D GIS data of this province to planning and optimizing network infrastructure [3] , [32], [33] for covering Internet 's signal throughout the city. Despite the fact that some Internet access points are not well-organized in suitable locations, the quality of signal is low as a result. This may prevent the deployment of high-quality applications over the Internet [35].

The area to study is the whole Bolzano-Bolzen, Italy. The Province of Bolzano-Bozen or South Tyrol is an autonomous province in northern Italy. It is one of the two provinces that make up the region of Trentino-Alto Adige/Südtirol, which is itself an autonomous region. The province has an area of 7,400 square kilometers and a total population of more than 500,000 inhabitants. Its capital is the city of Bolzano. Entirely located in the Alps, the province's landscape is dominated by mountains. The highest peak is the Ortler (3,905 m) in the far west, which is also the highest peak in the Eastern Alps outside the Bernina range.

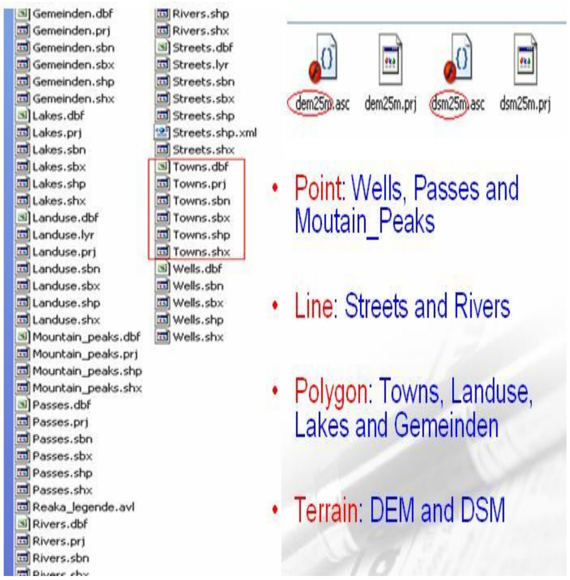

Figure 11. 2D and 3D GIS data of Bolzano

Data of this case study are in DEM and ERSI standard. As illustrated in Figure 11, the 2D Vector Data contain Point, Line and Polygon Shape files. We will use the Alov Map to display all Vector data in Web browser (Figure 12).

Figure 12. 2D WebGIS based on Alov Map

For Polygon Vector Data, we use splitting and mapping mechanism to map each area to equivalent terrain in DEM. Figure 13 shows the running time of our algorithms when splitting the original DEM terrain following by different number of polygons.

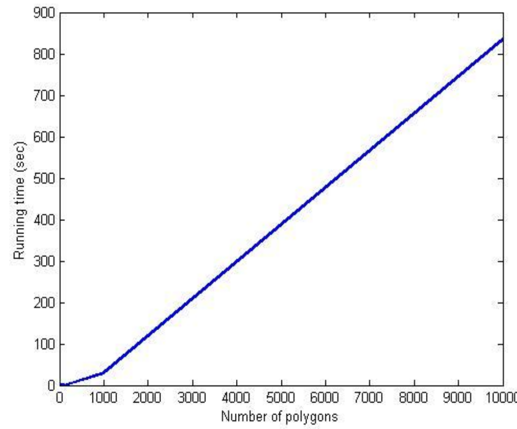

Figure 13. The running time of our algorithm

After dividing the original DEM terrain into small ones, we have used the conversion toolbox to convert these files to GML ones (Figure 14).

Figure 14. Conversion toolbox

Then, the results of outputted terrains in JSG are shown in these figures below.

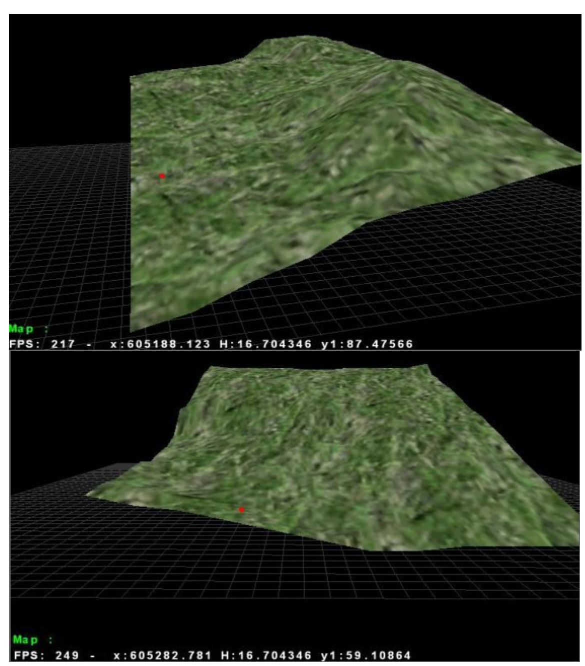

Figure 15. Outputted terrains

In Figure 16, we compare the terrain's display time between SGIS-3D and JSG in the same configuration which is described in [22]. From this result, we can recognize that the proposed JSG is faster than SGIS-3D in terms of displaying terrain following by various sizes of DEM.

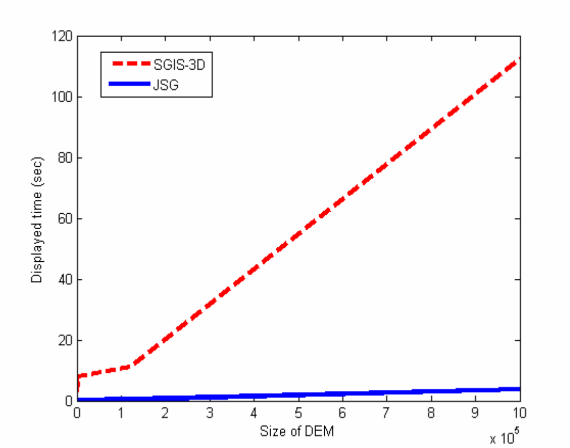

Figure 16. SGIS-3D vs. JSG

Finally, we illustrate some components in JSG. For example, the Figure 17 below shows Spatial Query Component. When users click on a point in this terrain, attribute information such as terrain's name and area will be displayed.

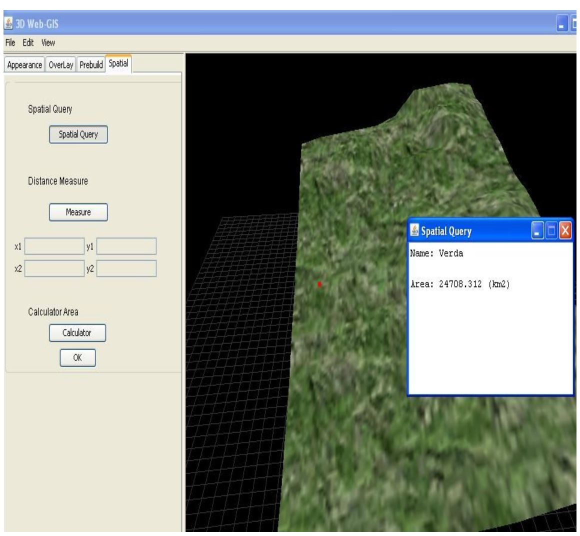

Figure 17. Query Component

VII. Conclusion and future works

In this paper, we present a development of our early work in [22] and [26]. Originated from three major disadvantages of SGIS-3D systems which are browsers incompatibilities, large terrain display and query capabilities, we have proposed a framework so called JSG to deal with them. A survey of some current striking 3D WebGIS standards as well as splitting and mapping mechanism are the main solutions for these weaknesses. Besides, JSG also extend the number of components in comparison with SGIS-3D. Additionally, this framework utilizes a hybrid solution between 2D- Alov Map and 3D WebGIS-JME for best representation and interaction in client side. A comparison between our framework with some state-of-the-art ones has shown its efficiency. Finally, we apply this framework for the COMGIS project. Some experiments and results also reconfirm our consideration.

In the future, we will study an effective method to store terrains in databases as well as fast displaying terrains through parallel computation.

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