3D DATA INTEGRATION FOR WEB BASED OPEN SOURCE WebGL INTERACTIVE VISUALISATION

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ABSTRACT:

Recent advances in open-source geospatial technologies in WebGIS allowed the visualization of a 3D complex environment on the web, exploiting realistic Globe reproduction of the real territorial asset. At the same time, in the field of gaming technologies, the new possibilities offered by open-source WebGL JavaScript libraries allowed the creation of Virtual Reality navigation models on the web. The integration between 3D GIS globe navigation models and VR environment navigation is a solution that offers a further level of detail in web navigation, exploiting the capabilities of web browsers in the best way. This research further contributes to this field, showing a workflow to integrate different 3D data in a VR and 3D WebGIS navigation model. The case study for this research is the new building of the University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC) of Enschede (The Netherlands). This work tests the online integration of variety of 3D input data that can lead to different Levels of Details (LoD) of the buildings inside the Globe-based WebGIS platform. The developed solution works on desktop and mobile devices using the capabilities of the most common web browsers, avoiding any software installation. The result of this work is based on completely open-source solutions that offers the possibility to navigate within a 3D model, which is useful for citizens, governmental or private institutions in decision-making processes. This work represents a first step towards the ambition to generate a web Digital Twin platform to combine datasets from different sources in a unique open-source solution.

1. INTRODUCTION

Recent advances in geospatial technologies allowed the visualization of a 3D complex environment on the web, exploiting realistic Globe reproduction of the real territorial asset (Pirotti et al., 2017; Pispidikis and Dimopoulou, 2016). This solution employs the features of GIS (Geographic Information System) for sharing geospatial information on the web (WebGIS). The last decades were characterized by the development and the diffusion of geospatial services based on the fruition and the visualization of vectorial and raster geo referred datasets connected with semantic information stored into a database (Zlatanova and Stoter, 2006). GIS development starts there. Then, the diffusion of a standard open-source protocol developed by the Open Geospatial Consortium (OGC) allowed the use of this technology to share online geospatial information using open-source local software of web applications developed with open-source technology (Brovelli et al., 2012).
To share the geospatial information online web server and Geospatial server implementation is needed. WMS (Web Map Service) and WFS (Web Feature Service) allow sharing of geospatial information, connecting the WebGIS visualization module to the Geospatial server (Michaelis and Ames, 2012). Various open-source solutions and libraries have recently been developed based on web services. At the same time, recent research in this field developed JavaScript opensource libraries able to generate a Globe-based WebGIS visualization exploiting the capabilities of web browsers (Scianna and La Guardia, 2018). This kind of solution exploits the capabilities of web servers that can host the .html pages and the JavaScript libraries necessary to visualize the WebGIS environment.
In recent research, the integration of software calculation or open-source remote operation modules based on Python and connected with the WebGIS platform through RDBMS (Relational Database Management System) server improved these solutions by offering further possibilities for real-time territorial analysis (Grippa et al., 2017; Shankar et al., 2018).
Several research fields employ this kind of technology because the online fruition of geospatial analysis data is a strategic tool for many scientific aims (Koeva et al., 2021; Li et al., 2020).
In the field of 3D modelling, recent advances in computer science allowed finding immersive 3D visualization solutions, usable in many research sectors. The development of VR (Virtual Reality) visualization technologies allowed developers to find new solutions for sharing different levels of information where the real fruition is not accessible (Bekele et al., 2018). Recent advances in VR tested many experimentations introducing AR (Augmented Reality), which integrates the real experience with the virtual one, offering users new levels of knowledge (Frontoni et al., 2018; Scianna et al., 2019). The recent spread of smart

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internet accessibility and the diffusion of fast internet connection allowed developers to test new possibilities to share online VR models. WebGL technologies emerged and allowed sharing on web complex environments. This open-source solution, based on Html 5 standard, exploits the capabilities of modern web browsers, allowing the visualization of complex 3D environments. These models are created dynamically inside Html pages (hosted in a web server) and integrated with JavaScript libraries, so-called WebGL libraries.
These developments in the last decade opened new opportunities in the field of VR, with the possibility to test and explore new solutions for complex 3D models navigation on the web for different purposes (Bian and Wang, 2020; Yuan et al., 2017). In this way, a complex 3D environment could be online navigable by users without installing any application on the device (pc, tablet, smartphone). This solution allows the employment of videogame technologies to create an interactive 3D environment on browser windows compliant with Html 5 standards (Scianna and La Guardia, 2020). WebGL technologies are used in many fields of research, from archaeological site exploration (Vennaricci et al., 2021) to medical simulations (Min et al., 2018), from industrial robot kinematic analysis (Dey et al., 2016) to flood simulation (Kilsedar et al., 2019). This solution allows the online navigation of complex 3D environments, offering users real-time interaction with the visualized environment (Huixian, 2020).
Therefore, the current research integrates the latest open-source achievements on WebGIS with the latest WebGL technologies to offer users information freely available on the web. In the next sections, state of the art in 3D WebGIS technology will be described, incorporating a variety of examples and applications. Then the structure of the integrated WebGIS platform will be shown, focusing on the WebGL environment integration. Afterwards, the results and the conclusions of the research will be presented, with a particular focus on the possible future integrations.

2. 3D WEBGIS: STATE OF ART

The evolution in computer science allowed in recent years to integrate 3D building visualization in virtual urban environment models for territorial analysis (Noardo et al., 2020). The creation of digital open libraries of 3D buildings inside a geospatial Globe visualization by public entities allowed in recent times to acquire and share information about municipalities, giving the possibility to freely download specific parts of the datasets to make further analysis (Sun et al., 2019). The complexity of the geospatial information useful for urban planning and governing needs the development of spatial information systems to manage large extent of 3D spatial and non-spatial datasets (Zlatanova, 2000). Recent experimentation integrated urban spatial databases and non-spatial information (buildings, parcels, and property owners) to improve cadastral data management (Ostadabbas et al., 2021). In this field, the use of WFS, based on the OGC protocol, allows to load the shared dataset into GIS software and then store the semantic features of each building into an RDBMS server. Recent experimentations in WebGIS also considered the integration of automated workflows based on python modules that load the acquired geospatial dataset to generate and publish elaboration for territorial analysis (Binh et al., 2020; La Guardia et al., 2021).
The integration between 3D GIS globe navigation models and VR environment navigation is a solution that offers a variety of opportunities for web navigation, exploiting the capabilities of web browsers in the best way (Wang et al., 2015). Using 3D city models as a dataset source for further analysis by municipalities technicians needs more accuracy in management and data updating (Eriksson and Harrie, 2021). Recent applications in many sectors of research also tested the integration of GIS and VR 3D environments produced from SfM (Structure from Motion) modelling, allowing the virtual fruition of the territory for touristic and educational purposes (Antoniou et al., 2020; Scianna et al. 2021; Pepe et al. 2021). For these applications, integrating different types of 3D geospatial datasets used in various devices available on the market leads researchers to focus their interest on new solutions. Therefore, WebGL technology represents a smart and open-source solution to share geospatial dataset for research, fruition, and educational purposes (Buyukdemircioglu and Kocaman, 2018; Huixian, 2020; Zhu et al., 2019). In fact, this choice provides stable navigation and fruition of complex geospatial datasets exploiting the capabilities of the common web browsers (Lee and Jang, 2019).
The possibilities for 3D data integration on the Web have evolved a lot in recent years. The overall ambitions towards digital twinning incorporate the integration of models based on 3D complex and big datasets such as 3D point clouds generated from TLS (Terrestrial Laser Scanner) SLAM (Simultaneous localization and mapping) survey, BIM (Building Information Modelling) models, or also 3D visualization of real-time IoT (Internet of Things). Some of these tasks are still very challenging to achieve and are still in the exploration phase within the scientific community.

3. MATERIALS AND METHODS

This research aims to develop a workflow to integrate different 3D data in a VR and 3D WebGIS navigation model with exclusive use of open-source libraries and software.
The selected case study is the city of Enschede, the Netherlands and more particularly the new building of the University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC). As visualised in Figure 1 the developed platform for web visualization integrates part of the 3D BAG open national geometric dataset with Image Based Model (IBM) and a Point Cloud Based Model (PCBM).

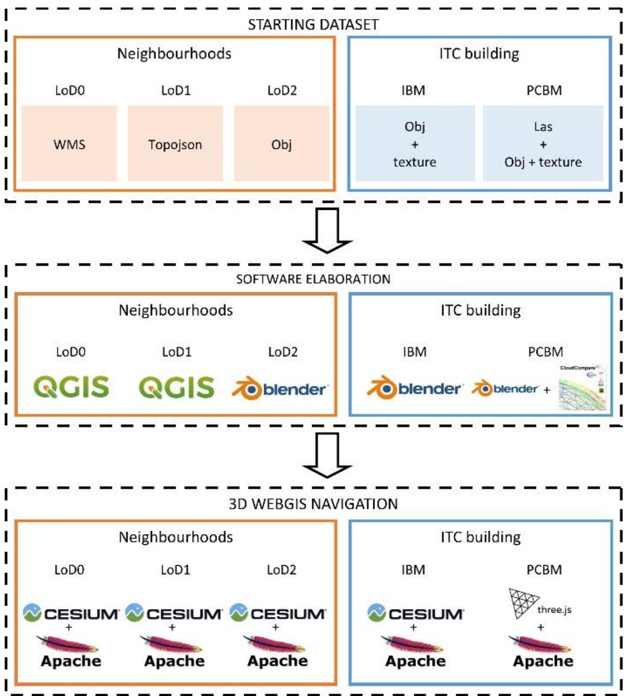

Figure 1. The schema of the dataset and the open-source solutions involved in the platform.

The integrated datasets consist of 2D WMS maps, 2.5D topojson files, 3D textured meshes from photogrammetric reconstruction and 3D point cloud models. In addition, a comparison highlighting the strengths and weaknesses of these loaded datasets is made.
The general workflow for this research has been divided into a chain of steps to achieve the final web navigation of the platform (Figure2).

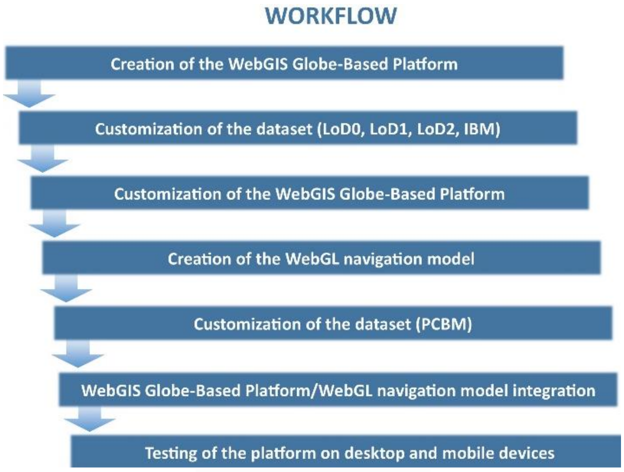

Figure 2. The workflow

The first step consists of the generation of the WebGIS Globe-based platform. Configuring an open-source web server, such as Apache (https://httpd.apache.org/) that hosts the environment is necessary. Then, the globe visualization is built using Cesium.js open-source JavaScript libraries (https://cesium.com/platform/cesiumjs/), which allows configuring the 3D GIS environment inside a .html page. Then the input datasets were integrated, considering different kinds of data in correspondence of different LoD in the web visualization (Table 1). In addition, functionality has been developed for the users to switch between the different visualizations of the 3D WebGIS environment (Figure 3).

Input dataset	Type	Acquisition Format
2D buildings map	2D polygon	WMS
2.5D buildings map	2D extruded polygon	WFS
3D buildings model	3D model	OBJ
ITC building (Images Based Model)	3D textured mesh	OBJ
ITC building (Point Cloud Based Model)	3D point cloud	LAS

Table 1. Input dataset integrated into the platform

The 2D layer that represents the buildings of Enschede (LoD0) is real-time provided by the WMS service directly from the 3D BAG site (https://3dbag.nl/en/viewer). A script inside the Html page allows to activate the WMS service and visualize the WMS map containing the 2D information of the buildings on the browser navigation. If the WMS service is denied by CORS (Cross Origin Resource Sharing), it is necessary to configure the "access control allow origin" in the Apache configuration files.

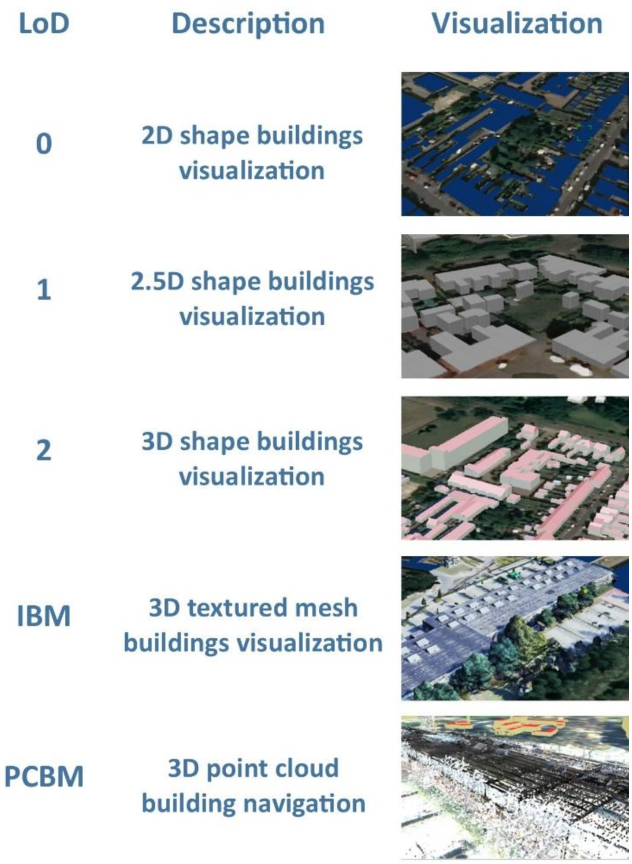

Figure 3. Description of the different LoDs.

The 2.5D topojson dataset (LoD1) is based on 2D polygon visualization extruded by the height value for each building. The base dataset is acquired by WFS in QGIS software. Then a QGIS plugin (https://plugins.qgis.org/plugins/topojson_writer/) converted the WFS extracted dataset into a topojson format. Then, the topojson dataset was loaded into the WebGIS platform, where the polygons were automatically extruded according to the height feature. The height of the represented structures has been considered a reference to automatically extrude the buildings on the WebGIS platform visualization (configured in the main .Html file).
The 3D models of the buildings of Enschede (LoD2) have been downloaded from 3D BAG choosing the corresponding tilesets available in the site (https://3dbag.nl/en/download). The tilesets have been downloaded in .obj format, with the maximum level of detail available on the 3D BAG dataset, showing the shapes of the buildings with the roof details. These tilesets have been merged and prepared for the WebGIS visualization using two open- source software solutions: Cloud compare (https://www.danielgm.net/cc/) and Blender (https://www.blender.org/). The first has been used to reset the localization of the datasets, the second has been used to define the boundaries of the focused area to visualize in WebGIS and to export the 3D model into Gltf. The final .Gltf file contained the colored surfaces of the buildings. It was loaded into the Apache web server, and then into the WebGIS platform (configuring the code on the main Html file to load and localize the 3D model).
Aiming at the complex 3D data integration, Imaged Based Model (IBM) and even the Point Cloud Based Model (PCBM) are tested in the current work. The 3D photogrammetric reconstruction (IBM) of the new ITC building visualized in the 3D WebGIS environment was based on draping of the openly available Google imagery over the geometries. It is necessary to underline that the dataset acquisition used for the photogrammetric

reconstruction represents only an example of possible dataset source to be inserted inside the 3D WebGIS platform and is not the focus of this paper. Structure from motion (SFM) based software was used to make the 3D mesh reconstruction of the ITC building, and then the textured models were simplified and exported in .obj format. The 3D mesh was finalized in Blender and then loaded into the Apache web server as a Gltf file. The 3D textured model was finally loaded into the WebGIS environment and located properly, scripting the code on the main Html file.
The last data integration experiment incorporates the VR visualization of 3D terrestrial laser scanning data acquired in April 2022 when the new ITC building was in construction. This 3D visualization of the PCBM was created in a WebGL environment where a 3D point cloud of the new ITC building was loaded inside the environment and properly aligned with the 3D model of the neighborhoods and the orthophoto base plan. The input dataset of the point cloud (in las format) was too big to be directly loaded into the WebGL environment. A strong simplification process in Cloud Compare software was necessary to obtain the final 3D point cloud (about 200 MB), which was finally converted in pcd format. The PCBM visualization has been configured with orbit controls command and enriched with a fog effect to add a more realistic experience on navigation.

3. RESULTS

The structure of the WebGIS Globe platform is visualised on Figure 4. It integrates different data sources and different visualization environments connected by links to offer users a smart web fruition experience. The current study used the new ITC building only as an example of data integration possibilities.

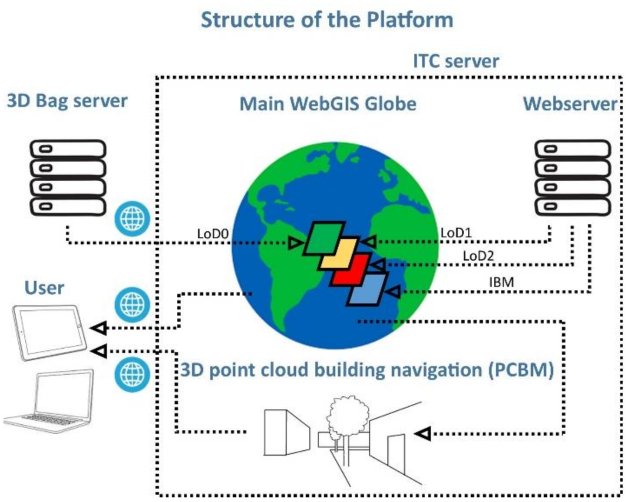

Figure 4. Structure of the platform and the connections between the different parts that involve the system.

A JavaScript popup link connected the 3D WebGIS Globe with the PCBM environment in correspondence with the image-based model of the new ITC building (Figure 5). The link connects the Globe navigation with a popup window that show a preview of the building visualization, including a photo, a short text description of the building and a rotating zoomed 3D model visualization (created in WebGL). The structure of the window was created in JavaScript inside the main Html page.

Figure 5. The popup link that connects the 3D WebGIS Globe with the VR environment of the new ITC building.

The popup window is connected with the web navigation model of the new ITC building, allowing users to explore the selected building in an outdoor point cloud-based environment (Figure 6). This building's navigation model (PCBM) is developed using Three.js (https://threejs.org/) open-source JavaScript libraries, based on WebGL technology and fully compliant with HTML 5 standards. Every web navigation model is created inside an .Html page that hosts JavaScript codes. These scripts activate and customize the 3D web visualization on the web browser.

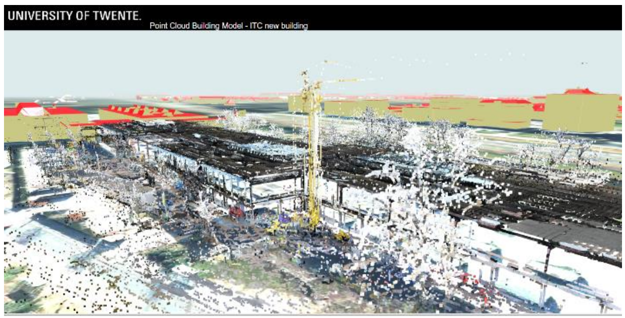

Figure 6. The VR web navigation (PCBM model) of the new ITC building.

The process followed for the construction of the WebGIS platform employed exclusively open-source solutions. Cloud Compare, Blender 3D modelling software and QGIS application have been used to convert the loaded dataset properly for the integration on the interactive web visualization. At the same time, Cesium.js and Three.js JavaScript libraries have been employed and customized to create the Globe WebGIS environment and the VR navigation based on WebGL (Figure 7).

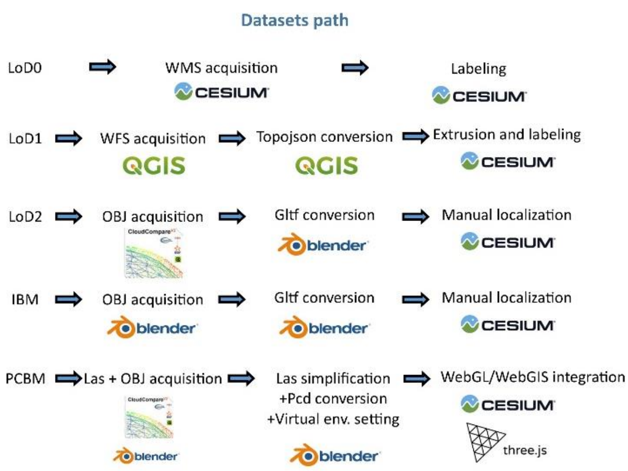

Figure 7. The description of the different elaboration paths of the datasets.

Different LoDs of the neighbourhoods' buildings can be visualized in the 3D WebGIS. We tested 3D data integration:

- The LoD0, that is based on the 2D visualization of the city buildings allowed by the WMS service.
- The LoD1 represents the 3D visualization of the buildings' volumes automatically generated by extrusion operations.
- The LoD2 represents the volumetric representation, including the roof shapes of the buildings.
- The IBM generated a 3D textured mesh visualization of the ITC buildings based on photogrammetric reconstruction.
- The PCBM, represents the point cloud visualization of the ITC buildings, allowed by the popup link connection with the virtual 3D navigation model.

The 3D WebGIS main environment is developed using an Html template connected with Cesium.js libraries, an open-source solution for sharing Globe WebGIS visualization on the web. For the current research, an Apache open-source web server was set up to host the necessary libraries and Html files to build the Globe navigation platform.
Comparing the different 3D model visualizations on web browsing tests, all of them appear whenever users activate them. On these tests, LoD1 environment is slower on loading, probably due to the real-time extrusion of the buildings' surfaces generated from the TopoJson file. The accessibility to the LoD0 strongly depends on the 3D BAG WMS connection. Instead, the LoD2 and the IBM are instantly loaded. The PCBM model takes more time to load the point cloud due to its dimension (about 200MB). The system can be visualized and navigated using the main common web browsers (Chrome, Safari, Firefox), offering a smart solution for WebGIS navigation. Furthermore, it is working on different devices (pc, tablets, and smartphones) with perfect compliance and web navigation performances.

4. CONCLUSIONS

The results of this work are useful for experts and users that want to share complex geospatial datasets, publishing sources at different scales and with different 3D input data models in a unique solution, avoiding the use of property software. Specialists can follow the developed workflow in the municipalities or private companies who want to build geospatial navigation models of complex scenarios accessible on the web. Future studies in this field of research could consider this work as an initial step for 3D data integration on the web. For instance, this solution allows integrating different datasets such as point clouds from TLS (Terrestrial Laser Scanner), 3D models from digital photogrammetric reconstruction, or also IFC (Industry Foundation Classes) models from BIM (Building Information Modelling) integration. In particular, considering the spread of interest in the scientific field of Digital Twins, the shown solution represents a first step for the development of Digital Twins navigation models on the web. In fact, this infrastructure could be integrated in the future with the implementation of real-time IoT sensor information. This integration provides a smart solution to visualize and elaborate real time analysis, opening new scenarios for the management of structures and urban environments.

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