

Web-based 3D GIS Spatial Visualization for Karunagappally Municipality, A Fast Growing Town in the Southern Kerala using Open Source Standards

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Abstract

The 3D modeling is an important research area in Geographical Information System (GIS) and related fields. Many of the GIS applications need the actual data of the three dimensional (3D) value for their modeling. The 3D visualization of the spatial data gives more ideas about the terrains. The 3D GIS technologies comprise of the combination of GIS and Information Technology (IT). The advancement in the computer and web related technologies boosted the research of 3D GIS. Currently several open source software are available for modeling and developmental purpose. The present study used Cesium JavaScript library for 3D rendering and its customization. Wamp server one of the premier webserver is used for the webhosting. For the development of user interface, HTML and PHP based scripting language was used. The present study aims to design and develop a 3D Web GIS application for effective visualization, utilization of information and dissemination of spatial data of Karunagappally Municipality, a fast growing town in the western coast of the peninsular India.

Keywords: Web-based 3D GIS, CesiumJS, Node.js, Wamp Server, JavaScript, HTML

1. Introduction

The 3D Geographic Information System (3D GIS) is an emerging technology in the field of Geoinformatics and is very useful and capable to produce to a great visual experiences modeling paradigms. The advancement in the field of Computer graphics and Web technologies entirely revolutionized the visualization concepts. Effective use of dynamic contents, third dimension and objects help to visualization and interpretations much better than before. This technology widely used in military affairs, geology, mining and oil exploration, town planning, medicine, pollution modeling, waste collection and management, urban planning etc. The model developed by 3D GIS was derived from a spatial data model, this models capable for provides basic geographical information from fetching the spatial data structure and spatial database. (Lichao *et al.*, 2004). Now these days many kinds of application require 3D data both for visualization purposes as well as carry out many spatial analysis. The spatial modeling methods used in 3D GIS are different from modeling objects that are present in the system.

The 3D models are available in commercial and open source platform. Premier commercial software which offering 3D visualization and manipulations are De Lorme is produces of Xmap, with 15% of the cost and at 80% of the functionality found in a traditional GIS. The manifold is the another commercial software having wide array of features and it can import around 80 different GIS formats and work with vector, raster and 3D terrain visualizations. This also includes exceptional Database Management System (DBMS) capabilities and built in map server for GIS based project publishing through internet. These can performs functions such as coordinate transformation, image rectification, geocoding and 3D visualizations. The premier GIS software called Arc GIS also provide applications called ARC Globe and Arc Scene for 3D Visualization. The open source software's are very important in the present scenario because of the availability and developmental easiness. The premier open source 3D models are virtual globe and Virtual 3D city models. City GML is the best standard used in the Virtual 3D city models. The major components of visualization models include data models, web services, 3D services and visualization. If City GML W3DS was used as the 3D service, X3D is the 3D representation and X3DOM for the visualisation purpose. Generally the City GML is not used for desktop applications because of its large size and extreme complexity. There are several 3D standards like Collaborative Design Activity (COLLADA)/Keyhole Mark-up Language (KML) and JavaScript Object Notation (JSON) are used in different projects over the world. JSON open standard format is used for data interoperability but KML is an XML based file format to represent geo-location on web applications such as Google Maps and Google Earth. COLLADA is also an open standard XML scheme to represent 3D models. With COLLADA integration, KML is being successfully used for 3D visualization on the web browsers.

The mid of 2002, Araya S. *et al.* proposed a compact and effective VRML-based terrain model. This model was capable to shorten the changes of display range and attach an automatic change over by employing the given terrain tiles in 3D space. In the beginning of 2003, Elizabeth introduced two paradigms for professionals using 3D GIS. This model was capable for handle the 3D models such as view shed, buildings and other manmade objects (Burson, 2003). Jing *et al.* presented the urban GIS using 3D GIS modeling technology especially in infrastructure design by coalescing the virtual reality and traditional GIS. The precise 3D GIS information and useful methods for promoting Kolbe *et al.* proposed a new method to combined model to represent spatial objects in regional models and 3D city, this model was capable of handle the real world entities like topological, thematic and geometric properties (Kolbe *et al.*, 2003). Zhu Qing *et al.* presented 3D GIS usage for the digital documentation of a special T'ang-wooden buildings based on personal computer. This study was the first 3D GIS modeling technology used in the digital cultural heritage (Qing, 2006).

The web-based development of a system by integrating GIS and web services helps the users to operate the system without having any prior knowledge in web technologies and geographical information systems. This web-based system, allows the sharing of geographical information and technical expertise related to GIS among users like professionals, researchers and even nonprofessionals (Huang *et al.*, 2016; Minner *et al.*,

2017; Ledoux *et al.*, 2018 and Chen *et al.*, 2019). The present study describe various steps and technologies adopted for the 3DWebGIS development as part of infrastructure mapping for urban development in “Karunagappally” in the Kollam district of Kerala, India. The present development done by integrating the PHP, Node.js Web Server, Object-Relational database by using a Web-based client/server environment and Cesium JavaScript Library. The major aims of the developed system was to develop a web-based 3D visualizing platform for data sharing and collaboration between experts from planning agencies, private entities and citizens. To access this geographical database often called spatial database by the user community, access to the internet facility and a web browser only is required.

2. Materials and Methods

2.1 Design of the 3D GIS

The design part of the present study is divided into various modules. The Node.js acted as the web engine. In the same time CesiumJS, a powerful java script library was used as the 3D GIS Engine. The Hyper Text Markup Language (HTML), PHP and Wamp Server were used as 3D GIS Graphical User Interface (GUI), 3D GIS GUI engine and 3D GIS GUI web engine respectively. The HTML and PHP language was used for the development of the frame work and interfaces. For web hosting, Wamp sever, one of the premier web servers was used. Cesium is worked as a 3D GIS Engine under the node.js runtime library. The Cesium app contains mainly dynamic scene, scene, render and core part.

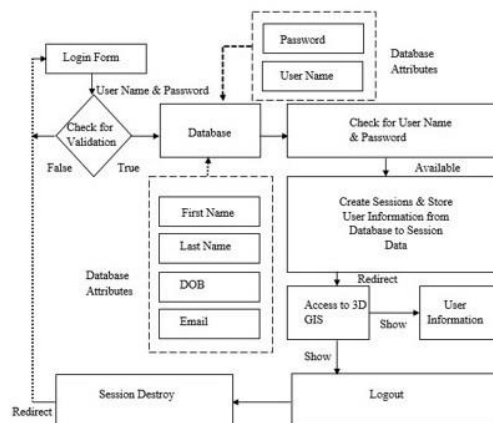


Figure 1 Overall System Architecture

The different layers of the architecture are responsible to add specific functionality and to raise the level of abstraction. The layer is usually dependent on the layers underneath it. Core is the lowest layer in Cesium and includes mainly low-level functions. These functions majorly include computations and calculations such as mathematical conversions, transformations and projections. Renderer layer is a thin abstraction over WebGL, which is the available GLSL function to provide shader programs, textures and buffers. The Scene layer is mainly responsible to provide overall functionality of the globe. It includes high-level globe and map constructs such as 3D globe or map, handling layer imageries from multiple sources, creation of geometries

and materials, camera control and animation. Dynamic Scene is the top-most layer of Cesium, which provides dynamic visualization of the data with the help of CZML. It allows storing the data in dynamic objects, loads and renders the lively objects altogether instead of rendering every frame.

Cesium virtual globe is based on Scene.js JavaScript 3D render engine and utilizes several third party scripts such as require.js, dojo.js and almond.js, which helps in developing highly interactive and user-friendly applications. Cesium is a 3D library developed to create digital earth, with rendering which is amazingly accurate to the real Earth. With 3D tiles, a developer can completely re-render almost everything to a digital canvas within a browser. The basic rendering principles guiding Cesium are not so different from Three.js. Three.js is a powerful 3D library for rendering 3D objects. By duplicating Cesium's spherical coordinate system and matching digital globes within both scenes, the coordinate system is very easy to integrate both separate rendering engine layers into one main scene. Various integration methods used in this work are as follows:

- Initialize Cesium renderer
- Initialize Three.js renderer
- Initialize 3D object of both libraries
- Loop the renderer

There are so many propriety and open source software available for 3D development. The advantage of open source over proprietary software's are mainly they are freely available in the case of Cesium all the proposed solutions are still in early development stage, it is quite difficult to select any one of the solution to provide entire functionality. They are provided with extensive collection of libraries related to import data from multiple sources, mathematical computations, and creation of 3D.

2.2 Implementation of the 3D GIS

The ultimate goal of the present project is to implement a dynamic 3D GIS map visualization of the study area. It was also included the visualization of different satellite imageries. The users were able to select different types of maps or satellite data depending on their need. The developmental activities of this project was classified into two parts for the easiness of the implementation.

The first part was the development of the Graphical User Interface using Wamp webserver, PHP scripting and MySQL as the database. The second part includes installation and development of 3D GIS using Node.js as web server and CesiumJS as the 3D engine. HTML and PHP scripts developed the design part of GUI. The user entry was verified with validation mechanism. MySQL Database Management System was used for the user management, it is a freely available database management software. If the verification is authentic it will allow the access to the 3D visualization rendering otherwise it will redirect to login module for the authentic login credentials. Wamp server was used as webserver for this module, which is also a freely available premier

web server. This server itself configured smoothly the PHP packages and My SQL database based environmental framework immediately after the server start. The second phase includes the installation of required software components and hardware configurations. The present project used 8.11.4 LTS version this is a client-side server with npm module. This module capable of handling modules that can be used with any AMD-aware loaders, such as require js, webpack, and browserify. In nutshell, it includes everything for application development. The Cesium Java Script library contains a Node.js-based development server for getting up and running quickly. The successful installation of CesiumJS will run on local host 8080 or 127.0.0.1:8080 port. Notepad++ a premier text editor used for the creation of Java Script library. In the current work, 3D Models in Cesium via the Primitive API for 3D spatial visualization and animations were used. This library supports three-dimensional models including skinning, individual node picking and key-frame animation using glTF an emerging industry-standard format for 3D models on the web by the Khronos Group, the consortium behind WebGL and COLLADA (.dae). With the help of JavaScript, the extents of the study area were coded as geographic coordinates. A WebGL enabled web browser will allows rendering 3D animated view of the study area. The CesiumJS has inbuilt Web Map Services (WMS) which allows to change the inbuilt maps or imagery services.

2.2.1 Implementation of the 3D GIS Web Engine

The Node.js is a JavaScript runtime library, which was built on Chrome's V8 JavaScript engine. The JavaScript engine V8 is the Google's high-performance open source engine, written in C++ and presently used in Chrome, the open source browser from Google. This can establish ECMA Script, and runs on Windows 7 or later, mac OS 10.5+, and Linux systems that use IA-32, ARM, or MIPS processors. The V8 JavaScript engine is powerful and capable to run standalone, or possible to embedded into any application made by C++.

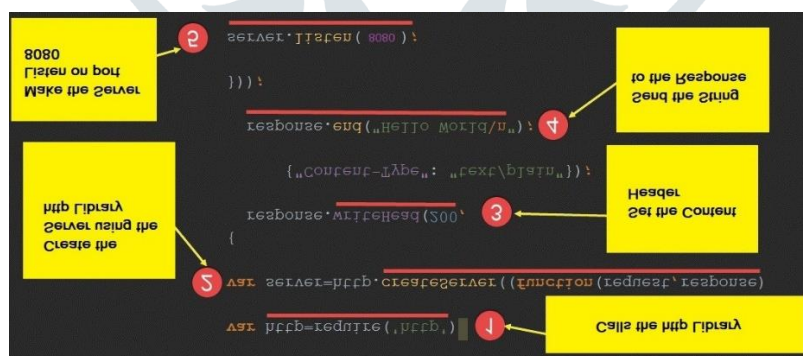


Figure 2 3D GIS Server Implementation

2.2.2 Implementation of the 3D GIS Engine

The CesiumJS is an open-source JavaScript library developed by an open-source community, with support from the Cesium Consortium. This library was mainly used for the creation of world-class 3D globes and maps. The main advantage of this is to create the leading 3D based globe and map for static and time-dynamic

content, with the best visual quality, possible performance, platform support, community, precision and ease of use. This library has been used to support a large number of open 3D geospatial formats. The open formats responsible for the interoperability of the full system of tools. The major open formats which has been used the Cesium library are 3D Tiles, gITF, quantized –mesh and CZML.

The 3D tiles format is capable for streaming massive heterogeneous 3D geospatial datasets such as Computer Aided Designs, three dimensional building models and photogrammetry. This graphics technology is very useful for the movie, research, expeditions and game related industries. The 3D tiles capable of define and design a spatial data structure and set of tile formats was used for 3D and optimize for better rendering and streaming of the geographical data. gITF is an open standard for 3D runtime asset format. Quantized-mesh enables the efficient 3D terrain streaming and rendering of spatial data. The CZML is a JSON based schema for describing time-dynamic 3D scenes such as of satellites and aircrafts.

2.2.3 Implementation of the 3D GIS Graphical User Interface (GUI)

The HTML page provided with web server makes a home page for the application. These pages were made up of html-based template files. The user can open this template files using a web browser. The queries, maps and objects which related to cartography are easily implemented through this html-based templates which designed by the web designer to the user community or common public. The Common Gateway Interface (CGI) program processes the map file settings and template files.

2.2.4 Implementation of the 3D GIS GUI Engine

The user interface of the present web mapping developed by PHP based scripting language. This module consists of tags and PHP scripts. The tags were added to the html-based template pages and the scripts provide the access to widgets and functions related to web mapping.

2.2.5 Implementation of the 3D GIS GUI Web Engine

The Wamp Server is a web development platform working on windows based operating system that allows creating dynamic web applications with, PHP, Apache2, MySQL and MariaDB. Best of all, Wamp Server is available free (under GPML license) in both 32 and 64 bit versions.

2.2.6 Interacts among Modules

The 3D GIS Graphical User Interface (GUI) was developed with Hyper Text Markup Language (HTML) and PHP scripting. Wamp server acted as the web server for the system. The GUI module consists of login module and database module. A registered user can provided username and password through the login form. The login module responsible for validating the credentials. If the credentials are genuine it allows accessing the 3D GIS visualization. If a new registration done through the register form, the credentials were stored in the

database. The present system was used MySQL as the database. The 3D GIS part consists of a 3D GIS engine and 3D web server. Node.js and Cesium are working respectively and they are interacting in a bidirectional way.

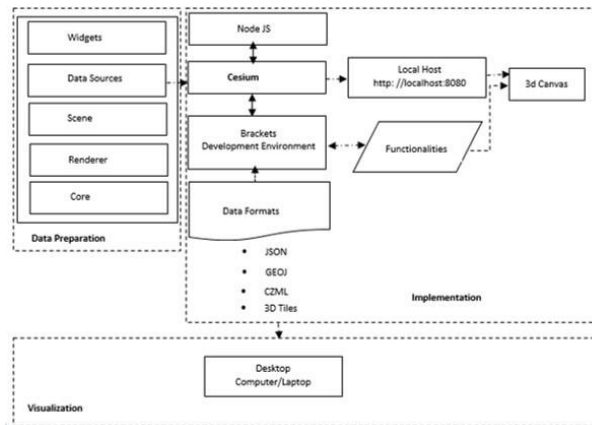


Figure 3 Interaction of modules

The Cesium architecture consist of data sources, scene, render and core. The Cesium also interacts with brackets development environment in a bidirectional way. The bracket development environment was responsible for dealing with various functionalities like displaying different views, zoom in and zoom out and also to interact with various data formats (fig.3).

2.3 Functions, Installation and Configuration of the 3D GIS

The major functionalities of the system include pan views, zoom views and rotate views. It also supports various satellite imagery likes Bing Aerial maps, Earth at Night, Bing Road Map and ESRI Satellite Imagery. The entity relationship diagram explains the structural illustration of the database design. The present data base consists of two entities name login and registration which is having attributes of username, password, first name, last name, date of birth and email. All attributes are used varchar data type except date of birth (fig.4).

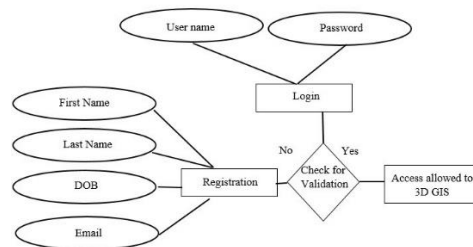


Figure 4 Entity-Relationship Diagram

Use cases help to determine the functionality and features of the software from user's perspective. A user case describes how a user interacts with the system by defining the steps required to accomplish a specific goal. Variations in the sequence of steps describe various scenarios. In the use-case diagram the use cases are displayed as ovals. The actors are connected by lines to the use cases that they carry out. The use cases are placed in a rectangle but the actors are not. This rectangle is a visual remainder of the system boundaries and that the actors are outside the system.

The present system has five modules they are,

- System Setup (Deals with working environment)
- Login Module (Handle the registered users)
- Visualization Module (Manage 3D layer rendering)
- Views Module (Perform Switching of different views)
- Functional Module (Perform pan, zoom and rotate)

In the case of 3D GIS, the user has no privilege on system setup (fig.5).

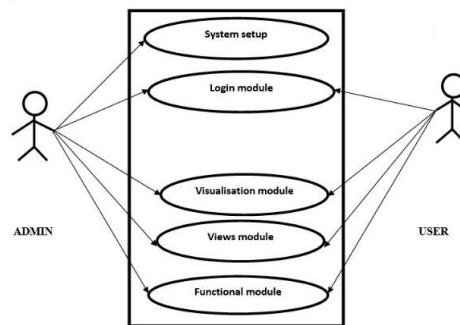


Figure 5 Use Case Diagram

In the present work, Wamp server version 3.2.0 was used as the web server. The windows based installer was downloaded from the official sites of the Wamp server and initiate the server installation process and was configured. The major functionalities include switch online/offline, manage Apache, MySQL services, manage server settings and logs. The PHP 7.4 was used for the development of GUI engine. For the proper functioning of PHP 7.2 to 7.4 require VC CRT 15 (Visual Studio 2017). The HTML codes were used to build the web pages. HTML Pad version 16.0, one of the premium web developing environment was used for the development. This frame work provide all in one HTML,CSS (Cascade Styling Sheets) and Java scripts code editor in a single environment and become more productive. CesiumJS 1.64, Node.js 13.4.0 was used as the 3D GIS engine and 3D GIS Webserver respectively.

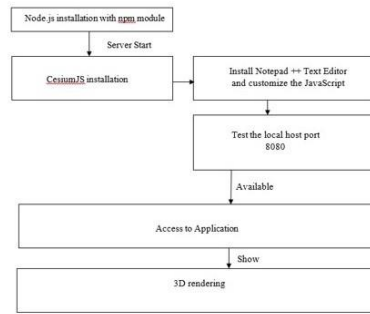


Figure 6 System Configuration

The create Server () method of http was used to creates a new HTTP server and returns it. The server was set to listen on the specified port (8080) and hostname. When the server is ready, the callback function is called, if it is fine informing that the server is running. Whenever a new request is received, the request event is called, providing two objects, a request (an http. Incoming Message object) and a response (an http. Server Response object). Those two objects can handle the HTTP call effectively.

```

const http = require('http');

const hostname = '127.0.0.1';
const port = 8080;

const server = http.createServer((req, res) => {
  res.statusCode = 200;
  res.setHeader('Content-Type', 'text/plain');
  res.end('Hello 3DGIS');
});

server.listen(port, hostname, () => {
  console.log(`Server running at http://${hostname}:${port}/`);
});
  
```

Figure 7 Server Configuration

3. Result and Discussion

The study area lies between North latitude $9^{\circ} 6'$ to $9^{\circ} 35'$ and East longitudes $76^{\circ} 33'$ to $76^{\circ} 53'$ comprising major parts of Kollam district, the second southernmost district of Kerala state, South India. The developed 3DWebGIS portal is very helpful and useful for the geographical or spatial data querying and visualization. The officials and public can use the system for governance and planning. The adopted methods and its implementation using MySQL, PHP, Node.js and Cesium JS were used to develop 3D and web-based GIS application. As per the visualized spatial data design, the application developed was rendered successfully. The Geographical Information Systems and web related technologies integrated through share geographical information effectively and easily, more than that 3D GIS modeling technology can provide a more lively and instinctive visual angle. The below figure shows that login and registration form of the application. This will allow only authorised access to the application. It should mandatory to registration for the accessing of 3D Visualisation. The application provides a synoptic view of the study area. It is modelled by gITF model of aircraft with animated propellers. It delivers an aerial view in open street map, high contrast black and white map, night time map and finally the views of the municipal area in a panoramic visual mode.

The main advantage of this development over proprietary and open source 3D software like Google Earth, City GML and iTowns was it is customized through a specific study area and the visualization supported 3D models, including key-frame animation, skinning, and individual node picking, using glTF an emerging industry-standard format for 3D models. Moreover the present work use ready-to-use binary glTF model for its visualization.

3.1 Screen shots

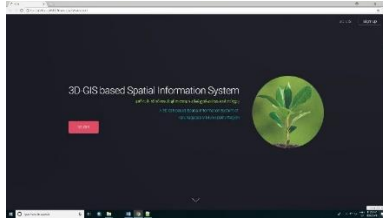


Figure 8 Home page of the 3D GIS

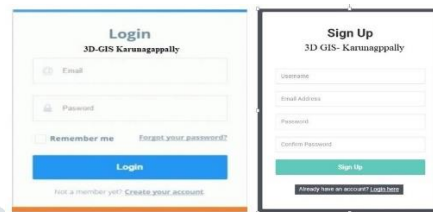


Figure 9 User Login and Registration



Figure 10 Aerial Views of the study area in different backgrounds



Figure 11 Study Area at Night Time and High Contrast Black & White Background



Figure 12 Panoramic View of the Study Area

4. Conclusion

Three dimensional Geographical Information System (3D GIS) is an emerging area with multiple applications in different fields starting from mining, geology, oil exploration, medicine, pollution modeling, natural resource management and inventory, disaster management, urban planning to military affairs. The major advantages of the 3D web-based services in GIS are the better visualization, easy and efficient data dissemination, sharing and processing of spatial data and that can be incorporated in the decision making of various natural resource applications and modeling. More over the system is also cost effective, easy to implement, operate and maintain the geographical content over the internet. Furthermore, the present work designed and developed a 3DWeb GIS application as part of infrastructure mapping for urban development in “Karunagappally” in the Kollam district of Kerala, South India. This development integrated the PHP, Node.js web server, Cesium Java Script Library and HTML based web templates. The main aim of the developed system was to provide a web-based GIS platform for collaboration and sharing of spatial content between

planning agencies, researchers, specialists and common users with minimum requirements of a web browser and internet facility access.

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