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Scalable Interactive Geo Visualization Platform for GIS Data Analysis

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***Abstract*—Visualization of geographic data finds enormous applications in location finding, disaster management, resource allocation, mobility pattern detection etc. In this Big Data era, location information is embedded in most of the available data. While many general purpose visualization tools available today fail to scale when handling big data and also lack visually appealing output, this paper aims to design and implement a web based application that offers Geographic visualization platform for users to create and publish interactive geographic maps based on large static as well as streaming geo datasets. The application is capable of integrating, analyzing and visualizing Big Data from a Geographic Information Systems (GIS) perspective and here the application is tested with urban data sets and twitter streaming data to perform visualization and data driven analysis of mobility patterns and social networking activity. The application can be deployed in the cloud and can be accessed by any browser on any smart device.**

Keywords- Geographic Visualization; GIS data; Online Interactive Visualization; Big Data Visualization; Cartography; Maps.

I. INTRODUCTION

Data Visualization, the pictorial or diagrammatic representation of data, has been in use to tell stories since ancient times. The history of visualization from early ages to modern times is detailed in [1]. Humans can comprehend a picture in an easier and faster way and hence proper data visualization that expose hidden patterns in data can lead to quick and intelligent decision making compared to analysis by other means on data stored in databases, reports or spreadsheets. With the availability of many tools, visualization of small datasets never seem to be a problem. But in the current Big Data era, we have to face the challenge of dealing with extremely large and highly complex datasets as the present day visualization tools fail to handle huge volume, varied velocity or variety of Big Data. Modern data visualization demands programmatic approach to achieve dynamic nature, high interactivity, identification of key variables and hidden patterns among large datasets exposing its current focus and to perform reliable predictions.

Interactivity provided by the visualization which deals with the ability of a user to directly seek, interact with or modify the underlying data, is a key element in the visualization effectiveness. Interactive nature of visualization opens up various perspectives of the same data leading to a clear picture than that obtain from monotonous static diagrams. This work aims to provide an online platform to generate map based interactive visualization on geographic data provided, catering to various user requirements, and which can be published..

II. GEOGRAPHIC VISUALIZATION/ GEO VISUALIZATION

Geographic Information systems (GIS) are those systems which enables to envision the geographic information of your data so that the data can be queried to receive results in geographic map forms. GIS were initially meant for storage, retrieval and display of geographic information [2], but analysis of spatial data is gaining more importance now. Apart from its use as a navigation aid, GIS have widespread uses in weather predictions, land and other resources planning, population forecasting, migration pattern identification etc.

According to [3], Geo visualization integrates methodologies from scientific/information visualization, exploratory data analysis and Geographic Information Systems to deliver tools, techniques and processes for visual exploration, analysis, creation and presentation of geo spatial data. It involves conversion of geographic data or location information to a format suitable for map plotting, creating tools for the visualization process, analytical study of the geo data to determine what is to mapped and mapping the information to the coordinates. While traditional maps being mostly static, modern maps demands more functionalities like zooming, panning, ability to drill down or detailing, interactivity.

III. RELATED WORKS

Information visualization techniques presents data and related patterns in visual form that is understandable and that provides new insights while supporting user interactions [4]. Many available visualization tools have to be downloaded and installed in the system of user before performing visualization on GIS data, which takes memory and hence not suitable for memory restricted systems like smartphones. On the other hand web based visualization tools can reduce the data volume, computing resources and hence the memory overload on user's side [5]. In a web based environment maps becomes dynamic, interactive and reachable to a wide section of users as a communication tool [6]. Online analysis and visualization of spatial data is topic of work given in [7]. In [8] a framework for online visualization of 3D city models which utilizes CityGML, an xml based

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format for storage and exchange of city models, and X3DOM, a DOM based HTML5/ X3D integration model.

In [9] authors explain a spatial data analysis and visualization system built as an extra layer on the TerraFly [10] map API. In [11], GIS data from an intelligent transport system (ITS) is used to visualize and analyze the performance measures related to the transportation management center is explained. Though it is an example of GIS data visualization, it is not a general purpose one. A visualization technique for spatiotemporal data is discussed in [12] that allows multi attribute visualization. Usage of GIS data for enhanced road map visualization is explained in [13], which is also meant for a specific purpose.

IV. GEO VISUALIZATION APPLICATION

This work aims to develop a web based application which receives GIS data, integrate and analyze the same and deliver interactive map based visualization as per user requirement which can be published. The application is capable of handling and analyzing social networking activity, mobility patterns, route mapping, resource consumption etc. Development of this application involves usage of several new open source cutting edge software tools. The approach followed in this work involves choosing the right representation strategy to the problem at hand while including the required information attributes and developing an appropriate and accurate model..

A. Dataset

Visualizations can be created based on existing data sets in the application library or user supplied geo datasets. Openly available urban datasets are used for testing this application. An example is the usage of metro extracts of Open Street Map (OSM) data of Dubai-Abu Dhabi available in GeoJson format at https://mapzen.com/data to create visualizations related to the city, like mapping Dubai Abu Dhabi aero ways. There is also provision to connect to twitter to access and plot geolocation of tweets. The NoSQL database MongoDB [13] is used to store the data.

B. The Architecture

This visualization platform is having a Single Page Application (SPA) architecture as shown in figure 1.

The frontend components of the application are grouped into three main layers. The data layer is responsible for connecting to the data sources and its processing. Initial data filter converts the data to an application compatible format and hand it over to the GIS detection module which analyze the data and identify underlying GIS patterns. Urban data plugins handle the urban data information and decoupling as different layers.

The data parser module in the second layer handle the parsing and error correction of the data and convert it into a plotting ready form. Data storage module handle storage of data and map relation manager module handle user and publishing management.

The third layer is the visualization layer which consists of data-view module that creates the views, structures, map-objects and data points from the data. This will be interacting with the visualization code module which consist of rendering engine and the drawing canvas. The rendering engine and two way binding handle the display of processed map as well as live interactions from the user.

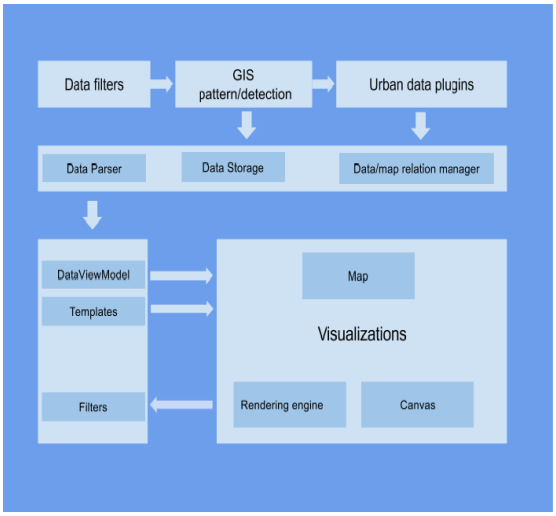

Figure 1. Architectural Diagram

C. Choice and Usage of supportive frameworks

The web based application is built on top of various HTML5 technologies. It uses nodejs as backend server and MongoDB as the database. Leaflet.js , Mapbox, knockout.js are used in the front end to create visualization. The application is to be hosted in Google cloud and can be accessed through any modern web browser.

HTML5 offers better connectivity with server, offline operations, options for local storage of webpages, diverse presentation schemes, varied device access, improved speed etc. This application is able to leverage the power of HTML5 compared to similar applications built around other technologies.

Nodejs [14] is one of the prevalent web servers in the current web development scenario mainly due to its event driven nature, simple configurations and scalability. JavaScript being its programing language, web application developers find it comfortable to use the same language to develop end to end features of a project. The main reason for choosing nodejs for this work is its event driven nature as it increases request handling capability drastically. For this work, the main source of traffic will the public requests of the published projects of the application, which can be effectively handled by nodejs. Admin user sessions and project management requests will also be handled by nodejs server. Server codebase is divided into sections like request handlers, functional modules and data access layers.

In the frontend of the visualization platform application, a combination of several open source mapping tools are integrated to offer users an easy to draw canvas with few mouse clicks. The application structure is created using

Knockout.js, a compact javascript library meant to create interactive display and editor user interfaces, with a Model-View-View Model [15](MVVM) design pattern

Leaflet is a light-weight javascript library for creating interactive maps suitable in mobile environment where memory and other resources are restricted. Here leaflet is mainly used to handle GeoJSON data and to plot the same to respective maps. The basic free version of Mapbox, which is a mapping platform for developers, is also utilized for zooming and related options in this application.

The datasets used by the application need not necessarily be relational in nature. Projects saves the working data as it is and retrieve and display the same without much modifications. Hence a document oriented database is required for this work and MongoDB the nosql open-source database is chosen which provides high availability and automatic scaling. MongoDB offers horizontal scalability and automatic sharding. MongoDB stores information as JSON-like field and value sets. The GIS data sets are stored as it is with a link in the data filed for the required tables. Most of the map plotting data is on GeoJSON and will not be converted into database field.

D. Implementation

This geo visualization platform is designed as a single page application resulting in a flexible solution in consideration of usability and performance. Here the project page once loaded will not be reloaded on saving or editing and in this way bandwidth is conserved. Initially loaded resources will be retained in the browser and extra resources if needed are loaded dynamically upon user requests. The edited or added data will be saved to the backend dynamically on the fly. User can upload new data or add any interactive feature in it without navigating from the current state of the project. Dynamic selection of maps and themes, customization of markers and highlights can also be performed in this way. All requests are made through AJAX and the server responds with the aid of a REST service.

In the frontend, different frameworks are utilized for templating, data binding, map rendering, data parsing etc. The application structure is created with knockoutjs and leafleat.js handles plotting of GeoJSON data to respective maps.

V. APPLICATION USE CASES

A. General Use Cases

This web application is a decoupled from any specific functionality or methodology of creating visualization. The core functionally is to bind GIS data with a geographical map. The application user can decide on the kind of visualization he needs. The map customization options can lead to various design options and heterogeneous maps.

GeoJSON data format is the standard data exchange protocol across the application and user can add any GeoJSON data to his project and choose from the various options that the project wants to be exposed to the public user. The published project can be rendered to any public user who is viewing that public URL through the browser. Depending on the options chosen by the creator users can interact with the map in different ways. The general data display methods include adding markers, drawing the map with polygons respective to data, adding circles and rectangular areas with selected colors on the map etc.

Publishable interactive Maps created using urban dataset of Dubai-Abu Dhabi is shown in figures 2 and 3. Figure 2 shows the map of water areas of Dubai and Abu Dhabi, while figure 3 displays Dubai Abu Dhabi aero-ways.

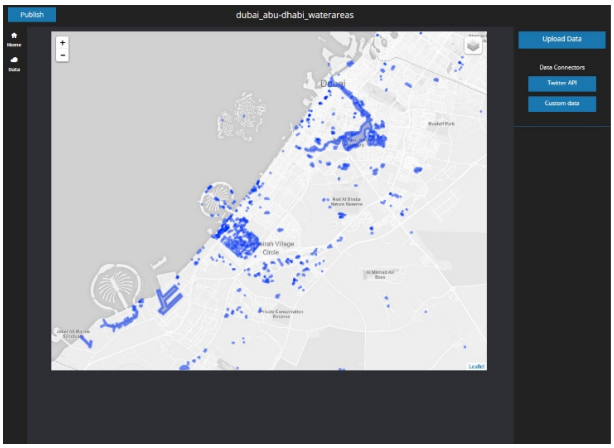

Figure 2. Map of Dubai-Abu Dhabi Water Areas

Application includes provision to add data through connectors and enabling data addition on maps by the user. Connectors include social networking applications APIs or any custom API source of GIS data. Another method is to enable addition of data to maps by users so that public users can also contribute new data to the map by following the application guidelines

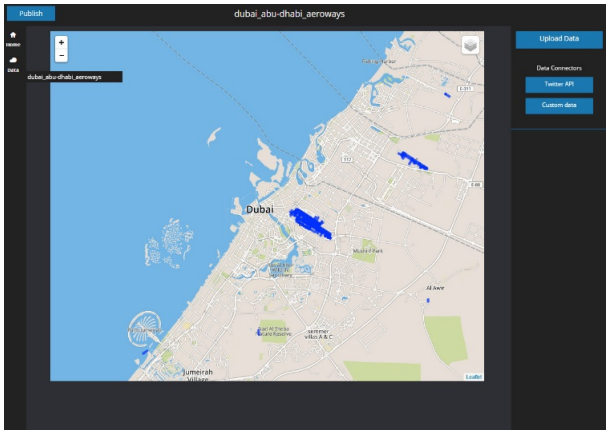

Figure 3. Map of Dubai-Abu Dhabi Aero-Ways

B. Social-centric data visualization

Geo data can be collected from social networking activities of users and in the current application prototype, the feature of connecting to twitter API is integrated. Tweets contains some textual data and related tags and APIs are available to collect these public tweets. The response data from the API contains the geographical information of the user along with the textual information. This data can be filtered against the context of required information which can be visualized on the map.

Two types of rendering is available, static data and streaming data. Static data is collected through the API and stored in GeoJSON format which can be used like any other data. Streaming API provides live streaming data which converted in to GeoJSON format in real time and plotted in the map. Streaming data visualization is having wide applications including live traffic analysis, crisis analysis or analyzing real time public response to a particular event.

C. Data collection and visualization by crowdsourcing

The feature of allowing users to add data on the map opens up a new source for data collection. Data thus added is used for rendering maps and at the same instant it is available to all the public users. Any new data addition will be shown across all the active viewers. Each map has its own way of adding data, the instructions and methods for data addition will be provided along with rendered view of the map. Based on the way the admin designed the user maps, data addition can be done with a few mouse clicks or by filling some information fields.

These kind of maps can be very helpful for survey, getting a detailed view of calamities or emergencies like flood, earthquake or epidemics. By integrating the bits and pieces of data supplied by various users can provide a clear picture of the actual situation. As an example, with wireless internet connection, people isolated in floods can supply geo data of their local area to the application and with the combined data from multiple users, severity of the calamity can be understood. In a real life scenario, when the South Indian city of Chennai was hit by the worst floods in December 2015 claiming hundreds of lives and thousands of people got stranded with no food or electricity, the information collected through crowdsourcing was used to map the flooded streets based on severity to have a clear picture of the situation aiding relief work..

VI. CONCLUSION AND FUTURE SCOPE

In this work, a web based single page application was developed and hosted on google cloud that provides a geographic visualization platform that can be used by the clients to create customizable interactive geographic maps based on GIS datasets and publish the same. It offers the crowd sourcing provision of data addition by users which can be shared among users and it is capable of handling static as well streaming data. The application is mainly targeting the possibilities of big urban datasets to gain insights with just few mouse clicks, which can be effectively utilized in areas like traffic control, route mapping, crisis management, mobility analysis etc.

This work can be expanded to integrate with WebGL for provision of 3D visualization and plotting algorithms can be developed for 2D to 3D rendering engine. Support for heterogeneous data types other than GeoJSON and inclusion of advanced analytic options can be implemented in the future. Facility of search option in published maps is another area where work can be proceeded further. As the dataset for visualization becomes bigger, application can use Hadoop Distributed File System (HDFS) to store data.

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