GeoViz Explorer: An Interactive Data Visualization Tool for Non-Experts

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***Abstract*—Geographical data visualization has played a crucial role in interpreting and analyzing location-related data in various fields and professions. GeoViz introduces an interactive web application designed to dynamically visualize geographical data. Users can upload data of specific areas, including required location names, which the application maps and places markers onto a United States map.**

Each mapped point allows users to explore detailed insights by displaying various types of charts such as bar charts, pie charts, doughnut charts or polar areas for that particular location. The application utilizes modern web technologies, including mapping APIs and advanced charting libraries, to provide a seamless and intuitive user experience. By integrating geographical mapping with dynamic visualization, this tool enhances the accessibility and interpretation of geographical based data, making it valuable for decision-making in various fields such as urban planning, marketing, and public health.

I. Introduction

The ability to effectively visualize geographical data has become increasingly important across many fields such as urban planning, marketing, public health, and environmental studies. Geographical data visualization allows users to find patterns, relationships, and trends within spatial datasets, leading to informed decision-making. However, available tools for geographical visualization nowadays often lack user interactivity or require complex configurations, making them less accessible to non-expert users.

GeoViz aims to handle these challenges by developing an interactive web application for visualizing location-specific data on a map of the United States. The application allows users to upload data related to geographical areas, with an optional condition of the inclusion of locations names for accurate mapping. By integrating modern mapping technologies and dynamic charting libraries, the application visualizes data points on a map and displays diverse types of charts such as bar charts, pie charts, or doughnut charts for each location. When clicking a map point, These charts provide detailed insights into the underlying data.

The primary objective of this project is to bridge the gap between raw geographical data and meaningful visualization, ensuring accessibility and ease of use for a broad range of users. GeoViz demonstrates a better understanding and interpretation of location-based data, making it essential for industries and researchers who depend heavily on analysis of Geographical data. Furthermore, the application's interactive features enhance user engagement, setting it apart from traditional static visualization tools.

This report discusses the GeoViz's design and implementation, including the methodologies, technologies, and results. It also explores the tool's potential applications, the challenges faced during development, and opportunities for future enhancements.

II. Related Works

Geographical data visualization has become important in spatial data analysis, enabling researchers and experts to interpret patterns and trends effectively. Existing solutions can be categorized into **general-purpose data visualization tools**, **specialized geospatial platforms**, **and interactive web-based mapping libraries**.

A. *General-Purpose Data Visualization Tools*

Tools like Tableau and Datawrapper provide powerful platforms for data visualization, including interactive mapping capabilities. Tableau supports geographic analysis with dashboards that can be customized, allowing the integration with various chart types like bar and pie charts[1].

Datawrapper offers simplicity and accessibility for non-expert users, enabling the creation of choropleth and symbol maps[2].

While these tools have some merits in usability and visualization features, their reliance on external software or platforms can limit user customization, particularly for domain-specific requirements like embedding real-time visualizations into web applications.

B. Geographic Information Systems (GIS)

GIS tools such as ArcGIS and GRASS GIS offer comprehensive spatial data analysis capabilities. ArcGIS provides a robust environment for advanced geospatial operations, including heatmaps and territory analysis. GRASS GIS, an open-source alternative, supports complex geospatial modeling and analysis.

However, GIS platforms often require specialized training for the users, making them less usable to general users or small-scale applications like the one proposed in this project.

C. Web-Based Mapping Libraries

Libraries like Leaflet and Deck.gl offers lightweight solutions for embedding interactive maps into web applications. Leaflet is widely adopted for its simplicity and support for custom overlays, while deck.gl supports large-scale data visualization with 3D capabilities.

These libraries provide a strong foundation for creating interactive visualizations, aligning closely with the goals of this project to integrate map-based interaction with data visualizations like bar charts and pie charts.

Specialized Geospatial Visualization Tools:

Kepler.gl and CARTO are advanced tools for geospatial data visualization. Kepler.gl supports large-scale, high-performance visualization with features like 3D maps and animation. CARTO, on the other hand, combines GIS functionality with data analytics, making it suitable for location intelligence applications.

While these tools are powerful, they are designed for large-scale, enterprise use cases, and their features may exceed the requirements for focused applications like the one presented in this project.

Visualization Techniques for Geospatial Data:

Common techniques for geospatial visualization include:

Choropleth Maps : Used to display data variations across geographical regions using color gradients. *Proportional Symbol Maps* : Representing data values with variable-sized symbols at geographic locations. *Hexagonal Binning* : Aggregating data points within a grid of hexagons to visualize density. These methods provide a range of approaches to visually encode spatial data, enhancing its interpretability and aiding decision-making processes.

Interactive Mapping for Web Applications:

Platforms like Flourish and Mapbox enable interactive data exploration through maps embedded into web applications. Flourish emphasizes ease of use with customizable templates for mapping, while Mapbox offers robust APIs for custom map design and interaction[3].

Interactive features align with the project's objective to enhance user engagement through clickable map points that reveal detailed visualizations such as bar and pie charts.

III. DESIGN

the flowchart of how GeoViz is designed is shown in figure below. The user uploads the dataset they desire to visualize and analyze, GeoViz then applies pre-processing on the dataset, separates locations in the dataset and analyzes the data. then the user have the option to choose if they want to mark these locations on the map. the user also have the option to filter the data by choosing only one location or compare to locations with each other GeoViz will visualize the data filter in various types of charts such as pie chart, bar chart and doughnut chart. if the user wishes to share their findings they have the option to export their outcomes as an image.

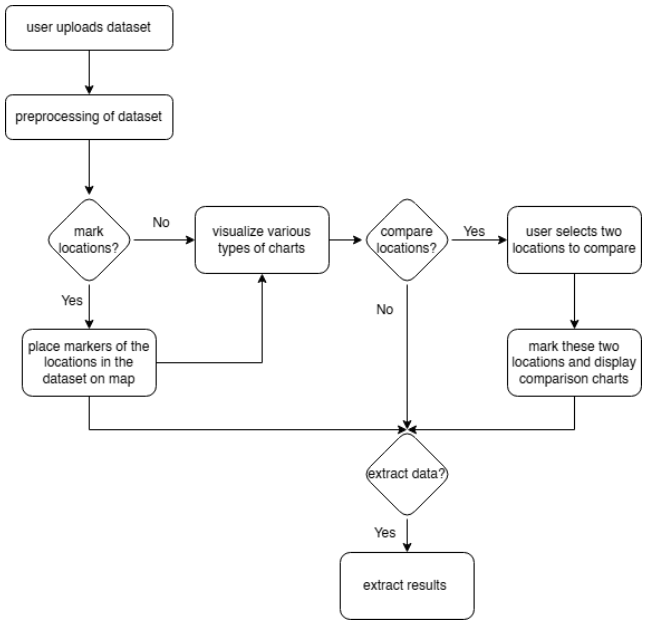

Fig. 1. GeoViz Flowchart

A. Front-End Design

The front end of the GeoViz Explorer web application is designed for intuitive user interaction and responsive data visualization. It leverages React.js to build a modular and efficient user interface, enabling seamless data input, geographical mapping, and dynamic chart generation. the figure below shows the major sections of GeoViz front-end design.

1) Navigation Bar: Implements a responsive header displaying the application title ("GeoViz Explorer") and an "Export as JPG" button for map downloads. Designed using custom styles for a polished appearance.

2) Upload Data this sections users can select and upload thier data set to GeoViz for pre-processing

3) Dataset Details This section will show the main details of the data uploaded to GeoViz such as the number of rows and columns in the data uploaded, the headers of columns that contain numeric and string characters that will be visualized in charts.

4) Progress Bar this section will show the progress of uploading the data and the preprocessing of data done and

if there is any error the progress bar will show incomplte and will show what are the errors to the user.

5) Map View: A central component that integrates Mapbox GL for rendering interactive maps. Users can upload datasets, visualize locations on a U.S. map, and interact with data points to generate detailed charts.

6) Side Bar: Provides options to filter data by properties and values using dropdown menus. Allows users to switch between chart types (Bar, Pie, Doughnut, Polar Area) and compare data for multiple states.

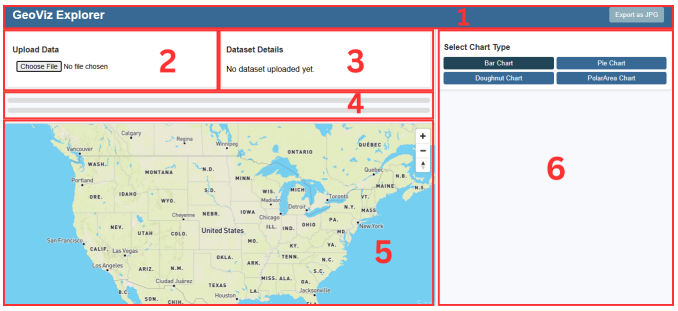

Fig. 2. GeoViz User Interface 1)Navigation bar. 2)Upload Data 3) Dataset Details. 4)Progress Bar. 5)Map View. 6)Side Bar

B. Back-End Design

For the Back-End Design GeoViz is hosted on localhost and all data are stored on local machine

1) Environment: the project code was implemented in visual studio code which is a suitable code editor for building and debugging web and cloud based applications and it offers good environment for both front and back end modules.

2) Language Choice: for the language choice for this project React was chosen to be the front lend language as it offers solid, cross-platform frameworks allowing GeoViz to be deployed on various types of platforms(Eg. web, phones, tablets..,etc). in addition GeoViz is focused on the visualization of Geographical data so the need of libraries that offer interactive, intuitive and responsive data visualization is essential and because React is open source it offers many useful and powerful libraries

for the back end NodeJS was used to open a local port and host GeoViz on local machine as the server for GeoViz.

IV. Implementation

GeoViz contains several files each handles one or multiple functionalities of GeoViz but the major files are ***MapView.js*** is handling most of the functionalities of GeoViz such as viewing the map for the user, places markers on the map, handling uploading of data and showing progress bar, handling the visualization of charts and exporting the data. ***preprocessData.js*** handles pre-processing the data and separating columns in the data set to be passed to the map.***FilterControls.js*** handles filtering of data whenever the user selects a location to display.***styles.js*** contains all styles of GeoViz of layout, containser and buttons sizes, fonts,..etc

Key Features

1.User-friendly data import and pre-processing capabilities: GeoViz offers modern User interface and easy access to all its functionality and performs pre-prcessing to data to ensure all locations are separate and located in the right place in map and offers accurate outcomes.

2. Dynamic, interactive visualizations: GeoViz offers various types of charts to visualize data and displays a map which contains locations that are provided in the uploaded data set. GeoViz also display details about the data set such as: number of locations, numeric data and string data.

3. Insight discovery and highlighting: GeoViz allows the select a specific location and get its own details and also it allows user to compare two locations and displays charts of both locations to help the user analysis and take decisions.

4. Collaborative features for saving and sharing User's visualizations: GeoViz allows the user to extract their outcome as an image so they can share their findings 6.Responsive design for desktop and/or tablet use: GeoViz is web-based so it can be used on various types of devices

Functionalities Implementation

a) Map Integration: this function of GeoViz is handled in MapView.js file. MapBox GL library is used to display and render the map of GeoViz this library offers user interactivity and it is flexible to customize and render.the user will be able to zoom in and out and navigate through the map. when the user uploads the dataset and chooses to display the locations on the map renderMarkers() is called and it will render and display the markers on the map. whenever the user clicks on one of these markers the handleLocationSelect() is called and it will highlight the location and charts and the map will change accordingly

b) Chart Visualization: this function is handled in MapView.js. Once the user uploads the data they have the have the option to select a specific location, locationselected() is then called and it will render and display one type of chart on the side bar, the user will have the ability to change between 4 types of charts(Bar chart, Pie Chart, Doughnut Chart and Polar Area)

c) Data Handling and Filtering: filtering function is handled in FilterControls.js. When the user selects a specific location on the map, FilterControls() is called and it will highlight the marker click on and change data set details and the charts display accordingly to this location showing only the data related to location selected, GeoViz also allows the user to compare two locations at once. GeoViz also performs Pre-processing to dataset when the user uploads the data this is handled in PreprocessData.js file when dataset is uploaded GeoViz will get transform the location names into Geo-Location coordinates to be displayed as a marker on the map, if the locations are already in coordinates GeoViz will recognize it and continues to mark the locations. GeoViz also separates different locations with their rows to be displayed in charts.the Limit for locations that GeoViz can handle is up to 100,000 locations

d) Export Functionality: This function is handled in MapView.js file. When the user clicks on export as JPG, handelExportImage() is called and GeoViz will render all the components and it will download the outcomes as an image to the user and then they can easily share their findings throughout all types of platforms

V. Results And Discussion

GeoViz could be used as an essential tool for non-experts that will help analyize and visualize complex Geo-location based datasets. When GeoViz Launches it successfully shows an empty map for the user and the user is able to see where they can click to upload the dataset as shown in figure 3 below

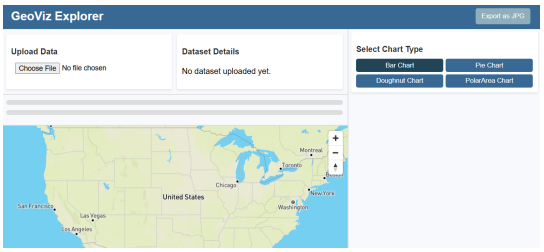

Fig. 3. GeoViz main Display before uploading data

when user upload data to GeoViz it displays the progress bar indicating that uploading and processing data was done successfully and shows all details about the dataset in the dataset details section(Rows,Columns,Numeric Columns,String Columns) as shown in figure 4 below

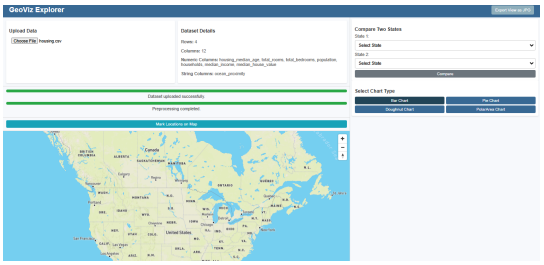

Fig. 4. GeoViz display after uploading data

when the user clicks on the "Mark Locations On Map" button GeoViz immediately marks the locations of the cities in the dataset uploaded on the map as shown in the figure 5 below.

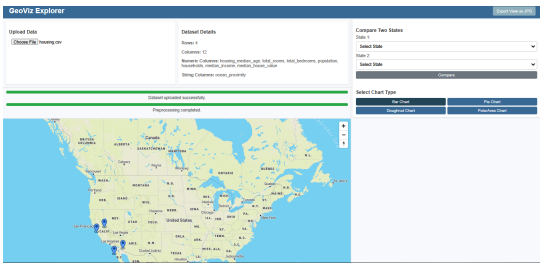

Fig. 5. GeoViz display after marking on map

when the user clicks on any of the markers on the map, GeoViz highlights that marker on map and displays charts on the sidebar and indicates the name of the location selected(if the dataset has names instead of coordinates) as illustrated in figure 6 below.

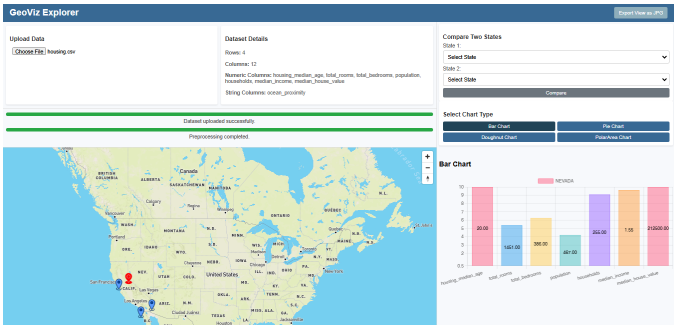

Fig. 6. Chart display of GeoViz

if the user wishes to compare two locations they can select two locations from the drop down menu which contains all locations from the uploaded dataset, GeoViz then highlights "Compare" button in green indicating that the user can interact and click on the button, after clicking on the button GeoViz highlights the markers of the two locations selected on the map and displays two chart for the user to compare the results generated as figure 7 below demonstrates.

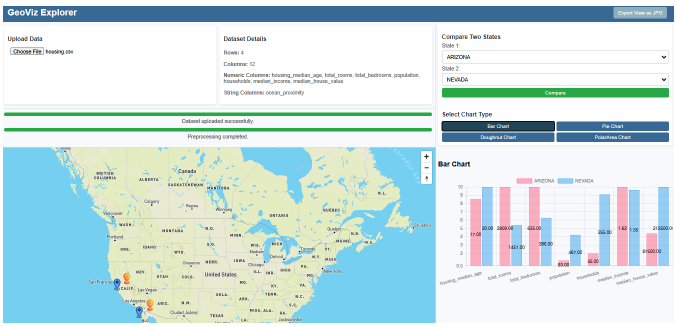

Fig. 7. Data Comparison of GeoViz

if there is only one location in the dataset uploaded, GeoViz will indicate that comparison in not possible and the need of two locations at least is required to do comparison as shown in figure 8 below

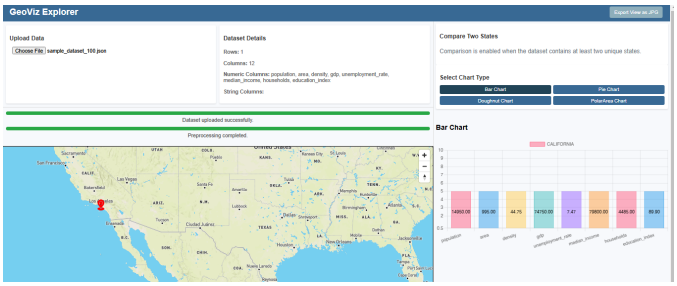

Fig. 8. Enter Caption

If the user wishes to export their findings as an image to share it they can click on ”Export as JPG” and GeoViz will capture and download a JPG image of the user’s findings as shown in figure 9 below.

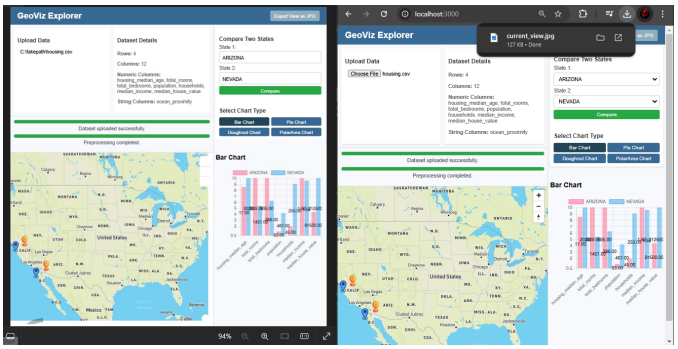

Fig. 9. Data export of GeoViz

Challenges and Limitations

One of the challenges faced was displaying a large amount of markers on the map, GeoViz initially was signed to pre-process and display the markers immediately on the map, and it used to crash due to having lots of markers being placed very close to each other,also it is not appealing to display a high number of markers at once for the user, as it will confuse the user and they might miss-click on once of the locations to visualize it because there will be a large number of markers condensed in one spot of the map. This issue was fixed by creating the ”Mark locations on map” button, so GeoViz will only mark on the map if the user chooses to by clicking on the button, and also the comparison is created so that the user can select the locations from a drop down menu which is more convenient than clicking on marker on the map.

another challenge was to determine the way GeoViz will handle data comparison and how the comparison is going to be displayed for two locations. The decision taken was to highlight the markers of the two locations on the map and display the chart in a double-display fashion on the same chart.

one of the limitations for GeoViz is that it is designed to handle data for 100,000 locations only.Another Limitation of GeoViz is that this version of GeoViz is made to handle data taken from locations in USA only

VI. Conclusion

GeoViz is a tool designed to help non-expert users to Visualize and analysis Geographical data easily and in an interactive and intuitive way where users can upload their data and mark locations on a map and be able to display the data in charts and do comparisons to data for two locations

Future works for GeoViz is adding data prediction by allowing users to upload data from different time and use machine learning algorithms to give predictions and suggest some information for the user. also expanding the scope of GeoViz to include and being able to handle larger dataset and display data taken from various locations and countries.

References

[1] **Steven Batt,Tara Grealis,Oskar Harmon Paul Tomolonis.**(2020). Learning Tableau: A data visualization tool

[2] **Mohaiminul Islam; Shangzhu Jin.**(2019). An Overview of Data Visualization

[3] **Charla M. Burnett**. (2023). Evaluating Participatory Mapping Software