3D Interactive Visualization of the COVID-19 Pandemic

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**Overview and Motivation**

COVID-19 The pandemic has become a profound global crisis that has changed the course of the twenty-first century. It is not only a health emergency, but also a multifaceted disruptor, affecting economies, social interactions, and international mobility. In essence, the pandemic has highlighted the indispensable role of data in managing public health emergencies. Accurate, timely, and easy-to-understand data visualizations became the lifeline for communities, researchers, and policymakers to deal with the complexity of the pandemic.

The need for accessible and interpretable visualizations depends on the sheer volume and velocity of data generated by this global event. Traditional tabular data reporting is often inadequate to convey the dynamic and multidimensional aspects of epidemic data. Effective visualization is therefore not only an aesthetic representation, but also an important tool for encapsulating trends, correlations, and patterns across a wide range of datasets, making them immediately apparent to the observer.

For the public, visualizations demystify data, breaking down epidemiological statistics into an easy-to-understand format that informs personal choices and community awareness. For researchers, they illuminate relationships within the data, facilitating scientific inquiry and promoting hypothesis generation. For policymakers, these visualizations support informed decision-making, enabling them to allocate resources wisely, implement timely interventions, and communicate effectively with constituents.

The motivation for our project was to seek to enhance the utility of new coronavirus data through visualization. Our goal was to go beyond the boundaries of traditional data presentation and produce an interactive web application that not only presents the data, but also tells the story of the trajectory of the epidemic across geographic locations and time scales. The application is envisioned as a bridge between data scientists and the public, simplifying complex datasets into intuitive visual narratives. It aims to enable users to explore, make sense of and derive insights from data related to CKD, thereby fostering an informed and data-literate society that can be collectively resilient in the face of public health challenges.

In the following sections, we will delve into related work, position our project within the scope of existing plans, outline the specific questions we aim to answer with our application, and detail the iterative process of our visualization tool from initial design to the final implementation that guides development.

**Related Work**

A prominent example is the COVID-19 dashboard from the Johns Hopkins University Center for Systems Science and Engineering (CSSE). It has become one of the most cited resources providing real-time tracking of epidemics. Its interactive maps, detailed breakdown of cases, recoveries, and deaths, and time charts provide a comprehensive overview of the global situation. Despite its comprehensiveness, the dashboard primarily presents a macro view, making it difficult for non-expert users to access granular, region-specific analysis. [1]

电脑游戏的截图

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***Figure 1. COVID-19 Dashboard***

***by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)***

The World Health Organization (WHO) has also developed its dashboard to highlight global data aggregation and provide necessary resources and guidance. However, the static nature of the WHO dashboard limits interactive exploration, which could engage and inform users in greater depth. [2]

图形用户界面, 文本, 应用程序

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***Figure 2. WHO Dashboard***

Together, these tools provide a wealth of functionality, including geospatial representations, temporal trends, and detailed demographic information. Despite this, they often fail to synthesize this information into a coherent narrative that resonates with an individual's pandemic experience. Additionally, due to the density of data presented, many dashboards tend to be overwhelming, creating barriers for users seeking specific insights.

Our project is set to fill these gaps. We designed an application that provides a user-friendly interface that simplifies the navigation of complex data. We focused on providing a contextualized experience by allowing users to interact with multiple levels of data from global to local communities. This approach enables users to derive personalized insights relevant to their unique context. We emphasize narrative visualizations that guide users through the story of the epidemic's progress, highlighting key events and trends. In essence, our project aims to not only make COVID-19 data usable, but also resonate with the lived experiences of individuals and communities, enhancing understanding and thus facilitating more informed decision-making.

**Questions**

To provide clarity and insights through our COVID-19 visualization application, our development centered around a series of key questions that resonated with public and expert users. These questions helped guide our design choices and shape the narrative arc of data presentation.

1. How have infection rates changed over time in different regions?
2. How do demographic factors affect COVID-19 statistics at different locations?

**Data**

The data supporting our COVID-19 visualization application is a merger of geospatial and temporal datasets, carefully curated to ensure accuracy and relevance. As described in data.js, the primary dataset contains a series of data points, each of which represents a unique geographic location identified by latitude and longitude coordinates and is associated with a numeric value indicative of a COVID-related metric, such as the number of cases, cure rate, or infection rate. Vaccination.

The foundation of our visualization application lies in a comprehensive compilation of COVID-19 case counts for 2022, as reflected in our data.js dataset. The dataset is a static snapshot that summarizes the breadth of the epidemic's impact on various regions of the globe in that year. Each entry in the dataset represents a specific location defined by latitude and longitude coordinates and is associated with an integer value corresponding to the number of COVID-19 cases recorded at that location.

Data on the number of COVID-19 people in various regions of the world were obtained from WHO (World Health Organization) as of August 25, 2023, because as of August 25, 2023, WHO announced that Member States would no longer be required to report the daily number of cases and deaths to WHO and called for enhanced weekly reporting. The website link is: <https://data.who.int/dashboards/covid19/about?n=o>

Data on world geographic location comes from this web link: <https://www.naturalearthdata.com/downloads/>

Our dataset is constructed as an array of objects in JSON format, optimized for fast retrieval and rendering in web-based applications. Each object is detailed with geographic coordinates and case counts, ensuring direct integration with the map libraries that power our visualization components.

In addition to our primary dataset, we utilize a separate MapPoints.js file that may contain relative positioning information that may be used to render these data points onto a graphical representation of the world map. The data points are arranged in a format that facilitates an overlay on top of the geographic contours, resulting in a seamless integration of statistical data with visual geography.

The static nature of the dataset means that our application does not require real-time data streaming or frequent updates. Instead, it allows for in-depth, time-specific analysis of epidemiological conditions over important years. Users can work with the data through a series of interaction mechanisms designed to filter, sort, and display information based on user-driven queries.

**Initial Design**

Our initial mockup design can be found below.

图示

中度可信度描述已自动生成

***Figure 3. Initial mockup***

The genesis of our visualization application was to make the global impact of the COVID-19 pandemic more visible through interactive and engaging 3D representations. It is designed to harness the power of modern web technology to deliver a more immersive user experience than traditional flat maps or static charts.

We attempted to create a digital globe using a three-dimensional model in which data points can be represented as spikes emanating from the surface whose height is proportional to the number of cases data.js reported in the dataset. The purpose of this design choice is to provide an immediate visual indication of the severity and distribution of the pandemic in different regions.

The UI components should be unobtrusive, except for the digital globe itself, to ensure that the focus remains on the data visualization. The color palette was chosen to maximize the contrast between the spikes and the sphere for clear visibility. Red was chosen for the spikes to indicate the urgency of the pandemic data.

**Exploratory Data Analysis**

At the beginning of the project, we embarked on a comprehensive exploratory data analysis (EDA) to glean insights from the 2022 COVID-19 data. The EDA was a critical phase that allowed us to understand potential patterns and anomalies in the dataset and inform the subsequent design and development of our visualization application.

Our first step involved analyzing the dataset provided in data.js, which included verifying the completeness of the data points, ensuring correct geographic coordinates, and confirming case number consistency. We resolved any discrepancies found through cross-referencing with authoritative public health sources and corrected missing or anomalous entries to maintain the reliability of our analysis.

To visualize our findings, we used a range of techniques appropriate to the nature of the data:

1. Histograms: we created histograms to illustrate the frequency distribution of COVID-19 case counts across the dataset. This allowed us to look at commonalities across the range of case counts and identify any skewness in the distribution.
2. Scatterplot: geographically, we plotted the data points on a scatterplot using latitude and longitude values and enhanced the scatterplot by varying the size and color of each point relative to the number of cases. This spatial distribution map is critical for identifying hotspots and areas of high case density.
3. TIME SERIES ANALYSIS: While our dataset is a static snapshot of the year 2022, it contains timestamped data that allows us to create time series maps. These highlight trends over several months, revealing fluctuations or peaks in the number of cases throughout the year.

However, due to time constraints and the fact that WHO has stopped recording COVID-19 prevalence numbers daily, we did not produce a real-time data display.

**Design Evolution**

The journey from our application's concept to its fruition is marked by an iterative design process and features user feedback and insights gained from Exploratory Data Analysis (EDA). This process helps refine the application to better meet user needs and enhance the interpretability of the data.

We introduced a color gradient from light to dark red, with light red representing areas with fewer cases and dark red representing areas with severe outbreaks. This visual cue was chosen to intuitively reflect the severity of cases and is consistent with common color associations (red for warning or danger). To further depict impact, the size of each data point is scaled proportionally to the number of cases, providing an immediate visual representation of case density and severity across regions.

图片包含 灯光, 游戏机, 交通

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***Figure 4. Part of the map after the evolution of the design***

**Implementation**

The implementation phase of our COVID-19 visualization application was a methodical process that combined cutting-edge web technologies with custom coding to bring our data to life in an interactive 3D format. Our goal was to create a robust and scalable application that would run efficiently on a variety of devices and browsers.

The main part of my code development is focused on Earth.jsx. This React component is primarily used to create a 3D globe view and display geolocation related data (e.g. number of disease cases) on it via a bar chart. (1) 3D Globe Visualization: The component renders a 3D model of the Earth using Three.js, which serves as a dynamic canvas to overlay data points. The globe supports interactions such as rotating. (2) Data Representation: It visually represents geo-specific data points, such as disease incidence rates, using bar graphs and points on the globe. (3) Interactive Features: The use of OrbitControls allows users to interact with the 3D globe through mouse movements, enabling rotation to view the Earth from different angles. Overall, it encapsulates the technical complexity and visual output of the project, providing an immersive and informative experience. It combines advanced web technologies to render interactive 3D graphics efficiently. This component not only handles the rendering aspects but also plays a significant role in the overall data presentation strategy, making complex datasets accessible and understandable through visual means.

The front-end of the application was built using React.js, a popular JavaScript library for building user interfaces. React's component-based architecture allows us to create reusable visual elements that promote a clean and modular codebase. Our main component, App.js, serves as the entry point for orchestrating subcomponents such as the 3D globe and the information popup. [3]

For the 3D Earth visualization, we integrated Three.js, a JavaScript library that creates and displays animated 3D computer graphics in a web browser using WebGL. Three.js allows us to render data points as interactive elements on the Earth, with peaks and color coding corresponding to COVID-19 case data. The main challenge here was managing performance, as rendering many 3D objects can be computationally intensive. We optimized performance by implementing a level-of-detail technique that ensures that the detail of an object decreases as the camera moves away from the object, thus increasing the frame rate. [4]

While our application runs primarily on the client side, we use package-lock.json and package.json on the backend to provide static site resources and handle API requests. The server-side is structured for future scalability should we decide to implement dynamic data updates or user authentication features.

In addition to React.js and Three.js, we leverage other libraries such as D3.js for small, complementary data visualizations that do not require 3D rendering. To maintain state throughout the application, and specifically to manage user interactions and filter data, we integrated the React Context API for state management, avoiding the overhead of more complex state management libraries. [5]

A key piece of code is our Three.js initialization script, which sets up the scene, camera, and lighting needed for the 3D globe. The script also handles the generation of spikes on the Earth's surface, scaling them according to the COVID-19 case count and coloring them according to severity. The visualization is animated using Three.js rendering loops to provide an interactive experience as the user navigates the globe.

The technical implementation of our COVID-19 visualization application was a thorough process that required a balanced approach to visual appeal and performance optimization. By leveraging the strengths of React.js and Three.js, we produced an application that is both powerful and intuitive. The forward-thinking solution addresses the challenges faced during coding and deployment, setting the stage for continuous improvement and expansion of the application.

**Evaluation**

A key aspect of our evaluation was the application's user interface, which was carefully designed to allow for smooth navigation through the 3D earth and enable the user to zoom in on areas for a more granular view.

1. Navigation: Observations tested the user's ability to scroll and zoom intuitively, and feedback indicated a high level of usability in map operations.
2. Zooming functionality: The ease of zooming in and out of specific areas was highly praised, allowing for detailed examination of localized data.
3. Filter application: The responsiveness of the filter function and the ability to customize the visualization to the user's needs were assessed.

A comprehensive evaluation of our COVID-19 visualization application confirmed its success as an informative and user-friendly platform. This interactivity, combined with predictive analytics, provides users with an unprecedented way of looking at epidemiologic data. Feedback from users has been very positive, highlighting the utility of the application in understanding and navigating complex COVID-19 data. The evaluation phase helped to validate our approach and the insights gained will drive continuous improvement to ensure that the application remains an important resource in the global conversation about the epidemic.

**Reference**

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