# Real-Time Data Analytics of COVID Pandemic Using Virtual Reality

Sharad Sharma(✉), Sri Teja Bodempudi, and Aishwarya Reehl

Department of Computer Science, Bowie State University, Bowie, MD, USA
{ssharma,sbodempudi}@bowiestate.edu,
reehla0924@students.bowiestate.edu

**Abstract.** Visualizing data effectively is critical for the discovery process in the age of big data. We are exploring the use of immersive virtual reality platforms for scientific data visualization for COVID-19 pandemic. We are interested in finding ways to better understand, perceive and interact with multidimensional data in the field of cognition technology and human-computer interaction. Immersive visualization leads to a better understanding and perception of relationships in the data. This paper presents a data visualization tool for immersive data visualizations based on the Unity development platform. The data visualization tool is capable of visualizing the real-time COVID pandemic data for the fifty states in the USA. Immersion provides a better understanding of the data than traditional desktop visualization tools and leads to more human-centric situational awareness insights. This research effort aims to identify how graphical objects like charts and bar graphs depicted in Virtual Reality tools, developed in accordance with an analyst's mental model can enhance an analyst's situation awareness. Our results also suggest that users feel more satisfied when using immersive virtual reality data visualization tools and thus demonstrate the potential of immersive data analytics.

**Keywords:** Virtual reality · Immersive VR · Data analytics · Data visualization

## 1 Introduction

Data visualization is an interdisciplinary field that deals with the graphic representation of data. It is an efficient way of communicating when the data is big as for example COVID-19 [1]. Data Visualization techniques are extremely effective in communicating graphical data around COVID-19 to major audiences like policymakers, scientists, healthcare providers, and the general public. Data visualization in an immersive environment can take the concept a step further by using techniques to immerse the user in the environment. The charts and graphs can be presented for detailed analysis and interactivity. Graphical representations of data are fundamental for the understanding of scientific knowledge [2]. Visualization always plays a key role in exploring data especially when the data sets are large. Decision making increasingly relies on data, which comes at us with an overwhelming velocity, and volume, that we cannot comprehend it without adding some layer of abstraction to it. Without visualization, detecting the inefficiencies hidden


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in the data, patterns, and anomalies of that data would be impossible to find [3]. Data visualization fills this gap and gives the user the user flexibility to visualize and analyze the data in a better way.

An immersive environment is an artificial, interactive, computer created world to engage the user. It creates a perception of “being there” in a physical environment. This perception is created by encompassing the user of the VR system with images, sound or other visual effects to provide an engrossing environment. An immersive experience pulls a person into a new enhanced environment with more engagement. With an immersive environment, the end-user can respond to issues more rapidly and they can explore for more insights – perceive data differently, more imaginatively. It promotes creative data exploration. Data Visualization in an immersive environment allows for a more human-centric approach for visualizing data. The user can find new relationships and hidden patterns that one cannot find otherwise. The concept of using bar graphs and charts to understand data has been around for centuries, however data visualization in 2D vs 3D provides an immense impact on how the data is perceived. It helps in analyzing the data more accurately. COVID-19 cases have been on a rise and are increasing rapidly. We have developed an immersive environment for data visualization of COVID-19 data as shown in Fig. 1.

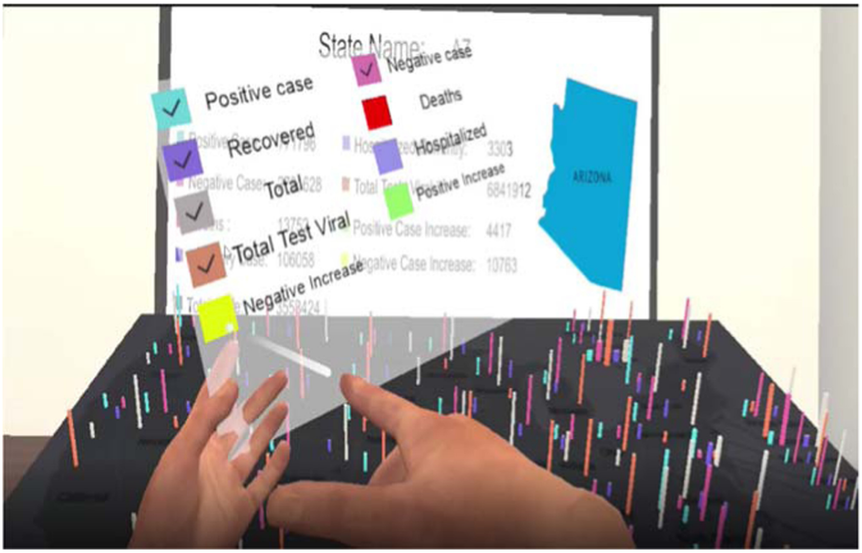


**Fig. 1.** 3D data visualization in an immersive environment

Our proposed data visualization tool focuses on immersive data visualization of the COVID-19 data on top of a geographical map, to give the user a better understanding of the pandemic data in the USA. We have tested the data visualization tool in an immersive and mobile environment for enhancement and decision-making process. The data visualization tool was developed using unity 3D gaming engine. As a result, the tools can be easily exported to an immersive environment using Oculus Rift S or a mobile environment using smartphones. Our proposed environment in Fig. 1 shows a table with a USA map showing the fifty states. On top of the map, 3D bar graphs are displayed for different variables related to the COVID-19 pandemic. The use of the Oculus controller provides a true hand-based input for virtual reality, which provides a way to interact with data on the map. The map displays nine different variables related to COVID data for each state such as

- Positive Cases
- Negative Cases
- Deaths
- Recovery Cases
- Total Cases
- Hospitalized Currently
- Total Tests Viral
- Positive Cases Increase
- Negative Case Increase

The rest of the paper is organized as follows: Sect. 2 discusses the related work in data visualization as well immersive VR; Sect. 3 details the system architecture of the data visualization tool; Sect. 4 describes the implementation of the application in both phases; Sect. 5 describes the results of the user study and evaluation of the data visualization tool, and Sect. 6 discusses the drawn conclusions and proposed future work. Finally, Sect. 7 states acknowledgments and references.

## 2 Related Work

Data visualizations allow the user to display the data in numerous formats. The most common techniques for the display of data are [4]:

- Line graph: This shows the relationship between items and can be used for time comparison.
- Bar chart: This is used to compare different quantities
- Scatter plot: This is a two-dimensional plot showing variations.
- Pie chart: This is used to compare the pieces to the whole data.

Therefore, it is important to understand which chart of graphs should be used for data exploration. Prior work in 3D visualizations in virtual reality environments shows the clear mapping between a mental model of the data that is expected to be reviewed, and the manner the data is depicted in the visualization [5]. Perl et al. [6] have documented analyst's mental models to guide the development of 3D visualizations. Data visualization is also important during evacuations for emergency response and decision making. Sharma et al. have conducted virtual evacuation drills in an immersive environment for an aircraft evacuation [7], a building evacuation [8], a subway evacuation [9], a university campus evacuation [10], and a virtual city [11]. Real-time data visualization for location-based navigation in multilevel spaces by generating ARI visualizations for evacuation have also been explored [12–14].

Livnat et al. [15] have discussed that situational awareness is the continuous extraction of environmental information, its integration with previous knowledge to form a coherent mental picture, and the use of that picture in anticipating future events. Situational awareness involves the continuous extraction of environmental information with its integration with previous knowledge to form a coherent mental picture [16]. Data visualization is an evolving field and its advancements in technology and healthcare systems are increasing at a rapid rate [17]. Bryson [18] has defined virtual reality as human-computer interface for creating interactive objects that provide a three-dimensional presence. On the other hand, data visualization researchers have suggested that virtual reality's three-dimensional presence adds value for analyzing scientific data, and will enable more natural and quicker exploration of large data sets [19]. Our proposed work is based on a VR visualization by Brunhart-Lupo et al. [20]

## 3 System Architecture

Data collecting techniques have improved a lot in the past decade. With the data collection techniques, a large amount of data has been collected. To analyze and understand this data, the old techniques are insufficient because sometimes human intervention is needed to find the new relationships and patterns. One needs a new way of analyzing and visualizing the data. In this paper, we present an immersive 3D data visualization tool to visualize COVID data. We have implemented this tool for Oculus, which gives an immersive feeling to the users.

With the advent of COVID 19, there is a lot of data accumulated in the databases. To visualize this kind of data in 2D with so many variables is a challenging task. Also, understanding that representation requires a certain level of knowledge on the 2D charts. In our proposed data visualization tool, the data is represented as 3D bar charts.

Figure 2 describes the system architecture of our proposed 3D data visualization tool. We have also used the COVID-19 tracking API to get the real-time COVID-19 data. Our proposed data visualization tool extracts COVID-19 data from the real-time API for analyzing the data which can be helpful in predictive analysis. This data is pulled from the database with the help of API calls. When the 3D data visualization application is launched the API call extracts the updated data automatically. For getting the live data updates, we are using an open source Database (DB). This is being updated from time to time with different variables. We are getting our data from this Database by sending API calls from time to time. For the data visualization tool, we focus on nine different factors or variables (i.e. Positive Cases, Negative Cases, Deaths, Recovery Cases, Total Cases, Hospitalized Currently, Total Tests Viral, Positive Cases Increase, Negative Case Increase). To display all these nine variables for individual states, we chose bar graphs as the data visualization medium. The bar graphs are displayed on top of the USA map where each state contains nine bar graphs with different colors. The color coding is maintained consistently for all states so that color code can be used to identify each variable.

A control panel is implemented to provide control to the user for toggling on/off the nine variables on the map. This is implemented with aid of checkboxes. The check boxes

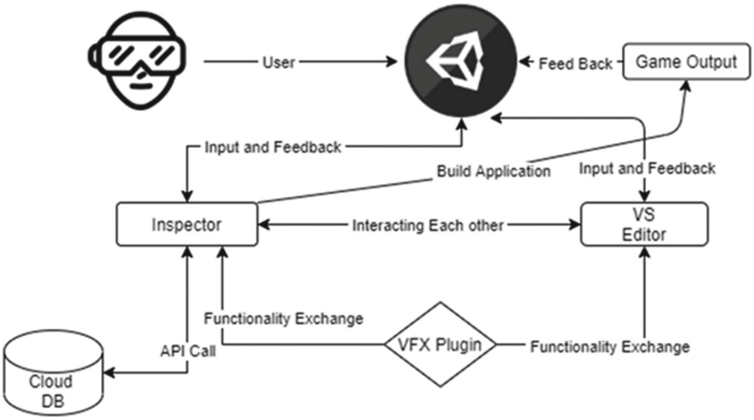


**Fig. 2.** System architecture diagram for CVE using photon networking asset tool in Unity 3D.

for every nine variables are used to enable and disable the bars on the graph. This allows the user to compare a particular variable such as Positive COVID Cases across all fifty states by just looking at bar graphs. To get the exact numbers, a screen is arranged on the wall in the virtual environment. The screen is configured to display all nine variables for each state, that is selected by the user. If the user selects any state by clicking on that state on the map, the information related to that particular state is populated on the screen. With the help of C# script, the API call is made. This call happens when the application is launched to get updated data. Through this API call, Visual Studio loads with raw data. Based on the filter conditions the data is extracted for all fifty states. This extracted data helps to populate the bar graphs on the map. Based on the user selection the data visualization tool will control the rendering of data on the wall-mounted screen. The visual effects have been implemented for achieving special animations through the use of custom Visual Studio code attached to the objects in the environment.

## 4 3D Data Visualization Tool

This paper presents the 3D data visualization tool for representing nine COVID variables on the USA map. In this paper, we are introducing a new way of visualizing the COVID data with help of oculus HMD and controllers. It allows a more human-centric approach in analyzing the data in 3D space. Our proposed work shows that virtual reality can be used as a data visualization platform. The oculus integration allows human-centric situational awareness and visualization that is needed for analyzing big data.

The 3D Data Visualization tool is developed for both mobile and Oculus devices using the Unity3D gaming engine. Initially, all asserts like USA map, Hands, Texture, etc. are loaded in Unity 3D. A reasonable scene is created after placing all objects in the environment. The environment includes a room with a table in the center to represent the USA map. Objects such as tables, desks, boards, chairs, and computers are added to create realism. The map helps the user to differentiate and visualize neighboring state data. To display the different factors of the COVID data, we have chosen to display the bar graphs on the map. All these bar graphs are integrated with C# code. This code is responsible to maintain the height of the bar based on the values received for that variable. Figure 3 and Fig. 4 show the 3D Data visualization tool in a non-immersive environment and mobile environment respectively.

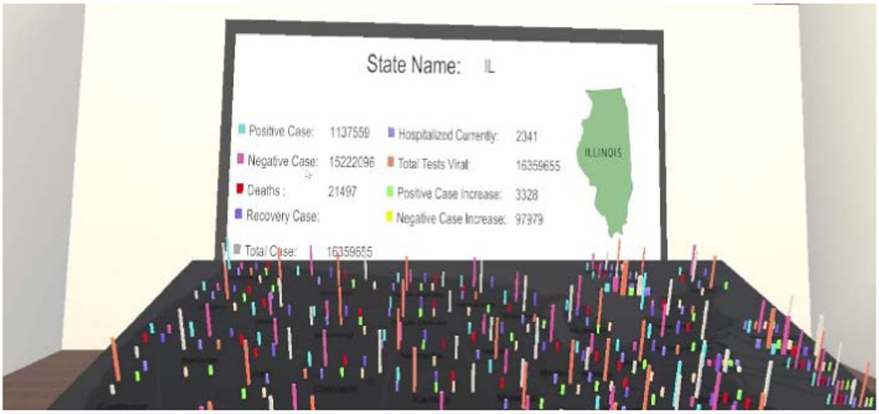


**Fig. 3.** 3D data visualization in non-immersive environment

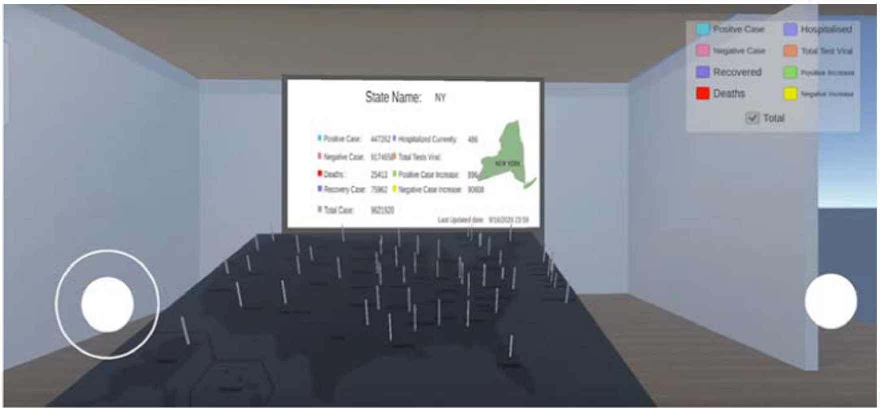


**Fig. 4.** 3D data visualization in a mobile environment

For each state on the USA map, interactive nonvisible buttons are implemented. This allows the user to select a particular state on the map by clicking on the map. For interaction in the immersive environment, two hands are implemented. These two hands are the two Oculus controllers visible as left and right hands, as shown in Fig. 5.

One of the buttons on the left-hand controllers triggers a canvas. This canvas is capable of displaying all nine-variable data for the selected state along with the last updated date. A C# script written to extract the data from the cloud database through an API call.

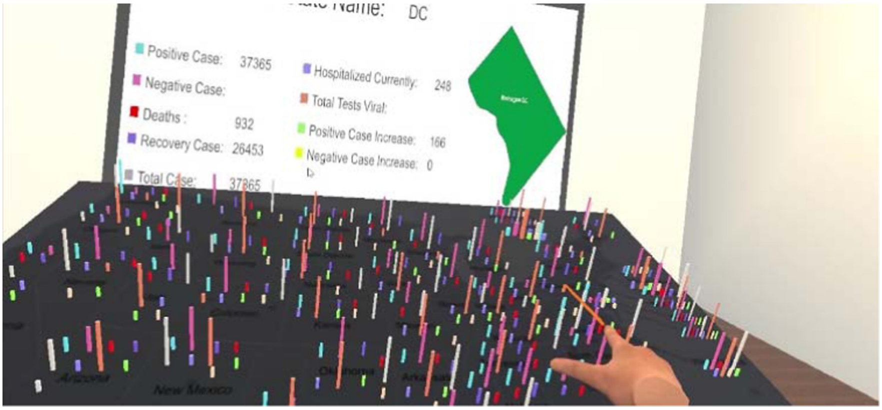


**Fig. 5.** Interacting with the map through Oculus touch controllers.

After mapping all the variables with proper oculus controller scripts the application is deployed into the Oculus Rift S. When the application is launched, the user is able to see two hands. The two oculus controllers are represented in the environment as the user's hands. In the left hand, the menu panel appears, as shown in Fig. 1 earlier. This panel contains nine check boxes for selecting and deselecting the nine COVID -19 variables. These check boxes aid in enabling and disabling the bars on the map. The right hand controller also triggers a laser beam that helps in selecting the check boxes. By deselecting all boxes, all the bars on the map disappear. The user has a green circle as shown in Fig. 6 for navigating in the virtual environment. The right hand controller allows the user to place the green circle in the environment for navigation. The green circle implements the teleporting to the location option in the environment. By using this feature, the user can move around the map and can have a better look at required places on the map, as shown in Fig. 6.

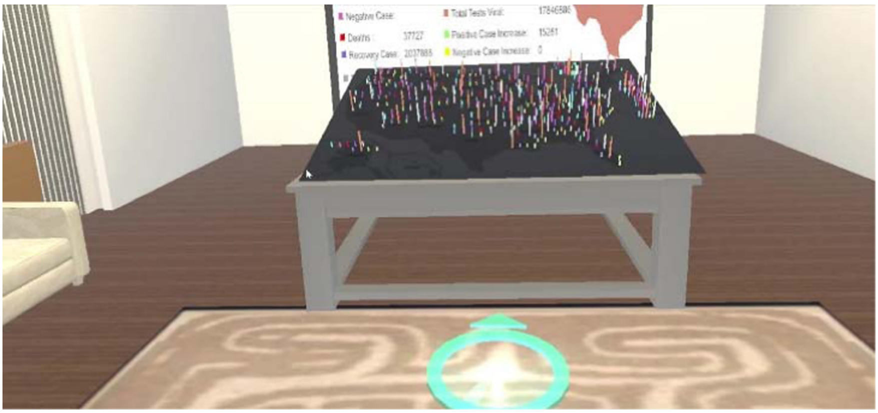

**Fig. 6.** Navigation in the immersive environment through oculus touch controllers

The 3D visualization tool is also implemented for the mobile devices to reach out to the audience who are not having access to the Oculus Rift S. Unity allows the application to be deployed to an android device, by changing interactive controllers to touch controllers. Instead of hands, two-controller joysticks are implemented for the mobile application as shown in Fig. 4. Using these two controllers, the user can navigate in the environment. When the user touches any state on the map, the information regarding that state is displayed on the wall screen. After these changes were implemented, the APK (Android Package) file was generated. The APK file can be used by anyone to install the 3d Visualization application on their mobile device. For better results we suggest using the immersive environment. In the immersive environment, the user will see a bigger model, so that it will be easy to read the data. Whereas in mobile devices, the screen size is limited and it becomes difficult to observe the data. For testing the Samsung S9 device was used. The specifications of the device include OS: Android 9.0, CPU: Octa-Core, GPU: Mali-G7, RAM: 4 GB [21].

## 5 Simulation and Results

A limited user study was conducted for evaluating the effectiveness of the 3D visualization tool. The study involved 10 participants and evaluated the two versions of the 3D visualization application namely the mobile version, and the Oculus (immersive) version. The user study was composed of 80% male participants and 20% female participants. The results were collected from the user study, with the help of a questioner. Initially, the participants were shown how to use the 3D visualization application for the phone and oculus. Then, each participant was allowed to use each device independently to visualize the COVID data for different states. Then, they were given a satisfaction questionnaire about their overall experience.

The above chart is the summary of the test results. By observing these results shown in Fig. 7, one can say more participants were able to understand the data in oculus as compared to mobile devices. People were more comfortable using the oculus and were able to interact in the virtual environment better than in the mobile environment. The majority (60%) of the users felt that the oculus was more suitable for visualization than the mobile phone version of the application.

The implementation of User Interaction (UI) is the main difference between the Oculus version and the Mobile version of the data visualization tool. In Oculus version, the user has the menu option attached to the left-hand controller. The right-hand controller triggers the laser beam for selecting and clicking the checkboxes. The menu attached to the left hand is responsible for enabling and disabling the bars on the graph as shown in Fig. 7(a). Whereas in the mobile version, all these options are replaced with touch interaction. On the right top corner of the screen the menu is arranged, which is responsible for enabling and disabling the bars on the graph, as shown in Fig. 7(b). All interactions in the mobile version happen through touch interaction, whereas in the Oculus version, the user can interact using two oculus controllers (Fig. 8).

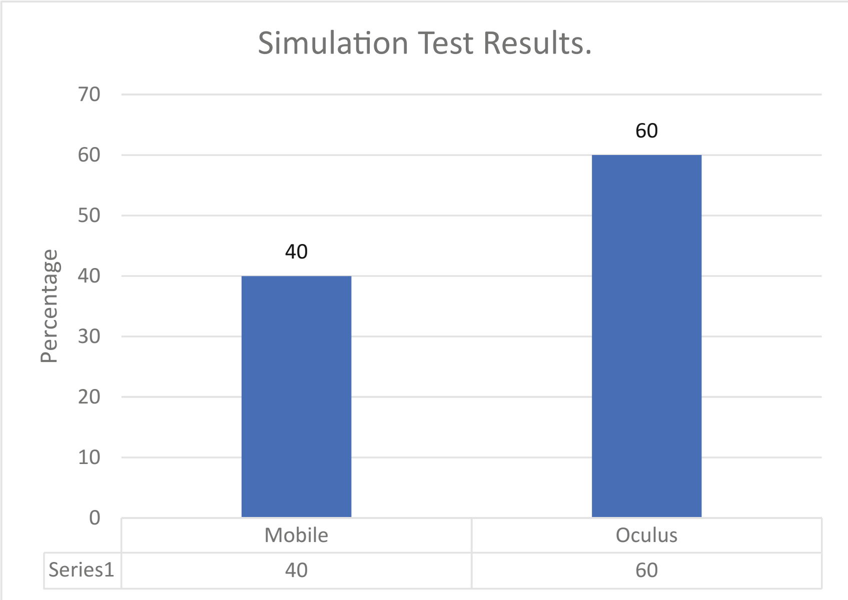


**Fig. 7.** Device suitability and effectiveness.


**Fig. 8.** Oculus and mobile version UI interaction

## 6 Conclusions

In conclusion, this paper presents a data visualization tool for 3D data visualization developed using Unity gaming engine for an immersive and mobile environment. The data visualization tool can visualize the COVID-19 pandemic data for the fifty states in the USA. This data is pulled from the database in real-time with the help of API calls. Immersion provides a better understanding of the data and leads to more human-centric situational awareness insights. Oculus controllers were used to creating a hand input to help the user immerse in the environment and provide more user engagement through the use of a laser pointer. We believe the data visualization tool enables the user to make human-centric insights by engaging with data in an immersive environment.

Our findings so far should be interpreted with appropriate consideration of the small sample size in our initial limited study. We aim to expand our investigation in our ongoing work, evaluating the visualizations with more participants and incorporating a more detailed analysis of insights. We also plan to enable user interaction and improve usability. We are also interested in adapting our VR visualization tools to enable multi-user data exploration capability and to explore the impact of VR on collaborative analytics tasks.

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