Real-Time Data Visualization to Enhance Situational Awareness of COVID pandemic

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Abstract— **Real-time data visualization can enhance decision making and empower teams with human-centric situational awareness insights. Decision making relies on data which comes in overwhelming velocity and volume, that one cannot comprehend it without some layer of abstraction. This research effort aims to demonstrate the data visualization of the COVID pandemic in real-time for the fifty states in the USA. Our proposed data visualization tool includes both conceptual and data-driven information. The data visualization includes stacked bar graphs, geographic representations of the data, and offers situational awareness of the COVID-19 pandemic. This paper describes the development and testing of the data visualization tool using the Unity gaming engine. Testing has been done with a real-time feed of the COVID -19 data set for immersive environment, non-immersive environment, and mobile environment.**

Keywords— Situational Awareness, Data Visualization, COVID-19 Pandemic, Virtual Reality, Immersive Environment.

I. INTRODUCTION

Visual processing is far more effective in determining the change in underlying data. The properties of data are presented in visual forms so users can browse through large amounts of data efficiently. Without data visualization, detecting the hidden patterns and anomalies is a challenging task. Complex systems and businesses demand visual expression. We are trying to answer the research question: Is the information conceptual or data-driven? Our approach incorporates both conceptual and data-driven information by providing situational awareness of the COVID-19 pandemic dataset. The goal of our work is to combine neural networks predictions with human centric situational awareness and data analytics to provide accurate, timely and scientific strategy for data visualization. We have used the virtual reality device, Oculus to achieve better data visualization results. We have also used the COVID-19 tracking API to get the real-time COVID-19 data. This tool aims to discover patterns in COVID-19 cases, analyze it, and display it to the user. The exploration of Big Data can be improved by integrating human intuition and perception for situational awareness. Processing, analyzing, and communicating this data visually and analytically helps in data visualization. Data visualization communicates information more clearly and effectively through graphical means.

COVID-19 real-time data is huge. The data is rapidly growing and the numbers are changing exponentially. Our proposed data visualization tool provides situational awareness of COVID-19 data by incorporating the real-time API to help in analyzing the data change which can be helpful in predictive analysis. The data visualization tool is developed for the immersive, non-immersive, and mobile environment. Visualizing data in 3D overcomes the 2D limitation (X and Y axes) and space limitation. Data

visualization in 3D gives more options to the user. For example, the use of 3D graphs can depict more data points in a given time. The immersive environment includes a data visualization tool in 3D where the user can interact with the data using oculus touch controllers. 3D data visualization enables users to visualize data in 360 degrees. 3D environment enhances user's experience in visualizing data attributes that can be easily missed in a 2D environment. COVID-19 real-time data can help in advanced data analytics and modeling. Using innovative tools, agencies can alert if there are new cases in any region. The data visualization tool was developed in unity 3D. As a result, the tools can be easily exported to an immersive environment using Oculus or a mobile environment using smartphones. We have chosen Oculus as the output device because it provides a true hand-based input for virtual reality. which gives a real feeling to interact with data on the map.

Our proposed 3D data visualization tool (refer figure 1) is divided within the geographical boundaries to give a user a better understanding of the pandemic data in the USA. We have tested the data visualization tool in an immersive, non-immersive, and mobile environment for enhancing the decision making process. The tool incorporates bar graphs to represent different attributes for visualization. A bar graph shows comparisons among discrete categories. In our tool, one axis of the graph shows the data attributes of COVID -19 being compared to the number of cases for the respective attribute for that state.
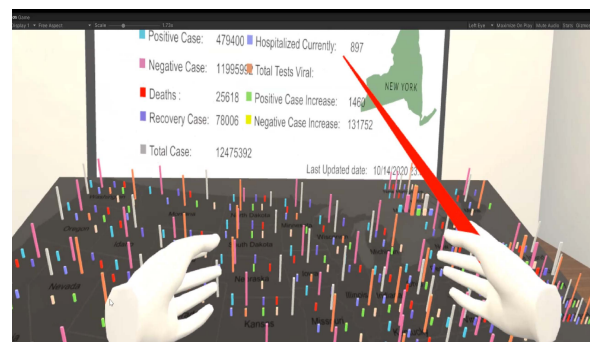

Figure1: 3D data visualization in an immersive environment

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

II. Related work

A. Situational awareness

Situational awareness is the ability to assess the huge volume of raw data to determine its relevancy, synthesizing, and acting on it. The goal of performing analytics and visualization is to discover underlying patterns and display it to the user effectively. Early hands-on experience with the augmented/ mixed reality devices like HoloLens and Oculus has given better results in data visualization [1]. Analyzing data is one task, on another hand analyzing data based on the user requirement and situational awareness is a tough task [2]. Situational awareness works by taking into consideration the user search history and preferences of the user in the past.

Visualization plays a key role in exploring and understanding of Big data and large datasets. Therefore, the key idea of effective data visualization is to represent the complex raw data in a way that is more manageable for the user to understand. Situational awareness incorporates perception, comprehension, and projection, that leads to decision-making and actions [3]. Timonen et al. [4] have used a situational awareness during public healthcare emergency for collecting and synthesizing patients' information.

B. Real-time data visualization

Augmented reality (AR) has been widely used to teach a concept since it offers a captivating learning environment where computer-generated objects are combined with users' physical surroundings. Sharma et al. [5-7] have presented a real-time data visualization for location awareness in multilevel spaces by generating ARI visualizations which are three-dimensional spatially contextualized communication of evacuation plans. They have implemented the ARI modules and reported the results of the pilot studies conducted for evaluating the perceived usefulness, ease-of-use, and usability. The results suggest the desirability of further heuristic examination of three-dimensional situational awareness-based ARI application effectiveness in multilevel building evacuations.

AR also promotes imagination and immersion so that users can interact with the objects to obtain the desired view of the environment [8]. The combination of imagination and immersion helps users to not only gain knowledge but also to retain what was learned. Sharma et al. [9-11] have used AR for developing an emergency response system for building navigation and evacuation. Immersive VR environments have been used for early concept design [12] as product design [13]. There have been lot of tools and techniques developed for data visualization that incorporates Data Management Systems or as software or plugins [14]. Pedrycz et al. [15] have used the human-centric model to analyze and interpret time series data.

III. System Architecture

Currently, everyone is trying to monitor and analyze the COVID data. Dealing with 2D charts or excel sheets data is difficult with multiple variables. To analyze multiple variables simultaneously 3D visualization is the best way. By using 3D visualization one can analyze data more efficiently. Our 3D visualization tool data visualization includes stacked bar graphs, geographic representations of the data, and offers situational awareness of the COVID-19 pandemic.

A. Bar graphs

A bar chart or bar graph represents data with rectangular bars with heights or lengths proportional to the values that they represent. A bar graph shows comparisons among discrete categories. One axis of the chart shows the specific categories being compared, and the other axis represents a measured value. Figure 2 shows the 3D data visualization tool in a non-immersive environment. When the user clicks on a state in the USA map, it shows the COVID-19 data for that state.
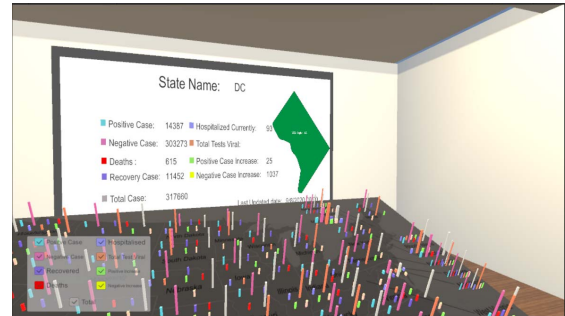

Figure 2: 3D data visualization in non-immersive environment

B. Geographic Representation:

Geographic representation plays a key role in representing all USA fifty states on a map. A common use of data visualization is a geographic map that displays the COVID data for each state. By putting it into a graph or other types of visualization, one can easily look at a large amount of data at once and see the trends to give a better understanding of the COVID data in USA and its states. In the proposed 3D visualization tool, the USA map is used to represent the updated COVID data. For each state bar graphs are arranged, so that the borders of the state will help the user to distinguish between the data (as shown in Figure 2 below).
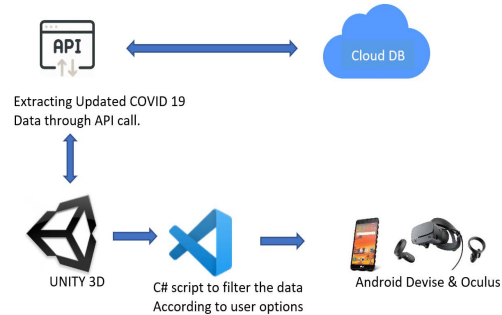

Figure 3: System Architecture

Figure 3 shows the system architecture of our proposed 3D data visualization tool. The COVID data from the cloud database is populated on the USA map in the form of a bar graphs. This data visualization tool was deployed into various devices to give an enriched experience to the user with the help of multiple scripts to filter the raw data. The proposed 3D data visualization tool was developed for

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visualizing the real-time COVID data set in an immersive environment, non-immersive environment, and mobile environment. The target device deployment took place in three devices as shown in figure 4.
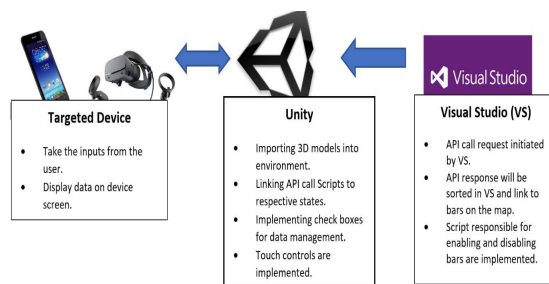

Figure 4: The life cycle of the 3D visualization tool.

IV. IMPLEMENTATION

This paper introduces a 3D visualization tool to analyze COVID data with multiple variables. The implementation of this 3D visualization tool was done in three phases. Phase I incorporated the development of the 3D environment, Phase II implemented the basic functionalities of the 3D visualization tool, and phase III deployed the 3D visualization application into various devices. Phase III was further divided into three versions. Version 1 developed for desktop. Version 2 implemented for android devices like phones and tablets. Version 3 implemented for Oculus. The implementation of the data visualization tool began with the designing of the 3D environment and using SketchUp and 3dsMax. This step was followed by the implementation of the functionality of the tool using Unity before they were packaged into an executable file and transferred onto the target device for installation. The development of the data visualization tool involved three distinct phases as shown in figure 5.
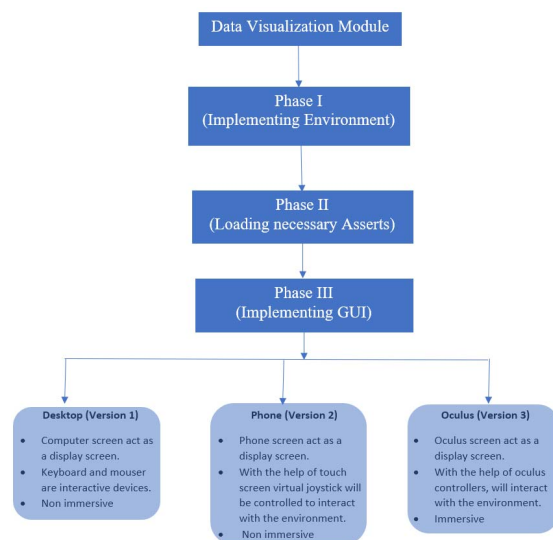

Figure 5: Implementation of the 3D data Visualization tool

A. Phase I

In the first phase of implementation, SketchUp was used to model the 3D environment. The environment included a room with a table in the center to represent the US map. Objects such as tables, desks, boards, chairs, and computers were added for adding realism. After modeling the 3D environment, the whole model was exported into a unity gaming engine.

B. Phase II

In the previous phase, the 3D model was imported into unity. In this phase, the imported model was adjusted to the right scale, and the coordinates of the object were modified to place it in the right spot. After incorporating the 3D model in the scene, required asset files were loaded into the asserts field. This allowed the use of required scripts in the environment. As our aim was to display the COVID data in the USA, a map with proper representation of all USA states was chosen. This map was implemented in the Unity gaming engine. The map displayed nine different variables related to COVID data (Positive Cases, Negative Cases, Deaths, Recovery Cases, Total Cases, Hospitalized Currently, Total Tests Viral, Positive Cases Increase, Negative Case Increase) for each state. For the implementation, nine cubes were created to represent bar graphs with different colors to differentiate from other cubes. All these nine cubes were implemented for all states on top of the map. Initially, the height of the cubes was set to one unit, these cubes were linked with the script to increase height according to the number of cases. The updated COVID data is stored in the cloud database. This data was pulled from the database with the help of an API calls. When the 3D data visualization application is launched in the device, the API call extracts the updated data automatically. The data that is received from the database is raw data. As a result, it contains some unwanted data. The raw data is then filtered with the help of our developed C# script and assigned to the bars on the map.

The bars on the map are only configured to increase the height according to the number of cases. To get an exact number a canvas is implemented on the opposite wall (as shown in figure 2). To implement this display, a local canvas was implemented toggle on/off the different variables. This allowed the developer to display data at the required location. Displayed data related to all stated at a time does not give a better result, to customize the data visualization according to user choices interactive boxes (similar to buttons but not visible) are implemented on top of all states. This will allow the user to select the state. One's user selects the state, the data related to the state will be displayed. On the canvas, all nine variables are represented with exact numbers and the last data updated date is also displayed. This helps the user to know when the last time the data was updated. On the right side of the canvas, state map is displayed (as shown in figure 4).

A data display control panel is implemented, to provide better control over the data population on the map. This is implemented with the help of checkboxes. For all nine data bars, nine checkboxes were implemented. These nine checkboxes are for enabling and disabling the bars on the graph. This gives control to the user to compare data between the states.

C. Phase III

By the end of phase II, all major functionalities were implemented. In phase III, the user interaction (UI) was developed. As there were too many targeted devices the implementation of UI is divided into three versions (as shown in figure 5). The implementation of versions are as follows:

1) Version I

This version was built for the desktop environment. Initially, the environment was set up in Unity. Unity allows the developer to set up the USA map, projector screen, and the surrounding environment. As mentioned earlier, to show the COVID data according to each state, a USA map with proper state division was chosen and implemented in the Unity. The map allowed the user to identify each state very easily. For each state, nine different variables (Positive Cases, Negative Cases, Deaths, Recovery Cases, Total Cases, Hospitalized Currently, Total Tests Viral, Positive Cases Increase, Negative Case Increase) were displayed on the map. These nine variables were displayed for all states in the USA map.

On the map, the user can select a state for detailed information on the projector screen about the state. When the user selects the state on the map, the user will see the data about the state on the projector screen arranged on the wall of the room. This screen will display the shape of the state, nine variables with exact numbers, and the last updated date to know the age of the data (as shown in figure 2). For a better analysis of data, for all nine variables, nine checkboxes were implemented. These checkboxes allowed the user to enable or disable the bars on the graph. This gives an advantage to the user to see the selective data for analyzing more accurately. As this version was developed for desktop, it can run on all windows computers

During this phase of the implementation, a first-person controller was included in the environment. This allowed the user to move around in the environment with the help of a keyboard and mouse. An interaction script was added to the first person, to allow the user to interact with the map and toggle the boxes on/off. Once the development was done, an exe file was created. Using this file one can run this application on any windows desktop.

2) Version II

This version of the 3D data visualization tool was built for smartphones. Fewer changes took place for making the data visualization tool compatible with smartphones. To navigate in the environment, two controllers were incorporated at the bottom of the screen on each side (as shown in figure 6). By using these two touch screen controllers, the user can navigate inside the environment smoothly. 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: 4GB. The main aim of this version was to implement the similar functionality into mobile devices. To make the 3D visualization application available to most of the users, the application was implemented for smartphones. In smartphones, there will not be any keyboard and mouse. To replace the interactive device touch screen was used. For providing controls to the first person in the scene for navigation, two joystick

controllers were implemented. The left side controller is for navigating in the X and Y axis and the right-side controller for the Y and Z-axis. Once the scripts were implemented successfully, with a proper setting to the targeted device an SDK file was created. This SDK helped in the installation of the application in the mobile device.

Figure 6: 3D Data visualization tool for the mobile device.

3) Version III

This version of the data visualization tool was built for Oculus. This immersive version was developed similar to the version I. An immersive environment provides a platform for users to interact in a virtual environment. With the use of Oculus Rift and the Oculus Touch controllers, the user can navigate in the environment and interact with 3D objects. The Oculus headset allows users to navigate in the environment with full immersion. Whereas Oculus Touch controllers give haptic feedback to the user by allowing the user to interact in the environment.

In this version, the application was deployed into the oculus. The non-immersive version of the application had interaction controllers as keyboard and mouse. These were replaced with Oculus controllers, and the first person was replaced with an oculus camera. This enabled camera movement in accordance with the oculus head movement. The selection of the check boxes was done through the use of oculus controllers. The user can use the oculus rift controller to trigger a laser beam for toggling the variables on the map. In addition, C# scripts were added to the user-controlled agents in order to give users the ability to communicate with the map and laser pointer for selection as shown in figure 1. Oculus Touch controllers also give haptic feedback to the user when using laser pointer. An interaction script was also added to the first person, to allow the user to interact with the map and toggle the boxes on/off.

V. SIMULATION AND RESULTS

With the help of the proposed 3D data visualization tool, one can visualize the COVID data more accurately and compare the data with other states by seeing it on the map. A limited user study was done, with 10 users for evaluating the effectiveness the 3D visualization tool. The study evaluated all three versions of the 3D visualization application namely desktop, mobile version, and Oculus version. The results were collected from the user study, with the help of a questioner. Initially, the participants were

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shown how to use the 3D visualization application the desktop, phone and oculus. Then, each participant was allowed to use each device, personally. The evaluation process consisted of two steps. Initially, the participants tried to visualize the COVID data for different states through different devices. Then, they were given a satisfaction questionnaire about their overall experience. All of the questions, except for one, permitted a Likert response bipolar scaling with an interval from 1 to 5. The other question, which asked the participants' which device (desktop, mobile, and oculus) was the most suitable for the module, using a Likert scale with an interval of 1 to 10. After using the 3D data visualization tool on the phone and the oculus, the participants answered the questionnaire regarding their perceptions of this Version's usability and effectiveness. The user study was composed of 80% male participants and 20% female participants.
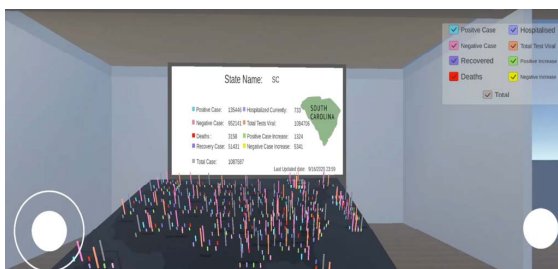

Figure 7: 3D Data visualization tool for the mobile device.

Figure 7 shows the bar graphs that represents data with rectangular bars with heights or lengths proportional to the values that they represent. For each state bar graphs are arranged on the map, so that it helps the user to distinguish between the data for each state. The map displays nine different variables related to COVID data as bar graphs with different colors. The user can toggle the boxes on/off to visualize the different COVID related statistics (variables).
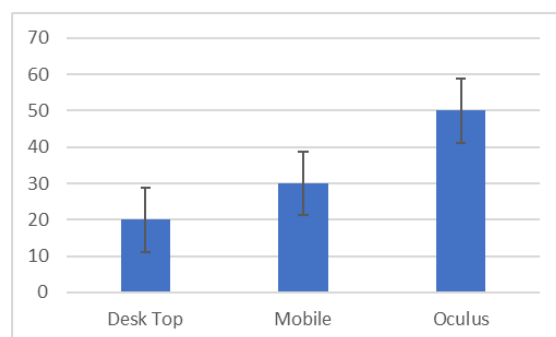

Figure 8: Device suitability and effectiveness.

Figure 8 indicates that the majority of the users felt that the oculus was more suitable for visualization than the desktop or mobile phone version of the application. With the help of these above results, one can compare both desktop results and mobile results. More people had chosen the mobile phone, this may be because of familiarity with the device. The data visualization project got a positive response to the survey. Most of the participants were interested in it, most

of them are able to handle the devices successfully with taking the training. All the devices were able to automatically load the COVID data and were able to interact with data.

VI. CONCLUSIONS AND FUTURE WORK

The proposed 3D data visualization tool was developed for immersive (Oculus rift), non-immersive (desktop), and mobile environment (phone, tablet). The tool extracts the raw COVID data in real-time data and shows it to the user in a specific manner, so that the user can visualize the data more accurately and efficiently. COVID-19 tracking API was used to get the real-time COVID-19 data. The use of the tool aides in discovering and visualizing new patterns in COVID-19 cases for analysis. The tool automatically loads the COVID data from current COVID-19 tracking API. Implementing Unity's UI system allows for 3D visualization, text and more engagement through touch controllers. The controllers of oculus were used to create a hand input that helps the user immerse the player and manipulate the data more effectively. This research has shown (1) virtual reality can be used as a data visualization platform, (2) a more immersive environment with oculus integration allows human-centric situational awareness and visualization that is needed for analyzing the big data, (3) The mobile version allowed user to navigate in the environment using two controllers that were incorporated at the bottom of the screen on each side. 4) big data visualization can be represented in two-fold, focusing on both visualization and interaction. Although we have useful analytics developed, we intend to add more features that allow further user engagement. Some potential future features we plan to implement in the user interface include multi-selection, annotation, and time series data visualization capability We plan to continue to find other ways to enable user interaction and improve usability.

REFERENCES

[1] Stigall, J., Bodempudi, S.T., Sharma, S, Scribner, D., Grynovicki, J., Grazaitis, P., "Use of Microsoft HoloLens in indoor evacuation", International Journal of Computers and their Applications,IJCA, ISSN 1076-5204, Vol. 26, No. 1, March 2019.

[2] Klein, G.; Moon, B; Hoffman, R.R, "Making sense of sensemaking 1: Alternative perspectives". IEEE Intelligent Systems. 21 (4): 70–73, 2006.

[3] Endsley, M.R, "Toward a theory of situation awareness in dynamic systems", Human Factors: The Journal of the Human Factors and Ergonomics Society, vol. 37, no. 1, pp. 32–64, 1995

[4] Timonen, J., "Improving situational awareness of cyber physical systems based on operator's goals", International Conference on Cyber Situational Awareness, Data Analytics and Assessment (CyberSA). doi:10.1109/cybersa.2015.7166121. 2015.

[5] S. Sharma, S, Stigall, J., Bodempudi, S.T., "Situational awareness-based Augmented Reality Instructional (ARI) module for building evacuation", Proceedings of the 27th IEEE Conference on Virtual Reality and 3D User Interfaces, Training XR Workshop, Atlanta, GA, USA, pp. 70-78, March 22-26, 2020.

[6] Stigall, J., Sharma, S, "Evaluation of Mobile Augmented Reality Application for Building Evacuation", Proceedings of ISCA 28th International Conference on Software Engineering and Data Engineering (SEDE 2019) in San Diego, CA, USA, vol 64, pages 109--118, 2019.

[7] Stigall, J., Sharma, S, "Mobile Augmented Reality Application for Building Evacuation Using Intelligent Signs", Proceedings of ISCA 26th International Conference on Software Engineering and Data Engineering (SEDE-2017), pp. 19-24, San Diego,CA, USA, October 2-4, 2017.

[8] M. Dontschewa, D. Stamatov, and M.B. Marinov, "Mixed Reality Smart Glasses Application for Interactive Working", *2018 IEEE XXVII Int. Scientific Conf. Electronics – ET*, © IEEE. doi: 10.1109/ET.2018.8549615, 2018.

[9] Sharma, S., Bodempudi, S.T., Scribner, D., "Identifying anomalous behavior in a building using HoloLens for emergency response", IS&T International Symposium on Electronic Imaging (EI 2020), in the Engineering Reality of Virtual Reality, https://doi.org/10.2352/ISSN.2470-1173.2020.13.ERVR-224, Burlingame, California, 26 January- 30 January 2020.

[10] Stigall, J., Bodempudi, S.T., Sharma, S, Scribner, D., Grynovicki, J., Grazaitis, P., "Building Evacuation using Microsoft HoloLens", Proceedings of 27th International Conference on Software Engineering and Data Engineering (SEDE 2018), New Orleans, Louisiana, USA, pp. 20-25, October 8-10, 2018.

[11] Sharma, S, Jerripothula, S., "An indoor augmented reality mobile application for simulation of building evacuation", proceedings of SPIE conference on the Engineering Reality of Virtual Reality 2015, paper 9392-7, San Francisco, CA, USA, 9 - 10 February 2015.

[12] J. Stigall, R. Baskar, S. Sharma, "Assembly VR: An Immersive Virtual Reality Environment for Concept Design", Proceedings of ISCA 27th International Conference on Software Engineering and Data Engineering (SEDE 2018), New Orleans, Louisiana, USA, pp. 57-62, October 8-10, 2018.

[13] Sharma, S, Bodempudi, S.T., Arrolla, M., Upadhyay, A, "Collaborative Virtual Assembly Environment for Product Design", Proceeding of the IEEE International Conference on Computational Science and Computational Intelligence (CSCI'19), in Symposium on Signal & Image Processing, Computer Vision & Pattern Recognition, Las Vegas, Nevada, USA, pp. 606-611, doi: 10.1109/CSCI49370.2019.00114, Dec 05-07, 2019.

[14] Caldarola, E. G. & Rinaldi, A. M., "Big Data Visualization Tools: A Survey - The New Paradigms, Methodologies and Tools for Large Data Sets Visualization", Proceedings of the 6th International Conference on Data Science, Technology and Applications. doi:10.5220/0006484102960305. 2017.

[15] Pedrycz, W., Lu, W, Liu, X., Wang, W. & Wang, L., "Human-centric analysis and interpretation of time series: a perspective of granular computing", Soft Computing, 18(12), 2397-2411. doi:10.1007/s00500-013-1213-5. 2014.

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