Data Visualization Tool for Covid-19 and Crime Data

Sean Walker and Sharad Sharma, Senior Member IEEE
Department of Computer Science
Bowie State University
Bowie, MD, USA
walkers1116@students.bowiestate.edu, ssharma@bowiestate.edu

***Abstract*— Data visualization gives a visual context through maps or graphs and makes it easier for the human mind to identify trends, patterns, and outliers within large data sets. The understanding of patterns and location of crime through data visualization and data mining techniques approaches is a very useful tool which can help and support police forces. Identification of crime characteristics and types are the first step for developing further analysis. This paper describes the development of data visualization tool using Unity 3D and Maptitude GIS for visualization of Baltimore COVID-19 and crime data. This effort aims to determine parameters that influence the vulnerability of African Americans to COVID-19 during the pandemic. The study has found that the factors shown to be influential in a person's susceptibility include neighborhood and physical environment, housing, occupation, education, income, and wealth gaps. The data collected from Baltimore incident reports and findings shared by Maryland SOA office shows that crime has increased and decreased in different areas during the time of COVID pandemic.**

Keywords*— *Data Visualization, Crime analytics, COVID-19 Pandemic, GIS, Information Visualization, Big data.

I. Introduction

The advances in data visualizations have opened new opportunities for the use of automation in crime mapping. Crime analysis includes identifying, discovering, and predicting crime incidents. The complex nature of crime and its related data have made data mining a rapidly growing field for criminologists. The large volume of data exists in police department and sometimes it becomes difficult to ascertain the complexity of relationships between these kinds of data for crime investigators and crime analysts. Sometimes a human intervention is needed to discover new hidden features and relationships that data mining techniques cannot discover. The existing traditional crime analysis techniques like intelligent crime analysis and crime data mining techniques become in ineffective when large volumes of crime data are involved. Thus there is a need for more human intrinsic approach for visualizing crime data. Data Visualization in a virtual reality environment allows for a more human-centric approach for visualizing data. With the increase in the size of data, more 3D data interaction techniques are being explored to achieving desired levels of interactivity.

Visualization through graphs reveal new insights into the relationship between people, times, crime and location. Data visualization is a vital tool in learning and exploring crime data at any scale. This paper describes the development of visualization tool of Baltimore COVID-19 and crime data analysis using Unity 3D and Maptitude. Several data sources were used to compare statistics and find relevant correlations between COVID-19 and crime in Baltimore city. The Baltimore City Coronavirus Dashboard, which contained data provided by the Maryland Department of Health, was used for up-to-date COVID data. It was compared with data retrieved from Open Baltimore, a site containing many datasets of the city. A bar graph was made containing data from Open Baltimore showing the number of crime incidents by category show a decrease in overall crime. However, there were categories that showed an increase in crime. The coronavirus pandemic may have had an influence in this decrease through the legislative actions taken by Maryland local and federal government, which influenced crime opportunities, and which crimes were being prosecuted.

People from racial ethnic and minority groups are disproportionately affected by Covid-19 [1]. There were 593,490 citizens in Baltimore city in 2019, and 62.4% of those citizens were African-American [2]. The determinants for why the black community in the city was disproportionately affected by the coronavirus was explored, and the CDC's social determinants of health [1] were used as a guideline to analyze demographic datasets of Baltimore city. This data, in addition to crime and covid-19 data was visualized through the Maptitude and Unity software's. Figure 1 is a thematic map created with Maptitude that shows the number of healthcare providers by zip code for Baltimore city. The darker orange regions of the map indicate areas of a higher number of healthcare providers. The relevance is its visualization of areas that have relatively less number of healthcare providers, thus posing a possible obstacle in terms of access to treatment for COVID-19. It can be seen that the very center of the city has the highest number of healthcare providers, while the outskirts generally have a lesser number. Notably, the northeast, west, and southernmost areas of the city have the least number of providers.

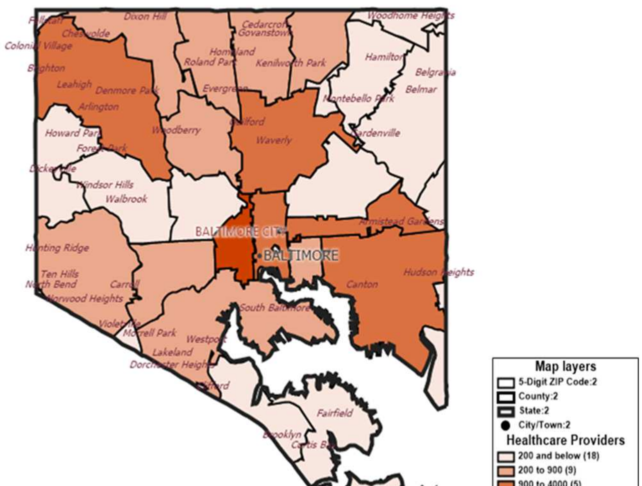

Fig. 1. Map of Number of Healthcare Providers by Zip Code for Baltimore City

Sharma et al. [3] have explored the use of immersive virtual reality platforms for scientific data visualization for the COVID-19 pandemic. Their data visualization tool is capable of visualizing the COVID-19 pandemic data in real time for the fifty states in the USA. Their work identifies how graphical objects like charts and bar graphs can be depicted using Virtual Reality tools for situational awareness. Data visualization tools have been developed to represent the COVID-19 pandemic data on top of the geographical information [4].

The rest of the paper is organized as follows: Section 2 discusses the related work in crime and health data analysis during COVID-19; Section 3 details the analysis of COVID-19 and crime using Maptitude. Section 4 details the analysis of COVID-19 and crime using Unity 3D; Section 5 discusses the drawn conclusions.

II. Related Work

Researchers in visual analytics and information visualization have explored various data for visualization applications [5]. The most common data visualizations techniques for the displaying the data are [6]:

- Line graph: used for showing relationship between items and for time comparison.
- Bar chart: used for comparing different quantities
- Scatter plot: used for displaying two-dimensional plot.
- Pie chart: used to compare the pieces to the whole data.

The African American race and the Hispanic race is disproportionately impacted more than the white population for infection rate [7]. Data analysists mental models has been used to guide the development of 3D visualizations. Real-time data visualization for location based navigation has been explored by generating ARI visualizations [9-11]. On the other hand, HoloLens has been used to create situational awareness based navigation [12-14]. Bryson [15] has created interactive objects that provide a three-dimensional presence using a virtual reality interface.

Boman et al. [16] have investigated the extent to which governmental responses to COVID-19 have impacted crime rates in the U.S. Their findings compared 911 calls of data servers for the years 2019 and 2020, and found that crime overall decreased. They explored the distinction between different crimes, expressing that although crime overall went down, mostly the occurrence of minor offenses decreased, while violent crimes such as homicide "have either remained constant or increased" [9]. They emphasized that the overall, downward movement of crime may overshadow the instances in which certain crimes actually increase. The steadiness of serious crimes is reflected by Abrams et el. [17]. They collected data from 25 large U.S. cities to find that there is a widespread drop in both criminal incidents and arrests. But there was no decline in homicides and shootings [17].

Baltimore Open Data website provides datasets published by the city and its partners for a greater transparency, accountability and access [16]. This site was used to retrieve an incident report provided by the Baltimore City Police Department. The data in this report goes along with the overall previously mentioned findings that although crime overall went down, homicides and nonfatal shootings actually increased. The compound effect of executive orders and the State Attorney's policies may have brought crime down overall. The Attorney's office reported that violent crime was down 20% and that property crime was down 36% [18].

III. Data visualization of Crime Data using Maptitude

Data acquired from Baltimore Current Employment Statistics shows occupation being a significant factor in the black community's susceptibility to Covid-19 within Baltimore city. With around 300,000 jobs in the city, the largest percentage of people worked in Educational and Health Services, a total of 119,400 jobs, and over 70,000 jobs in the city were government occupations [19]. These numbers are important because they show that Baltimore City has a significant number of workers with a medium to high exposure risk, which are those working in healthcare delivery, healthcare support, medical transport, and those who may have contact with the general public.

Maptitude's provides availability of demographic datasets, in the software which references Census and American Community Survey data and it proved useful for making correlations relevant to the visualizations. The maps that were created and implemented in the 3D environment were thematic maps by zip code displaying data on healthcare providers, educational services, and percentages of families in poverty crossed with the number of police posts. Healthcare access has an influence on a person's quality of life, and people from racial minority groups (such as the Baltimore city predominantly black population) experience multiple barriers to health care [20]. Covid-19 has negatively affected the Black community nationwide in the aspect of education, as black students were shown to be behind in learning compared to White students, and were shown to have less access to learning resources [21].

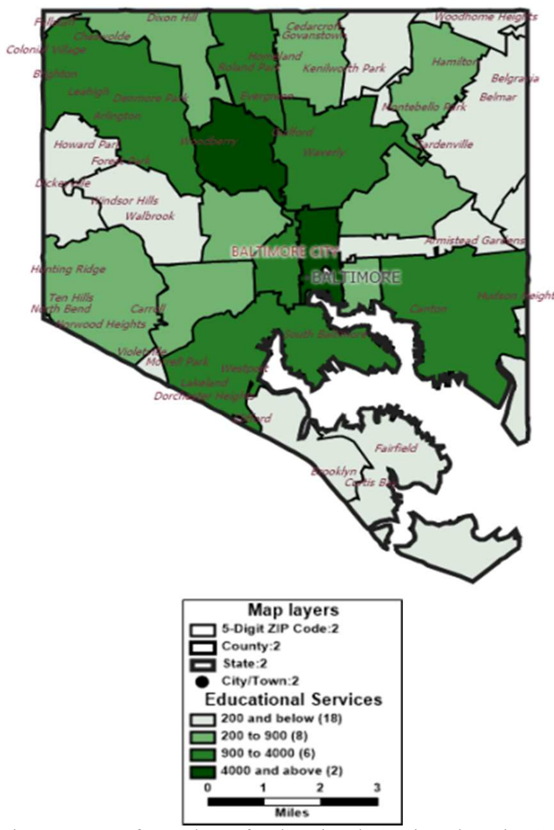

Fig. 2. Map of Number of Educational Services by Zip Code for Baltimore City

Figure 2 is a map of Baltimore City that shows the number of educational services available in each zip code. There is overlap between areas with a low number of healthcare providers and areas with a relatively lower number of educational services, notably the 21206, 21287, 21207, and 21216 zip codes. These zones are indicative of areas of citizens that may be more susceptible to the coronavirus relative to the areas with a greater number of educational services or number of healthcare providers.

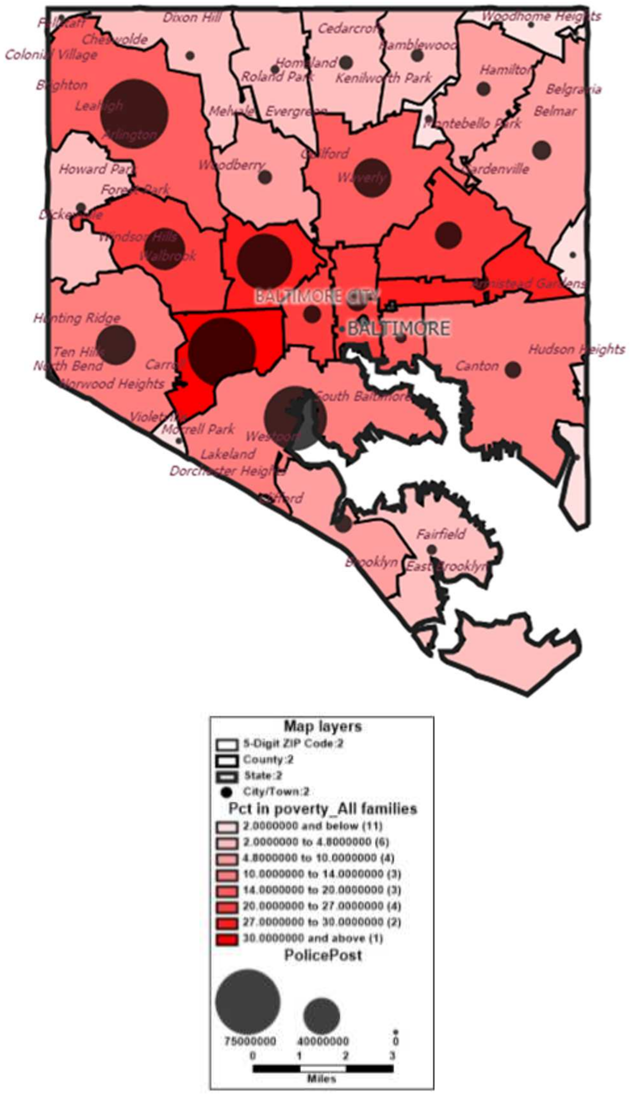

Fig. 3. Map of Percent in Poverty (indicated by red color) and Number of Police Posts (indicated by black dots) by zip code.

Figure 3 shows the percentage of families in poverty by zip code, indicated by the shade of red. The black dots on the map represent the number of police posts in these regions. Notably, the areas with the lower percentage of families in poverty in the extreme edges of the city have a significantly lower number of police posts compared to those just outside of the inner city. An area's level of poverty impacts its rate of crime [5], which ultimately affects the police presence within that area. This may be why there is a positive correlation between the number of police posts in a zip code and the percentage of people in poverty in that same area, shown in Figure 3 in areas such as the 21223 and 21217 zip codes.

IV. Data Visualization of COVID-19 and Crime Data using Unity 3D

Virtual Reality (VR) has been shown to lead better discovery in domain of data visualization in the context of high-dimensionality parameters. One of our goals was to explore the VR and abstract visualization for human perception to generate insights into COVID data and crime data analysis. We propose that VR visualization will become one of the foundations to explore the higher dimensionality and abstraction that are related with "big data". We have developed a data visualization tools using the Unity 3D platform, which is now emerging as a dominant immersive VR platform that is widely used for the game development. Unity 3D is a gaming engine that can be used for visualizing virtual worlds for players to explore the multidimensional data or navigate in the environment. However, exploring real world data in a gaming engine has always been a complex task, since most gaming engines have limited or very little support for geospatial data. This paper presents our findings from maptitude software for visualization of crime and COVID data from mixed sources. Unity 3D gaming engine provides rich set of libraries and assets for user interaction and custom C# scripts to provide a bird's-eye-view mode of 3D zoom, pan, and orbital display. We have incorporated basic 3D navigation tools; a first-person view of the scene was utilized to enable users to gain a walk-through experience while virtually inspecting the data visualizations. The implementation of the data visualization tool was done in three phases:

A. Phase 1: Modeling

Phase 1 of the data visualization tool consisted of modeling the 3 D environment using 3Ds max and google sketch up. The environment was modeled to scale and imported real-time textures. This phase includes adding 3D models of furniture to add realism. After modeling the 3D environment, it was exported to unity 3D gaming engine.

B. Phase 2: Exporting to Unity 3D and 3D data visualization

In phase 2, the modeled environment was exported from Google Sketch-to Unity 3D gaming engine. Initially, functionalities were added to provide the user the flexibility to navigate in the environment. The development of the 3D environment consisted of making bar charts, as well as the implementation of third party assets via the asset store. The bar charts were created with an asset provided by Viitorcloud Technologies, known as 3D Interactive Bar chart. The museum environment that the user can walk around was implemented with a second asset provided by Sun Suite called Showroom. The combination of these assets were used to create a four-room museum environment that displays bar charts and Maptitude maps related to Baltimore city data on Covid-19 and crime. In Unity 3D, the data visualization application is represented as composable 3D scenes in which designers can add and manipulate GameObjects which encapsulate objects and its behavior. Example GameObjects include cameras, 3D models, lights, input handlers, etc. GameObjects are organized as a parent-child hierarchies or scene-graphs. GameObjects can be saved as prefabs that can be reused. Unity also has an on-line Asset Store that is used for sharing reusable scenes, prefabs, and other assets. C# scripts are attached to the GameObjects as components and used to manipulate GameObjects at runtime. The scene can be configured to run in either AR or VR, by specifying the target device in Unity 3D deployment settings.

C. Phase 3: User Interactions

With all the data in place, user interface and interaction logic were built into the Unity Game Engine. Custom scripts were written using C# were utilized for camera navigation, player movements, and user interaction. Unity provides a set of basic navigations for setting camera position. However, custom scripts were developed to better suit navigation in the 3D environment. Camera navigations were divided into the following:

- Bird's Eye View: Users can control the camera movements on the environment, i.e., panning, rotating/tilting, look-around, and zoom in/out.
- FPV (First Person View): Camera is attached to the player, where users control their movement freely.

FPV includes the Unity standard asset for the first-person shooter (FPS) controller. This asset is used for user navigation, including a FPV. The first-person controller uses keyboard (W-A-S-D, shift, and arrow buttons) for controlling the movements of the player, while the mouse pointer was used for the viewing direction of the camera. Bird Eye View and First Person View could be used to navigate the museum environment, using a mouse and keyboard for interactions. Several scripts were combined with game components and assets in unity 3D for the control the user interaction. The C# scripts for user interaction provided functions related to user input, mouse movements, displayed information, and loaded attribute information based on user interaction. The interaction between the scripts and game components allowed the interactions in various visualizations required for 3D exploration.

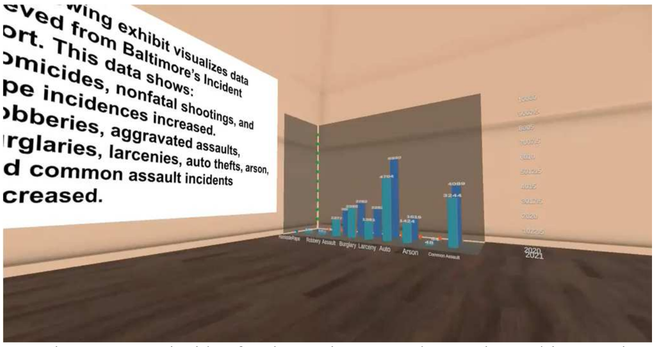

Fig. 4. A room inside of Unity environment showcasing Baltimore crime data retrieved from Open Baltimore.

The first room in the Unity 3D environment showcases Baltimore crime data, as shown in Figure 4. To the left is a description of a bar graph that visualizes the crime incidents for the years 2020 and 2021. As the description mentions, homicides, nonfatal shootings, and rape incidents increased, while robberies aggravated assaults, larcenies, auto thefts, arson, and common assault incidents decreased. In the same room to the right is a crime map that has been visualized using Maptitude. Here it can be seen that the areas with the greatest density and occurrence of crime are in the very heart of the city, as can be expected for most populations with an urban center. Figure 5 shows the Maptitude Map of Baltimore crime density showcased in the museum environment. The main scene adapts to the user's selection of navigation mode, whether Bird Eye View or First Person View. Users can use keyboard buttons W-A-S-D to move forward and backward as well as to move right and left in the VR environment.

Fig. 5. Maptitude Map of Baltimore crime density showcased in Unity environment.

Data from the Maryland Poverty Profiles and the 2017 Neighborhood Health Report were used to construct bar graphs shown in Figure 6. The leftmost bar graph, which shows the income distribution for the city, shows that a majority of Baltimore's residents either make the lowest ($0-$24,999) or the highest ($75,000+) range of incomes in the area.

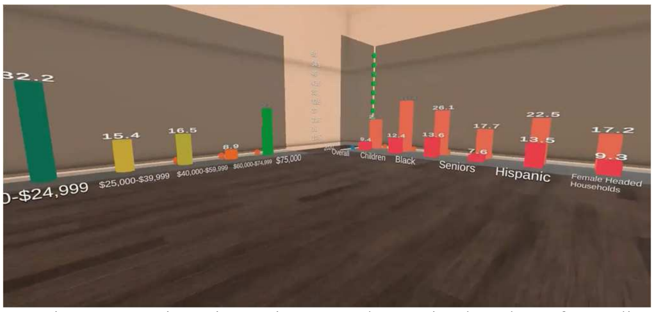

Fig. 6. Room in Unity environment showcasing bar charts for median income and poverty percentage for Baltimore City.

The citizens with income within the lowest quartile were likely to have more difficulties with the pandemic, and the overall shape of the graph indicates income inequality. The rightmost graph showcases how residents in Baltimore city (indicated by the peach colored bars) experience higher rates of poverty compared to the residents statewide (indicated by the red colored bars). Notably, children and minority groups experienced the highest poverty rates both statewide and citywide. This is an indication of groups that were most directly affected by the coronavirus pandemic and the changes it brought to the daily lives of members of these groups.

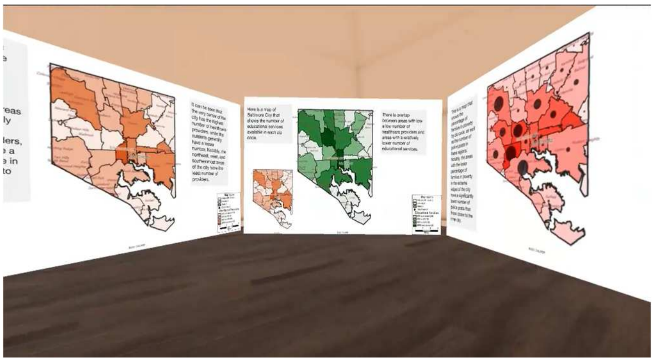

Fig. 7. Room in Unity environment showcasing map visualizations created with Maptitude.

The Maptitude visualizations discussed in section III are displayed in the final room of the Unity environment. Each map visualization has a caption that lists what the map is displayed and its relevance as shown in Figure 7.

V. CONCLUSIONS

The factors shown to be influential in a person's susceptibility include neighborhood and physical environment, housing, occupation, education, income, and wealth gaps. The data collected from Baltimore incident reports and findings shared by Maryland SOA office shows that crime has increased and decreased in different areas during the time of COVID pandemic. The data collected and visualized shows that residents in Baltimore, a predominantly African American city, have characteristics that may lead to an increased risk for the coronavirus to spread. The efforts of federal, state, and local government, with the intention of preventing the spread of the disease, may have also had influence on the crime landscape of the city. This paper presents our findings in developing a 3D visualization system for an integrated visualization tool of Baltimore COVID-19 and crime data analysis using Unity 3D and Maptitude. Custom scripts based on Unity C# scripting were developed to provide a user interaction for exploring the scene.

Effective visualization in the context of high-dimensionality parameters remains as one of the key challenges in the era of "big data". Humans have the ability for knowledge discovery in data-driven science which depends critically in our ability to perform effective and flexible visual exploration. We believe that sometimes a human intervention is needed to discover new hidden features and relationships that the traditional data mining techniques cannot discover. Our goal is to maximize the intrinsic human intervention for pattern recognition skills through the use of emerging technologies associated with virtual reality. Overall, our VR data visualization tool was perceived as satisfying and successful in visualizing Baltimore crime data and COVID pandemic data. The VR data visualization tool gave insights and helps in engaging the user more effectively in data analysis with human-in loop interaction. Thus, we see a potential for VR applications involving multi-dimensional data that require users' engagement for analysis of data.

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