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# Crime Data Visualization Using Virtual Reality and Augmented Reality

Sri Chandra Dronavalli, Rishitha Reddy Pesaladinne, Sharad Sharma
Department of Information Science
University of North Texas
Denton, Texas 76207, USA
srichandradronavalli@my.unt.edu, rishithareddypesaladinne@my.unt.edu, sharad.sharma@unt.edu (0000-0001-7528-4616)

***Abstract*— Crime data visualization is a crucial aspect of understanding and addressing criminal activities. By combining the capabilities of Virtual Reality and Augmented Reality, users are immersed in a three-dimensional environment that enables them to interact with crime data in unprecedented ways. The focus of this paper is on leveraging the unique features of HoloLens 2 and Oculus Quest Pro to develop intuitive and comprehensive visualizations of crime data. These technologies allow users to compare crime data across different cities, visualize crime patterns in both spatial and temporal dimensions, and uncover hidden connections within the data. By immersing users in an environment, virtual reality enhances understanding and facilitates the identification of crime hotspots, trends, and potential intervention strategies. This innovative approach empowers police officers, analysts, and researchers to immerse themselves in crime data, enabling them to gather valuable insights, make informed decisions, and develop effective crime prevention strategies. This advancement in crime data visualization can improve the effectiveness of law enforcement efforts, aid in proactive crime prevention, and foster better collaboration and information sharing among relevant parties. Overall, this paper demonstrates the potential of utilizing HoloLens 2 and Oculus Quest Pro to transform the visualization of crime data. It highlights the benefits of an immersive and interactive approach, paving the way for advancements in crime analysis and facilitating evidence-based decision-making in the field of law enforcement.**

***Keywords*— *Crime Insights, Data Visualization, Virtual Reality, Augmented Reality, HoloLens 2, Oculus Quest***

## I. Introduction

Emerging technologies that provide fresh methods for examining and analyzing complicated datasets have significantly advanced the subject of crime data visualization in recent years. The immersive and interactive qualities of these technologies have drawn attention to Virtual Reality (VR) and Augmented Reality (AR). The purpose of this paper is to showcase the advantages of two popular VR/AR devices—HoloLens and Oculus Quest—for visualizing crime data. This paper delves into the exploration of VR and AR technologies for investigating crime scenes through the visualization of ambient data. The immersive nature of VR enhances situational awareness and promotes collaboration among various stakeholders. By harnessing VR and AR technologies, this research opens up new possibilities for visualizing complex crime data. It enhances the understanding of crime patterns and dynamics by providing a more immersive and interactive experience.

Crime data visualization is critical for analyzing patterns, trends, and connections within criminal activities. The effective communication of the spatial and temporal characteristics of crime data is hampered by conventional methods, such as static charts and graphs. The advent of VR and AR technology offers a new paradigm for displaying criminal data, allowing users to visit crime scenes, evaluate data in three dimensions, and interact with the information in real-time. When using HoloLens 2 and Oculus Quest for crime data visualization, there are a number of issues that must be resolved in addition to the advantages. These difficulties include integrating data, guaranteeing scalability to manage enormous datasets, and enhancing user experience to reduce pain and increase usability. To fully utilize these technologies' potential and assure their practical relevance in actual criminal analysis settings, it is imperative that these hurdles be overcome.

In this paper, we look at the advantages of using HoloLens 2 and Oculus Quest Pro to visualize criminal data. These tools give realistic crime scene simulations and immersive experiences that improve spatial perception. Users can enter virtual surroundings that closely match real-world settings by donning these headsets, allowing them to review criminal data in a setting that closely resembles the actual scene. The use of an immersive method improves comprehension and enables users to spot spatial relationships, hotspot regions, and potential patterns that might not be seen in conventional visualizations. Furthermore, HoloLens 2 and Oculus Quest enable group investigations of criminal data. The virtual environment allows multiple users to interact at once, facilitating teamwork, information exchange, and group decision-making. These groups can collaborate to study and evaluate crime data, resulting in more thorough insights and efficient crime-solving techniques. This collaborative feature is particularly beneficial for law enforcement agencies, forensic teams, and researchers.

This paper also highlights the advantages of using HoloLens 2 and Oculus Quest for crime data visualization. These tools provide enhanced spatial perception, lifelike simulations, and group research capabilities. Law enforcement organizations and researchers may better understand crime patterns, encourage evidence-based decision-making, and improve stakeholder engagement by utilizing the immersive and interactive aspects of VR/AR. But in order to improve the efficiency and usefulness of these technologies in the field of crime data visualization, thorough consideration of issues like data integration and user experience optimization is required.

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The rest of the paper is organized as follows: Section II discusses studies related to the one reported in this paper; Section III details the immersive data visualizations in virtual reality and augmented reality; Section IV describes the discussion about graphical representation, interactive dashboard and comparative analysis for AR dashboard as well as spatial visualization and interactivity for VR dashboard; Section V concludes this paper and gives ideas for future work regarding this study.

## II. Related Work

Crime analysis involves methodical analysis for trends and patterns. The data analysis of trends leads security agencies to effectively plan an enquiry to execute their resources. De Bruin et al. [1] have explored four important factors that play a key role in the analysis of criminal careers: crime nature, frequency, duration and severity. They have described a tool to extracts these four factors from the crime database to create a digital profile for an offender. Their approach compares all offenders by a distance measure and clusters them according to a crime type. Their crime analysis consists of a visual two-dimensional clustering of the results that can be used by police experts. Xiang et al. [2] have proposed a COPLINK Criminal Relationship Visualizer that uses hyperbolic tree view and a hierarchical list view to visualize criminal relationships. Their results show that the hyperbolic tree view performs better in some tasks and user experiences. Reehl and Sharma [3] have developed a data visualization tool to visualize crime data by incorporating 3D interaction techniques over geographical information. Their virtual reality visualization tool allows users to immerse themselves in the environment to analysis crime data with human-in loop interaction. Their VR visualization incorporates Baltimore city map showcasing different layers of crime data for decision making.

Sharma et al. [3-7] have developed a VR visualization tools in VR for visualize COVID-19 data and crime data using Unity 3D and Maptitude GIS. Their work emphasized the relationship between crime and the rates of hospitalization during COVID-19. Sharma et al. [8-13] have also presented data visualization tool for visualizing building data for navigation in multilevel spaces by using AR instructional visualizations. Their AR visualizations provide contextualized 3D visualizations for promoting and supporting spatial knowledge acquisition and cognitive mapping. Cocx and Kosters [14] have used a distance measure for determining similarity between criminal investigations. Their work discusses a way to extract logical concepts from police narrative reports and documents found on crime scenes for predicting what crimes may be committed by the same criminal.

Cozen et al. [24] mention about surveillance, territoriality, activity support, access control, target hardening, and image management as the six categories to divide the crime physical characteristics. On the other hand, Aigner et al. [25] have presented time, data, and representation as the three categories for a systematic review of visualizing data. Malik et al. [57] have developed the Visual Analytics Law Enforcement Toolkit (VALET) that uses calendar and line charts to assist users in understanding the time evolution of crimes.

## III. Immersive Data Visualization

This work compares and visualizes the crime data for four different cities in the USA, namely Chicago, Baltimore, Dallas, and Denton in virtual reality and augmented reality.

### A. Data Visualization using AR

Data visualization using AR enhances the user experience by incorporating digital elements by allowing visual aspects to be added to the environment. It allows for graphic elements to be overlaid on real-time data. Through 3D visualizations, AR allows the user to have an immersive experience that facilitates contact with and internalization of this type of information. AR allows the user to interact with data in remote locations. AR allows the user to experience data graphs from multiple viewpoints. Visualizing data in 3D allows users to uncover trends and patterns that may not be immediately visible through traditional 2D visualizations. A dynamic experience can be created for criminal data visualization utilizing Unity 3D and HoloLens in the context of augmented reality (AR).

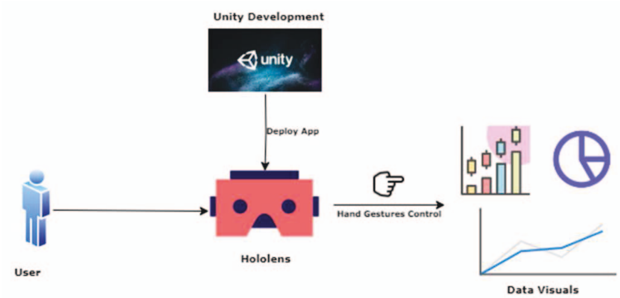


Fig. 1. User Interaction flow with HoloLens.

Fig. 1 shows the user interaction of the user interactivity with HoloLens. Hand gestures are used by the user to control visualizations on the HoloLens device. The software that supports this interaction was made using the Unity programming environment. As shown in Fig. 1, the flowchart includes the following procedures:

*a) User Interaction Flow:*

1. Wearable HoloLens are worn by the user.

2. The application launches and loads the visualizations of crime data.

3. The HoloLens display allows the user to view the virtual surroundings.

*b) Hand Gesture Recognition:*

4. The HoloLens gadget makes use of its cameras and depth sensors, as well as other sensors, to detect the user's hand motions and gestures.

5. The user's hand motions are translated using Unity's hand gesture detection tools.

*c) Gesture-Based Controls:*

6. The HoloLens device detects a hand motion made by the user.

7. The gesture is recognized by the Unity application, which associates it with a particular interaction or control.

*d) Managing Visualizations:*

8. To utilize FPS Controller to browse the available visualizations, the user makes a motion.

9. The next or previous visualization is shown as a response from the application.

*e) Interacting with Visualizations:*

10. To open the settings menu or visualizations' choices, the user makes a motion.

11. The program shows the options menu, which gives the user the option to change the visualization style, modify the display parameters, and more.

*f) Controlling Visualization Settings:*

12. To access the settings menu or options for the visualizations, the user makes a motion.

13. The program shows the settings menu, which gives the user the option to change the display's appearance or change the parameters.

*g) Exiting the Application:*

14. A gesture is used by the user to close the application.

15. The HoloLens device goes back into standby mode after the application stops.

The user's engagement with criminal data visualizations using hand gestures on the HoloLens device is shown in this flow diagram. Users can navigate through visualizations, interact with data points, change settings, and update the visualizations as necessary thanks to Unity development's ability to recognize and interpret these actions.

### B. Data Visualization using VR

VR immerses the user in the data by allowing a more natural interactions and analyzing multi-dimensional data. VR visualizations take advantage of VR's strength of offering an intuitive way of interacting, analyzing and manipulating the data.

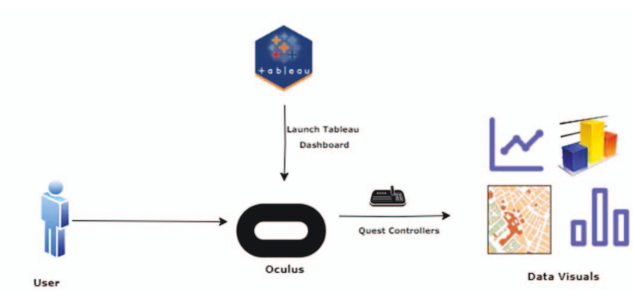


Fig. 2. User Interaction flow with Oculus Quest pro.

Fig. 2 shows how the user interacts with the Oculus quest pro device to manage visualizations on a Tableau dashboard using controllers. The flow diagram illustrating the process is as follows:

*a) User Interaction Flow:*

1. User wears the Oculus device.

2. On the Oculus device, the Tableau dashboard application is started.

3. Through the Oculus display, the user can view the virtual environment.

*b) Controller Recognition:*

4. The user's handheld controllers are recognized by the Oculus device.

5. The Oculus sensors monitor the controllers, enabling accurate movement and interaction.

*c) Launching Tableau Dashboard:*

6. The user chooses the Tableau dashboard application from the Oculus interface by interacting with the controllers.

7. The available visualizations are shown when the Tableau dashboard program has loaded.

*d) Navigating Visualizations:*

8. The user chooses a particular visualization to investigate using the controls to travel through the visuals.

9. The chosen visualization is then shown on the Tableau dashboard in response.

*e) Interacting with Visualizations:*

10. The user interacts with the visualization by using the controllers to choose data points or apply filters.

11. The Tableau dashboard picks up on the controller inputs and updates the visualization accordingly.

*f) Managing Visualization Settings:*

12. To access the settings menu or options for visualizations, the user uses the controllers.

13. The Tableau dashboard shows the settings menu, which enables the user to modify the display, alter parameters, or switch visualization types.

*g) Exploring Data Details:*

14. For a deeper look at the data specifics, the user uses controller actions to zoom in, pan, or rotate the visualization.

15. In response, the Tableau dashboard modifies its visual representation.

*h) Updating Visualizations:*

16. To update or refresh the visualizations with fresh data, the user executes a controller action.

17. The data update procedure is started by the Tableau dashboard, which also shows the updated visualizations.

*i) Exiting the Application:*

18. To close the Tableau dashboard application, the user executes a controller action.

19. The Oculus device goes back into standby mode after the application stops.

The user interacts with visualizations on a Tableau dashboard using controllers on an Oculus device, as shown in this flow diagram in Fig. 2. The controller program application navigation, interaction with data points, setting management, data detail investigation, visualization updating, and, eventually, program exit.

## IV. Discussion and Ressults

To particularly evaluate crime statistics in cities like Chicago, Baltimore, Dallas, and Denton, an immersive visualization technique using Unity 3D for HoloLens 2 was used to create bar charts, line charts, and other graphs in a single dashboard. Here is an explanation of how this method might be applied for immersive visualization in certain cities:

### A. AR Dashboard

*1) Graphical Representation:*

Bar charts, line charts, and other types of graphs can be modeled and made into 3D models. For the specific city, each graph can provide pertinent crime data. For instance, a bar chart can represent how frequently a certain sort of crime occurs, and a line chart can demonstrate how crime rates have changed over time.

*2) Interactive Dashboard:*

Using HoloLens 2 users were able to observe and interact with crime data. A dynamic dashboard was created within the Unity 3D environment. Users were able to choose individual city and display the associated graphs on the dashboard. To explore different sections of the cities, users can move about the virtual environment. Fig. 3 shows the interactive dashboard for crimes using HoloLens.


Fig. 3. Dashboard for crimes Vs Factors affecting crime with HoloLens.

*3) Comparative Analysis:*

Allow users to compare crime data from several cities by putting graphs side by side on the dashboard. As a result, crime patterns, types, or categories can be visually compared between Chicago, Baltimore, Dallas, and Denton.


Fig. 4. Dashboard for crimes Vs Factors affecting crime with HoloLens.

### B. VR Dashboard

Using Oculus Quest pro, we directly launch Tableau and visualized the following:

*1) Spatial Visualization:*

Use the crime data's latitude and longitude coordinates to precisely place the graphical representations within the virtual setting. Users are able to visualize crime patterns spatially as a result, finding crime hotspots or regions in each city.

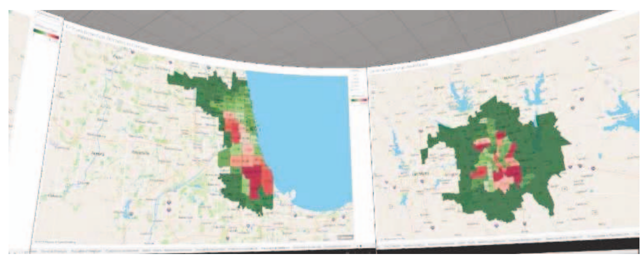

Fig. 5. Comparison of crimes for Chicago and Dallas using Oculus quest pro.

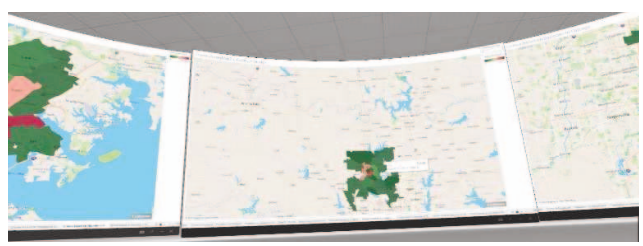

Fig. 6. User Interaction with Denton crimes.

Fig. 5 and Fig. 6 shows the comparison of crimes for Chicago and Denton using Oculus quest pro.

*2) Interactivity:*

Using Oculus Quest pro users were able to observe and interact with crime data in VR. The Oculus platform was used in spatial analysis to look at crime statistics for four cities (Chicago, Dallas, Denton, and Baltimore). In order to examine and comprehend the geographic patterns of crime episodes in various cities, this investigation makes use of Oculus' immersive capabilities. Users can interact with the data in a spatial context and obtain insightful knowledge about crime patterns and hotspots by utilizing virtual reality technology.

Importing and analyzing the crime statistics for each city is the first step in the analytic process. The information is then geocoded, which entails giving each crime incidence a set of geographic coordinates based on its address or location data. The data may now be accurately viewed and evaluated in a spatial context thanks to this phase. The geocoded crime data is then connected to the Oculus platform, enabling users to explore and engage with the data in a virtual setting. The Oculus VR headset allows users to fully immerse themselves in a 3D picture of the city, with criminal incidences shown as markers or heat maps at specific areas. This geographical depiction offers a more immersive and natural method to investigate crime trends and their connections to geographic areas.

Users can focus on areas or neighborhoods by zooming in, panning, and rotating the virtual environment using Oculus controllers to engage with the crime data. They can also choose specific crimes or collections of crimes to access further information, including crime kinds, dates, and times. Users can find crime trends, geographic patterns, and potential problem spots in the cities with this interactive exploration.

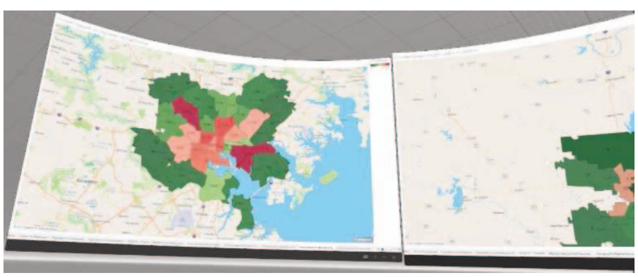

Fig. 7. Zooming functionality for user to identify the hotspots.

The Oculus platform also makes it easier to conduct comparison studies among the four cities. To examine crime rates, hotspots, and distribution patterns, users can switch between several city perspectives. For law enforcement organizations, urban planners, and policymakers, this comparative research supports evidence-based decision-making by highlighting similarities, variances, and potential contributing causes to crime in each city.

## V. Conclusions

The integration of HoloLens 2 and Oculus Quest in criminal data visualization presents a ground-breaking chance to provide insights related to crime. This technology has the potential to transform crime investigation, boost proactive crime prevention initiatives in our communities, and improve public safety by leveraging the pervasive power of mixed reality. HoloLens 2, Tableau, Oculus Quest Pro, and Unity 3D immersive visualization technology offer consumers an immersive experience while engaging with crime data. Users can tour virtual cities, view crime data in 3D, and learn more about crime trends and patterns. The technology's interactive features increase user engagement and enable a more thorough study of crime data.

Crime data from cities like Chicago, Baltimore, Dallas, and Denton may be evaluated in an interesting and educational way by using immersive visualization techniques using Unity 3D for HoloLens and Tableau for Oculus. This method helps data-driven decision-making for crime prevention and law enforcement policies in these cities, permits comparison analysis, and facilitates a thorough understanding of crime patterns.

In conclusion, the Oculus platform's spatial analysis of crime data for Chicago, Dallas, Denton, and Baltimore provides a rich, interactive experience. Users can better comprehend crime patterns and their spatial links by utilizing the capabilities of virtual reality. This analysis enables the creation of focused plans to combat crime in these cities and data-driven decision-making.

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