Interactive Visualizations for Crime Data Analysis by Mixed Reality

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Abstract. Crime data visualization plays a key role in understanding and dealing with criminal activities. This paper focuses on the integration of mixed reality (MR) and crime data analysis. There are many barriers and challenges when developing MR three-dimensional (3D) environments for visualization and inspection. The main problem is the lack of commonly shared data structures and interfaces between them. The rise in crime rates over the past few years is a huge source of issue for police departments and law enforcement organizations. As the crime rates significantly changed throughout time, both upward and downward, these changes are then compared to external factors, such as population, unemployment, and poverty. There is a need for visualizing the multiple crime datasets in multiple states with external factors. This work proposes a novel interactive approach for loading crime datasets into the HoloLens 2 device and displaying them in a mixed-reality setting for data analysis. By allowing people to engage and analyze datasets in a 3D space, the suggested system seeks to close the gap between data analysis and machine learning. Users can import many datasets, such as spatial, category, and numerical data, into the HoloLens 2 device and interactively visualize crime data for different states simultaneously. The system offers user-friendly capabilities for interactive data visualization in mixed reality once the data has been imported. The dataset is manipulated and transformed by users, who can also rotate, scale, and position it in 3D. To depict various characteristics and dimensions of the data, the system also supports a variety of visual encoding techniques, such as color mapping, size scaling, and spatial layout with the use of the imported datasets and the HoloLens 2's visualization capabilities, users can discover new insights and intricate linkages within the data. Natural movements and voice instructions allow users to engage with the visible data, enabling a hands-free and immersive data exploration experience. This paper also visualizes the crime data for four different cities: Chicago, Baltimore, Dallas, and Denton. Analyzing crime against factors such as population, employment, unemployment rate, and poverty rates provides information about the complex relationship between social factors and criminal behavior. The results and outcomes of this work will help the police department and law enforcement organizations better understand crime issues and supply insight into factors affecting crime that will help them deploy resources and help their decision-making process.

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1 Introduction

The fusion of MR technology with crime data analysis is highlighted in this work and offers a fresh approach to data presentation and exploration. The suggested approach gives users the ability to engage spatially and interactively with datasets, creating new opportunities for education, cooperation, and data-driven decision-making across a range of fields, including science, engineering, and data-driven storytelling. With the increase in new VR/AR headsets and smartphone platforms, there has been an increasing interest in MR applications [1, 2]. Although there is a large variety of tools in AR/VR for design and development, there is less support available for evaluation. MR applications allow for interactions for user studies as well as usability evaluations [3]. This paper focuses on the integration of MR technology with crime data analysis, aiming to overcome barriers and challenges in developing MR environments for visualization and inspection. The rise in crime rates in recent years has posed significant challenges for police departments and law enforcement organizations. Understanding the dynamics of crime rates and their relationship with external factors, such as population, unemployment, and poverty, is crucial. There is a need for effective visualization of multiple crime datasets across different states, considering these external factors.

This work proposes a novel interactive approach that utilizes the HoloLens 2 device to load crime datasets and visualize them in a mixed-reality setting for data analysis. By leveraging the capabilities of MR technology, the suggested system aims to bridge the gap between data analysis and machine learning. Users can import various types of datasets, including spatial, category, and numerical data, into the HoloLens 2 de-vice and interactively visualize crime data for different states simultaneously. One of the key advantages of using MR technology for crime data analysis is the ability to create three-dimensional (3D) visualizations. Traditional two-dimensional (2D) charts and graphs often fall short of capturing the spatial aspects of crime patterns. By visualizing crime data in 3D, analysts can gain a better understanding of the geographical distribution of crime incidents, hotspots, and their relationships with other factors such as demographics or socioeconomic variables. The system offers user-friendly capabilities for interactive data visualization once the datasets are imported. Users have the flexibility to manipulate and transform the datasets, including rotating, scaling, and positioning them in a three-dimensional (3D) space. To represent different characteristics and dimensions of the data, the system supports a variety of visual encoding techniques, such as color mapping, size scaling, and spatial layout.

By utilizing the imported datasets and the visualization capabilities of the HoloLens 2 device, users can explore the data and uncover new insights and intricate linkages within the crime data as shown in Fig. 1. The system allows users to engage with the visible data using natural movements and voice instructions, creating a hands-free and immersive data exploration experience. Another benefit of MR technology is the ability to overlay crime data onto real-world environments. By using spatial mapping and augmented reality techniques, crime incidents can be visualized in their actual geographic locations, superimposed onto the physical world. This has practical implications for law enforcement agencies as they can better understand crime patterns in specific areas and make informed decisions about resource allocation and patrol strategies.

Fig. 1. Dashboard for crimes Vs factors affecting crime.

2 Related Work

Shama et al. [4–7] have developed an integrated situational awareness mobile augmented reality (AR) application for smart campus planning and emergency response by providing contextualized 3D visualizations that promote and support spatial knowledge acquisition and cognitive mapping. Microsoft HoloLens has also been used for providing contextualized 3D visualizations to support knowledge acquisition for indoor evacuation and emergency response [8–10]. Lately, immersive and MR environments have received increasing interest from researchers as well as developers. MR combined with spatially tracked mobile devices offers natural and embodied user interaction to support visual analysis of data.

The crime rate is a big concern for society living in large metropolitan cities worldwide. Based on the previous research done [11] in the United States based on COVID-19 on various racial demographics, the African American race is majorly impacted due to coronavirus, and also this analysis is majorly compared with the impact indexes such as infection rate, death rate, and death to infection ratio Latino population are there second most impacted with large infections. Furthermore, research [12] towards COVID-19 in comparison with crime data clearly stated that racial ethnic, and minority groups are disproportionally affected by COVID-19, especially in Baltimore City in 2019, and 62.4% of citizens were African American which determines while the city is disproportionally affected, had influenced to increase in the crime landscape of the city. According to [13], there was a decrease in crime as a result of the pandemic, more African Americans than Whites, Asians, Hispanics, and Indians were admitted to hospitals for COVID-19, 14.4% of African Americans lack health insurance, the median sale price of homes in Baltimore City increased by 11%, and 3.6% of occupied housing units designated as Black or African American were occupied. If there were better living circumstances, more access to healthcare, and better healthcare, the African American population may be affected more favorably. According to Walker et al. [12] researchers in the data analytics for crime data in different cities, there are some common data visualization techniques used to represent the data are line charts, bar charts, and maps.

In Baltimore due to the racial ethnic and minority groups, citizens belonging to the African American proportion is high, which is the major community affected by coronavirus. Jia et al. [14] have studied how African American race is impacted the most when comparing the infection rate impact index, death rate index, and the death to infection impact index, and other races less impact on the infection rate, but the highest death rate due to infection rate ratio is high in African American and Latino. Roth. et.al. [15] have described the current state of the science and practice of spatiotemporal crime analysis in medium to large law enforcement agencies in the northeastern United States. The study included a review of the literature in the areas of criminology/crime analysis and geoinformatics/mapping and interviews with seven law enforcement officials. Comparing science and practice provides insight and identifies four unmet needs. Improves access to government records, user interface design for crime mapping tools, integrates geographic and temporal representations for better analysis of criminal activity, and improves support for strategic crime analysis and policymaking. The results were reflected in the development of a spatiotemporal crime mapping application called GeoVISTA Crime Viz. Santos [16] has emphasized the importance of crime analysis ineffective policing tactics and suggests that police departments engage crime analysts to help with crime reduction initiatives. It also emphasizes the importance of additional research on crime analysis techniques and their impact on crime reduction [17]. Santos has further conveyed that GIS has a broader role than just being a mapping tool in the analysis of crime. This differs from the impression one might get from crime mapping research, which may unfairly limit the scope of GIS.

3 Data Visualization Using HoloLens

Data visualization using HoloLens, a mixed reality (MR) device, offers a unique and immersive way to interact with data in three-dimensional (3D) space. HoloLens can be used for Spatial Data Visualization which enables the visualization of data in a spatial context. Instead of traditional charts and graphs, data can be represented as holograms placed in the user's physical environment. For example, geographical data can be projected onto a map, allowing users to explore and analyze data points in their spatial context. It can be used for Interactive Manipulation where users can manipulate and interact with the data using gestures, voice commands, and gaze-based interactions. They can resize, rotate, and move visualized data elements, allowing for dynamic exploration and analysis. This interactive manipulation provides a hands-on experience and facilitates a deeper understanding of the data. HoloLens is used for the representation of complex relationships and multidimensional data. By leveraging holograms and spatial depth, users can gain insights into patterns, correlations, and trends that may not be easily apparent in traditional 2D visualizations Fig. 2.

Fig. 2. GUI for Interaction

HoloLens allows for the overlay of data visualizations onto the user's real-world environment. For example, users can view real-time data overlays on physical objects or locations, providing context-rich visualizations. This capability is particularly useful for applications such as crime mapping or architectural design, where data can be superimposed onto real-world objects or spaces. HoloLens also supports collaborative data visualization, allowing multiple users to share the same holographic environment. Users can see and interact with each other's visualizations, fostering collaboration, discussion, and knowledge sharing. This feature is particularly valuable for team-based data analysis and decision-making processes. It provides an immersive and engaging experience for data exploration. Users can step into the data environment and move around, gaining different perspectives and uncovering hidden insights. By leveraging spatial sound and visual cues, HoloLens creates an immersive environment that enhances the understanding and analysis of complex datasets. HoloLens enhances collaborative data analysis and decision-making processes in several ways like.

- Shared Holographic Environment: HoloLens allows multiple users to share the same holographic environment, enabling them to view and interact with data visualizations together. This shared experience promotes collaboration and facilitates real-time discussions and brainstorming sessions among team members.
- Co-located Collaboration: HoloLens enables users to see each other's avatars or representations within the shared environment, creating a sense of co-presence even if the collaborators are physically located in different places. This co-located collaboration fosters a more natural and immersive communication experience, facilitating effective teamwork and coordination.

- Simultaneous Data Exploration: Collaborators using HoloLens can simultaneously explore and manipulate data visualizations in real-time. They can interact with holographic elements, annotate or highlight specific data points, and discuss their findings with others. This simultaneous exploration promotes a deeper understanding of the data and allows for the identification of insights that may not be evident when working individually.
- Gesture and Voice-Based Interactions: HoloLens supports gesture and voice-based interactions, allowing collaborators to intuitively manipulate data visualizations and issue commands. This hands-free interaction frees up users' hands and enables more fluid collaboration, as they can focus on the data and communicate without the need for additional devices or tools.
- Remote Collaboration: HoloLens enables remote collaboration by leveraging mixed reality. Collaborators can connect from different locations and interact with the shared holographic environment, regardless of their physical distance. This capability is particularly beneficial for distributed teams, experts located in different regions, or situations where physical presence is challenging.
- Enhanced Data Communication: HoloLens provides a powerful medium for data communication. Instead of relying solely on verbal descriptions or static visualizations, collaborators can use holographic elements to represent data, relationships, and insights. This visual and interactive representation enhances comprehension and facilitates effective communication of complex data concepts among team members.
- Decision-Making Support: HoloLens can support decision-making processes by enabling collaborators to analyze data, compare scenarios, and visualize potential outcomes. By immersing themselves in the data environment, collaborators can gain a holistic understanding and make more informed decisions based on shared insights.

In summary, HoloLens offers a powerful platform for data visualization, enabling spatial data exploration, interactive manipulation, and collaboration. By leveraging the capabilities of mixed reality, HoloLens provides a novel and immersive way to interact with data, facilitating deeper insights and more informed decision-making. While HoloLens is not a dedicated data analysis tool like traditional statistical software, its capabilities as a mixed reality device provide unique opportunities for visualizing, exploring, and collaborating on data analysis tasks. It offers a more immersive and interactive approach to data analysis, enabling users to engage with data in new ways and derive meaningful insights.

3.1 Interactivity

HoloLens provides seamless integration with the Unity game development engine, enabling developers to create interactive mixed reality experiences. Unity is a popular and powerful platform for building 3D applications, and it offers extensive support for HoloLens development. Here are some key aspects of the interactivity between HoloLens and Unity:

- Spatial Mapping: HoloLens uses spatial mapping to understand the surrounding environment. Unity provides APIs and tools to access and utilize spatial mapping data. Developers can use this data to create interactive experiences that respond to the

physical world, such as placing virtual objects on real surfaces or detecting collisions with the environment.
- Gesture Recognition: HoloLens supports gesture recognition, allowing users to interact with holograms using hand gestures. Unity provides gesture recognition APIs that can be utilized to detect and respond to gestures like air tap, bloom, or pinch. Developers can implement gesture-based interactions to manipulate objects, trigger actions, or navigate through the application.
- Voice Commands: HoloLens includes a built-in microphone and supports voice commands. Unity integrates with the HoloLens voice recognition system, enabling developers to create voice-controlled interactions within their applications. Developers can define voice commands and associated actions, allowing users to interact with holograms using voice input.
- Gaze Interaction: HoloLens tracks the user's gaze direction, and Unity provides APIs to access gaze information. Developers can use gaze tracking to create interactive experiences where the user's gaze can trigger actions or provide input. For example, activating an object by looking at it or displaying additional information when the user gazes at a specific location.
- Spatial Sound: HoloLens allows for spatial sound, meaning that audio can be positioned in 3D space to create a more immersive experience. Unity supports spatial audio integration, enabling developers to incorporate realistic 3D audio effects that match the position and movement of virtual objects in the mixed reality environment.
- Input Management: Unity provides an input management system that abstracts the different input methods available on HoloLens, such as gaze, gestures, voice, and controllers. Developers can utilize this system to handle different input sources and create unified interactivity within their applications.
- UI Elements and Interactions: Unity offers a wide range of UI development tools and frameworks. Developers can create interactive user interfaces (UI) for HoloLens applications using Unity's UI system, which includes buttons, sliders, panels, and other UI elements. These UI elements can respond to user interactions, such as gaze or gesture inputs.
- Application Lifecycle: Unity provides hooks and events that allow developers to handle the application lifecycle on HoloLens. This includes events for application startup, pause, resume, and shutdown. Developers can use these events to manage the state of their applications and implement custom behaviors based on the application lifecycle.

Figure 3 shows a high-level overview of a system that uses Unity and Visual Studio to create mixed reality (MR) experiences. The user interacts with the MR experience using hand gestures. Unity is used to create the 3D world of the MR experience, including importing assets, designing the virtual environment, and defining interactions. Visual Studio is used to write the C# code that controls the behavior of the MR experience, including handling hand gestures input, managing virtual objects, and implementing desired functionality. The C# code is compiled into machine code, transforming it into a format that the computer or MR device can execute. The XChart Asset, a custom Unity asset, is utilized to display charts and graphs within the MR experience, providing visual representations of data. The Mixed Reality Toolkit (MRTK) simplifies the development process by offering pre-built scripts, input handling, interaction models, and other utilities for creating immersive MR applications.

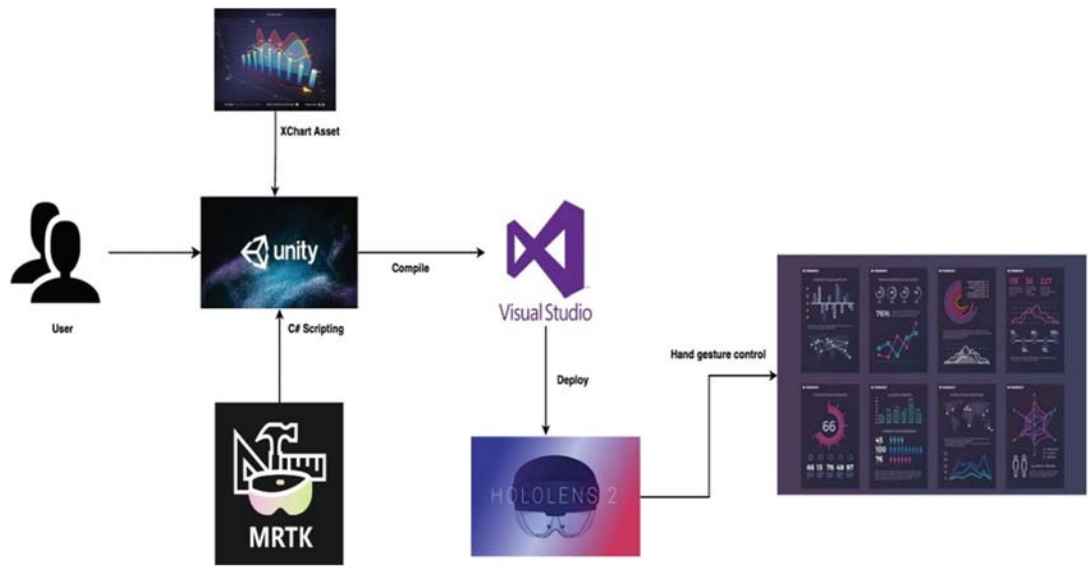

Fig. 3. User Interactivity with HoloLens

The MR experience is packaged and deployed to the target device, such as a HoloLens headset, following the specific deployment process for the platform and device. The deployed MR experience is ready for the user to interact with, utilizing hand gestures to control and manipulate virtual objects within the 3D environment. Below is a detailed description of each component.

1. User: The user is the person who will be experiencing the MR application. They interact with the MR experience using hand gestures, which provide a natural and intuitive way to control and interact with virtual objects.
2. Hand Gesture Control: Hand gesture control is a component of the MR experience that enables the user to interact with virtual objects or elements within the 3D world using hand gestures. This can include gestures like air tap, pinch, swipe, or hand tracking for manipulating objects, selecting options, or triggering actions.
3. Unity: Unity is a powerful game engine commonly used for creating interactive 3D applications, including MR experiences. It provides a visual development environment where developers can design and build the 3D world, import assets, define interactions, and create the overall user experience. Unity supports scripting in C#, allowing developers to write code to control the behavior of the virtual objects and handle user interactions.
4. Visual Studio: Visual Studio is an integrated development environment (IDE) that provides a comprehensive set of tools for software development. In the context of creating an MR experience, Visual Studio is used to write the C# code that controls the behavior of the virtual objects and handles user input. It offers features like code editing, debugging, and project management, making it easier for developers to create and maintain their MR applications.

5. Compile: After writing the C# code in Visual Studio, the code needs to be compiled into machine code that can be executed by the computer or the MR device. Compilation translates the human-readable code into a format that the computer can understand and execute.
6. XChart Asset: The XChart Asset is a custom Unity asset specifically designed for displaying charts and graphs within the MR experience. It provides convenient tools and functionality for creating, customizing, and rendering various types of charts and graphs, allowing developers to present data visually within the virtual environment.
7. Mixed Reality Toolkit (MRTK): The Mixed Reality Toolkit (MRTK) is a collection of tools, components, and APIs that simplify the development of MR experiences in Unity. It offers pre-built scripts, input handling, interaction models, and other utilities that accelerate the development process and provide common functionalities required for creating immersive MR applications. MRTK streamlines the integration of hand gesture recognition, spatial mapping, spatial sound, and other MR-specific features into the Unity project.
8. Deploy: Once the MR experience is created and tested, it needs to be packaged and deployed to the target device, such as a HoloLens headset. This involves preparing the application files, assets, and dependencies, and transferring them to the device for installation and execution. The specific deployment process may vary depending on the target platform and device requirements.

3.2 GUI Elements

In the MR application created using Unity and Visual Studio, various GUI elements are incorporated to enhance the user experience and provide different modes of interaction. Below are the GUI components that are utilized:

1. Buttons: Buttons are a common GUI element used to trigger actions or perform specific functions within an MR application. Unity provides a UI system that allows developers to create and customize buttons with different visual styles, such as 3D buttons or holographic buttons. Users can interact with these buttons using hand gestures, such as air tapping or pressing and releasing a virtual button using hand tracking. On a click of these buttons, the graphs can be displayed and hidden.
2. Voice Commands: Voice commands provide a hands-free mode of interaction in an MR application. By integrating voice recognition capabilities, users can control the application by speaking specific commands. Unity, along with the HoloLens platform, supports voice recognition, allowing developers to define voice commands and associate them with corresponding actions or functionalities within the application. Users can simply speak the voice command, and the application will respond accordingly.
3. Laser Pointer: A laser pointer is an interactive tool that allows users to point and interact with virtual objects or UI elements in the MR environment. It can be simulated using hand gestures, where the user's hand is recognized as a laser pointer. As the user moves their hand or finger, a virtual laser pointer is projected in the direction of the user's gaze, enabling precise selection and interaction with objects or UI elements. The laser pointer can be used to activate buttons, select menu options, or manipulate virtual objects. Using the laser pointer, button on click and off-click events are triggered.

4. Gesture-based Interactions: In addition to buttons and voice commands, the MR application can incorporate gesture-based interactions. Unity, combined with HoloLens, supports hand gesture recognition, enabling users to interact with virtual objects or UI elements through predefined hand gestures such as air tap, pinch, swipe, or grab. These gestures can be used to manipulate objects, navigate menus, or trigger specific actions within the application. With this gesture control, movement of the graph is achieved, and the graph can be zoomed in and zoomed out. The distance between the graph and the eye was adjusted using this control. Figure 4 shows the UI interactions using hand gestures.
5. Spatial UI Elements: Spatial UI elements refer to user interface components that are positioned in 3D space in the MR environment. Unity provides tools and frameworks for creating spatial UI elements, such as panels, tooltips, or information displays that can be anchored to virtual objects or positioned relative to the user's gaze. These spatial UI elements can provide additional information, options, or visual feedback to enhance the user experience and improve interaction within the application.

Fig. 4. User interaction using hand gestures

By incorporating these GUI components, users get an interactive experience in the MR application. Users can interact with virtual objects, trigger actions through buttons or voice commands, use hand gestures for manipulation, and receive visual feedback through spatial UI elements. This combination of GUI elements expands the range of interaction possibilities and makes the MR experience more intuitive and engaging for users.

4 Analysis of Crime Comparison with Factors

Analyzing crime against factors such as population, unemployment, and poverty rates provides valuable information about the complex relationship between social factors and criminal behavior. Unemployment is a factor that can affect crime rates. A high unemployment rate can create an environment conducive to crime, as people with financial difficulties and limited employment opportunities may turn to illegal means to support themselves. Unemployment can also affect the general economic conditions of an area and affect the availability of resources, social services, and community well-being, all of which can indirectly affect crime rates. The poverty rate is also closely related to crime.

4.1 Analysis of Crime with Population

Crime is often high in areas with higher poverty rates. Poverty can create social and economic inequality, lack of access to education and health care, and limited opportunities, leading to frustration, hopelessness, and an increased likelihood of engaging in criminal activity. Poverty can perpetuate the cycle of crime, so it is critical to address economic inequalities and provide support systems to rebuild disadvantaged communities.

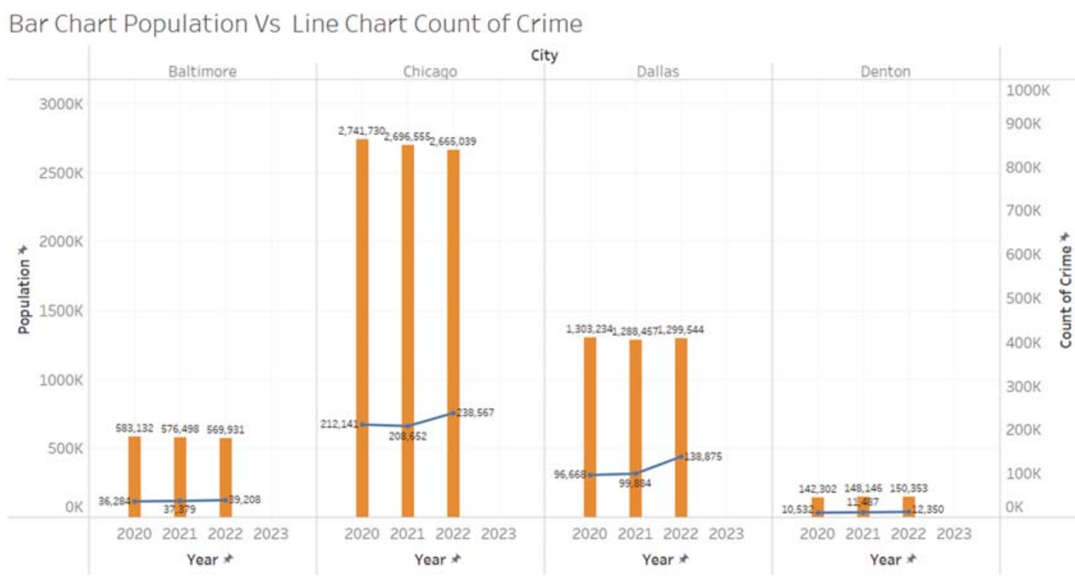

Fig. 5. Population Vs Crime in 4 Cities from 2020 to 2022.

Figure 5 shows the population dynamics of Baltimore, Chicago, Dallas and Denton show interesting trends compared to crime in 2020–2022. Despite the population decline, Baltimore experienced an increase in crime during the same period. This shows an alarming trend where crime has increased even as the population has decreased. The rate of change in crime is significant, with an increase of 8.05. This suggests that despite population declines, other factors such as socioeconomic conditions, community dynamics, or changes in police strategies may be contributing to crime growth. Chicago experienced a similar pattern of population decline followed by a decline in crime in

2020–2021. However, crime increased in 2021–2022. Resulting in a 12.45 increase in crime between 2020 and 2022. This indicates a variable crime trend, suggesting that some factors such as population dynamics, socioeconomic conditions, or changes in police strategies can influence the level of crime in Chicago. Dallas experienced a population decline in 2020–2021 followed by an increase in 2021–2022. At the same time, crime has continuously increased in the same period; the rate of change is 43.3. This shows that despite changes in population size, crime has increased in Dallas. Understanding the factors that influence crime growth is critical to effective crime prevention and community safety. Denton's population grew from 2020 to 2022, in line with crime growth at a rate of change of 17.26. The increase in crime indicates that a growing population can affect community dynamics and crime patterns in Denton.

4.2 Population Comparison with Employment

By analyzing the relationship between population and employment, we can better understand the labor force participation rate and possible effects on economic conditions. A higher employment-to-population ratio indicates a healthier labor market and better job opportunities. On the other hand, lower employment-to-population may indicate a less favorable labor market, where job opportunities are limited. Analyzing population and employment together can help identify areas of potential labor market imbalances. In addition, understanding the relationship between population and employment can inform workforce development strategies and policies. In summary, comparing population and employment provides valuable information about labor market dynamics, labor force participation rates, and economic conditions. By analyzing these factors together, decision-makers and stakeholders can better understand the labor market, identify potential challenges, and develop strategies to promote employment growth and overall economic well-being.

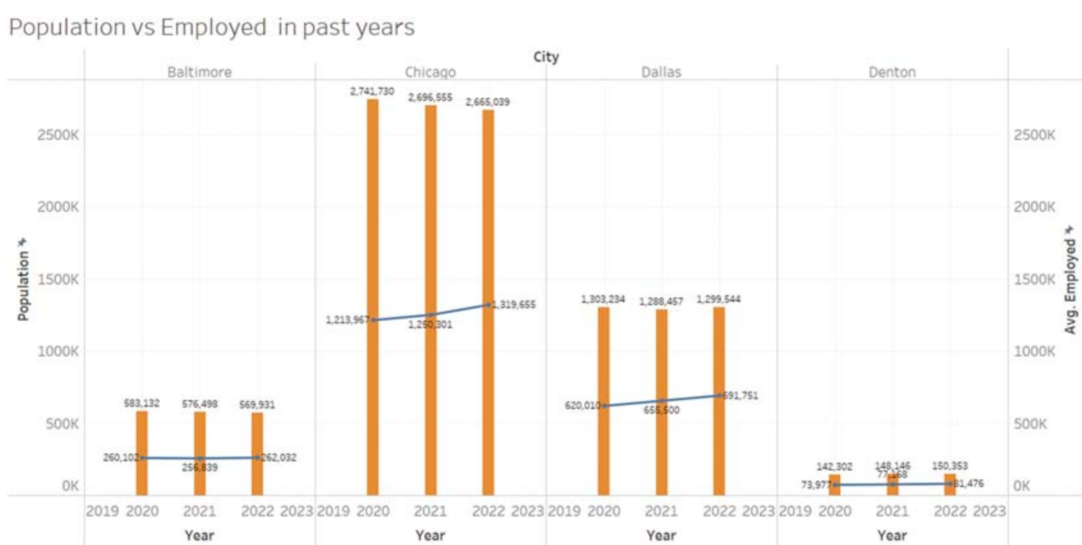

Fig. 6. Count of Population Vs Employed in 4 Cities from 2020 To 2022.

Figure 6 shows that despite the population decline, employment in Baltimore initially declined in 2020–21, but then increased in 2021–22. This suggests an unstable labor market where there may have been some instability in working conditions. The change in employment levels in the face of population decline indicates that background factors influencing these trends, such as changes in industries, economic conditions, or local politics, require further investigation. Despite the population decline, Chicago showed employment growth from 2020 to 2022. This suggests a resilient labor market that has managed to create opportunities despite population decline. Increases in employment during times of population decline may be due to factors such as industrial diversification, economic development initiatives, or changes in the composition of the workforce. Understanding these dynamics can provide valuable insight into the causes of Chicago's employment growth.

Dallas experienced a population decline in 2020–2021, followed by an increase in 2021–2022. At the same time, employment increased over the same period. This indicates a positive development, where both population and employment are increasing. Rising employment rates combined with demographic changes point to a growing job market and potentially expanding job opportunities in Dallas. Denton's population grew between 2020 and 2022, consistent with rising employment levels over the same period. This suggests that population growth was accompanied by job growth and expanded job opportunities. Employment growth combined with population growth means a healthy job market in Denton.

4.3 Population Comparison with the Unemployment Rate

Comparing the population with the unemployment rate gives an idea of the dynamics of the labor market and the unemployment rate of a certain population. By studying the relationship between population and unemployment, we get a better understanding of the availability of job opportunities and the economic well-being of the population. When comparing the population with the unemployment rate, it is imperative to consider the share of the unemployed in the workforce. This metric helps measure the extent of unemployment in the population and gives an idea of the level of economic difficulties and potential socio-economic challenges.

A higher unemployment rate indicates a weaker labor market and fewer job opportunities relative to the available workforce. This shows that a significant part of the population is actively looking for work but is unable to find a suitable job. Higher unemployment rates can lead to financial stress, reduced consumer spending, and potential social consequences. Figure 7 shows that in Baltimore, the unemployment rate rose initially in 2020–2021, but then fell in 2021–22, despite the population decline. This suggests a volatile labor market, where unemployment conditions fluctuated somewhat. Changes in unemployment rates against the background of population decline indicate that background factors influencing these trends, such as changes in industries, economic conditions, or local politics, need to be further investigated.

In Chicago, although the population decreased, the unemployment rate showed a general decrease from 2020 to 2022. This indicates a positive development in the labor market, where job opportunities expanded, or unemployment decreased despite a population decrease. A decrease in the unemployment rate indicates a relatively healthier labor market in Chicago, which may be due to factors such as economic development initiatives, changes in the labor force share, or industry dynamics.

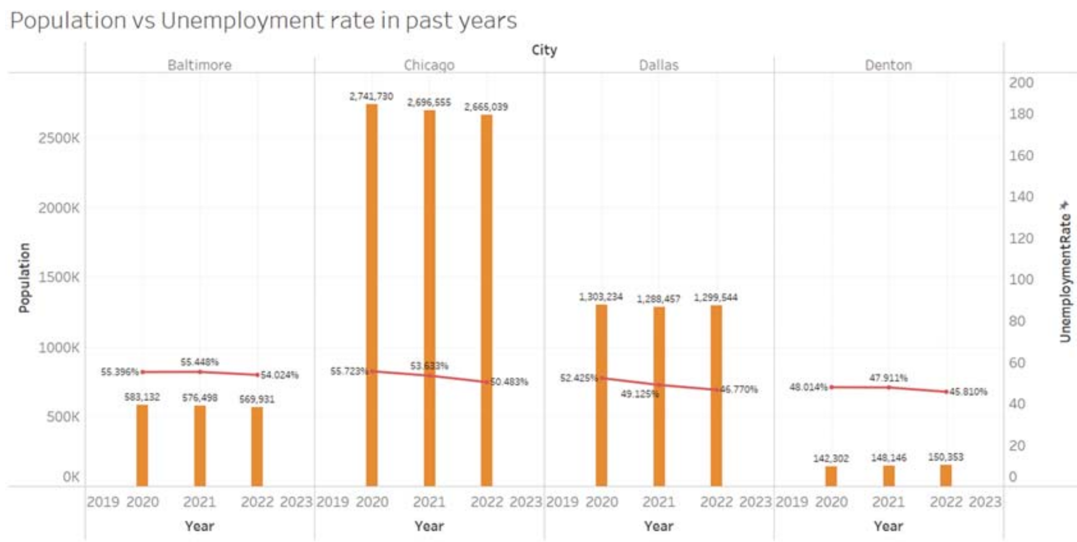

Fig. 7. Count of Population Vs Employed in 4 Cities from 2020 to 2022.

Dallas experienced a population decline in 2020–2021, followed by growth in 2021–2022. At the same time, the unemployment rate decreased during the same period. This indicates a positive development, where both the population and unemployment have improved. A decline in the unemployment rate amid population fluctuations indicates an improvement in the Dallas job market and possibly an expansion of job opportunities. Denton's population increased between 2020 and 2022, consistent with a decrease in the unemployment rate over the same period. This shows that the growth of the population was accompanied by a decrease in unemployment. Lower unemployment combined with population growth means a healthier job market in Denton.

4.4 Crime Comparison with Unemployment Rate

An analysis of the relationship between crime and the unemployment rate provides insight into the possible influence of economic conditions on criminal behavior. By examining the relationship between these two factors, we can better understand the complex dynamics between socioeconomic factors and crime.

When comparing the crime rate with the unemployment rate, it is important to consider the possible causal relationship between the two. High unemployment can increase the likelihood of criminal activity for several reasons. Economic pressures, economic desperation, and limited job opportunities can push people to illegal livelihoods or lead to greater frustration and social unrest, which can lead to an increase in crime. On the other hand, a decrease in unemployment can be a sign of an improvement in the economic situation and an improvement in legal employment opportunities. This can potentially lead to a reduction in crime as individuals have better prospects for financial stability and are less likely to resort to criminal activity.

However, it is important to understand that the relationship between crime and unemployment is complex and influenced by many other factors. Socioeconomic differences, educational attainment, community resources, and cultural factors influence crime rates and unemployment rates. Therefore, a comprehensive analysis that takes into account multiple variables is necessary to accurately understand the interaction between unemployment and crime.

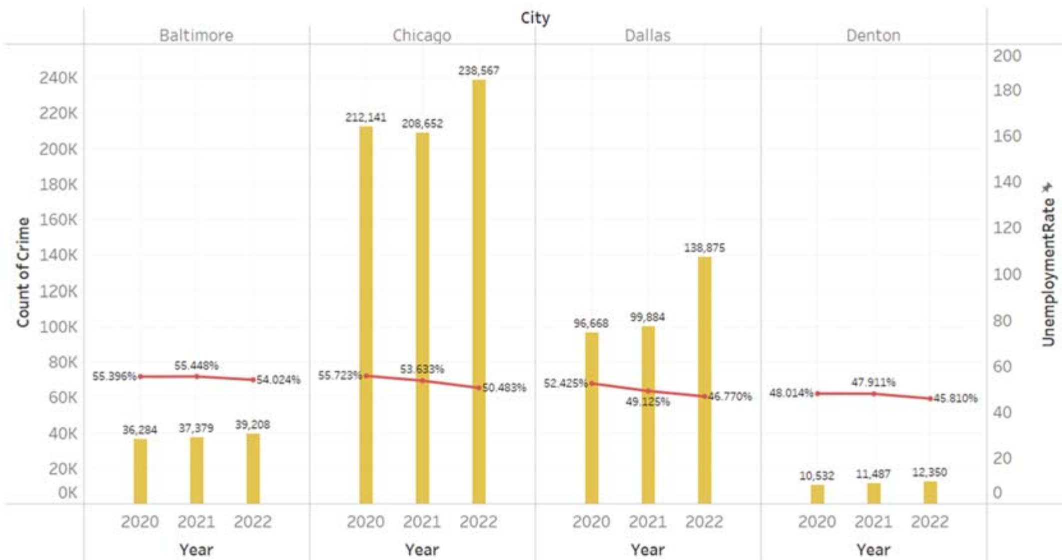

Fig. 8. Count of Crime Vs Unemployment Rate in 4 Cities from 2020 to 2022.

Figure 8 shows that the unemployment rate in Baltimore is expected to decrease by about 1 percent between 2020 and 2022, there is a slight increase in reported crime. This suggests that the drop in unemployment is not necessarily correlated with the drop in crime in Baltimore. Other factors such as socioeconomic conditions, systemic challenges, or community dynamics can also contribute to crime growth. Similarly, Chicago, with an unemployment rate of about 5 % between 2020 and 2022 but a slight increase in reported crime, is 12.4 %. This shows that the drop in unemployment does not directly translate to a drop in crime in Chicago. Other factors such as neighborhood dynamics, social inequality, or other causes may also contribute to the increase in crime.

Although the unemployment rate in Dallas decreased by about 6 percent between 2020 and 2022, reported crime increased slightly. This suggests that a reduction in unemployment alone does not guarantee a crime reduction. Other factors such as social factors, community resources, or changes in criminal behavior patterns may contribute to the increase in crime in Dallas.

Similarly, in Denton, while the unemployment rate decreased by about 3% between 2020 and 2022, reported crime increased slightly. This shows that the drop in unemployment does not directly correspond to the drop in crime in Denton. To fully understand the drivers of crime growth, it is important to consider other factors such as demographic changes, community dynamics, or changes in police strategies.

4.5 Population Below the Poverty Rate

The percentage of people living in poverty provides valuable insight into the socioeconomic conditions within a population. Comparing the poverty rates in Baltimore, Chicago, Dallas, and Denton reveals variations in the prevalence of poverty across these cities. However, it still indicates a significant portion of the population experiencing poverty. Efforts to address poverty in Chicago, Baltimore, Dallas, and Denton should focus on creating economic opportunities, promoting affordable housing, and strengthening social programs. Supporting initiatives that foster economic empowerment and provide resources to individuals and families in need can help alleviate poverty.

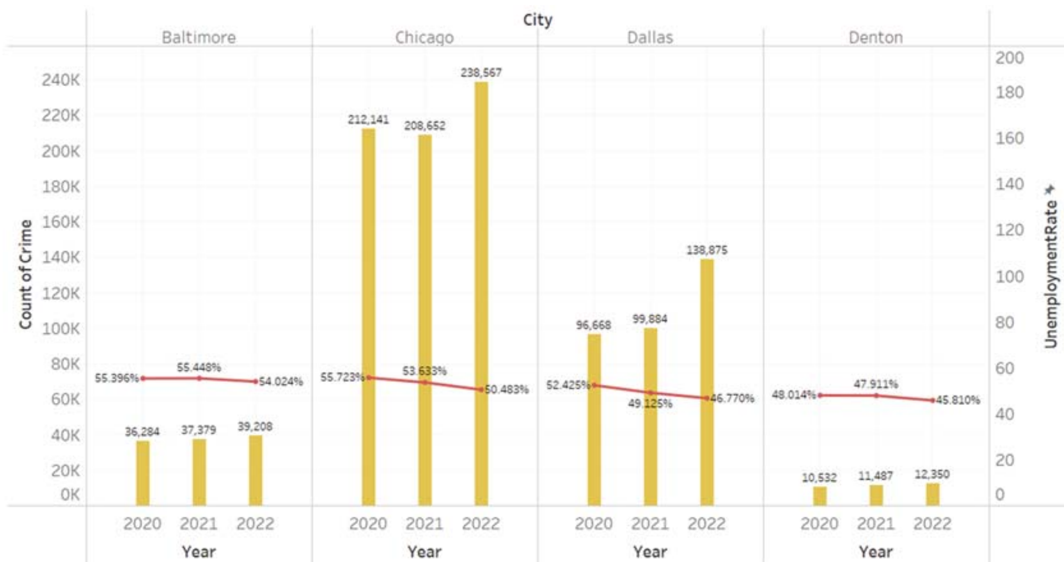

Fig. 9. Population Below Poverty Level Status in 4 Cities from 2016 to 2020.

Figure 9 shows that the analysis of poverty rates in Baltimore, Chicago, Dallas, and Denton from 2016 to 2020 shows some interesting trends and differences in the prevalence of poverty in these cities. A decrease in the poverty rate indicates possible improvements in economic conditions, resource availability, and socioeconomic support systems in Baltimore. However, it is important to note that the initial poverty rate in Baltimore was relatively high in 2016, indicating significant economic challenges that require attention and targeted action. It refers to efforts to fight poverty and improve the economic conditions of the city. The general trend indicates a change in the level of poverty during this period. The initial decline in the poverty rate indicates a positive development in poverty reduction efforts and improving economic conditions in Dallas. The overall trend indicates that poverty levels in Denton fluctuate during this period.

An initial increase may indicate socioeconomic challenges, but a subsequent decline followed by an increase indicates a dynamic socioeconomic landscape and possible changes in economic conditions in the city. In contrast, Denton had the lowest poverty rate in 2019 at 13.886%, indicating relatively better socioeconomic conditions. In general, a lower-level analysis of poverty rates in these cities shows a decrease or change in poverty rates.

5 Conclusions

The integration of MR technology with crime data analysis presents a promising approach for enhancing crime data visualization, analysis, and interpretation. This paper utilizes the HoloLens 2 device to import and visualize multiple crime datasets in a mixed-reality environment. The system enables users to engage with the data spatially and interactively, bridging the gap between data analysis and machine learning. The user-friendly capabilities of the system allow for the importation of diverse crime data types, including spatial, category, and numerical data, into the HoloLens 2 device. Once imported, users can manipulate and transform the datasets, providing flexibility in exploring the data from different perspectives. Visual encoding techniques, such as color mapping, size scaling, and spatial layout, facilitate a comprehensive understanding of the data, revealing intricate crime patterns and trends that may be challenging to discern in traditional 2D visualizations.

The immersive and hands-free nature of the system sets it apart, as users can interact with the data using natural movements and voice instructions. This enhances the data exploration experience and enables users to focus on analysis and discovery without the need for physical input devices. The proposed approach also extends beyond law enforcement, offering interdisciplinary applications in education, collaboration, and data-driven decision-making across various domains.

The practical benefits of this work are significant for police departments and law enforcement organizations. By gaining a better understanding of crime issues and mapping crime incidents geographically, these organizations can derive valuable insights into the factors influencing crime rates. This knowledge can inform resource allocation, strategic planning, and decision-making processes, leading to more effective crime prevention measures and improved community safety. In summary, the integration of MR technology with crime data analysis provides an innovative and promising solution for data presentation and exploration. It empowers users to engage spatially and interactively with crime datasets, opening new opportunities for understanding crime patterns, making data-driven decisions, and fostering collaboration.

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