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Beyond What is Visible: Enhancing Air Quality Awareness through Immersive Virtual Reality Visualizations

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Abstract

The levels of air quality found in some cities are a growing concern for environmental, healthcare, and government organizations worldwide due to the rise of environmental pollution. Thus, novel solutions for raising population awareness are of paramount importance. This work describes a platform for visualizing air quality data using Virtual Reality (VR), allowing having an aerial view of a given location, enhanced with air quality layers with the goal of helping raise awareness during education classes, fairs, or events. Using distinct visualization techniques, users can navigate through a map, position themselves in different points of view, and contemplate how air pollution is hiding from their view in the physical world, as well as filter using several parameters, e.g., removing roads, buildings, or displaying only a specific data range for a given period in time.

CCS Concepts

• ***Human-centered computing*** → ***Mixed / augmented reality;*** • ***Information systems*** → ***Spatial-temporal systems;***

1. Introduction

Nowadays, there is an urge to raise public awareness regarding the levels of air quality they found on streets every day. Air pollution contributes to environmental degradation, including damage to ecosystems, deforestation, and climate change. It also has severe health consequences, especially for vulnerable groups such as children, the elderly, and individuals with respiratory or cardiovascular conditions, among others. This problem has has gained more attention from environmental, healthcare, and government organizations worldwide due to the rise of environmental pollution.

Hence, there is an opportunity for creating new solutions capable of capturing public attention. Increasing air quality awareness fosters a better understanding of the causes and consequences of pollution. It can also lead to a collective effort to reduce pollution sources, adopt cleaner technologies, and promote sustainable practices, thereby protecting the environment for future generations [ORS*22]. This also helps people recognize the importance of scientific research, promotes critical thinking, and encourages the adoption of sustainable practices, empowering individuals to make more informed decisions about their lifestyles.

Although Augmented Reality (AR) solutions have already been proposed for in-situ air quality visualizations [MMDSS23], they require users to be positioned in specific locations for presenting additional information. If used for education purposes, AR solutions imply that teachers and students visit specific locations. This limits the adoption of such solutions, given that users must be at specific locations, which may not always be possible. Alternatively, Virtual Reality (VR) can provide a three-dimensional, interactive, and immersive experience for users. This can enhance understanding by providing a spatial context and making complex data more accessible and engaging. In turn, users can explore data and gain insights into the impact of air quality for a given location, enabling them to make informed decisions about outdoor activities, routes, and exposure risks [FAP*22, KKF*21].

2. Using VR for Enhancing Air Quality Awareness

The work described reflects an effort from a multidisciplinary team (backgrounds in environmental engineering, computer science, human-computer interaction, information visualization, and VR/AR) towards creating a platform for visualizing air quality data using VR. During the design and development process, domain experts were consulted to validate the proposed platform, following a Human-Centered Design (HCD) methodology.

The platform offers an aerial view of a given location, illustrated in 3D by displaying the silhouette of the surrounding buildings (creating a realistic representation of urban areas), which is enhanced with air quality data, previously collected for a given time period (see Figure 1). The pollution levels are displayed using color-coded virtual objects, following a heat-map approach. Light green is used to represent harmless (light/little) levels of pollution (under 10 units), while the darker green represents moderate pollution (between 10 and 25 units). Yellow represents unhealthy pollution

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levels (between 25-100 units), orange is used for unhealthy (between 100-200 units) and red represents hazardous levels (over 200 units). Units could be micrograms per cubic meter (μg/m3), or parts per million (ppm) depending on the pollutant being measured. Particulate matter (PM) is measured in μg/m3, while carbon monoxide (CO) and nitrogen dioxide (NO2) are often measured in ppm. These visualizations can help grasp the magnitude and distribution of pollution, facilitating comprehension and decision-making.

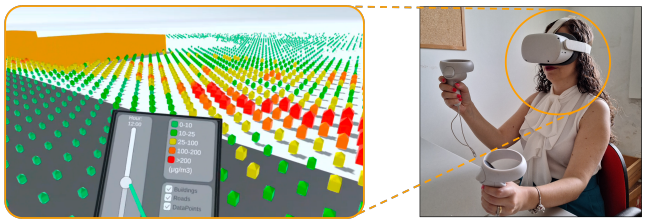

Figure 1: *Exploring air quality data through Virtual Reality (VR) visualizations. 3D representation having objects with distinct sizes and colors representing distinct levels of air pollution. The user can interact with the VR environment through the headset controllers. In the left hand of the user, at all times, a panel is visible, allowing to filter the data to be visualized for a specific period in time.*

In order for users to filter the air quality data, the left VR headset controller offers a panel that allows selecting the content to be visualized based on check boxes. Similarly, users can turn on and off the representation of the buildings, roads and the data set itself (see Figure 1). Moreover, it is possible to select the air quality data being displayed through a slider that adjusts the visualization to a specific hour of the day. To navigate through the virtual environment, a teletransport method was implemented, accessible through the VR headset's right controller, allowing the user to choose a distinct position and jump to it on desire. (see Figure 2-A). This way, users can explore virtual cities, neighborhoods, or other environments from different points of view, and observe how air quality varies across different areas. As illustrated by Figure 2-B, users can also position themselves at the ground level, enhancing the understanding of how pollution levels can vary.

Through the proposed visualizations, we argue that it is possible to influence users' air quality levels, as well as risk perception. The platform can serve as an educational tool to raise awareness and educate students of different degrees. It can be used in schools, public exhibitions, or community events to provide an interactive and engaging learning experience. By allowing users to interact with air quality data, VR can foster a deeper understanding of the subject and inspire action. Hence, developing a stronger sense of the consequences of pollution and become more motivated to adopt behaviors that reduce their exposure or contribute to air quality improvement. The air quality data was collected by our partners from the environmental field. The Unity 3D game engine was used, based on C# scripts, taking advantage of Google Maps SDK and the Meta Quest 2 SDK to enable its use in the VR headset.

3. Final Remarks and Future Work

This work proposed a platform using VR for visualizing air quality data. The features proposed allow its use in education classes, with students of various levels, as well as its disclosure in science fairs, conference workshops, or other relevant events.

This study is being expanded by planning a formal user study with domain experts and target users. Thereafter, we would like to integrate collaborative features to the proposed platform, allowing the air quality data to be explored in a collaborative manner. Furthermore, consider multiple locations, while also exploring air quality data at different heights.

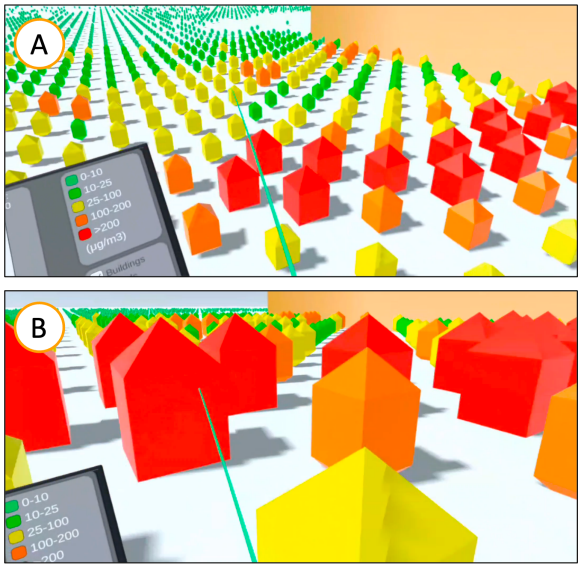

Figure 2: *Overview of some user interfaces presented in the VR environment: A- Teletransport method - User choosing a new position for observing the data from a distinct view; B- Navigation method - User visualizing data through a Human point of view.*

4. Acknowledgments

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References

[FAP*22] FRÖHLER B., ANTHES C., POINTECKER F., FRIEDL J., SCHWAJDA D., RIEGLER A., TRIPATHI S., HOLZMANN C., BRUNNER M., JODLBAUER H., ET AL.: A survey on cross-virtuality analytics. In *Computer Graphics Forum* (2022), vol. 41, pp. 465–494. 1

[KKF*21] KRAUS M., KLEIN K., FUCHS J., KEIM D. A., SCHREIBER F., SEDLMAIR M.: The value of immersive visualization. *IEEE Computer Graphics and Applications 41*, 4 (2021), 125–132. 1

[MMDSS23] MARTINS N. C., MARQUES B., DIAS P., SOUSA SANTOS B.: Expanding the horizons of situated visualization: The extended sv model. *Big Data and Cognitive Computing 7*, 2 (2023). 1

[ORS*22] OLIVEIRA K., RODRIGUES V., SLINGERLAND S., VANHERLE K., SOARES J., RAFAEL S., TROZZI C., BOUMAN E., FERREIRA J., KEWO A., ET AL.: Assessing the impacts of citizen-led policies on emissions, air quality and health. *Journal of Environmental Management 302* (2022). 1