Immersive Analytics for Spatio-Temporal Data on a Virtual Globe: Prototype and Emerging Research Challenges

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Figure 1: A look at our 3D globe currently displaying COVID infection numbers via country elevation and colour. Left/Middle: Two consecutive days where we can see the different reporting interval of countries. Right: Zoomed-in view.

ABSTRACT

We present our approach for the immersive analysis of spatio-temporal data, using a three-dimensional virtual globe. We display quantitative data as country-shaped elevated polygons and animate elevation levels over time to represent the temporal dimension. This approach allows us to investigate global patterns of behaviour, like pandemic infection data. By using a virtual reality setting, we intend to increase our understanding of spatial data and potential global relationships. Based on the development of our prototype, we outline research challenges we see emerging in this context.

CCS CONCEPTS

• **Human-centered computing** → **Visualization systems and tools**; **Virtual reality**.

KEYWORDS

pandemic data visualisation, virtual reality, globe visualisation

1 INTRODUCTION

Our interconnected world enables us to obtain a variety of global data from many application domains, often in the form of temporal data that has the potential to show how the world develops. In pandemic statistics, for example, we are interested to see the global development and spread of a virus over time. Important tasks in this context include highlighting how neighbouring countries might affect each other, or how they create potential localised phenomena. Global patterns and differences between multiple localised phenomena are of particular interest. Hence, we need efficient analysis solutions that are able to leverage the inherent spatial characteristics of global data. Globe-based metaphors can be an intuitive way of presenting such spatial data and are an ongoing research topic [6] in Immersive Analytics (IA). IA is re-examining 3D visualisations for modern immersive technologies [4] and can facilitate more engaging data *Presentation*, advantages for *Collaboration*, and analysis of *Spatial Data* [2]. Therefore, we decided to investigate immersive visualisations of spatio-temporal data on a virtual globe in virtual reality (VR). There exists a variety of visualisation methods for displaying quantitative data on a globe, e.g., bar or circle glyphs in various layouts [6], or using cartograms, which scale countries' shapes to convey the underlying data [5], but make little use of spatial perception in VR. Previous work has found that an exocentric globe in VR is generally the best choice for visualisation [9].

We propose an exocentric *visualisation of spatio-temporal data on a virtual globe* in VR, that uses countries' heights instead of bars to show quantitative data per country, and animations to depict temporal changes in the data. Based on our prototype development, we also identified several *research challenges* we see emerging in this context. With this work, we hope to provide the first step towards an *intuitive and natural data visualisation* that offers valuable insights into regional behaviour for *time-dependent data on a global scale*.

2 THE VIRTUAL GLOBE

We have created a virtual globe (see Figure 1), which can be viewed in a 3D desktop app (displayed on a 2D screen) or in VR. To visualise spatial data on this virtual globe, we use country-shaped data and relief shading maps[1]. The polygons for each country and the oceans are triangulated and remeshed[2]. With a texture created from the quantitative data of each country, we can create an efficient vertex shader that changes country elevation, instead of adding bars onto the globe. In addition to the elevation, we have added a colour map as a second channel for information.

Our data-visualisation approach is targeted at showing spatio-temporal data, using animations for, e.g. waves of propagation between countries during a pandemic. By changing the topology of the countries instead of using small glyphs for each country, we hope to better convey combined patterns. For COVID data[3], for example, it is possible to see a synchronised pulsing of European countries when animating over time. The large difference between reported cases between Africa and Europe is also visible. Potential disadvantages of this visualisation might come from its spherical shape. It is not possible to gain a quick overview of all countries due to the inherent occlusion from the curvature of the earth. Furthermore, smaller countries might be more difficult to analyse since we use the countries themselves for conveying magnitude.

3 EMERGING RESEARCH CHALLENGES

During our prototype's development, we identified several emerging research challenges for immersive analyses of spatio-temporal data on virtual globes that we plan to address in future work.

Evaluating the effectiveness of data visualisations is a particularly important challenge. We plan to compare our work to other approaches for data visualisations on virtual globes, such as length-based glyphs, and also compare a VR to a 3D desktop version of our globe to investigate how the spatial perception of a three-dimensional globe differs in both environments. Previous work [1] showed that participants were slower but more accurate in estimating the correct values with 3D heat maps than with 2D heat maps. Furthermore, an evaluation on cartograms [5] has found that participants preferred animations over static visualisations but were potentially slower. In future work, we plan to test the efficiency of the animated topography of our virtual globe when conveying information on spatio-temporal data. The investigation of the effectiveness of different animation speeds and maximum country elevations will be our initial focus.

Developing suitable focus+context techniques for virtual globes is important, considering the globe has inherent difficulties with occlusions, and further layers of visualisation to guide users, give different insights into the data, or provide additional detail might introduce clutter. To alleviate these issues, we will look into approaches such as focus lenses or zoom-and-detail techniques for detail on demand. For our current prototype, we focused on quantitative timelines per country, but we believe exploring the inclusion of additional detail via graph-based information [3], high-dimensional overlays [8] or trajectories could prove beneficial.

Developing intuitive interaction methods is an equally important emerging challenge in IA. Many interaction metaphors are closely connected to the above-mentioned challenges revolving around data presentation. To improve the interaction with and understanding of spatial data on virtual globes, some researchers looked into using tangible globes [7] as input devices for Augmented or Mixed Reality applications.

Combining 2D desktop views with VR visualisations of spatial data to enhance existing workflows in IA is another challenge we see emerging from this research. A seamless workflow between what desktop apps can do better–menu-based setups of the visualisation–and what immersion can provide–improved spatial understanding–is less disruptive than switching to immersive technologies completely, while offering their advantages.

4 CONCLUSION

In this work, we have presented a prototype for an immersive globe visualisation of spatio-temporal data on a global scale, using an animated globe where the topography is adapted based on countries' data. To the best of our knowledge, this visualisation method has not been explored yet in immersive systems and we see great potential for its ability to convey the spreading of, for example, viruses across the globe. In addition, we have outlined emerging research challenges that we will seek to answer in the future.

ACKNOWLEDGMENTS

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[1] using public domain map data *Natural Earth*: naturalearthdata.com
[2] using *Unreal Engine 5*: unrealengine.com
[3] courtesy of *Our World In Data*: github.com/owid/covid-19-data