

Towards In-situ Authoring of AR Visualizations with Mobile Devices

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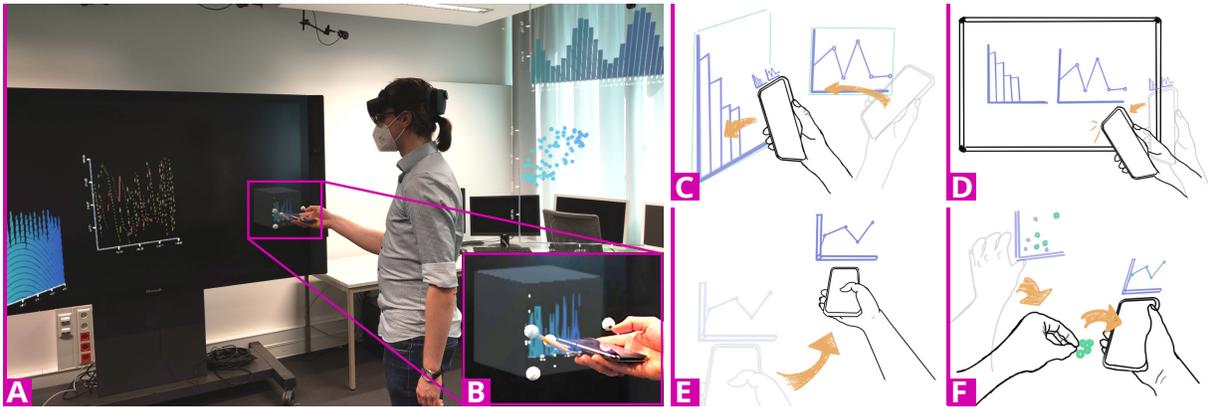


Figure 1: Our vision of the in-situ authoring process supported by a mobile device. (A) and (B) show an early prototype, while (C) to (F) show additional concept sketches. (A) The user is surrounded by several visualizations that he created. (B) A preview of another view he currently creates is attached to his smartphone. (C) The smartphone is moved as a fishnet, which allows the user to select several visualizations. (D) Those selected views can later be transferred to a physical whiteboard in the room, by touching it with a corner of the mobile device. (E) Visualizations in the immersive environment can be placed and oriented by the movement of the mobile device, which is used as a 3D cursor. (F) The user grabs a previously created selection of data points, which can then be used as a filter on a visualization that the user is currently working on, by dropping the selection onto the display.

ABSTRACT

Augmented Reality (AR) has been shown to enhance the data visualization and analysis process by supporting users in their immersive exploration of data in a real-world context. However, authoring such visualizations still heavily relies on traditional, stationary desktop setups, which inevitably separates users from the actual working space. To better support the authoring process in immersive environments, we propose the integration of spatially-aware mobile devices. Such devices also enable precise touch interaction for data configuration while lowering the entry barriers of novel immersive technologies. We therefore contribute an initial set of concepts within a scenario for authoring AR visualizations. We implemented an early prototype for configuring visualizations in-situ on the mobile device without programming and report our first impressions.

Index Terms: Human-centered computing—Mixed/Augmented Reality; Human-centered computing—Visualization

1 INTRODUCTION AND BACKGROUND

With Augmented Reality (AR), it is not only possible to embed 3D objects or machine manuals directly into the environment, but also to visualize and analyze complex data, as seen in the research area of immersive analytics [4]. In general, the use of AR for such analysis purposes “supports data understanding and decision making” [4], among others, through the in-situ presentation of the data visualizations. Besides the need to be able to read and understand

visualizations for analysis purposes, the configuration and placement of a single, but also the management and layout of multiple visualizations are equally important. At present, existing AR visualization frameworks and libraries [2, 6, 7] differ in how great the support for such configurations is. In the example of u2Vis [6], users have to define the visualizations on a desktop computer before the AR application is deployed, while in the case of MIRIA [2] or DXR [7], the users can either select from a list of predefined visualizations or create a view via a simple menu inside the AR application, respectively. The current lack of such in-situ visualization authoring tools is further shown and endorsed by other researchers [1, 5].

Along with the growth of immersive analytics, the research community is moving from traditional desktop setups to immersive environments, and also from two-dimensional to three-dimensional visualizations and interaction spaces. While desktop setups enable precise and easy-to-perform operations, currently available AR interaction techniques, like mid-air gestures, are limited (e.g., due to lacking precision), which in turn hinders users to author AR visualizations easily and quickly. Mobile devices can compensate for the shortcoming by providing precise and natural interactions (already demonstrated in, e.g., [3, 8]) and thus support the complex requirements for the authoring process. We therefore propose the use of a mobile device as a tangible and spatial input controller for the in-situ configuration and management of immersive visualizations. In the following we want to contribute (1) a preliminary set of concepts which make use of this combination for authoring AR visualizations and (2) insights in an early prototype, which enable the configuration of visualization directly in real-world environments.

2 ENVISIONING AR AUTHORIZING VIA MOBILE DEVICES

In this section, we will envision how a future data analyst would author and use visualizations in AR with the help of a spatially-

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tracked mobile device. To achieve this, we will present a rough scenario sketch in which we embed and propose an initial set of concepts (see Fig. 1). For the scenario, we will follow Mary as she explores a pandemic-related data set in a spacious meeting room.

Visualization Configuration: To begin the exploration, Mary creates a visualization via a configuration menu available on her smartphone. With this, she selects the targeted data set, a line chart representation, the attributes of week, country, and number of administered vaccines, and lastly the mapping of the attribute to the x and y axis as well as the line color. While she enters those parameters, a small AR preview of the view she currently creates will be visible, which is attached to the top edge of the mobile device (see Fig. 1B). This enables her to directly verify if the selected parameters are matching her imagined visualization.

Placement and Transformation: To place and rotate the newly-created visualization, Mary moves her mobile device, like a 3D cursor, with the still attached view through space (see Fig. 1E). She can even move, rotate, or scale this or other visualizations later on by bringing the mobile device close to the view in question. Thus, a context menu on the mobile device allows her to, e.g., change the scale with a pinch or one-finger zoom gesture on the mobile device screen.

Layout Management: After Mary created several visualizations, she wants to group them together, based on the month the data is from. For that, she changes the function of her mobile device from a configuration to a selection tool. Then she “catches” the desired visualizations by moving the device in her hand like a fishnet and all views crossed by this movement are now highlighted. Additionally, a small, corresponding preview stack of selected visualization is shown on the top edge of the smartphone (see Fig. 1C). Following, she moves them to a physical whiteboard where the selected visualization should be placed on. She then touches the whiteboard with a corner of her mobile device, which “releases” and transfers all the selected visualizations in the order of their selection to the physical plane. Based on how many visualizations were transferred, the layout could change from a single line to a simple grid, which also re-sizes the views (see Fig. 1D).

Drill Down: The now structured immersive environment gives Mary a better overview of the already created data representations. Therefore, she can further investigate the data related to European countries in the data set. For that, she already selected data points in another visualization via a mid-air gesture. As she now creates a new visualization with her mobile device, she wants to link and apply the mentioned selection to the new visualization in form of a filter. Thus, she picks up the selection via a mid-air grab gesture. After this, she moves her hand to the screen of the mobile device and “drops” the filter into the visualization she currently creates (see Fig. 1F), which applies this set of data points as a filter. This connection between the selection and the newly created view can be further visualized with a line between both.

3 PROTOTYPE AND FIRST IMPRESSIONS

Based on our vision, we implemented an early prototype (see Fig. 1A) to test our idea and to demonstrate the feasibility of our approach. The applications for both devices (HoloLens2, Huawei Honor 9) were developed in Unity and C#, while the visualizations are built via the u2Vis [6] framework¹. To track the position of the mobile device in the room, we used the motion capturing system OptiTrack² and a QR code for unifying the coordinate system of the motion tracking system and Unity. Lastly, we implemented an additional server application, also written in C#, which handles all network communication via JSON-RPC on top of WebSockets.

This prototype allowed us to test the feasibility of our idea as we can easily fill the room with an arbitrary number of visualizations

by only using a mobile device. Moreover, visualizations can be rearranged to form a meaningful layout based on the real-world environment, e.g., furniture or room’s structure. However, currently it is only possible to define simple configurations with u2Vis. Therefore, in our next iteration we aim to extend u2Vis to enable additional visual mapping specifications as well as filter definitions. Also using Unity for the mobile device application makes it possible to reuse code across device types. Lastly, our network code already worked quite well and enables us to extend it easily for multi-user support and server-based data and filter requests.

4 CONCLUSION AND OUTLOOK

With our scenario we showed how a combination of mobile devices and AR HMDs can help integrate the visualization authoring process into immersive environments. Additionally, we illustrated an initial set of concepts available by this combination, which in the future could allow for a rich interaction vocabulary. We implemented a preliminary prototype, which also shows the feasibility and versatility of our concepts. We already started on follow up research, which will provide a comprehensive design space with regard to interaction and content distribution between the two device types. Besides, we are further working on a full-fledged application, which aims to support the general authoring and data analysis process.

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REFERENCES

- [1] N. Ashtari, A. Bunt, J. McGrenere, M. Nebeling, and P. K. Chilana. Creating Augmented and Virtual Reality Applications: Current Practices, Challenges, and Opportunities. In *ACM CHI’20*. doi: 10.1145/3313831.3376722
- [2] W. Büschel, A. Lehmann, and R. Dachsel. MIRIA: A Mixed Reality Toolkit for the In-Situ Visualization and Analysis of Spatio-Temporal Interaction Data. In *ACM CHI’21*. NY, USA. doi: 10.1145/3411764.3445651
- [3] W. Büschel, A. Mitschick, T. Meyer, and R. Dachsel. Investigating smartphone-based pan and zoom in 3D data spaces in augmented reality. In *MobileHCI’19*. Association for Computing Machinery, Inc. doi: 10.1145/3338286.3340113
- [4] K. Marriott, F. Schreiber, T. Dwyer, K. Klein, N. H. Riche, T. Itoh, W. Stuerzlinger, and B. H. Thomas. *Immersive Analytics*, vol. 11190 of *Lecture Notes in Computer Science*. Springer International Publishing, Cham. doi: 10.1007/978-3-030-01388-2
- [5] M. Nebeling and M. Speicher. The Trouble with Augmented Reality/Virtual Reality Authoring Tools. In *IEEE ISMAR-Adjunct’18*, pp. 333–337. Institute of Electrical and Electronics Engineers Inc. doi: 10.1109/ISMAR-Adjunct.2018.00098
- [6] P. Reipschlagel, T. Flemisch, and R. Dachsel. Personal Augmented Reality for Information Visualization on Large Interactive Displays. *IEEE TVCG VIS’20*, 27(2):1182–1192. doi: 10.1109/TVCG.2020.3030460
- [7] R. Sicat, J. Li, J. Choi, M. Cordeil, W.-K. Jeong, B. Bach, and H. Pfister. DXR: A Toolkit for Building Immersive Data Visualizations. *IEEE TVCG’18*, 25(1):715–725. doi: 10.1109/TVCG.2018.2865152
- [8] F. Zhu and T. Grossman. BISHARE: Exploring Bidirectional Interactions between Smartphones and Head-Mounted Augmented Reality. In *ACM CHI’20*, vol. 20. Association for Computing Machinery. doi: 10.1145/3313831.3376233

¹u2Vis: <https://github.com/imldresden/u2vis>

²OptiTrack: <https://optitrack.com>