Subjective Views in Co-Located Augmented Reality–Initial Design

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Abstract

We investigate the use of subjective views for co-located collaborative Augmented Reality (AR) environments for 3D scientific visualization, i. e., views that are perceived differently per user, no matter their viewpoints. AR technology allows collaborators to benefit seamlessly from both their visualization and social spaces. However, those same collaborators might have different roles and expertise levels, which might need one visualization rather than another. When using one active screen per user, an AR collaborative system can render the scene with different parameters per user, yet with the same spatial reference. As 3D visualization often relies on multiple data layers, heavy filtering, and several transfer functions, the resulting multi-view representations may no longer all be shown or can lead to conflicts in the users' social space where they collaborate with others. Here we propose multiple designs to overcome this issue.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / augmented reality; Human-centered computing—Visualization—Visualization application domains—Scientific visualization

1 Introduction and Background

Augmented Reality (AR) allows 3D virtual objects to be 3D-spatially aligned in the users' real environment. Using Head-Mounted Displays (HMDs) as active devices, users can seamlessly see their environment and collaborators, to interact simultaneously between them and their visualizations. Because users wear their own active display, researchers have investigated the use of private and public workspaces [1, 5], where a private visualization is visible only by its owner, and the public visualizations are visible by all.

On the other hand, scientific datasets often rely on spatial 3D data—where the use of "3D displays" have merits—and usually contain multiple properties per data point. In meteorological datasets, for instance, each data point can embed temperature, pressure, and velocity properties, each useful to derive multiple meteorological phenomena (e. g., the strength of a possible hurricane). These multiple properties can be visualized by people with different scientific backgrounds and expertise, who will unlikely be interested in the same set of properties, but still benefits from analyzing together the data in the same space. In this project we extend the concept of private and public spaces further by searching for the implications of rendering the same scientific dataset to all the users but with different visualization parameters, which would depend on their expertise and roles. We refer to these visualizations as *subjective views* [4].

Smith and Mariani [4] introduced the *appearance* and *modifier* dimensions for the *subjective views*. The first dimension considers the geometry of the 3D object, while the second one considers global modifications such as transparency and wire-frame render mode. We focus in this work on volumetric datasets, which users parameterize using transfer functions. Such functions emphasize some parts of the dataset and not others by modifying the opacity (and color) of the dataset depending on the cell data, related to the *appearance* dimension, hiding some cells and increasing the opacity of others.

Compared to past work where virtual objects can be adjusted per user without introducing conflicts because these objects are just aesthetic [3], the volumetric visualization in our work is at the center of the discussion. If one user talks about a part of the volumetric visualization that is transparent for another user, a break happens between the social and the visualization spaces. Hence, significant different visualization parameter per user, i. e., significant differences on what information users have access, can break the workspace coherency, and may thus paralyze the discussion. However, one of the main benefits of AR-HMDs for collaborative work lies in merging the social and visualization spaces. Because this problem has no trivial solution, we propose some preliminary designs, concepts, and discussion about a possible implementation of *subjective views*, while keeping effective social communication.

2 Concepts and Designs

Based on Mahmood et al.'s study [2], we assume that a typical collaborative session consists of three parts that repeat themselves. First, collaborators talk and explore the dataset together to get a rough idea of what they are exploring. Second, based on their roles, they explore the dataset on their own to parallelize the work. Finally, they gather their insights and discuss together.

We focus on AR-HMDs as they allow collaborators to see each other and the visualizations without active focus transitions during all these listed collaborative phases. The visualizations of volumetric dataset are often not situated, so they have no pre-defined location in the collaborative space for the collaborators to explore and visualize them. Moreover, with AR-HMDs, collaborators have access to large virtual workspaces. We use this aspect to allow them to invoke multiple floating instances of a given dataset, where each instance possesses its own visualization parameters. However, while we can create multiple instances, the computing power of current commercially available AR-HMDs and general usability considerations limit the number of instances we can invoke, without making the system unresponsive and cluttering the workspace.

We propose to merge multiple related instances into a *visualization context*. Essentially, it consists of linking a *public instance* shared among all collaborators to other related instances that individuals may use, each using different user-defined visualization parameters. The *public instance* is used as a common frame of reference to not break the communication. While we propose to have multiple instances gathered together, each spatial instance might possesses multiple set of visualization parameters (e. g., one per user) to save space and computing power.

We then use an interaction design in which each collaborator uses a multi-touch tablet for input and control, in addition to the AR-HMD for the 3D visualization, to be able to move around in the workspace. This setup allows us to refrain from using mid-air gestures and speech recognition and still provides us with rich input possibilities to control the exploration and parameterize the visualizations (similar to the design by Wang et al.'s [6] for hybrid data exploration in particle physics).

3 Visualization Context Instances Layout

The instances of the *visualization context* can be arranged in various ways, but we consider two *layouts* to be most promising, as we

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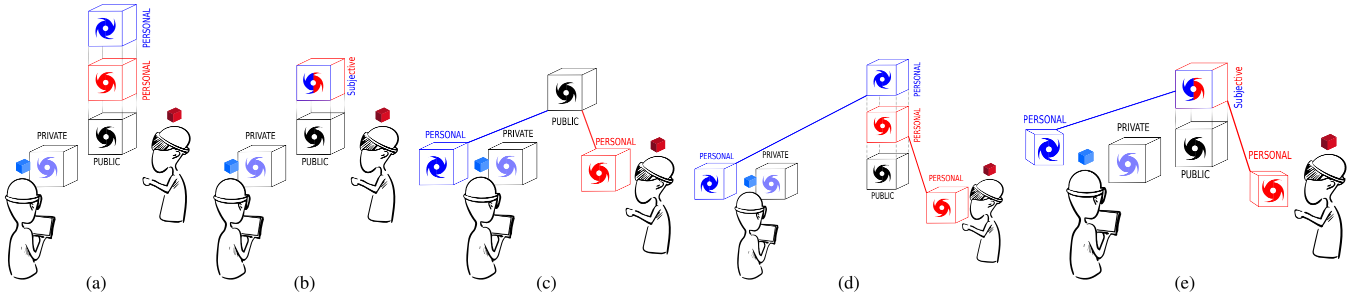

Figure 1: Set of the multiple designs to implement *subjective views*. The sketches represent two users, and the spawned instances of a hurricane dataset. Figures (a) and (b) are based on a vertical stacking of subjective instances above the paired public 3D window. If the public instance moves, every subjective instances attached to it will move. The subjective instance in Figure (b) is perceived differently per user. Figure (c) proposes to spawn an instance near the user of interest. This instance would be static in the 3D space regardless of the linked public instance. Figures (d) and (e) proposed to merge both modes.

summarize in Fig. 1. The first layout relies on *stacking* of visualization instances. This layout relates to the concept of small multiples, but links the visualizations based on the public reference. For this purpose we delimitate the borders of the visualization instances by adding a frame around them in form of a wire-frame cube. When stacking two instances, their frames can easily be related to each other as two of the three dimensions remain the same (Fig. 1a) and are linked to the public view. All these instances are normally public, i. e., all collaborators can see them the same way. We can also add private views visible only to a single collaborator, but this makes the space use less efficient. An interesting aspect here is thus that, due to our use of AR-HMDs, we can show different visuals to the collaborators for the identical position in physical space. We thus can put two theoretically private views at the same location in the virtual workspace, which turns them into *subjective views* due to their identical spatial reference frame (Fig. 1b). This mode allows us first to save space in the collaborative workspace, and may facilitate interesting collaborative exploration techniques. Yet it also poses questions on how to reveal the subjective view to collaborators during discussions. By allowing easy comparisons, we think that these modes would be suitable for discussion phases.

Our second layout relies on simple *linking* as we show in Fig. 1c. This mode allows the collaborators to arrange the *visualization context* instances more freely, potentially with easier access, thus providing a more comfortable work environment. The downside of this mode is that the spatial relationship between different instances is less clear. But this may be less important during independent work periods, as egocentric objects are suitable for private work.

None of the two modes is thus able to support all work phases equally. We thus explored a combination that uses both the stacked and the linked layout as we show in Fig. 1d and 1e: the stacked elements that provide collaborators with an easy way of understanding their spatial context are replicated using linking to be more easily accessible. The main drawback of this arrangement is that it requires us to render a lot more instances. As volumetric rendering typically requires ray-marching algorithms, the computational power of current HMDs may not be sufficient, and the design also may overly clutter the workspace. Nonetheless, the shared stacked visualization may not need to be rendered in full fidelity during independent work phases, and the linked copies are not needed in full fidelity during discussions. So an effective switching mechanism for the current work focus would be ideal. Moreover, these designs can be altered by adding visibility rights to all the instances, e. g., user A's visibility over user B's personal instances.

4 Discussion and Conclusion

These workspace designs use the capacity of the AR-HMDs to merge the social and the visualization spaces, while displaying custom contents per user depending on their roles. While only the designs represented in Fig. 1b and 1e really use the basic definition of *subjective views*, i. e., a spatial object that is encoded differently per user, we argue that this strict definition suggests that the common frame of reference is the only shared property (i. e., position, orientation, and sometimes scaling) of a visualization. In our *visualization context* concept we use thus a common, public visualization as a shared frame of reference, and rely on stacking or linking to relate other personal, private, or subjective views to it. Moreover, while the other designs do not directly use the basic subjective property, it is worth noting that a personal instance belonging to a particular user does not necessarily need to be rendered to all the other collaborators. Our proposed designs can then be altered by changing the visibility rights of the instances of the *visualization context*.

We are currently examining how users would use and interact with the *visualization context* and the embedded visualizations, in particular how they use and share insights from subjective views. By using a multi-touch tablet, multiple interactions such as filtering and spatial interactions can be done remotely. These need to be communicated well as they do not give deictic cues to the other collaborators. At the same time we need to avoid cluttering the common workspace with proxies or disturbing others with direct manipulations. We are preparing a formal user study to investigate the pros and cons of all the proposed designs and their derivatives (e. g., the visibility rights), and about effective exploratory interactions in a *visualization context*.

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