Augmented and Virtual Reality Interfaces for Crowd Simulation Software – A Position Statement for Research on Use-Case-Dependent Interaction

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Abstract

In this position paper, we claim that immersive technologies, such as Augmented and Virtual Reality, are well-suited interfaces for the usage of crowd simulation software in different contexts. We introduce three use cases; planning, awareness creation, and education. Based on an overview of different Augmented and Virtual Reality approaches, we identify the ones most suitable for each of the three scenarios and illustrate related implementations. Initial observations with their usage confirm our statements, but also highlight areas to explore with future research.

Index Terms: Human-centered computing—Mixed / augmented reality—Virtual reality; Computing methodologies—Simulation types and techniques; Software and its engineering—Virtual worlds software

1 Introduction & Motivation

In our research group, we developed a crowd simulation framework, ranging from global (AI) planning to local animation. Our system can create models for realistic crowd behaviors – which includes studying how (groups of) people move and avoid collisions in such environments – based on agent profiles and semantics, such as terrain annotations [3, 4]. An obvious usage of the created data is the visualization of realistic crowds in 3D simulations, for example, in 3D games on desktop PCs and immersive Virtual Reality environments. Yet, there are various other user scenarios for crowd simulation software. Event planners can use it to optimize their planning. For example, our software has been used by the city of Utrecht in the planning of the Grand Départ of the Tour de France (https://www.uu.nl/en/news/virtual-polka-dots-predict-spectator-flows-for-grand-depart), where thousands of visitors were expected, resulting huge challenges considering logistics, evacuation planning, etc. [2]. Yet, such software is not only useful for experts to plan such events, but also for the general public, for example, to create more awareness of related issues and problems. Finally, crowd simulation tools can also be helpful in education. For example, our software is currently used in a master course on Crowd Simulation in our computer science master program (http://www.cs.uu.nl/docs/vakken/mcrws/). We are currently also exploring how well (crowd) simulations are suited to educate high-school students about scientific principles.

People using crowd simulation to create 3D animations are commonly developers or designers, that is, people who are trained to use such tools. Yet, the three use cases illustrated above – *planning, awareness creation, education* – require non-experts to operate the software, raising the question of appropriate interaction design. The user interface must be adapted to the target user group and optimized for the related goals, which differ for the three use cases. In this position paper, we explore different interfaces for these three usages. In particular, we claim that immersive technologies, such as Augmented (AR) or Virtual Reality (VR), have benefits for users who are non-experts in crowd simulation software, but want to use it to achieve their respective goals. We present three interfaces that we have implemented; a desktop-based AR projection with a tangible interface, a table-based 3D AR projection, and a 3D VR simulation. Then, we discuss possible pros and cons, and initial experience with respect to the target user groups.

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2 VR/AR Interfaces & Their Characteristics

Immersive technologies such as VR and AR are commonly assumed to be more engaging, natural, and thus easier to use. Therefore, they seem well suited for the target users of the scenarios illustrated in the previous section. Yet, actual interaction in such systems can be difficult, especially when we are dealing with operations in 3D, such as the placement of obstacles in a 3D VR simulation. Most importantly, there are various incarnations of VR and AR that could be used, each of which having unique characteristics that make them more or less useful for particular contexts.

VR simulations are commonly used with head mounted displays (HMDs) that create a fully immersive environment. Users are completely placed in this virtual world, thus creating a sense of presence and a more realistic scenario. This can have advantages in the context of crowd simulation. For example, a first person view enables people to "be in the crowd" and thus better experience certain scenarios. Third person or abstract bird's eye views may enable people to better grasp a whole scenario and thus be better suited for planning. Yet, the full immersion provided by the HMD could be a disadvantage here, as it may hinder collaboration, for example, between two planning experts setting up the optimal environment for a festival.

AR enhances the real world with virtual elements and thus might be more suited for collaborative scenarios, which are not only relevant for planning, but also in educational contexts. Yet, there are different ways to realize AR, with a rough classification being hand-held AR, HMD-based AR, and spacial AR. *Hand-held AR* uses mobile phones or tablets and combines the life video stream from the device's camera (i.e., the reality) with 3D graphics (i.e., the augmentation). The major advantage of such AR is availability, as basically almost everyone these days has a mobile phone that can be used for it. Their lack of immersion make them less suited though for the usage scenarios of crowd simulation discussed above. *HMD-based AR* relies on glasses with see-through displays that add 3D graphics to the real world around the user. While being more intuitive and natural than hand-held AR, they often suffer from a limited field of view. State-of-the-art devices only allow for augmentation within a rather small area, thus making their usage for crowd simulation limited or, in some cases, even impossible. In *spatial AR*, virtual content is directly projected into the environment. Examples range from large installations, where one or multiple projectors are used to augment a huge area of the environment with virtual elements, to smaller setups, where AR projections are restricted to rather small and fixed spaces. In contrast to the personalized AR systems using hand-held devices or HMDs, the augmentations of spatial AR are visible to everyone in the room. This makes them more suited for collaborative scenarios. Yet, their fixed installation makes them less flexible than VR simulations and prevent on-location usage.

Figure 1: HP Sprout installation.

Figure 2: HP Sprout interface with blocks to build the environment and place start and target points for the crowd simulation.

3 Use-Case-Dependent VR/AR Interfaces

After identifying VR and spatial AR as suited interfaces for the usage of crowd simulation software in Section 2, we now illustrate what we assume to be the best user interface (UI) solution for each of the three use cases discussed in the introduction. We do this by describing three concrete implementations created in our lab.

3.1 A Desktop-Based Spatial AR UI for education

Using an HP Sprout computer (http://sprout.hp.com/), we implemented a simple, desktop-based AR system that enables users to easily and intuitively build environments to run crowd simulations. In addition to a regular desktop computer screen, the HP Sprout also features a flat surface in front of the user combined with down-facing image sensors (see Fig. 1). We use the integrated computer-vision software to recognize blocks of different shapes and colors, which in turn are used to create obstacles like buildings, walls, etc. in a virtual environment, as well as start and target points where crowds emerge from or move to, respectively (see Fig. 2). In addition, a line drawing can be input into the system that digitizes it into a 2D environment. Once an environment is created, the initial blocks can be removed and simulations can be run and observed.

Such an interaction design, commonly referred to as Tangible User Interfaces (TUI) [1], is known to be intuitive and easy to understand and operate. This is confirmed by initial observations of our system when used at open days and related public events at our university. The real blocks that can be grabbed, placed, and moved directly proved to be intuitive and provide a natural, easy to learn way to create and explore crowd simulations. Thus, we consider this setup well-suited for education and teaching scenarios, where individuals or groups of high school and university students can learn about crowd simulation using our software.

3.2 A Table-Based Spatial AR UI for awareness creation

While the desktop-based interface introduced above provides an intuitive and easy interaction, the resulting simulation is still a visualization on a 2D surface. While this may be well-suited for students and educational purposes, the abstract visualization might be less intuitive for the purpose of awareness creation and illustrating crowd simulation scenarios to the general public. In such cases, we propose a projector-based spatial AR system such as the one shown in Fig. 3. Here, a model of the city of Utrecht can be enriched with projections on the buildings, and, most importantly, the actual crowd simulation (see Fig. 4). TUIs, here in the form of blocks (see Fig. 5), are used to interact with the crowd simulation; areas can be (partially) blocked or opened, allowing the user to study the effects of adding, moving or deleting obstacles in the environment. The usage of this system at public events confirmed our intuitive assumption about its power and usefulness in context of public awareness creation and proved to be helpful in illustrating related problems and challenges.

Figure 3: Table-based spatial AR installation.

3.3 A VR UI for planning

The table-based spatial AR system provides a realistic simulation that is also well suited for collaborative scenarios. Yet, this comes at the price of a fixed installation, where a part of a real city has been re-created in a reasonably realistic real world model. In contrast to this, VR simulations using HMDs provide all the flexibility needed to create random realistic real world simulations. Another benefit of VR is that in addition to the bird's eye view realized with the AR table, other views can be supported, including a first person view, such as in our implementation illustrated in Fig. 6. Likewise, a VR simulation also provides more possibilities for the interactive manipulation of the environment; for example, event planners do not only want to place start and target locations for the crowd simulation, but other objects such as beer stands, mobile toilets, etc. in order to verify the impact of their placement on crowd behavior (Fig. 7). Our implementation is based on interviews with actual event designers who highlighted relevant aspects and important needs of their work and how they can be represented in the system.

4 Conclusion & Research Challenges

In the preceding sections, we introduced three scenarios for the usage of crowd simulation software, discussed the characteristics of different AR and VR interfaces, and mapped three concrete imple-

Figure 4: Crowd simulation on the table-based AR system.

mentations to the use cases. Some of our arguments for this mapping are obviously correct. For example, the flexibility needed by event planners make the AR-table-based interface unsuitable for their use case. Others, although intuitive, will need further verification by actual user studies. Likewise, each implementation offers various options, some of which again need to be optimized and verified by experiments. Areas to explore for the desktop-based AR setting with the HP Sprout computer include variations of the interface; for example, a comparison with of TUIs with touch-based interaction. Open research questions with respect to the table-based AR system include interface aspects as well (e.g., alternatives to TUIs, which lack flexibility and might be difficult to operate in the fixed environment) and the study of collaborative scenarios. VR-related research questions include the impact of viewing perspective and visualization on performance (e.g.: What view is best to achieve a certain goal? Which kind of crowd visualization is best suited in this context?). In conclusion, our three implementations of different immersive interfaces for crowd simulation software have demonstrated the great potential of AR and VR for the three use cases. The initial observations when used at public university events, in courses, at demonstrations to the public, and in the discussions with event planning experts confirmed this, but also highlighted the need for research to really optimize the interfaces for the respective needs.

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Figure 5: TUIs for input on the table-based AR system.

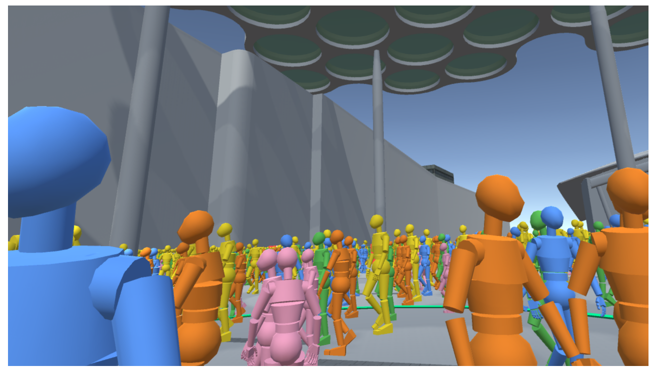

Figure 6: First person view in the VR crowd simulation using HMD VR glasses.

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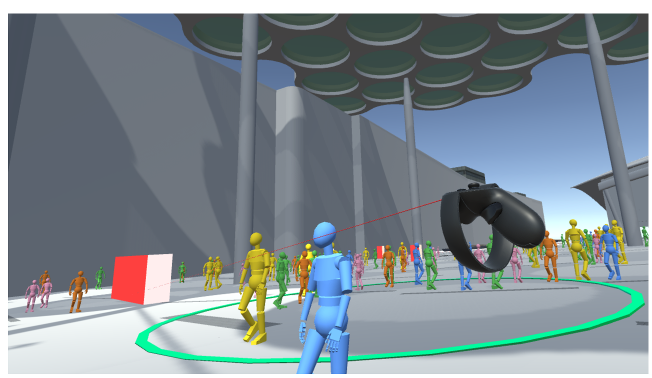

Figure 7: Manipulating objects in VR.