Virtual Crowds. A contributing factor to Presence in Immersive Virtual Environments

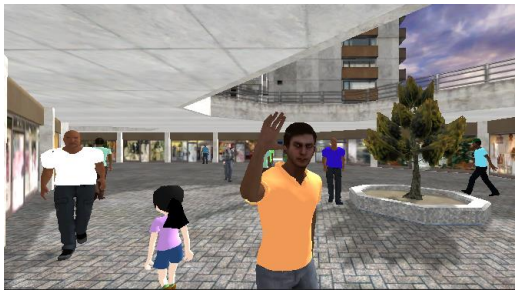
Aims and Objectives In certain applications of virtual reality we aim to immerse the users in a reconstructed virtual world, fooling theirs senses into believing it as real. Although many of the worlds that we would like to use, should ideally include virtual humans, quite often the latter are omitted due to the complexity of implementing their behaviour correctly. This is especially true for crowded environments where complex interactions should be appearing between the avatars and with the user. Recent progress in graphics hardware and software technologies have brought realistic animated humans within easy reach of a developer. One can buy a virtual character ready rigged and use it in a modern game engine. On the behaviour side though, things are different. Current state of the art engines include moistly path planning and collision avoidance methods. Adding behaviour to the characters is a slow and painstaking process with often questionable results. The aim of the proposed project is to investigate how far a developer needs to go when implementing a virtual crowd in an immersive environment. We aim to examine some of the characteristics of a virtual crowd and see if they are important in increasing the immersion of the user, and thus worthy of spending the effort to implement.

Methodology and Experiments The objective of this specific study is to investigate the user's behavior, perception of realism, and their sense of presence, concentrating on the degree of interaction between the user and the virtual crowd. Our hypothesis is that the level of interactivity of a virtual crowd towards the immersed participants would have an impact on participants' felt level of presence and their performance in the VE, and the same effect applies on both IVR and semi-IVR. In particular, we examined the socialization of the participant with virtual humans (VHs) that was implemented at different levels of interactivity in order to identify the user's reaction at a subjective and objective level. Taking also into consideration that navigation paths and especially collision avoidance are the main concerns of the crowd navigation methods that generate the low-level crowd behavior. We concentrate our experiments on two main crowd behavior characteristics, collision avoidance and basic interaction (such as salutation and look-at) between the VHs and the participant.

We have conducted two experimental studies with 50 participants in total: thirty of them participated in a semi-IVR system experiments and twenty in an IVR system. Each volunteer participated in three different scenarios; thus 150 single-user different sessions were conducted in total. The design of the experiment was repeated-measures (within-subjects), testing all participants under different levels of interaction. After each scenario, the participants were asked to fill in a web-based questionnaire. The first questions concerned their gender and their prior experience with video games, while the rest of the questions addressed their experience for the scenario they had just completed. The after experiment experience questions were based on the presence questionnaire of Witmer and Singer [1998]. Some questions were about the virtual human's awareness of each other and of the participant's presence, while others asked about the realism of the virtual characters and the environment. There were also questions about the participant's comfort, sense of presence and the ease of completing the task.

The experiments took place in two different VR systems: an immersive and a semi-immersive one. The first set of experiments was conducted in a Cave-like projection based system of

UCL. A custom-built semi-immersive VR system was used for the second set of experiments, using a large screen front-projected wall, driven by a workstation computer. Using a Kinect for motion sensing and human body tracking, the participants were able to navigate into the virtual world. In order to move forward in the virtual world, the participants walked in place and used had gestures for turning. We designed a 3D virtual environment representing an open-space mall with a significant number (33) of animated virtual characters, spatially distributed with different appearances and behaviors forming a crowd of virtual characters . All virtual characters were programmed with collision avoidance behavior and some basic interact-with-user predefined behaviors, which required no intervention by an operator but were enabled only in the third scenario. The participants were given the task to locate a child (a little girl) and follow her wherever she went. This was their primary goal and was clearly stated to them. In particular, the participants were told to try to be at a close distance to the child at all times, navigating into the virtual world. The virtual child was programmed to be singing loudly while following a trajectory, where she came across other virtual characters, mostly coming from the opposite direction, and avoiding collisions with them.

ResultsThe statistical results of the studied factors yielded several important insights regarding the user interaction with a virtual crowd, that are similar for both systems (IVR and semi-IVR). To begin with, enabling collision avoidance between the virtual crowd and the user in proved to be not a clear cut decision. On one hand, when collision avoidance between virtual characters and the user was enabled, the user judged the characters, the environment and the whole VR system as more realistic and lifelike. Moreover, extending the relationship between the user and the virtual crowd with more than collision avoidance, i.e., introducing some basic level of interaction between them, made the user's experience even more positive. The evaluation of all examined factors by the user was considerably better when there was a basic level of interaction with the virtual crowd. The behavior of the crowd was perceived as more realistic and the user reported a stronger sense of presence. Besides, the correlation analysis showed that the higher the crowd's realism is, the higher the participant's sense of presence gets. Moreover, the stated realism of the child is positive correlated with the sense of presence and the feeling of ease to follow the child. Though, it is interesting that facilitating collision avoidance by itself, even if it was a significant factor of lifelikeness of the virtual crowd, accommodated a feeling of discomfort and being more uneasy navigating into the VE following the child.

On the other hand, we found a small statistically significant increase in the distance between the user and the child in the virtual world in the IVR system, and a small non-statistically significant increase in the semi-IVR system when we enabled collision avoidance between the virtual characters and the participant. The growth in the distance was even bigger and statistically significant in both systems when we enabled both collision avoidance and interaction with the user. The observational analysis showed that participants were trying to "follow the rules" of the presented scenario in the VR environment. When the collision avoidance was enabled between the virtual characters and the participants, the latter were trying to avoid also the collisions in a much higher rate than when the collision avoidance was disabled. Moreover, when some virtual characters waved or verbally saluted the participants, they waved back or returned the salutation. This may justify that both the interaction and the

collision avoidance may reduce the user's performance regarding his/her primary goal, which included navigating into the VR environment with a certain target.
Our suggestion is that whatever the system is (IVR or semi-IVR) collision avoidance should be accompanied with basic interaction between the user and the virtual crowd, such as verbal salutations, look-at the user, waving and other gestures. This may increase both the plausibility and feeling of comfort in the VR system, thereby enhancing the sense of presence of the user.

The full details of our methodology and results have been written up and submitted for publication to the journal ACM Transactions on Applied Perception. The paper is now under the second round of reviews.