Using Extended Range Telepresence to Collect Data of Pedestrian Dynamics

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Abstract

In this article a new way to collect data of pedestrian dynamics is introduced. A virtual reality system consisting of an extended range telepresence system and a microscopic pedestrian simulation is used to simplify data collection. The extended range telepresence system allows a user to move through a virtual environment by natural walking instead of by using conventional input devices, like a joystick. The telepresence system is connected to a pedestrian simulation which produces real time 3D animated output which is presented to the user with a head-mounted display (HMD) capable of showing 3D imagery. The simulated pedestrians react to the user of the telepresence as if it were another simulated pedestrian. With this system data about pedestrian dynamics can be collected in experiments in which not all participants need to be real people, but some – ideally all except for one – can be simulated. This allows the general collection of data about pedestrian dynamics but also to calibrate model specific parameters. In this paper three experiments are introduced. However, the focus of the contribution is to give an idea and an overview of the combined telepresence-simulation system as data collection tool.

1 Introduction: Extended Range Telepresence

Telepresence systems give a user the impression of being present in a (remote or virtual) target environment. To achieve this visual and acoustic sensory information from the target environment is presented to the user on an immersive display. Furthermore, in extended range telepresence the user's motion is tracked and transferred to the target environment, so he can move around freely by using his feet instead of input devices like a joystick or keyboards. As a result, by using extended range telepresence, the user can use his proprioception, i.e., his own sense of motion, which is useful for navigation and way-finding.

To allow exploration of an arbitrarily large target environment while moving in a limited user environment, *Motion Compression* [1, 2] is used. Motion Compression consists of three parts. First the user's desired path is predicted, it is then transformed to fit in the limited user environment and finally the user is steered to move on the transformed path by slight displacements of his visual input. The transformation only slightly changes curvature and leaves length and turning angles intact. The user has the impression of walking on the original target path, since humans do not realize small changes in curvature. Figure 1 shows exemplary trajectories that a user would cover in both environments.

The telepresence system has been connected to the pedestrian and vehicle simulation software VISSIM [4–6] so that simulated agents can be placed in the virtual environment. These virtual agents react to the telepresence user as if he was a simulated agent allowing him to interact naturally with the pedestrian

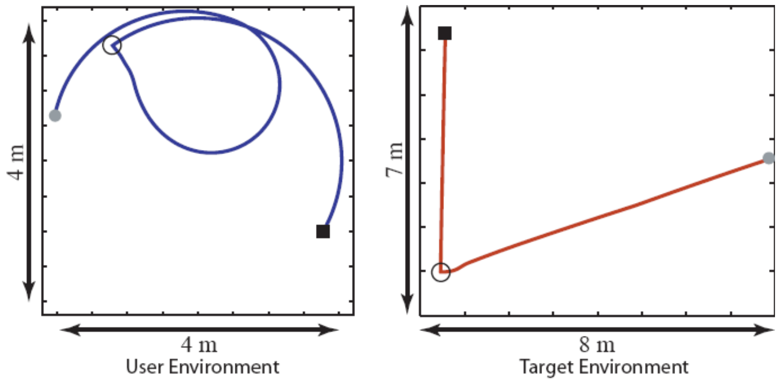


Figure 1: Trajectories in both environments. Trajectory that the telepresence user has actually walked (left). Trajectory the user believes he has walked (right). The transformation between both trajectories is called *Motion Compression*.

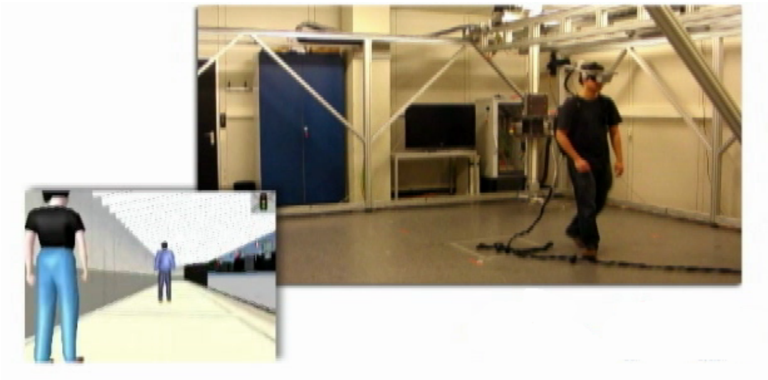


Figure 2: A user in the telepresence system (upper right) and the image he sees in the HMD (lower left). This is a still image of a video available at youtu.be/DpjpOpDGsFI

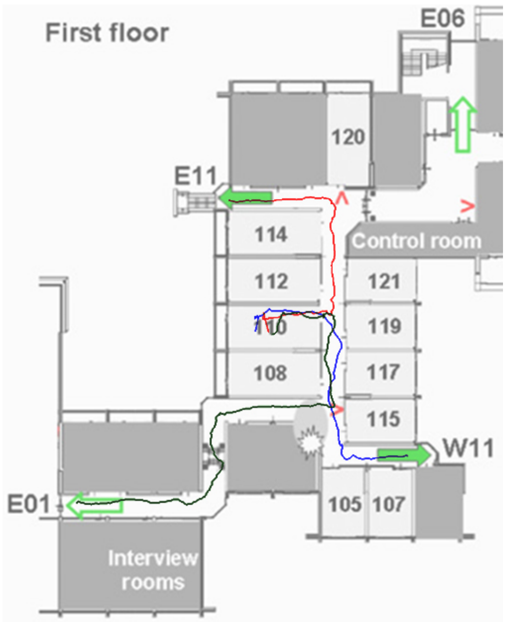


Figure 3: Example trajectories of users of the telepresence (the real trajectories have been transformed to the virtual remote environment). Base picture taken from [3].

Figure 4: Top-down view of the 3D scenario.

simulation [7, 8]. Figure 2 shows the user interface of the combined system. The user is no longer passively looking at the simulation, but he feels present in the simulation and can interact with other pedestrians.

2 Examples for Experiments

2.1 Route Choice in a Hotel Evacuation

Recently, a study has been published, in which data of route choice experiments under realistic conditions – unannounced and with smoke – was compared to route choice when participants were sitting in front of a computer and moving a virtual agent through an artificial environment [3, 9–11]. A drawback of the virtual experiment is that participants do not carry out actual locomotion.

The first step to validating that the extended range telepresence system can be a tool in the investigation of pedestrian dynamics was to check the user behavior considering the virtual walls. The users could consciously decide to move through the virtual walls, unlike a simulated experiment designed to be performed in front of a screen and controlled by keyboard, mouse or joystick, the extended range telepresence system has no mechanism to prevent this. Even more important is to check, if the visual information the user receives via the head-mounted-display is sufficient for him to move adequately through the virtual environment – provided he is willing to do so. That this works well can be seen in figure 3 which shows two examples of recorded user trajectories in the virtual environment (see figures 4 and 5).

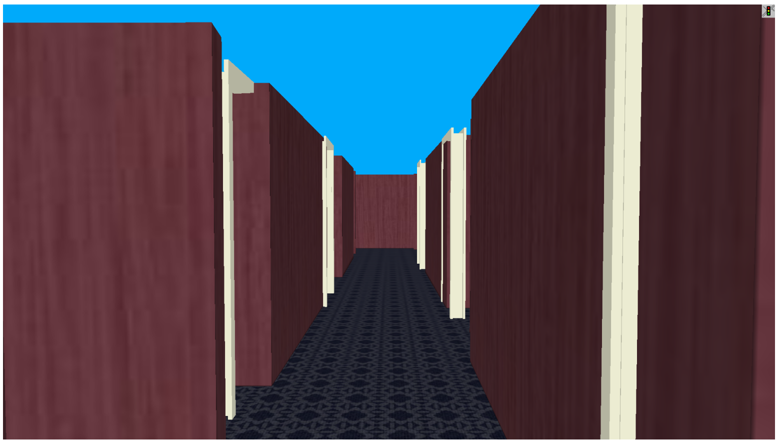


Figure 5: User view as shown inside the telepresence.

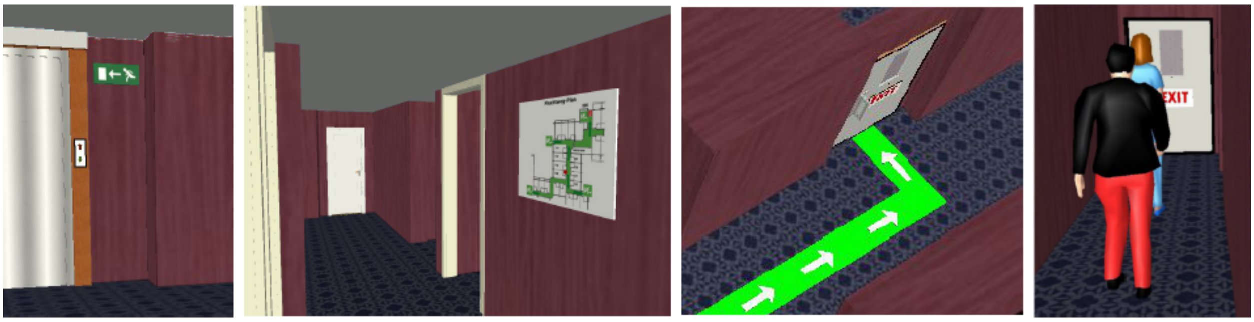


Figure 6: Variants of the experiment which include items that guide the way to the exit: emergency exit sign, floor plan, guiding line, and other pedestrians.

After this basic validation the system was used to compare exit choice and travel times using in an evacuation with different tools. The evacuation scenario was a replication of the evacuation scenario mentioned above. The different tools that have been compared were (c.f. Figure 6)

1. a guiding line on the floor,
2. standard exit signage above head,
3. an evacuation floor plan in the room where the evacuation starts,
4. other persons (simulated agents) walking to the exit.

Only the last includes simulated agents, in any other case the pedestrian simulation is only used to produce a static 3D environment. This first experiment therefore mainly serves to test the telepresence system and the user's behavior in it.

Preliminary results suggest that guiding lines on the floor lead users to the nearest emergency exit most often and in the shortest time. The floor plan helped second most participants to walk to the nearest exit, but the second smallest evacuation time was achieved with other pedestrians in the scenario (walking to the nearest exit).

2.2 Door Choice: Detour vs. Jam

It happens that a pedestrian is faced with a situation where he or she can decide to walk a more crowded but shorter path or take a detour with clearly lower density to reach his destination. The goal of the second experiment was to shed some light on this decision process. Figures 7 and 8 show the scenario which was used. Participants had to choose between one of two doors to reach to their destination. The door on the shorter path was crowded by simulated agents and the door on the longer path was free.

The participants were faced with different demand volumes on the shorter path ("none", "few", "capacity", and "jammed") as well as different starting positions (implying differentl detour lengths on the uncrowded path).

This experiment was not only intended to collect data independently of a particular pedestrian dynamics model, but to calibrate the parameters g and h of the dynamic potential as recently introduced in [12], i.e. the empirical results were compared to simulation runs with a number of different parameter settings to determine the best parameters. The dynamic potential was created to make agents walk in the direction of the least estimated remaining travel time and therefore exactly models the decision between a larger detour or higher densities on a shorter path.

20 participants' route choices were used to find a default value for the required parameters that fits the empirical results well. Other equally well scoring parameter sets mostly implied a stronger impact of the dynamic potential compared to a shortest path direction approach.

Although testing these parameters with only one scenario is not sufficient and a larger number of participants would have been desirable, it was possible to verify a parameter choice quantitatively in this experiment within the telepresence system.

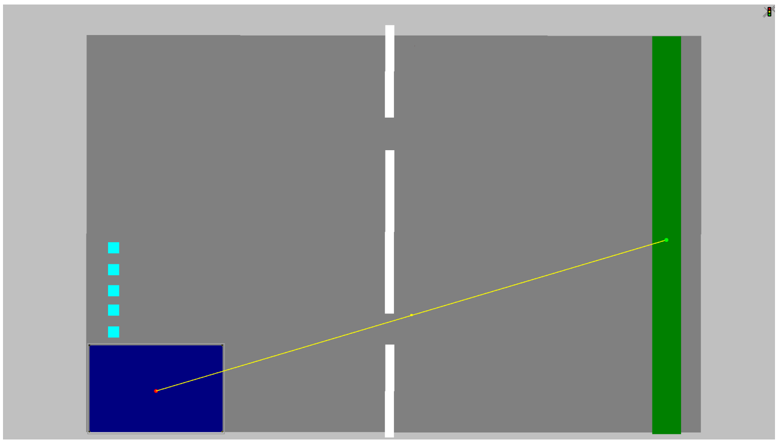


Figure 7: Top view of the scenario. Walkable areas are shown in dark gray, obstacles in white. Simulated agents are placed in the simulation on the dark blue area and use the right (bottom) door to walk to the dark green area on the right. On one of the cyan areas the telepresence user is placed in the simulated environment an example of his view from the starting position is shown in Figure 8.

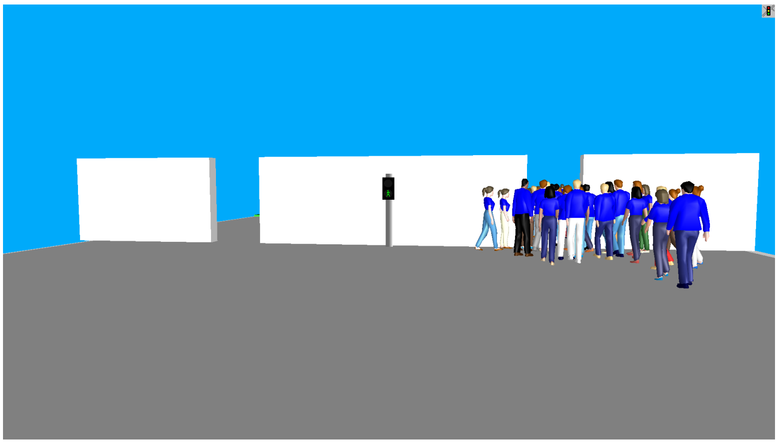


Figure 8: Scenario as seen by the participant at his starting position. The participant is instructed walk to the other side when the traffic light turns green.

2.3 Single File Fundamental Diagram

Recently very detailed data on the results of a single file movement experiment with pedestrians have been published [13–15]. This was a motivation to model the experiment for a simulation (see figure 9) and then use it in the telepresence system (see figures 10(a), 10(b)).

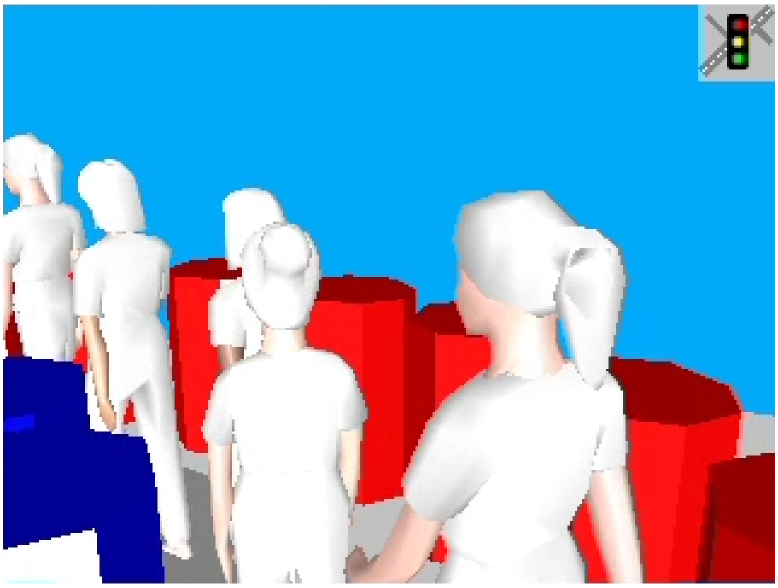
Figure 9: Snapshot from the animation of a simulation run with exactly the same numbers of agents as there were participants in the experiment.

The problem that occurred in this experiment was that the participants could not walk exactly on the intended line and deviated from it, which subsequently led to agents overtaking the telepresent user. In general, it became clear that high density situations are difficult to be reproduced within the telepresence system. As soon as the density is high enough that physical contact becomes unavoidable, the degree of immersion is not high enough to reproduce a realistic experience. Although the telepresence system includes a haptic interface to display haptic information (forces) at the user's hand [16], the haptic experience in a dense crowd is too complex to be reproduced by the existing system.

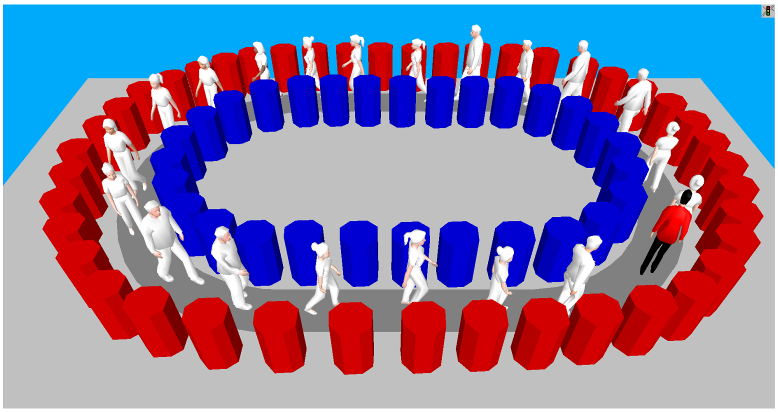
3 Conclusion and Outlook

The experiments carried out so far proved the extended range telepresence system to be a feasible setup for the experimental evaluation of pedestrian dynamics. While a comparison with real experiments is still necessary, it has been possible to compare exit choice and evacuation time for different exit signs in a simulated evacuation, and to quantitatively validate the parameter choice for the pedestrian dynamics model.

The degree of immersion of the user in the telepresence system resulted high enough when crowd situations



(a)



(b)

Figure 10: (a) Ego-view of the user in the telepresence system. (b) Animated scene in the target environment with the simulated agents (in white) and the user (shown red). The columns have been placed in the simulation model to give the participants a better orientation of the walkable path.

were displayed, in which physical contact did not occur and the motion was determined by the user's intentions and visual impressions. Therefore, this telepresence system is more adequate for route choice experiments (on the tactical level) than for experiments on the operational level. It is, however, not excluded that future developments of the haptic interface would overcome this limitation. One can think, for example, of a suite for the user of the telepresence, which could be able to reproduce physical contacts, as they occur in moderately high density situations, realistically.

At present, the data availability for the operational dynamics (for example, concerning the fundamental diagram) is unsatisfying [17]. However, data for route choice issues is even much scarcer, be it rather local motion (door choice) or route choice on a city level [18, 19].

The advantage of the telepresence system, compared to experiments in reality, is that supernumeraries can be embodied by simulated agents and that the position of the user is available in the system at every time, which makes its measurement trivial. Both facts make experiments cheaper. In addition, the experimenter has a tighter control over simulated than over human supernumeraries.

Also some situations that include some minor or major threat for the pedestrians (e.g., motion in dark or smoke filled rooms, behavior alongside or in road traffic [20], pedestrians' crossings at red light, etc.) appear well suited to be investigated in this telepresence environment. These situations and combinations of them are of great interest, for example, for safety research in road tunnels [21].

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