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Flexible Spaces: A Virtual Step Outside of Reality

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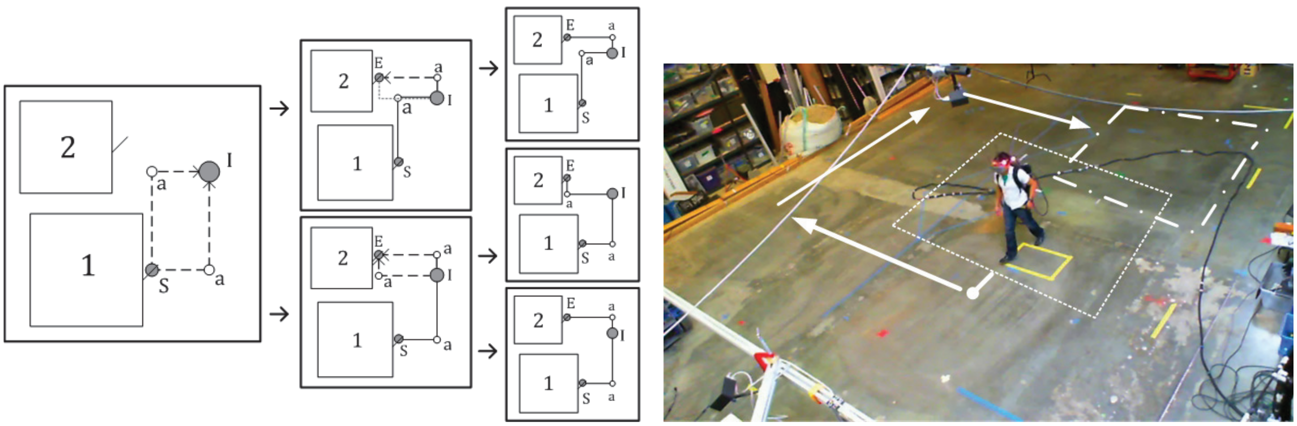

ABSTRACT

In this paper we introduce the concept of flexible spaces a novel redirection technique that generalizes the use of overlapping (impossible) spaces and change blindness in an algorithm for dynamic layout generation. Flexible spaces is an impossible environment that violates the real world constancy in favor of providing the experience of seamless, unrestricted natural walking over a large-scale virtual environment (VE).

Keywords: Virtual reality, walking, locomotion, reorientation techniques.

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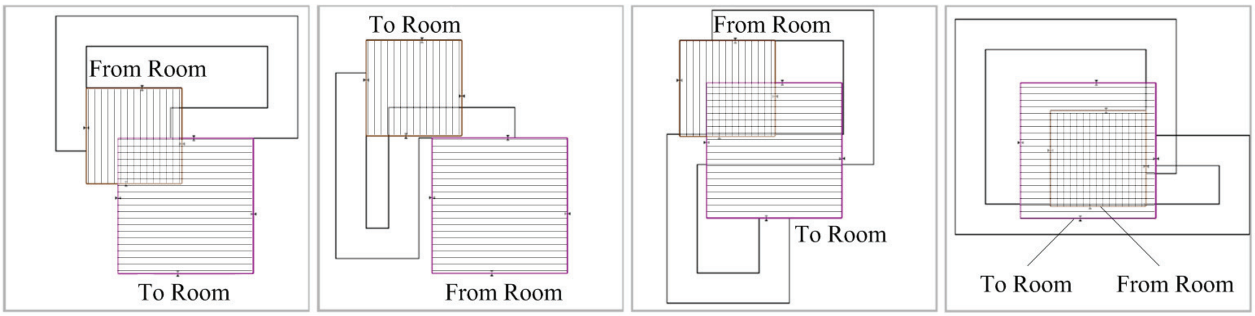

Figure 1:Our algorithm procedurally generates layouts that fit within the tracked space. Overlapping is allowed for all rooms and corridors. We show an example of possible layouts sequentially generated by the algorithm with different parameters for two rooms.

Abstract

In this paper we introduce the concept of flexible spaces – a novel redirection technique that generalizes the use of overlapping (impossible) spaces and change blindness in an algorithm for dynamic layout generation. Flexible spaces is an impossible environment that violates the real world constancy in favor of providing the experience of seamless, unrestricted natural walking over a large-scale virtual environment (VE).

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1 Introduction

Navigation is one of the most universal tasks performed in real and virtual environments. A natural way to fulfill the navigation's motor component is through walking. It is simple and intuitive for the user, but its implementation and support for large-scale VEs within a limited workspace is still a challenge.

Redirected walking techniques were developed to overcome the limits of the physical space [1]. Commonly, the VE is replicating the real world static structures and in order to fit in the workspace the mapping between the real and virtual environments is manipulated, resulting in a scaled rotation or translation in the virtual world. However, the human perceptual system can only tolerate a limited amount of visual-vestibular conflict introduced by these techniques [2]. Therefore, recent research turned to overlapping spaces and change blindness which introduce minor changes to the architectural layout of the VE. A change blindness phenomenon is a failure to notice changes in the scene. To utilize it the changes should appear outside of the user's field of view [3]. Therefore, the design should include diversion of attention. On the other side, impossible spaces employ self-overlapping architecture focusing on sensitivity to overlap between two adjacent rooms in a custom-built environment [4].

Both approaches have shown to be effective in creating unperceivable illusions. They show a perspective of spatial layout manipulations for redirected walking. Nevertheless, they are limited in application and complex in development, if conventional architecture layouts should be followed.

In contrast, we introduce a novel approach for procedural generation of architectural layouts that takes advantage of impossible spaces and change blindness (see Figure 1). We aim at the applications that do not require strict architecture and introduce the concept of *flexible spaces*. Our algorithm supports infinite walking through interior virtual environments by automatic rerouting.

2 Flexible spaces

Historically, many virtual environments have attempted to emulate the real world as closely as possible to avoid adverse impact on the spatial orientation and focused on the real to virtual mapping manipulation. However, detailed spatial knowledge might be useful for navigation, but is not obligatory [5]. As spatial cognition research has shown people typically form inaccurate cognitive maps that often contain not graphical, but categorical and hierarchical representations of the world [5], [6]. Building on this we relax the need to maintain real world architecture to develop a VE that is substantially more flexible in supporting locomotion on a large scale.

Our approach relies on impossible spaces and extends the limitations on the overlap ratio between rooms up to 100% by introducing distance between them in shape of a long crooked corridor. To avoid exposure of overlapping spaces we apply the

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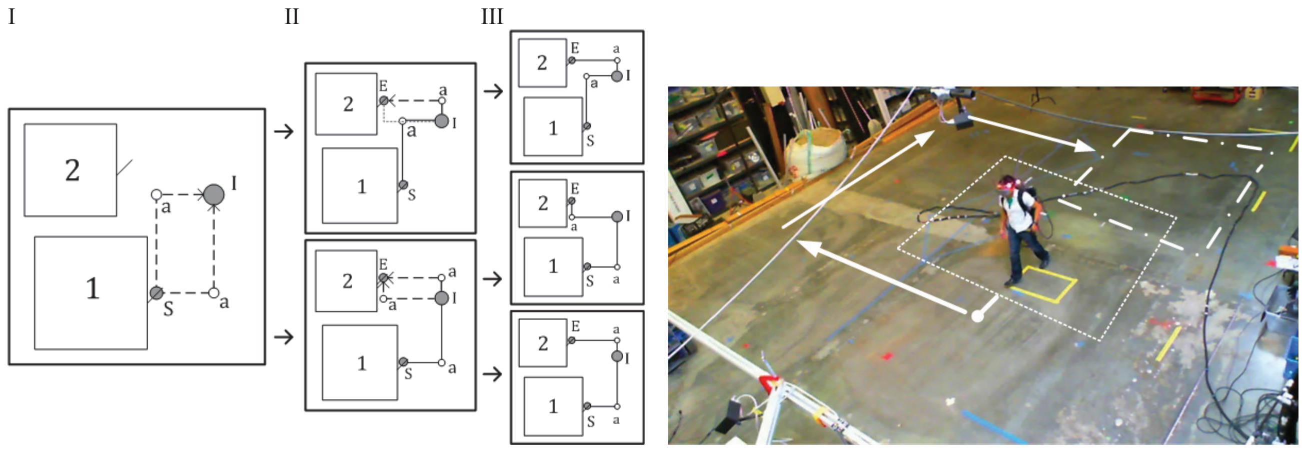

Figure 2: The path generation: (a) The algorithm has 3 main stages: I – random selection of the intermediate point I and additional points a, II – selection of the closes end-point E, III – random selection of the additional points between I and E. (b) An example of a simple path a user takes in our VE.

change blindness effect by defining corridors as a changeable part of the environment that we reroute every time when the user leaves a room according to the following algorithm (see Figure 2):

1) The user inside initial room 1 selects and opens a door (S) that corresponds to a target room 2.
2) The target room 2 is relocated randomly within the tracked space. An overlap up to 100% is allowed.
3) The door position is taken as a starting point "S" of the corridors. Then an intermediary point "I" is selected randomly in a way that a corridor will still fit into the tracked space.
4) A door of the target room 2 is selected on the basis of minimal distance to the intermediary point "I". The position of the door is taken as the end-point of the corridor – point "E" (see Figure 2, a).
5) To connect the main points of the corridor additional points "a" are calculated. The decision which additional point is chosen for corridor construction is also made randomly. Figure 2 (b), (c) shows the possible corridors that could be built depending on the choice of additional points.
6) After the corridor route is calculated and checked for errors, the corridor is built.

We limit the space available for rooms by excluding the corridor-wide space along the perimeter of the tracked space to ensure that rooms are accessible from all sides. Connectivity and content of the VE should be predefined. To generate a consistent view for the user the VE is rendered partially depending on the user's position in it.

The flexible spaces accommodate infinite walking, but are limited to spaces with natural constraints only. The algorithm was successfully implemented as a complicated building with 5 rooms and tested with a Wide5 head mounted display in a 9x9 m tracked space.

3 Conclusion and Future Work

The algorithm of the flexible spaces generalizes the application of impossible spaces together with change blindness. Our informal tests of a virtual environment suggest that the technique tends to be unnoticed given reasonable parameters. The simplicity of the algorithm and generation of one corridor at a time ensures that procedural generation does not introduce delays. Moreover, it removes the need to render the whole environment simultaneously.

Unlike impossible spaces we did not present the rooms as adjacent, but rather as connected with one corridor only. Theoretically, this approach will make the environment's perceived size to be even larger than impossible spaces of the same area. We have observed that a short corridor that has 3 or less turns (no intermediate points) is easily remembered and might expose overlapping, while a combination of length and a number of turns makes the technique unperceived. In our future research we plan to define the dependency between these parameters and perception of the impossibility of the VE. We also suspect that some combinations of right and left turns would be more effective in creating a perfect illusion than the others.

The potential issue in our environment is the lack of information for orientation. In our future research we plan to amend that by additional cues like a connection graph of the VE to assure that user can freely navigate.

The applications of VEs created with our algorithm include, but are not limited to simulations of museums, virtual games, fictional environments, where information in the VE is more important than its layout. It is also possible to apply flexible spaces for layout independent training in orientation using landmarks or other cues in VE. Hence, the flexible spaces approach is an important step towards usage of spatial manipulation for real walking.

Acknowledgments

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