Real Walking in Virtual Spaces: Visiting the Aachen Cathedral

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Abstract

Real walking is the most natural and intuitive way to navigate the world around us. In Virtual Reality, the limited tracking area of commercially available systems typically does not match the size of the virtual environment we wish to explore. Spatial compression methods enable the user to walk further in the virtual environment than the real tracking bounds permit. This demo gives a glimpse into our ongoing research on spatial compression in VR. Visitors can walk through a realistic model of the Aachen Cathedral within a room-sized tracking area.

1 Introduction

In this demo, users can experience real walking through a virtual scene that is much larger than the available tracking space, without resorting to indirect navigation modes such as teleportation. A *redirected walking* technique is used to create the illusion of walking on a virtual path that is different from the real motion. Users can walk on a predefined path through a virtual model of the Aachen Cathedral. By showcasing our ongoing research in this area, we aim to popularize this approach to a wider audience, get feedback from potential users on the applicability of the technique in different usage contexts and foster general discussion about redirection techniques in VR applications.

2 Redirected Walking

Real walking in virtual environments provides the highest perceived presence compared to other modes of navigation (Usoh et al., 1999). However, since most virtual environments exceed the size of the available tracking space, we typically resort to indirect modes of navigation such as teleportation or pointing-and-flying. A promising alternative are redirected walking

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techniques, which relax the one-to-one mapping between the virtual and the real space. While the user believes to be walking along a certain path in the virtual world, the real walking path is subtly manipulated such that real-world boundaries are avoided.

A number of redirected walking approaches have been proposed. *Dynamic motion gains* can be applied to the real head movement as initially proposed by Razzaque (Razzaque, 2005). The user in turn compensates for the amplified or weakened movement by adapting the real walking path. Steering algorithms make use of this in order to guide the user away from real-world obstacles or tracking boundaries. How strongly such gains can be applied has been investigated in psychophysical studies on detection thresholds (Steinicke et al., 2010) and in higher-level studies that measure when user immersion is adversely affected (Schmitz et al., 2018). To divert users' attention from the manipulation, or to induce movement that can be amplified, *distractors* are used to facilitate redirection (Peck et al., 2010). *Change blindness* phenomena have been leveraged, by modifying scene elements such as the position of doorways when the user is not looking at it (Suma et al., 2011), or by manipulating the user's view during saccadic eye movements or blinks (Bolte and Lappe, 2015; Langbehn et al., 2016). A new redirection method based on *planar map folding* has recently been proposed (Sun et al., 2016). Our work uses a similar approach, so we describe it in more detail in the following section.

2.1 Map Folding

We demonstrate a novel redirected walking technique that extends the recently proposed map folding approach to achieve spatial compression. The method precomputes a static mapping $f : S_v \to S_r$ between the virtual floor plan S_v and the real tracking space S_r that minimizes angle and length distortion. The mapping is enforced to be *locally* injective. This means that different parts of the map can fold over each other, however f is invertible in the proximity of any point in the domain. Due to local injectivity we can compute the Jacobian matrix of the inverse mapping f^{-1} by inversion of the Jacobian of f using the inverse function theorem.

$$J_{f^{-1}} = J_f^{-1} \tag{1}$$

When the user moves in the tracked area, we compute a position increment Δx in the virtual scene in each frame from the measured movement vector Δu.

$$\Delta x = J_{f^{-1}} \Delta u \tag{2}$$

Our work improves the folding method by computing a mapping f with much lower distortion. This is achieved by minimizing the dirichlet energy over the deformed domain, similar to another recently published map folding method (Dong et al., 2017).

Figure 1 shows the path through the cathedral, with a length of approximately 100 meters, along which the users walk in their virtual tour. It is compressed into a tracking space of about 4 by 4 meters, which is the typical size of optical tracking systems available for current consumer-level head-mounted displays. The folded path is visualized in Figure 2, showing how it curls up to obey the boundary constraints of the real walkable area, while at the same time keeping the distortion as low as possible.

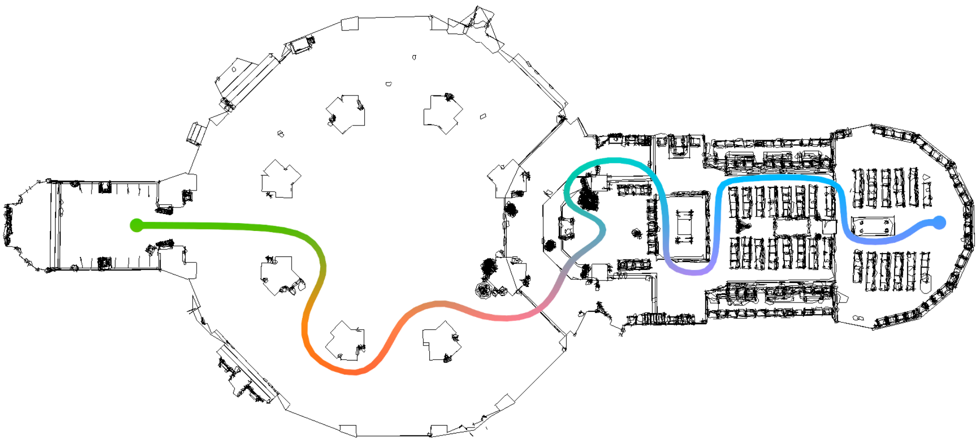
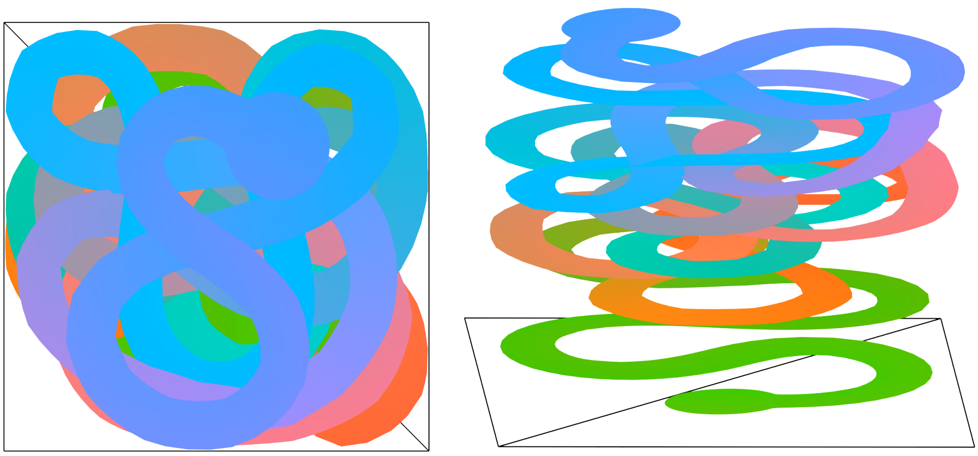


Figure 1: Floorplan of the Aachen Cathedral (approx. 70m×30m)



(a) Top view *(b) Side view*

Figure 2: Virtual path folded into the tracking space (approx. 4m×4m)

Figure 3: Digital model of the Aachen Cathedral

3 The Aachen Cathedral

Visitors get the opportunity to experience the novel navigation technique during a virtual walk through the Aachen Cathedral. It is one of the oldest cathedrals in Europe and was built under the emperor Charlemagne around 800 AD. It is a UNESCO World Heritage site and attracts more than a million visitors every year.

The Visual Computing Institute at RWTH Aachen University created very detailed 3D scans of the historic building and digitally reconstructed large parts of the cathedral. The huge amount of scan data was processed to create textured polygonal geometry that can be rendered on consumer-level hardware while retaining interactive frame rates necessary for a smooth VR experience.

4 Summary

We present a demonstration of our ongoing research on spatial compression in VR. Visitors can experience a novel redirected walking technique based on planar map folding during a virtual walk through the Aachen Cathedral.

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[1] https://scasa.eu/

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