Navigation in Immersive Virtual Reality: The Effects of Steering and Jumping Techniques on Spatial Updating

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Abstract: This thesis describes navigation by jumping, a range-restricted variant of teleportation commonly implemented in modern VR applications. It illustrates the design space of jumping techniques and evaluates them with respect to spatial orientation performance and simulator sickness. The results indicate that jumping is a viable alternative to steering.

Keywords: navigation, virtual reality, teleportation, spatial updating, simulator sickness

The interactive exploration and understanding of large virtual environments such as buildings, cities or whole landscapes requires virtual travel. In immersive head-mounted displays, however, the common steering metaphor easily triggers simulator sickness due to the introduced sensory conflict between the visual and the vestibular systems during motion [Kol95, Lac14]. Direct teleportation to the target avoids these conflicting cues, but negative impacts on spatial awareness during travel have been observed previously [BKH97]. Hence, both steering and teleportation can have undesirable side effects that should be considered carefully.

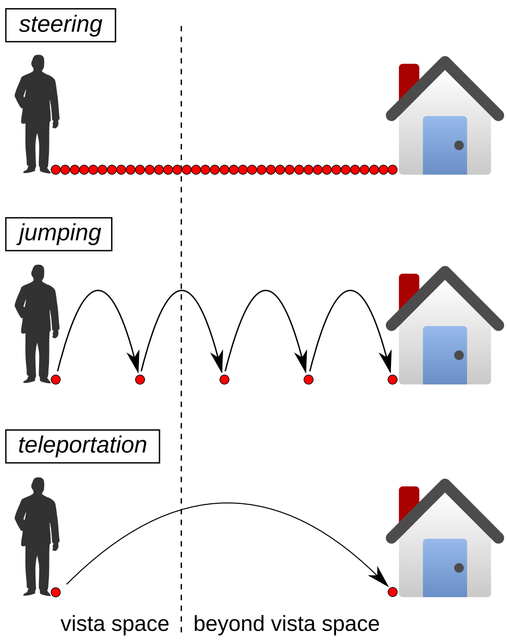

Figure 1: Steering, jumping and teleportation differ in their amounts of spatial information for path integration (red dots).

As a result, many modern VR applications and games implement short-distance teleportation in vista space (jumping), which requires users to perform several jumps along a route to a distant target. In contrast to teleportation beyond vista space, the traveled path between two locations can be perceptually integrated based on perceived spatial information during the specification of intermediate targets. From this stance, jumping is an intermediate technique between steering and teleportation beyond vista space (see Figure 1). However, no previous research particularly addressed the effects of jumping on spatial orientation performance and simulator sickness so far.

To bridge this gap, the thesis reports on a user study ($N = 24$) that compares jumping and steering with respect to their effects on spatial orientation performance and simulator sickness (see Figures 2a and 2b). For the study task, parametric virtual city models were

(a) Target indication for a jump (b) Study hardware setup (c) Spatial updating accuracies

Figure 2: User study with 24 participants testing spatial updating and simulator sickness.

designed that users had to travel through wearing a head-mounted display. At the end of each route, the user's *spatial updating* ability [Rie03, Section 12.2] was tested by pointing back to the start position. The usage of three-segment routes allowed for a larger variety of possible target directions than the commonly used triangular two-segment tasks in spatial updating studies of related work (e.g. [LKG+93, Mar99]), thus avoiding accurate responses resulting from guessing strategies.

The results show that despite significantly faster travel (and thus less encoding) times during jumping, the majority of users achieved similar spatial updating accuracies with both techniques (see Figure 2c). In particular, only six users (25%) achieved notably lower accuracies in the jumping condition (more than 10° worse compared to steering, highlighted in red). Furthermore, jumping induced significantly less simulator sickness symptoms, which altogether makes it a considerable alternative to steering for the exploration of immersive virtual environments. However, application developers should be aware that spatial updating during jumping may be impaired for individual users and offer a steering variant as fallback.

References

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