Evaluation of Navigation Techniques for Virtual Environments

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Overview

- Introduction
- Locomotion Devices
- Redirected Walking
- Discussion
Introduction Navigation

Navigation
- Wayfinding
- Locomotion

Translate Navigation to VE

Position and orientation must be known → tracking
Tracking Limitations

- HMD: cable
- Broadcasting range
- Room-size

VE larger than range in real world

Goal: enable real walking in VE larger than tracked space
How to move around in Virtual Environment?

Movement via Controller

Walking-in-Place (WIP)

Real walking in VE
- Higher sense of presence
- Reproduce inertial feedback
- Better user navigation
Solution 1

Locomotion Devices
Iwata's Locomotion Devices

- Prof. Hiroo Iwata – University of Tsukuba
- Virtual Peranbulator (1996)
  https://www.youtube.com/watch?v=uLgSjgMqkEQ
- Torus Treadmill (1999)
  https://www.youtube.com/watch?v=ZhcFMD4n9Jw
- GaitMaster (2001)
  https://youtu.be/RDDH1iqoDzU?t=18
- CirculaFloor (2005)
  https://www.youtube.com/watch?v=rYsvB2y2Ero
- String Walker (2007)
  https://www.youtube.com/watch?v=5i8muFt3rxM
Locomotion Devices

Device Examples
- Virtuix Omni
- Cyberith Virtualizer
- Kat Walk VR

Problems
- Unnatural Movement
- Can't reproduce inertial feedback
- Restriction
- Pricing
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Method Characterization

Navigation in VR, Unger
Redirected Walking
Redirected Walking - Overview

- Enable walking in VEs that are larger than tracked space
- Reorientation Techniques (ROT)
- Exploit imprecision of human perception of self-motion

Goals:
- Imperceptible to the user
- Break limitations of tracked space
- Prevent Cyber Sickness
Redirected Walking - Overview

2 Categories:

- Manipulation of Self-Motion
  - Resetting Techniques
  - Gain (Translation, Rotation, Curvature)

- Manipulation of Virtual Scene
  - Virtual Portals
  - Change Blindness Redirection
  - Impossible Spaces
Manipulation of Self-Motion
Resetting Techniques

- **Audio Instructions**
- **Visual Distractors**
  - Peck et al, 2009
  - Follow Distractor Movement for Reorientation

**Problems**
- Excessive use

**Best Practice**
- Failsafe, sparse use
- Adept to surroundings (children playing, dog...)

Navigation in VR, Unger
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Manipulation of Self-Motion

- Amplify or diminish a component of user's motion
- First mention: 2001, Razzaque et. al
  - Rotation of virtual scene
  - Limitations in human perceptual mechanism
  - User Study: Fire Drill Task

https://youtu.be/o92bG1_YGDM?t=53
Vision dominates vestibular sensation

Gains define how to map real-world motions to VE

Translation, Rotation and Curvature Gains

Threshold definition

Goal: Small manipulations allow free walking
Translation Gains
- Uniform vs non-uniform
- 14% more or 26% less possible

Rotation Gains
- Defined for each component (yaw/pitch/roll)
- 50% more physically or 20% less possible

Curvature Gains
- Camera manipulations, user compensates
- User unknowingly walks circular arc with 22m radius
- Manipulation of 13° after 5m walk possible
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Manipulation of Virtual Space
Virtual Portals

- Allow transportation through virtual room
Change Blindness

- Perceptual Phenomenon

- Fails detect visual change to an object or scene
Change Blindness Redirection

- Redirection: Suma et. al, 2011

- Possible scene changes
  - Distractor needed

- Example:
  https://www.youtube.com/watch?v=E_uZ6-0FsXo
Impossible Spaces

- Concept by Suma et al, 2012

- Implement Geometry that violates rules of euclidean space

- Self-overlapping architecture

- Compress building to be within smaller physical area
Impossible Spaces

Switch between architectural states

Conditions
- Corridor between two rooms
- Switch when halfway down corridor
- Only one room can be visible at the time

When is space detected as impossible?
Experiments

- Perceiving Impossible Spaces
- Experiencing Impossible Spaces
Perceiving Impossible Spaces

Setup
- Users were informed
- Tested overlap: 0%, 15%, 30%, 45%, 60%, 75%

Tasks
- Impossible Space Perception
- Distance Estimation
Results

- Participants with prior 3D gaming experience – fast detection
- Fixed 9x9m room – overlap up to 31%
- Larger rooms – more likely to alert users
- Large rooms, small hallway – quickly detected as impossible
- Smaller rooms – overlap up to 56%
- Distance estimation showed illusion worked
Experiencing Impossible Spaces

Setup
- Include Curvature, Rotation and Translation Gain
- Task to search through buildings
- Free exploration encouraged
- Questionaire at the end

Results
- 17 participants
- 12 didn't notice room manipulation
- 5 participants had prior experience
- Most problems with Gain
Singh 2017, KP Project

Design Factors for Impossible Spaces in Room Scale VR

HTC Vive, 9 Participants
- 3 had prior experience with 3D games

Add environmental design factors
- Windows into adjoining rooms
- Lighting differences
- Spatialized sound
- No significant improvement
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Navigation in VR, Unger
Recent Application

- Bending the Curve, Langbehn et al, 2017
- Proposal for redirected walking techniques in room-scaled VR
Proposal
- Straight paths in VR are uncommon
- Bending Gains
- Discrepancies between physical and virtual paths when both are bent

Experiment
- Available walking space of 4x4m
- https://youtu.be/oUBKxS2gdbc?t=48

Results
- Virtual curve can be bent up to 4.35 times
- 2.5m real $\rightarrow$ 10.875m virtual curvature radius
Examples

Problems
- Path layout has to be predefined
- Users can rarely leave predefined paths
- Use depends on applications
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Problems and Limitations

- Adaptation for each task/application
- Thresholds are lower for users experienced with 3D gaming or VE
- Large tracking area required

Worst case scenarios
- Constant need for redirection
- Dizziness
- User ignores failsafe mechanisms
Cable position
- Is noticed by user
- Breaks presence and redirection technique
- In experiments: cable is usually held
Prospect

- Combination of techniques seem to be most promising

- Impossible Spaces

- Possible to switch on/off on demand? Will user notice?

- Question of latest HMDs
  - Do thresholds change?
  - Will manipulation be noticed easier?
  - Repeated use?
Thank You for Your Attention!

Questions & Discussion
References


