Evaluation of Navigation Techniques for Virtual Environments

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Overview

- Introduction
- Locomotion Devices
- Redirected Walking
- Discussion

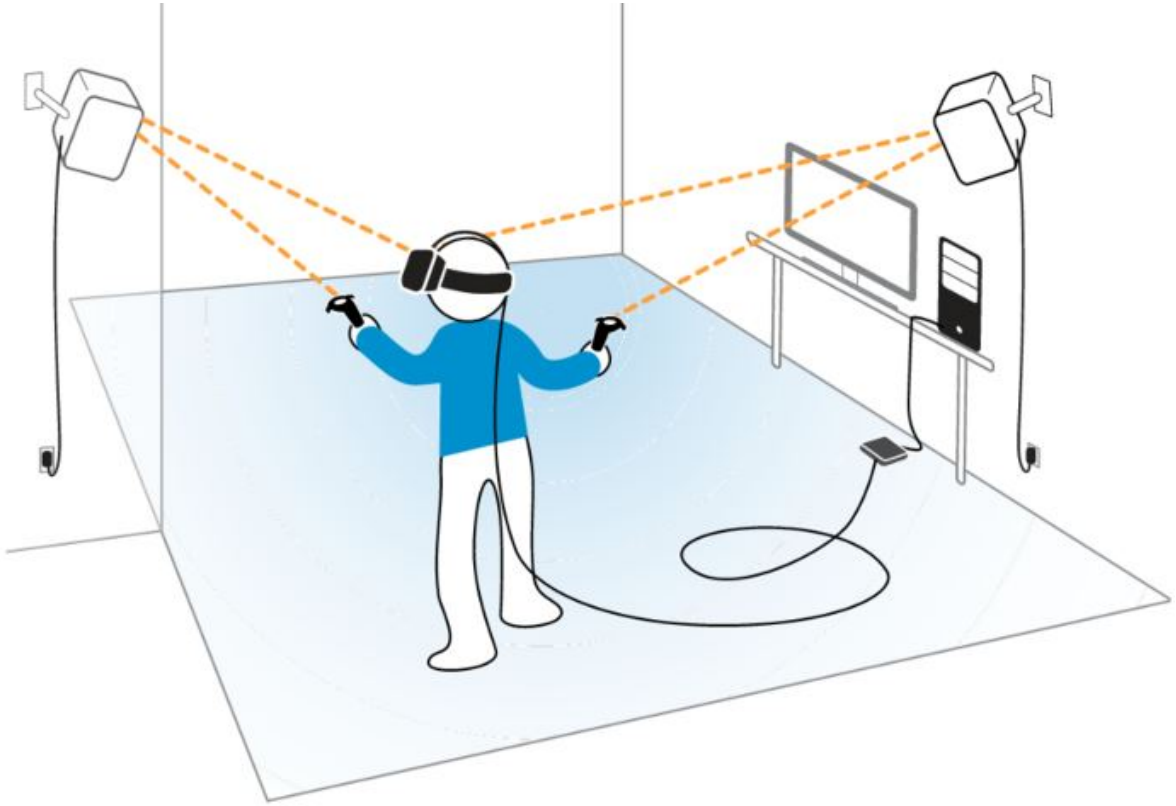
Introduction Navigation

- Navigation
  - Wayfinding
  - Locomotion
- Translate Navigation to VE

- Position and orientation must be known → tracking

Tracking Limitations

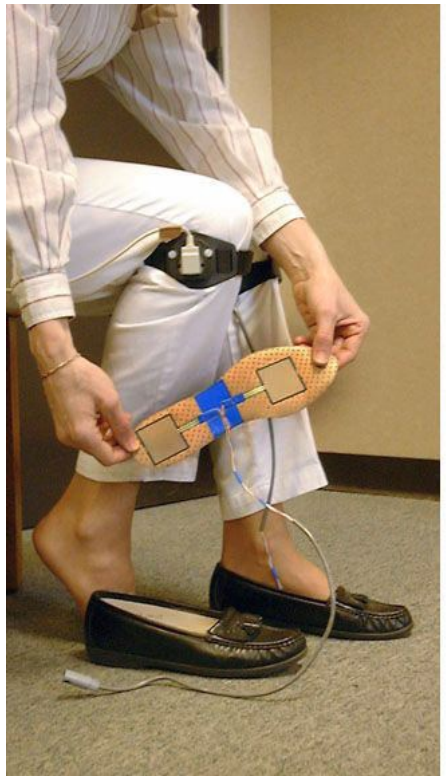
- Tracking Limitations
  - HMD: cable
  - Broadcasting range
  - Room-size



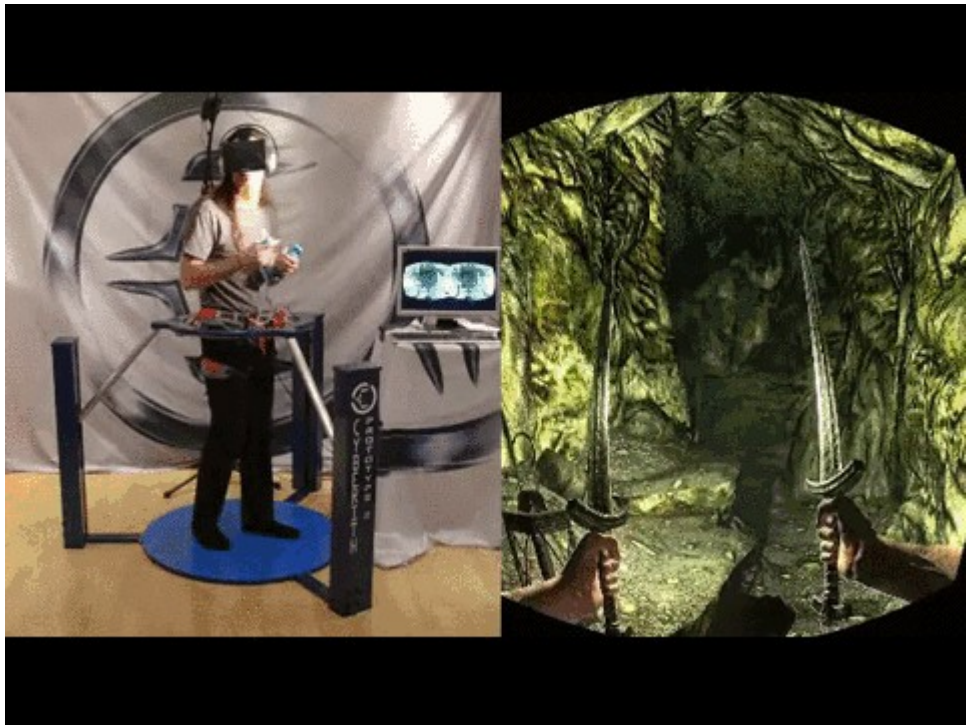
- VE larger than range in real world
- Goal: enable real walking in VE larger than tracked space

Locomotion in VR

- 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

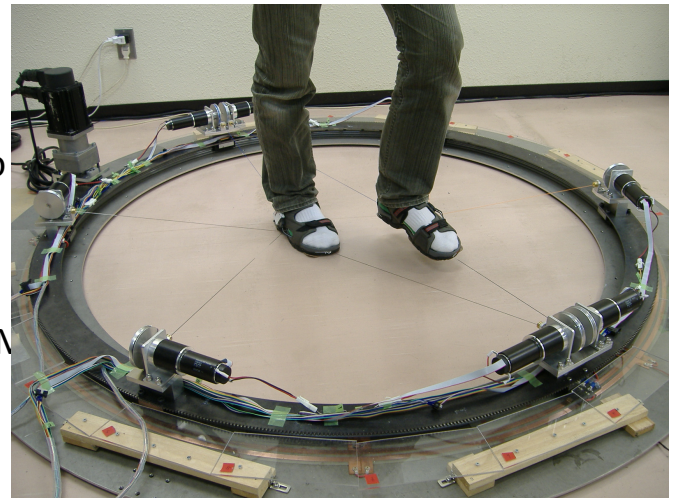


Locomotion Devices



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

Method Characterization

	Software only	Intuitive Movement	Unnoticed by user	Un-bounded	Software independent	Repeat-ability
Locomotion Devices						
Resetting Techniques						
Gains						
Impossible Spaces						
Bending the Curve						

Method Characterization

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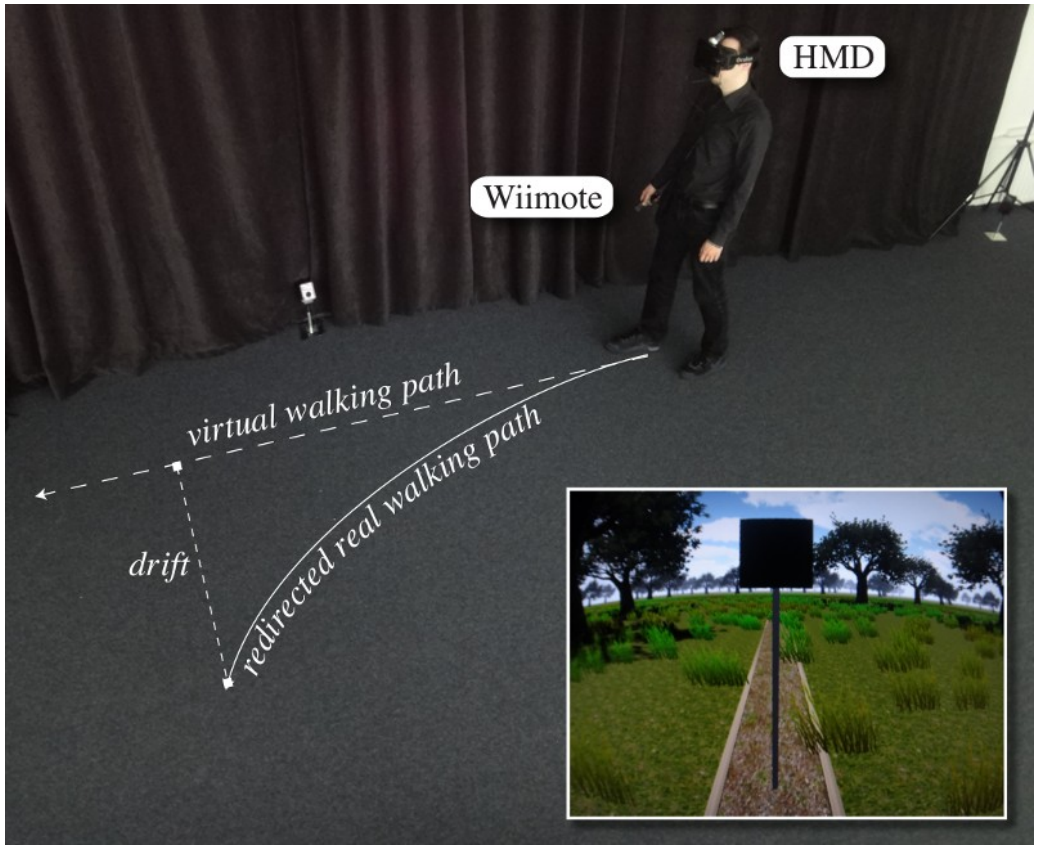
Redirected Walking



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

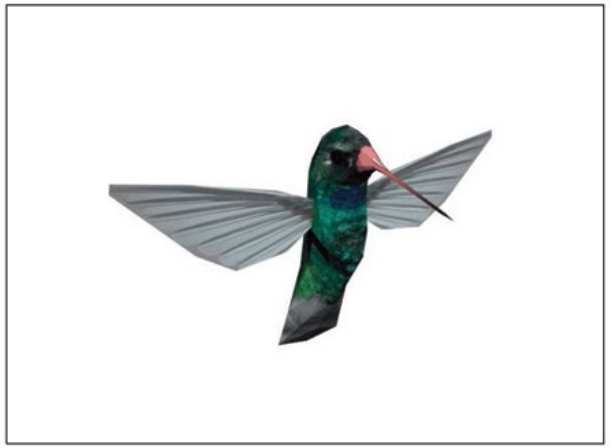
2 Categories:

- 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...)



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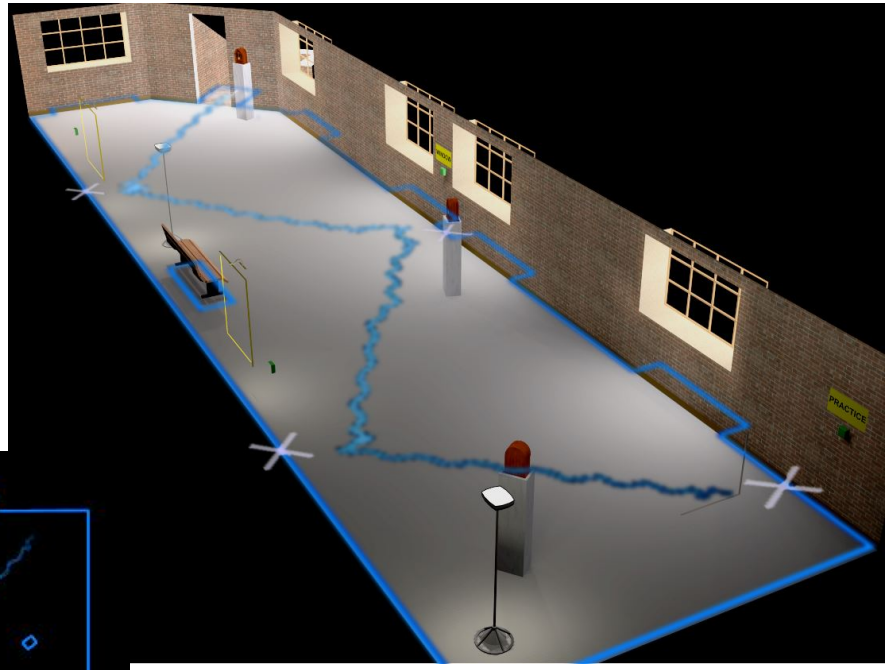
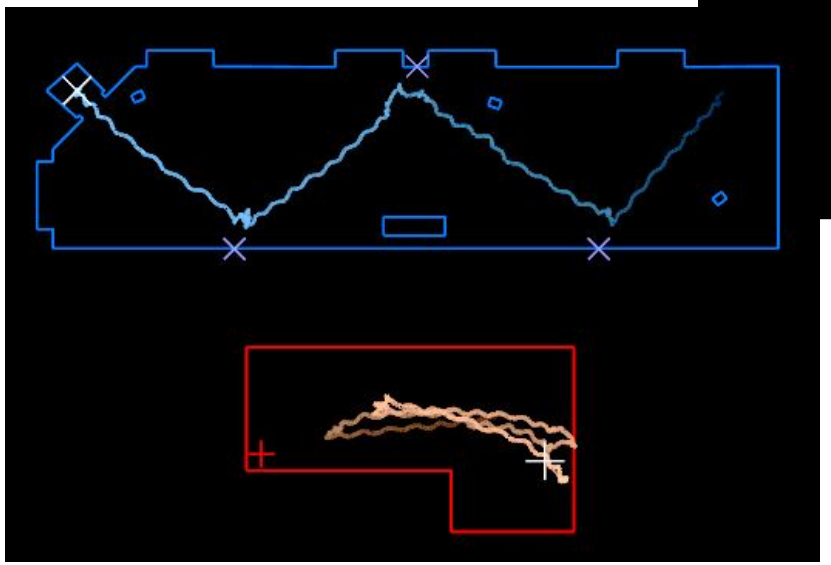
Gains						
Impossible Spaces						
Bending the Curve						

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





Gains, Steinicke et al, 2010

- 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

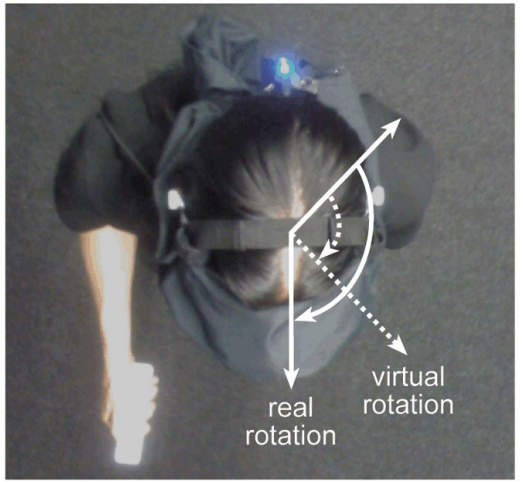
Gains, Steinicke et al, 2010

Translation Gains

- Uniform vs non-uniform
- 14% more or 26% less possible

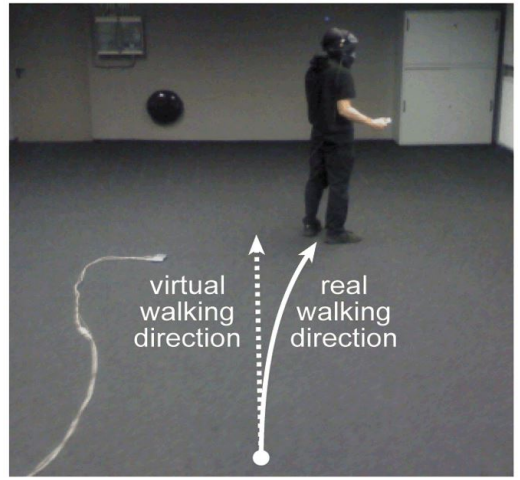
Rotation Gains

- 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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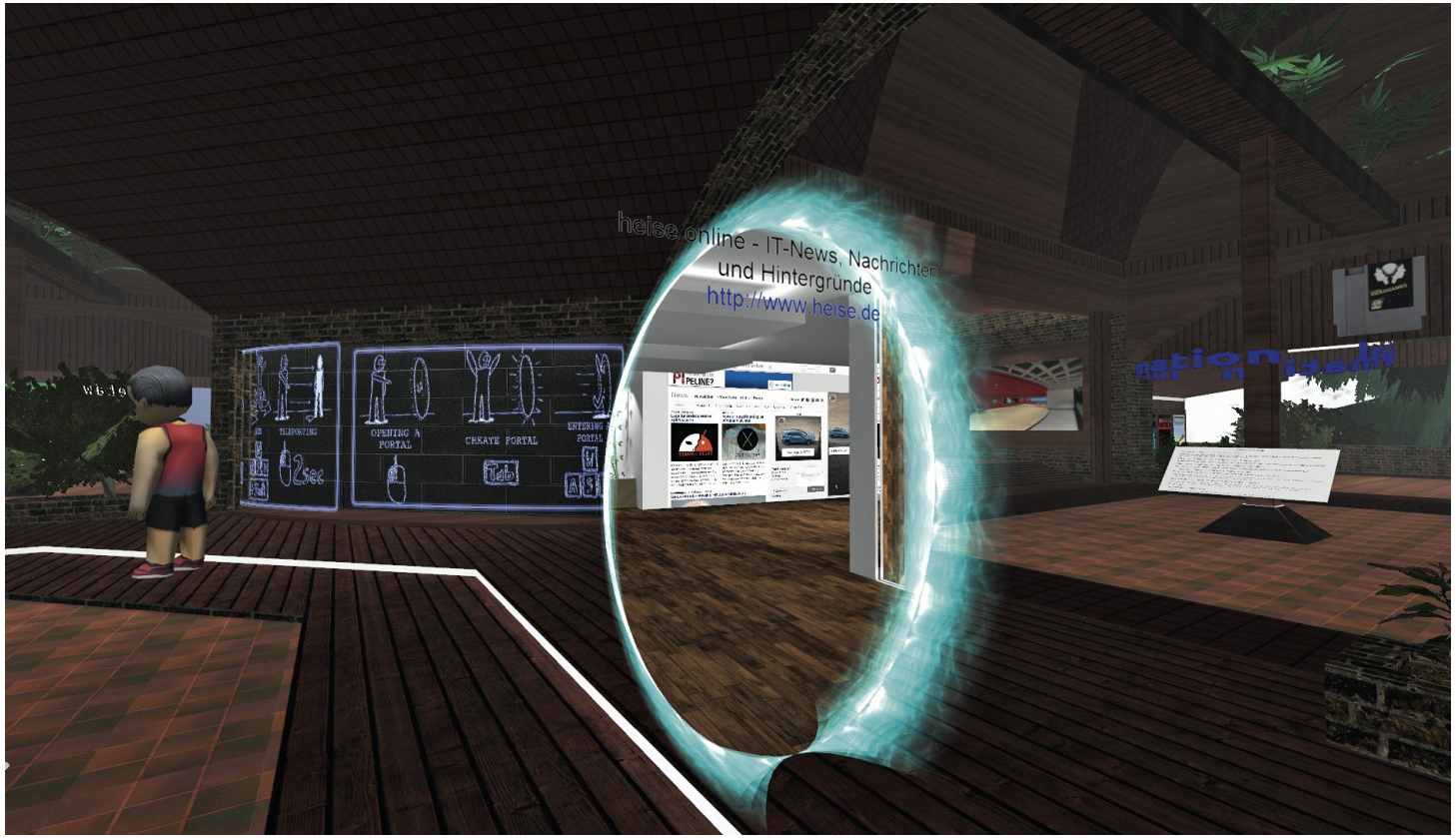
Impossible Spaces						
Bending the Curve						

Manipulation of Virtual Space

Manipulation of Virtual Scenes

- Virtual Portals
  - Allow transportation through virtual room

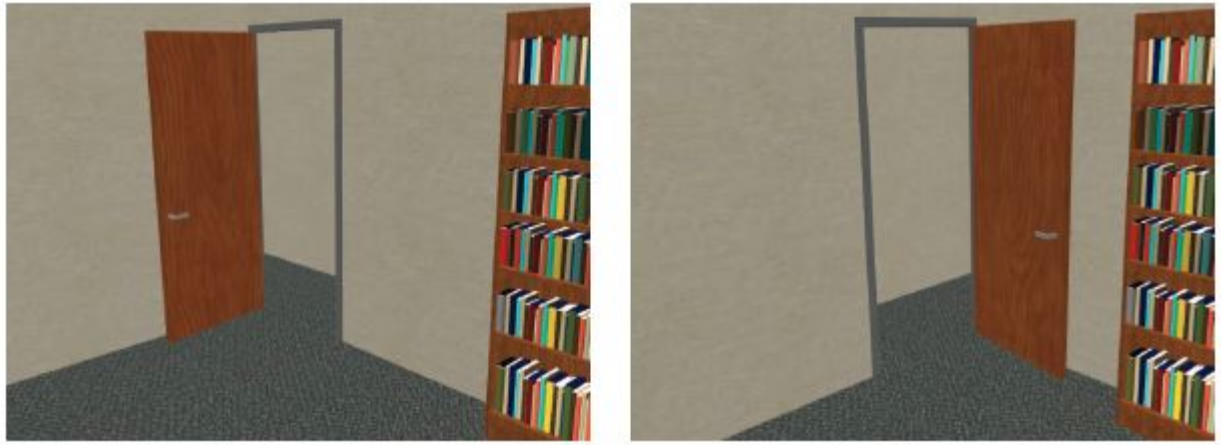


Change Blindness

- Perceptual Phenomenon
- Fails detect visual change to an object or scene

Change Blindness Redirection

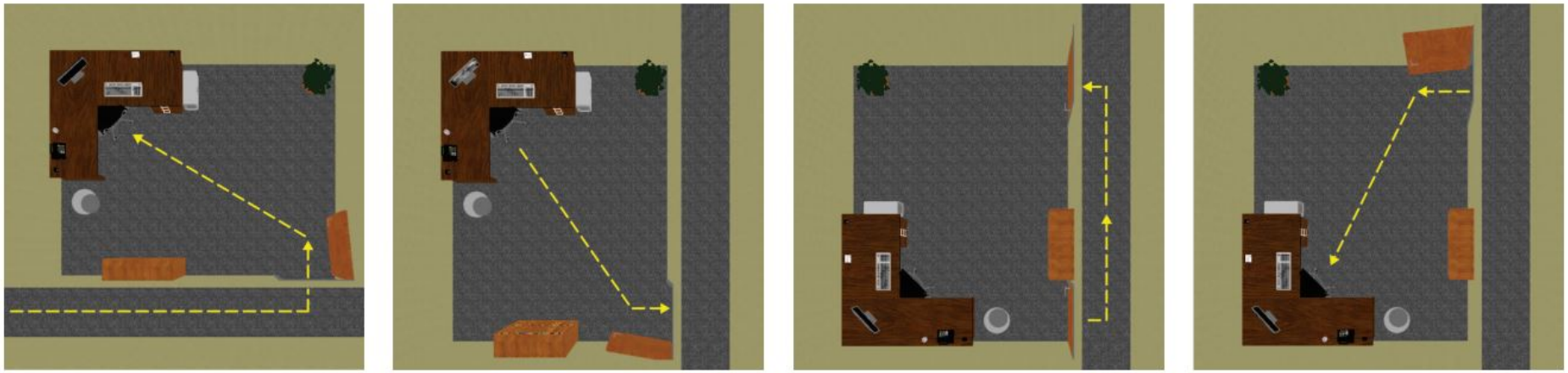
- Redirection: Suma et. al, 2011



(a) Before Scene Change (b) After Scene Change

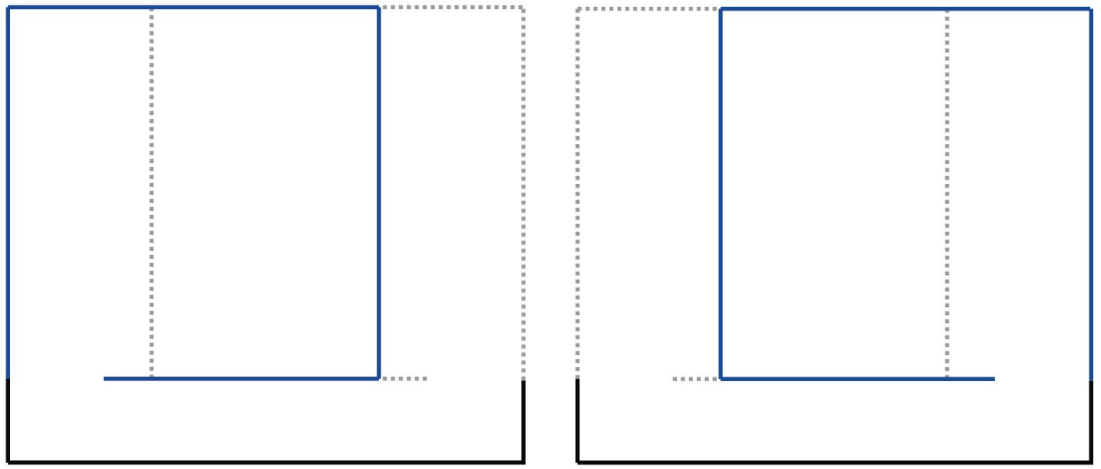
- Possible scene changes
  - Distractor needed
- Example:

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

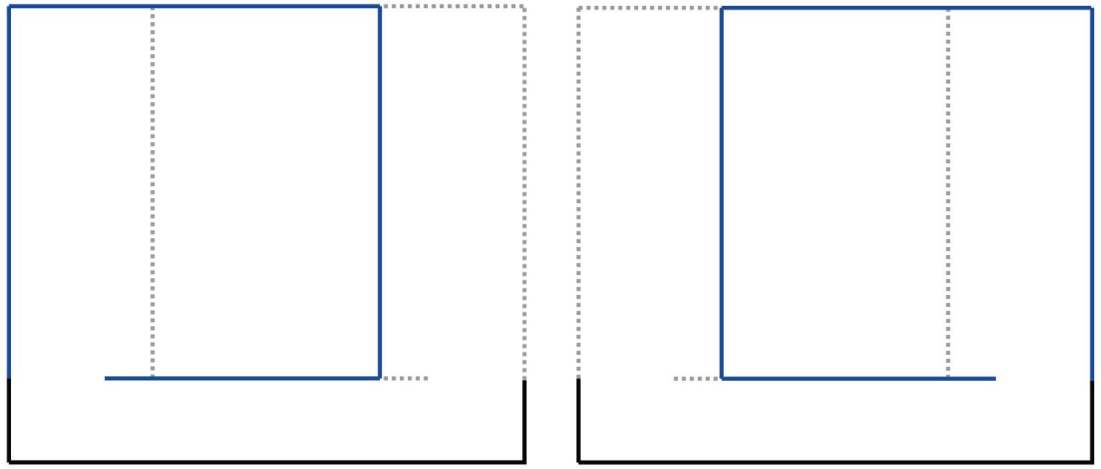


(a) State 1 (b) State 2

- 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

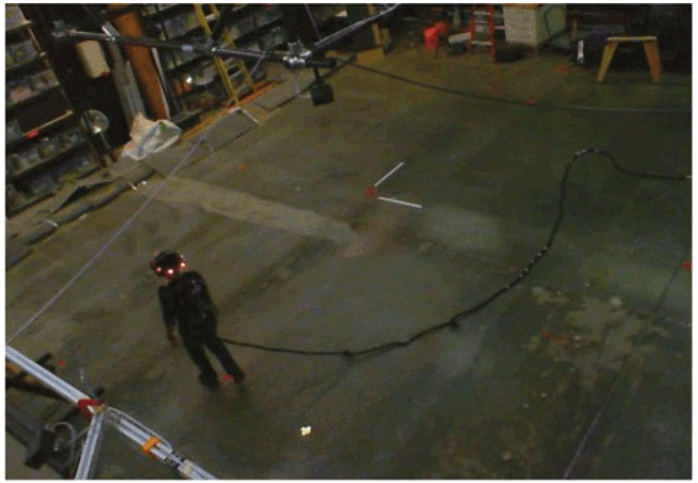


(a) State 1 (b) State 2

- When is space detected as impossible?

Experiments

- Perceiving Impossible Spaces
- Experiencing Impossible Spaces



(a)

(b)

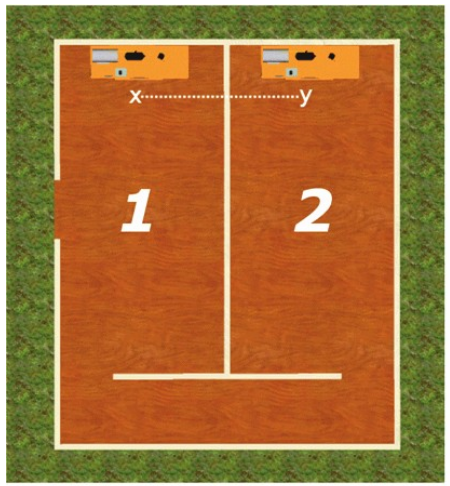
Perceiving Impossible Spaces

Setup

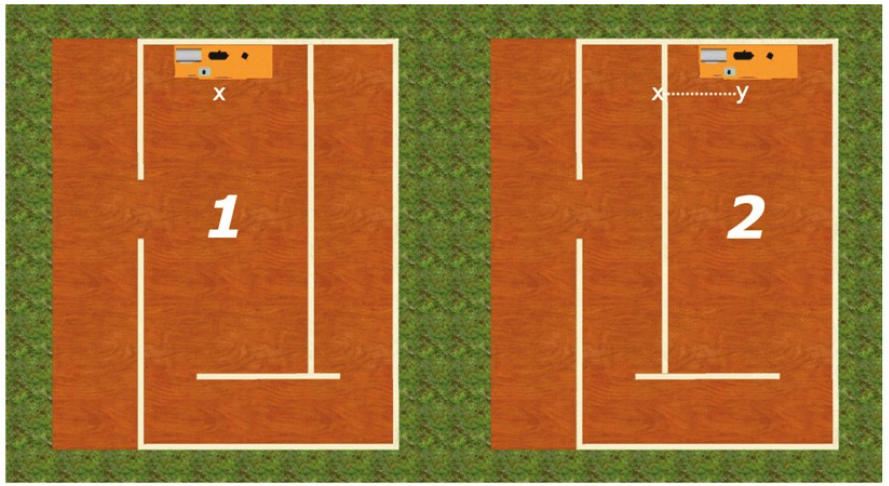
- Users were informed
- Tested overlap: 0%, 15%, 30%, 45%, 60%, 75%

Tasks

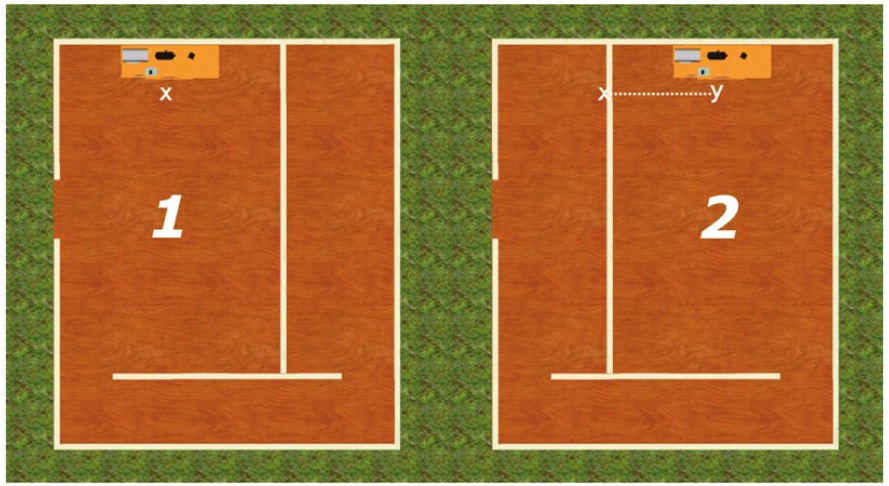
- Impossible Space Perception
- Distance Estimation



(a) 0% Overlap



(b) Fixed Room - 50% Overlap



(c) Expanding Room - 50% Overlap

Perceiving Impossible Spaces

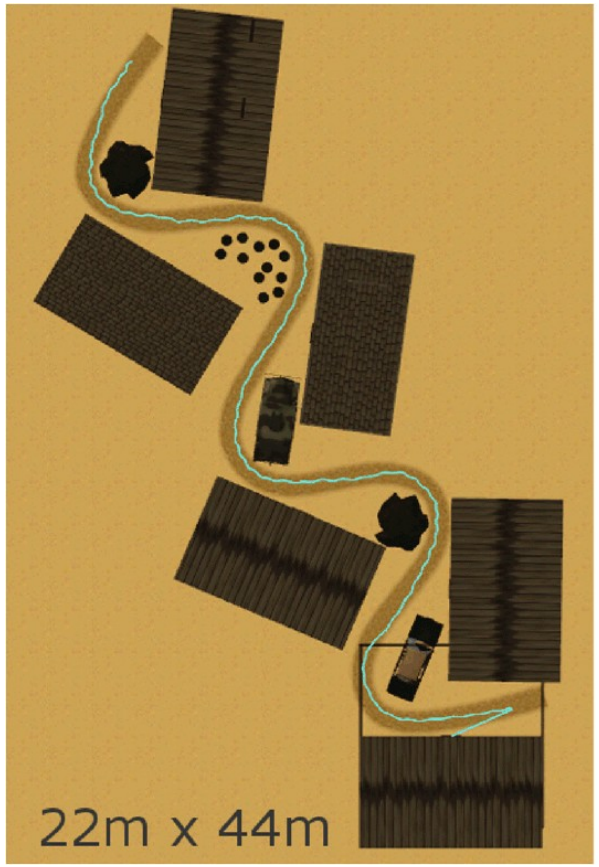
Results

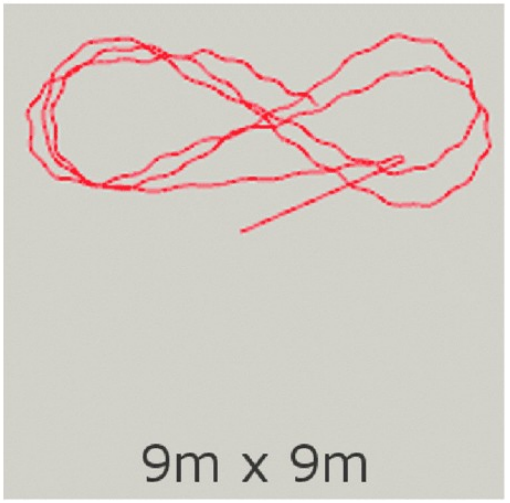
- Participants with prior 3D gaming experience – fast detection
- Fixed 9x9m room – overlap up to 31%
- Larger rooms – more likely to alert users
- Large rooms, small hallway – quickly detected as impossible
- Smaller rooms – overlap up to 56%
- Distance estimation showed illusion worked

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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Impossible Spaces	Yes	Yes	Yes	No	No	Partially
Bending the Curve						

Recent Application

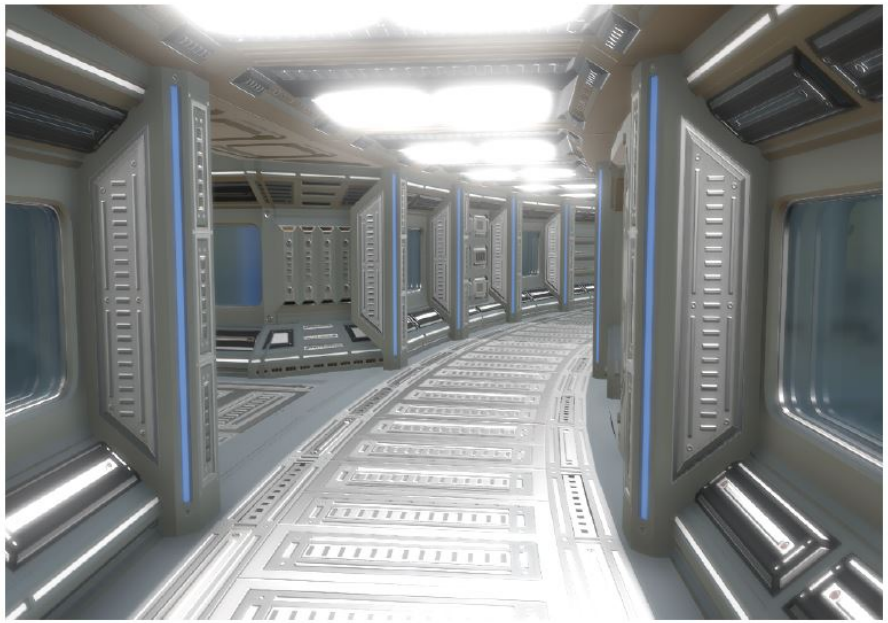
- Bending the Curve, Langbehn et al, 2017
- Proposal for redirected walking techniques in room-scaled VR

Bending the Curve

- 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 → 10.875m virtual curvature radius

Bending the Curve

Examples



Problems

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

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Bending the Curve	Yes	Yes	Partially	No	No	Yes

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
  - Dizzyness
  - User ignores failsafe mechanisms

Problems and Limitations

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

The Kat Walk VR treadmill can enhance the virtual reality experience of games, apps, and simulations (Credit: Kat VR)

References

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