Interaction: Locomotion

CS 6334 Virtual Reality

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Some slides of this lecture are courtesy Jin Ryong Kim

Locomotion

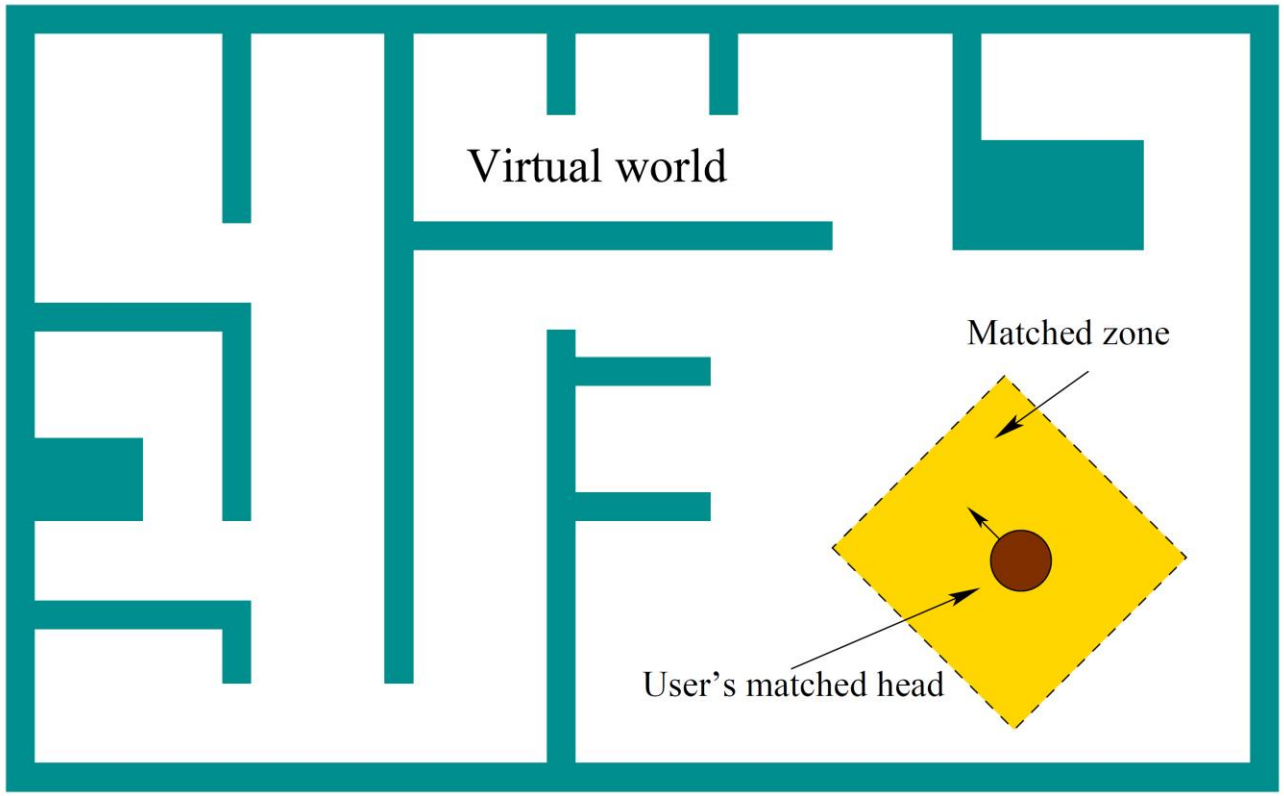
- An interaction mechanism that moves the user in the virtual world

https://circuitstream.com/blog/vr-locomotion/

Locomotion Tasks

- Exploration
  - Locomotion to build up knowledge of the space
- Search
  - Naïve search: locate a target not previously visited
  - Primed search: locate a target previously visited
- Maneuver
  - Locomotion to make small adjustment of viewpoint

Matched Zone



Matched zone: a safe region for the user in the real world

- Safety issue for larger matched zone

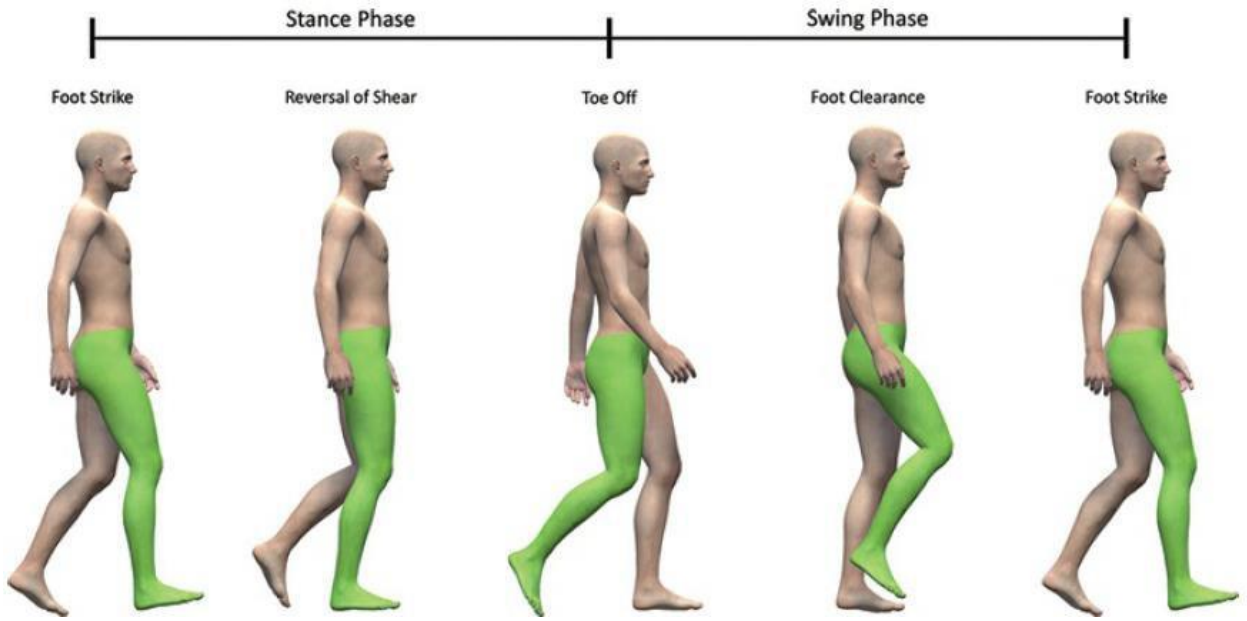
Real world

Walking Metaphors

- Most natural travel method is to physically walkaround
- Full gait techniques
- Partial gait techniques
- Gait negation techniques

Full Gait Techniques

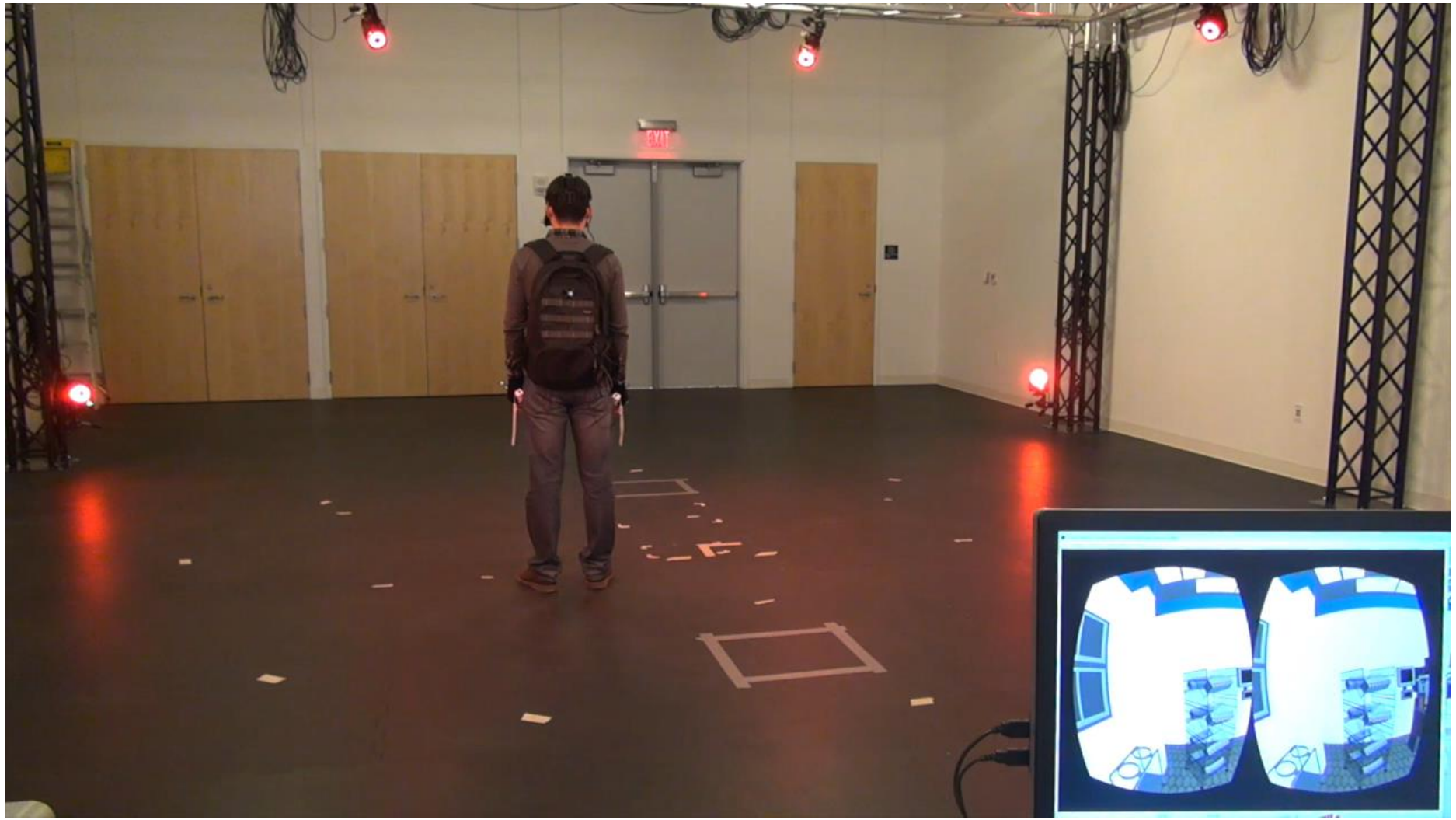
- Metaphors involve all the biomechanics of a full gait cycle
  - Real walking
  - Redirected walking
  - Scaled walking



Real Walking

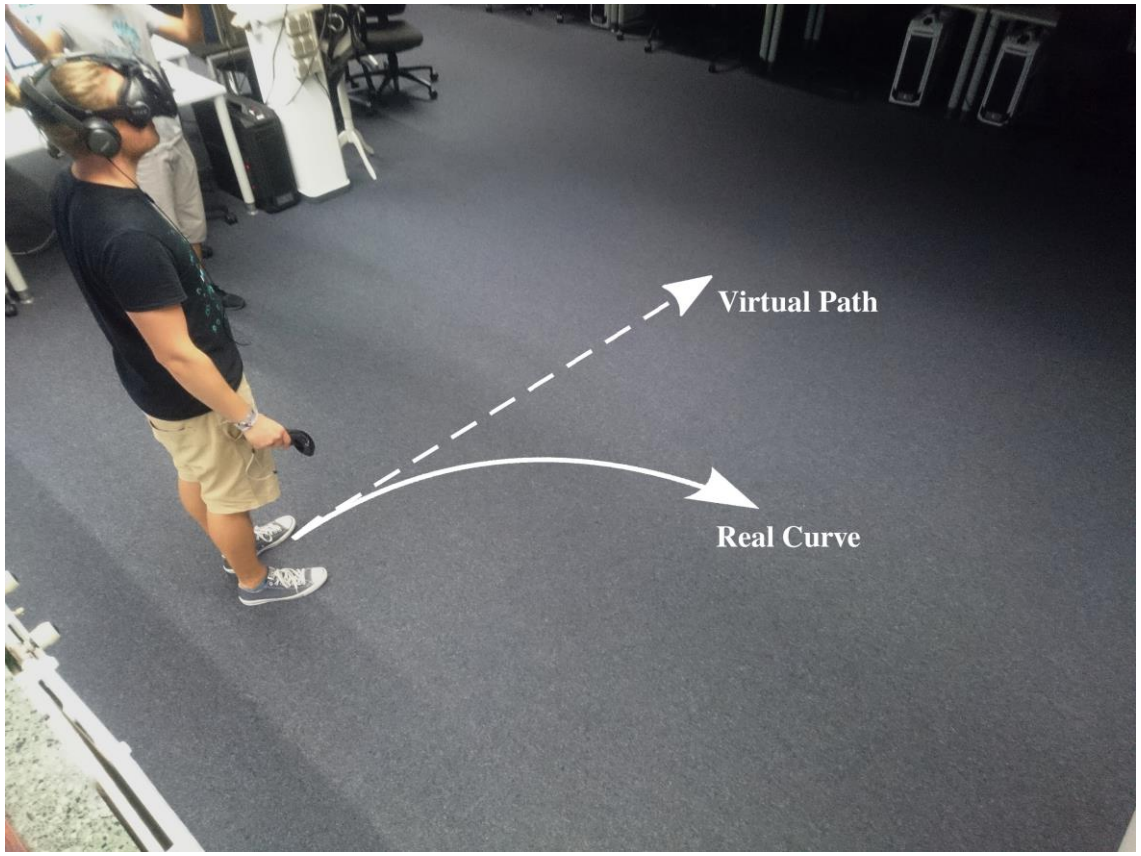
- Use a strict, one-to-one mapping of a 6 DOF head tracker to a user's virtual viewpoint
- Most natural locomotion technique
- Travel range is limited to the tracking volume

Real Walking



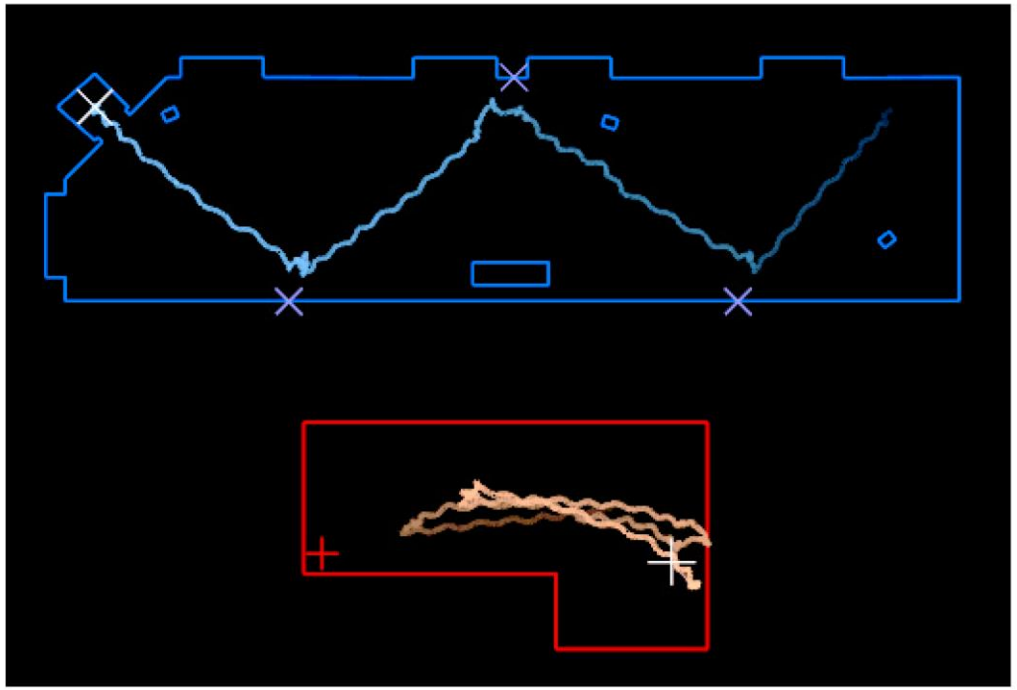
Redirected Walking

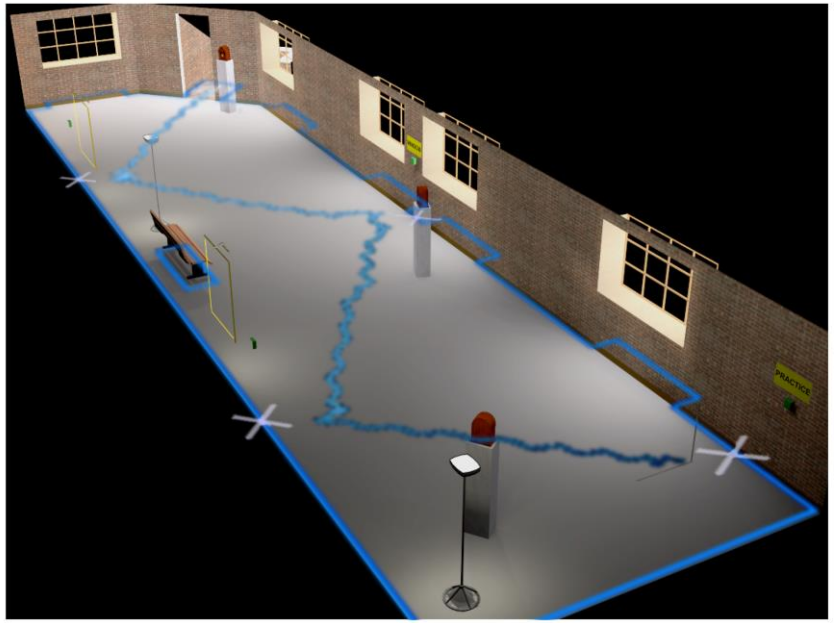
- Interactively rotating the virtual scene about the user
- The user does not notice this slight rotation distortion
- Helps to avoid physical space limitations



Redirected Walking in Virtual Reality. Eike Langbehn and Frank Steinicke

Redirected Walking





Redirected Walking. Sharif Razzaque, Zachariah Kohn, Mary C. Whitton, In EUROGRAPHICS 2001.

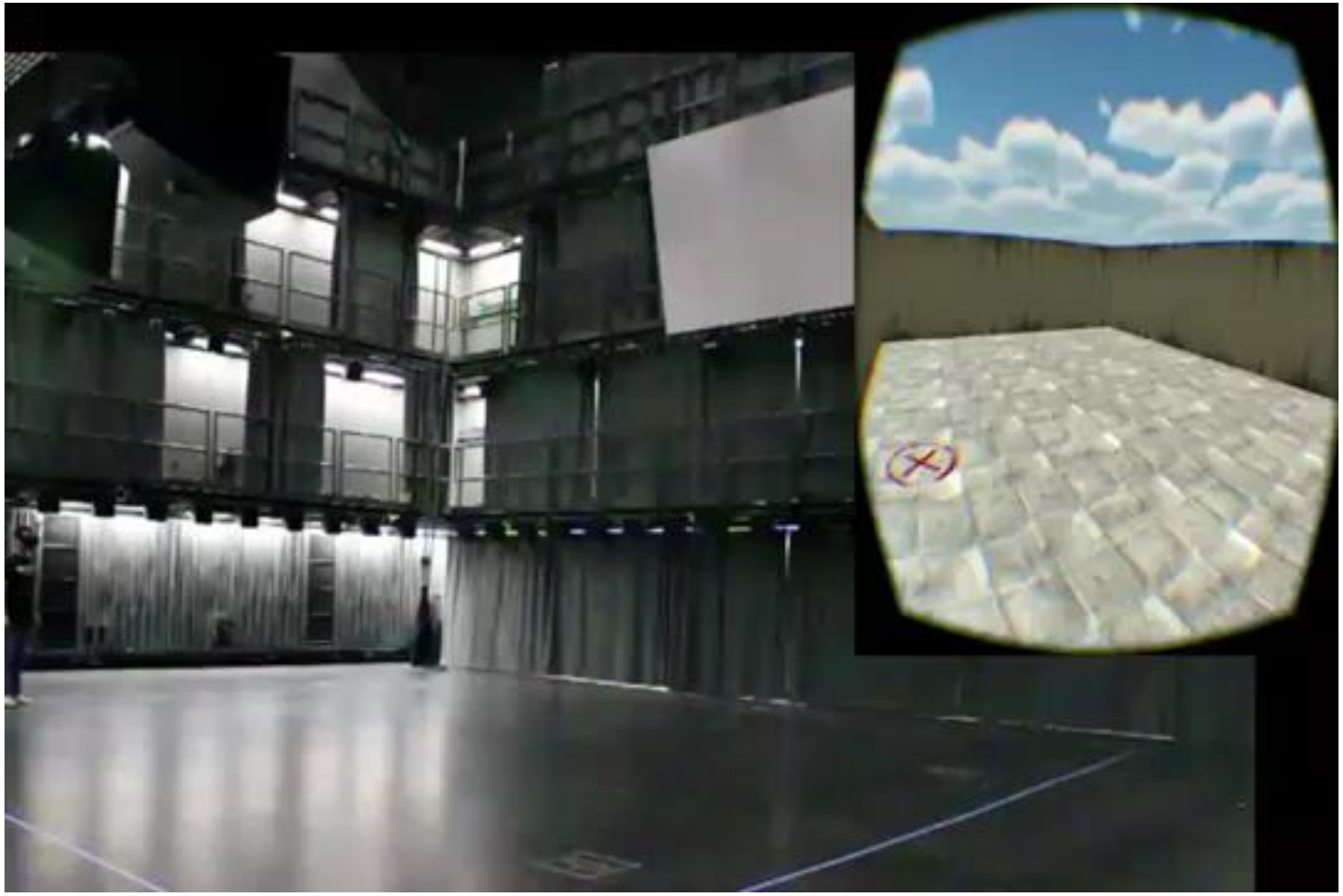
Redirected Walking

Scaled Walking

- Scales up the user's forward velocity
- Results in greater virtual travel distances than physical walking distances
- Helps to avoid physical space limitations
- Causes simulator sickness for some users

I'm a Giant:Walking in Large Virtual Environments at High Speed Gains. Abtahi et al., CHI'19

Scaled Walking

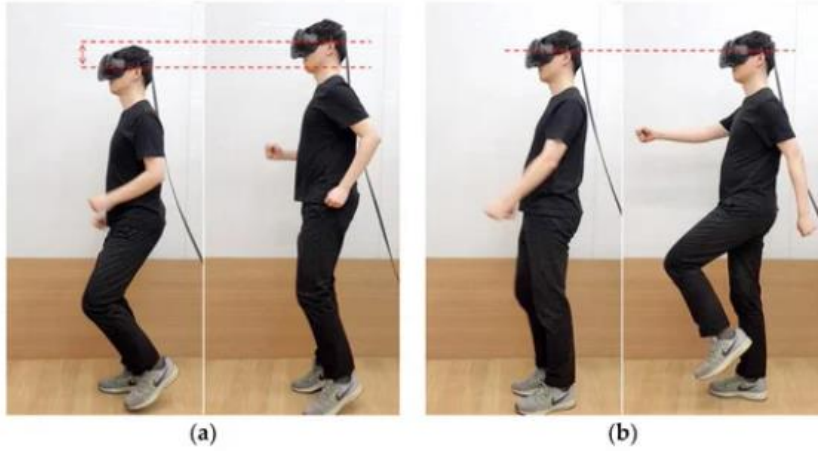


Partial Gait Techniques

- Metaphors represent only a subset of the gait cycle
  - Walking in place
  - Human joystick

Walking in Place

- The user physically steps in place to virtually walk
- Tracking
  - Tracking the bobbing of the user's head or body
  - Tracking the user's feet
- Avoids physical space limitations
- Causes fatigue for users

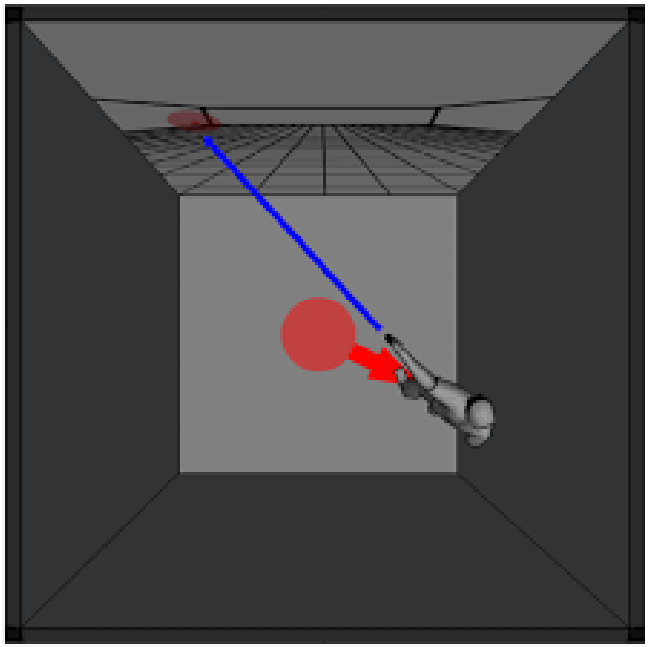


https://www.mdpi.com/1424-8220/18/9/2832/htm

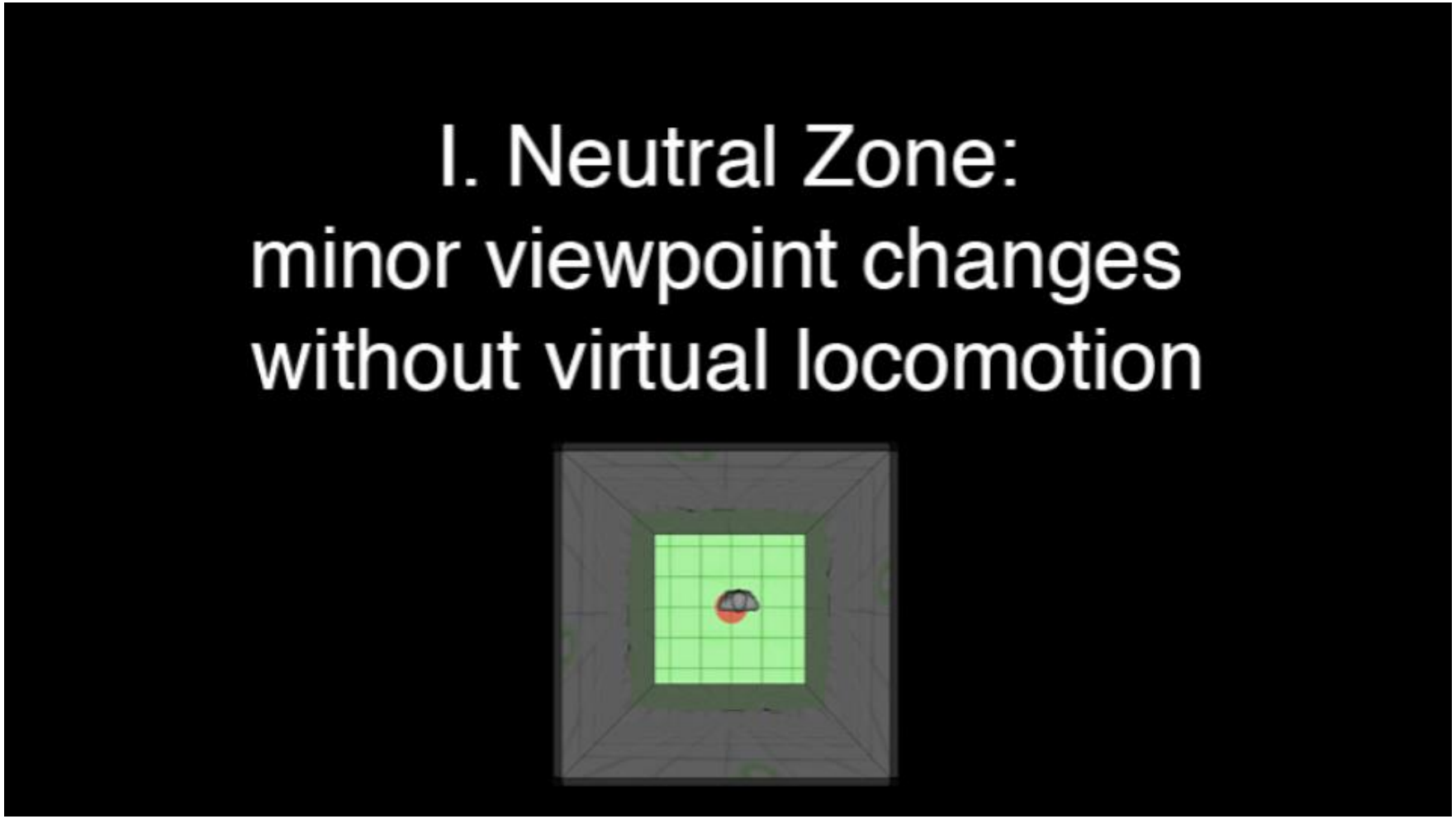
Walking in Place

Human Joystick

- The user's body acts like the handle of a joystick to initiate locomotion in different directions
- Uses the position of the user relative to the center of the tracked space to create a 2D vector
- This vector controls the locomotion direction and speed
- Causes simulator sickness for some users



Human Joystick



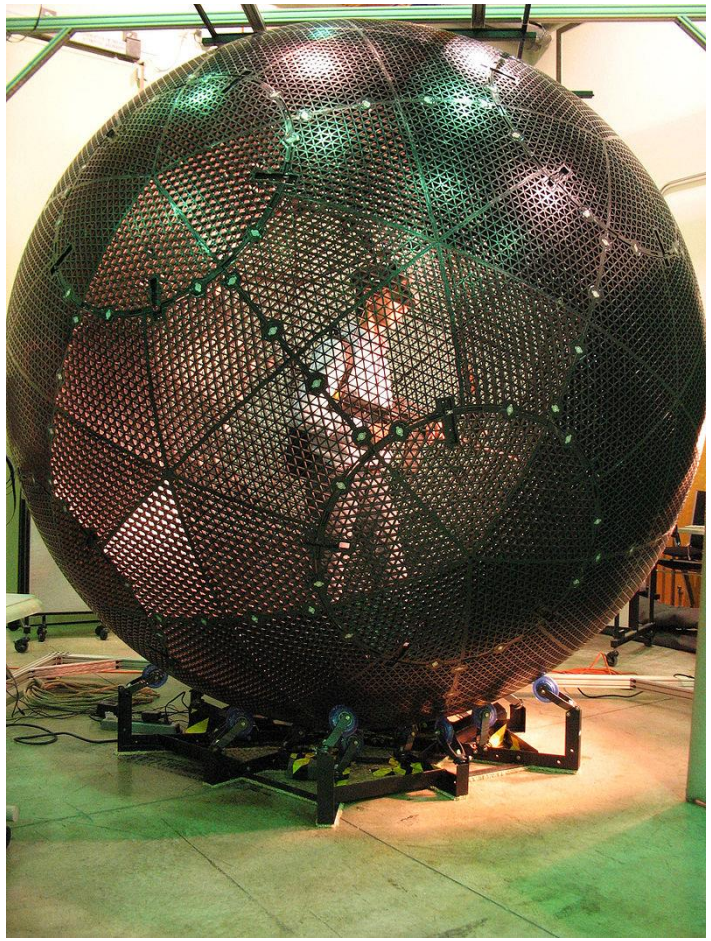
Gait Negation Techniques

- Metaphors that use special locomotion devices to provide a realistic walking motion
  - Negate the forward movement of the user's gait

- Treadmills
  - Walk or run
  - Restrict turning around
  - Difficult to immediately stop
  - Causes balance issues for some users

Passive Omnidirectional Treadmill

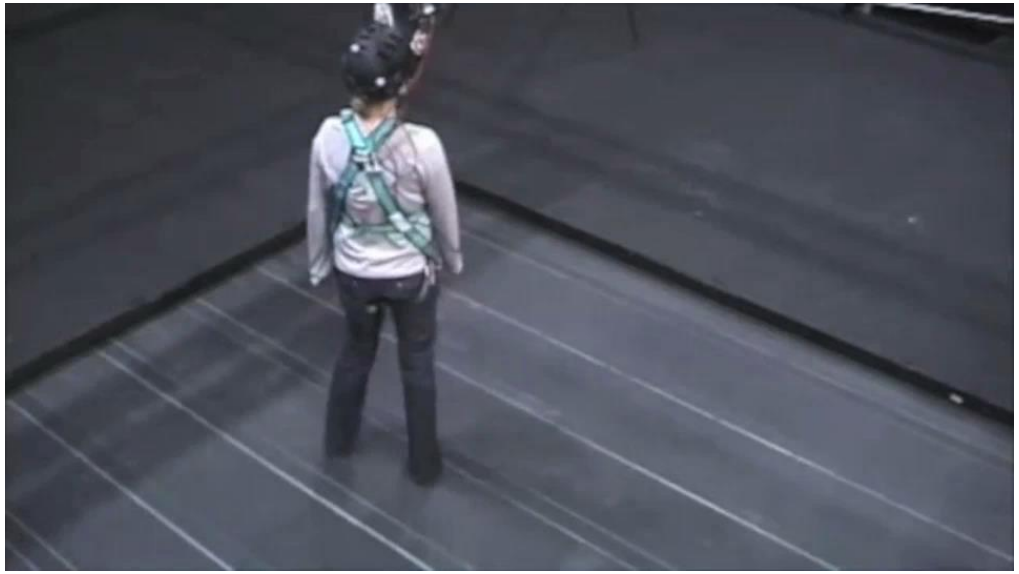
- Virtusphere
- Relies on the user's weight and momentum to start and stop the treadmill's surface
- Difficult to immediately start or stop



Passive Omnidirectional Treadmill

Active Omnidirectional Treadmill

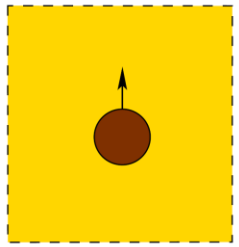
- Detects the user's movements and changes treadmill surface to negate them
- Difficult to immediately start and stop travel due to tracking latency and inertia of surface



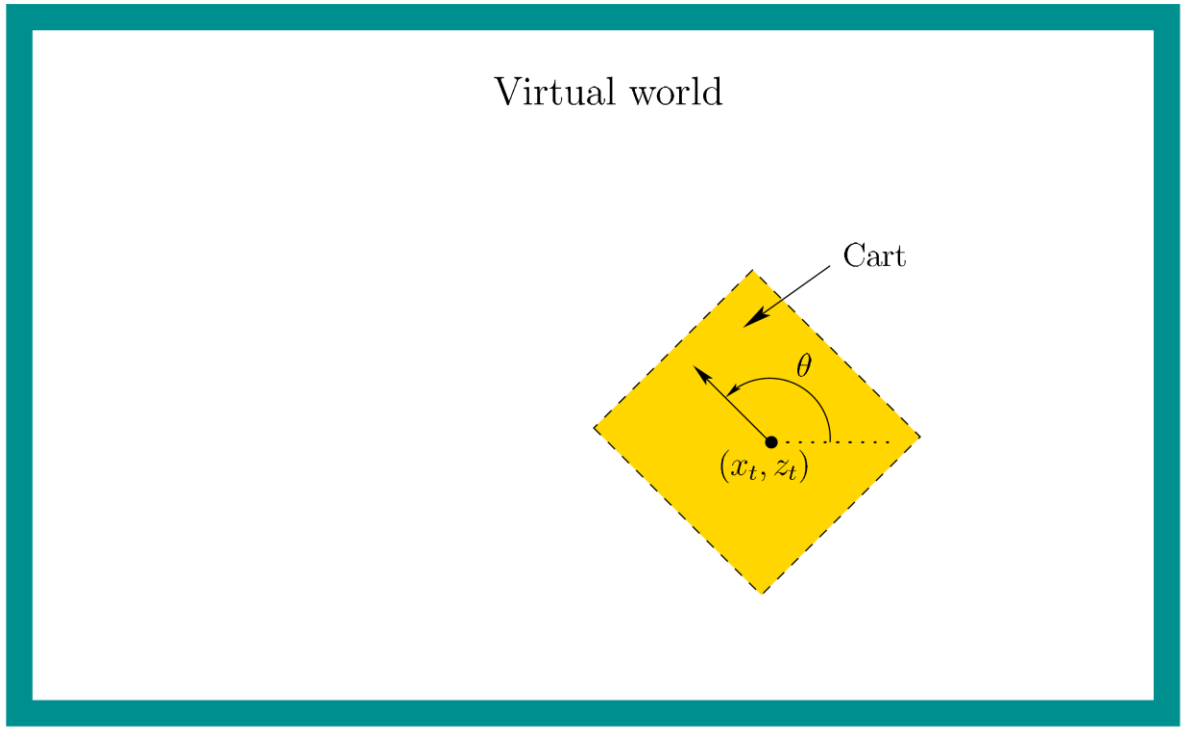
Walking Metaphors Summary

- Full gait techniques
- Partial gait techniques
- Gait negation techniques

An Implementation of Locomotion



Matched zone



Top-down view

- Position and orientation of the cart by a controller

$$T_{cart} = \begin{bmatrix} \cos\theta & 0 & \sin\theta & x_t \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & z_t \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$y_t = 0$$

- Moving

$$\dot{x}_t = s\cos\theta$$
$$\dot{z}_t = s\sin\theta$$

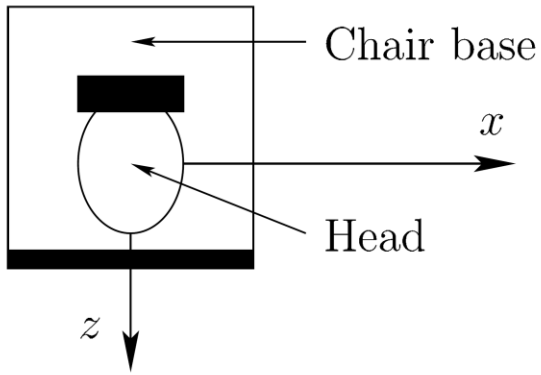
s is the forward speed.
1.4 m/s for walking

$$x_t[k+1] = x_t[k] + \dot{x}_t \Delta t$$
$$z_t[k+1] = z_t[k] + \dot{z}_t \Delta t.$$

Changing Orientation

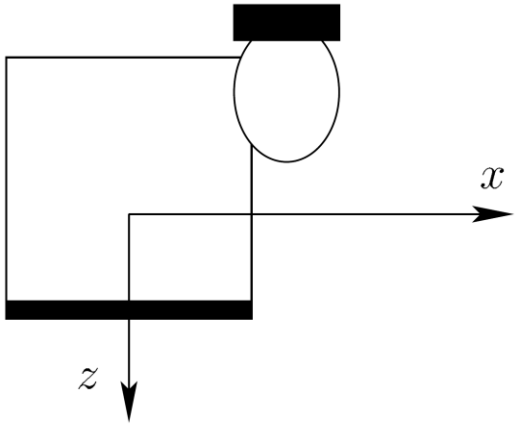
- Change orientation θ according to head orientation
  - Convenient and comfortable for a swivel chair
  - Limited to 60 degrees for a fixed chair, use controller (can caused yaw vection)

Sitting upright



Rotation axis is head center

Leaning in the chair



Should rotation axis be new head center or original xz origin?

Teleportation

- Point to the location you want to go and instantly move there
- Currently most popular technique for locomotion in VR
- Requires fading in and out of the scene to reduce motion sickness

Image from the Budget Cuts game on the HTC Vive platform

Teleportation

Further Reading

- Section 10.2, Virtual Reality, Steven LaValle

- Chapter 8, 3D User Interfaces: Theory and Practice, LaViola et al.