Interaction: Locomotion

CS 6334 Virtual Reality

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Some slides of this lecture are courtesy Jin Ryong Kim and Yu Xiang

Locomotion

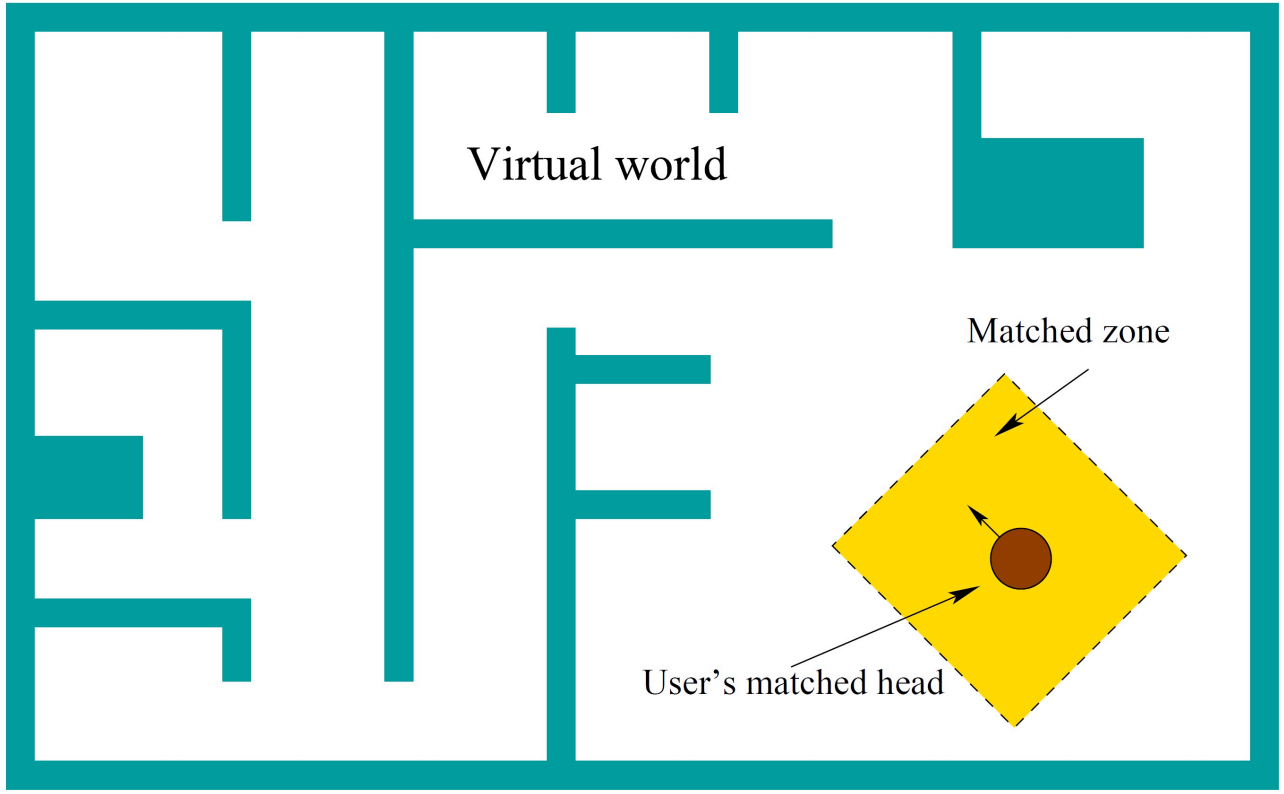
- An interaction mechanism that moves the user in the virtual world

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

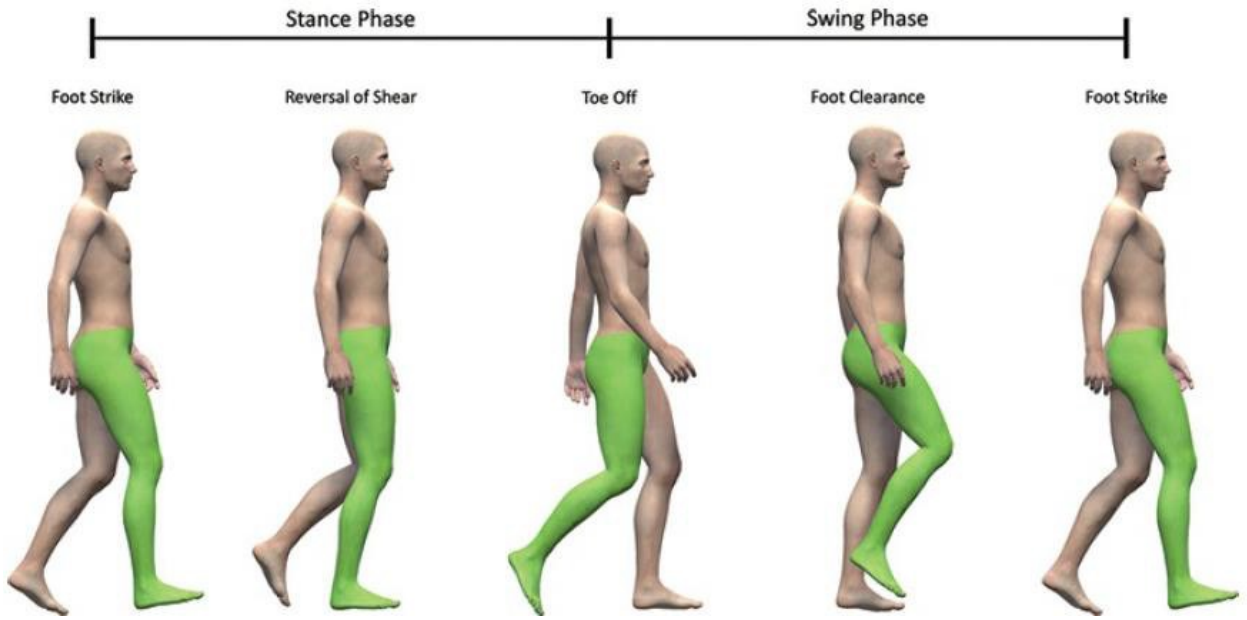
- Most natural travel method is to physically walk around
- Full gait techniques
- Partial gait techniques
- Gait negation techniques

Gait Cycle

https://www.youtube.com/watch?v=DP5-um6SvQI

Full Gait Techniques

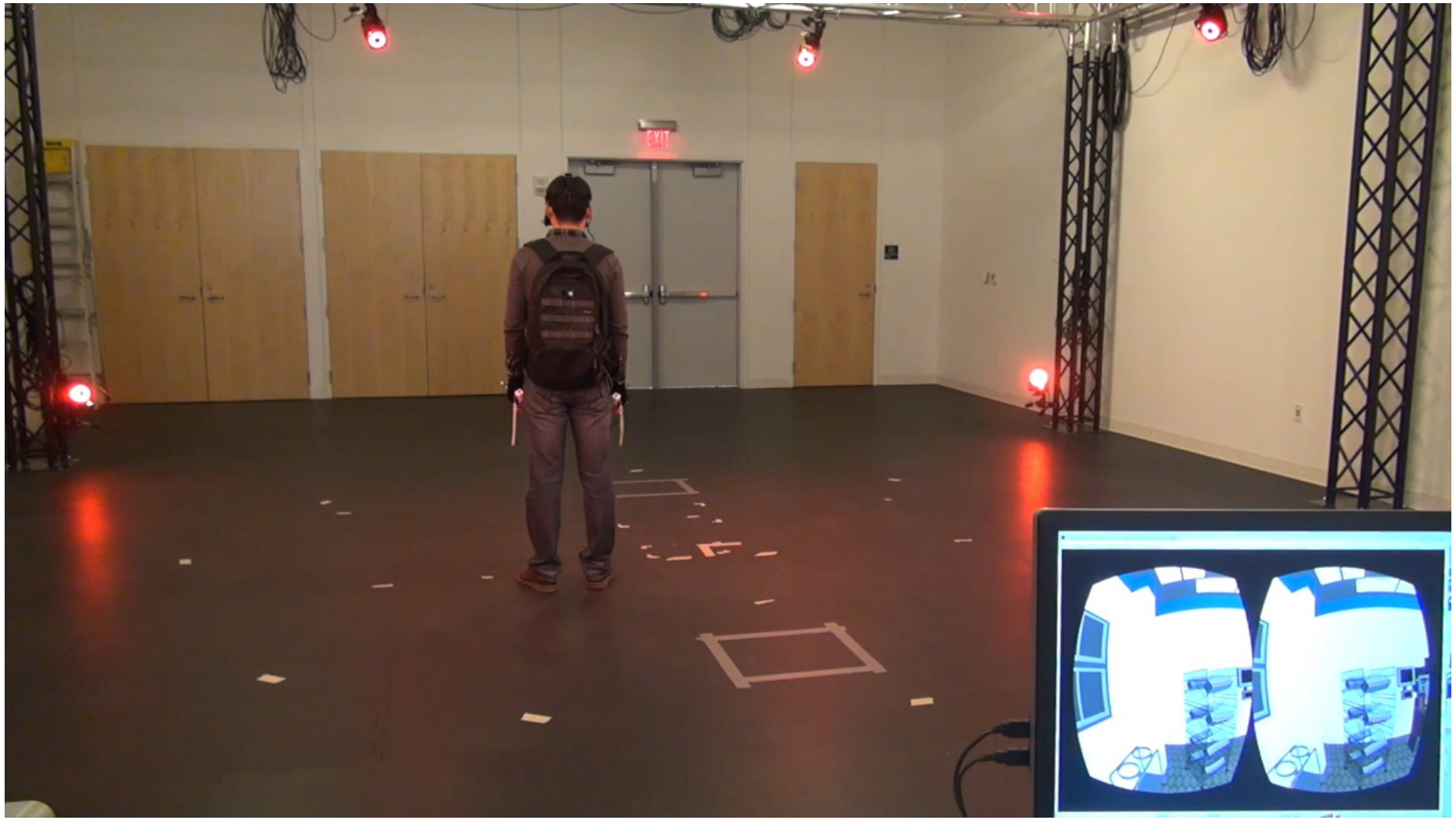
- Metaphors involve all the biomechanics of a full gait cycle
  - Real walking
  - Redirected walking
  - Scaled walking



Real Walking

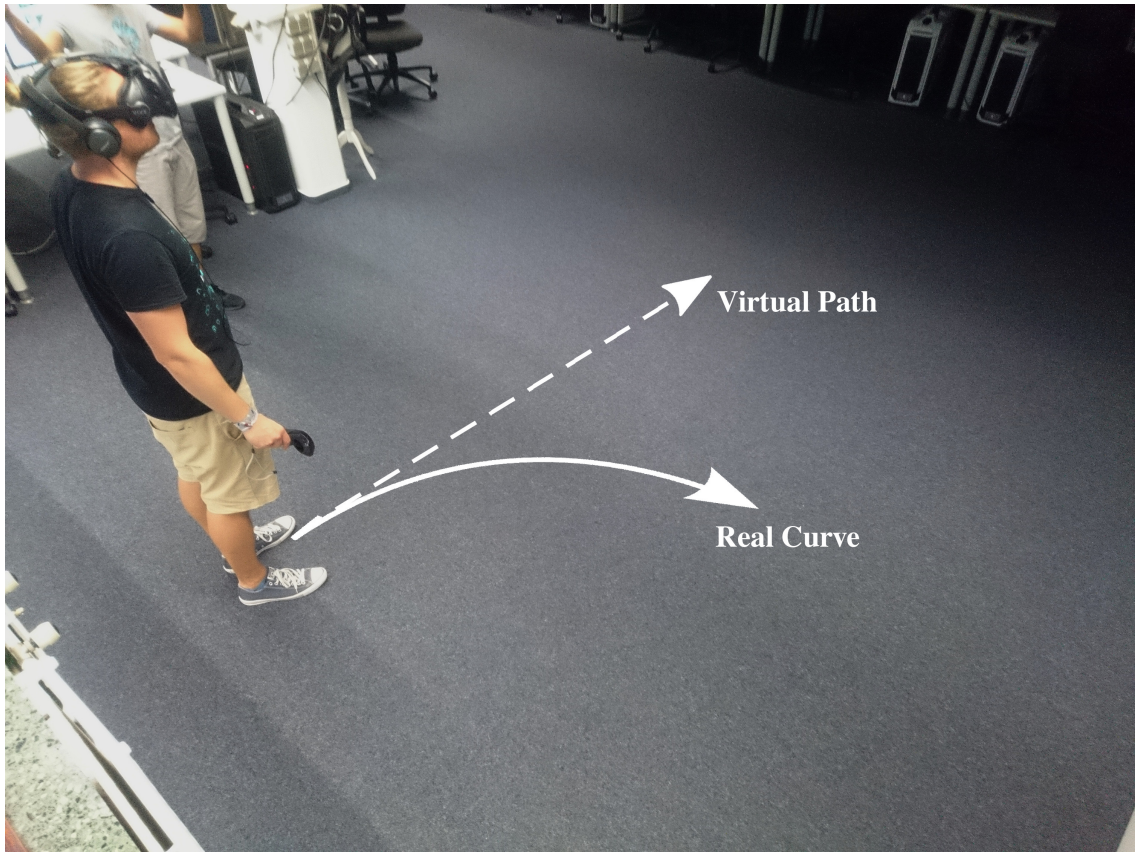
- Use a strict, one-to-one mapping of a 6 DOF head tracker to a user's virtual viewpoint
- Most natural locomotion technique
- Travel range is limited to the tracking volume

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

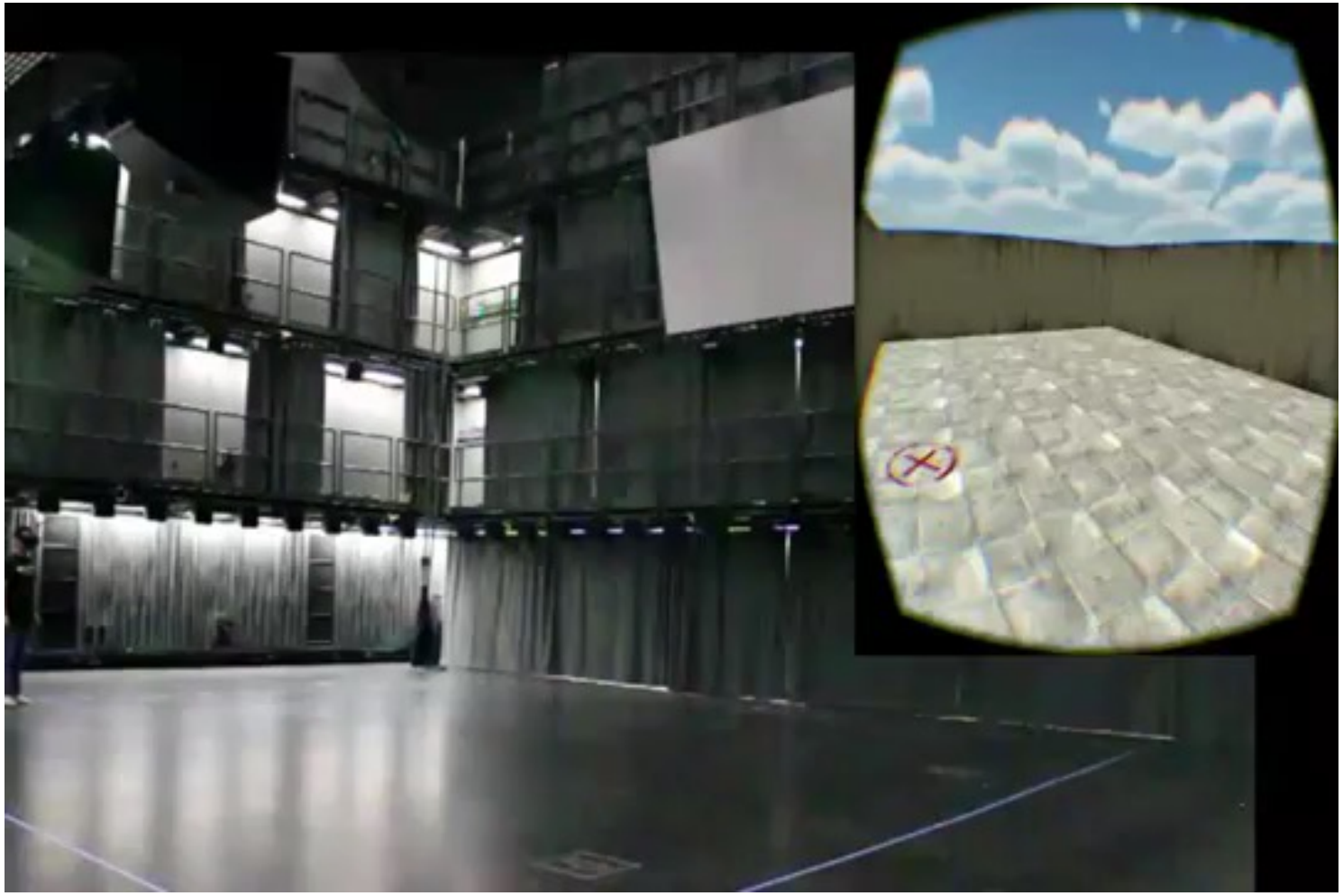
https://www.youtube.com/watch?v=THk92rev1VA

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

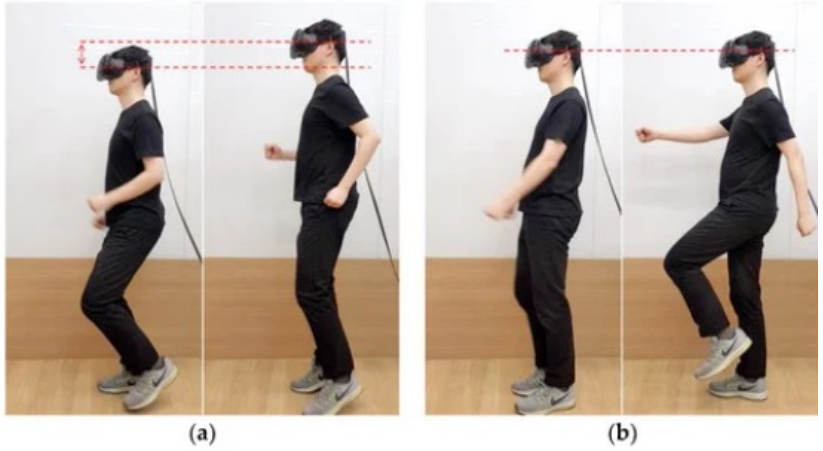


Partial Gait Techniques

- 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

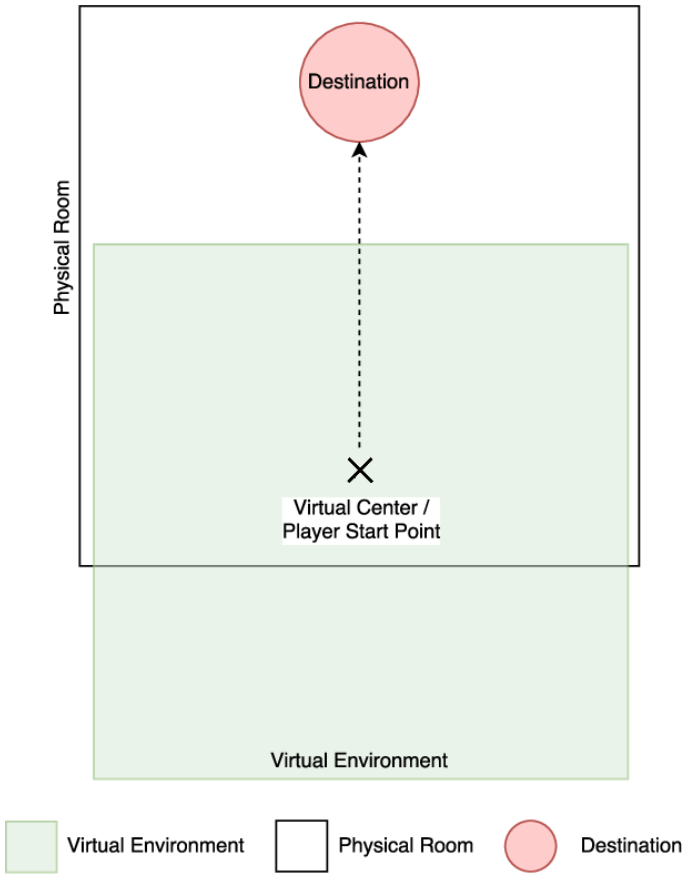


https://www.mdpi.com/1424-8220/18/9/2832/htm

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

https://www.youtube.com/watch?v=iyK94jFuniM

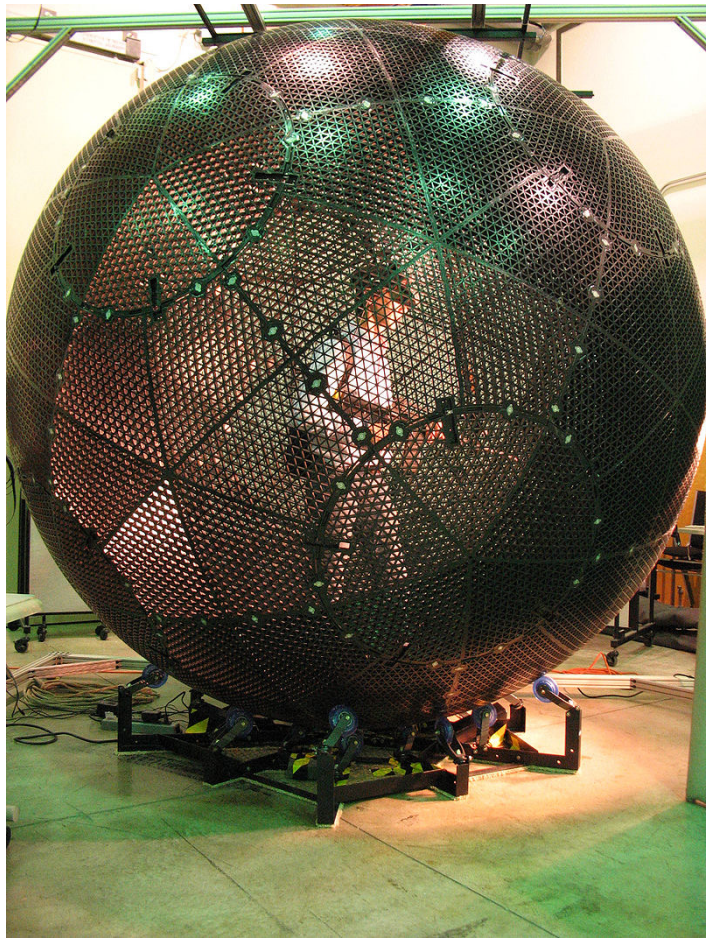
Gait Negation Techniques

- 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

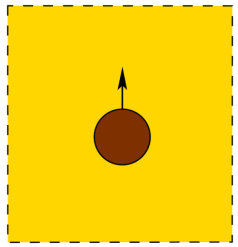


Passive Omnidirectional Treadmill

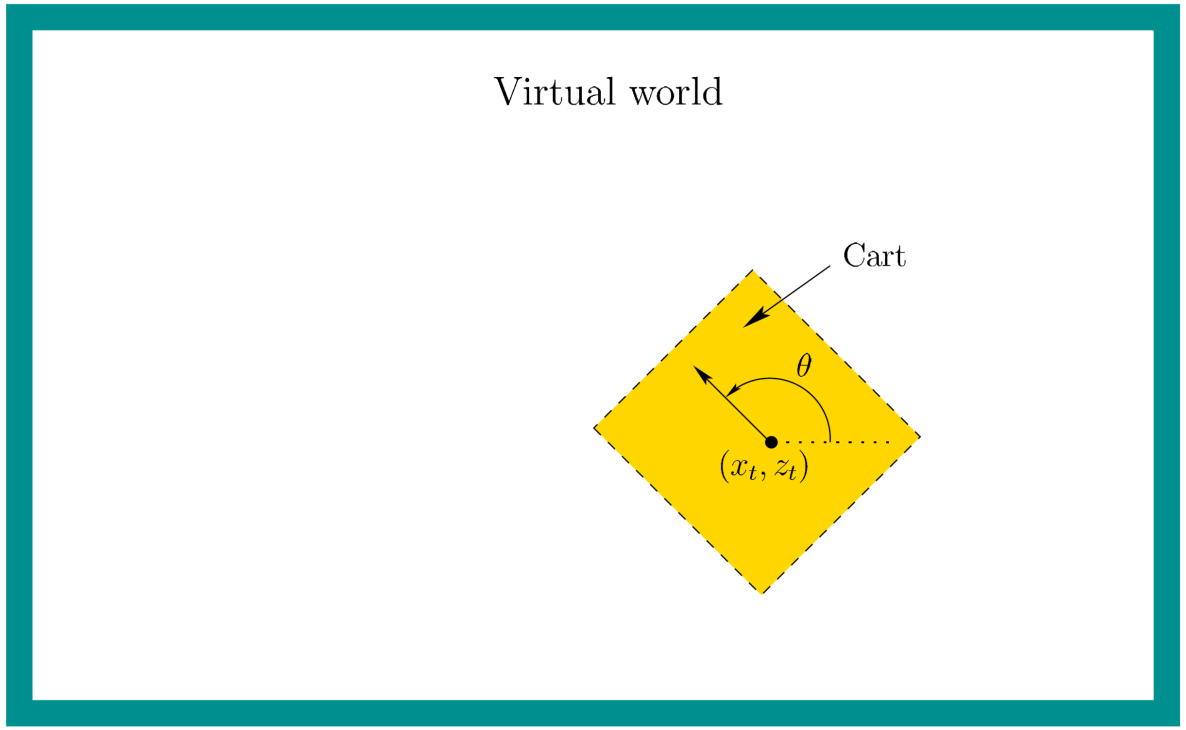
Walking Metaphors Summary

- 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

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

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

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.