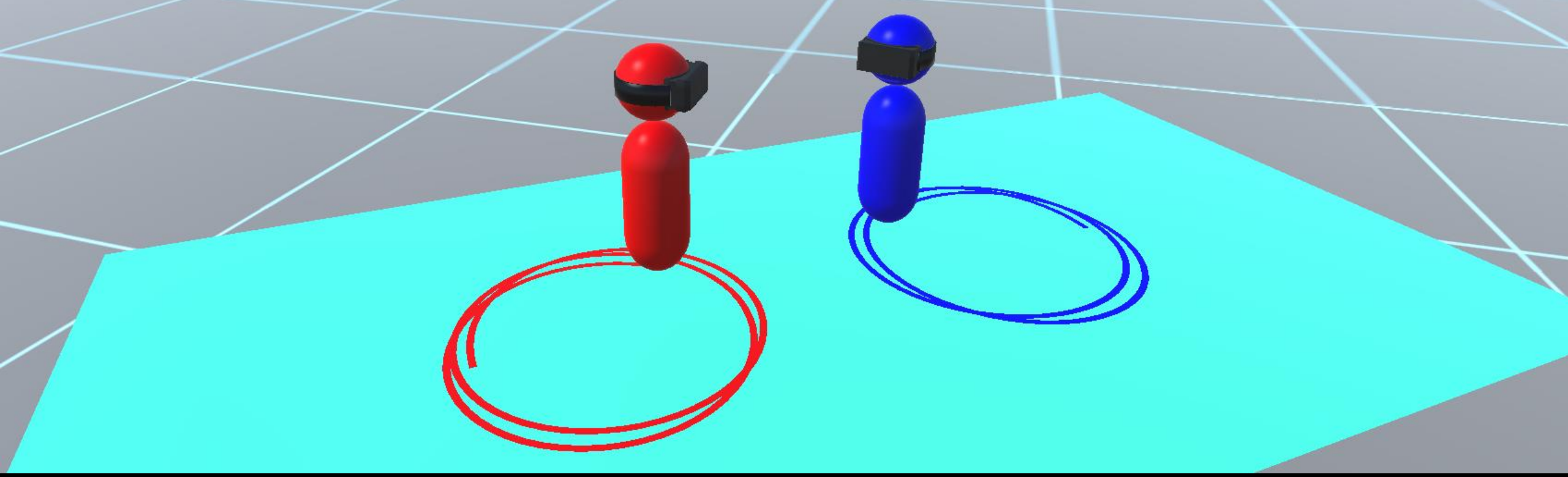

Redirected Walking

Optional Reading: *15 Years of Research on Redirected Walking in Immersive Virtual Environments*

UNIVERSITY OF MINNESOTA
Driven to Discover®

Evan Suma Rosenberg | CSCI 5619 | Fall 2020

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Virtual reality has a motion sickness problem

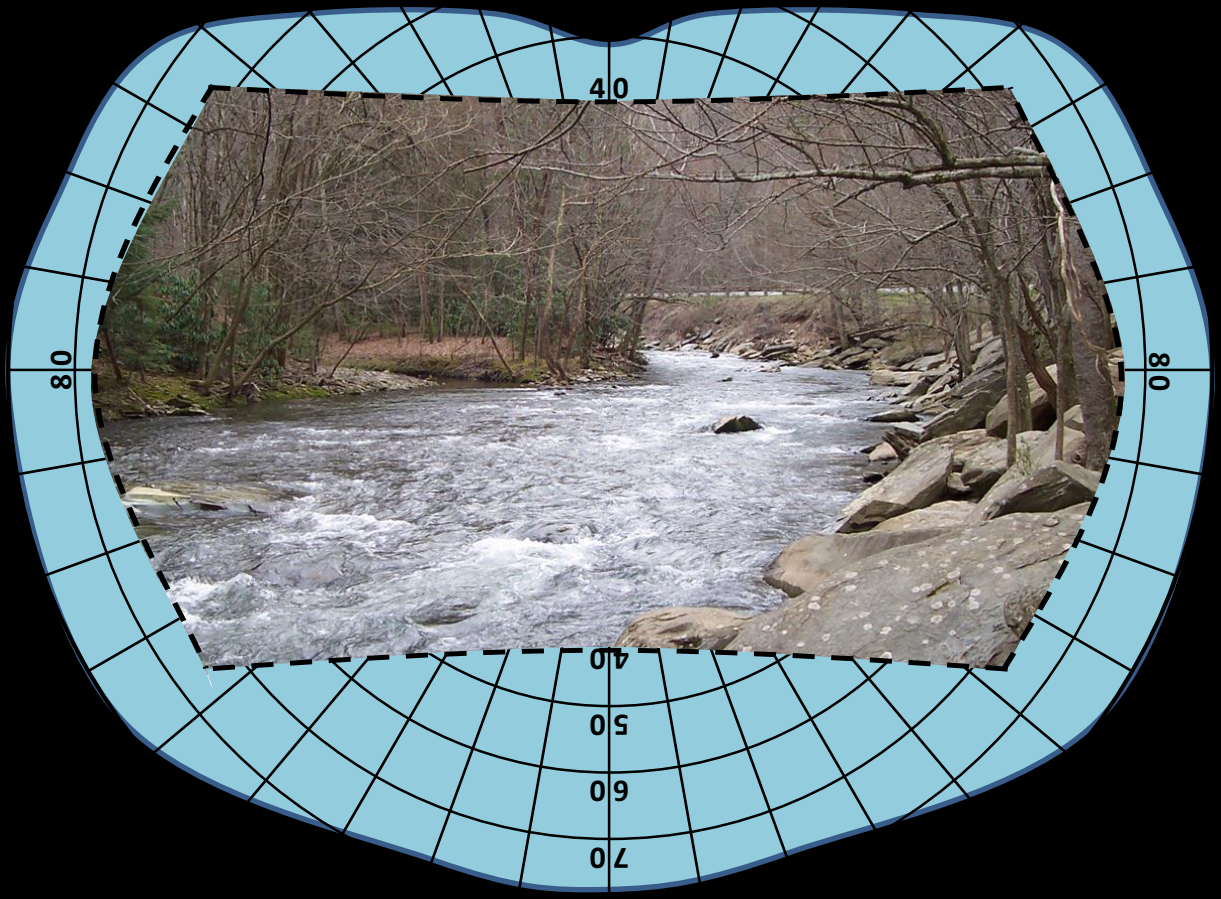
People prone to nausea may opt out of immersive experiences

Vomit Reality: Why VR makes some of us feel sick and how to make it stop

Nausea? Headaches? Eye strain? We find out about VR tech and motion sickness

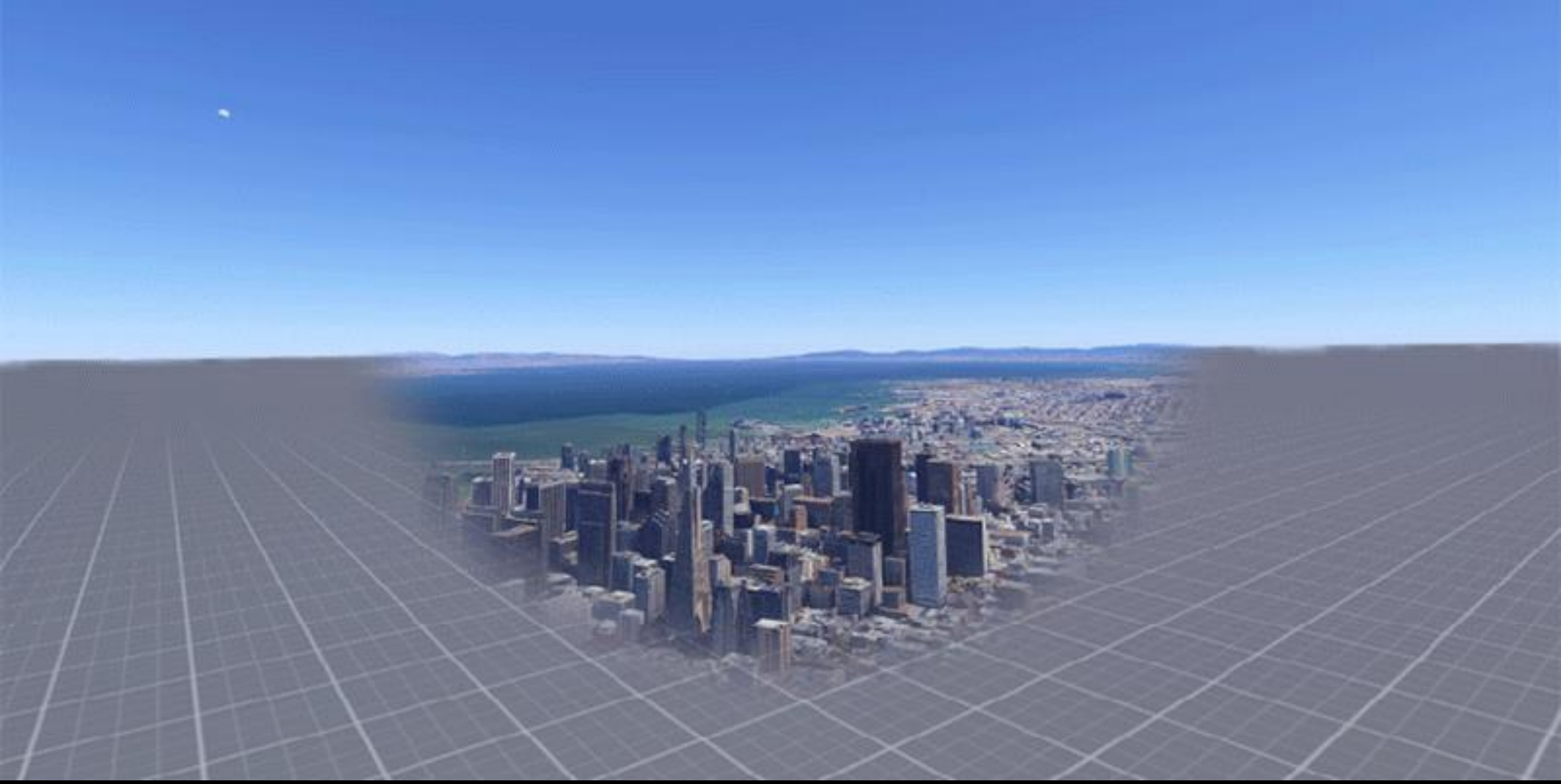
How to Play Virtual Reality Games Without Barfing

Credit: Digital Trends



U.S. Patent 9,645,395, Dynamic Field of View Throttling as a Means of Improving User Experience in Head Mounted Virtual Environments. M. Bolas, J. A. Jones, I. McDowall, E. Suma. Filed March 14, 2014. Issued May 9, 2017.

A. Fernandes and S. Feiner. Combating VR sickness through subtle dynamic field-of-view modification, IEEE 3DUI 2016.



Google Earth VR

STRESS LEVEL ZERO

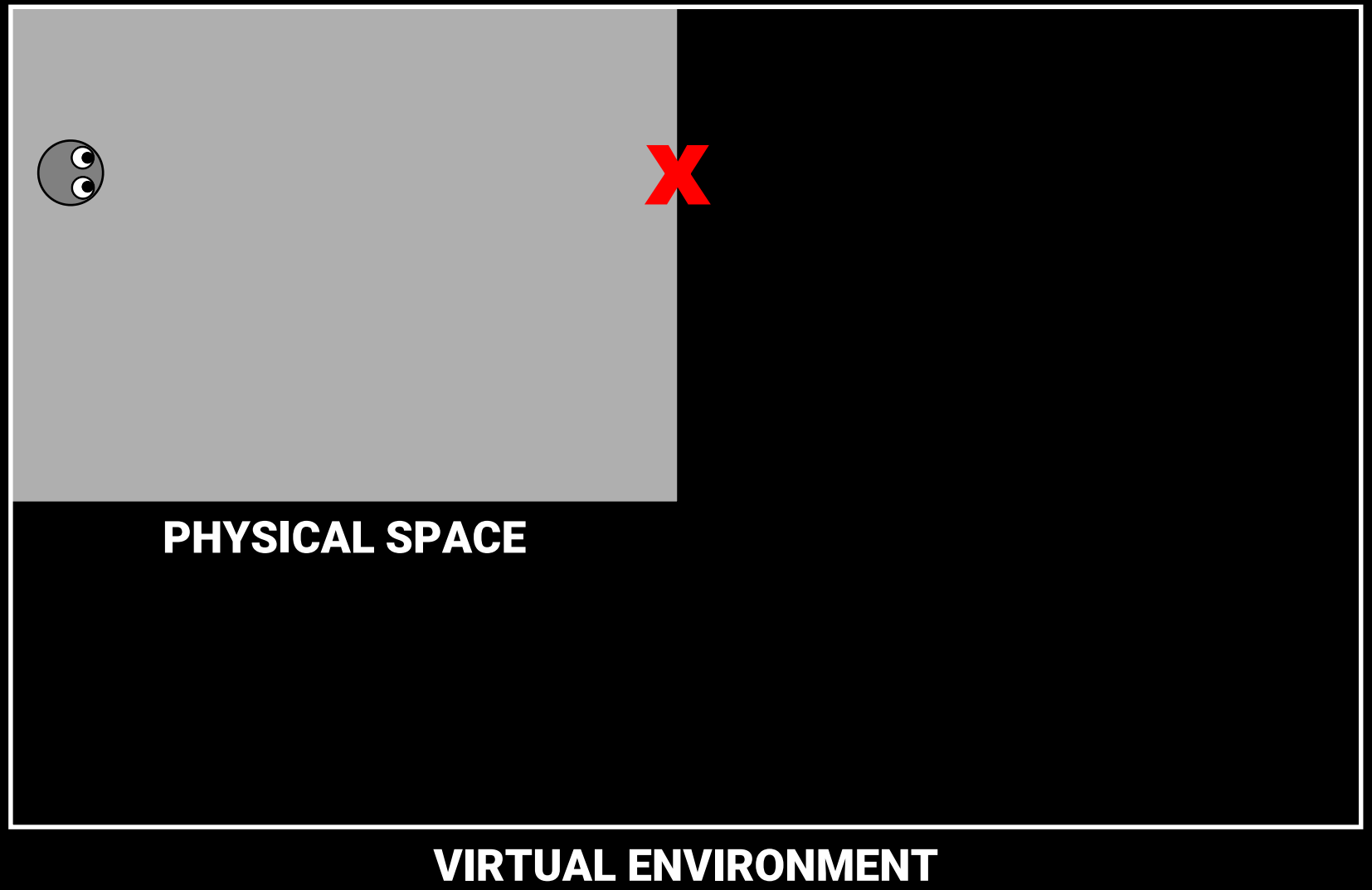
Every controller position is still being tracked

orange volume is our Primary hard bounds

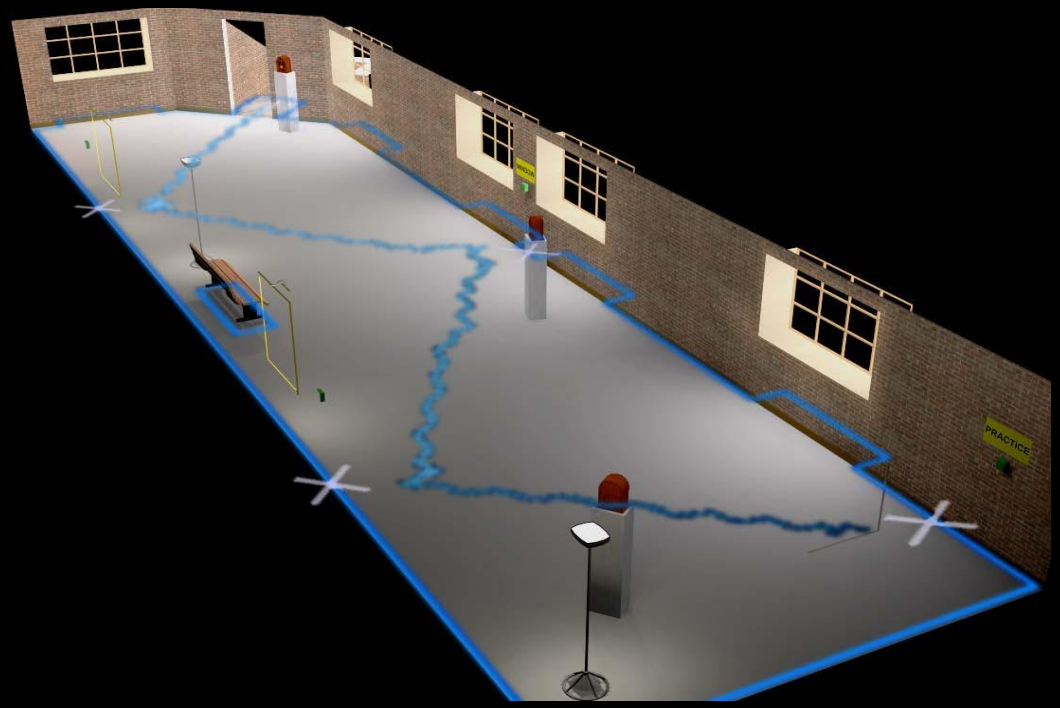
https://www.youtube.com/watch?v=0KcllPEe8y8

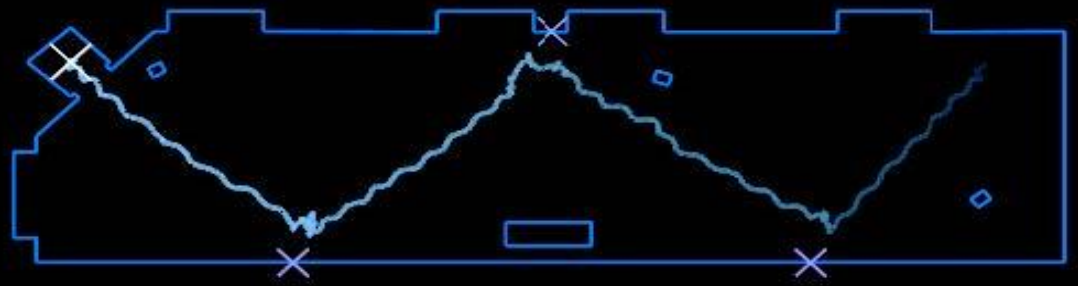
https://www.youtube.com/watch?v=0KcllPEe8y8

The Locomotion Problem



Redirected Walking



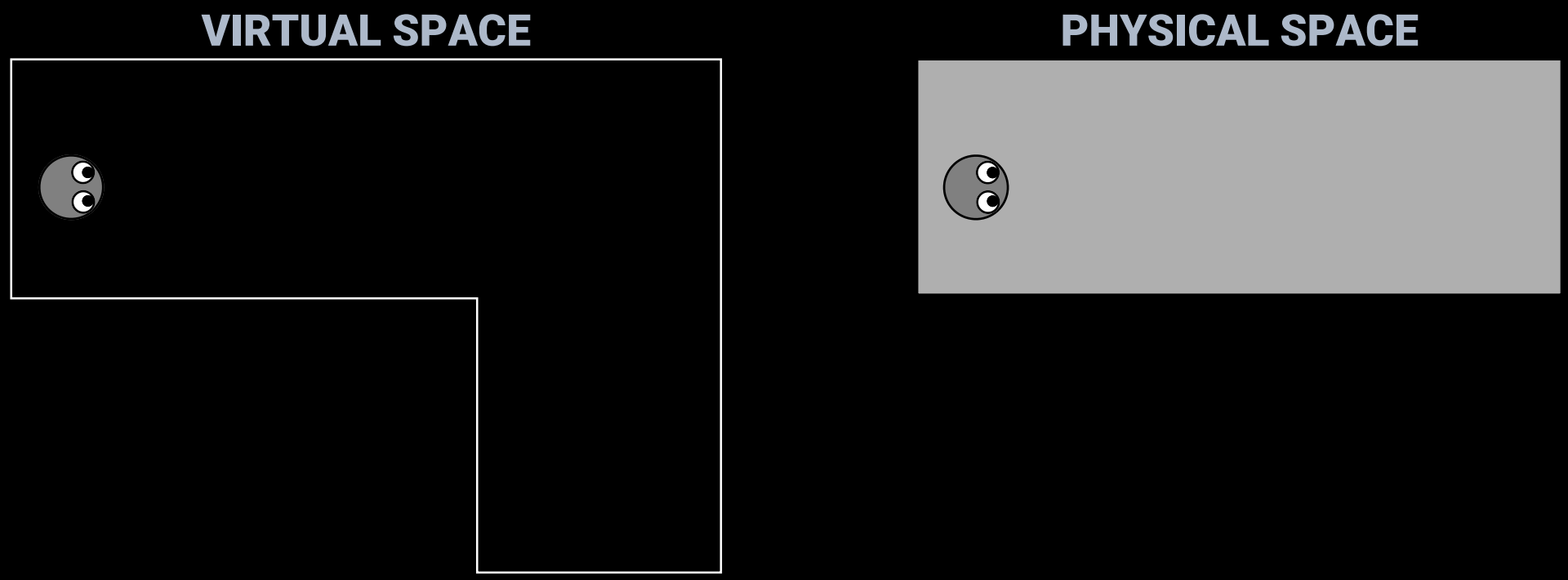


Virtual World Path

Real World Path

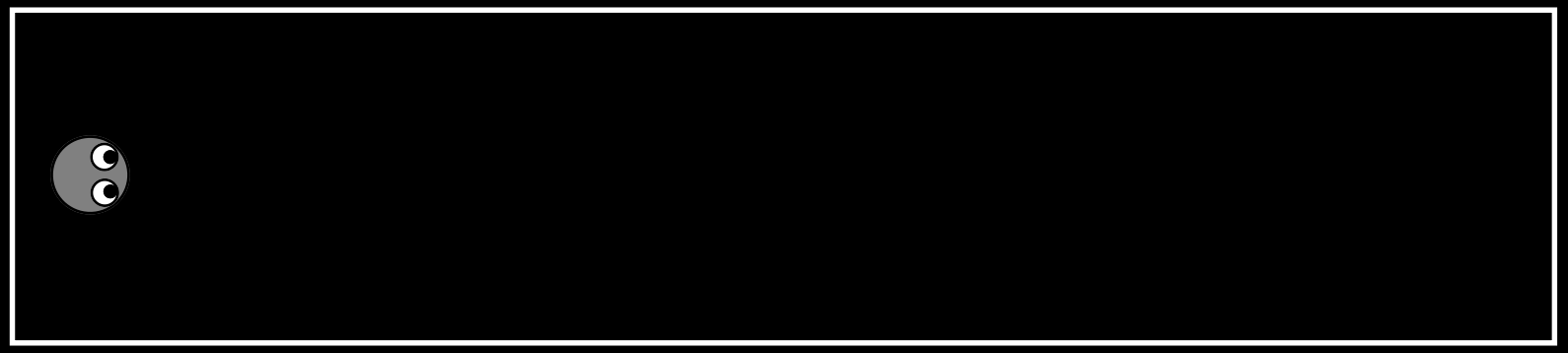
S. Razzaque, Z. Kohn, and M. Whitton. Redirected Walking, Eurographics 2001.

Rotation Gain



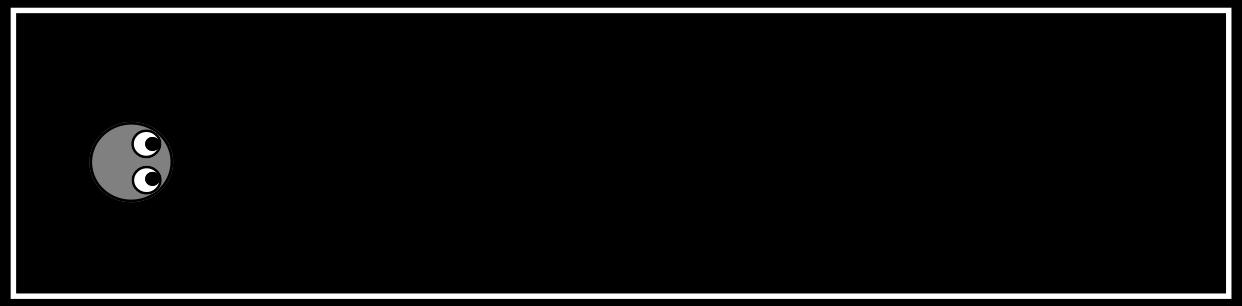
Translation Gain

PHYSICAL SPACE

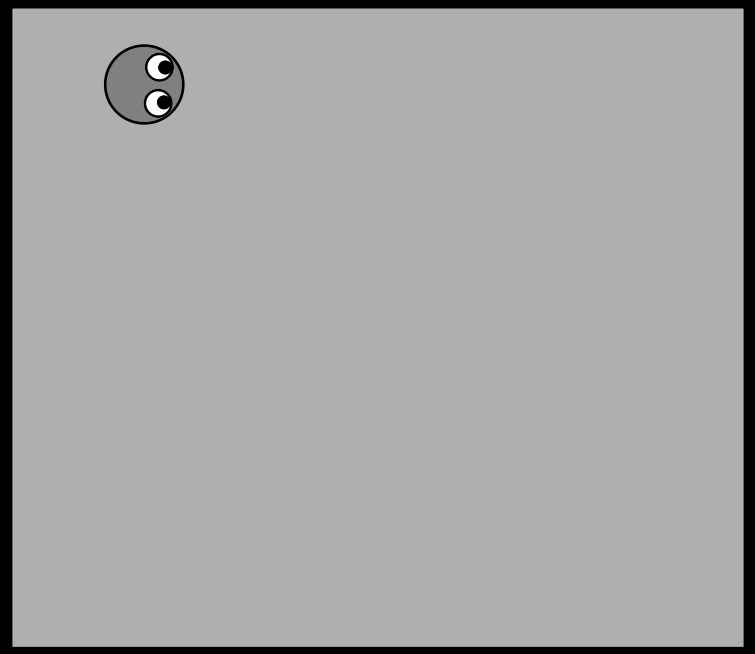


VIRTUAL SPACE

Curvature Gain

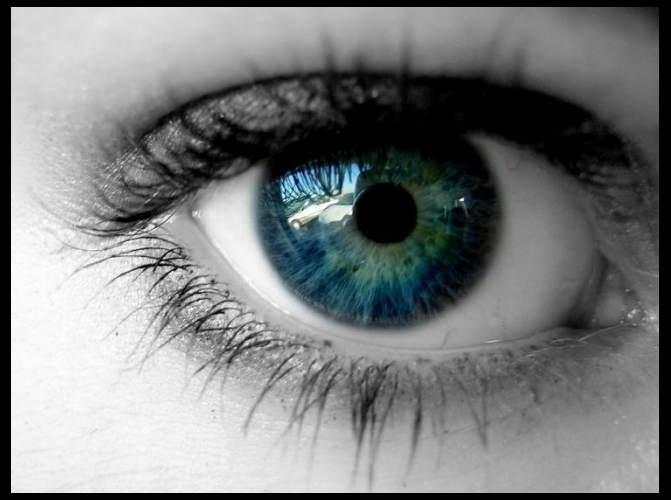


VIRTUAL SPACE



PHYSICAL SPACE

Why does redirection work?



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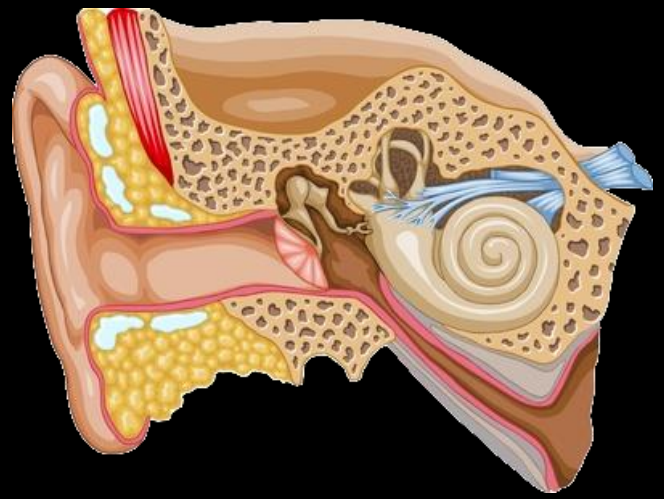
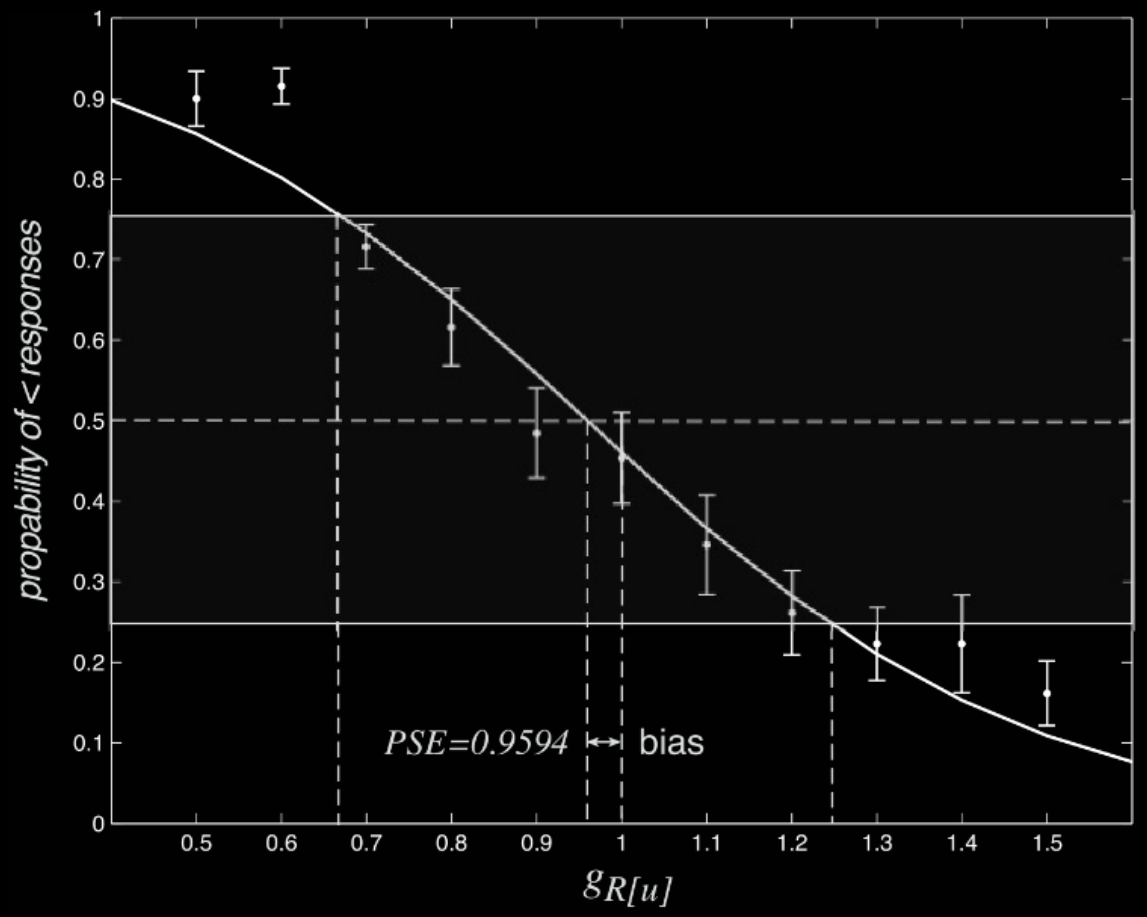


Vision tends to dominate over **vestibular** sensation.

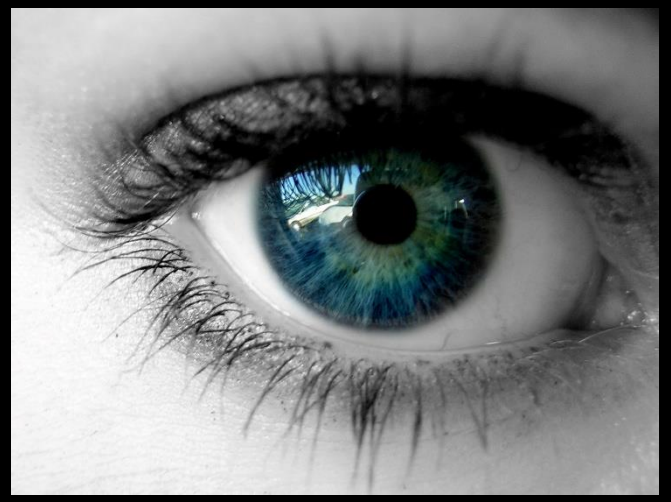
Measuring Detection Thresholds

- Two alternative forced choice task (2AFC)
- User repeatedly presented with a stimulus of varying level and asked to detect it
- Compute pooled probability of response (forced choice, no neutral option)
- Fit a psychometric function (sigmoid)
- Point of subjective equality (PSE) at 50%
- Detection thresholds at 25% and 50%



F. Steinicke, G. Bruder, J. Jerald, H. Frenz, and M. Lappe. Estimation of Detection Thresholds for Redirected Walking Techniques, IEEE TVCG 2010.

Detection Thresholds for Redirected Walking



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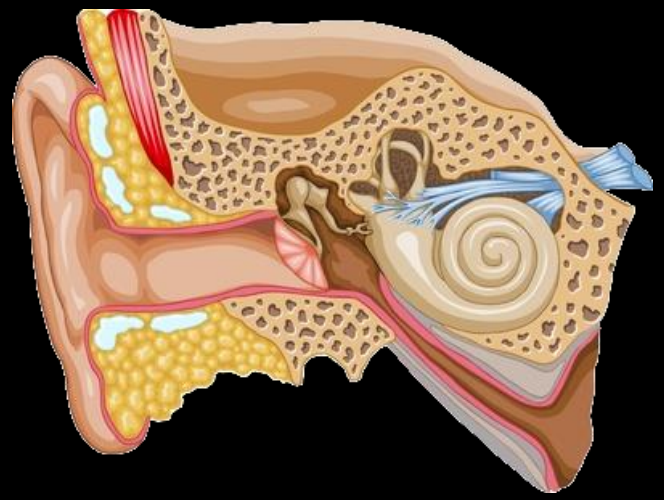
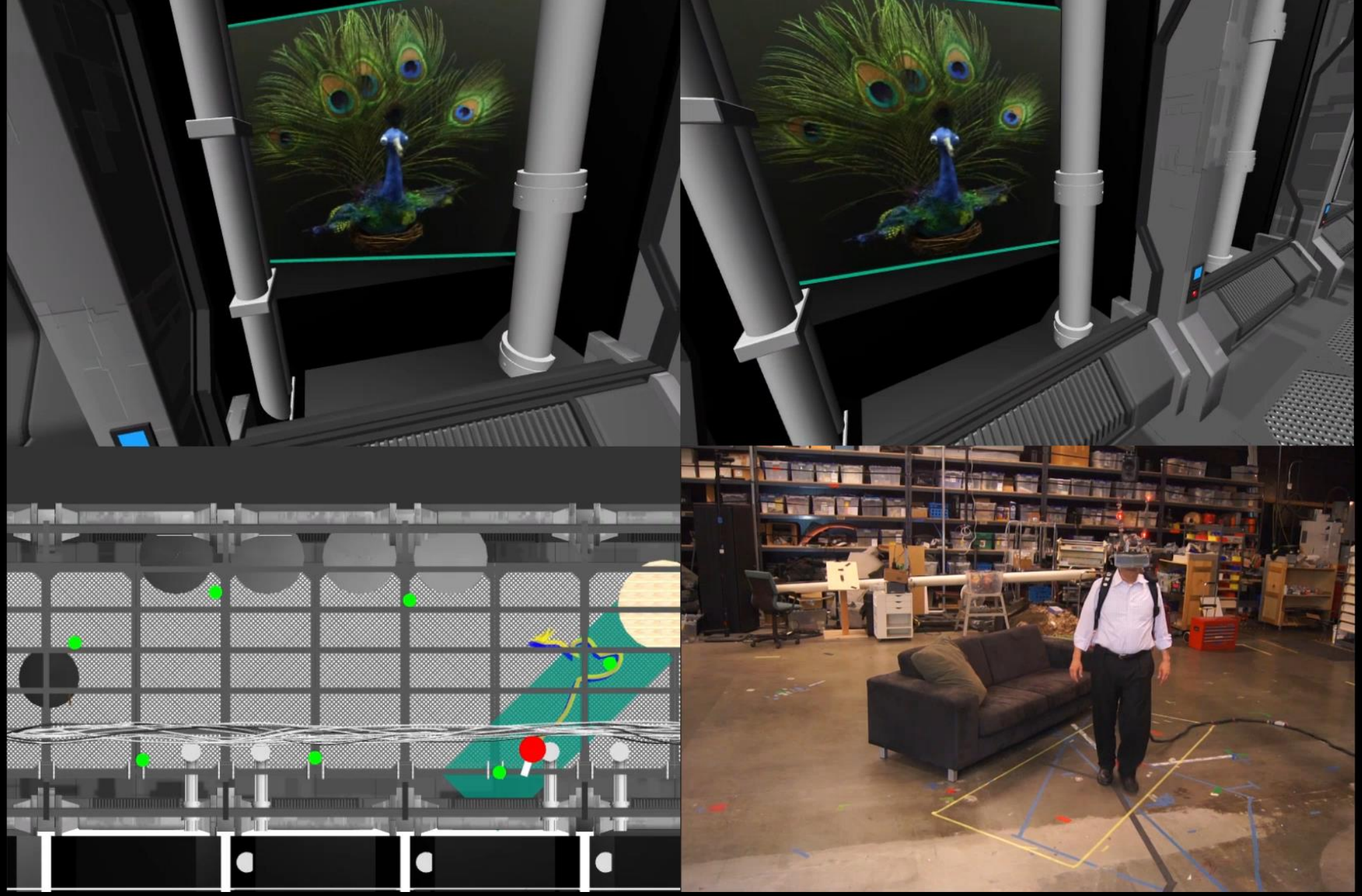


Rotation Gains
49% amplification
20% dampening

Curvature Gains
arc radius >= 20 meters

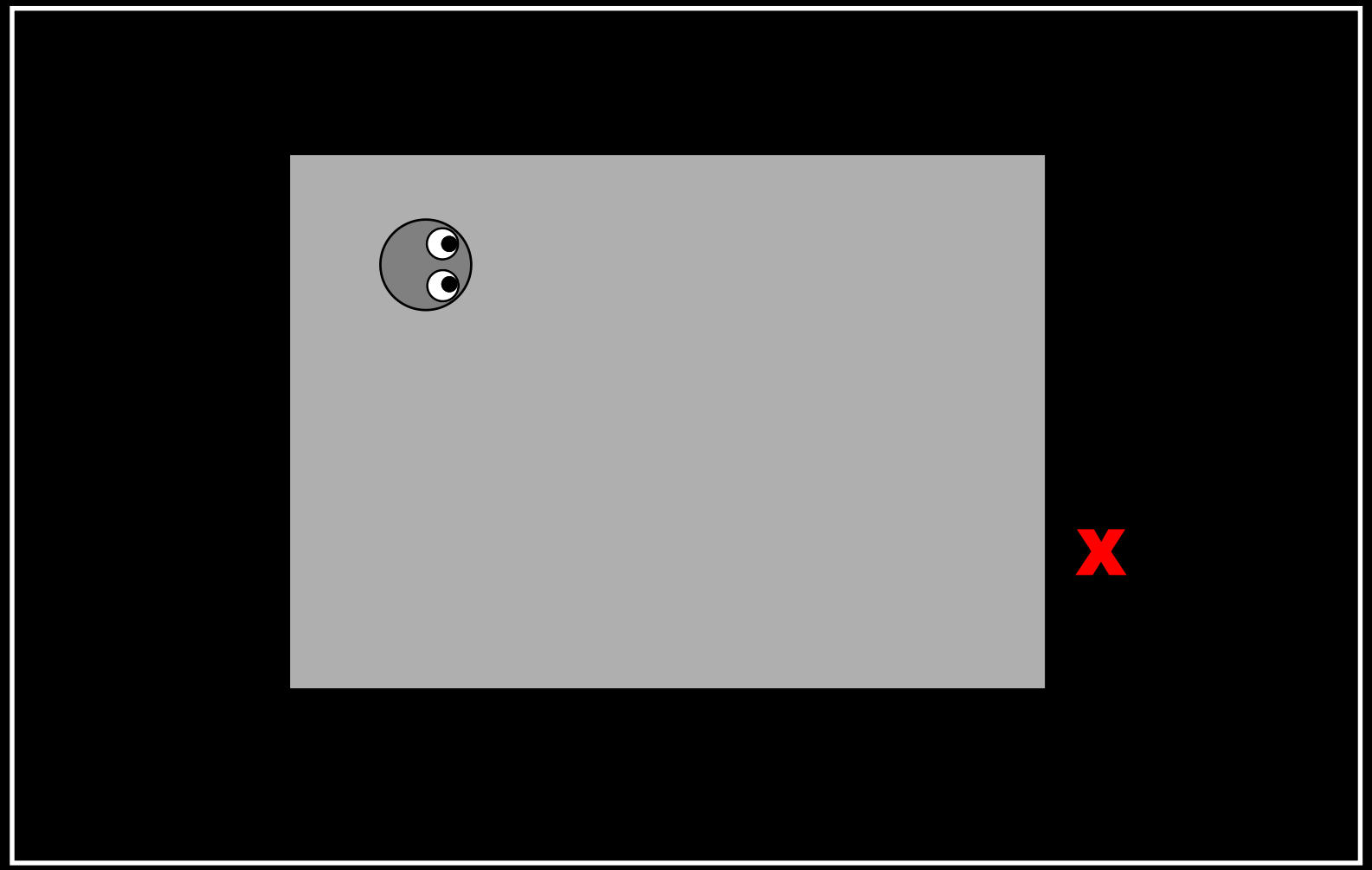
Translation Gains
26% upscale
14% downscale

F. Steinicke, G. Bruder, J. Jerald, H. Frenz, and M. Lappe. Estimation of Detection Thresholds for Redirected Walking Techniques, IEEE TVCG 2010.

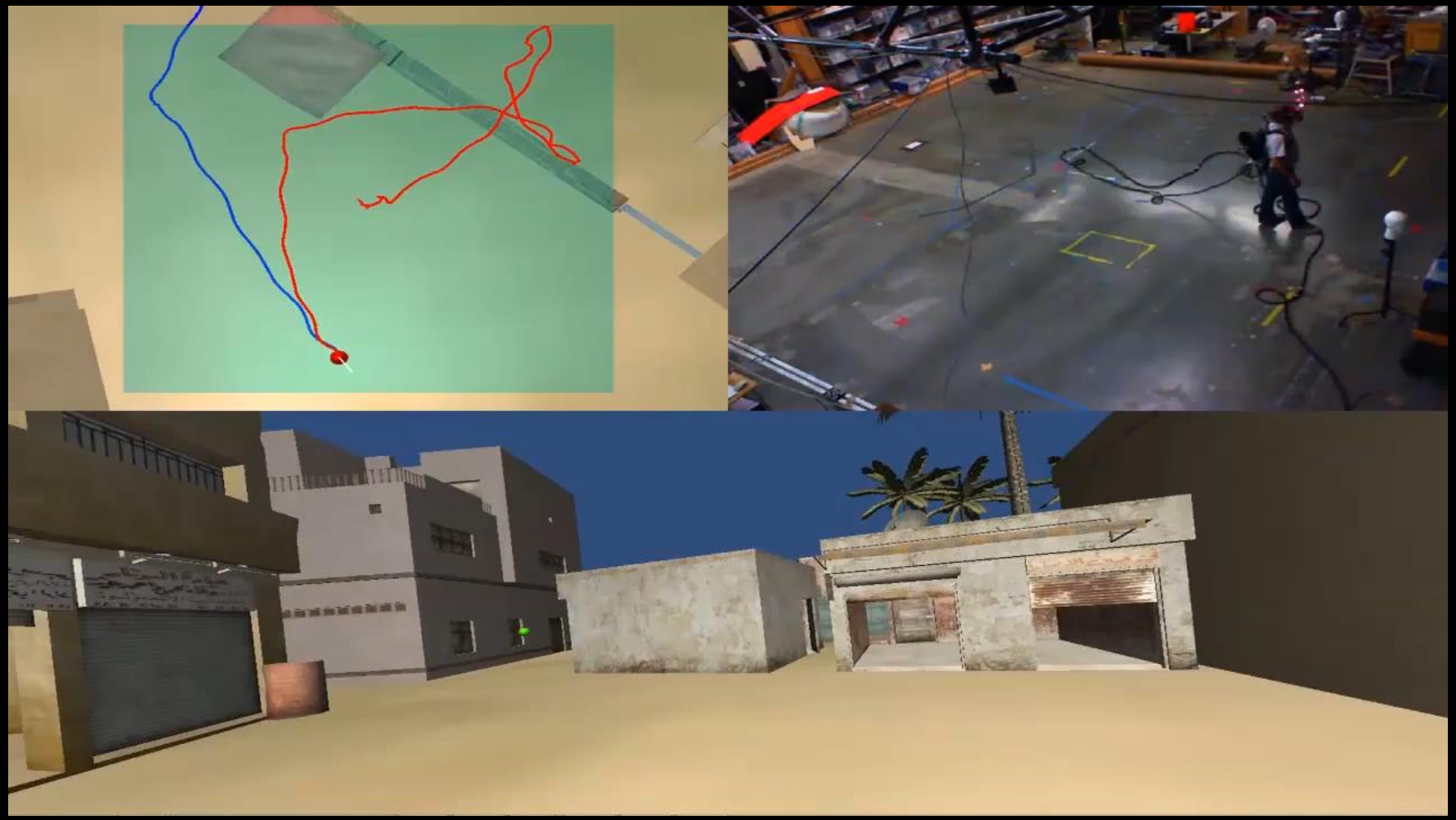


Discovering Near-Field VR: Stop Motion with a Touch of Light-Fields and a Dash of Redirection, 2015 SIGGRAPH AR/VR Contest Winner

Reorientation Events (Resets)



Reorientation Events (Resets)

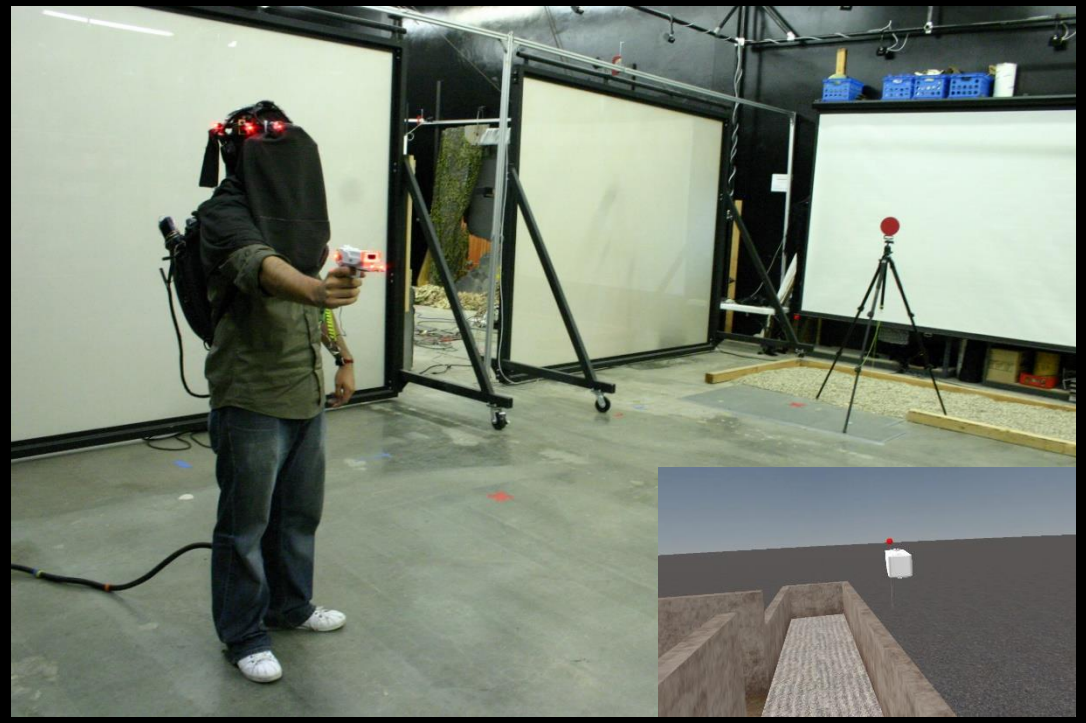


T. Grechkin, M. Azmandian, M. Bolas, and E. Suma. Towards Context-Sensitive Reorientation for Real Walking in Virtual Reality, IEEE VR 2015.

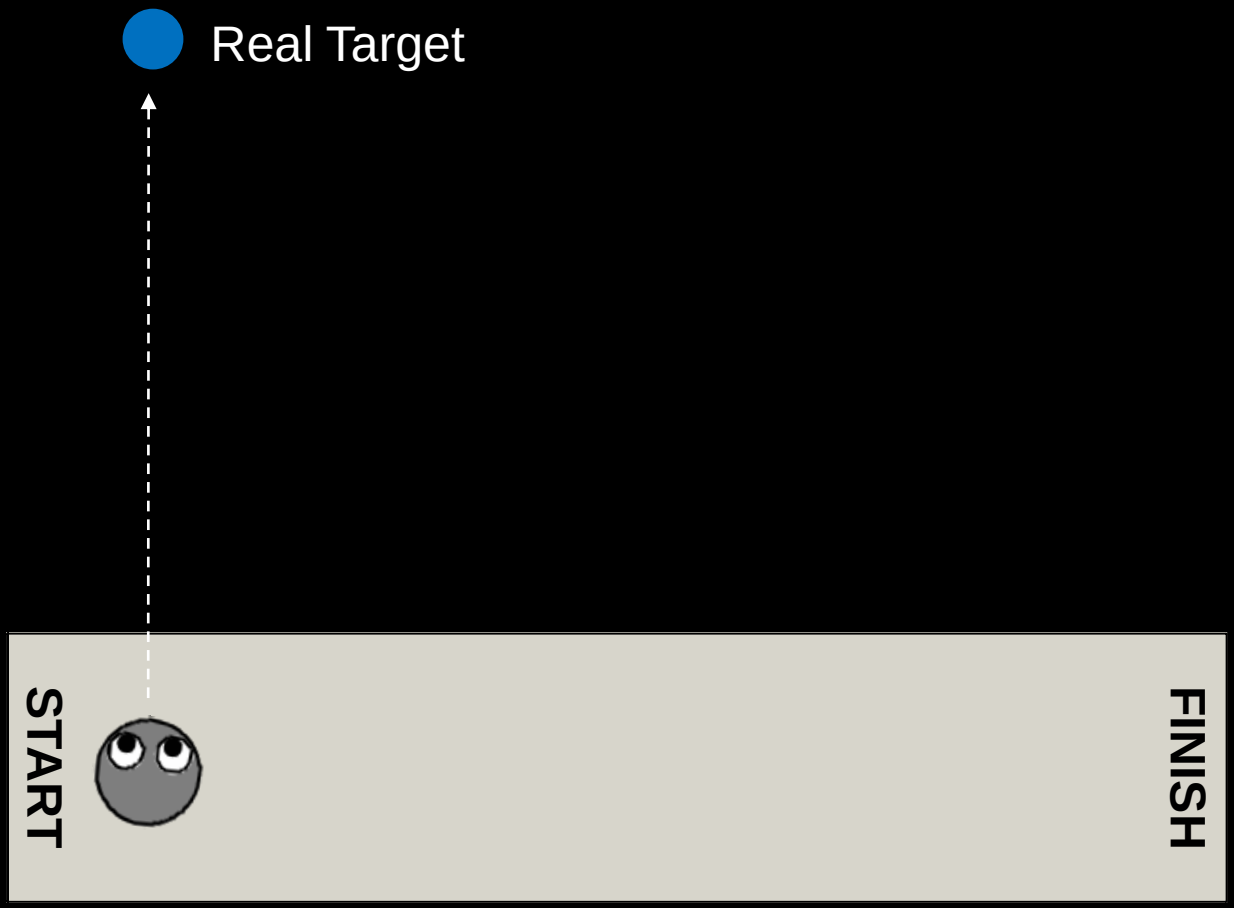
Research Questions

- How much redirection can we apply before it becomes **perceptible?**
  - *Answer: quite a bit!*
- How much redirection can we apply before it becomes **noticeable?**
  - *Answer: even more!*
- How does redirection impact the **user experience?**
  - spatial cognition
  - user behavior
  - task performance
- Solving **engineering challenges** for redirected walking systems

Spatial Orientation Experiment



E. Suma, D. Krum, S. Finkelstein, and M. Bolas. Effects of Redirection on Spatial Orientation in Real and Virtual Environments, IEEE 3DUI 2011.

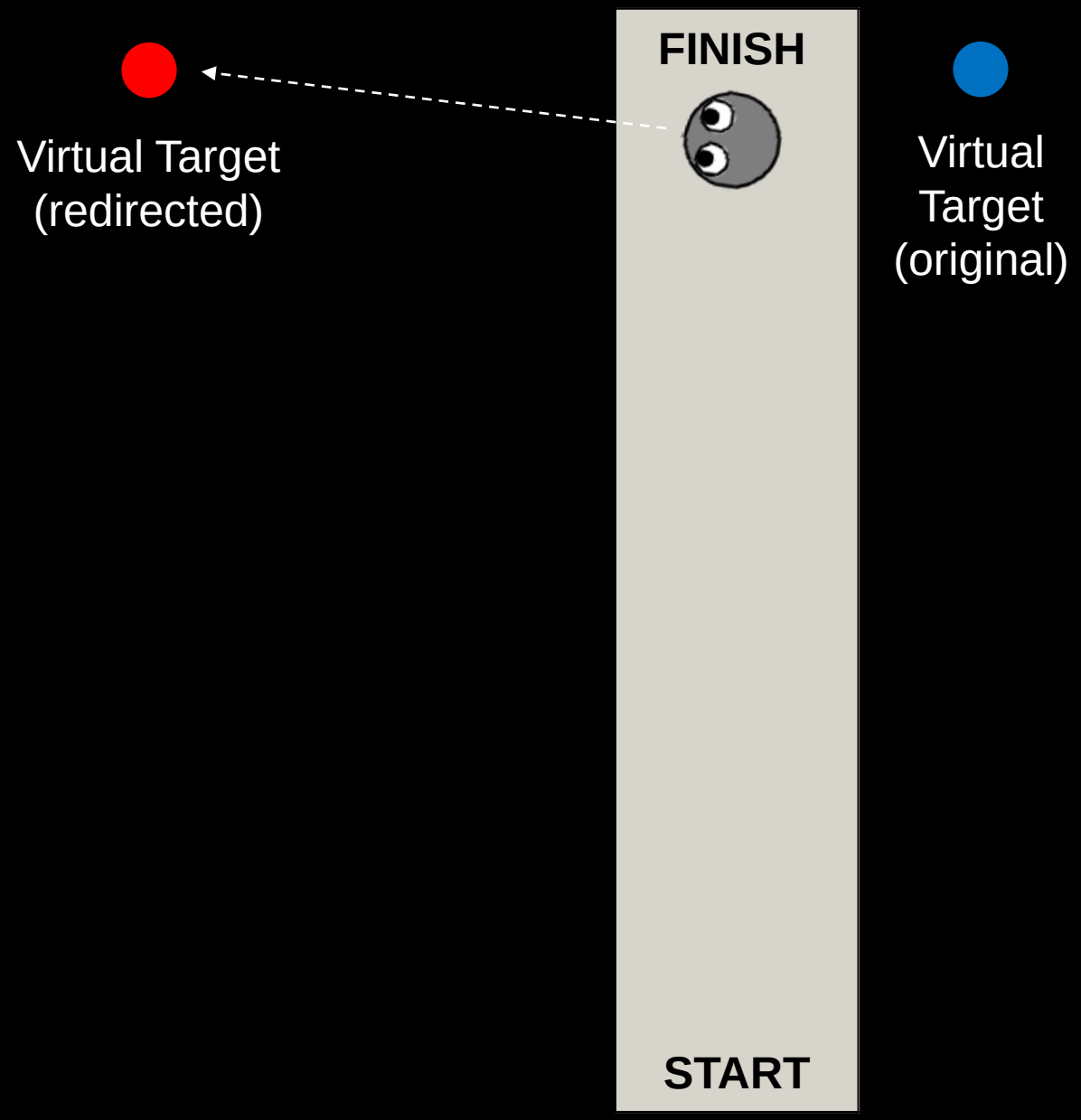

FINISH
START
Real Target

Virtual Target
START
FINISH

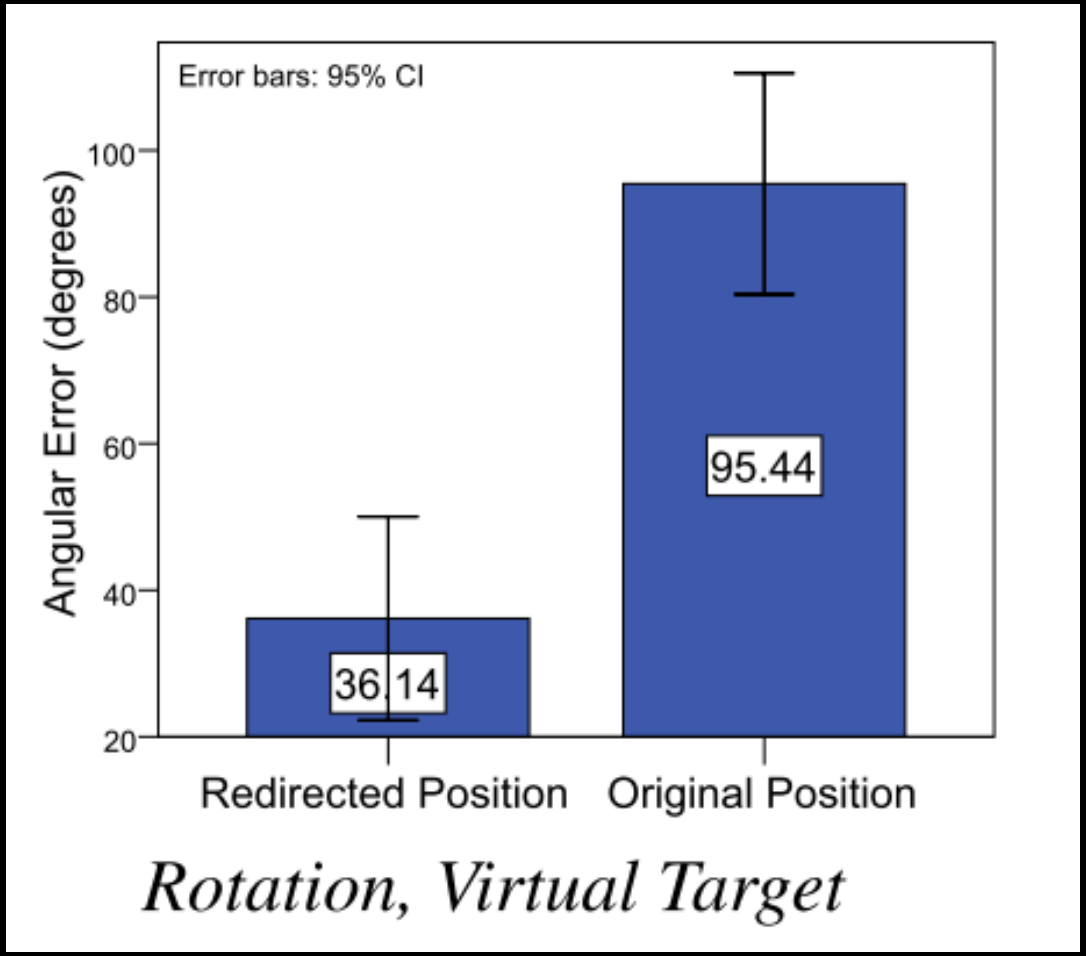
FINISH

START

Virtual
Target
(original)
FINISH
START


FINISH
Virtual Target
(redirected)
Virtual
Target
(original)
START

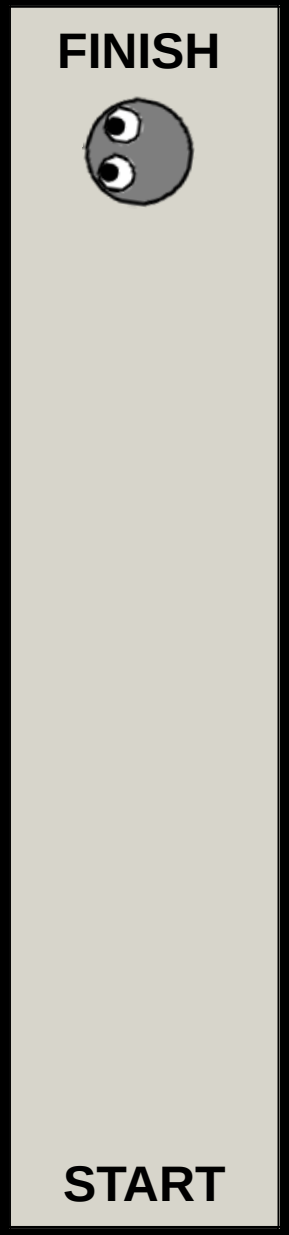
Angular Pointing Error

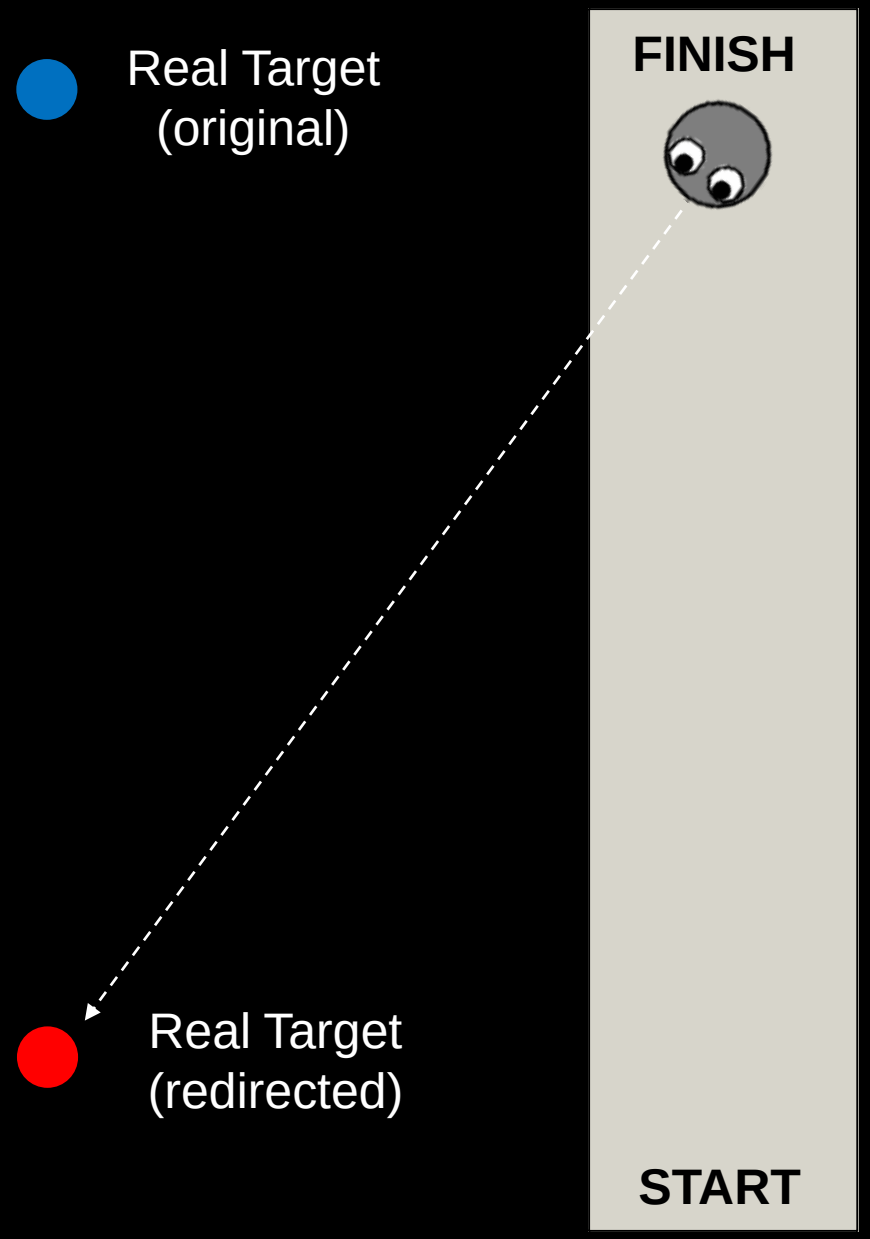


FINISH

START

Real Target
(original)

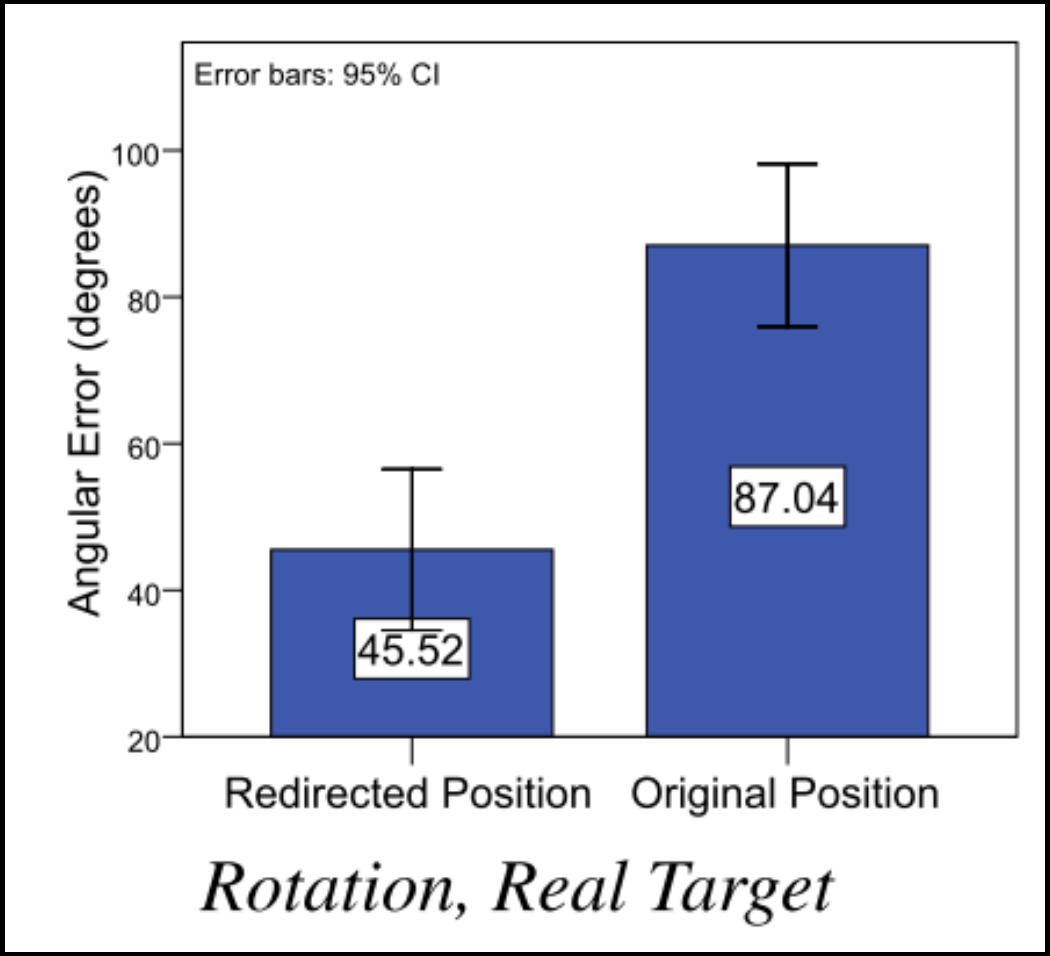



Real Target
(original)
FINISH
Real Target
(redirected)
START

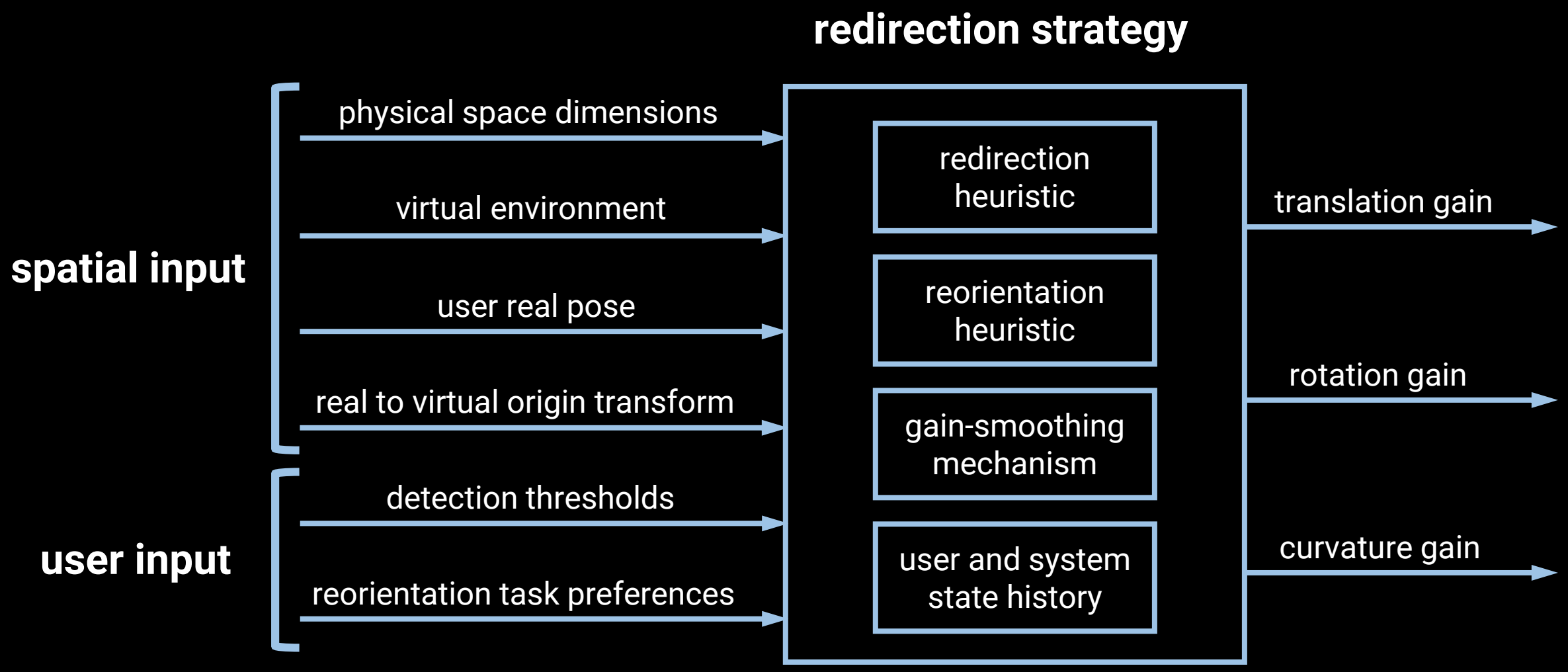
How does redirection influence the user’s **real world** orientation?

Can we maintain both spatial **reference frames** at the same time?

Angular Pointing Error

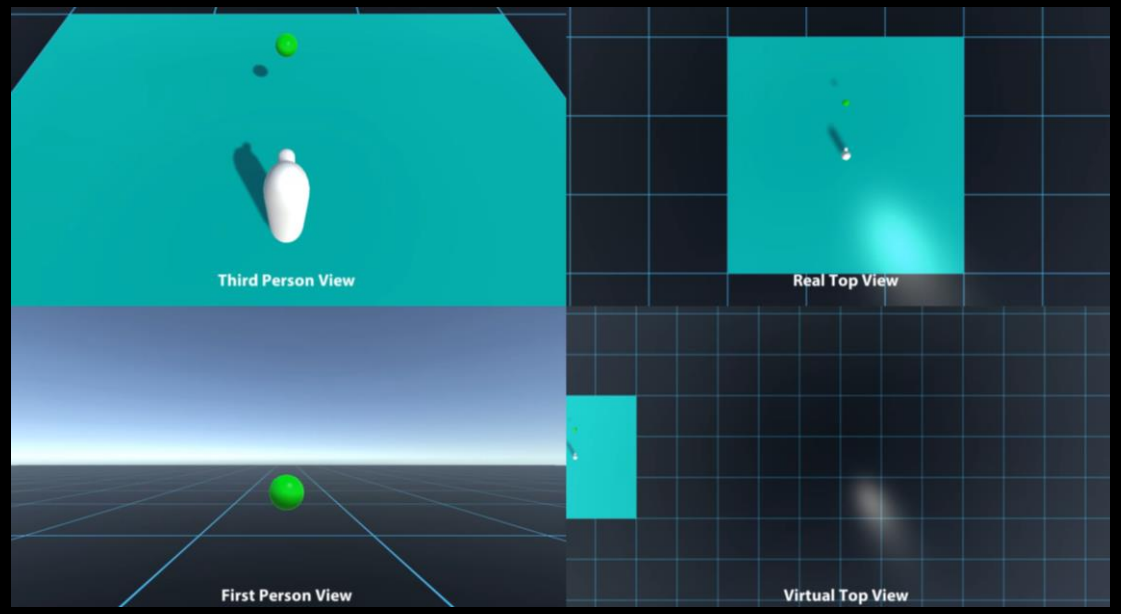


Redirected Walking Systems



Redirected Walking Toolkit

- Plug-and-play toolkit for Unity
- Open-source (BSD license)
- Free for commercial or noncommercial use



https://github.com/USC-ICT-MxR/RDWT

How much can we predict the user?

Freedom

Linear Route	Branching Pathways	Open World
Static Planning	**Dynamic Planning**	**Reactive Algorithms**

How much can we predict the user?

Freedom

Linear Route	Branching Pathways	Open World
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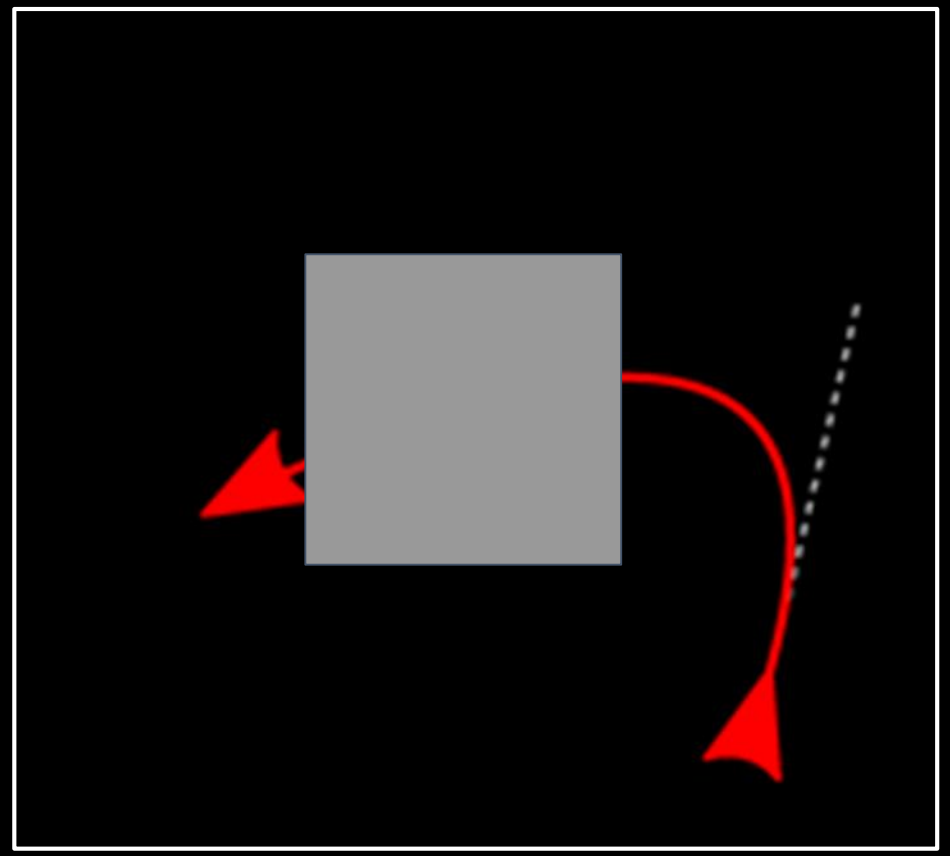
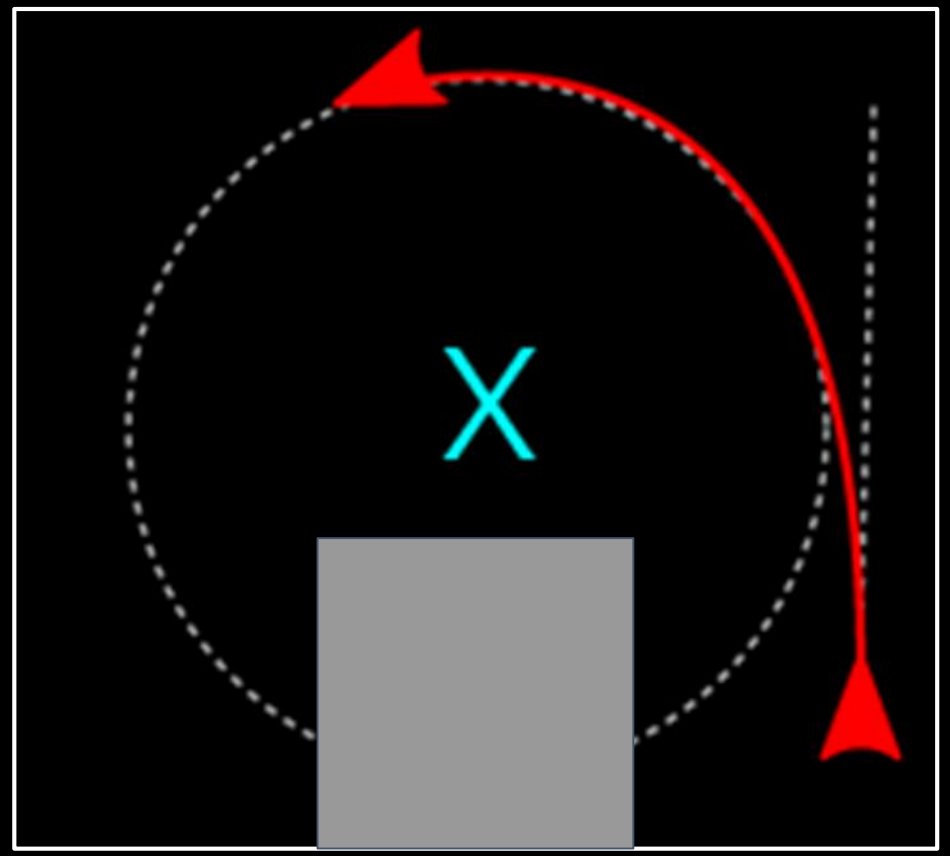
Reactive Algorithms

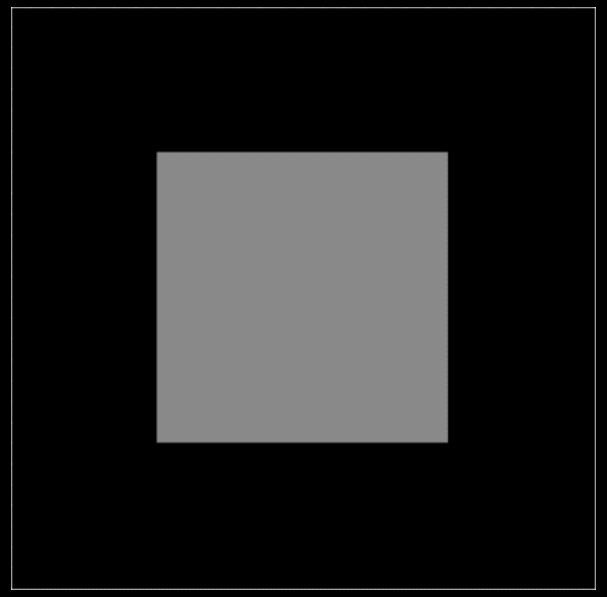


Steer to Center (S2C)

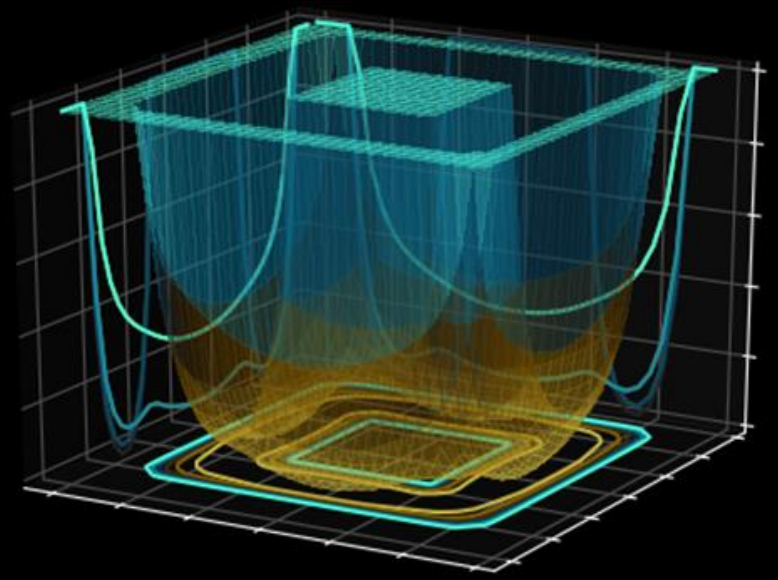


Steer to Orbit (S2O)

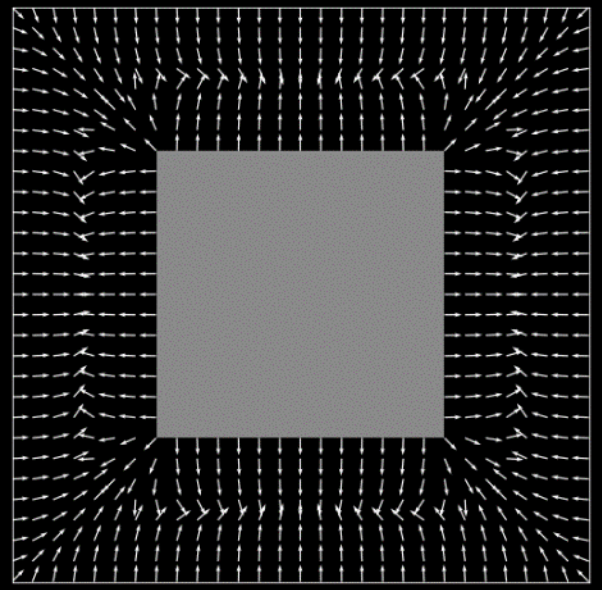
Push / Pull Reactive (P2R) Algorithm



Physical Environment



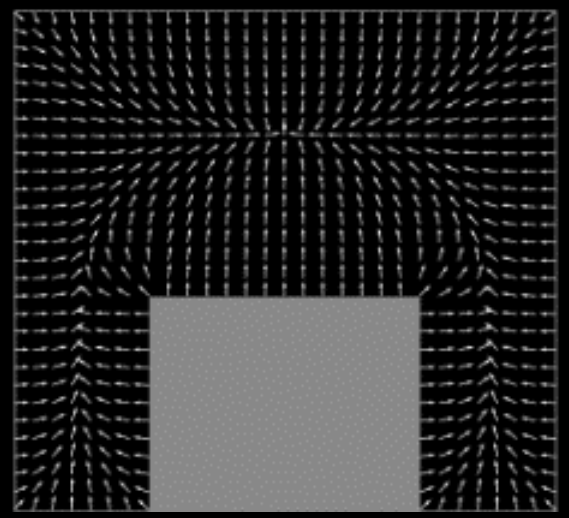
Artificial Potential Function

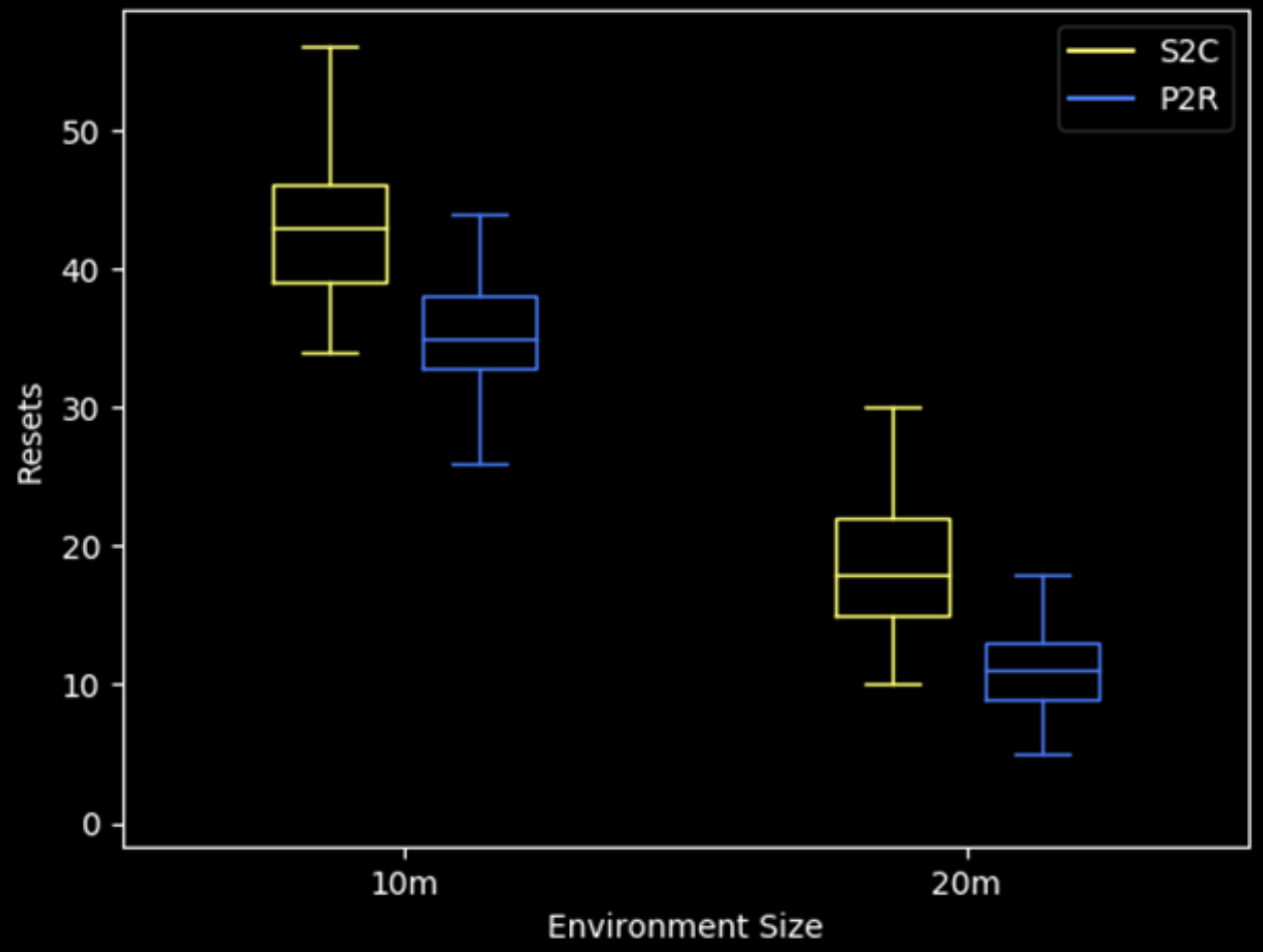


Gradient Field

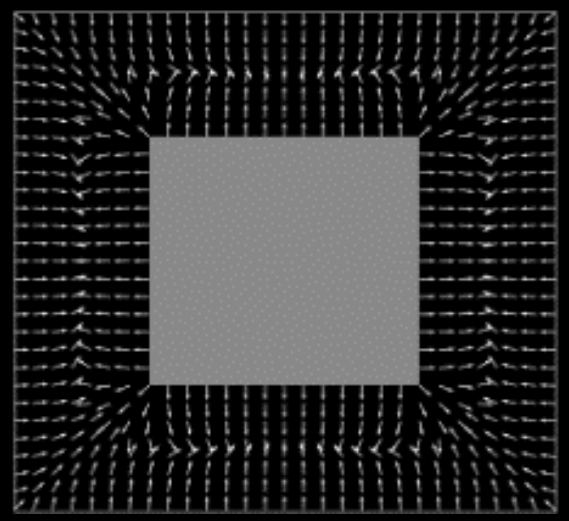
J. Thomas and E. Suma Rosenberg. A General Reactive Algorithm for Redirected Walking using Artificial Potential Functions, IEEE VR 2019.

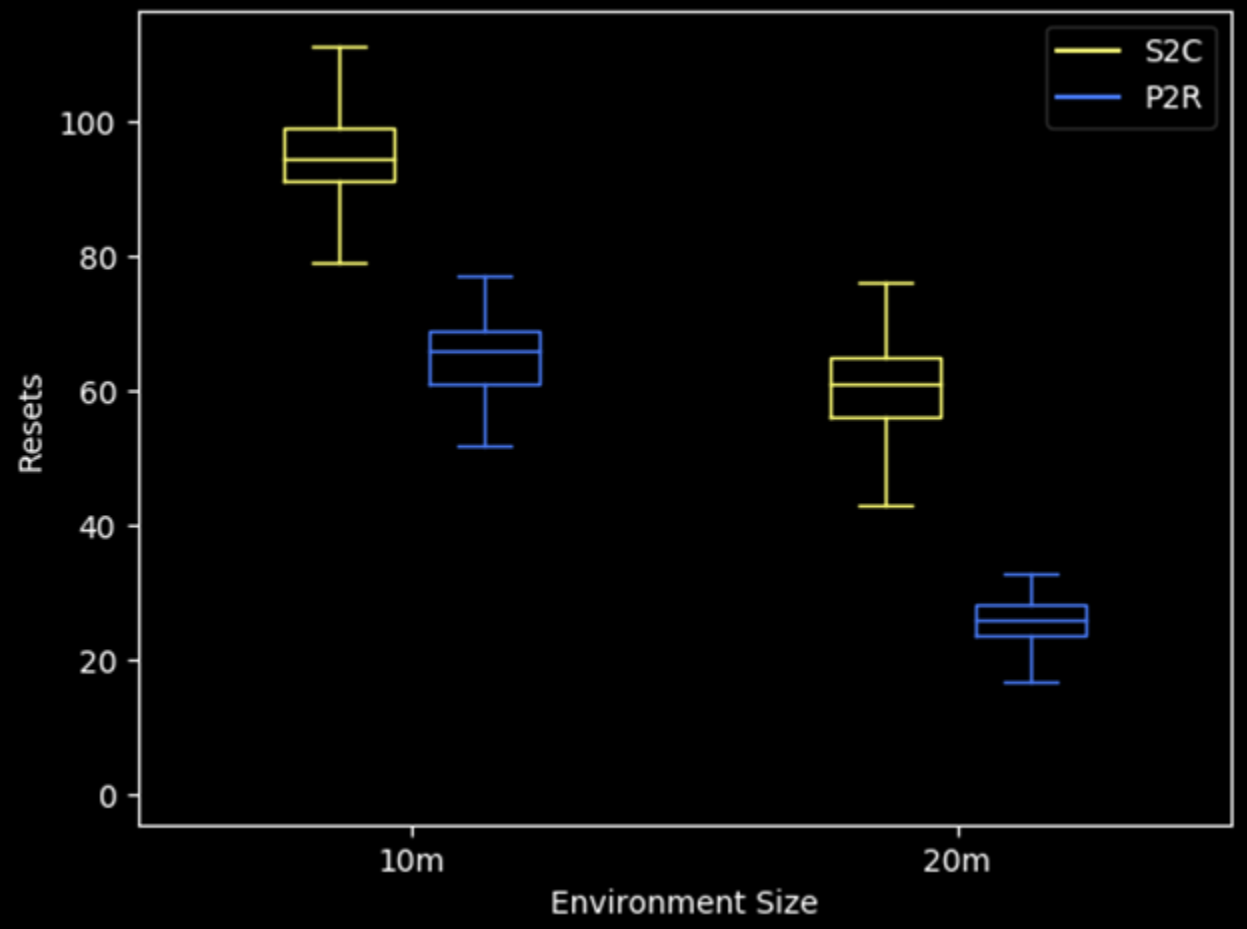
P2R Results: Non-Convex Boundaries





P2R Results: Interior Obstacles



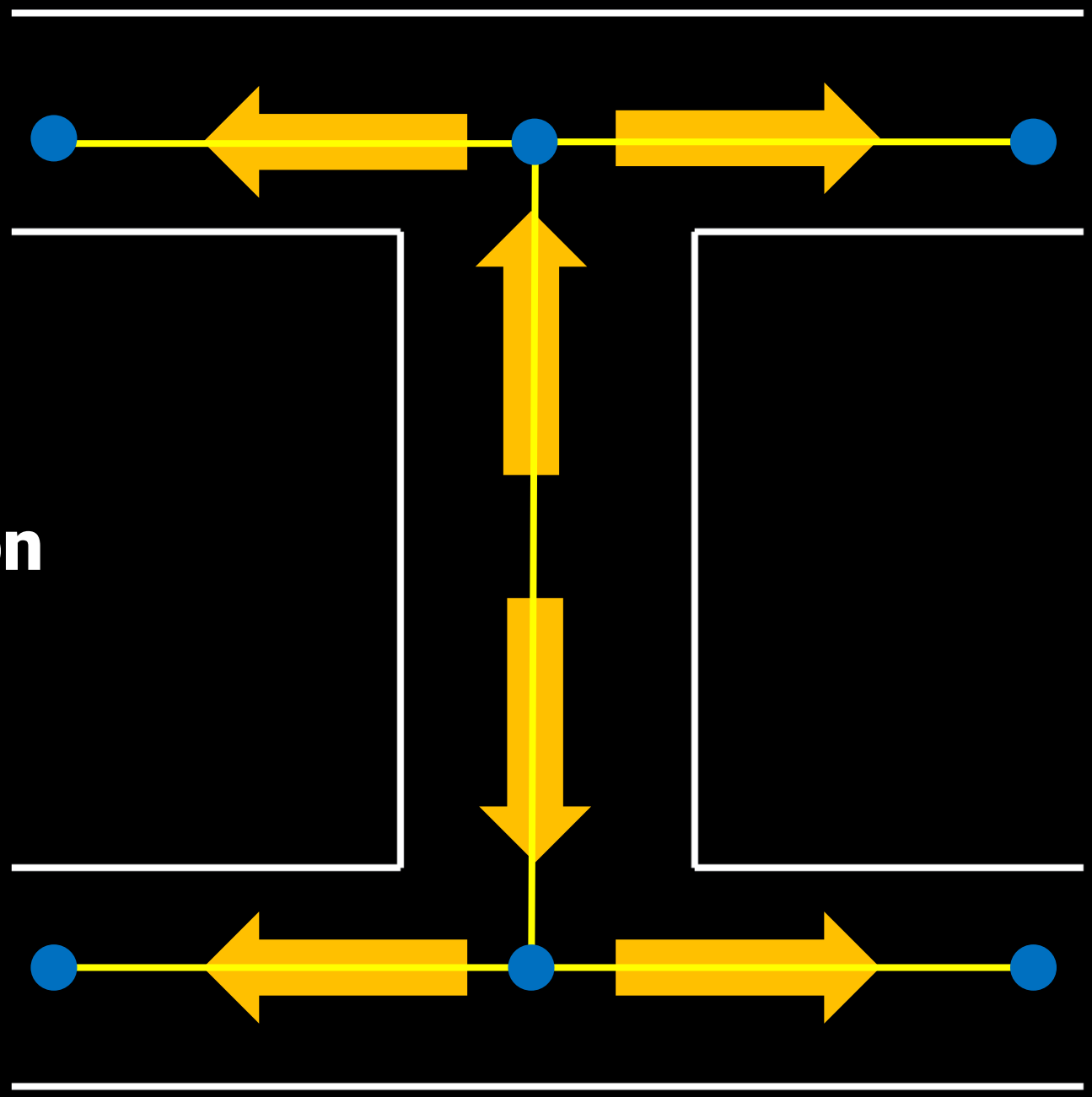


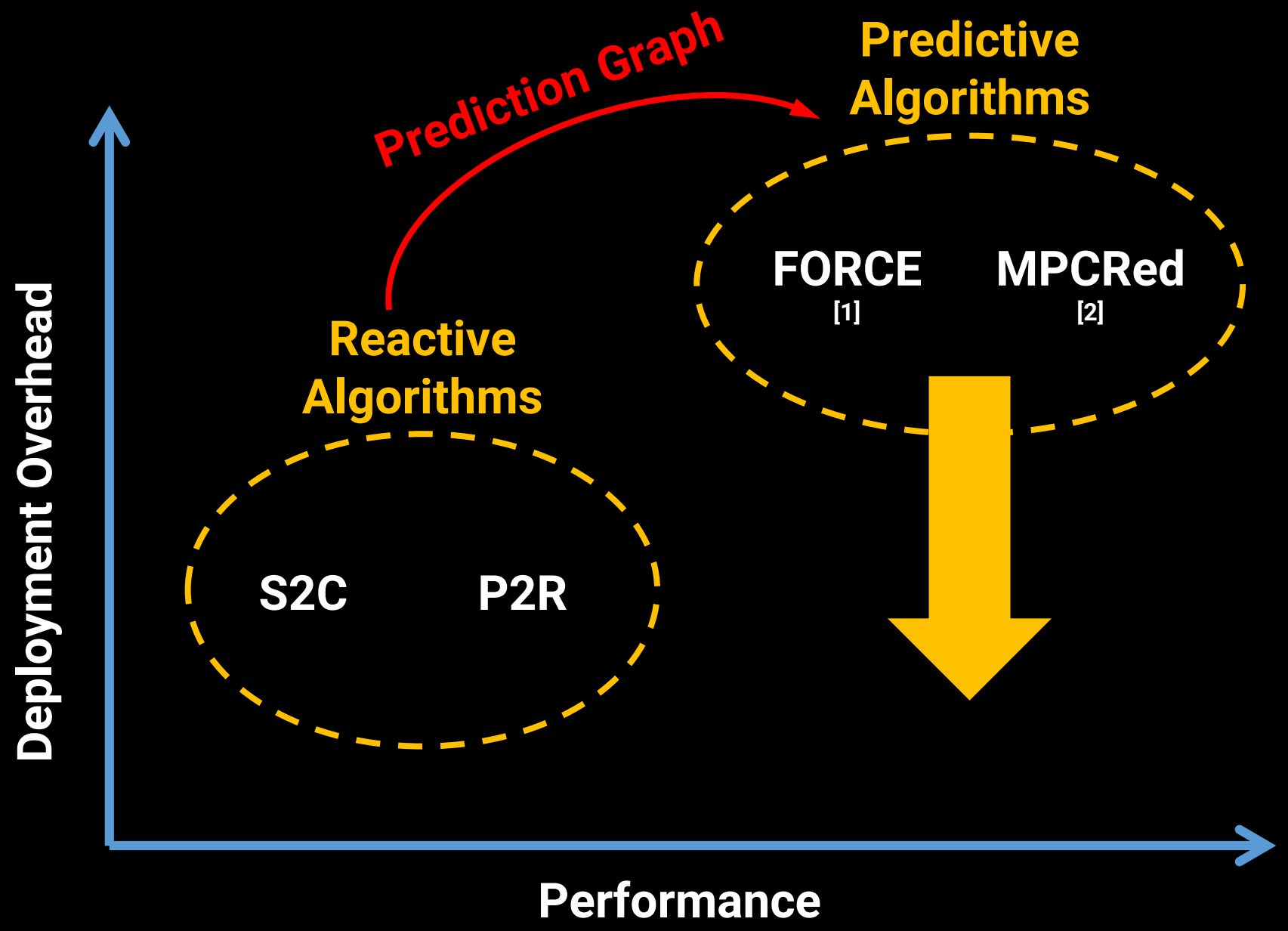
How much can we predict the user?

Freedom

Linear Route	Branching Pathways	Open World
Static Planning	**Dynamic Planning**	**Reactive Algorithms**

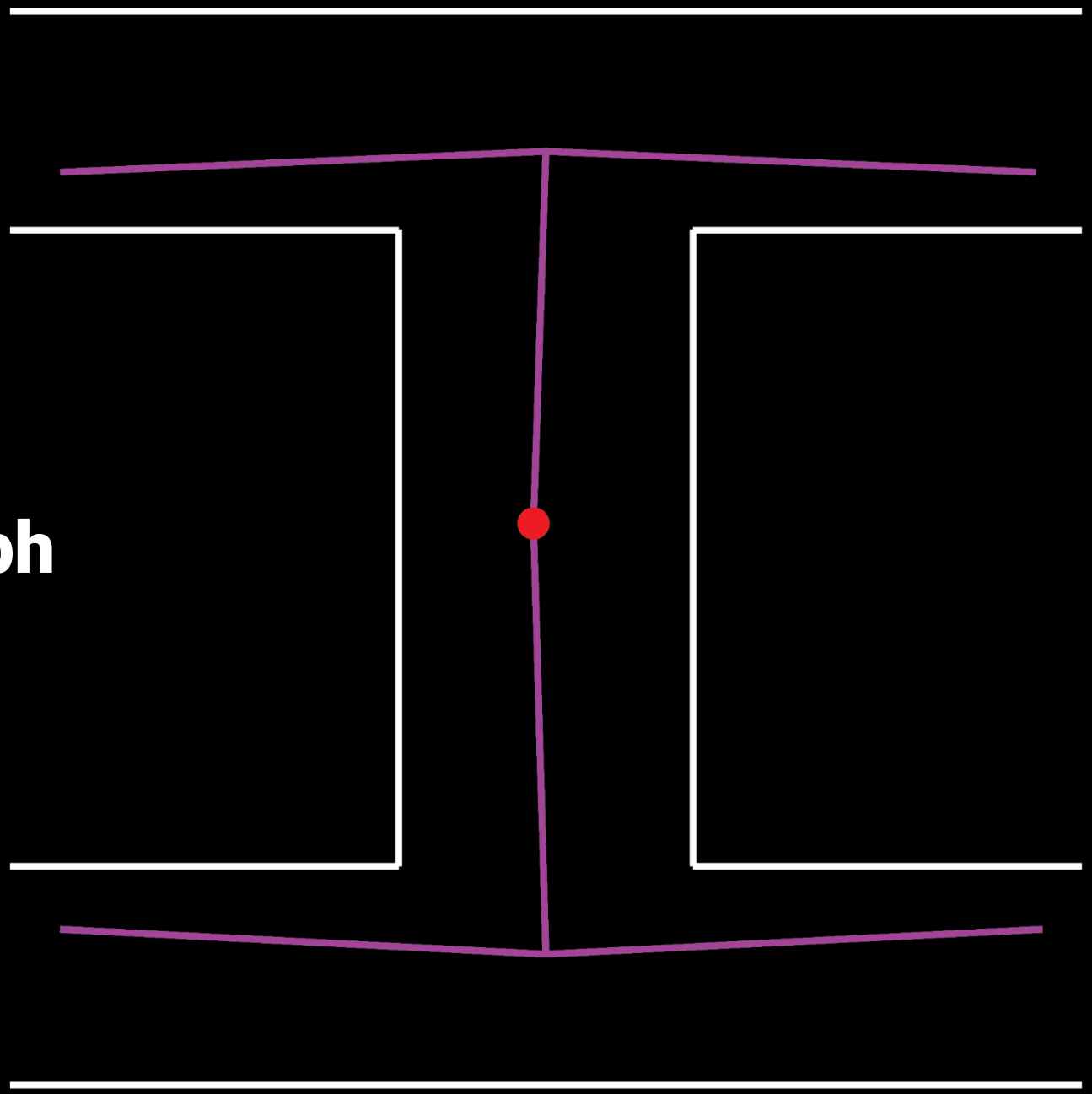
user prediction



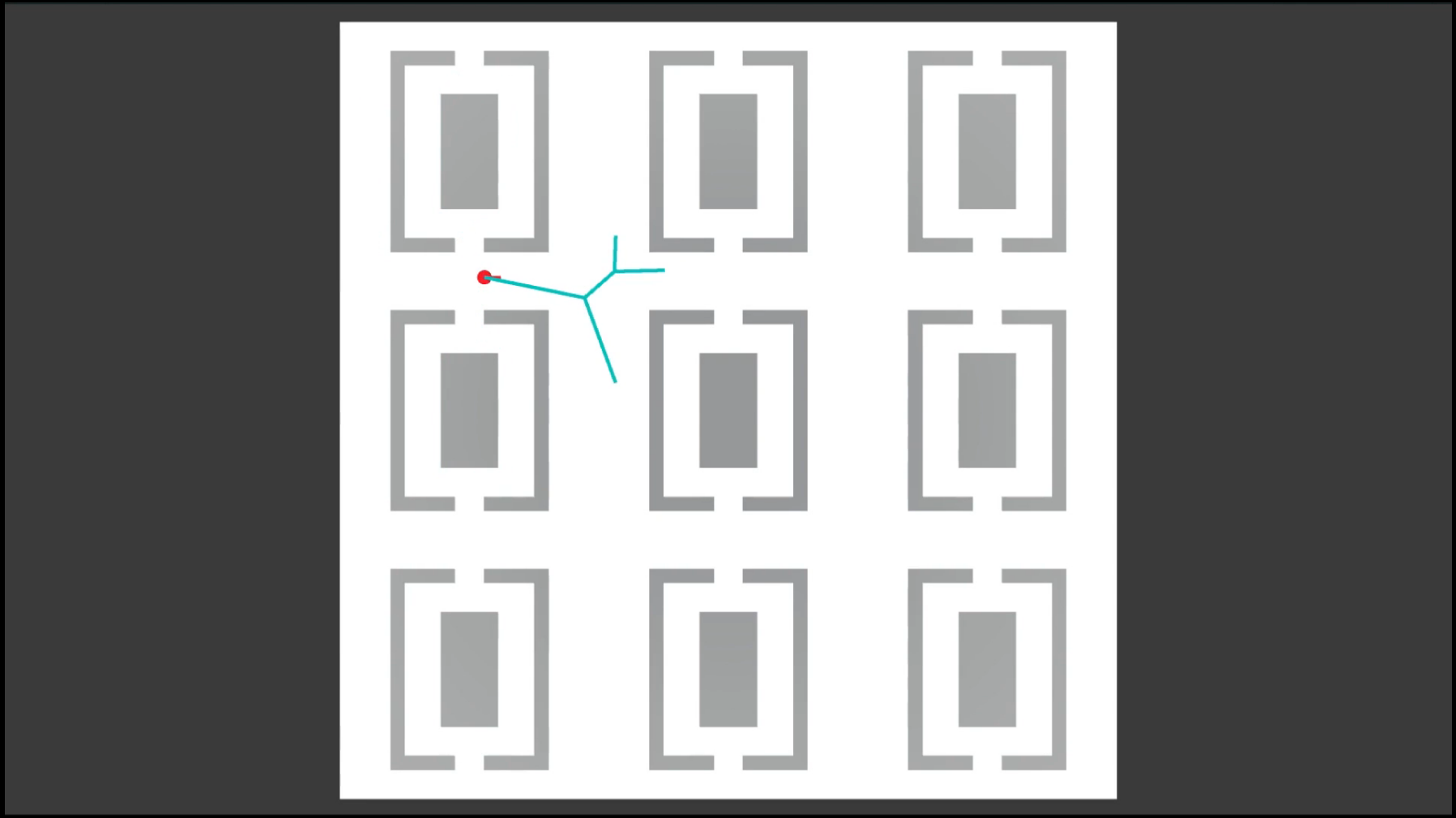


[1] M. Zmuda, J. Wonser, E. Bachmann, and E. Hodgson. Optimizing constrained-environment redirected walking instructions using search techniques, IEEE TVCG 2013.
[2] T. Nescher, Y. Huang, and A. Kunz. Planning Redirection Techniques for Optimal Free Walking Experience Using Model Predictive Control, IEEE 3DUI 2014.

prediction graph



Prediction Graph Generation



M. Azmandian, T. Grechkin, M. Bolas, and E. Suma. Automated path prediction for redirected walking using navigation meshes, IEEE 3DUI 2016.

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Freedom

Linear Route	Branching Pathways	Open World
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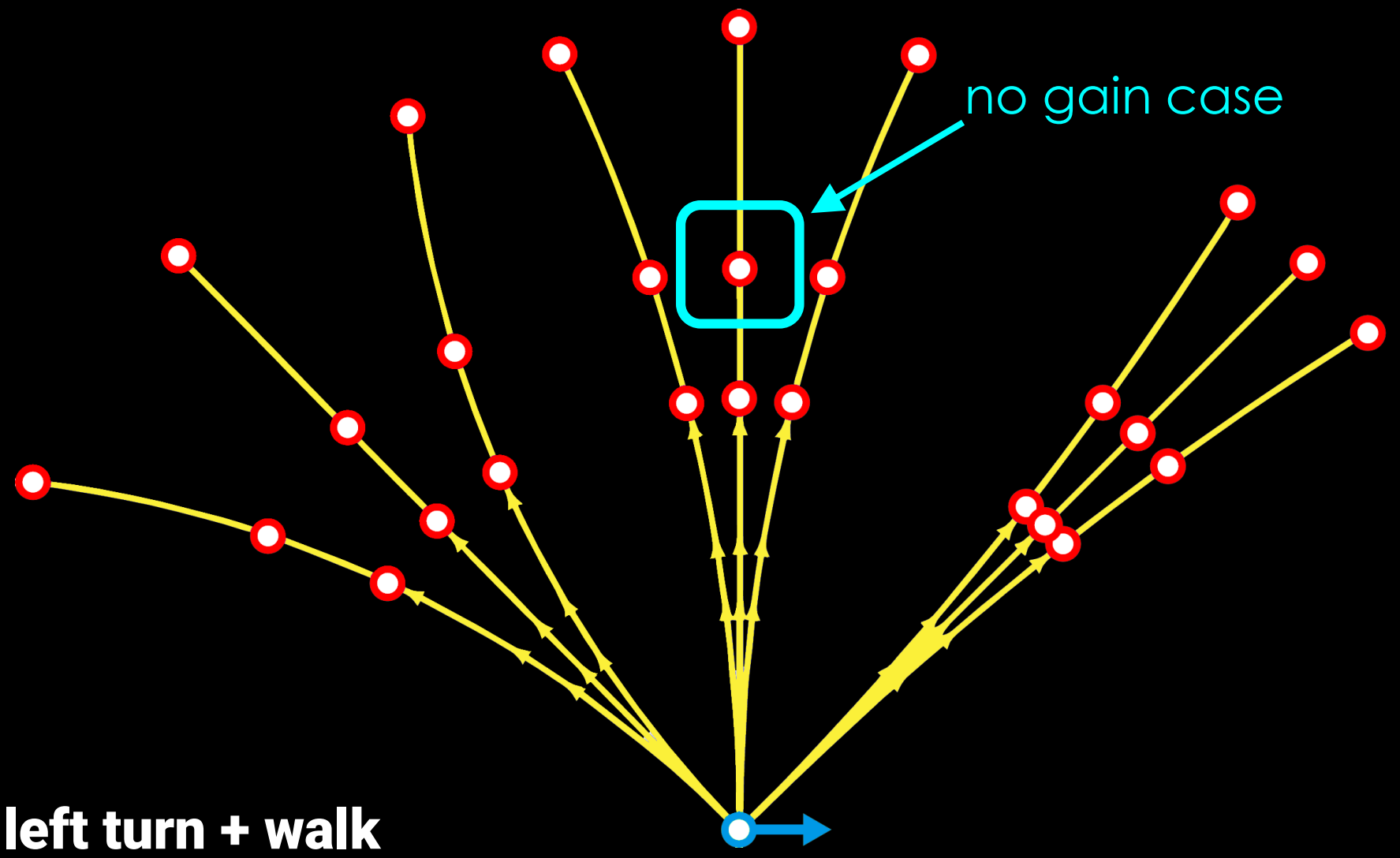
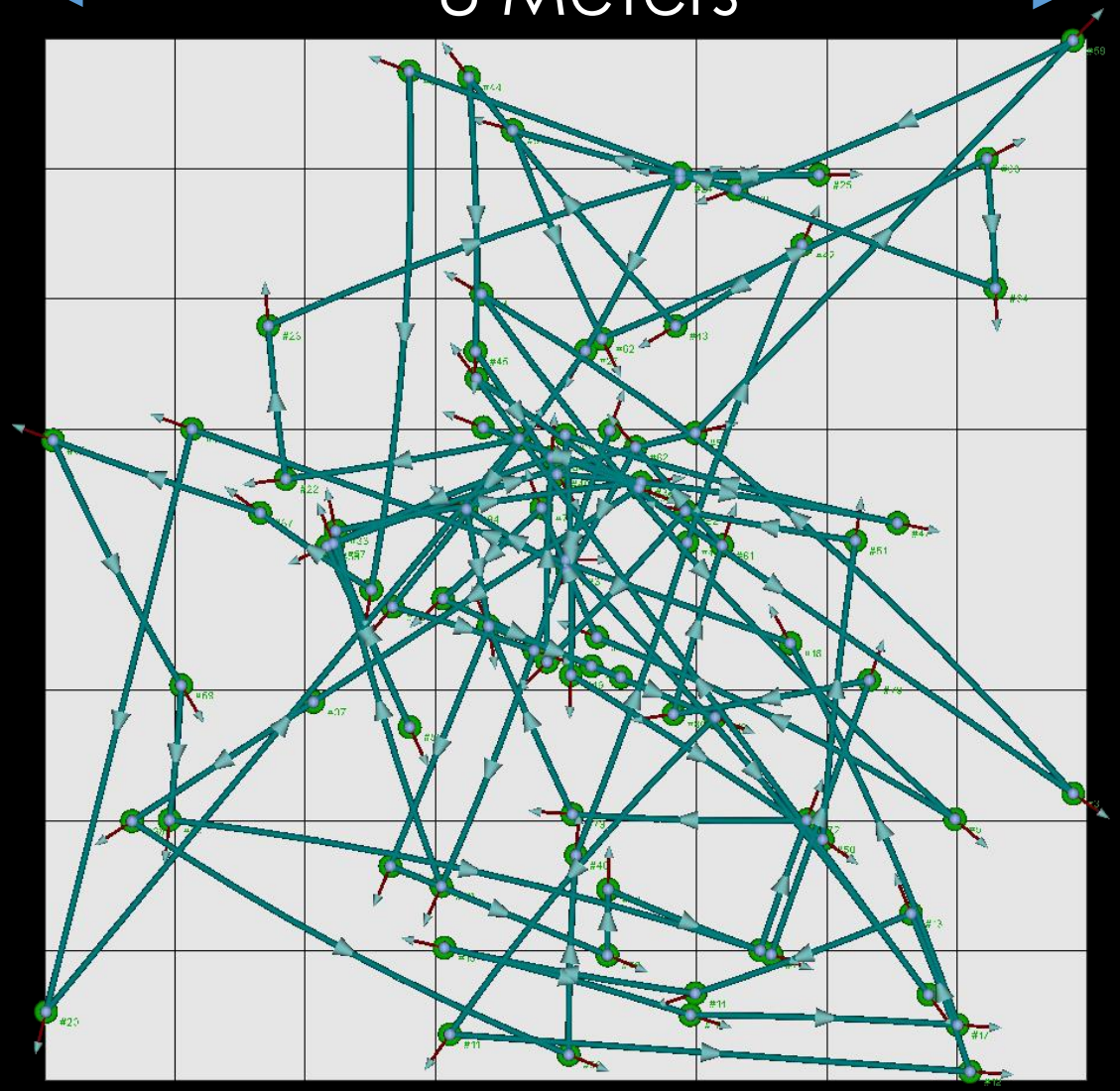
Combinatorial Optimization



90 degree left turn + walk

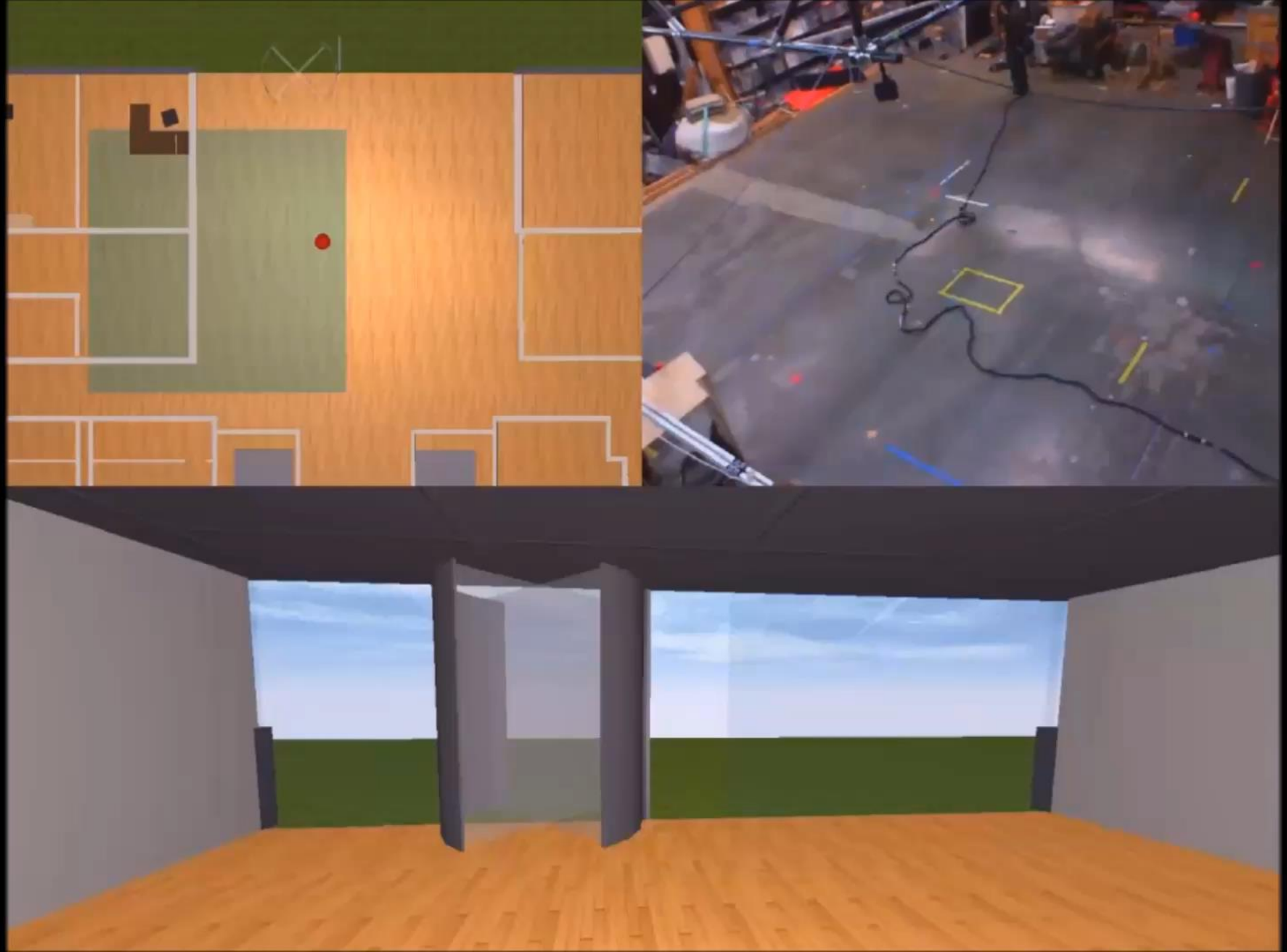
34 Meters

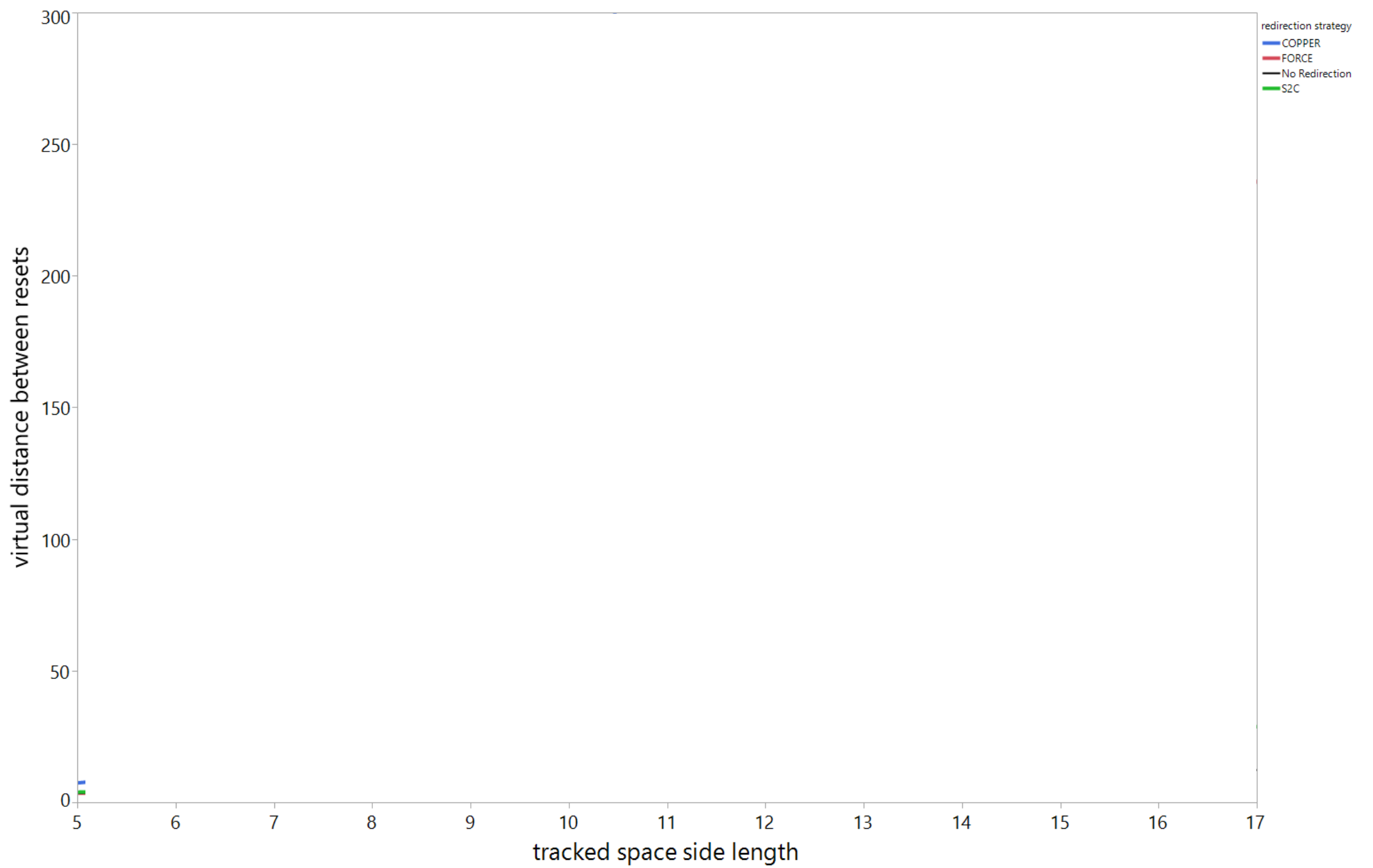
8 Meters



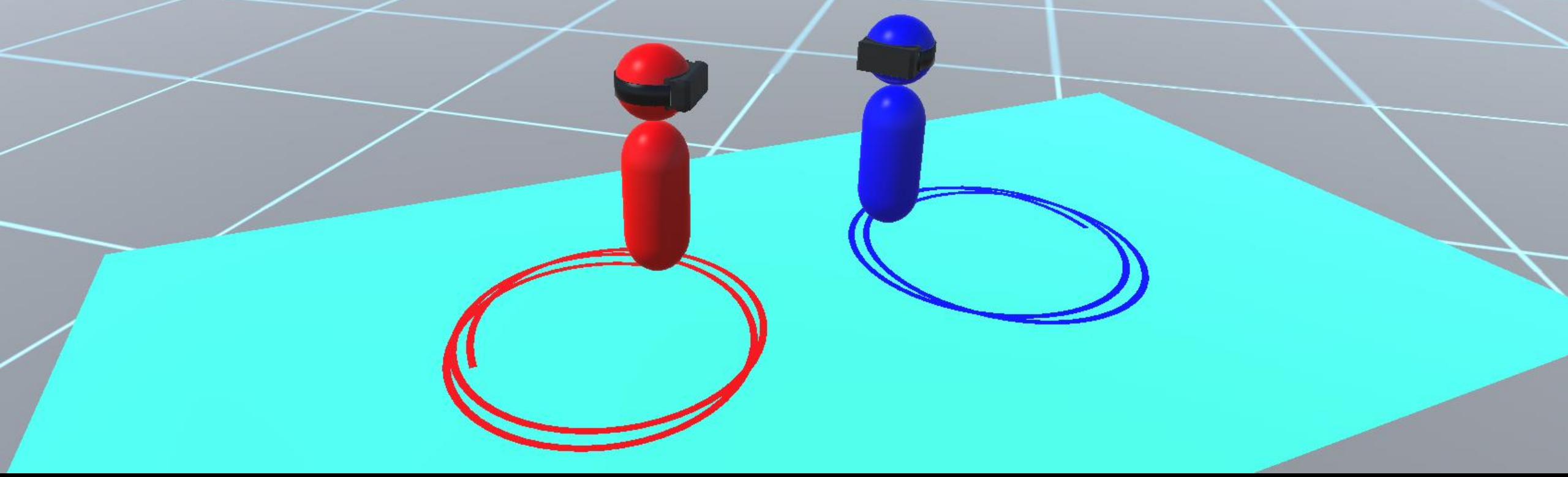
M. Azmandian. Design and Evaluation of Adaptive Redirected Walking Systems, Ph.D. Thesis, University of Southern California, 2018.

IEEE VGTC Virtual Reality Best Dissertation Award Honorable Mention.



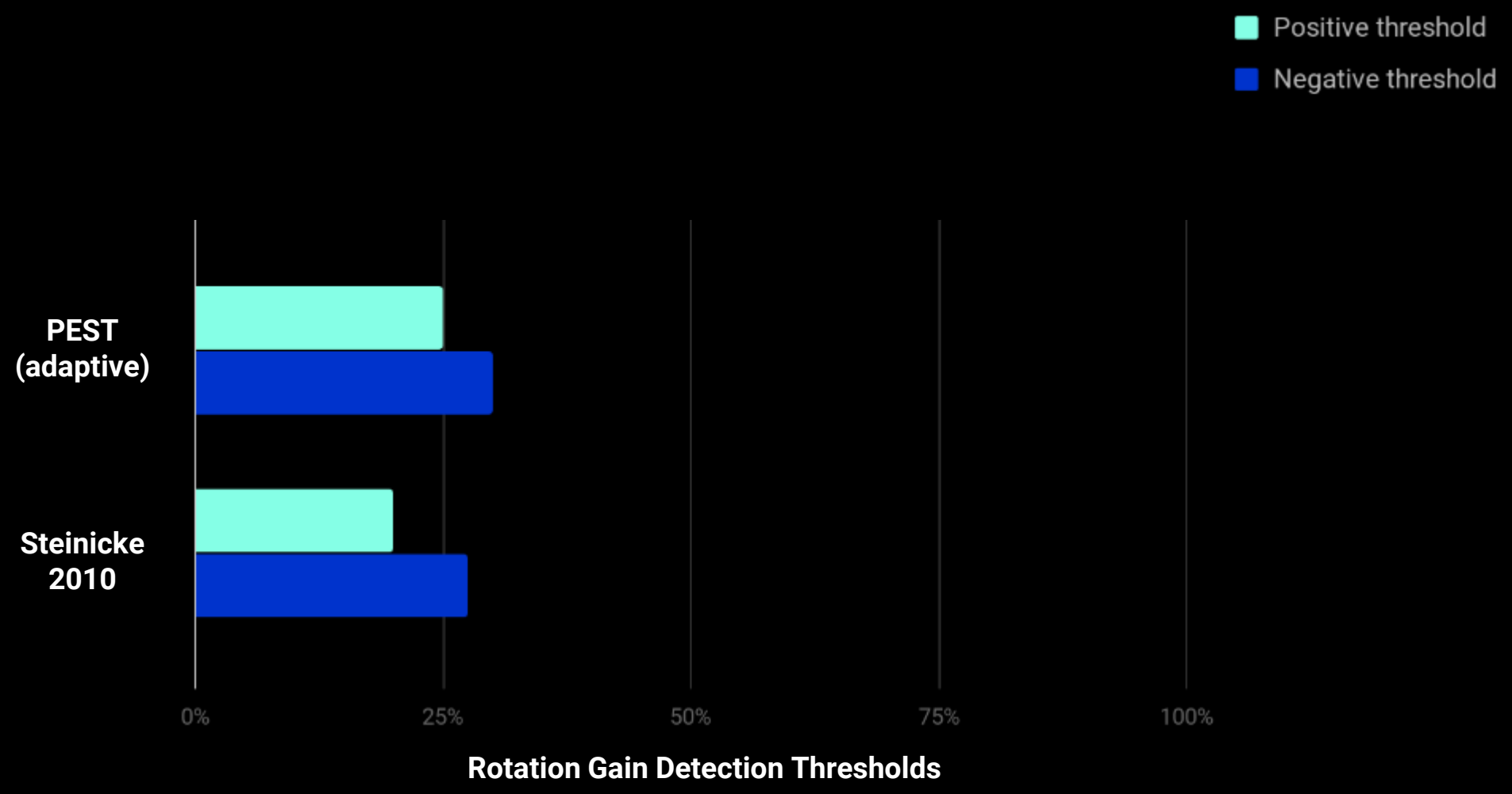

redirection strategy
COPPER
FORCE
No Redirection
S2C
virtual distance between resets
300
250
200
150
100
50
0
5
6
7
8
9
10
11
12
13
14
15
16
17
tracked space side length

THE VOID



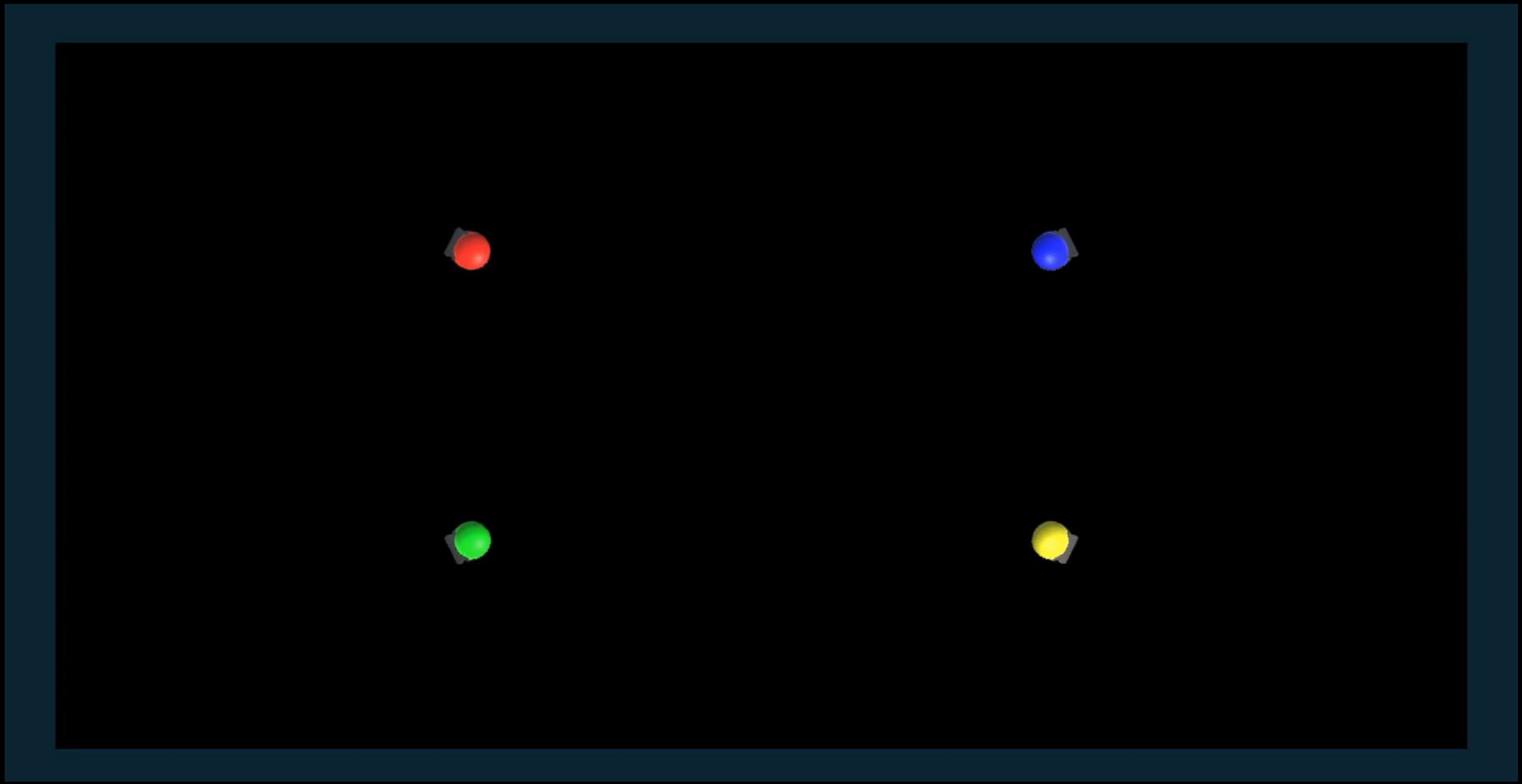
Current Research Topics

Individual Differences and Adaptation

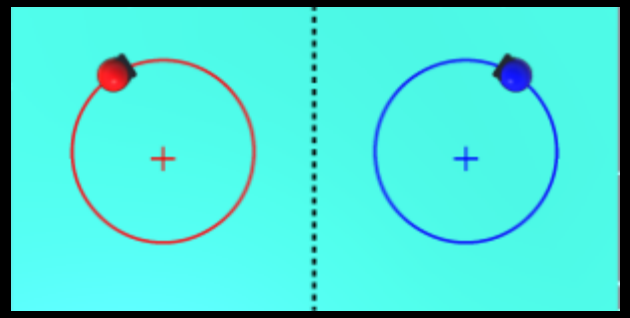


C. Hutton, S. Ziccardi, J. Medina, and E. Suma Rosenberg. Individualized Calibration of Rotation Gain Thresholds for Redirected Walking. ICAT EGVE 2018.

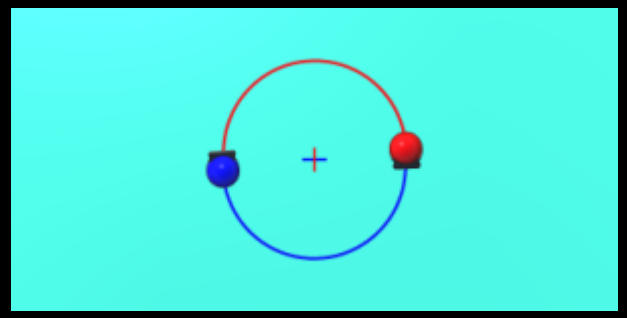
Multi-User Redirection



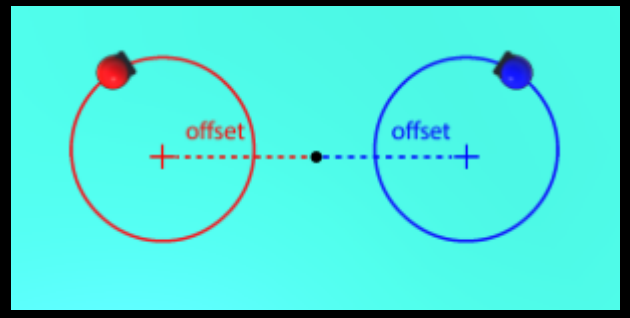
Multi-User Redirection



Subdivision



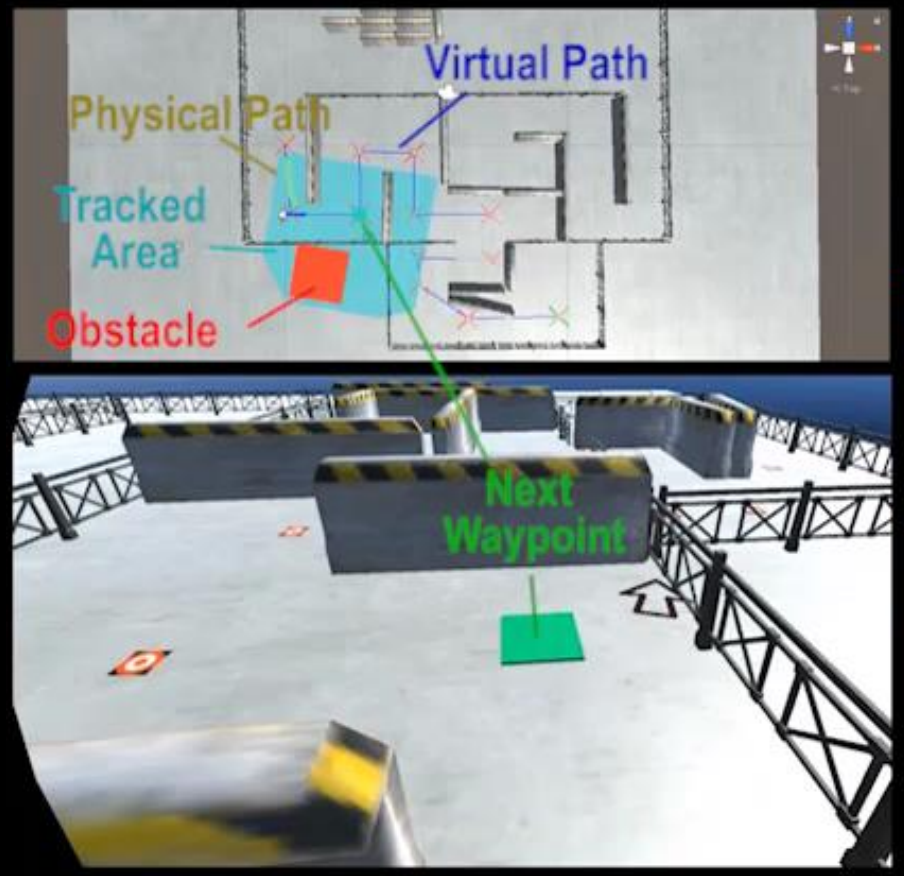
Shared Space
(Common Center)



Shared Space
(Offset Center)

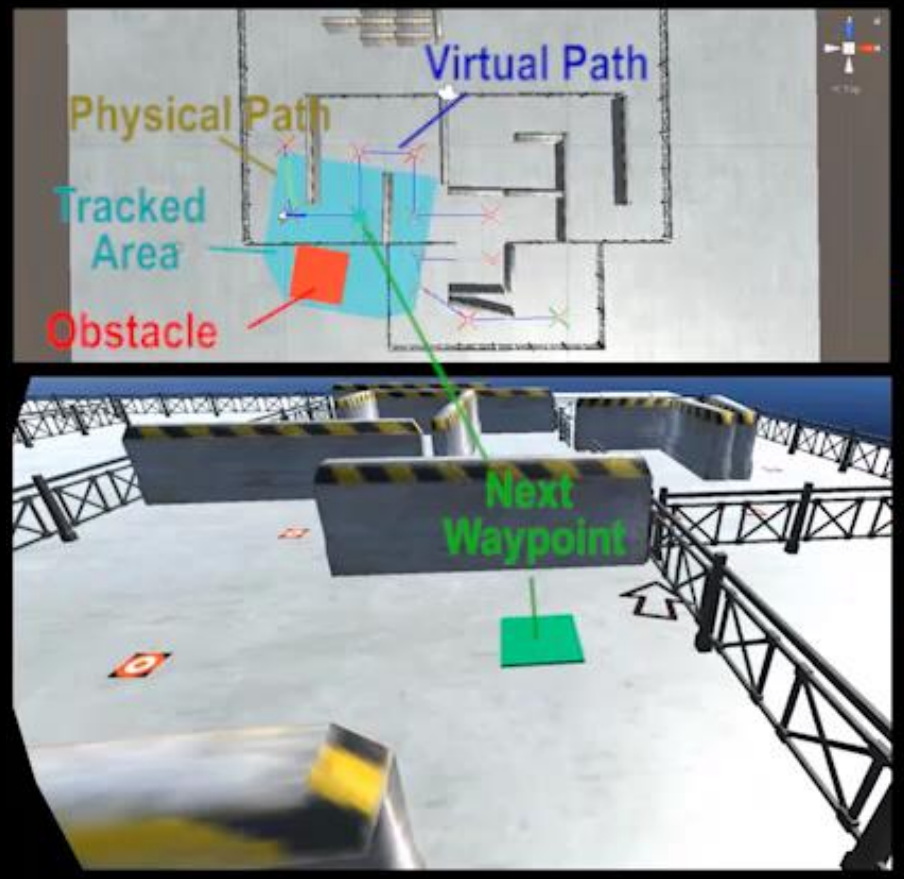
M. Azmandian, T. Grechkin, and E. Suma Rosenberg. An evaluation of strategies for two user redirected walking in shared physical spaces, IEEE VR 2017.

Walking in Cluttered Spaces



H. Chen, S. Chen, and E. Suma Rosenberg. Redirected Walking Strategies in Irregularly Shaped and Dynamic Physical Environments. WEVR 2018.

Walking in Cluttered Spaces



H. Chen, S. Chen, and E. Suma Rosenberg. Redirected Walking Strategies in Irregularly Shaped and Dynamic Physical Environments. WEVR 2018.

Physical Alignment with Redirected Walking

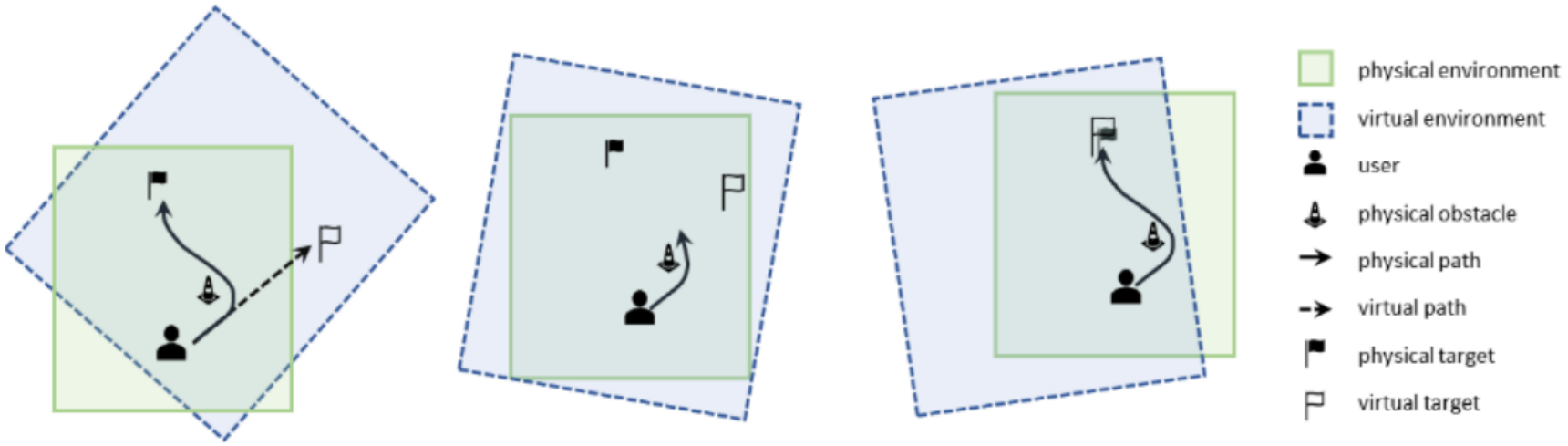
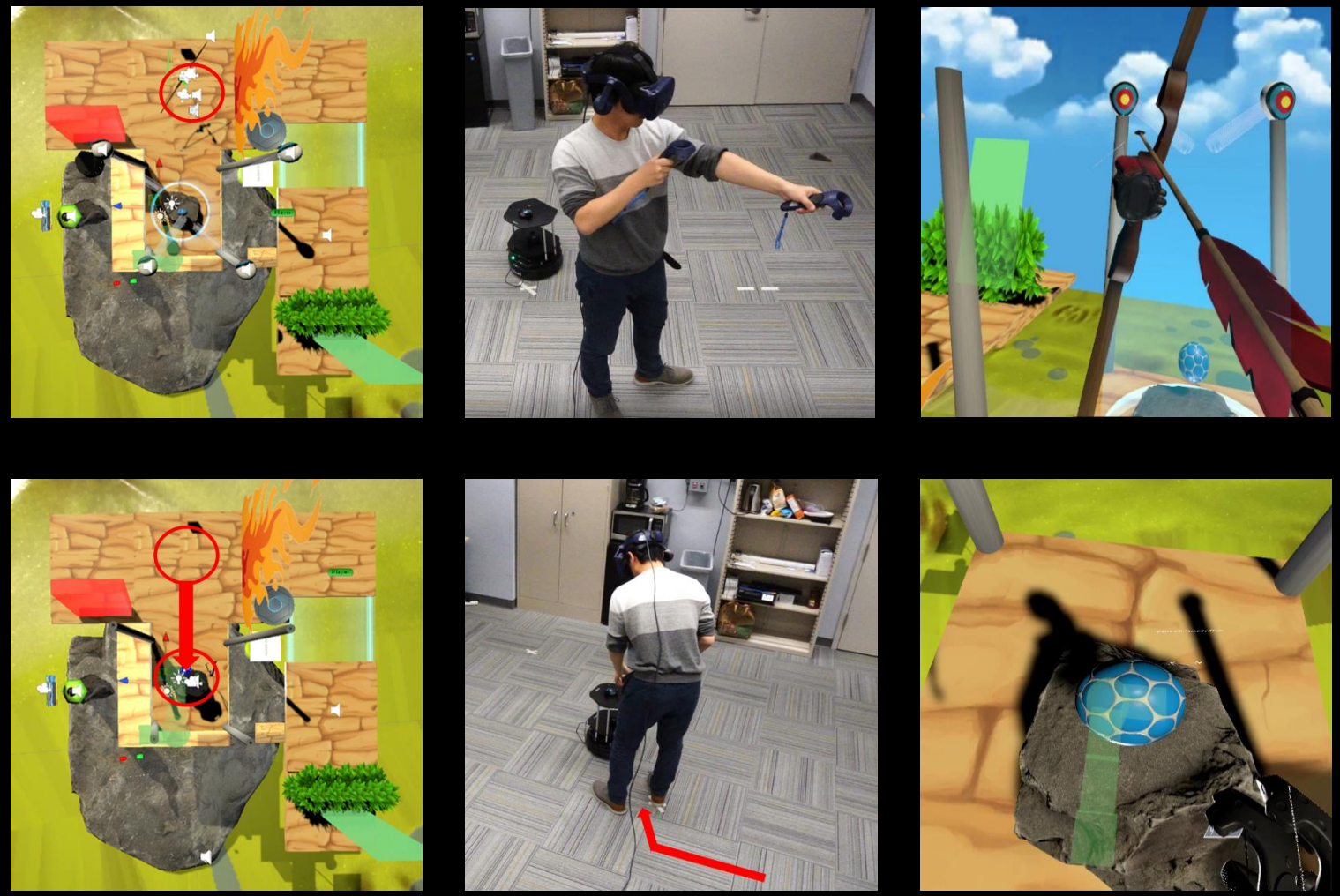


Figure 1: A demonstration of environmental alignment with obstacle avoidance. The left image shows the perceived path to a virtual target and the physical path to a proxy target. The middle and right images show the progression of the physical path to environmental alignment. When this occurs, the user can interact with the proxy target substituting for the virtual target.

J. Thomas, C. Hutton Pospick, and E. Suma Rosenberg. Towards Physically Interactive Virtual Environments: Reactive Alignment with Redirected Walking, ACM VRST 2020. **Best Paper Award.**

Robotic Actuation with Redirected Walking



Summary

- The virtual laws of physics are malleable
- Human perception can adapt and recalibrate
- VR can **transcend** the limitations of the real world
- Virtual reality systems can create **magic**

Teaching Evaluations

Please fill out the student rating of teaching at:

https://srt.umn.edu/blue

These forms will **close** on Wednesday, December 16!