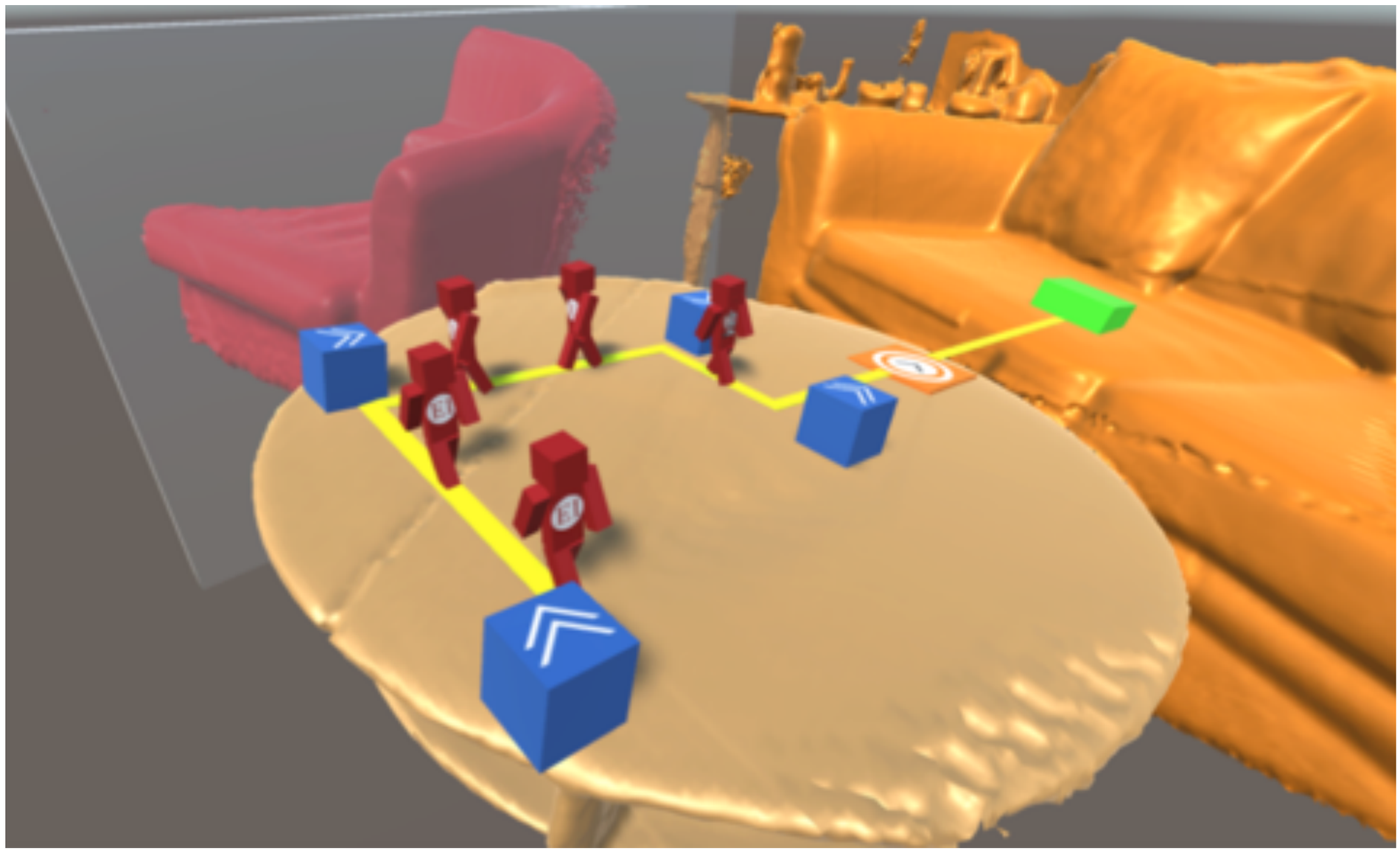
Georgia Tech

Entertainment Intelligence Lab

Prof. Mark Riedl, School of Interactive Computing



MIXED REALITY MEETS PROCEDURAL CONTENT GENERATION IN VIDEO GAMES

REAL LIFE EXPERIENCES

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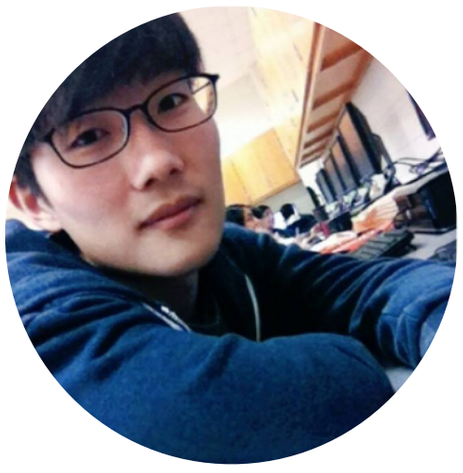
Mark Riedl

Sasha Azad

Carl Saldanha

Cheng Han Gan

Kristin Siu

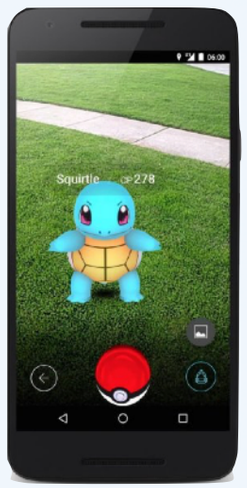


Kyung-Min Shin

MIXED REALITY

Mixed Reality (MR) *is the* ***merging of real and virtual worlds*** *to produce new environments and visualizations where* ***physical and digital objects co-exist and interact in real time****. MR is a mix of reality and virtual reality, encompassing both* ***augmented reality*** *and* ***augmented virtuality****.*

P. Milgram and A. F. Kishino (1994). "Taxonomy of Mixed Reality Visual Displays". IEICE Transactions on Information and Systems. pp. 1321–1329. Retrieved 2013-10-17.



Reality → **Virtuality**

Real Environment

Augmented Reality (AR)

Augmented Virtuality (AV)

Virtual Environment

Mixed Reality (MR)

Milgram, Paul; H. Takemura; A. Utsumi; F. Kishino (1994). "Augmented Reality: A class of displays on the reality-virtuality continuum". Proceedings of Telemanipulator and Telepresence Technologies. pp. 2351–34.

CURRENT GAMES

CURRENT GAMES

CURRENT GAMES

CURRENT GAMES

WHAT IF...

WHAT IF...

WHAT IF...

NEED FOR ARTIFICIAL INTELLIGENCE IN MIXED REALITY

- Spatial Reasoning
- Increase in dependence on real environment
- Every game-space is different
- Lack of control of the game worlds
  (a.k.a. Why cats are *evil*)
- Use of contextual world knowledge to make more compelling game design choices

OUR STORY

Motivating Factors

- Adoption and advent of AR/MR headsets
- Increase in Mixed Reality Games
- Unique experiences tailored to real spaces

Methods

- Mixed Reality Design Considerations
- Level Generation Preliminaries
- Procedural Content Generation

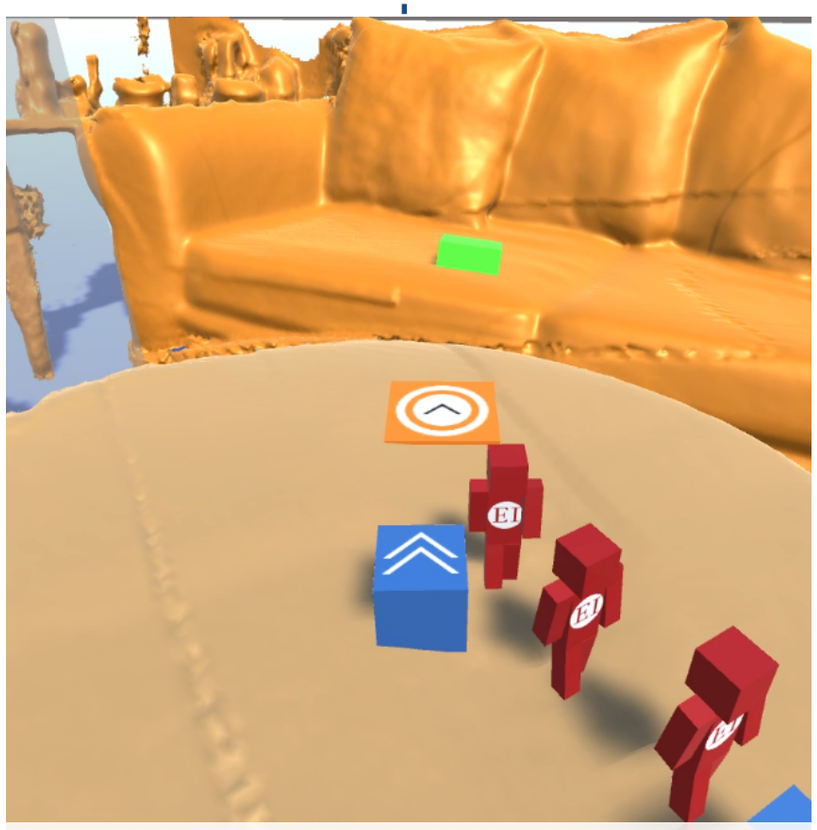
OUTLINE

DESIGN CONSIDERATIONS

New set of considerations - movement through real spaces, reach, etc.

LEVEL GENERATION PRELIMINARIES

Applying spatial reasoning to a real world environment to detect playable surfaces



PROCEDURAL CONTENT GENERATION IN MIXED REALITY

Need for PCG to create compelling levels, potential evaluation functions for MR environments to keep the game challenging

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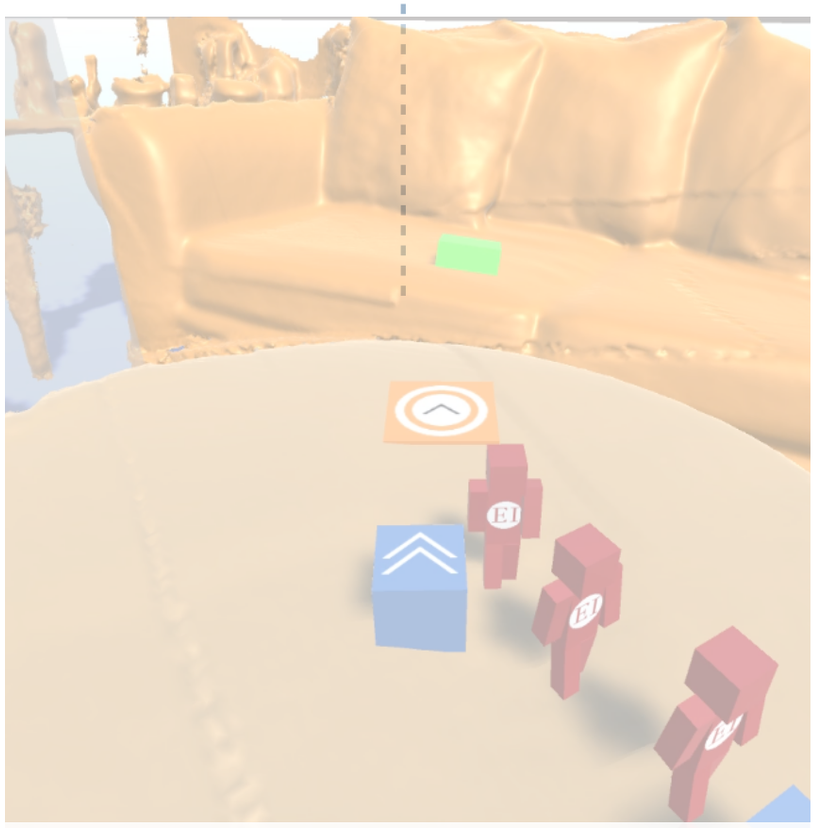


PROCEDURAL CONTENT GENERATION IN MIXED REALITY

Need for PCG to create compelling levels, potential evaluation functions for MR environments to keep the game challenging

DESIGN OBJECTIVES

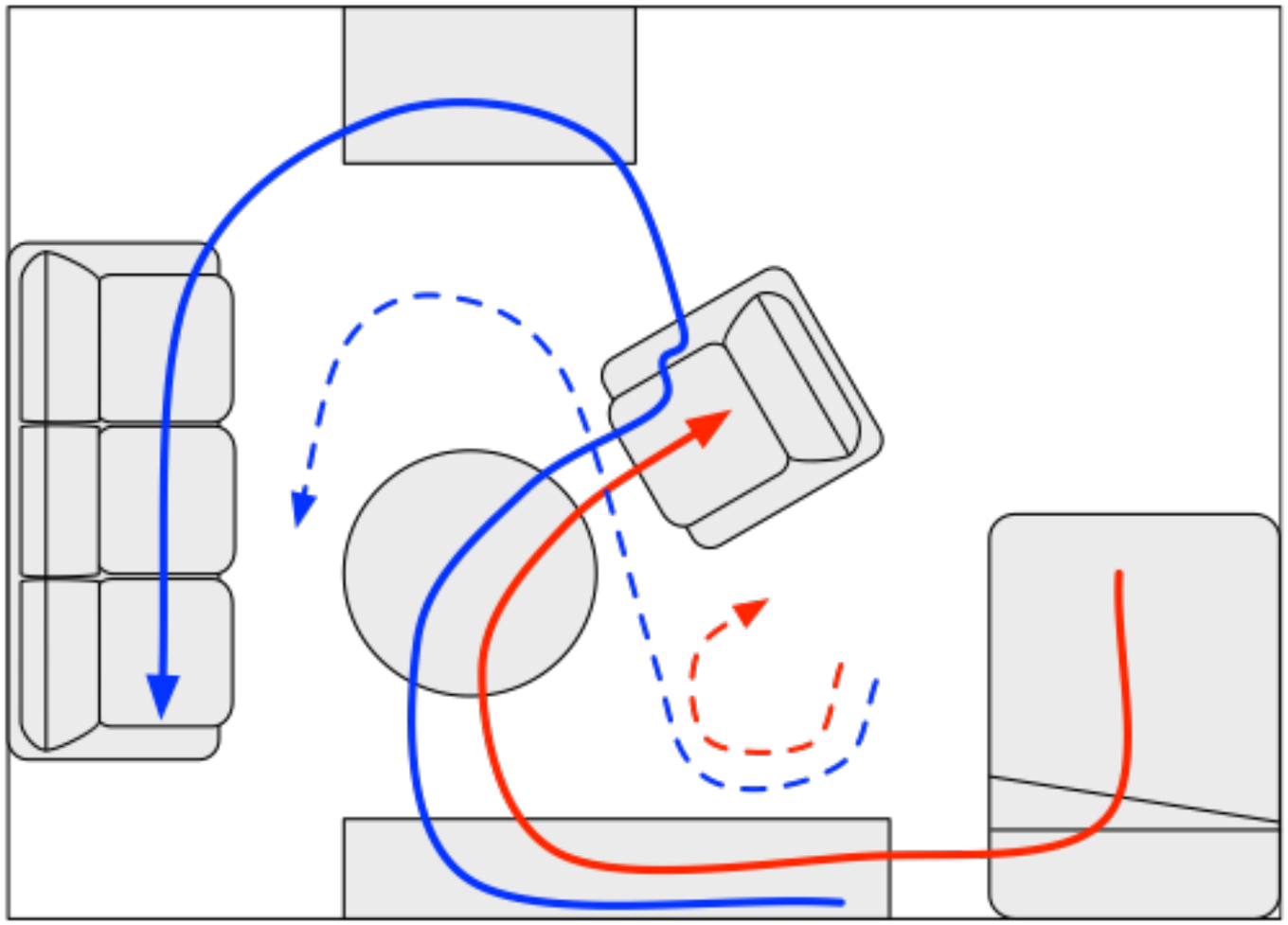
- Adapt to the physical surroundings
  (a.k.a. Environment Constraints)
- Adapt to player movement constraints
  (a.k.a. Navigation Constraints)

ENVIRONMENT FACTORS

- Cluttered or sparse spaces
- Context of environments
- Replayability of the game

NAVIGATION FACTORS

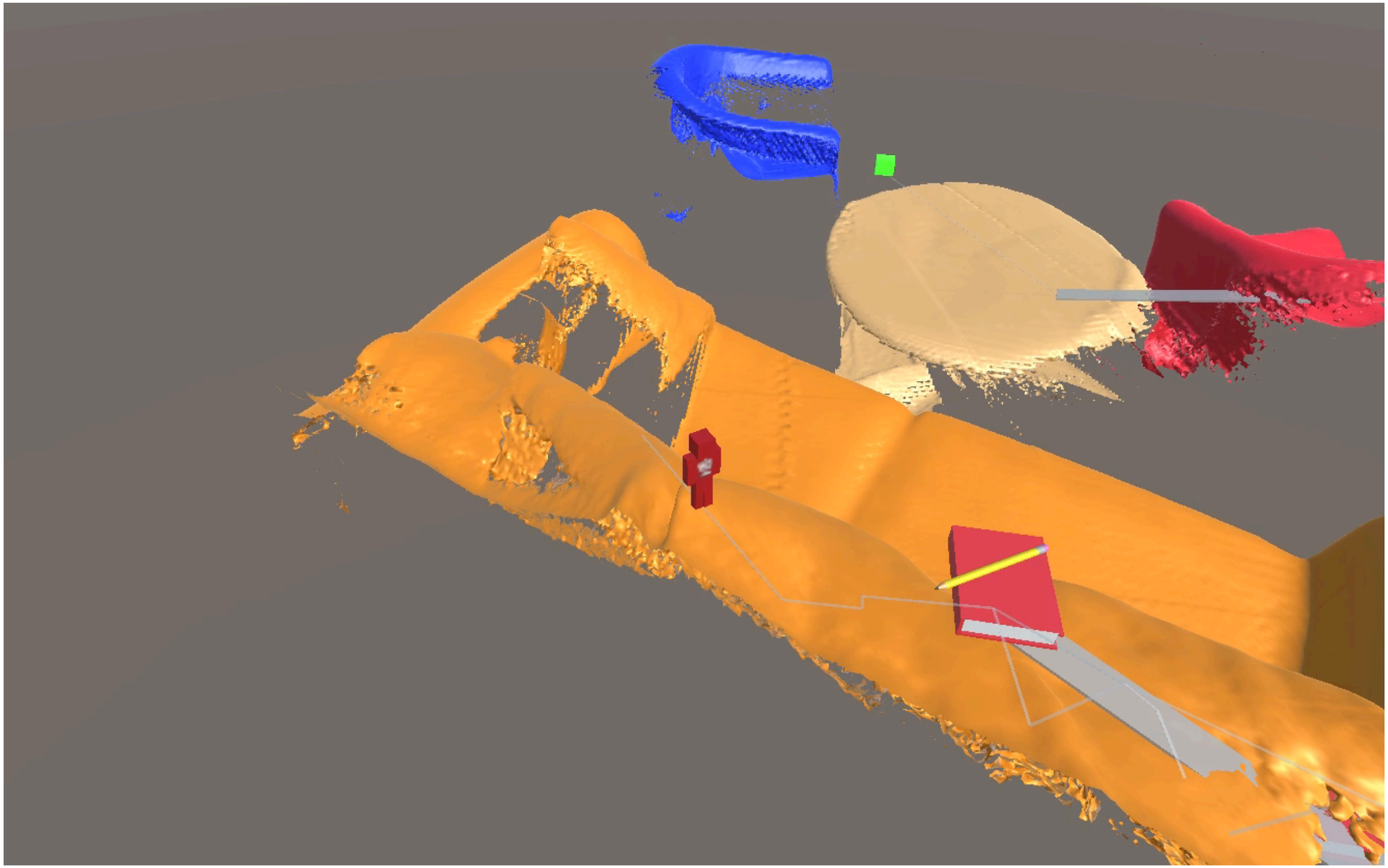
- Player's level of control
- Exploration of physical space
- Reachability



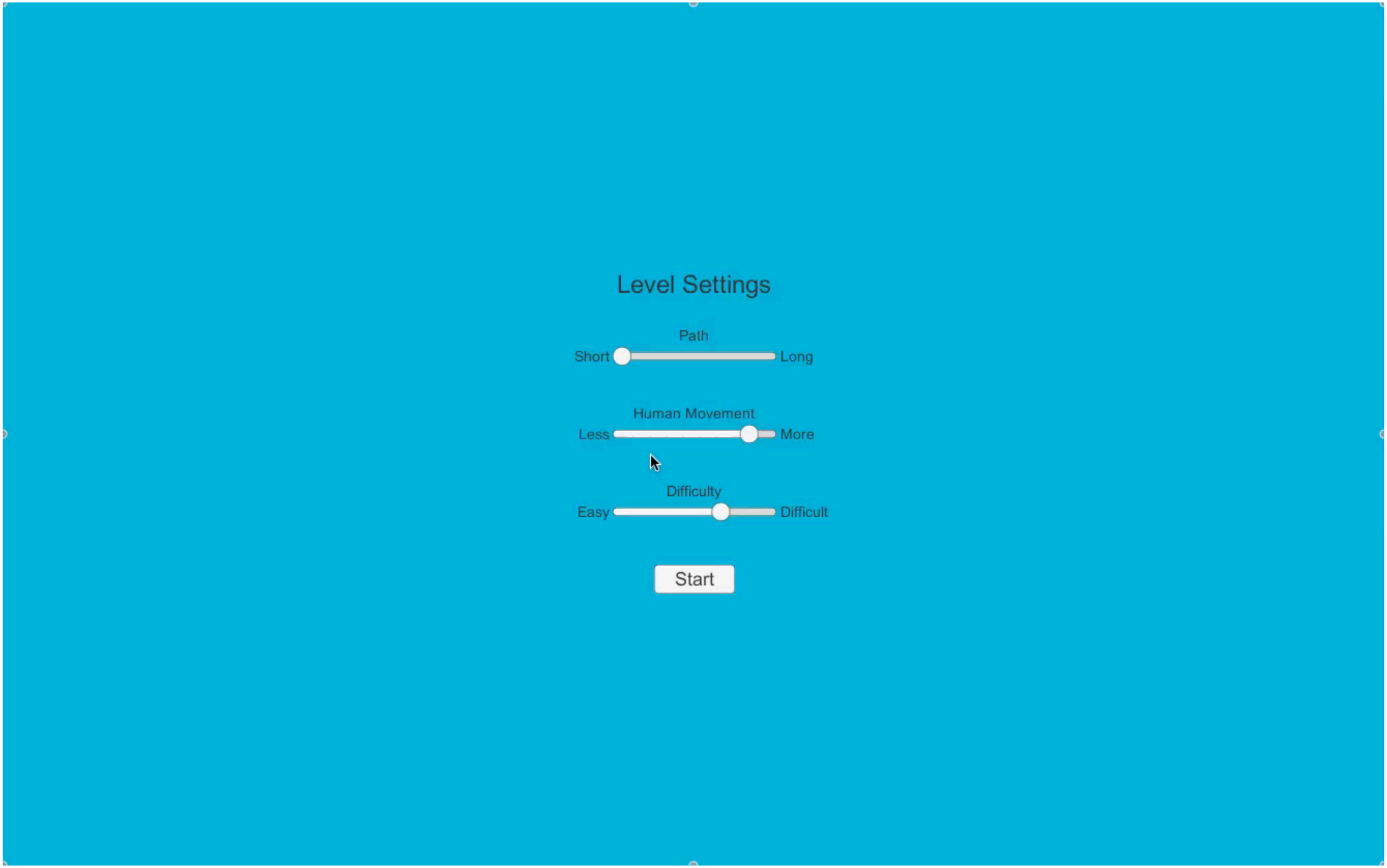
PROTOTYPE GAMES

- Two prototypes:
  - Mario & Lemmings
  - Simulated in Unity on a PC/Oculus
  - Mouse and keyboard interaction

MIXED REALITY MARIO



MIXED REALITY LEMMINGS



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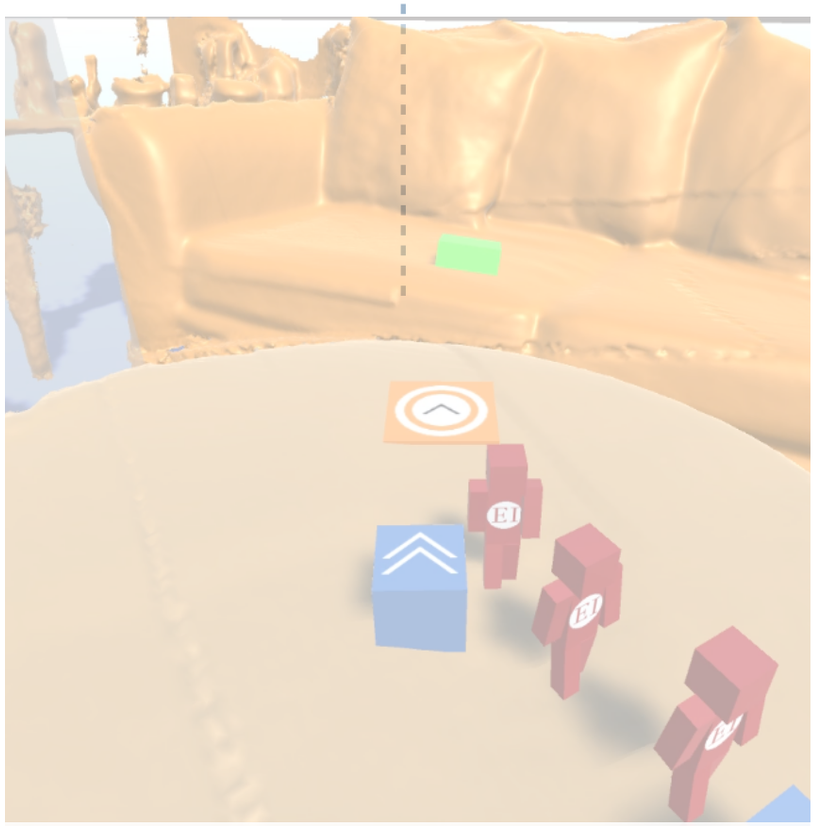


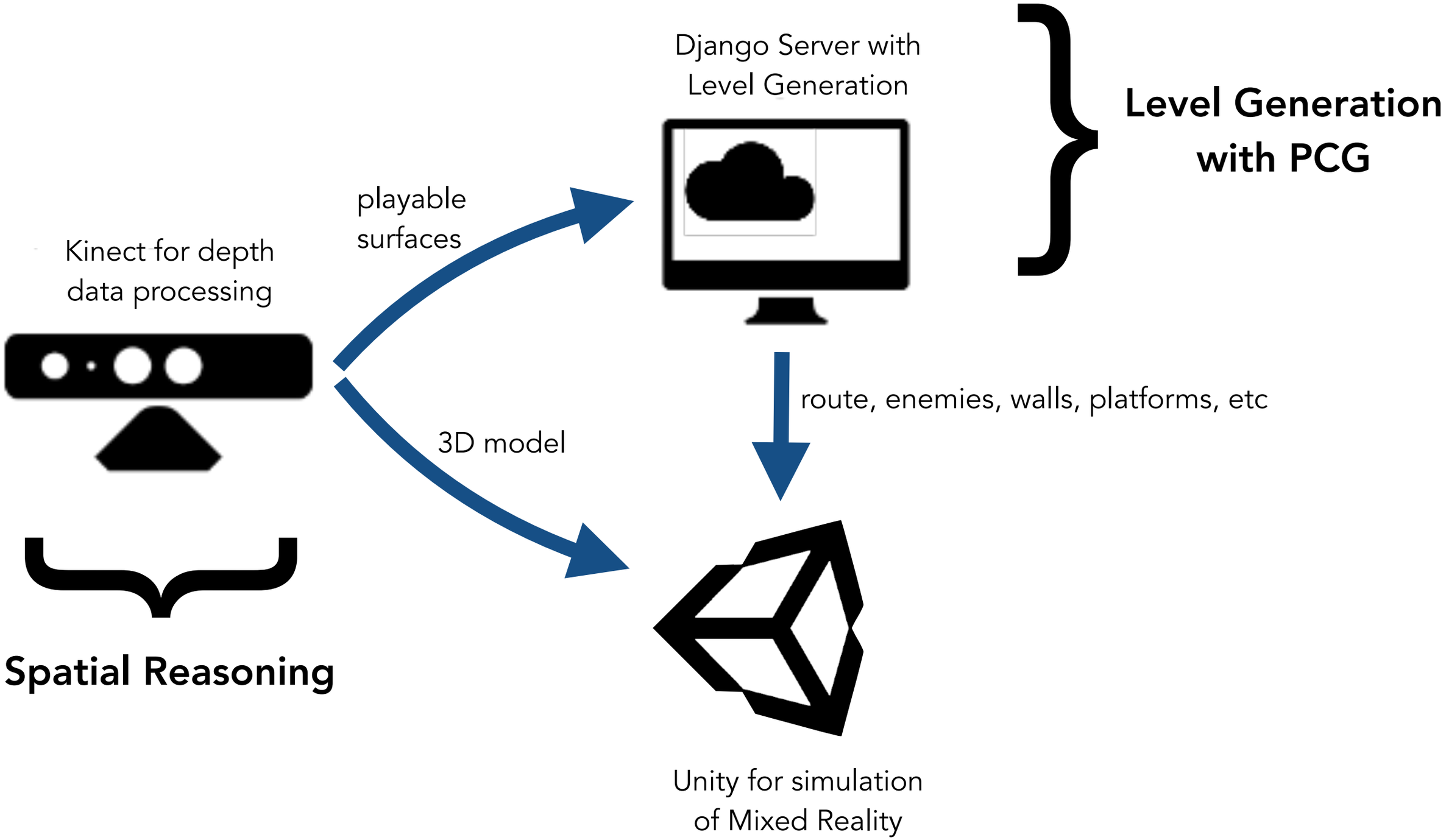
PROCEDURAL CONTENT GENERATION IN MIXED REALITY

Need for PCG to create compelling levels, potential evaluation functions for MR environments to keep the game challenging

PIPELINE

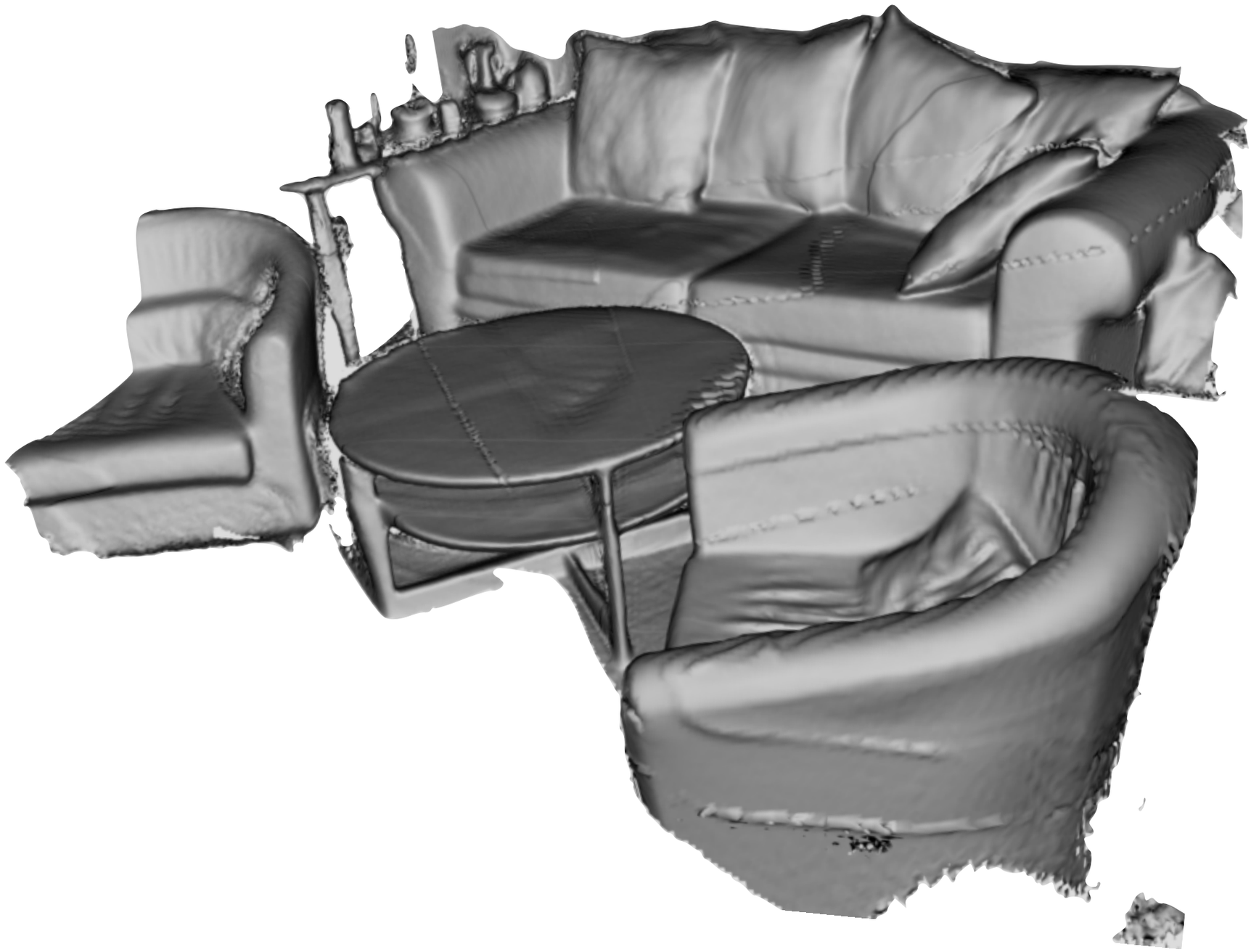
- Environment mapping / 3D modeling
- Playable surface detection
- Game World graph generation

ARCHITECTURE



3D MODELING

3D MODELING



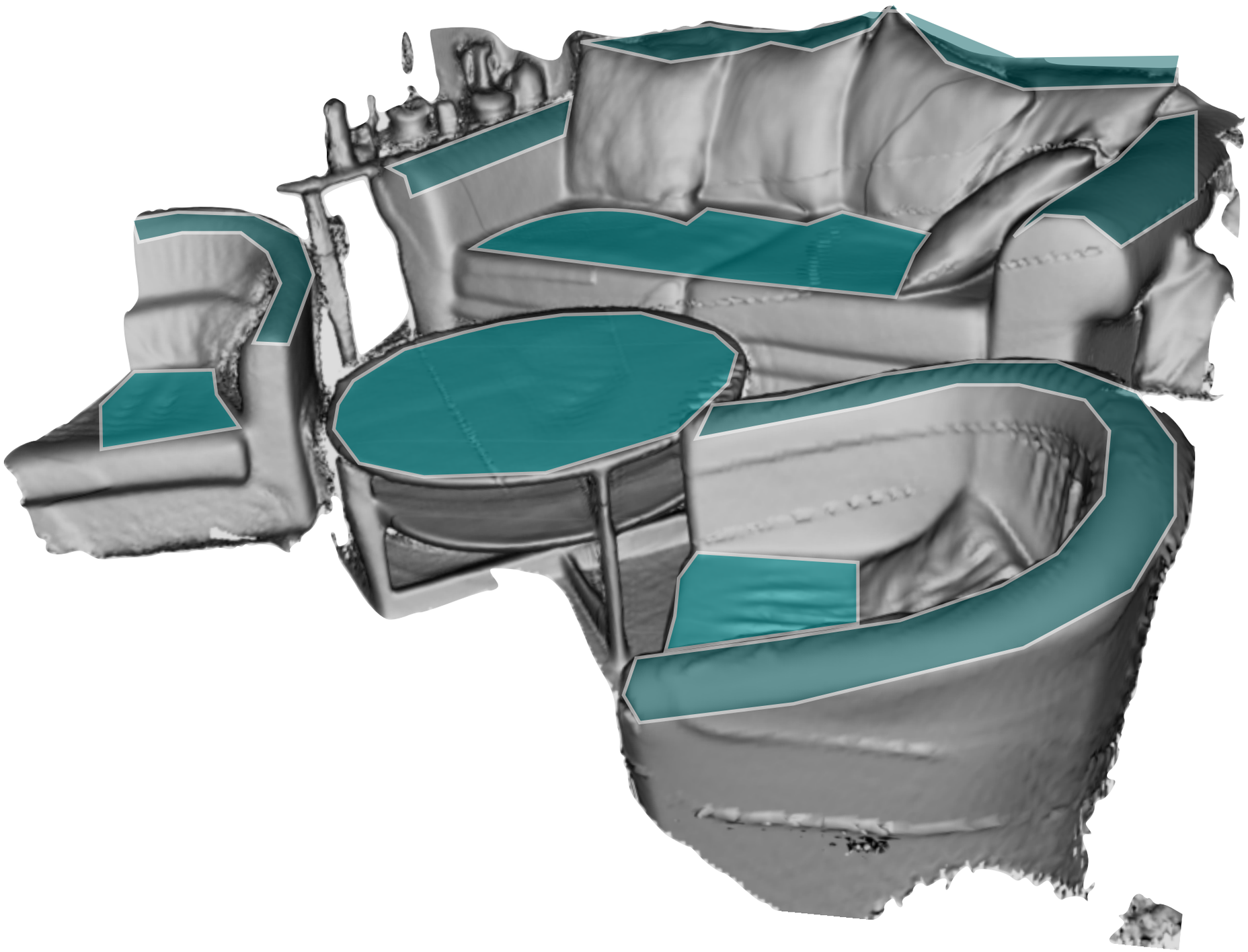
SURFACE DETECTION

- Normalize vertices & vertex normals
- Get rid of -y normals & corresponding vertices
- Find connected components using Union-Find algorithm

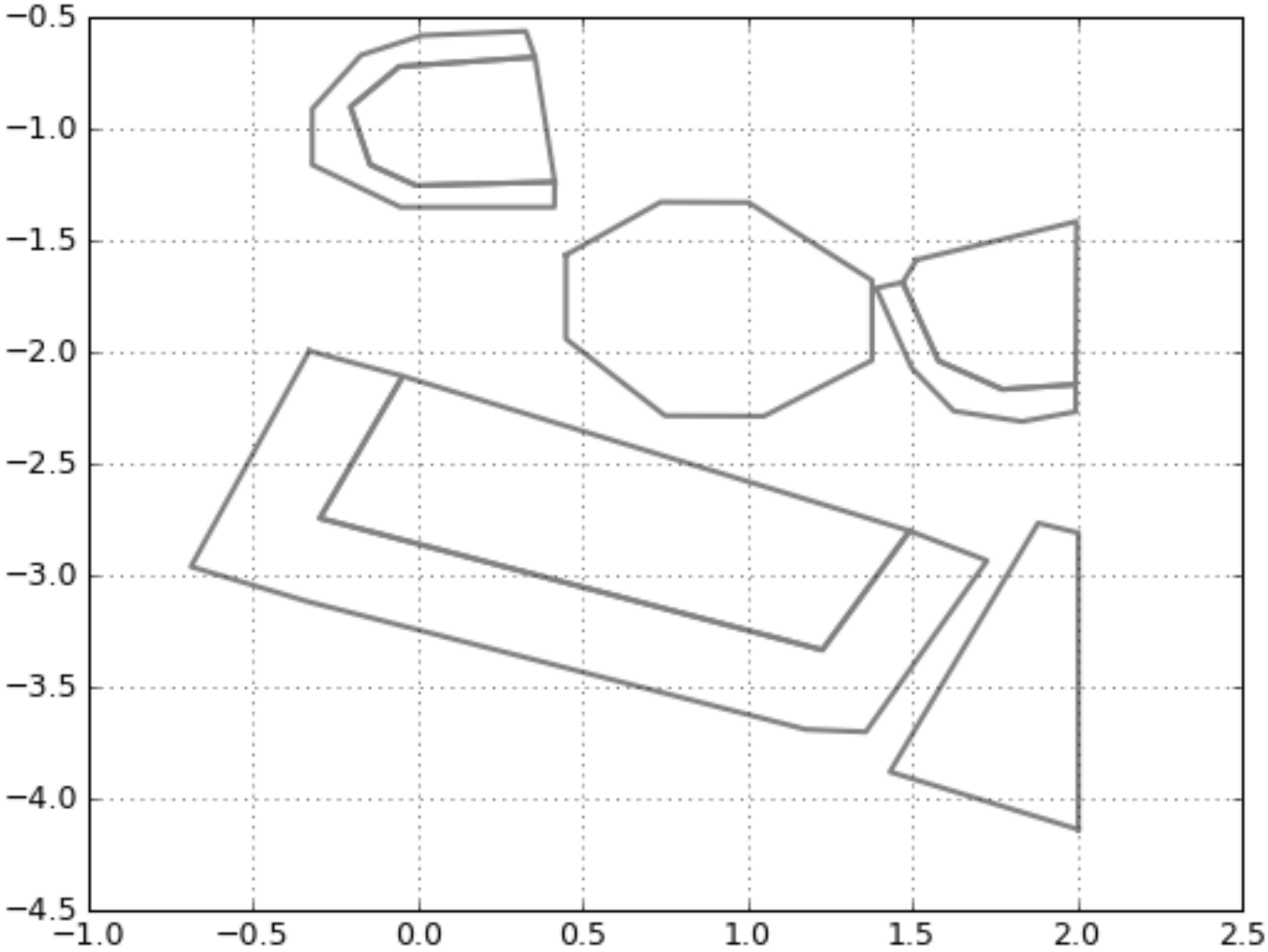
```
#List of geometric vertices
v 0.123 0.234 0.345
v ....
#List of vertex normals
vn 0.707 0.000 0.707
vn ....

#Polygon face elements
f 1//1 2//2 3//3
f 3//3 5//5 6//6
f ....
```

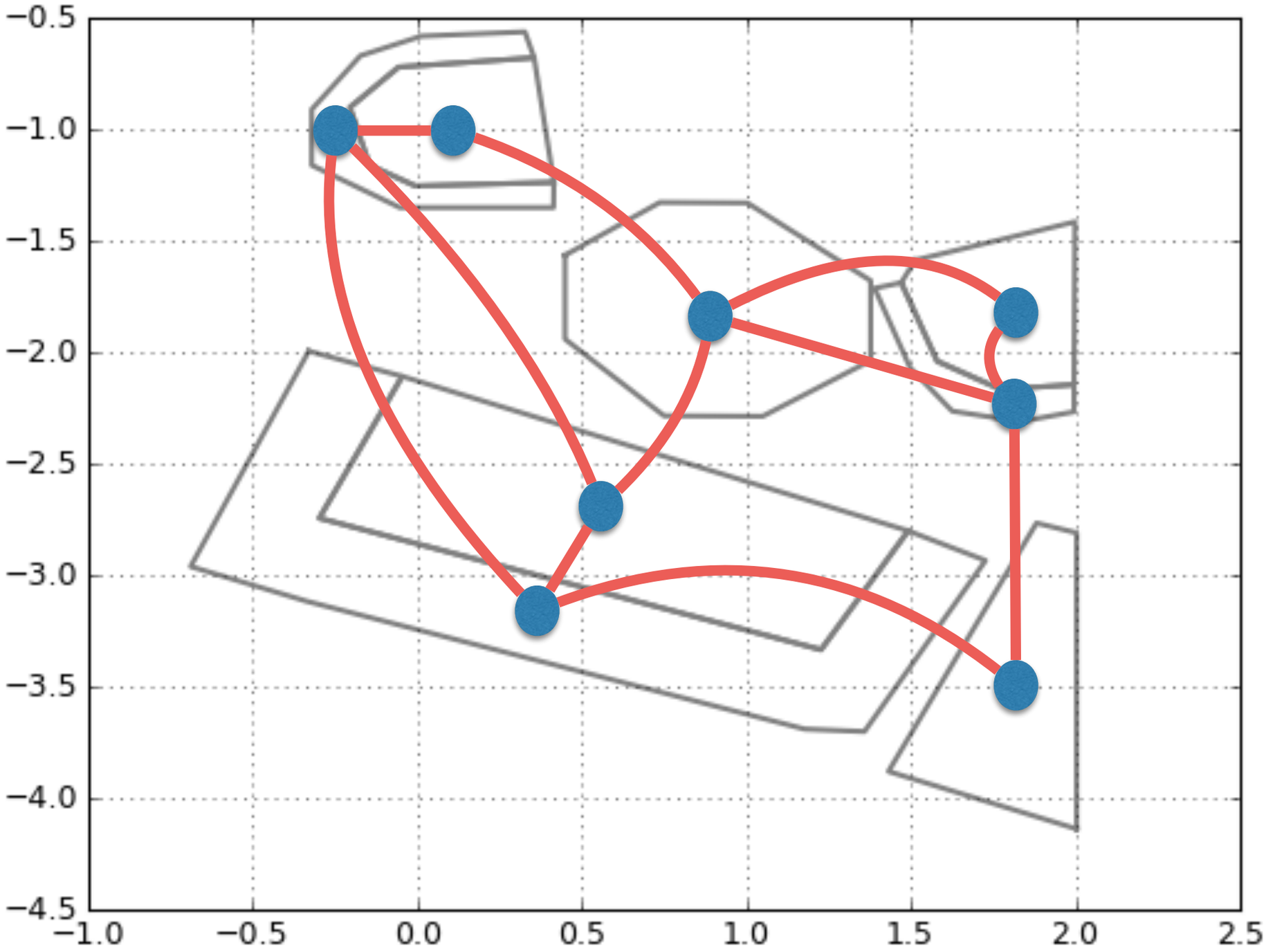
SURFACE DETECTION



SURFACE DETECTION



GAME WORLD GRAPH



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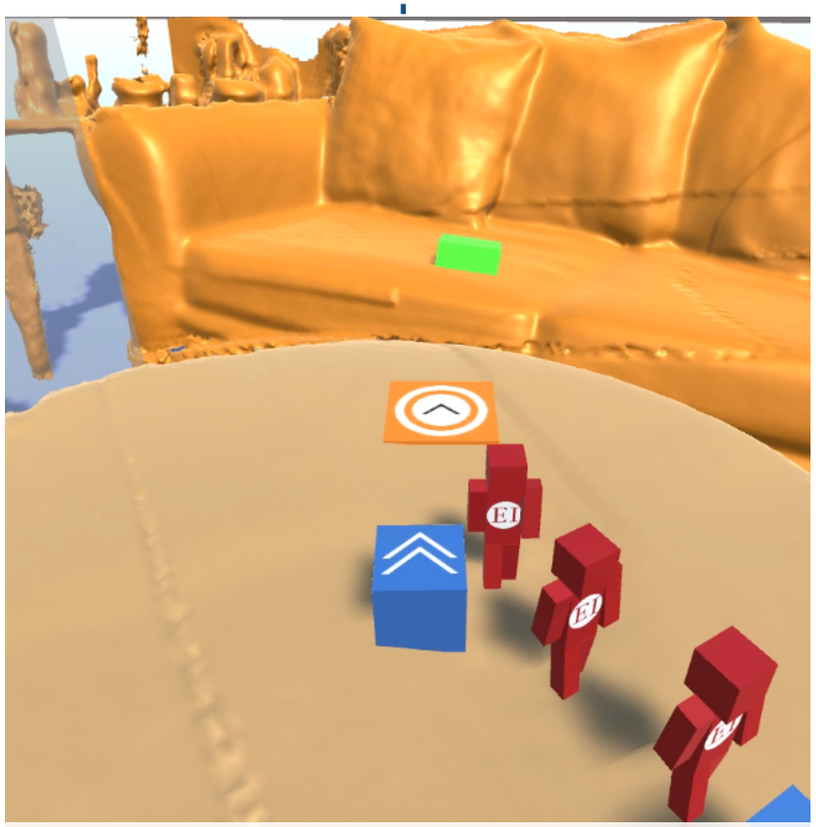


PROCEDURAL CONTENT GENERATION IN MIXED REALITY

Need for PCG to create compelling levels, potential evaluation functions for MR environments to keep the game challenging

OVERVIEW

- Design heuristics for levels that take both the real and virtual world into account
- Generate-and-test all possible tracks
- Generate accompanying virtual assets (walls, platforms, enemies) on selected route

HEURISTICS

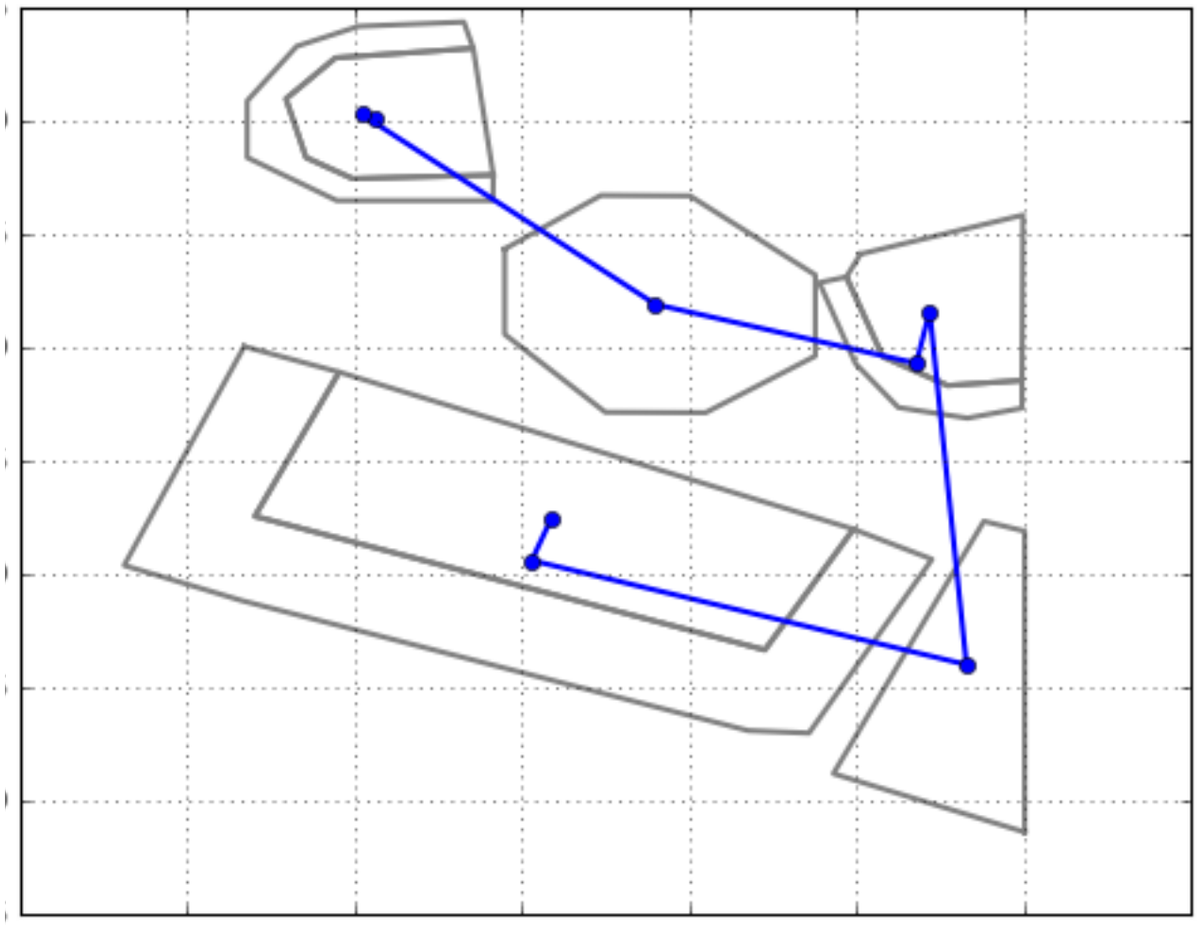
- Length of route / gameplay (h_{length})
- Player physical movements (h_{RRT})
- Target difficulty ($h_{difficulty}$)
  - #Enemies
  - Object_Placement
- Proportion of Surfaces Used ($h_{surfaces}$)

HEURISTICS

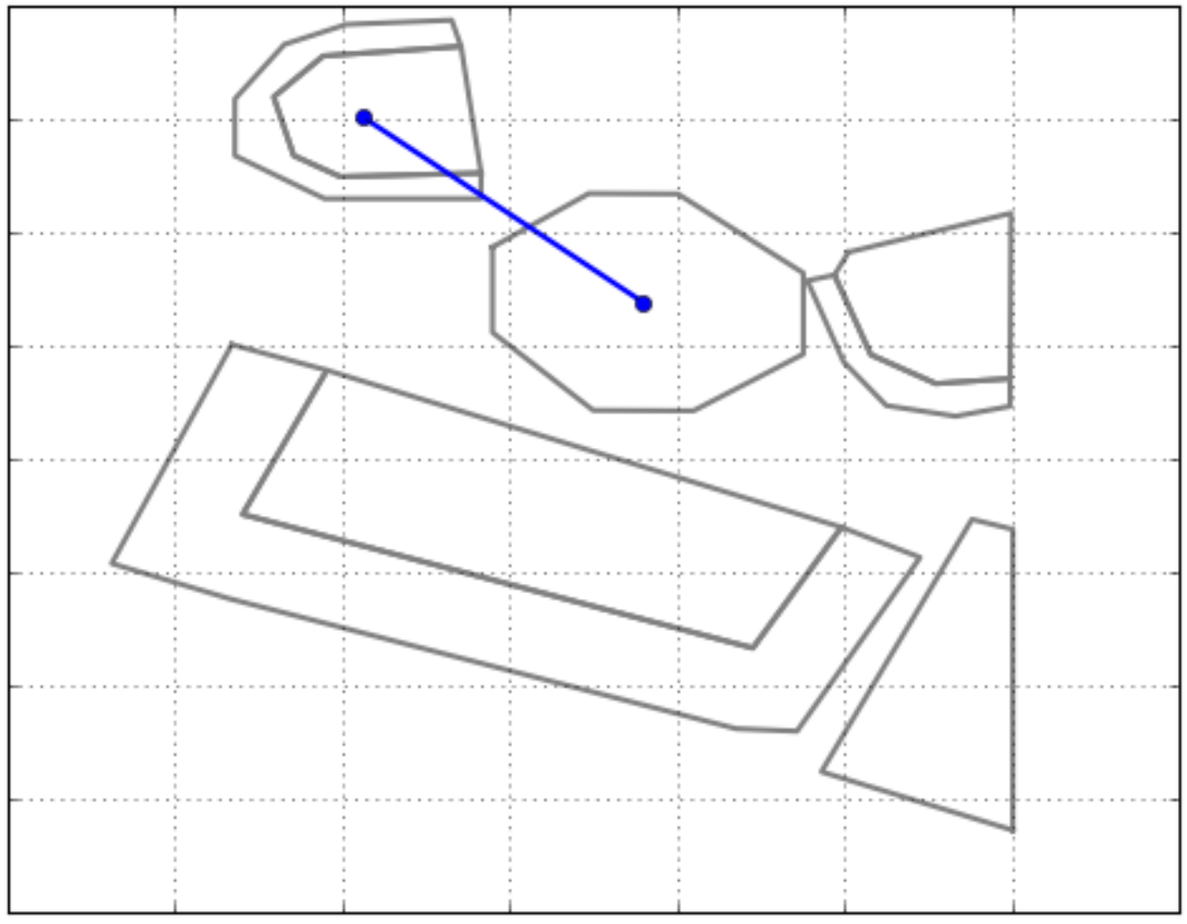
- **Length of route / gameplay (h_{length})**
- **Player physical movements (h_{RRT})**
- Target difficulty ($h_{difficulty}$)
  - #Enemies
  - Object placement in the scene
- Proportion of Surfaces Used ($h_{surfaces}$)

HEURISTICS

Length of Route / Gameplay (h_{length})



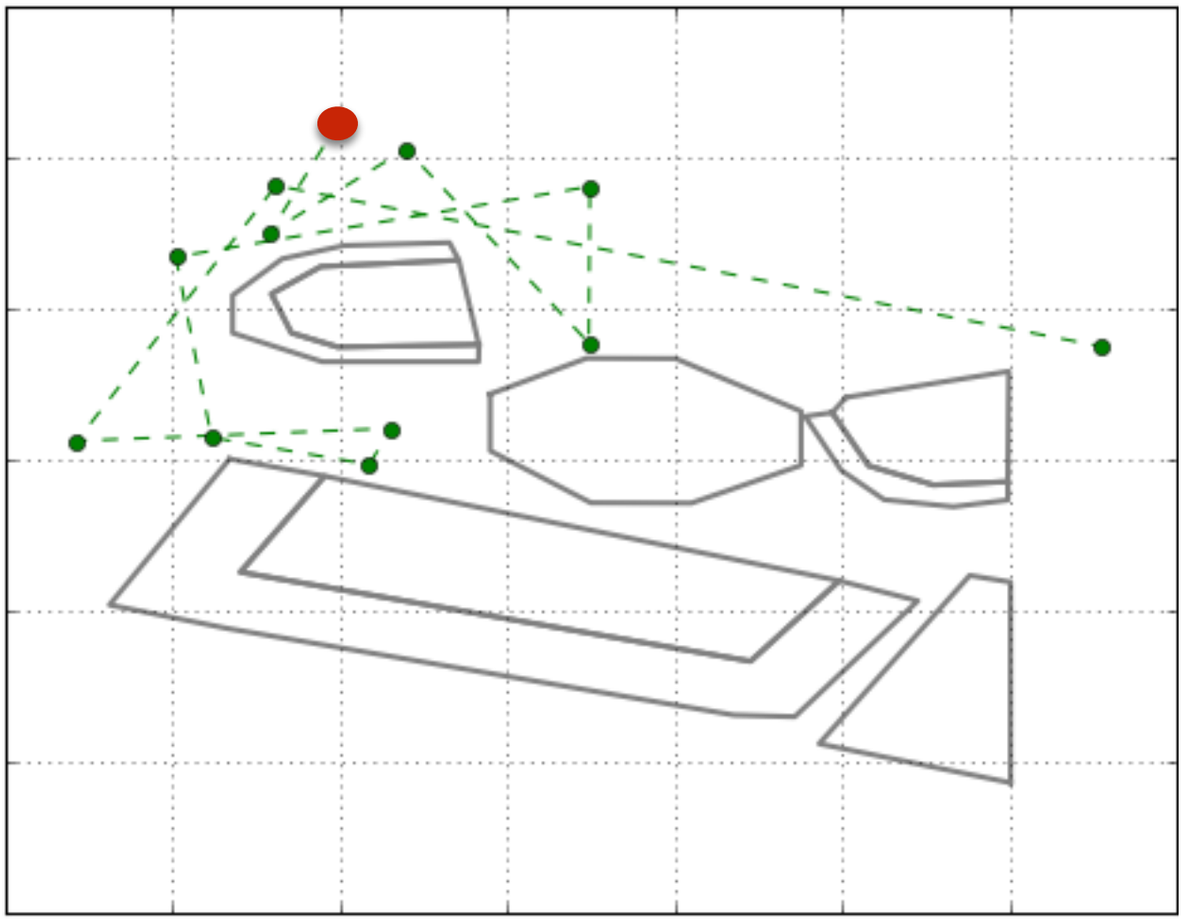
$h_{length} = 0.9$



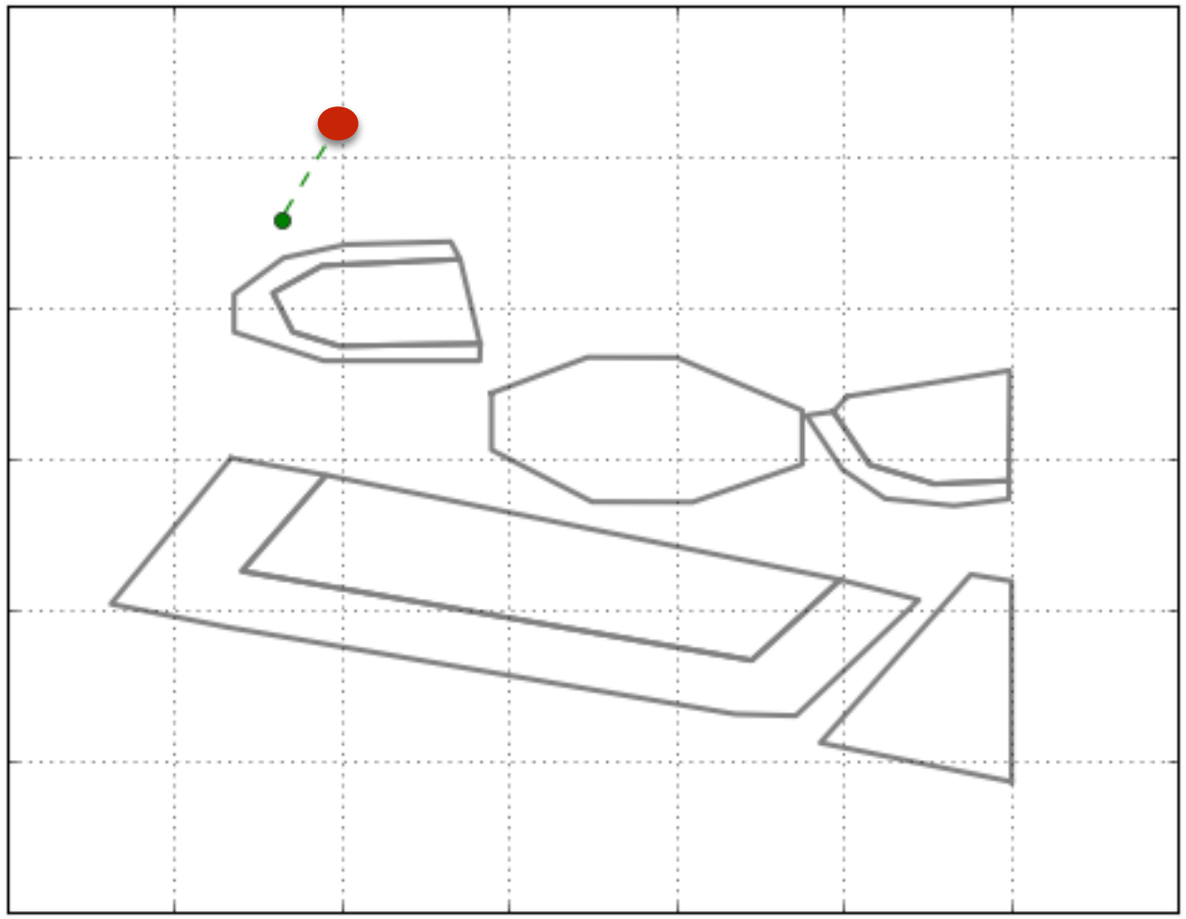
$h_{length} = 0.1$

HEURISTICS

Player Physical Movement (h_{RRT})



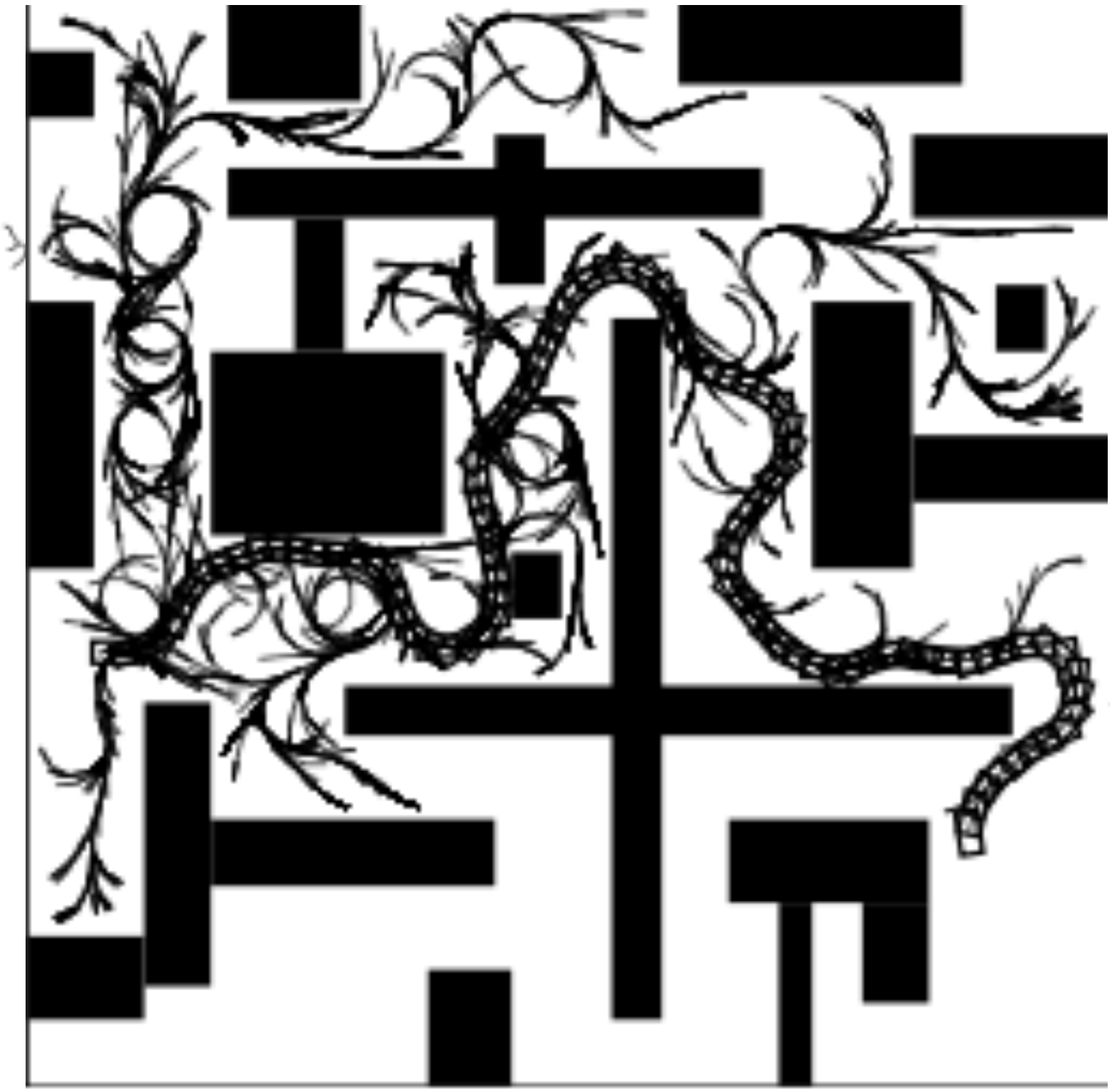
$h_{RRT} = 0.9$



$h_{RRT} = 0.1$

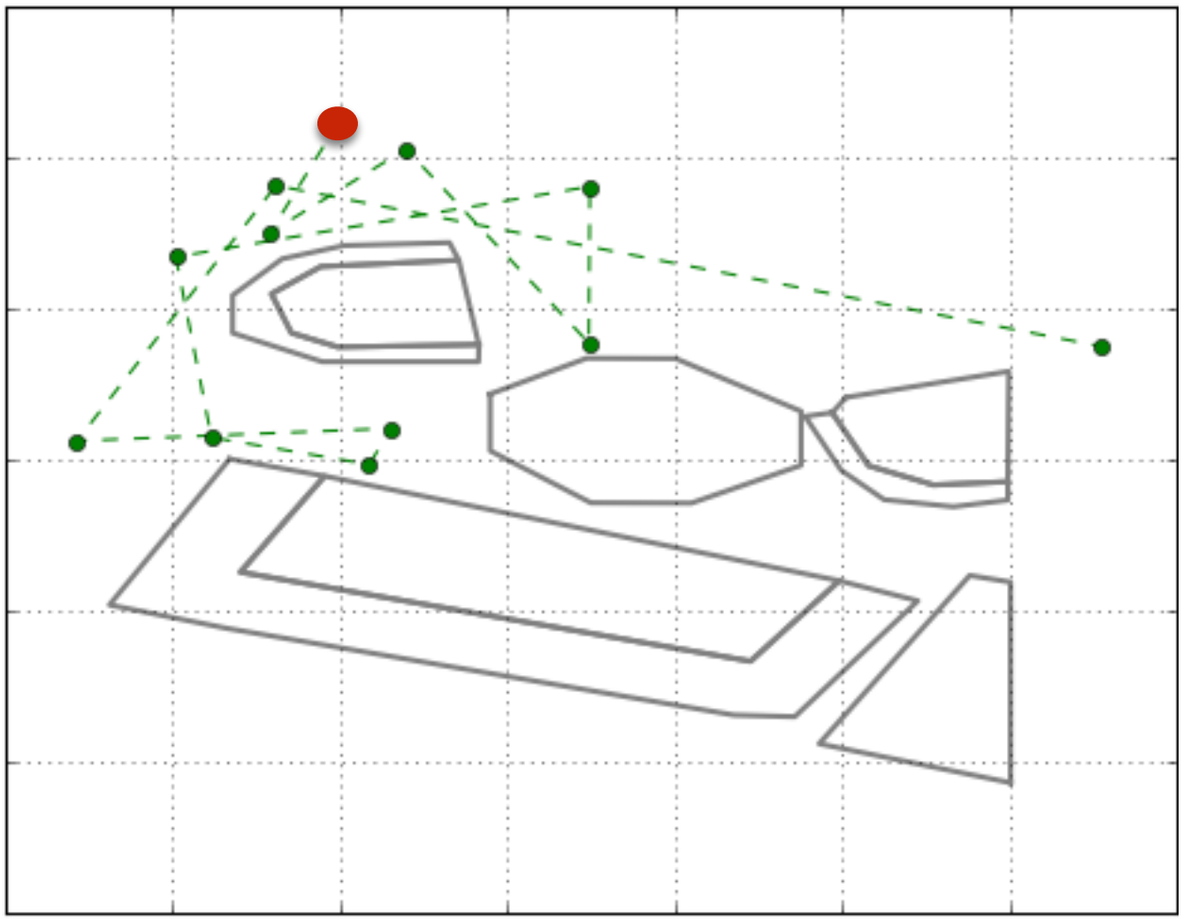
RAPIDLY EXPLORING RANDOM TREE

- Randomized data structure
- Works in continuous space
- Assume that $X_{obs} \subset X$



HEURISTICS

Player Physical Movement (h_{RRT})



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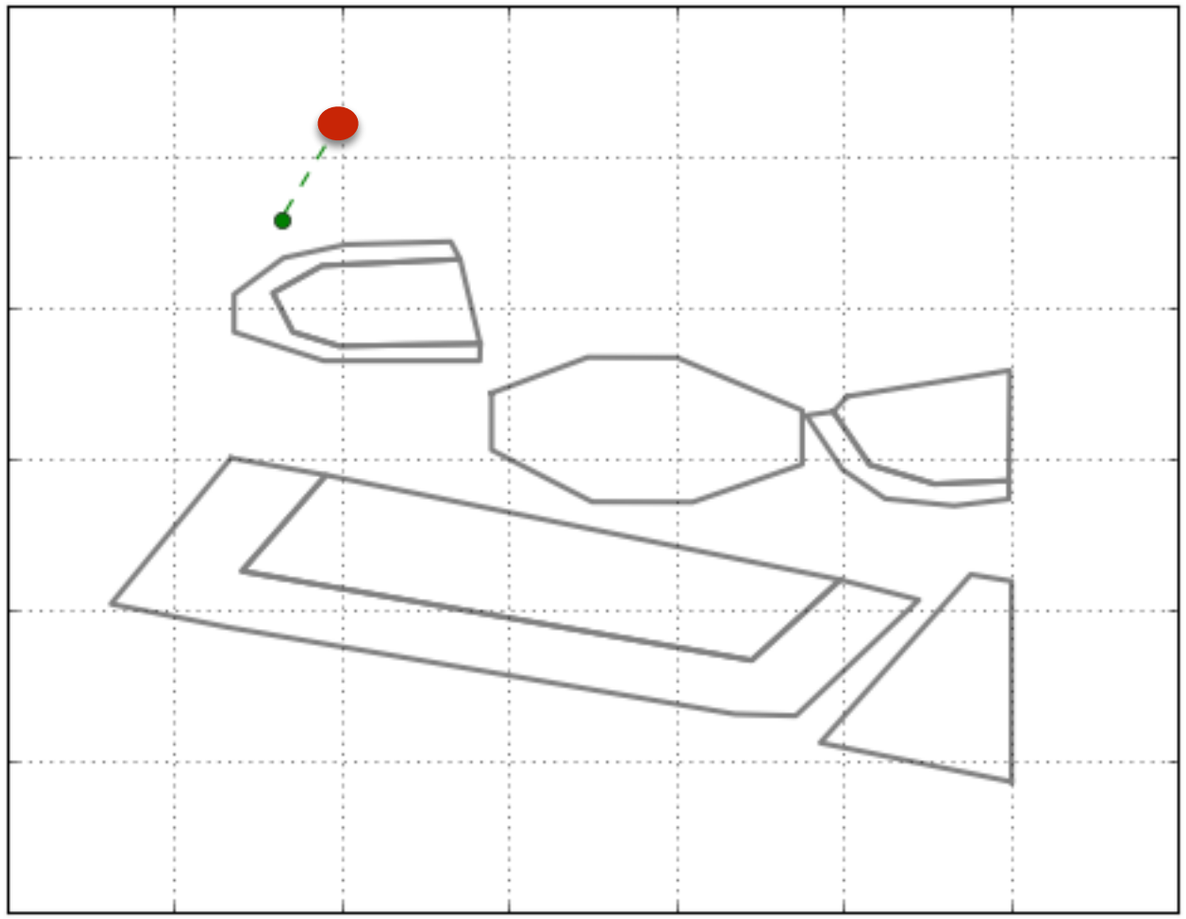

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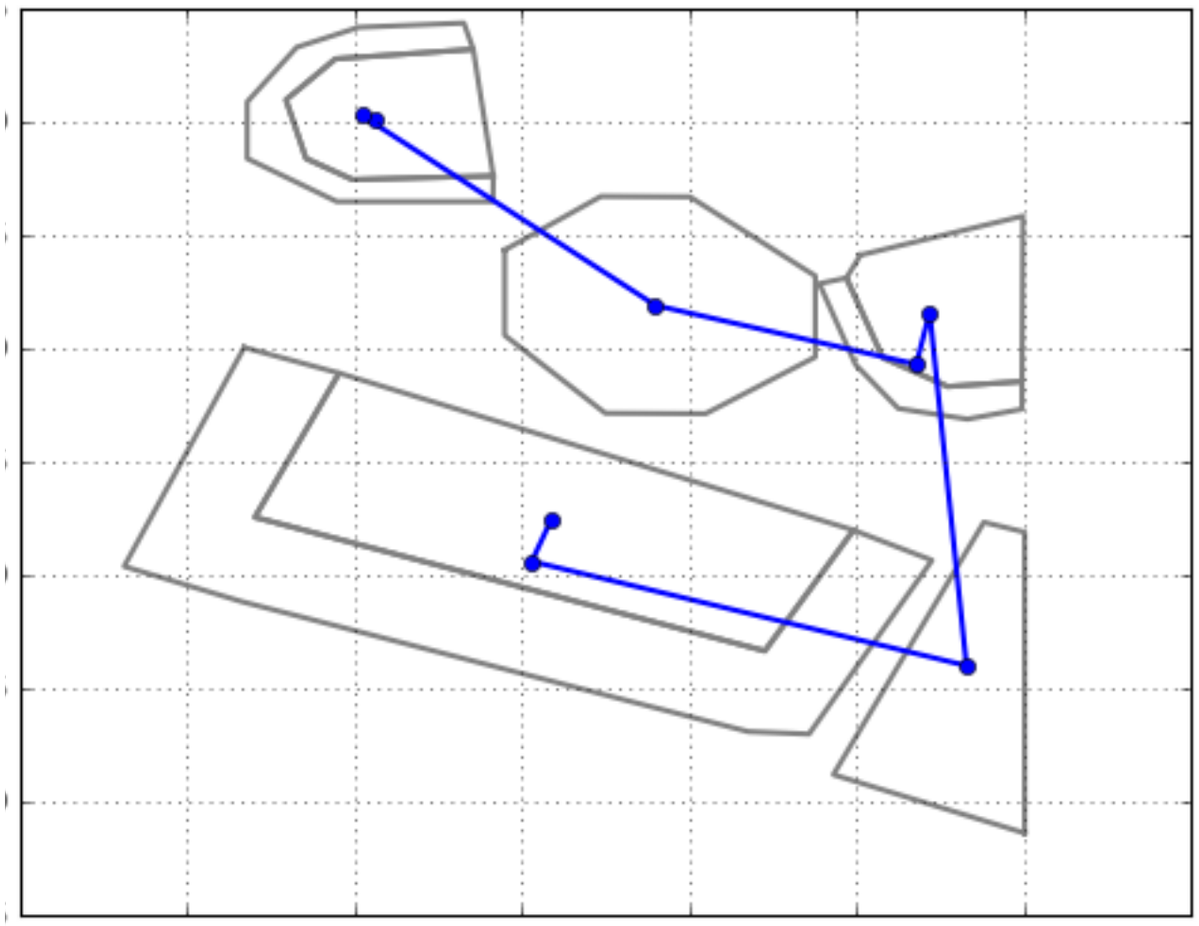
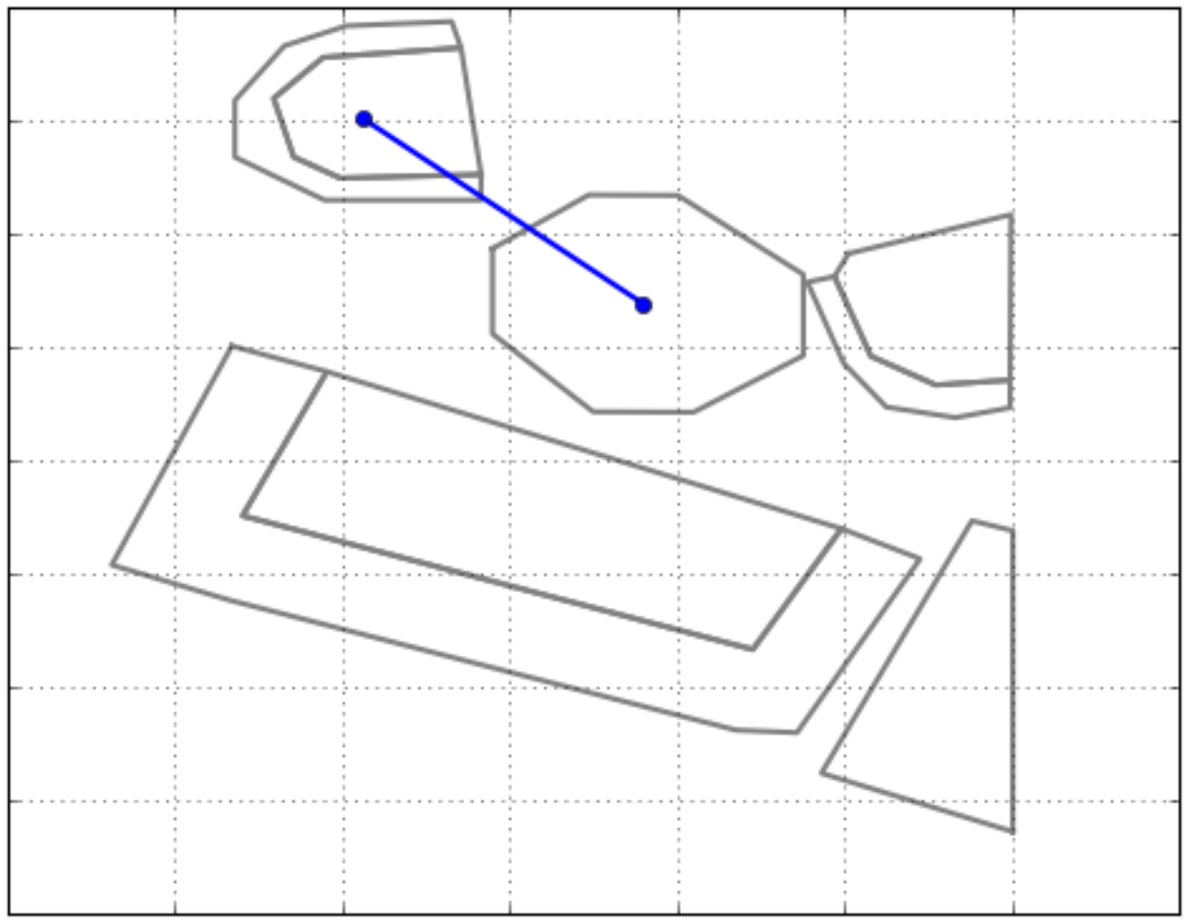
HEURISTICS

Length of route / gameplay (h_{length})





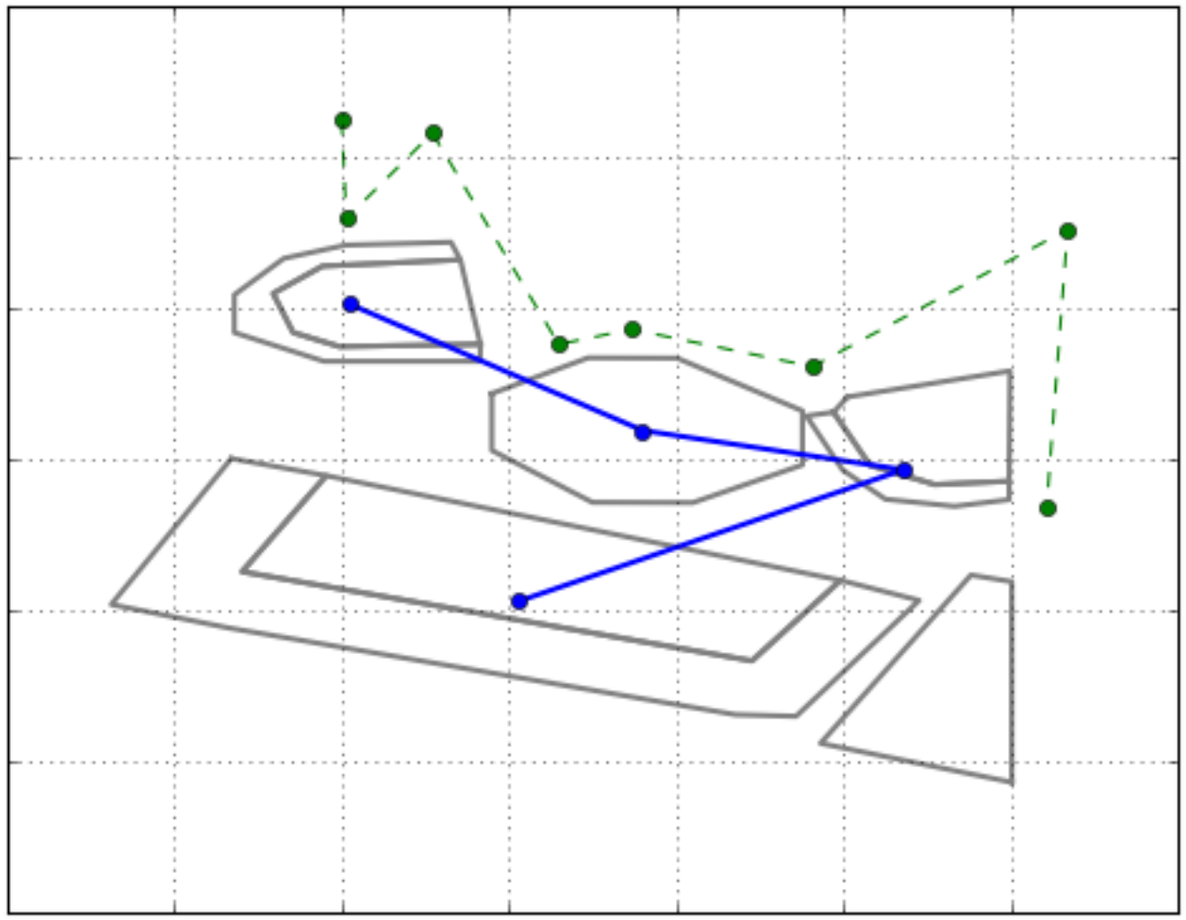
HEURISTICS

- Combination of heuristic functions: $h_{i...n}$ returning normalized results: (0...1)
- Weights: $w_i = (0 \ldots 1)$
  - Favor heuristics returning values closer to the weights

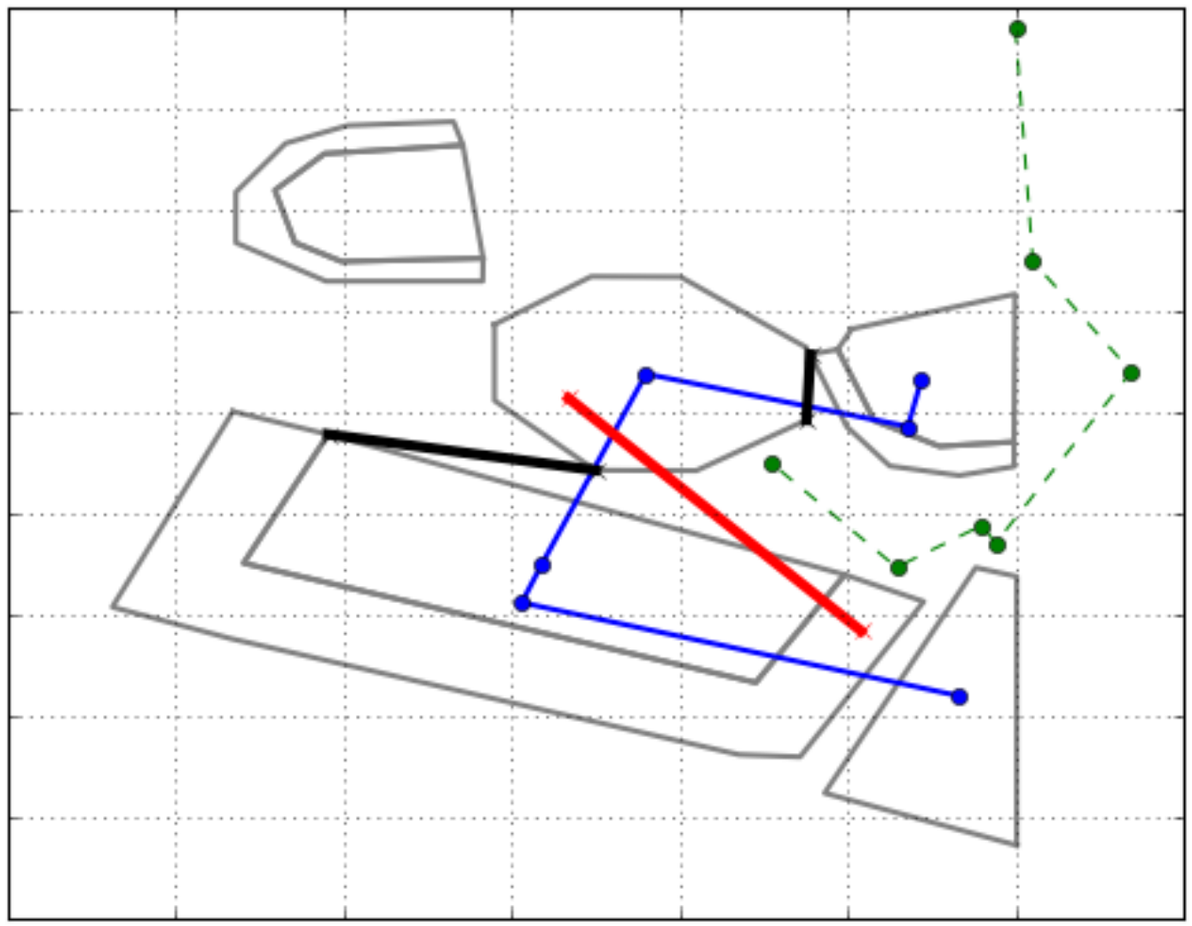
    $v_i = 1 - abs(h(i) - w)$
  - Value of each path: $\sum_{i=1}^{n} v_i$

HEURISTICS

$h_{length} = 0.5$, $h_{RRT} = 0.5$



$h_{length} = 0.8$, $h_{RRT} = 0.2$



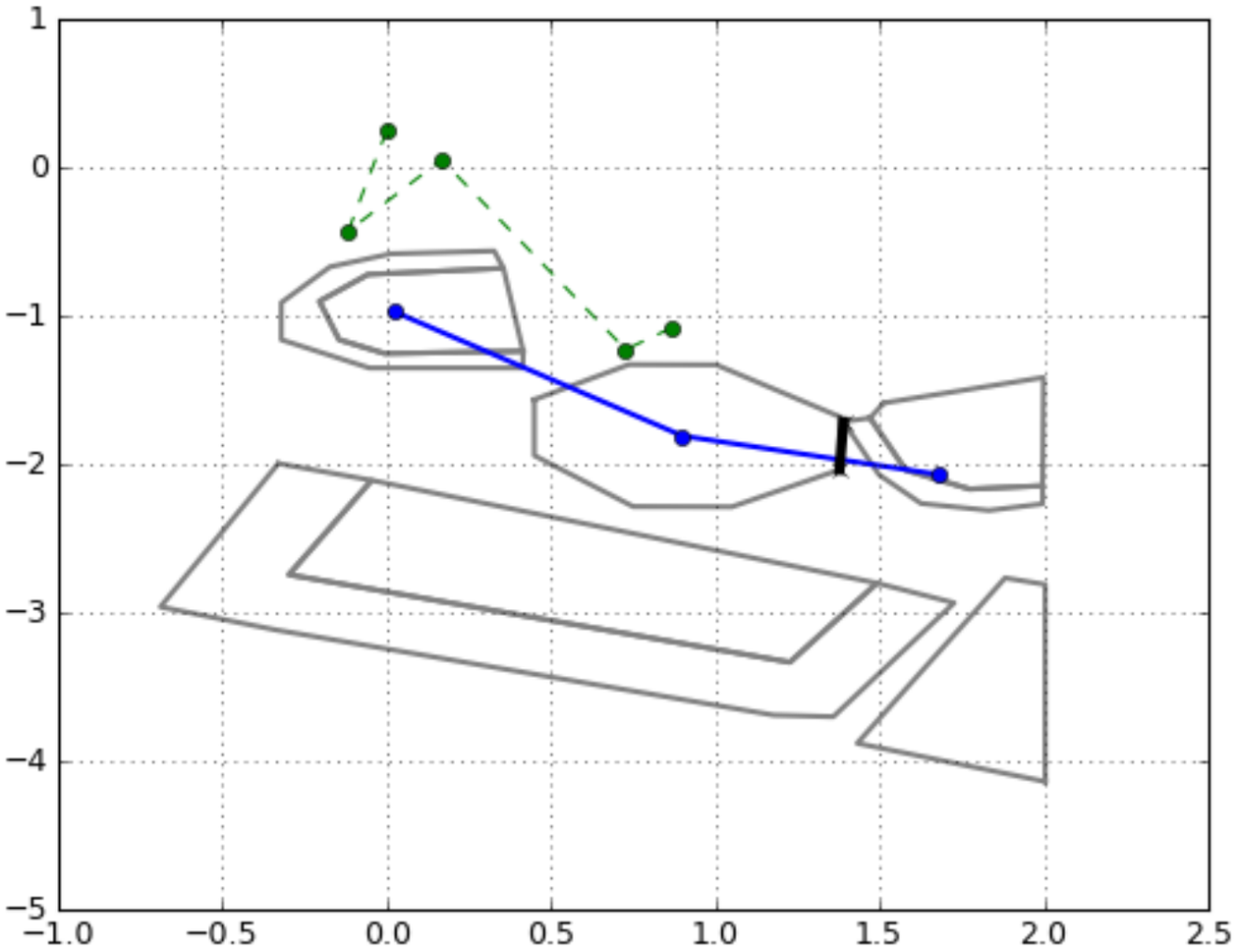
HEURISTICS

Path	v_{RRT}, w = 0.5	v_{length}, w = 0.5	$\sum v_i$
[0, 2, 6, 5]	**0.94**	**0.99**	**1.94**
[2, 6, 7]	0.71	0.98	1.70
[7, 6, 5, 0, 2, 1]	0.56	0.87	1.43

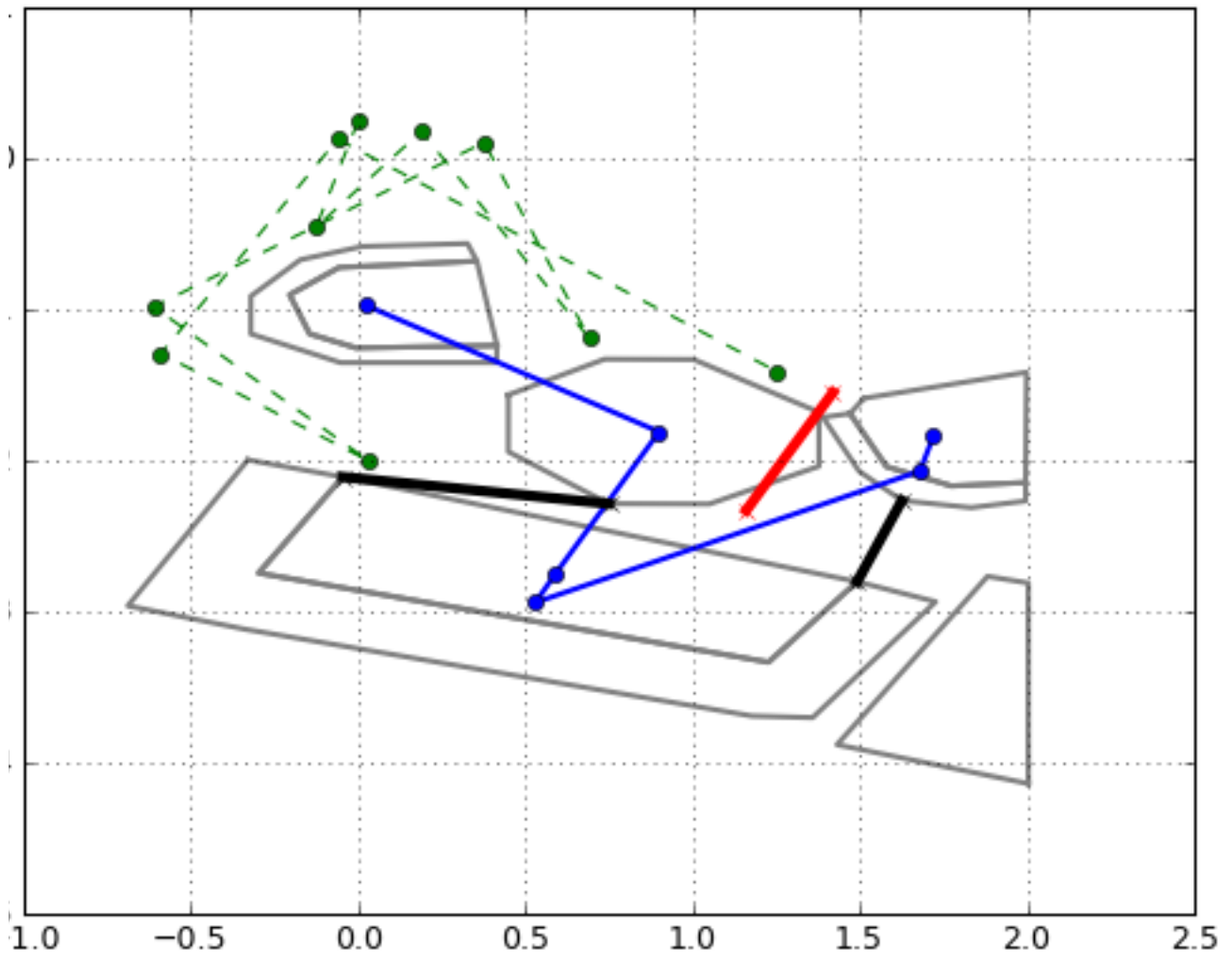
Path	v_{RRT}, w = 0.2	v_{length}, w = 0.8	$\sum v_i$
[0, 2, 6, 5]	0.76	0.84	1.60
[2, 6, 7]	0.41	0.89	1.30
[7, 6, 5, 0, 2, 1]	**0.86**	**0.99**	**1.85**

HEURISTICS

$h_{length} = 0.2$, $h_{RRT} = 0.2$

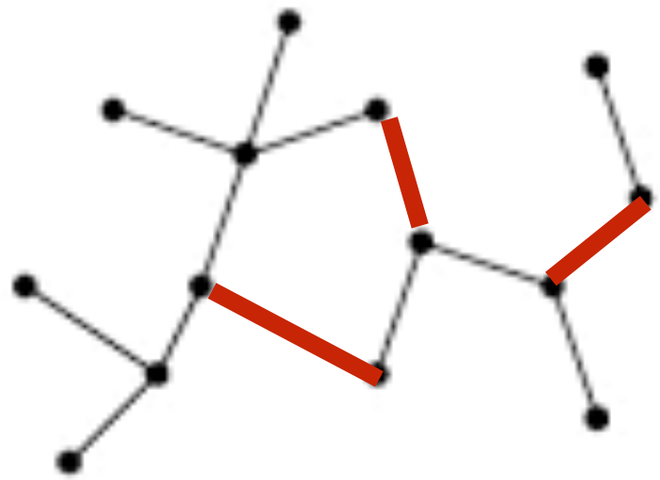


$h_{length} = 0.8$, $h_{RRT} = 0.8$



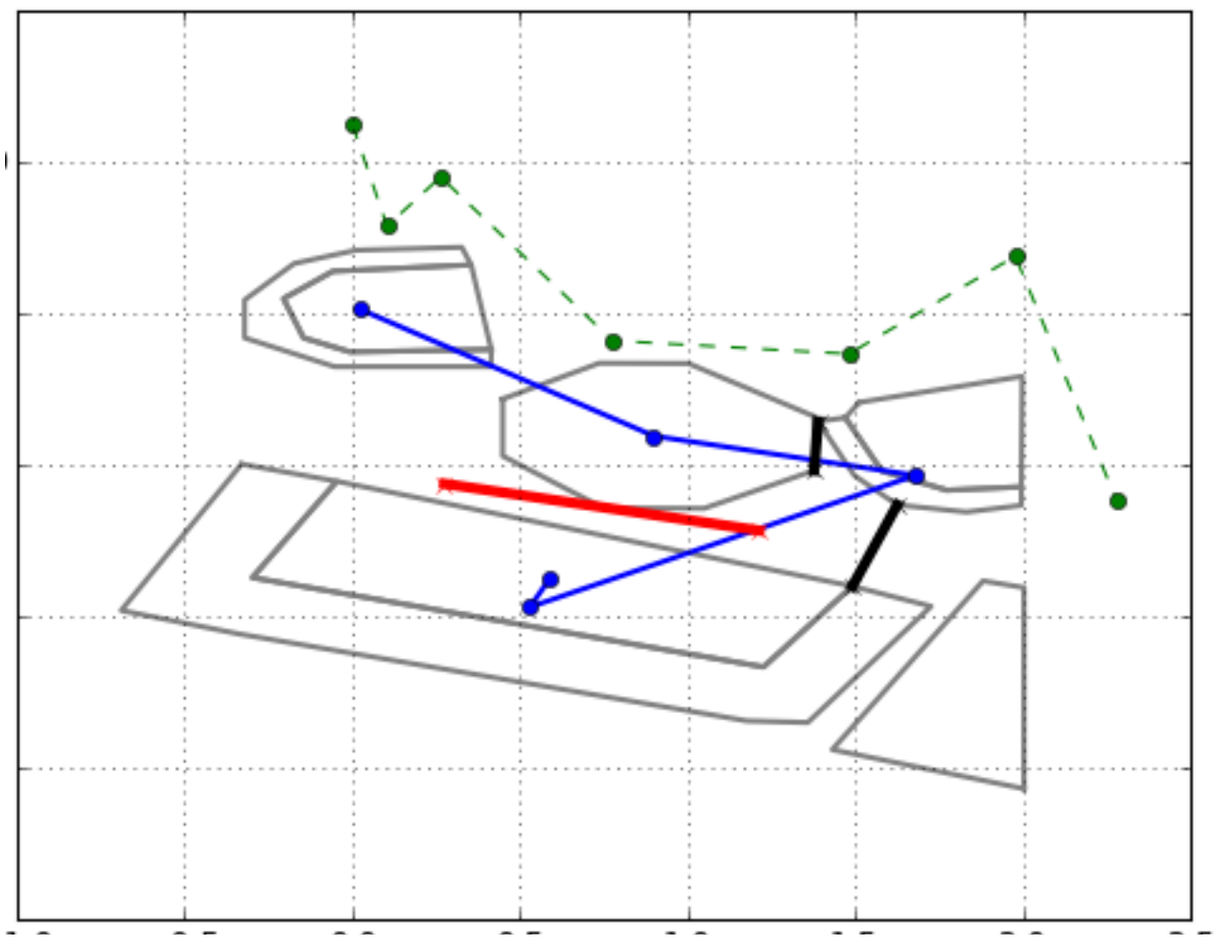
VIRTUAL PLATFORMS

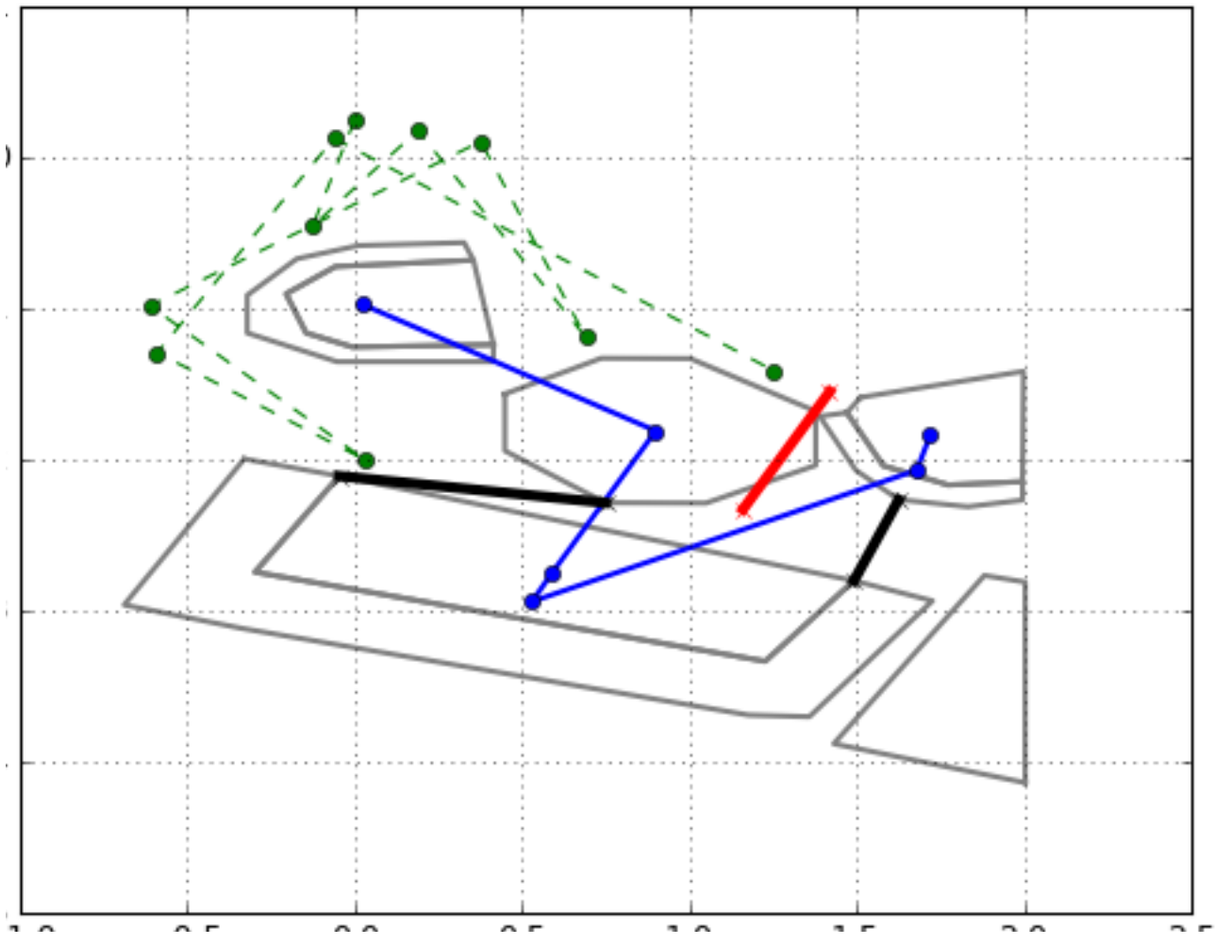
- Generated between surfaces too far to jump
- Connect disparate areas of the room to create unique areas of play
- Distance from platforms can be adjusted per difficulty level of the player



VIRTUAL WALLS

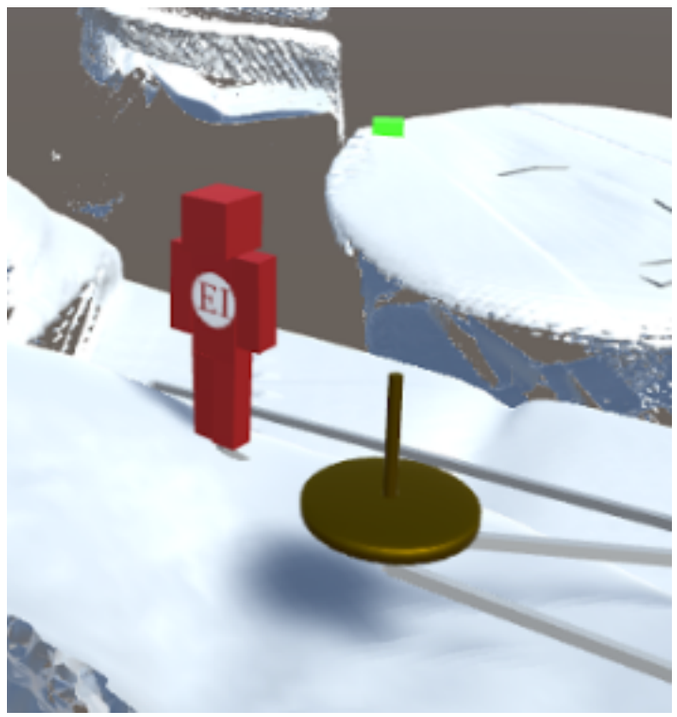
- Restricting the player from directing Lemmings through sub-optimal paths





VIRTUAL ENEMIES

- Currently associated with semantic rules
- For instance,
  - Virtual books follow you down long straight path segments and try to flatten you
  - Virtual paper tacks are generated near bends in the path



FUTURE WORK

- Integration with a mixed reality device
- Evaluation:
  - Choice of interactions
  - Heuristics
- Stronger coupling of the virtual and real world
  - Room identification for better PCG (IoT, Neural Net)

DISCUSSION

- Need to design levels considering the players' interactions with the real environment
- Player can affect the generation of levels
  - Rearranging furniture
  - Introducing new elements into the environment
  - Handle challenge progressions across environments

DISCUSSION

- Dynamic environments - Level generation doesn't happen just once!
- Rethink heuristics for Mixed Reality games
  - Physical movement, reachability are just a few
  - Eye tracking for player modeling data
- Beyond machine vision and surface detection
  - Believable embedding of virtual elements into the physical world
  - Semantic understanding and perception of the player's surrounding

WHAT'S NEXT?

> *Our kids are going to get really weird… All of a sudden, sights don't have to be sights, sound doesn't have to be sounds. Everything can be remapped and interchanged.* ***Reality in the future will mean something different than it does to us now, and the human experience is going to vastly expand.***
>
> *— David Holz, Leap Motion CTO (May 2015)*


THANK YOU