Paper Session: 3

IEEE VR 2019
OSAKA

Effects of Tracking Area Shape and Size on Artificial Potential Field Redirected Walking

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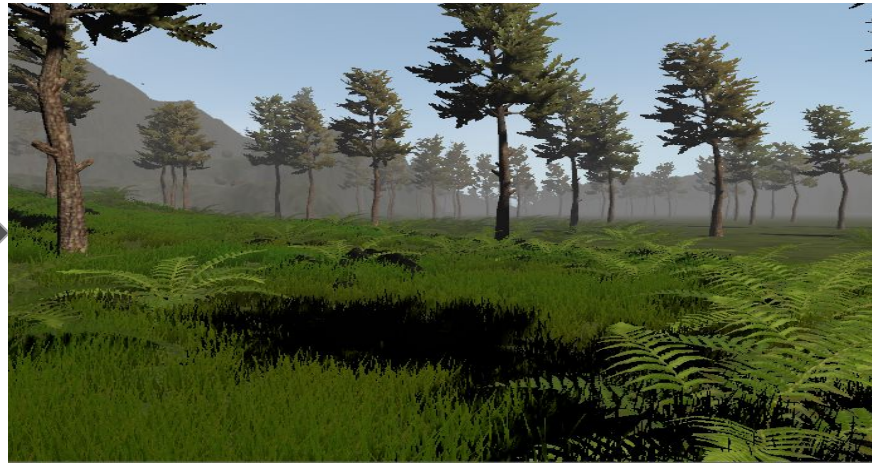
Conference Paper

Problem & Motivation

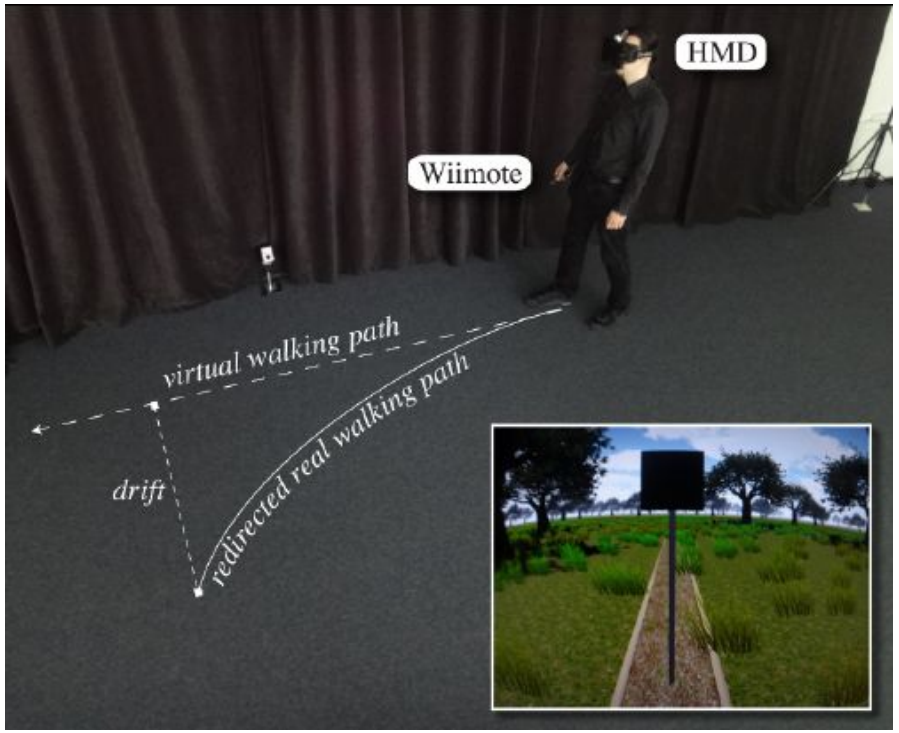
How do we allow users to navigate virtual worlds that are larger than the available tracking space?



Problem & Motivation

Redirected walking

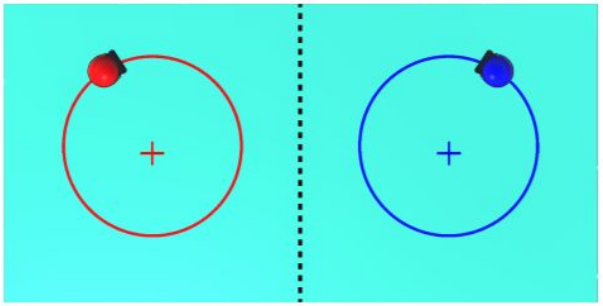
- Manipulate the virtual world to avoid obstacles in the tracking area
- Steer to Center (STC) requires a large space to work effectively.



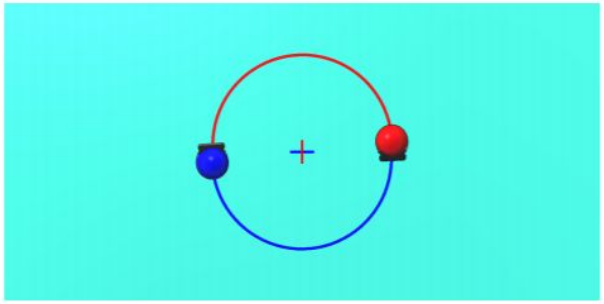
Source: Bruder, G., Lubas, P. and Steinicke, F., 2015.

Related Multi-user Results

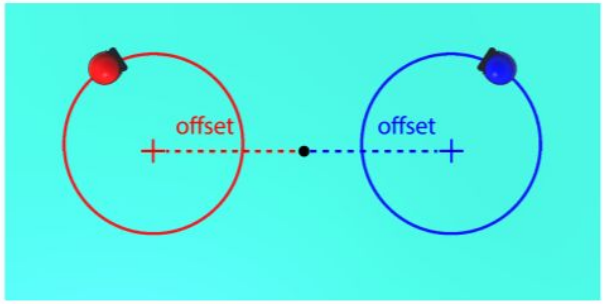
Azmandian, Grechkin, Rosenberg 2017



(a) Subdivision Strategy



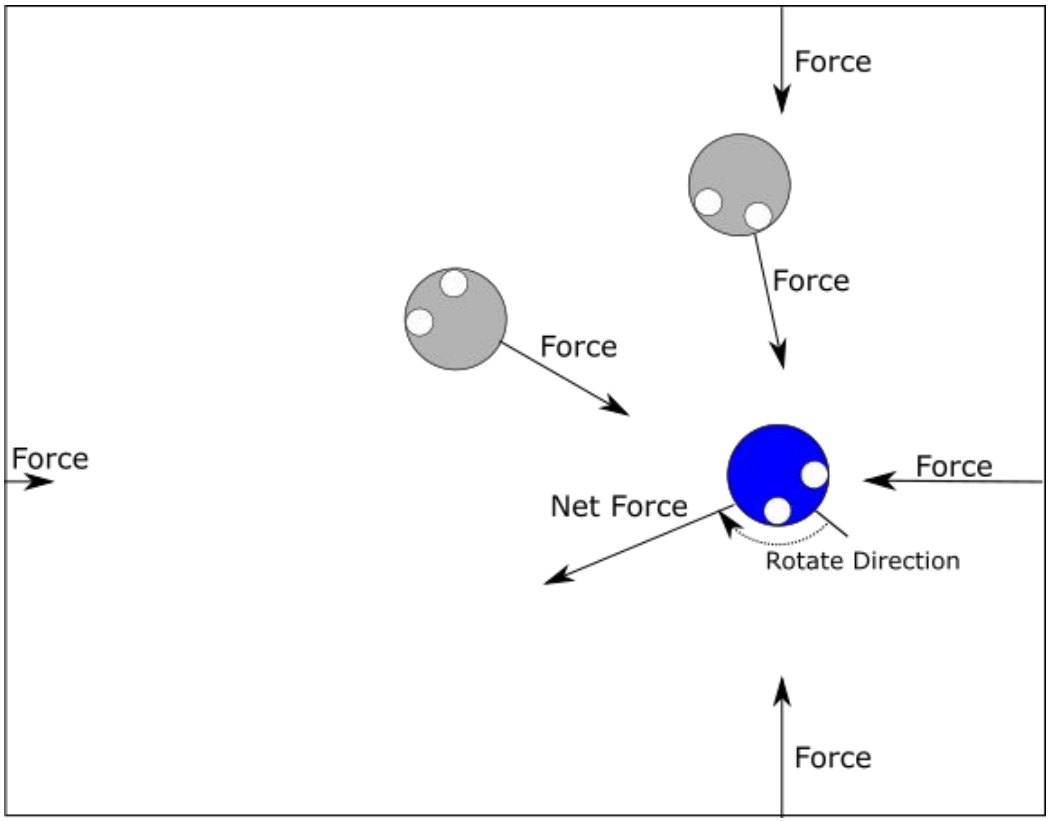
(b) Sharing Strategy with Common Center



(c) Sharing Strategy with Offset Center

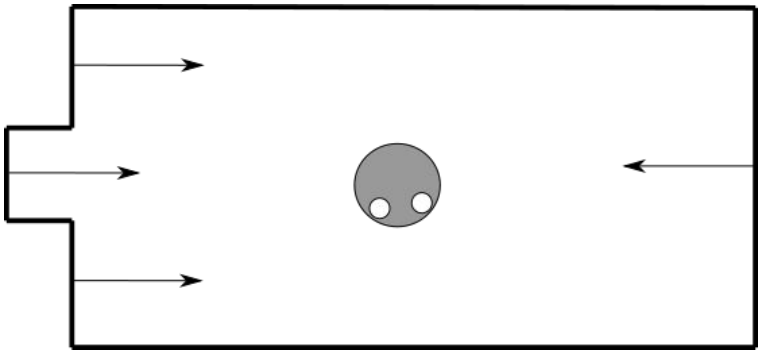
Artificial Potential Field (APF-RDW)

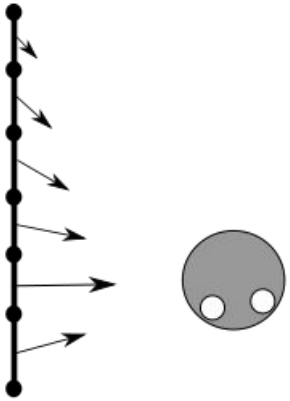
- Originally presented in (Bachmann 2019)

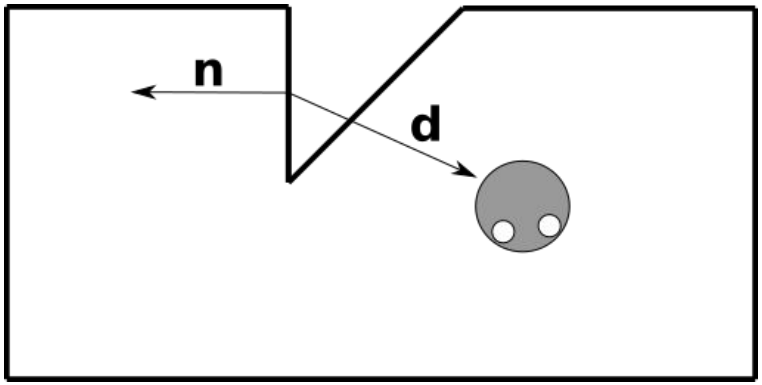


Modifications to APF-RDW

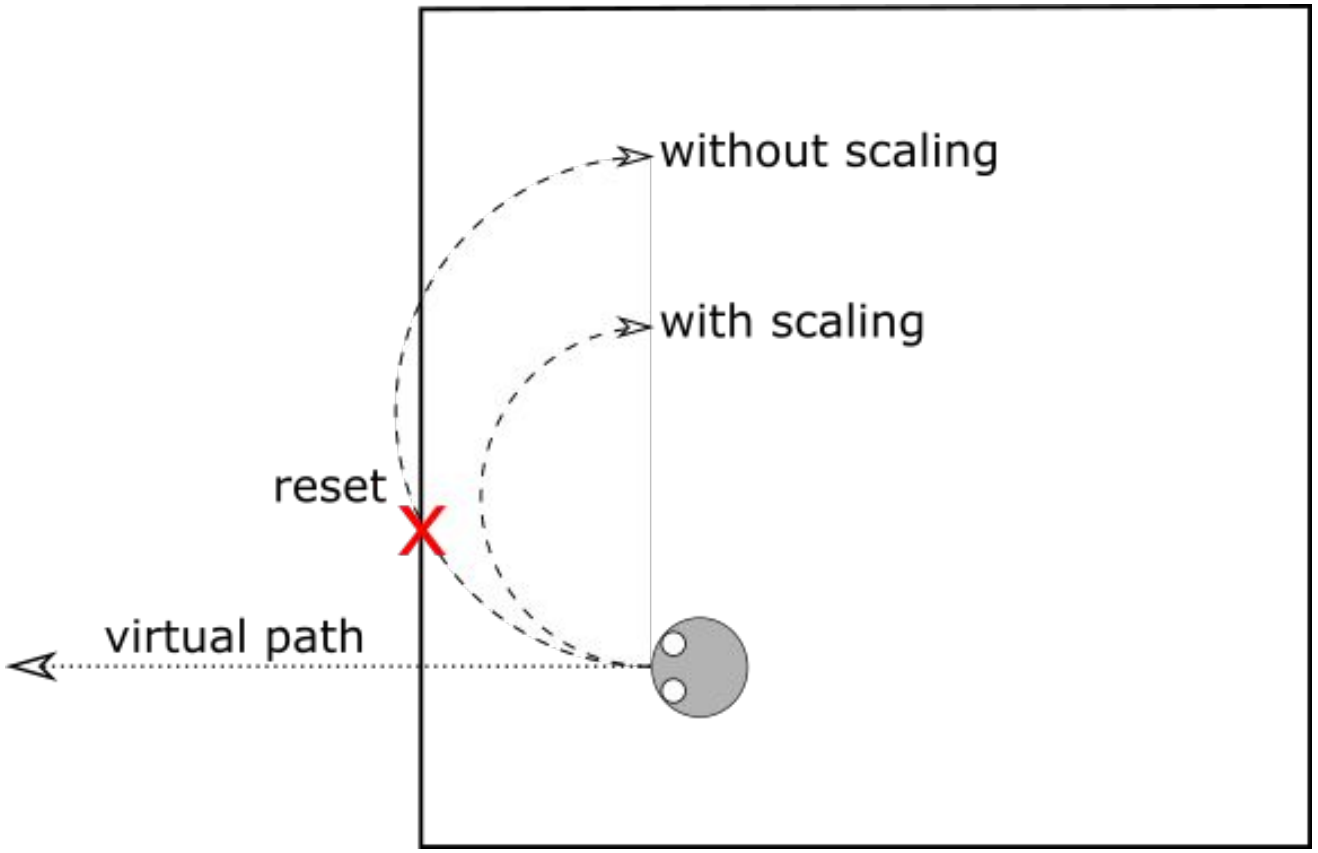
Goal: Allow APF to function effectively in irregular concave spaces.





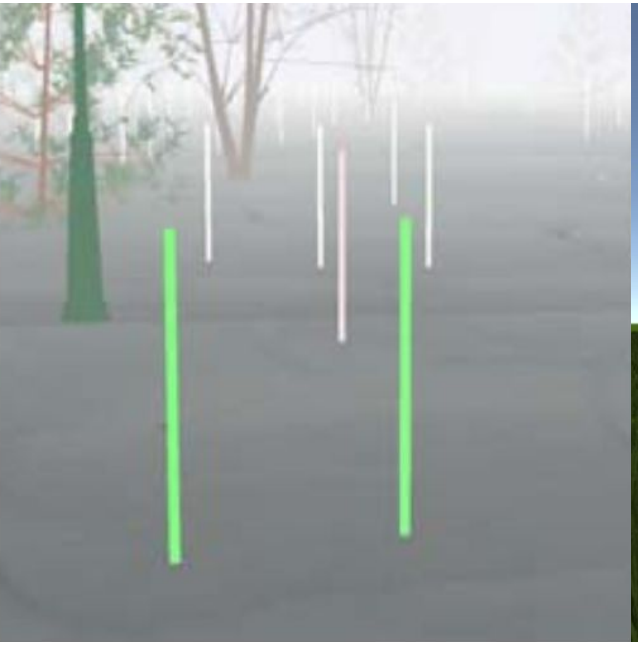


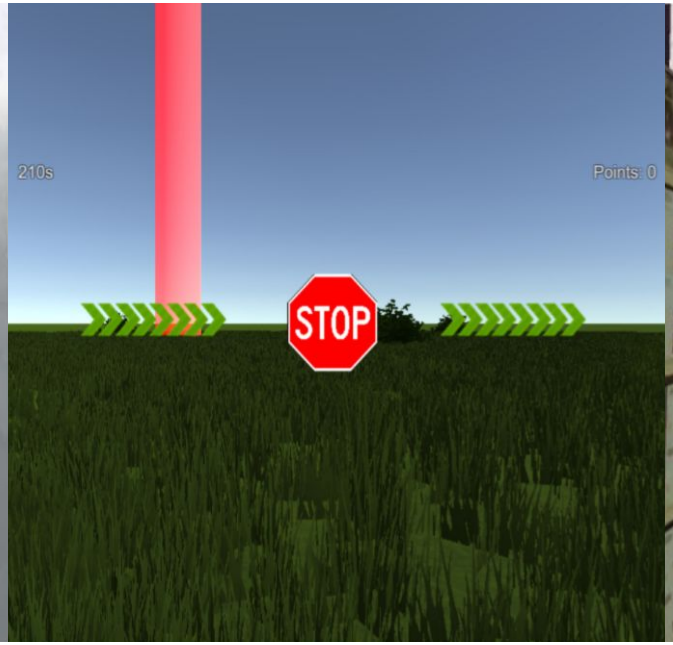
APF - Proximity Scaling



Method

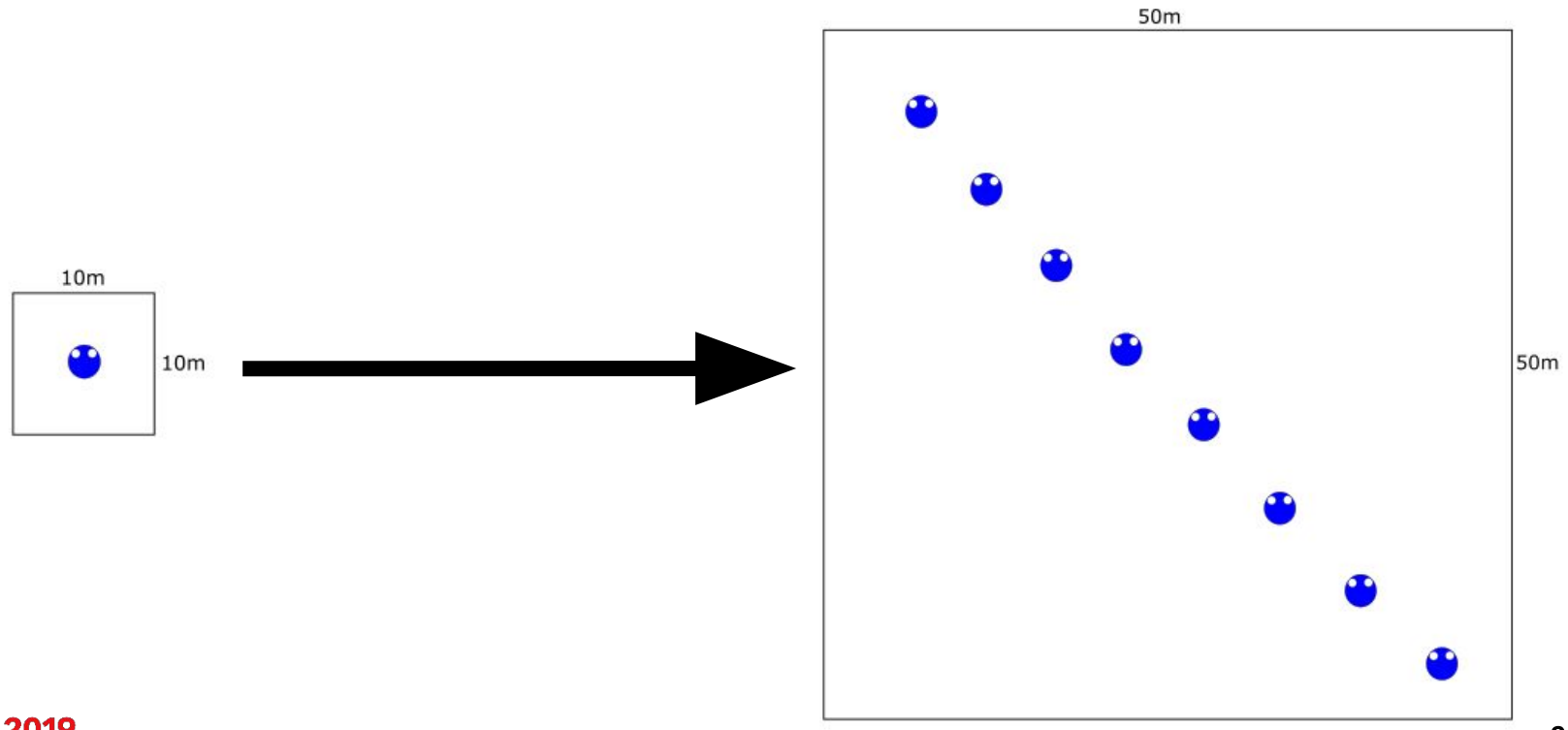
Simulations were based on 288 paths collected during four previous live user experiments





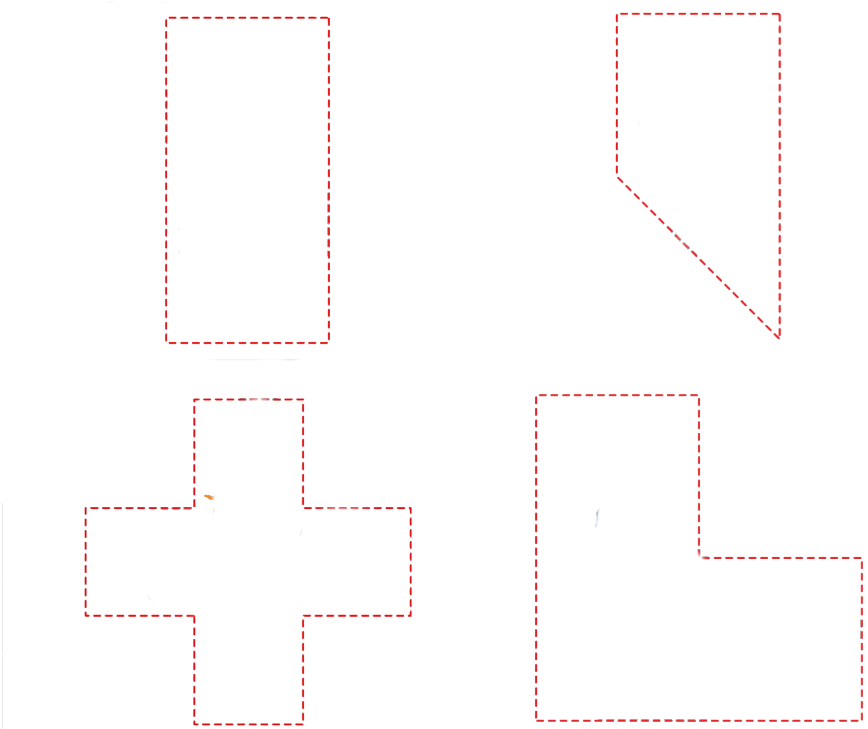
Room Sizes Tested

1. Square Rooms of size (in meters) 10x10, 15x15, 20x20, 25x25, 30x30, 40x40, 50x50



Room Shapes Tested

2. Four different shaped rooms: Rectangle (2:1 ratio), Trapezoid, Cross, and L-Shape



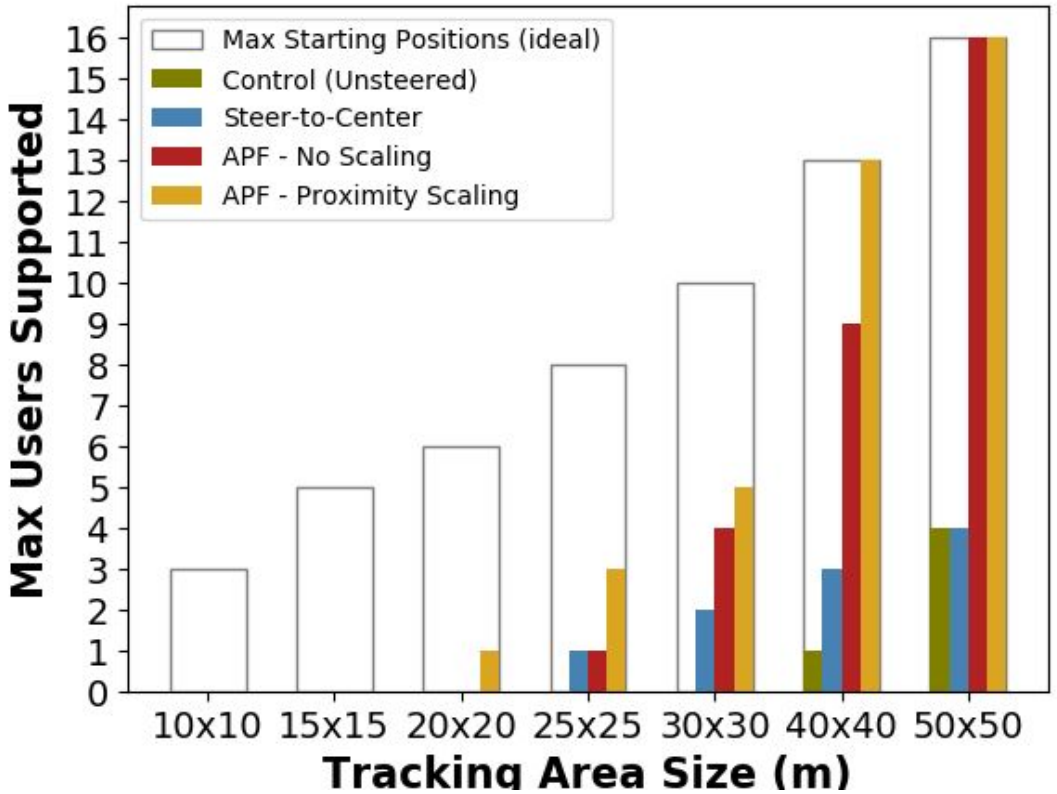
Conditions Tested

Four different conditions tested:

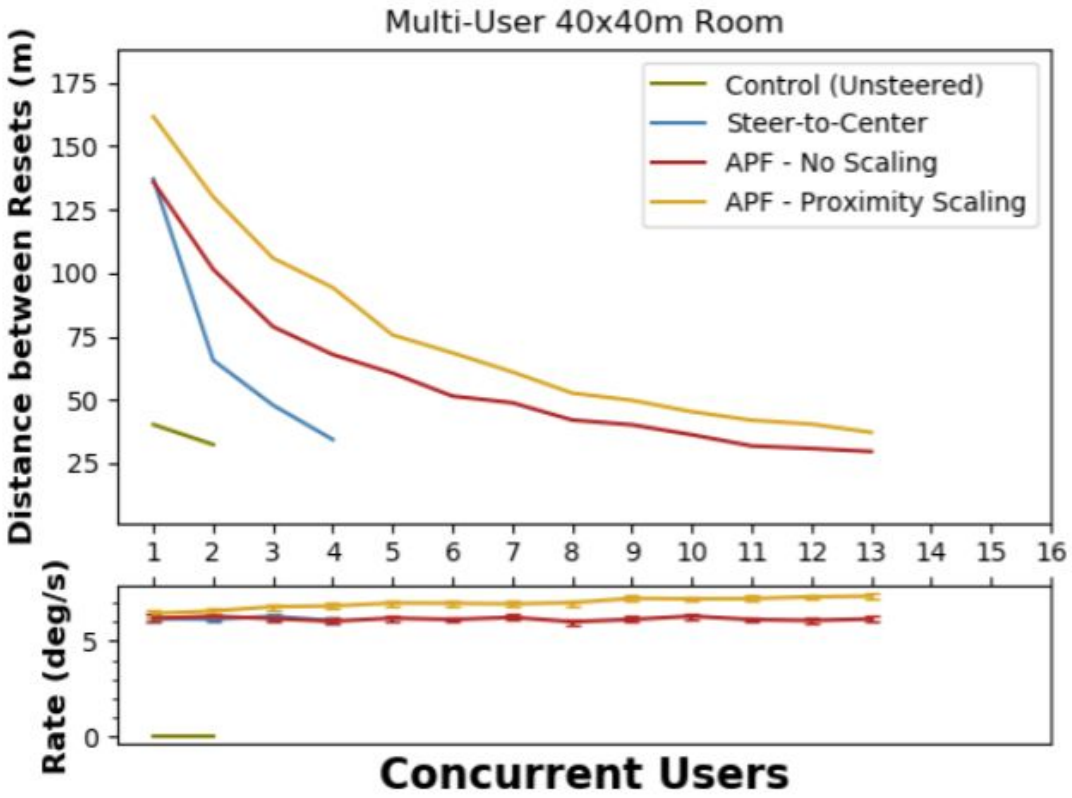
1. Control (no redirection)
2. Steer to Center
3. Artificial Potential Field without Scaling (APF-U)
4. Artificial Potential Field with Scaling (APF-SC)

APF-R (APF Resetting) used with all methods

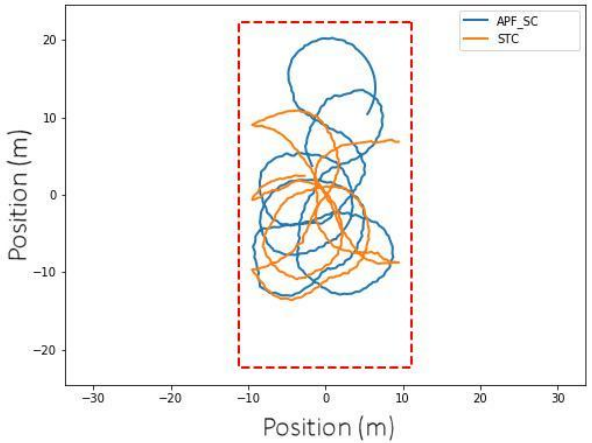
Results: Max Users Supported in Square Rooms at < 1 reset / min

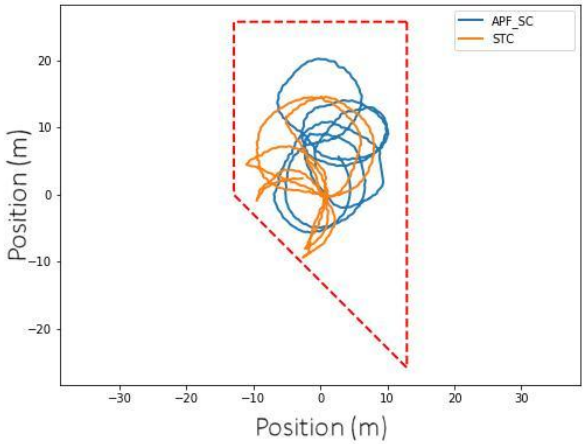


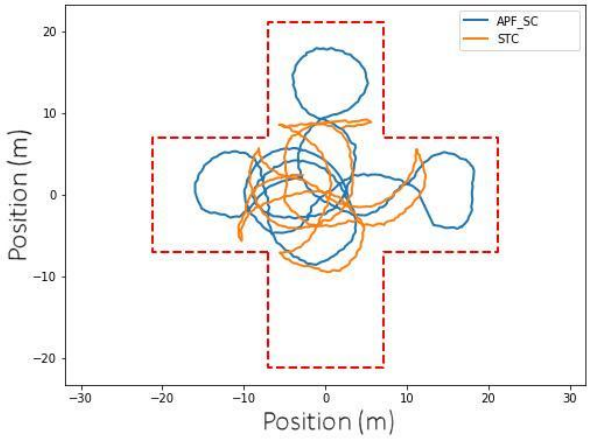
Multi-User Distance Between Resets and Steering Rates

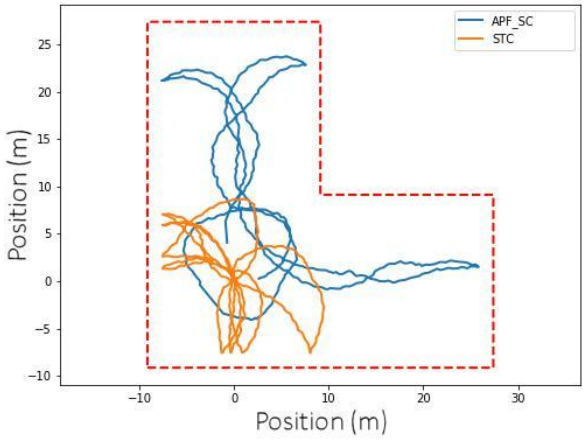


Performance with Different Room Shapes

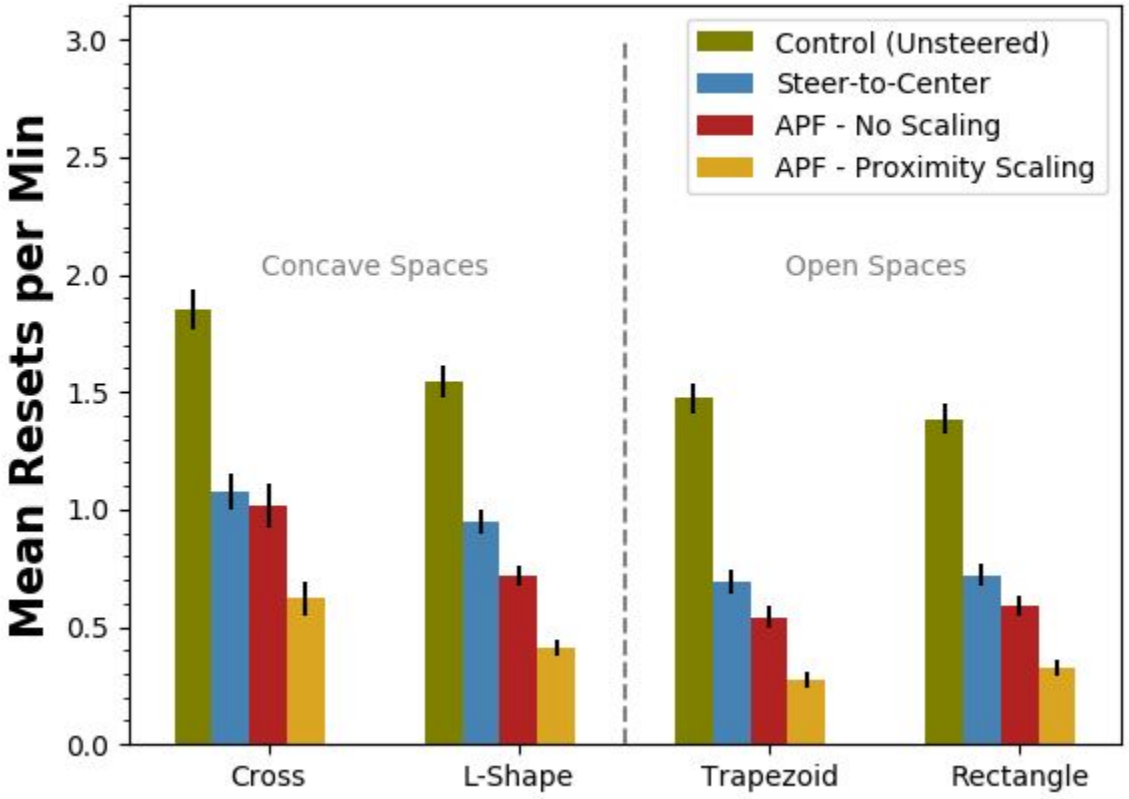








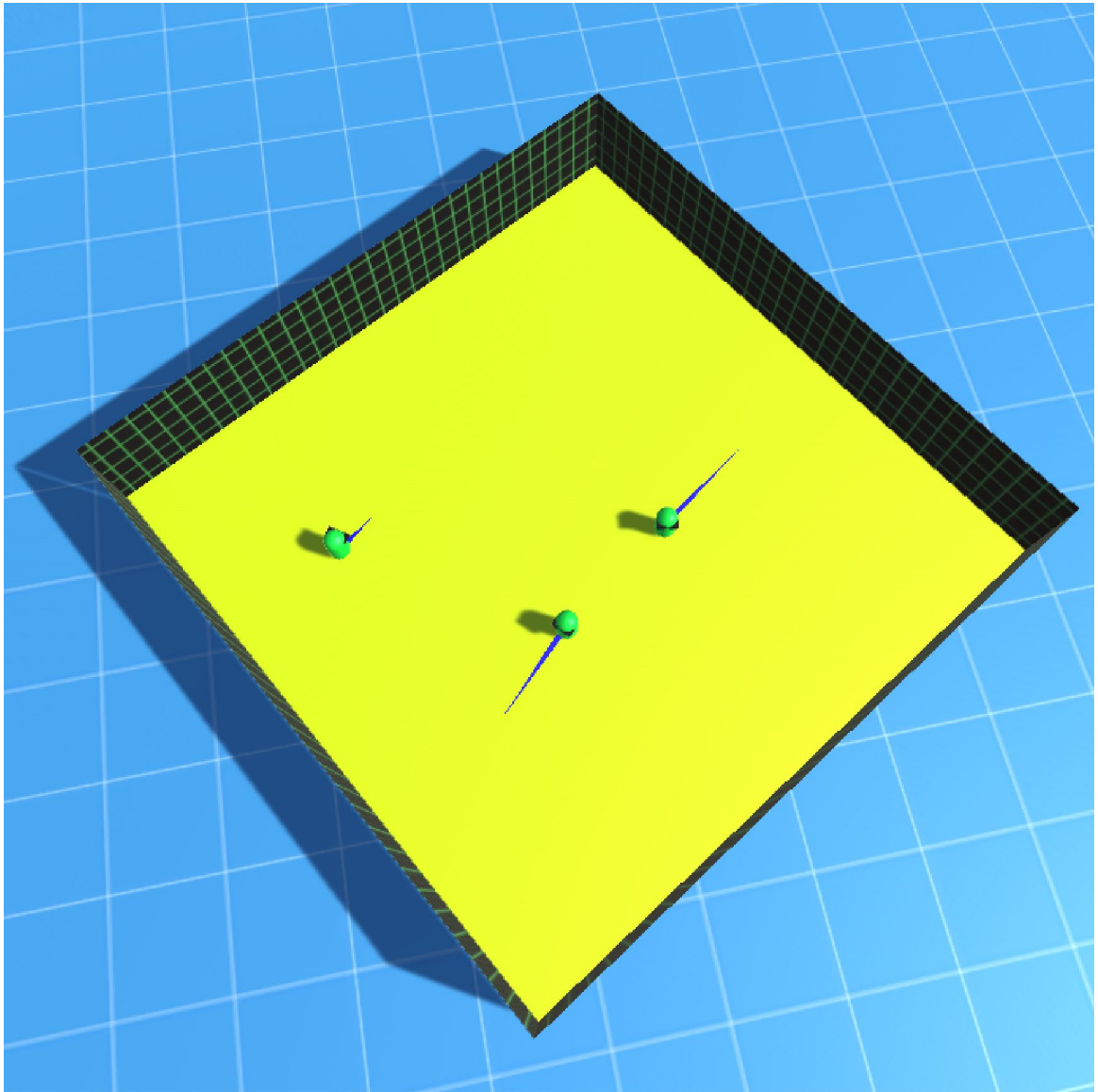
Performance with Different Room Shapes



Conclusion

- APF outperforms STC in the number of users that it can support
- APF outperforms STC in handling irregular concave rooms
- APF-SC displays clear advantages over APF-U while having a relatively small effect on the average steering rates.

Questions?



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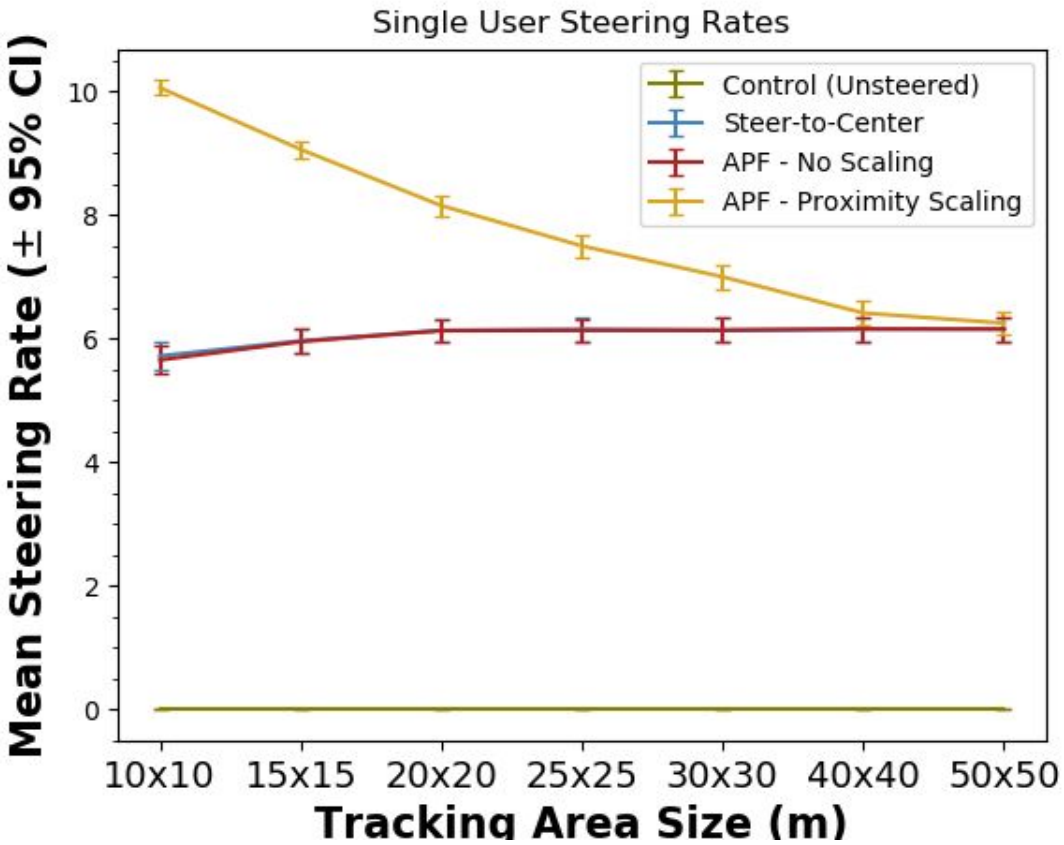
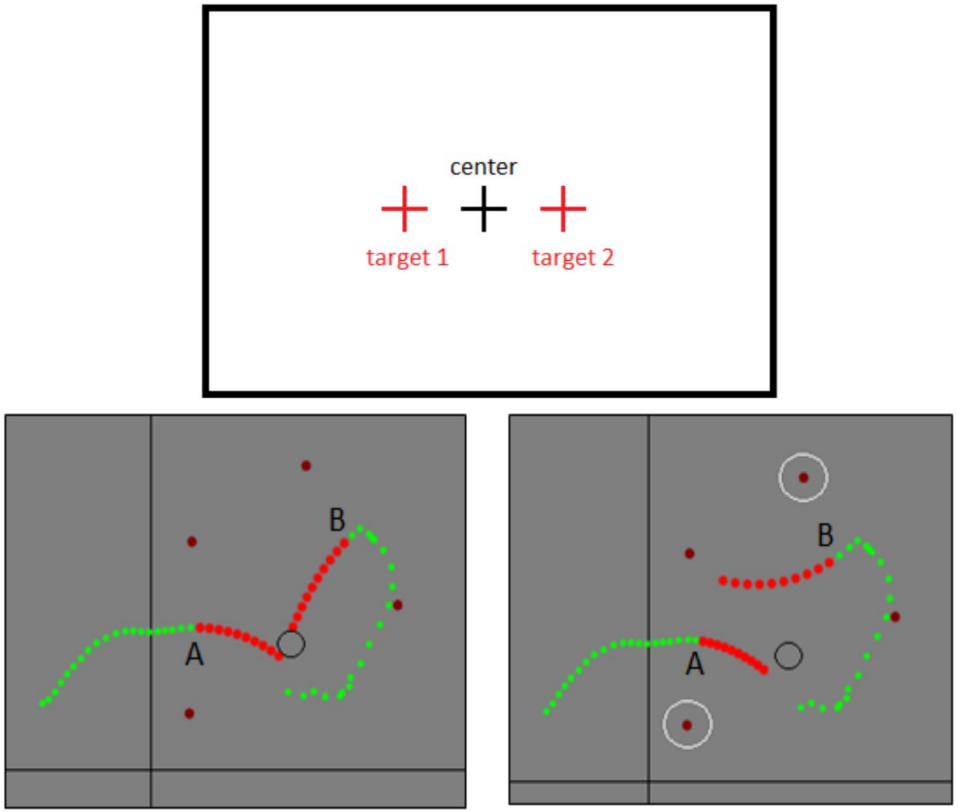
Appendix

Single User Steering Rates



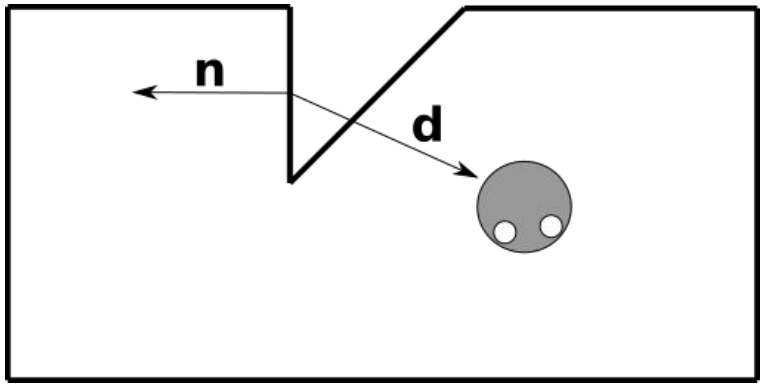
Related Multi-user Results

Holms 2012



Modified force function

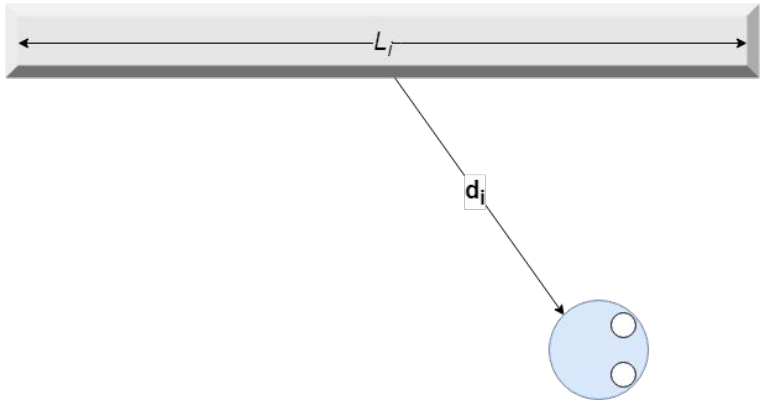
$$\mathbf{w}_i = \begin{cases} CL_i \frac{\mathbf{d}_i}{\|\mathbf{d}_i\|} \frac{1}{\|\mathbf{d}_i\|^{\lambda}}, & \text{if } \mathbf{n} \cdot \frac{\mathbf{d}_i}{\|\mathbf{d}_i\|} > 0. \\ \begin{bmatrix} 0 \\ 0 \end{bmatrix}, & \text{Otherwise.} \end{cases}$$



C is a scaling factor

λ is the wall fall-off factor

L_i is the length of wall i



Modified force function

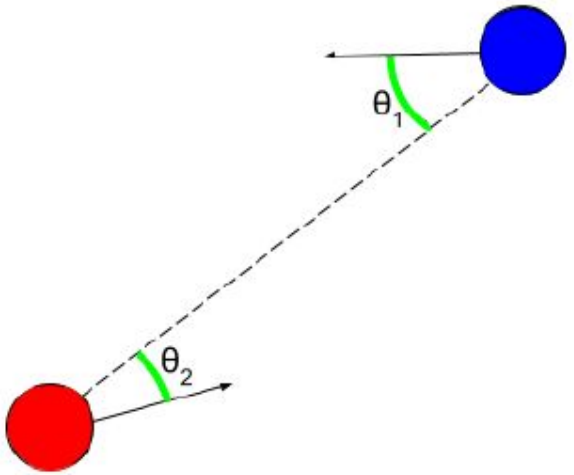
$$\mathbf{u}_j = \kappa \frac{\mathbf{d}_i}{\|\mathbf{d}_i\|} \frac{1}{\|\mathbf{d}_i\|^{\gamma}}$$

Table 1: Constant Parameter Values

Constant	Value	Constant	Value
C	0.00897	L_i	1 m
λ	2.656	γ	3.091
r	7.5 m	M	$15^{\circ}/sec.$

γ controls falloff of the force with distance

$$\kappa = \text{clamp}\left(\frac{\cos\theta_1 + \cos\theta_2}{2}, 0, 1\right)$$



Primary Metrics for Comparison

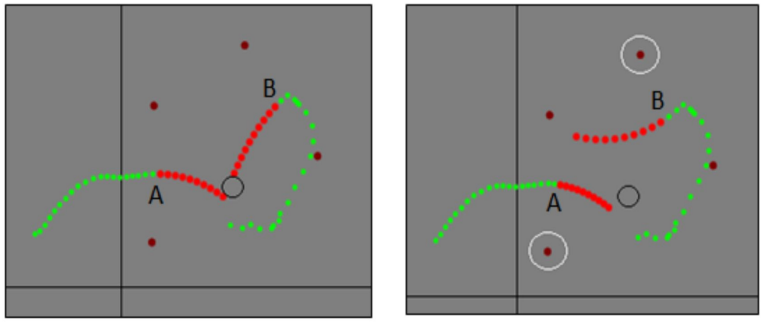
- Average number of resets per minute
- Average distance between resets
- Average steering rate

Support for multiple users required average number of resets to be less than one per minute.

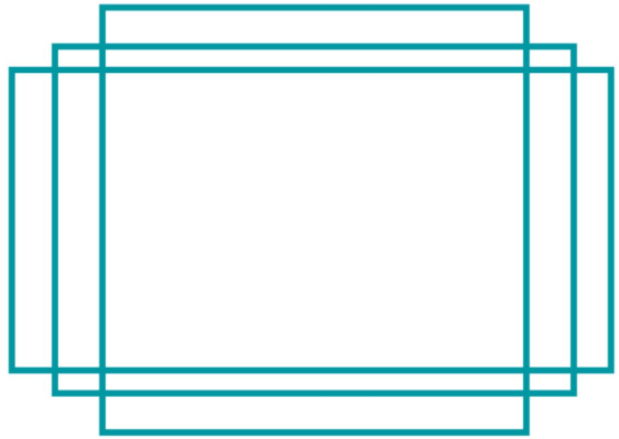
Contributions

- Modifications to a Redirected walking algorithm (APF-RDW) that enables it to support two design criteria:
  - Scalable for multiple users
  - Ability to support irregular concave tracking areas
- New method for scaling steering rates based on the proximity of obstacles

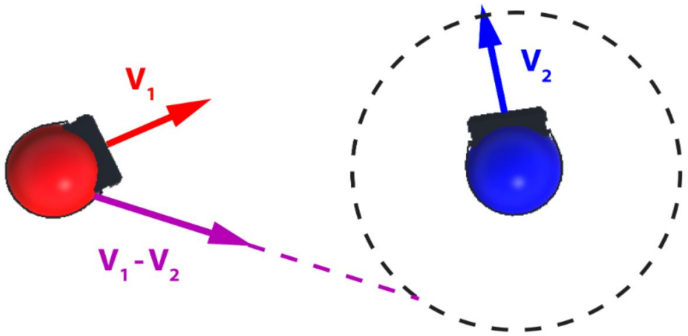
Related Research Results



Holms 2012: First study of multiuser redirected walking



Azmandian et al 2015: Studied the performance of RDW algorithms in 3 different ratio rectangles



Azmandian, Grechkin, Rosenberg 2017: Relative velocity heuristic

Method (old)

Conditions tested for each method:

1. Square Rooms of size (in meters) 10x10, 15x15, 20x20, 25x25, 30x30, 40x40, 50x50
   - Single user: 288 four minute user trials
   - Multi-user: 500 four minute user trials (until 1 reset per minute was reached).
1. Four different shaped rooms: Rectangle (2:1 ratio), Trapezoid, Cross, and L-Shape
   - Single user: 288 four minute user trials
   - All rooms scaled to 1000 square meters of tracking space

Method (old)

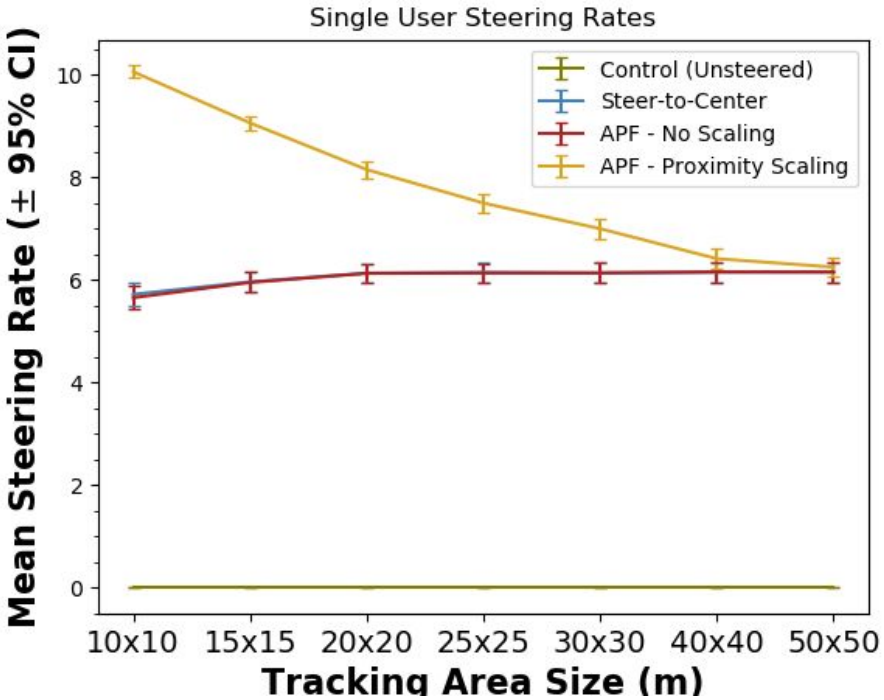
Navigational data for the simulations came from 288 logged paths from four previous user experiments.

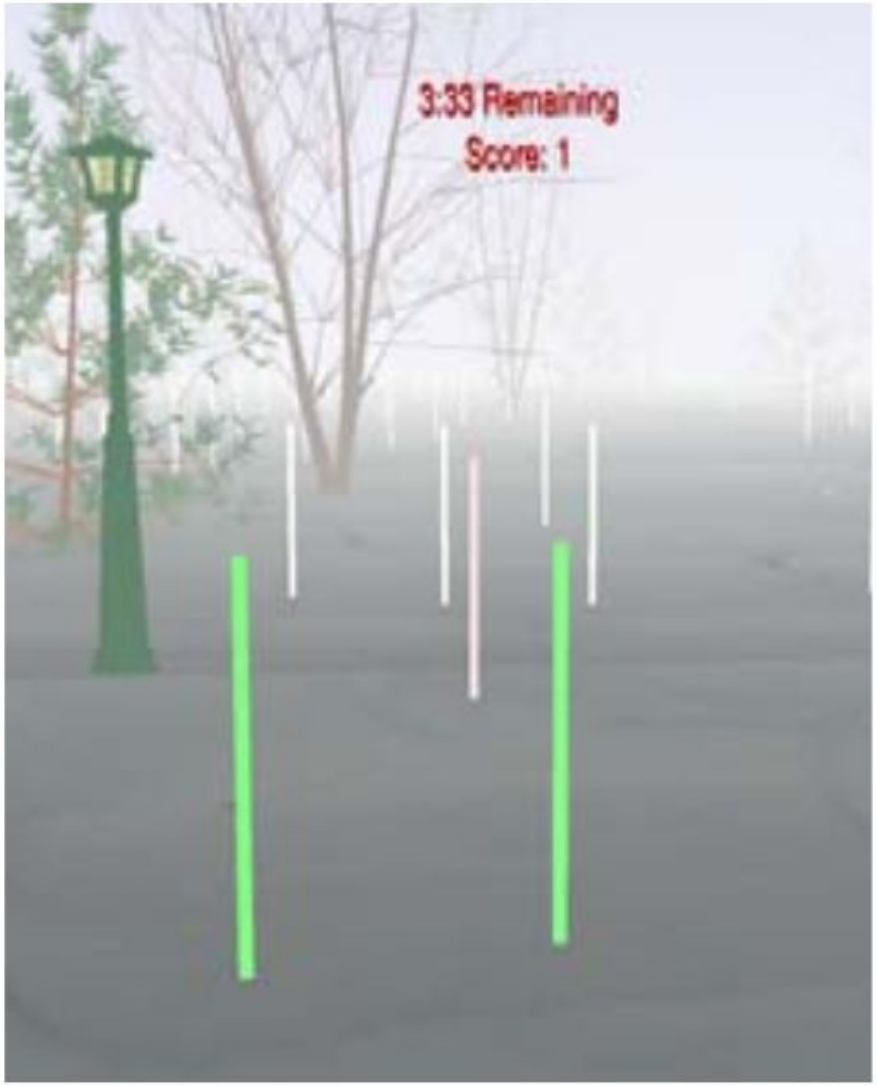
Four different methods tested:

1. Control (no redirection)
2. Steer to Center
3. Artificial Potential Field (APF)
4. Artificial Potential Field with Scaling (APF-SC)

Conditions tested for each method:

1. Square Rooms of size (in meters) 10x10, 15x15, 20x20, 25x25, 30x30, 40x40, 50x50 with increasing numbers of users until 1 reset per minute was reached.
2. Four different shaped rooms for single user: Rectangle (2:1 ratio), Trapezoid, Cross, and L-Shape


Single User Steering Rates
Control (Unsteered)
Steer-to-Center
APF - No Scaling
APF - Proximity Scaling
Mean Steering Rate (± 95% CI)
0
2
4
6
8
10
10x10
15x15
20x20
25x25
30x30
40x40
50x50
Tracking Area Size (m)



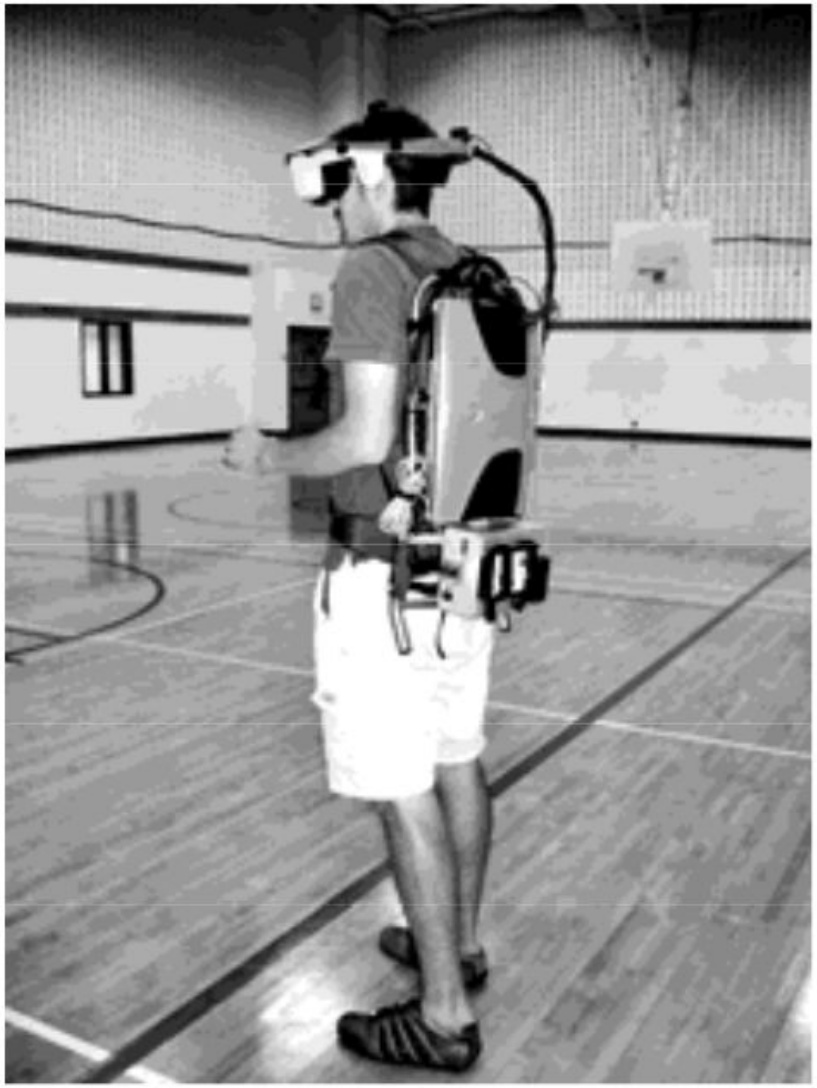
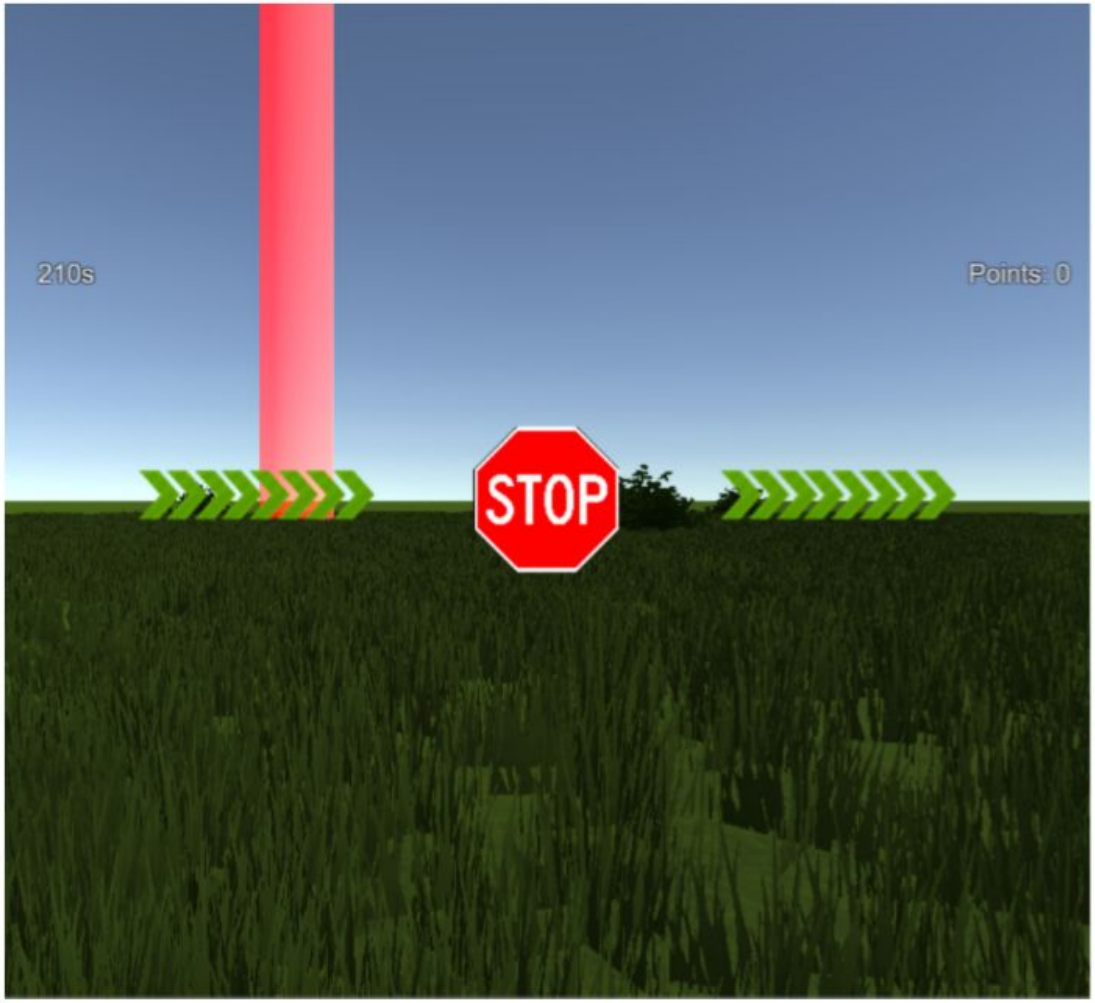
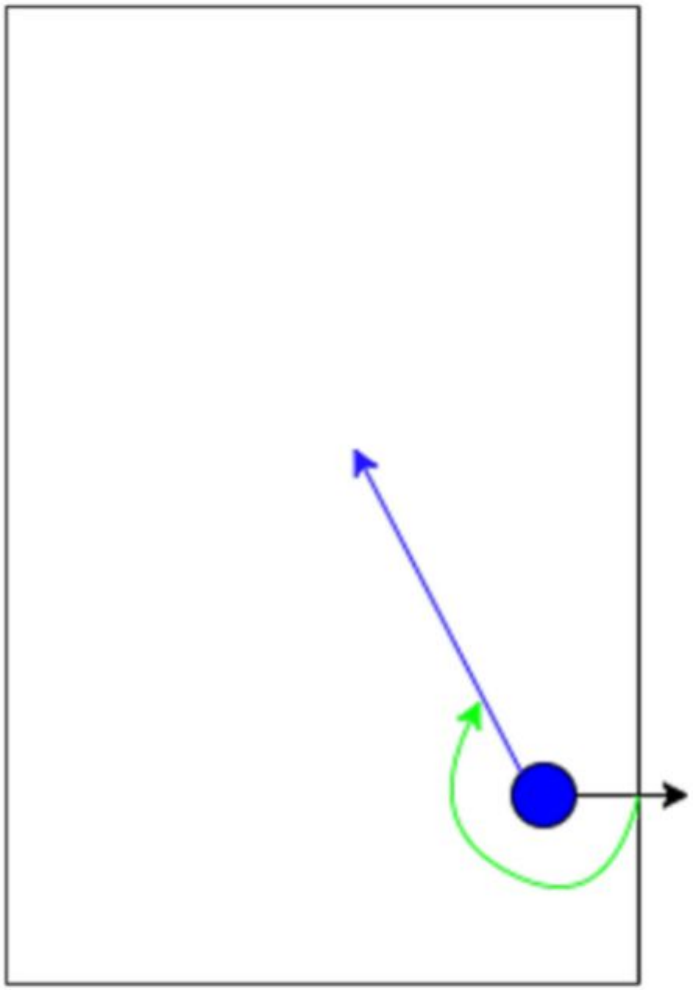
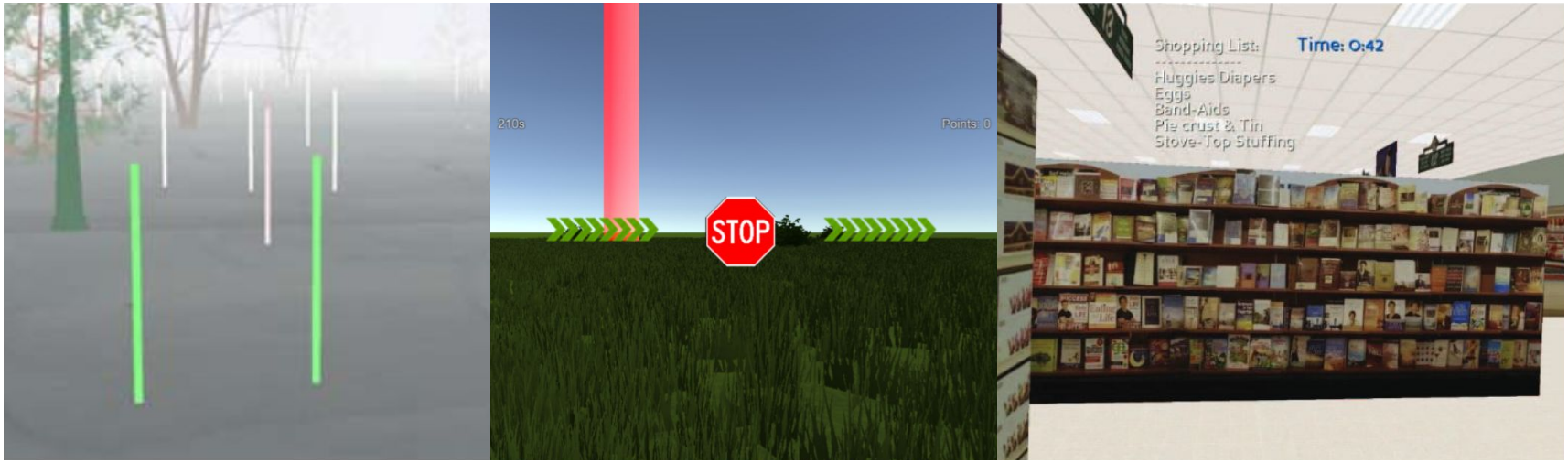


Fig. 9. Left panel – screen capture of the VE used in the live user experiment. Participants gathered posts for points. Right panel – an immersed user wears the HIVE's backpack rendering


Shopping List:
Time: 0:42
Huggies Diapers
Eggs
Band-Aids
Pie crust & Tin
Stove-Top Stuffing


210s
Points: 0
STOP




210s
Points: 0
STOP
Shopping List:
Time: 0:42
Huggies Diapers
Eggs
Band-Aids
Pie crust & Tin
Stove-Top Stuffing