

# Navigating Blind People with a Smart Walker

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# How Blind People Navigate



# How Blind People Navigate



**These techniques are of limited use for blind people with walking disabilities.**

# The Smart Walker

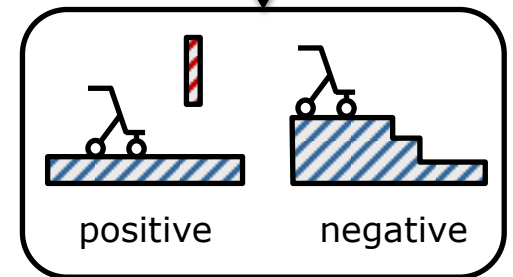
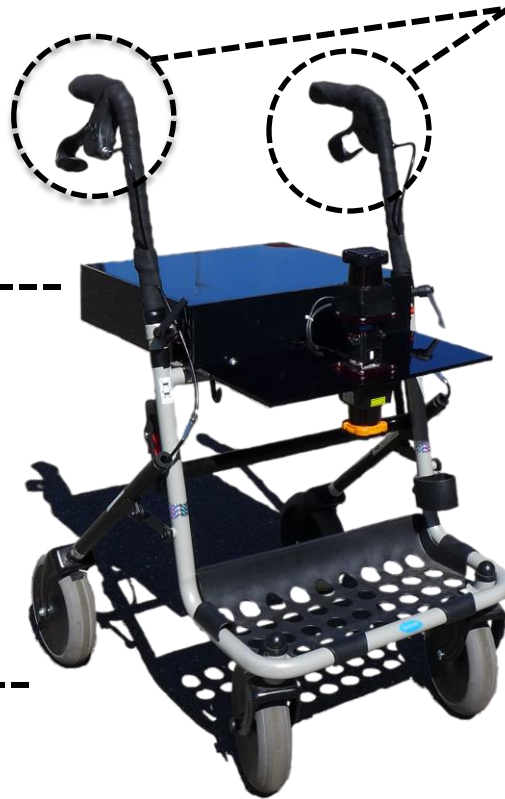
Navigation  
signals

*Vibration motors  
in the handles*

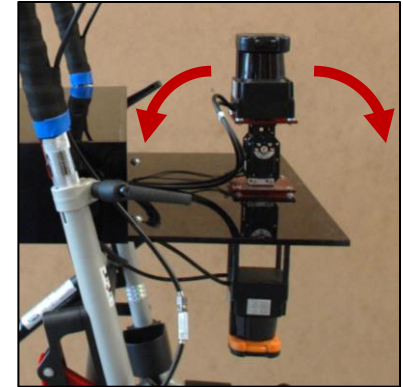
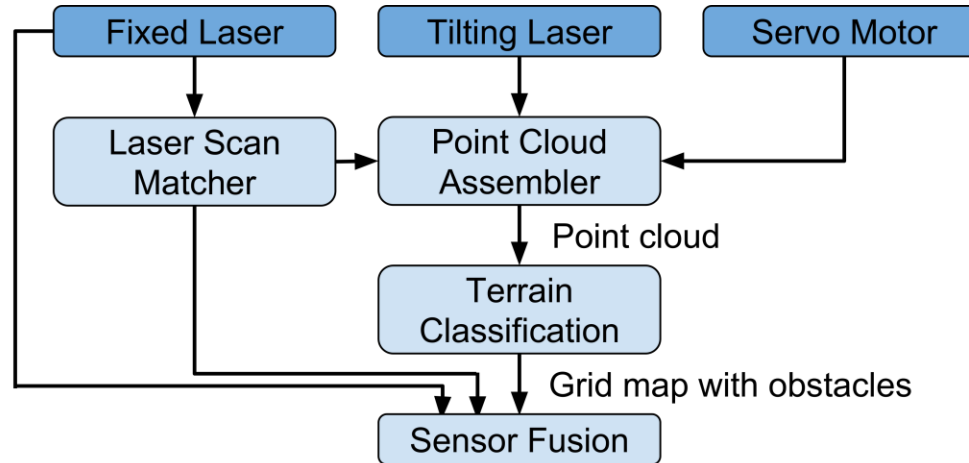
Computing  
capabilities

Obstacle  
Detection  
*3D laser range  
scanning*

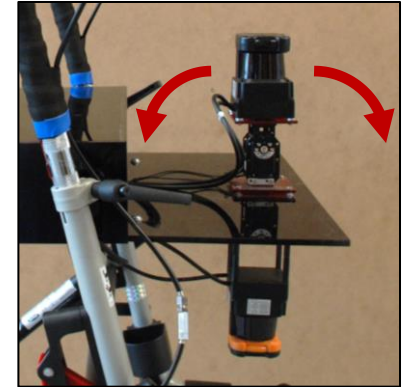
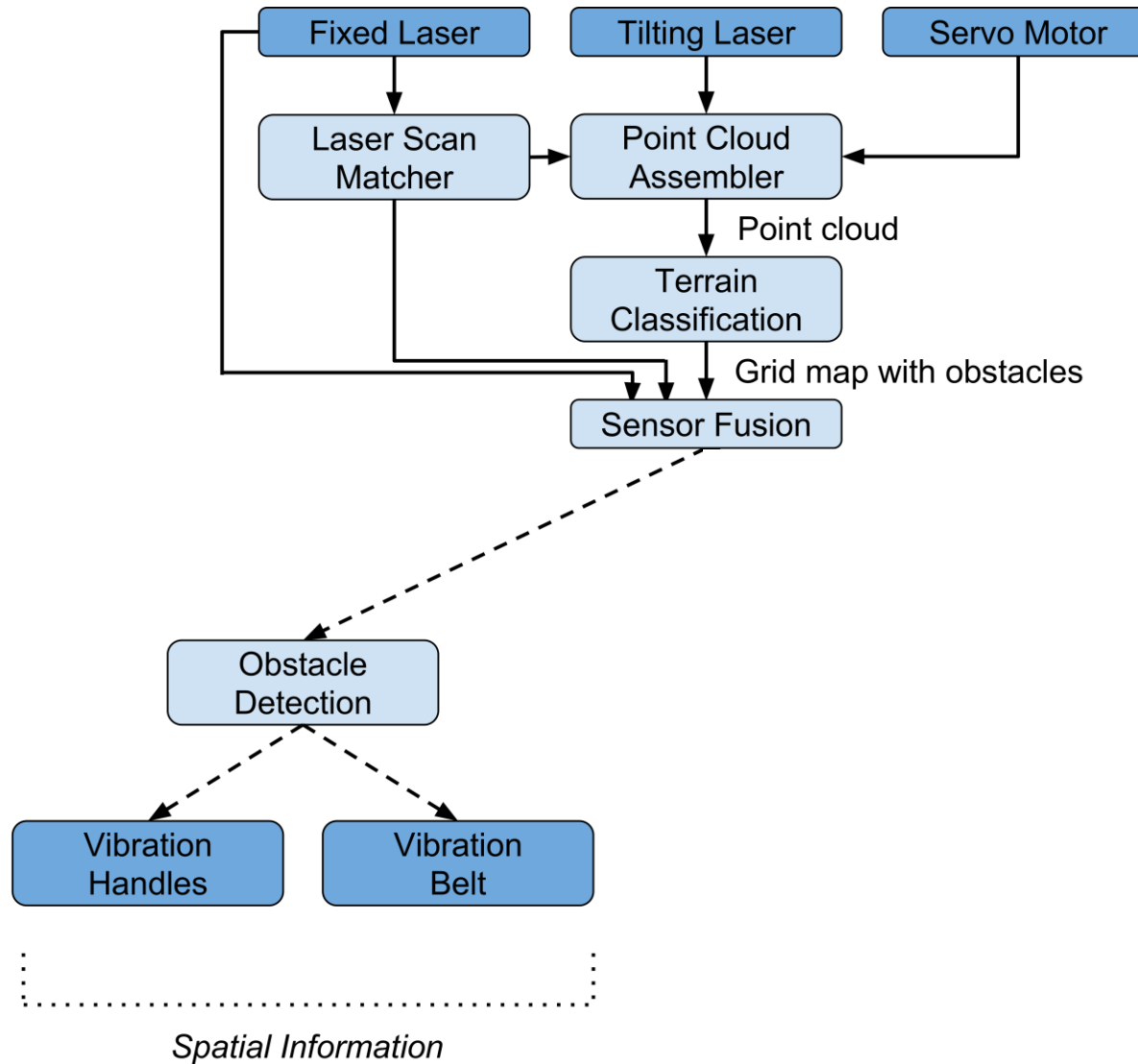
Platform  
*Off-the-shelf walker*



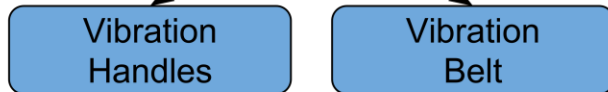
# Overview Architecture



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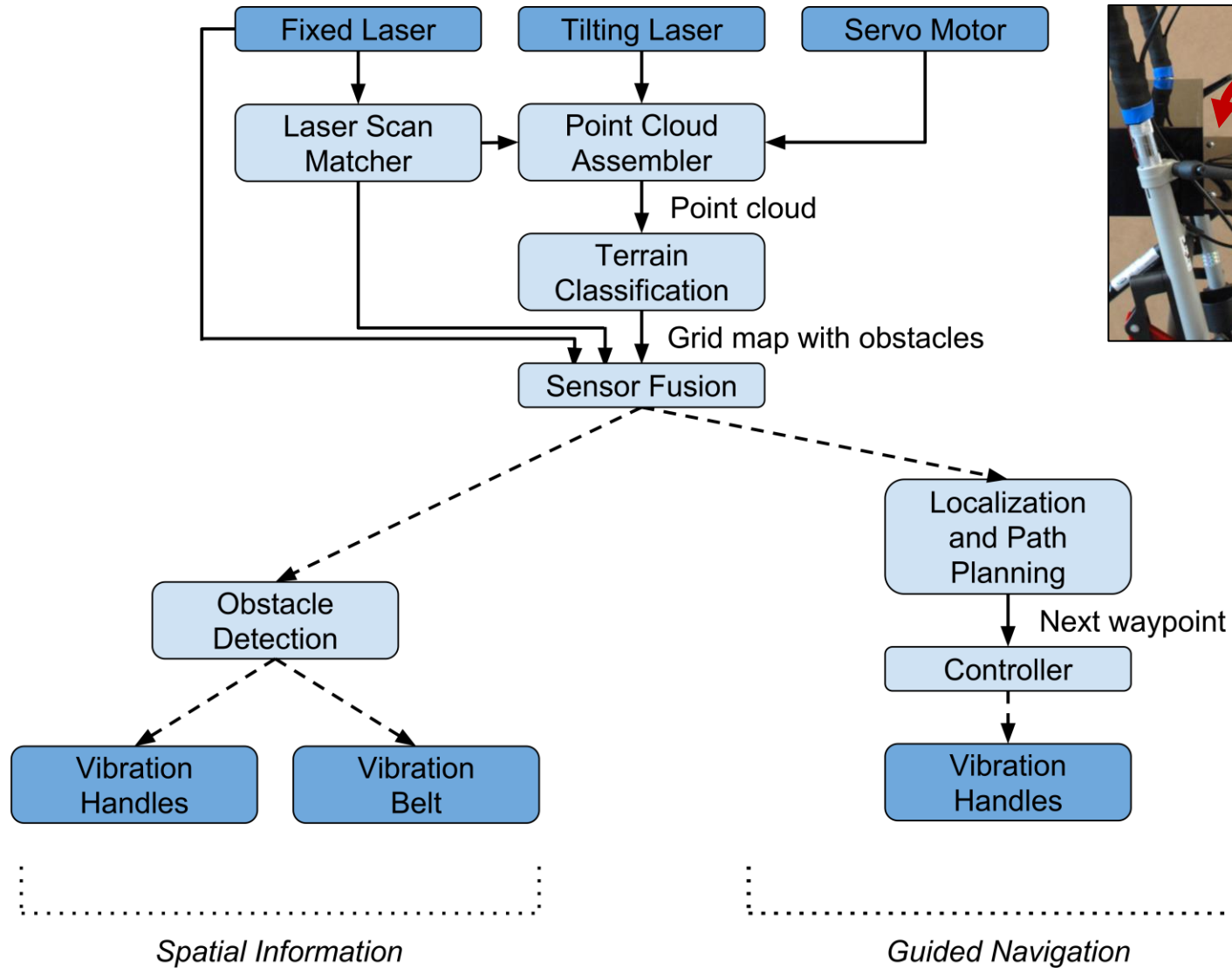
Mode



Setting

*Spatial Information*

# Overview Architecture



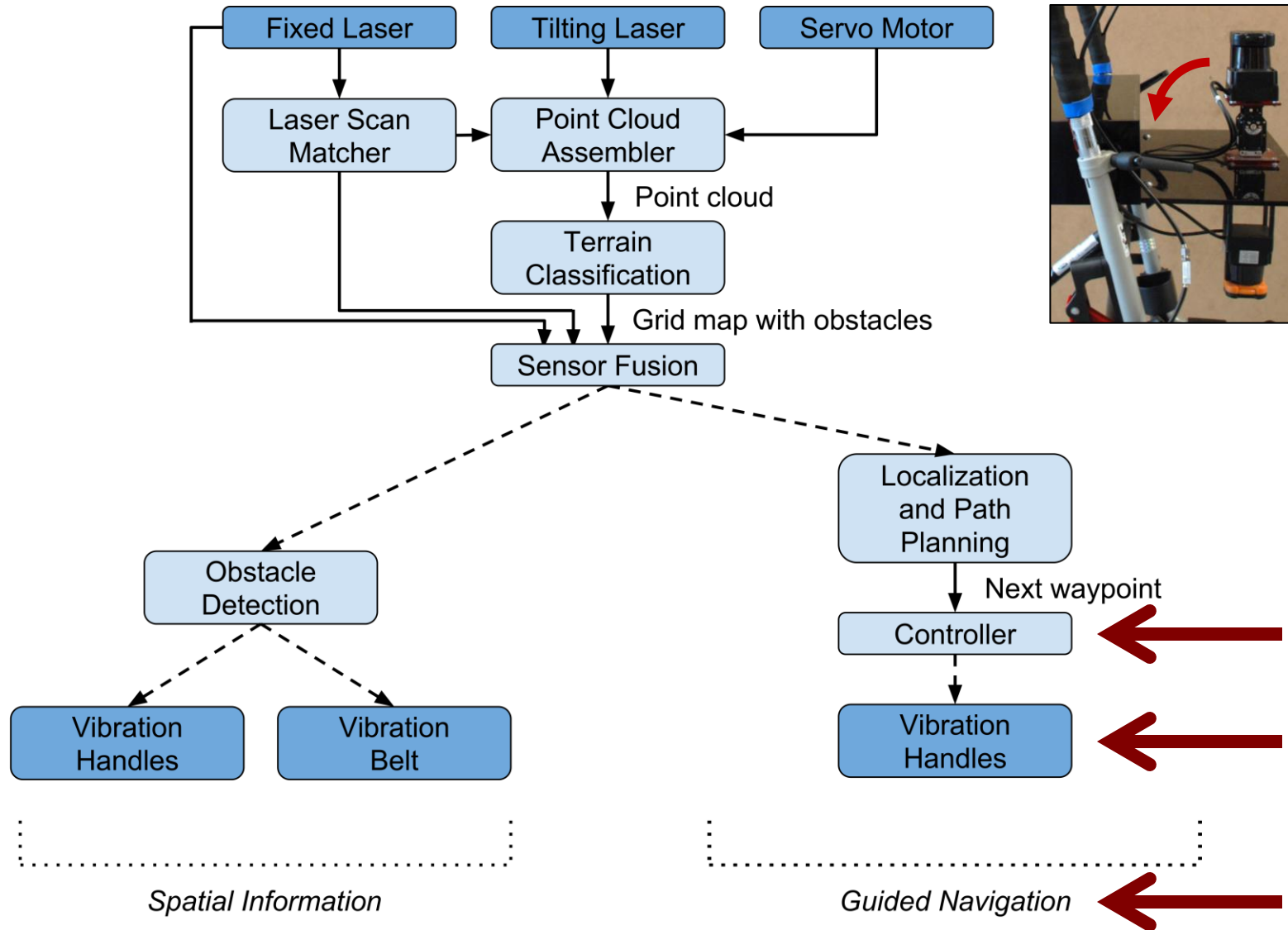
Mode

Setting

*Spatial Information*

*Guided Navigation*

# Overview Architecture



Mode

Setting

*Spatial Information*

*Guided Navigation*



# Navigation Signals

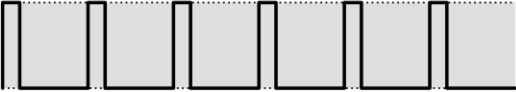
Go straight

Vibration intensity

100 %

0 %

Left handle



Right handle

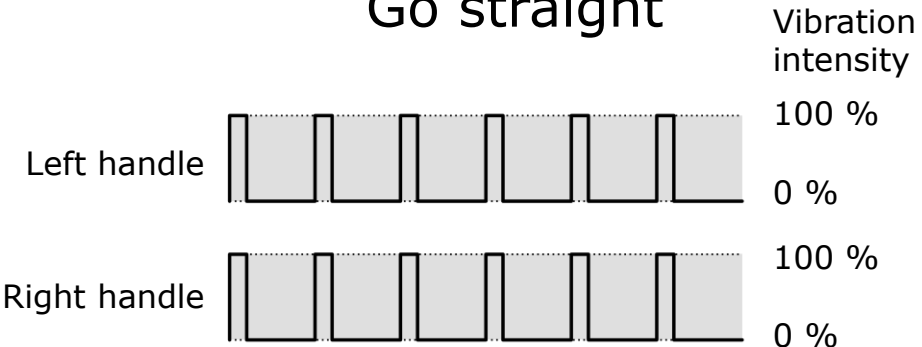


100 %

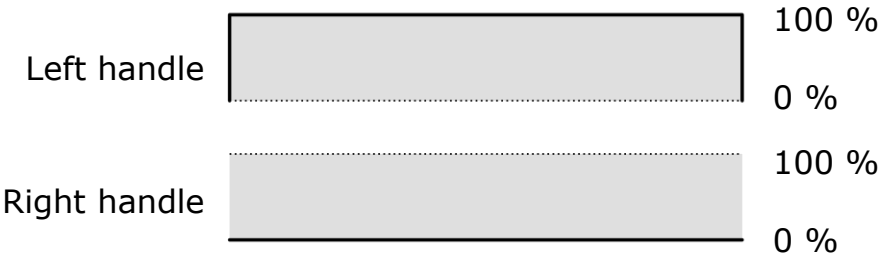
0 %

# Navigation Signals

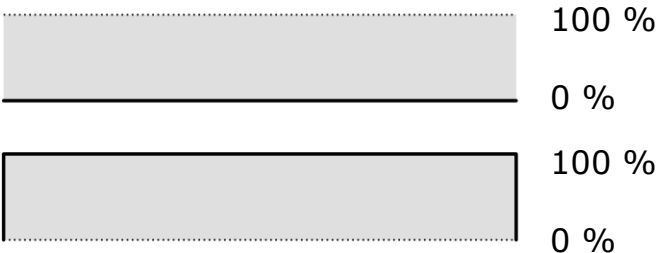
## Go straight



## Turn left

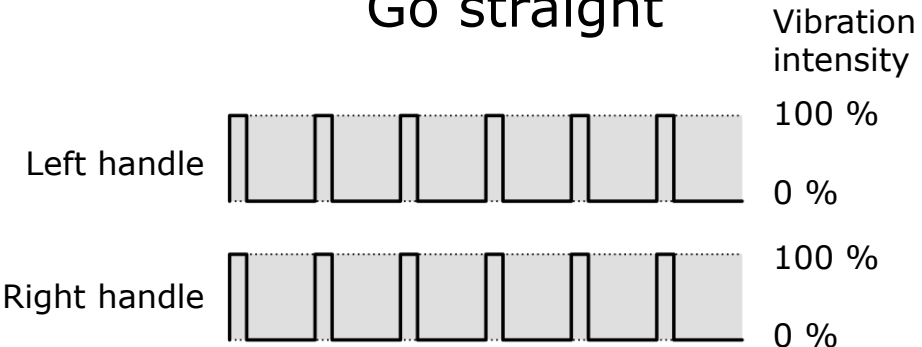


## Turn right

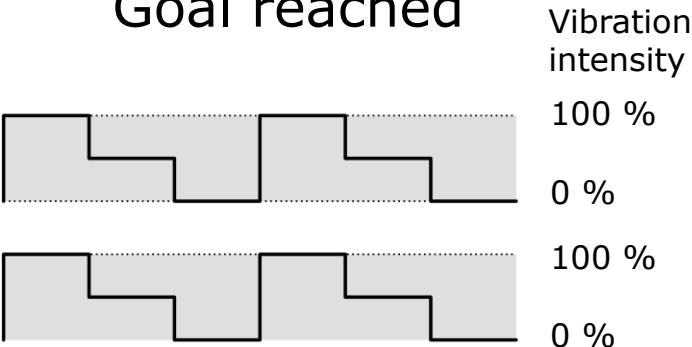


# Navigation Signals

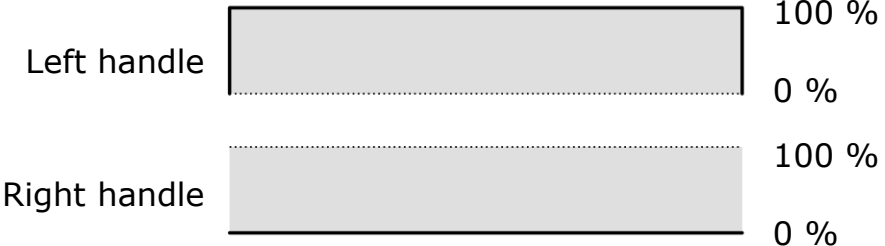
## Go straight



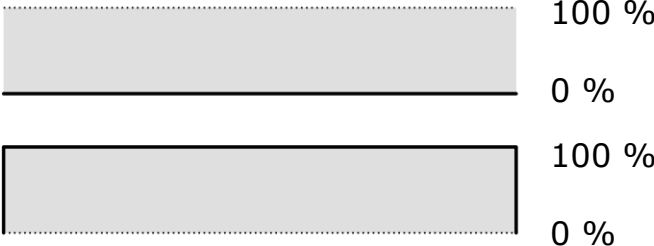
## Goal reached



## Turn left

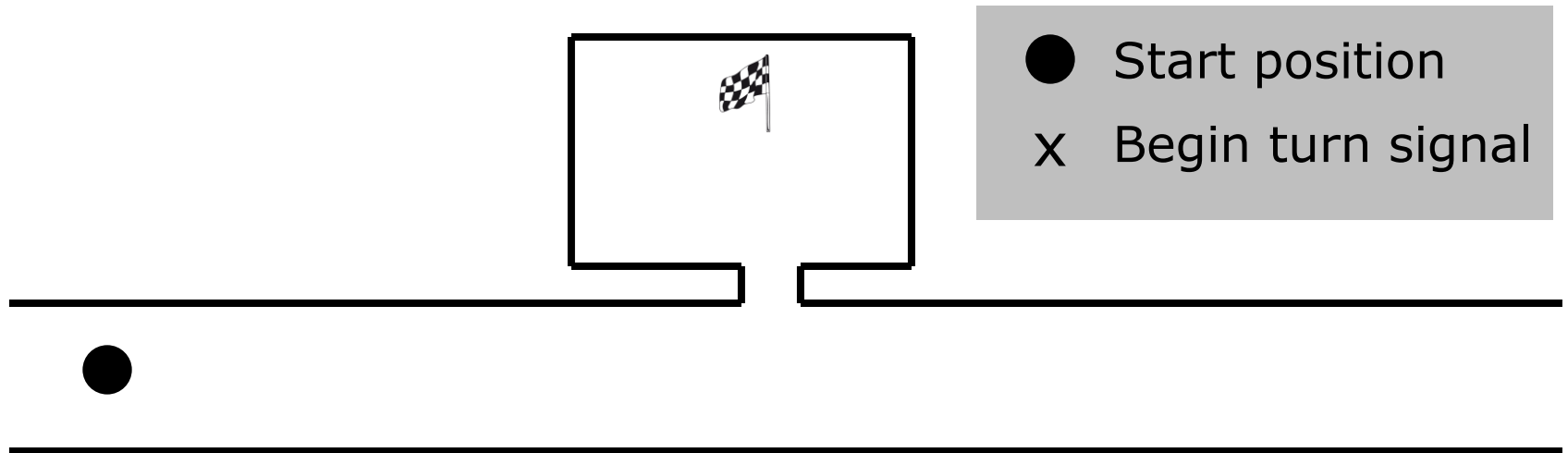


## Turn right



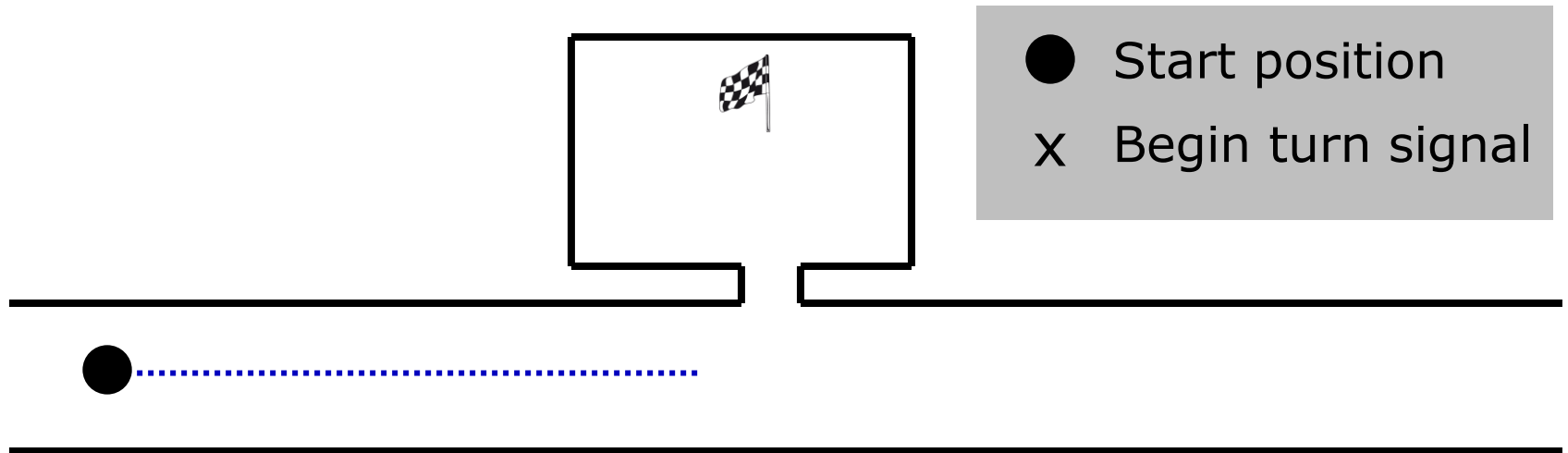
# Challenges in Human Navigation

- Limited vocabulary
- High uncertainty
- Delayed response



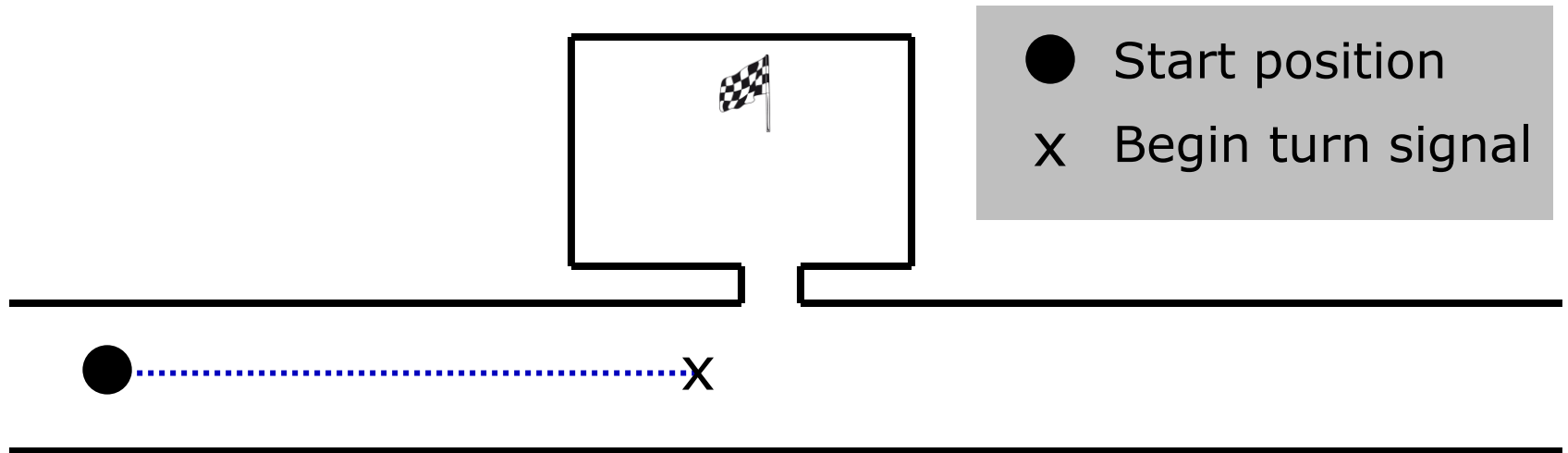
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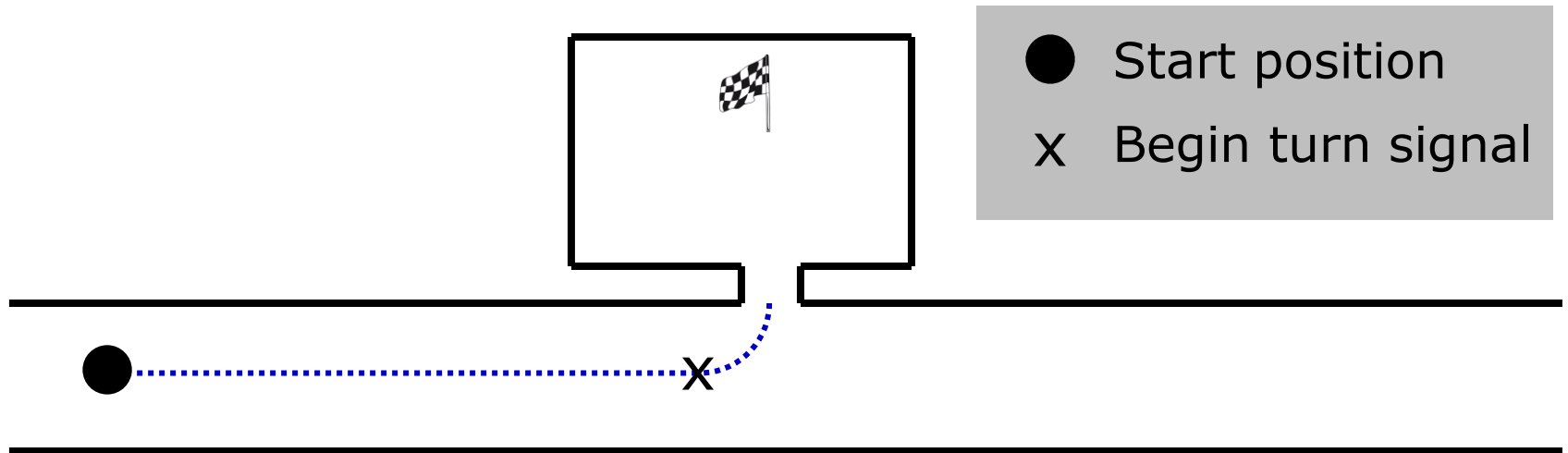
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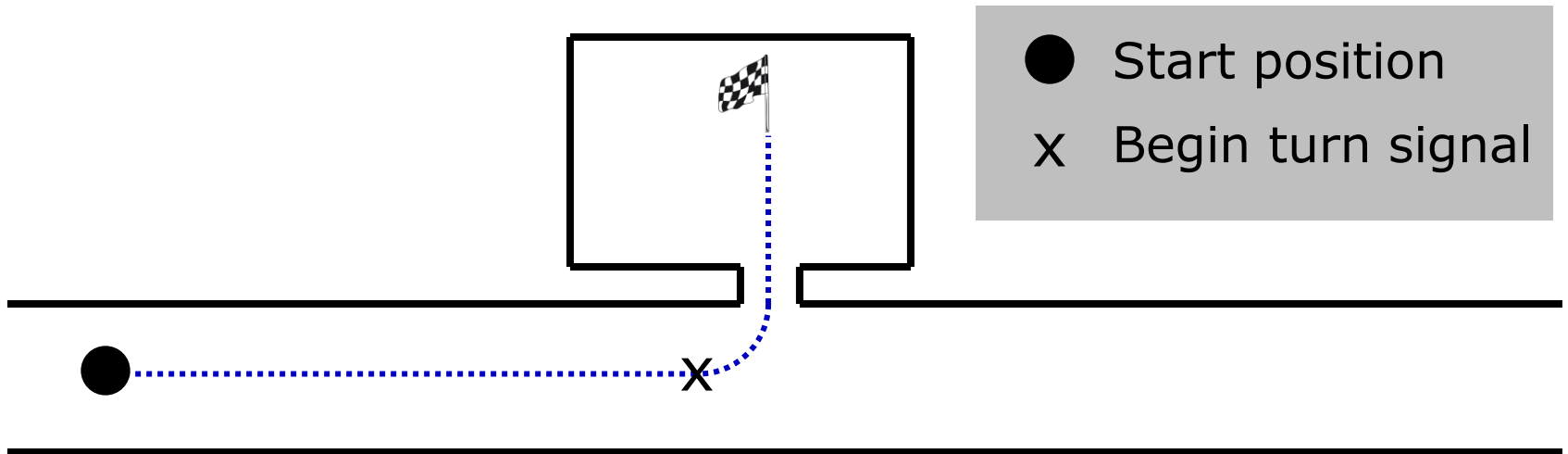
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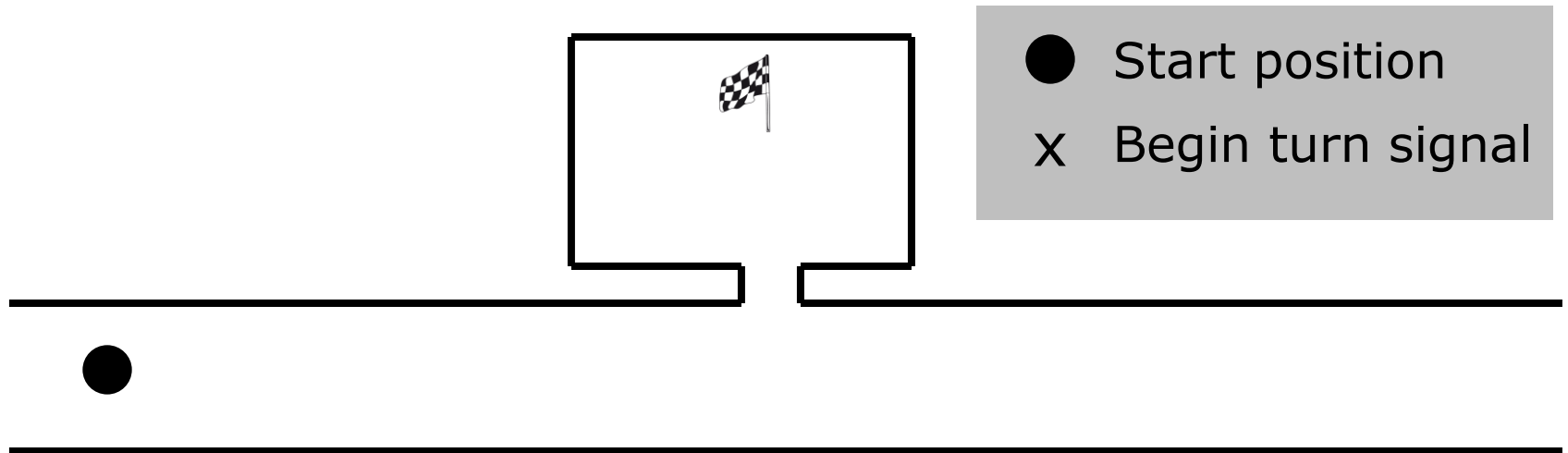
- Limited vocabulary
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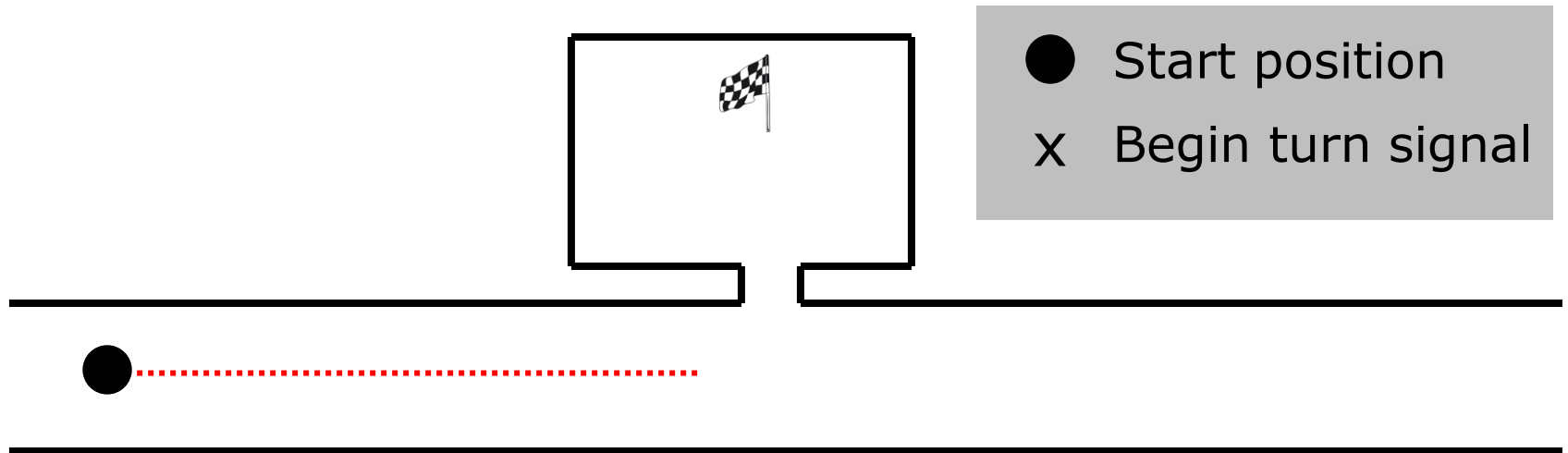
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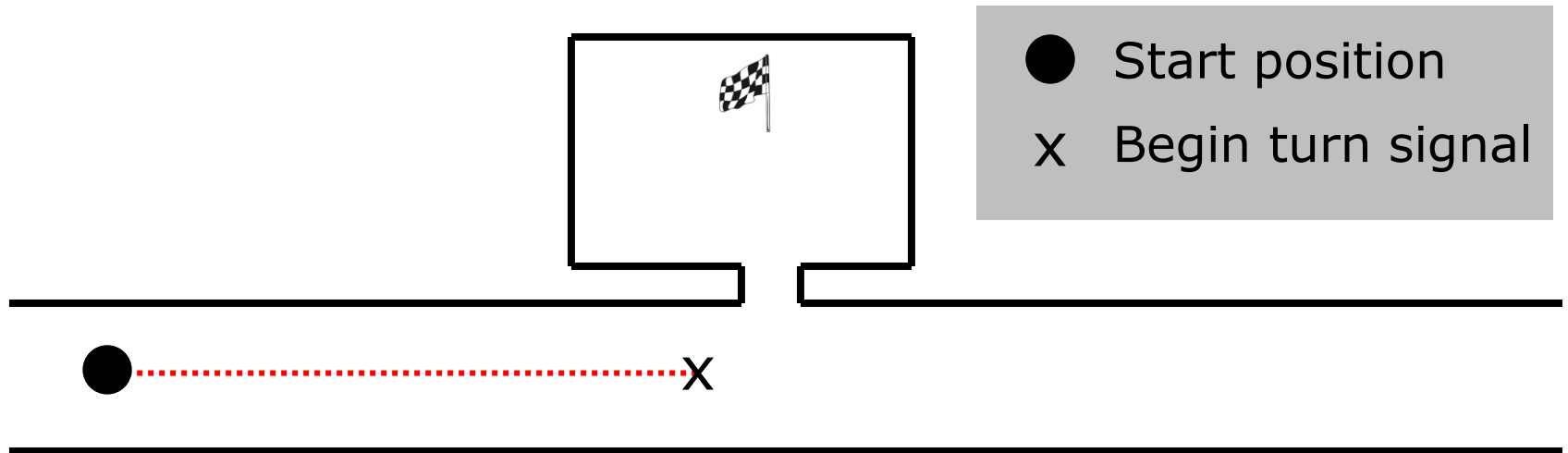
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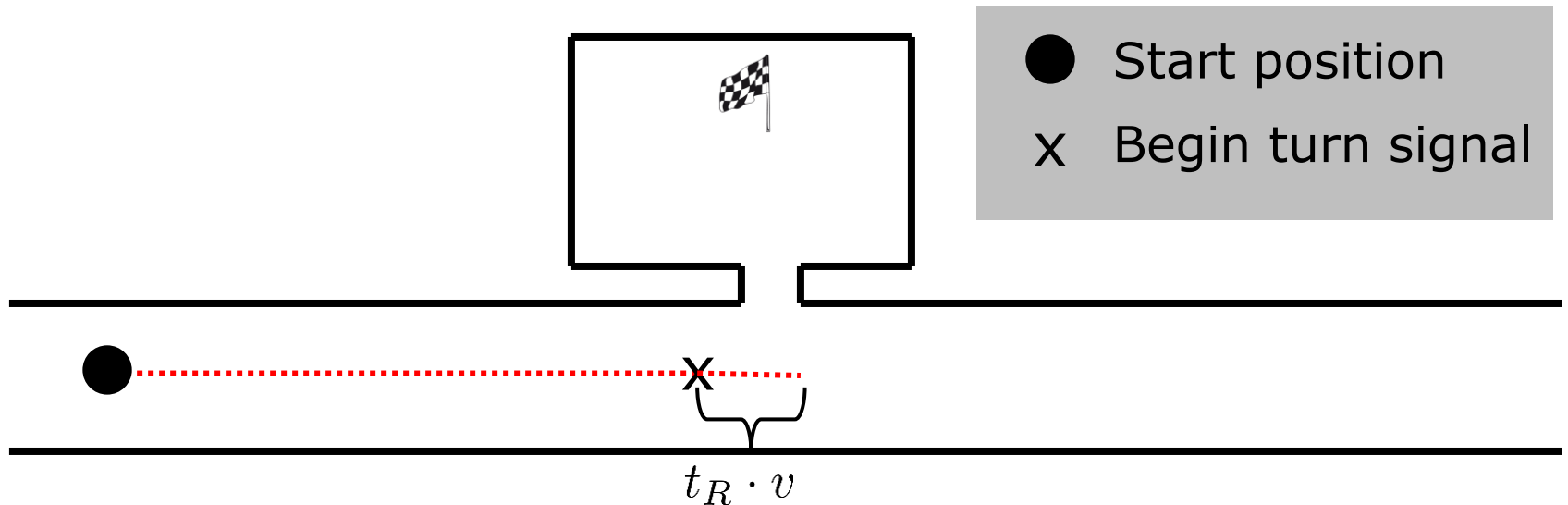
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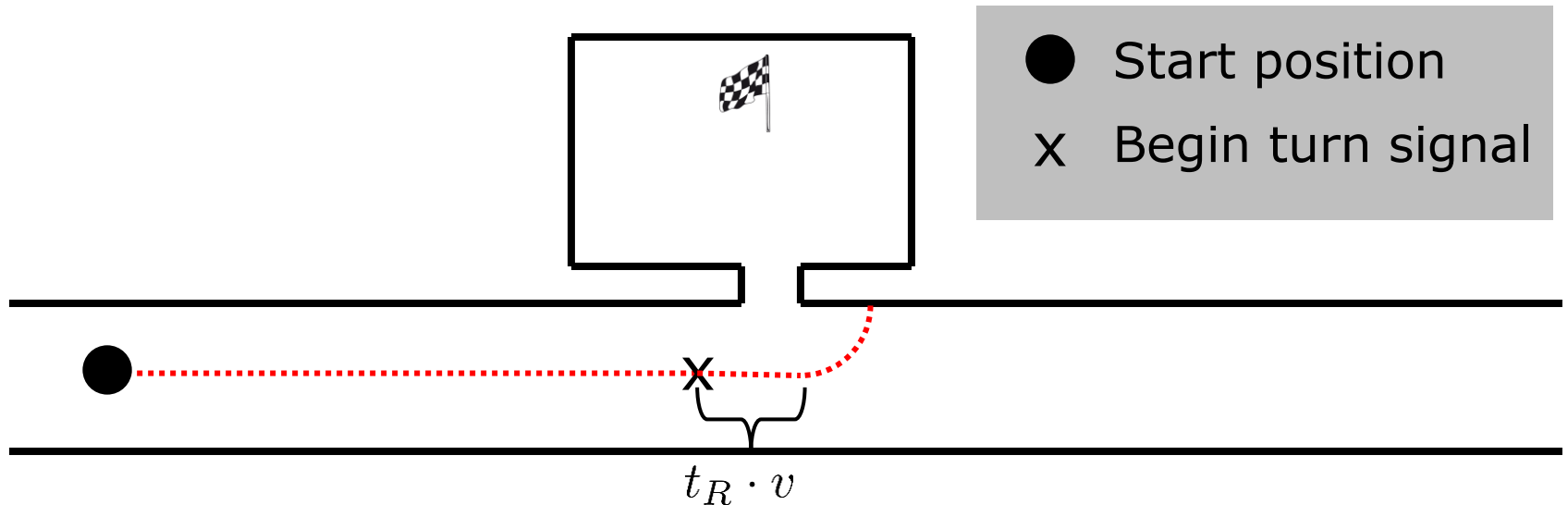
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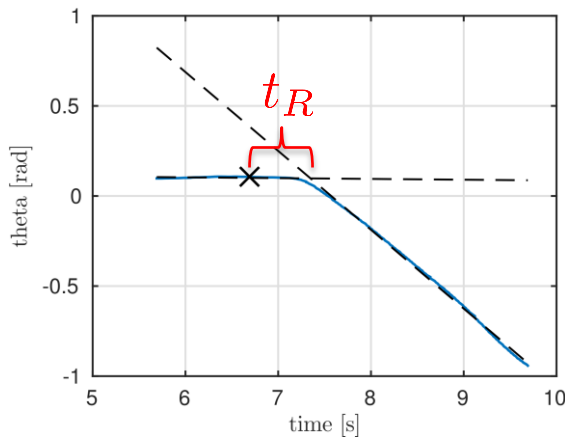
# Challenges in Human Navigation

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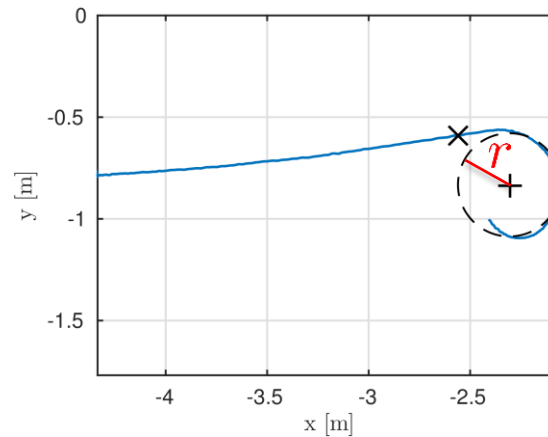


# System Identification

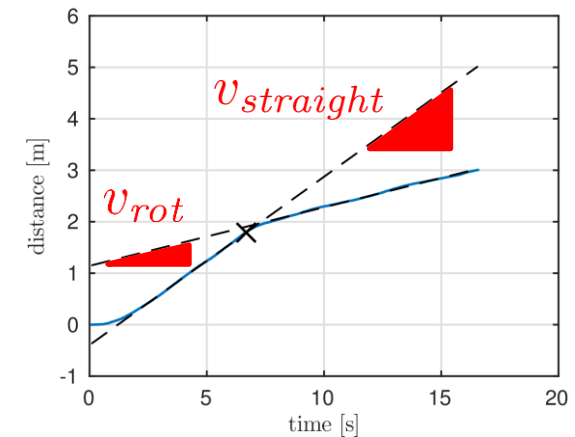
- Step response experiments
- K-means clustering for parameter estimation



Reaction time



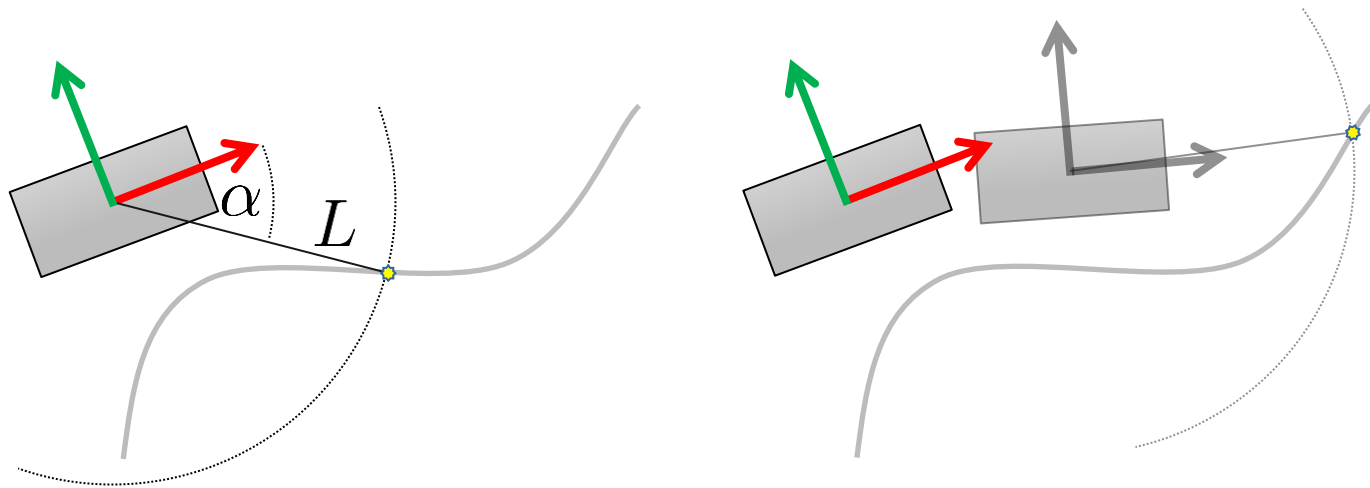
Rotational radius



Velocities

<b>Parameter</b>	<b>Mean</b>	<b>(std-dev)</b>
Rotational radius $r$ [m]	0.36	( $\pm 0.25$ )
Reaction time $t_R$ [s]	0.87	( $\pm 0.20$ )
Straight velocity $v_{straight}$ [m/s]	0.44	( $\pm 0.15$ )
Rotational velocity $v_{rot}$ [m/s]	0.18	( $\pm 0.08$ )

# Carrot Planner

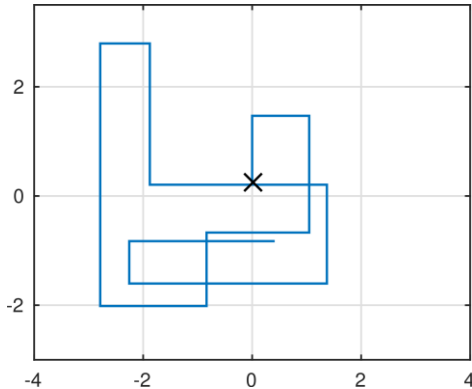


Without prediction

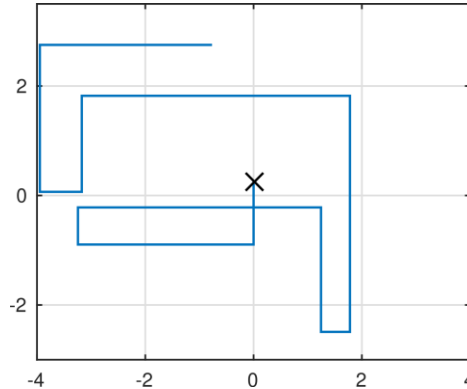
With prediction  
(our method)

- Turn-command for  $|\alpha| > \alpha_c$  with  $\alpha_c = f_1(r)$ ,  $L = f_2(r)$
- Go-straight-command for  $|\alpha| \leq \alpha_c - \epsilon$
- Input for prediction-based controller:
  - Navigation commands in the time frame  $[t_0 - t_R; t_0]$
  - Rotation radius  $r$
  - Current velocity

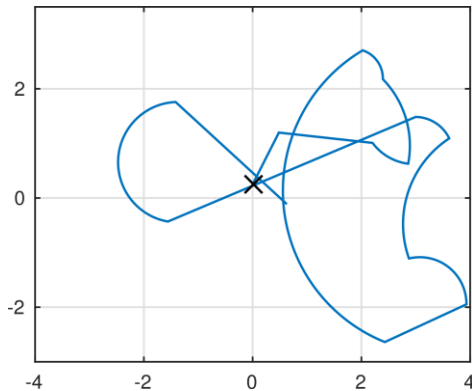
# Experiments



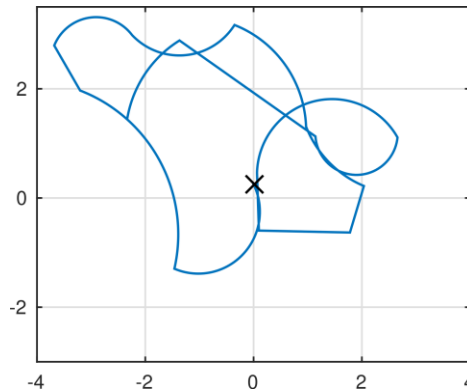
Path 1



Path 2



Path 3



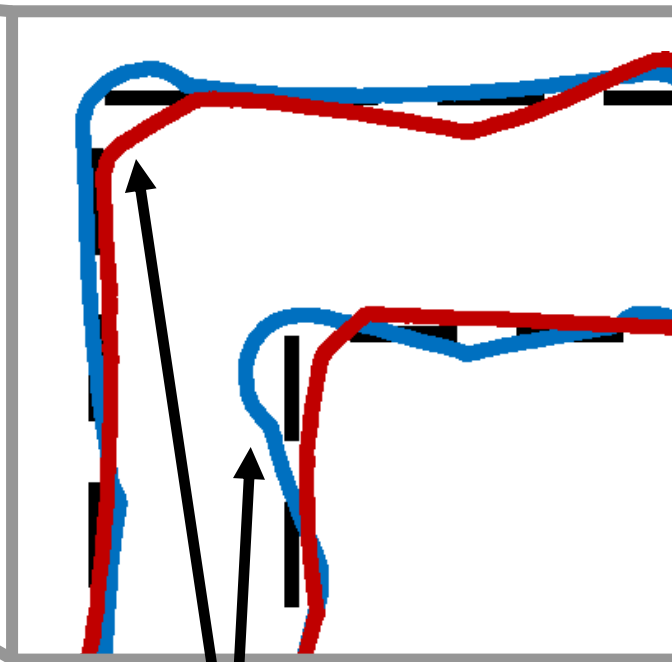
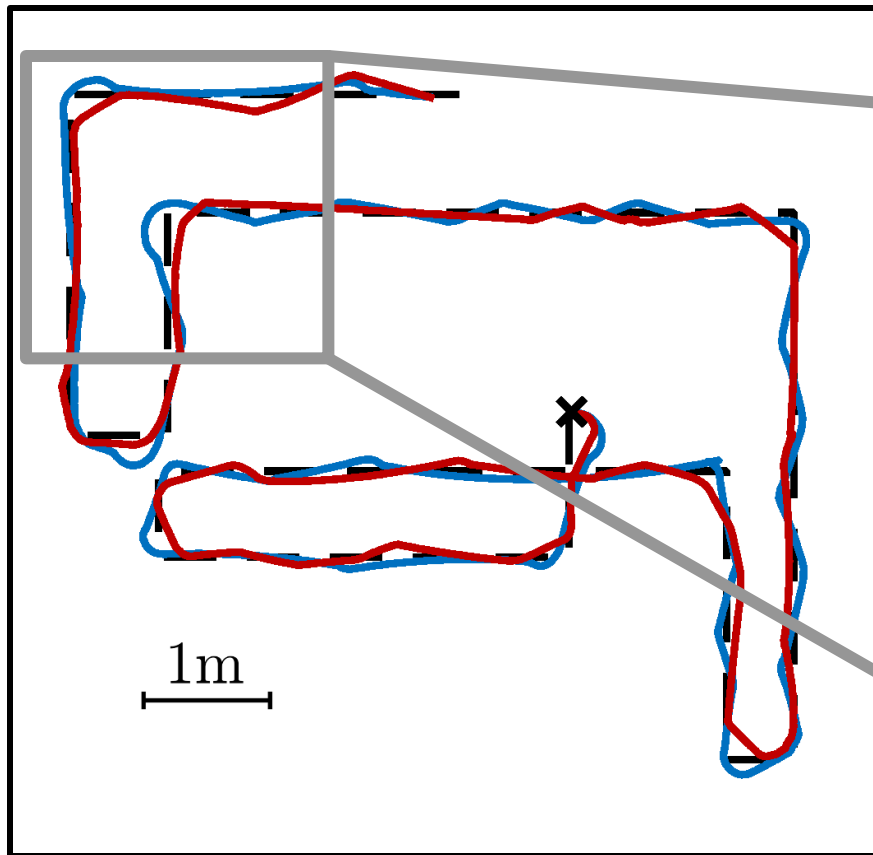
Path 4

Test paths

- 4 randomly created paths
- 8 blindfolded participants
- Randomized order of paths and controller type
- Qualitative and quantitative metrics for evaluation



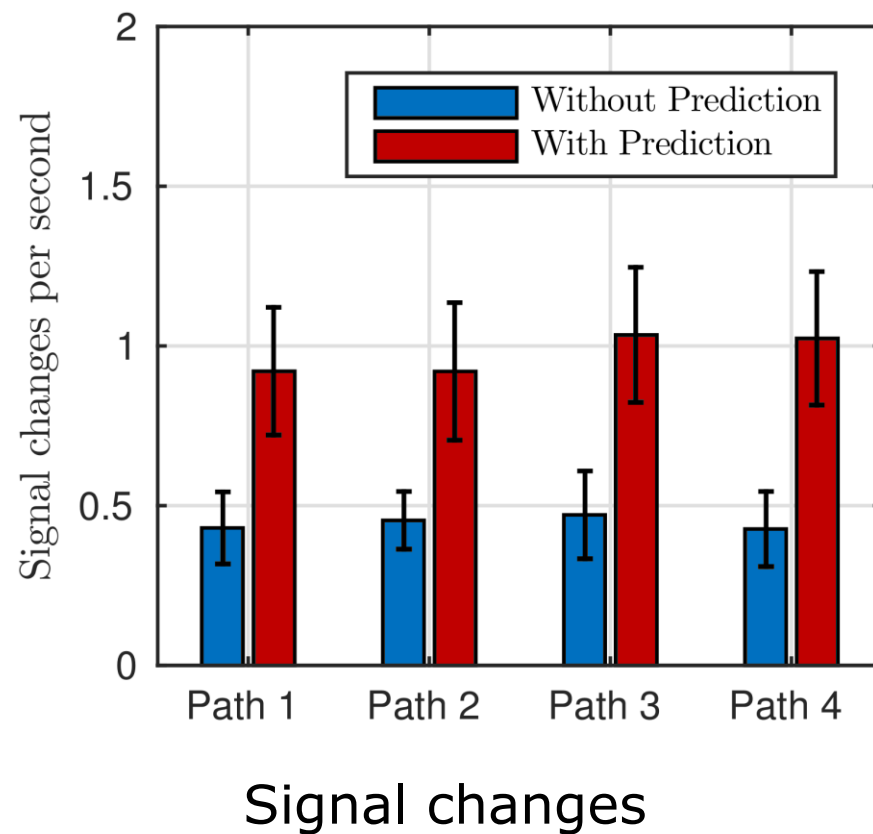
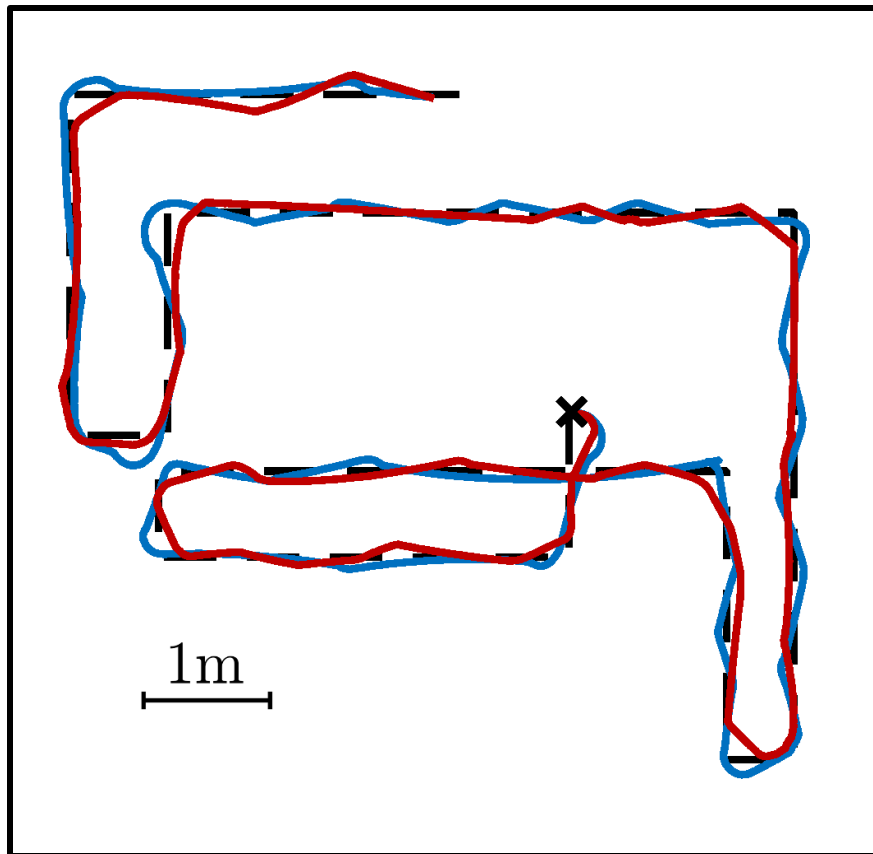
# Path Comparison



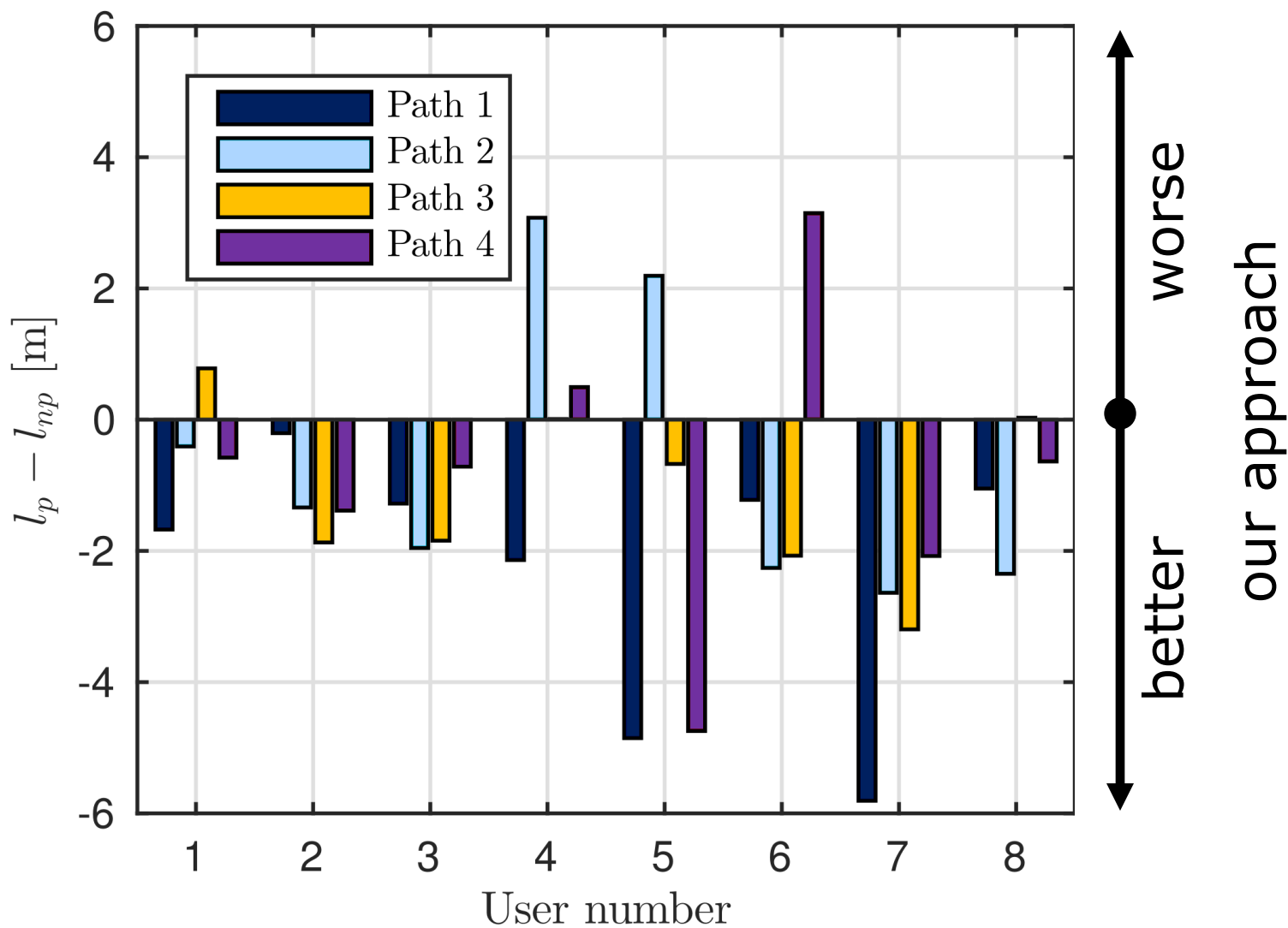
Controller without prediction overshoots



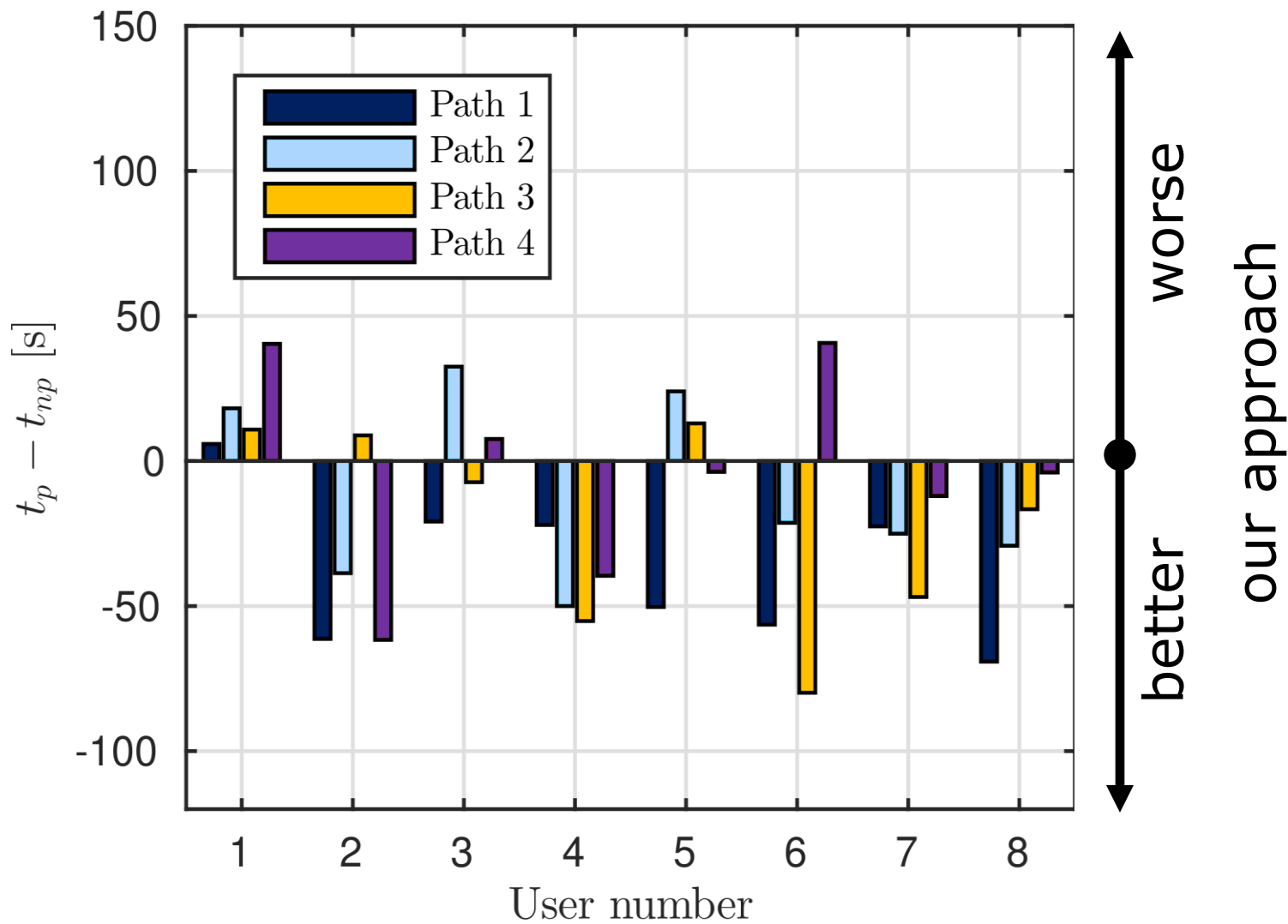
# Path Comparison



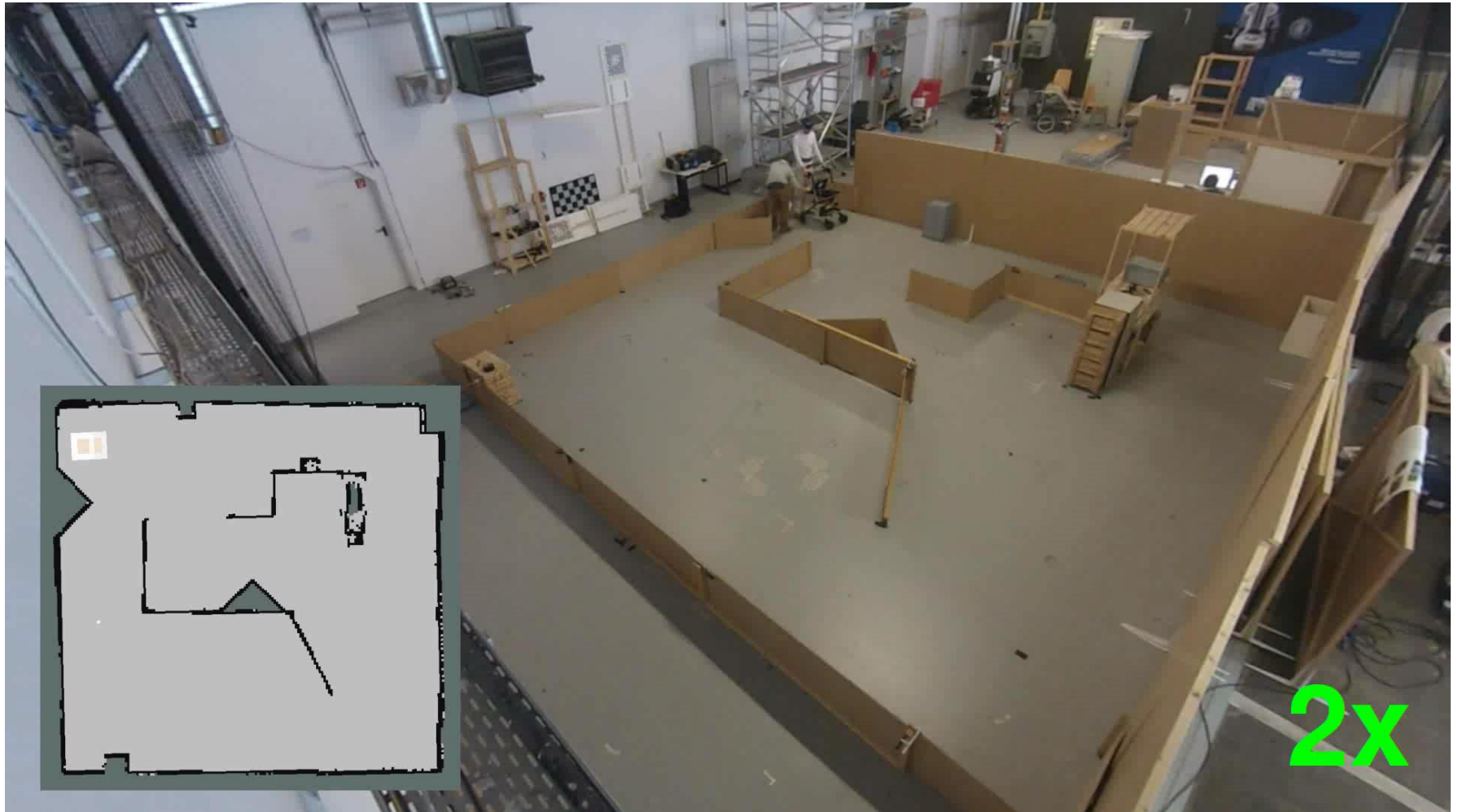
# Trajectory Length



# Travel Time



# User Test with Current System



# Conclusions

- Novel smart walker for blind people with walking disabilities
- Robotic technologies for safe guidance
- Modelling human behavior allows more accurate path guidance

# Thank you for your attention!



Baden-Württemberg

