

A Recipe for Mixed Reality in Mario Kart Live

Ed Tumbusch
Lead Mixed Reality Programmer, Velan Studios

What is Mario Kart Live: Home Circuit?



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Four Gates



Driving Experience



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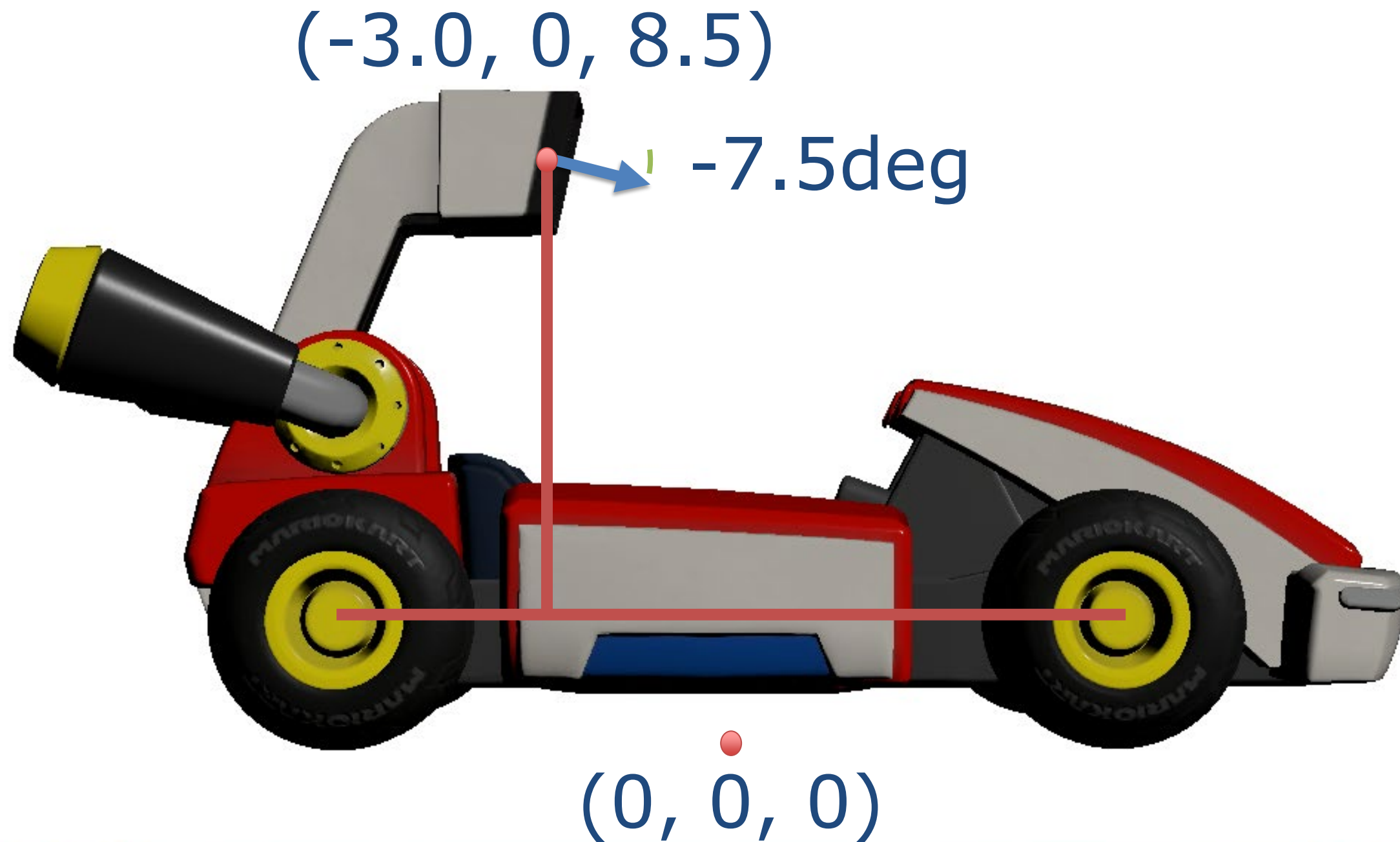
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Mixed Reality Racing



Ingredients

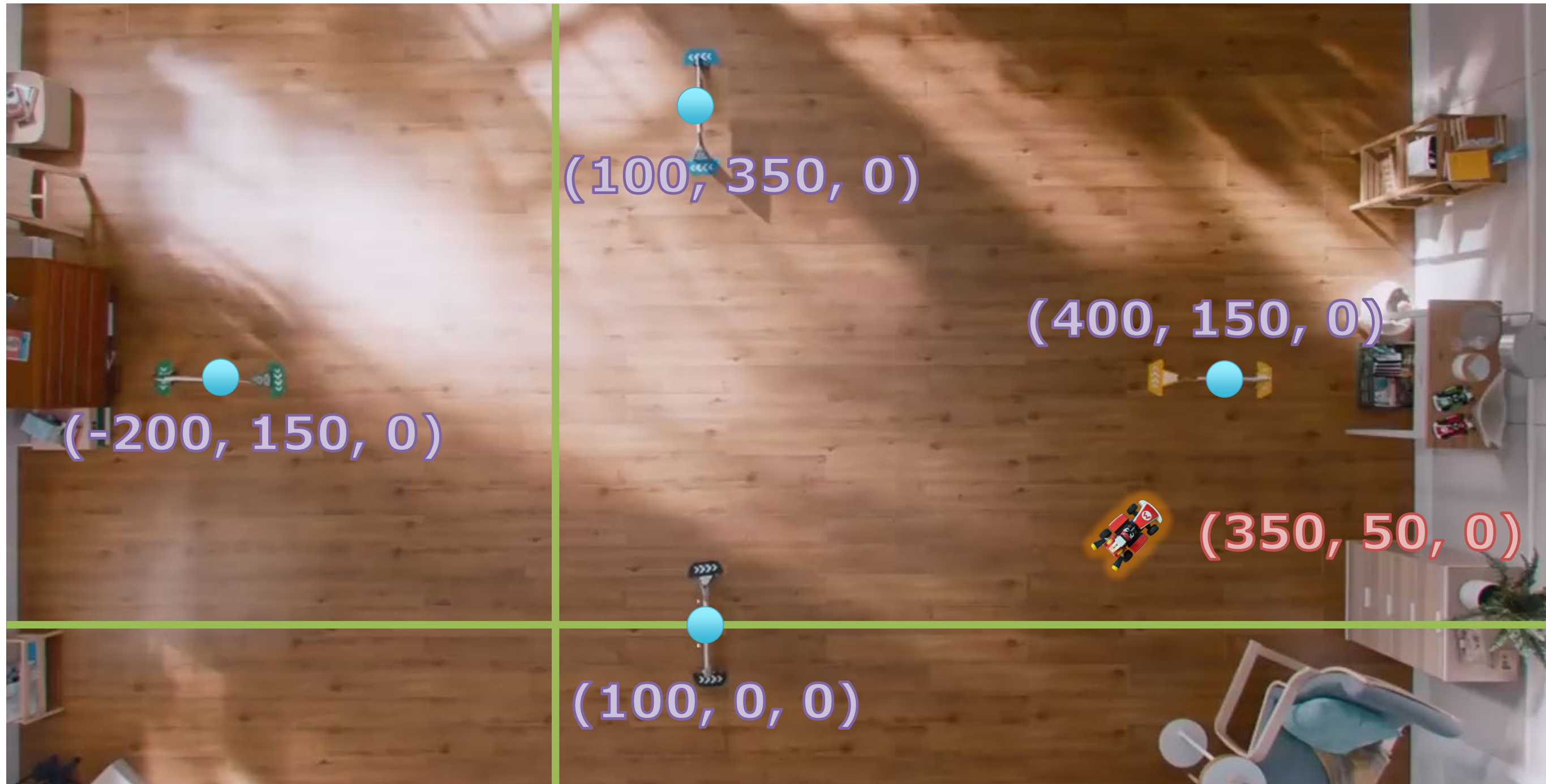
Physical Model – Kart



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Physical Model – Play Space



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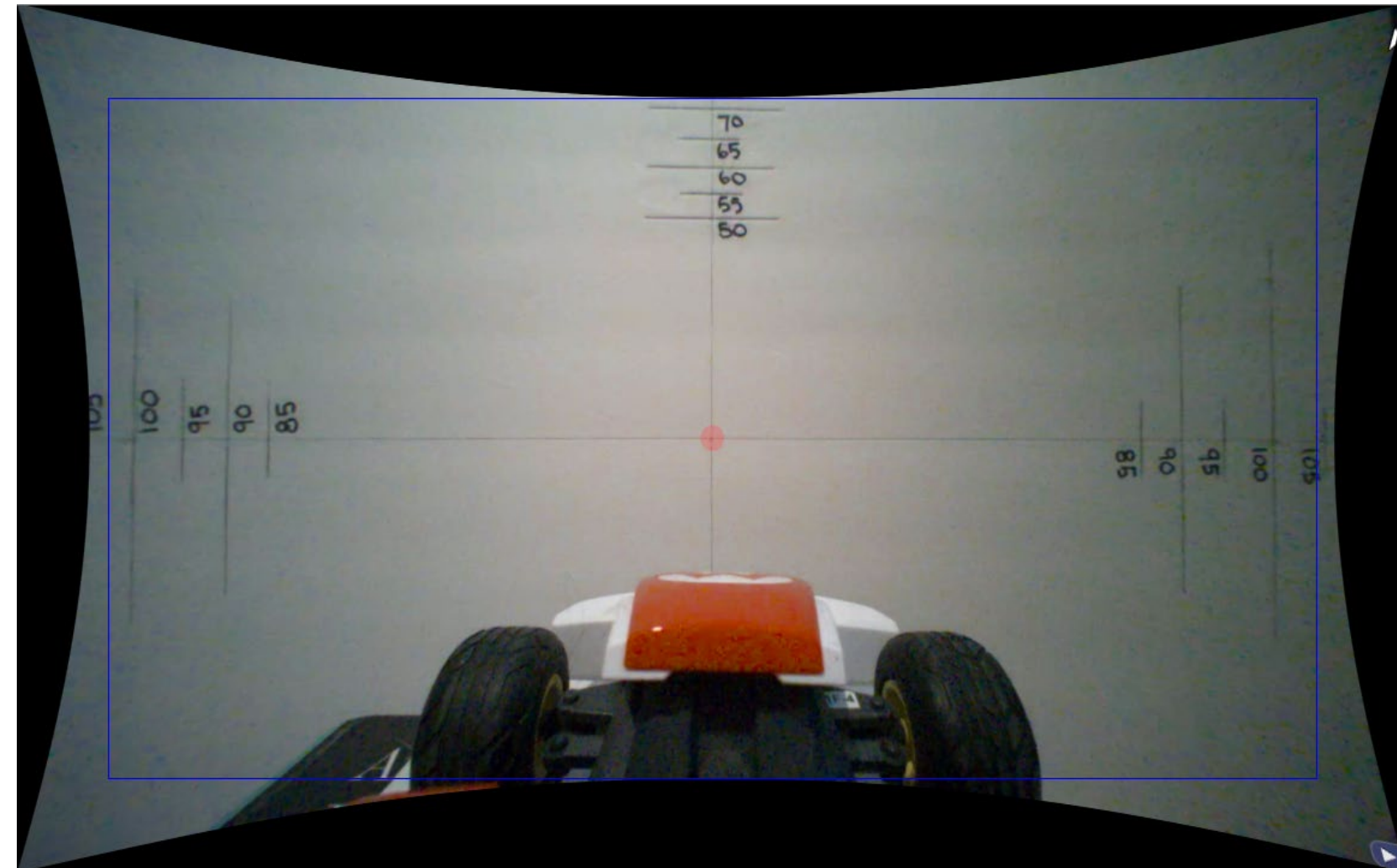
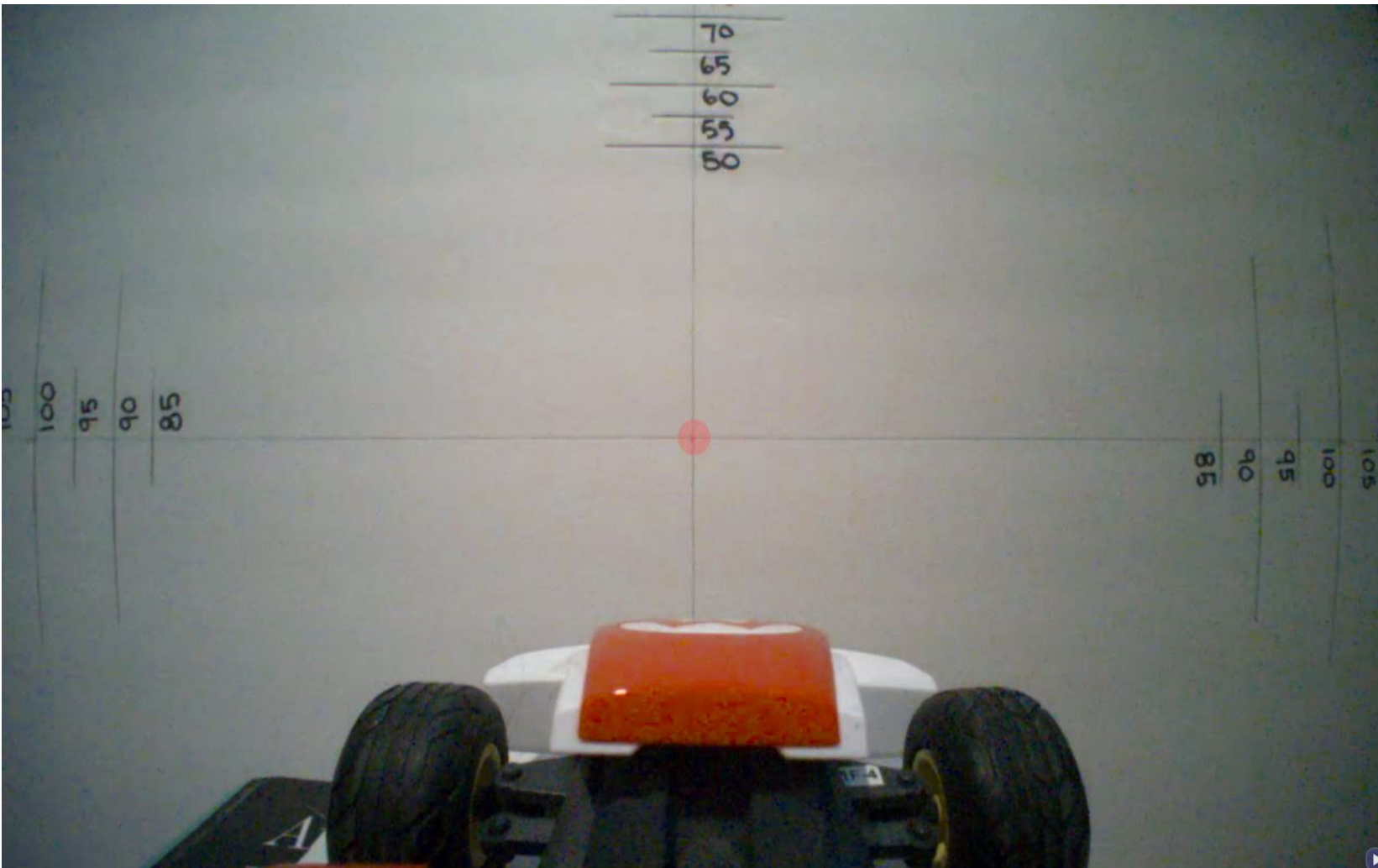
Camera Model



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Camera Model



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Camera Calibration



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Camera Calibration



Camera Model - Undistortion



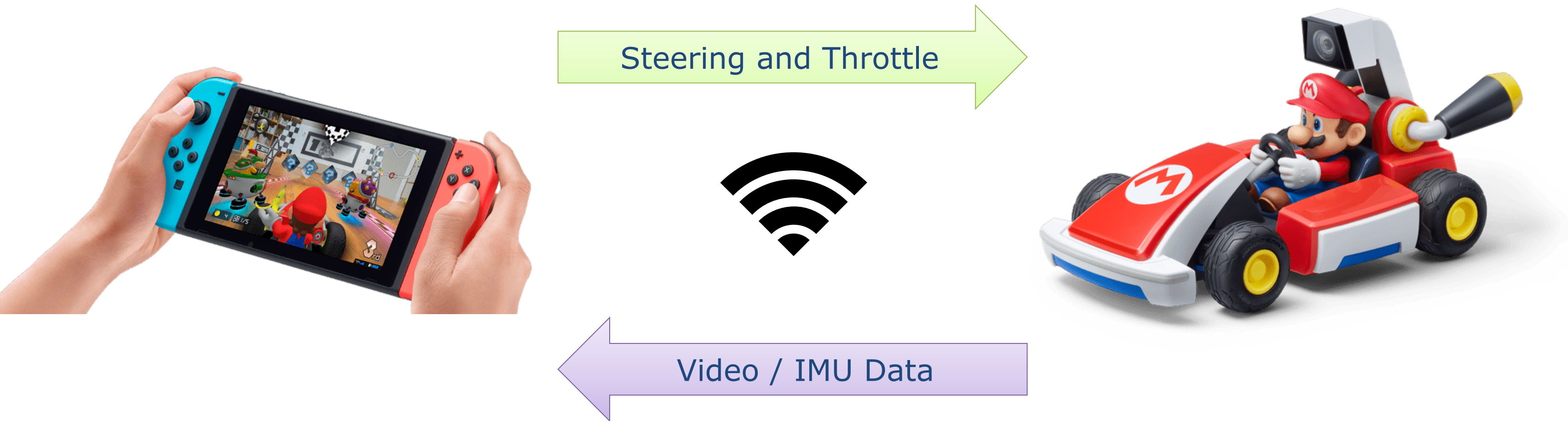
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Camera Model - Resources

- Google: “opencv calibrate camera”
- docs.opencv.org
 - `cv::findChessboardCorners()`
 - `cv::calibrateCamera()`
 - `cv::undistort()`

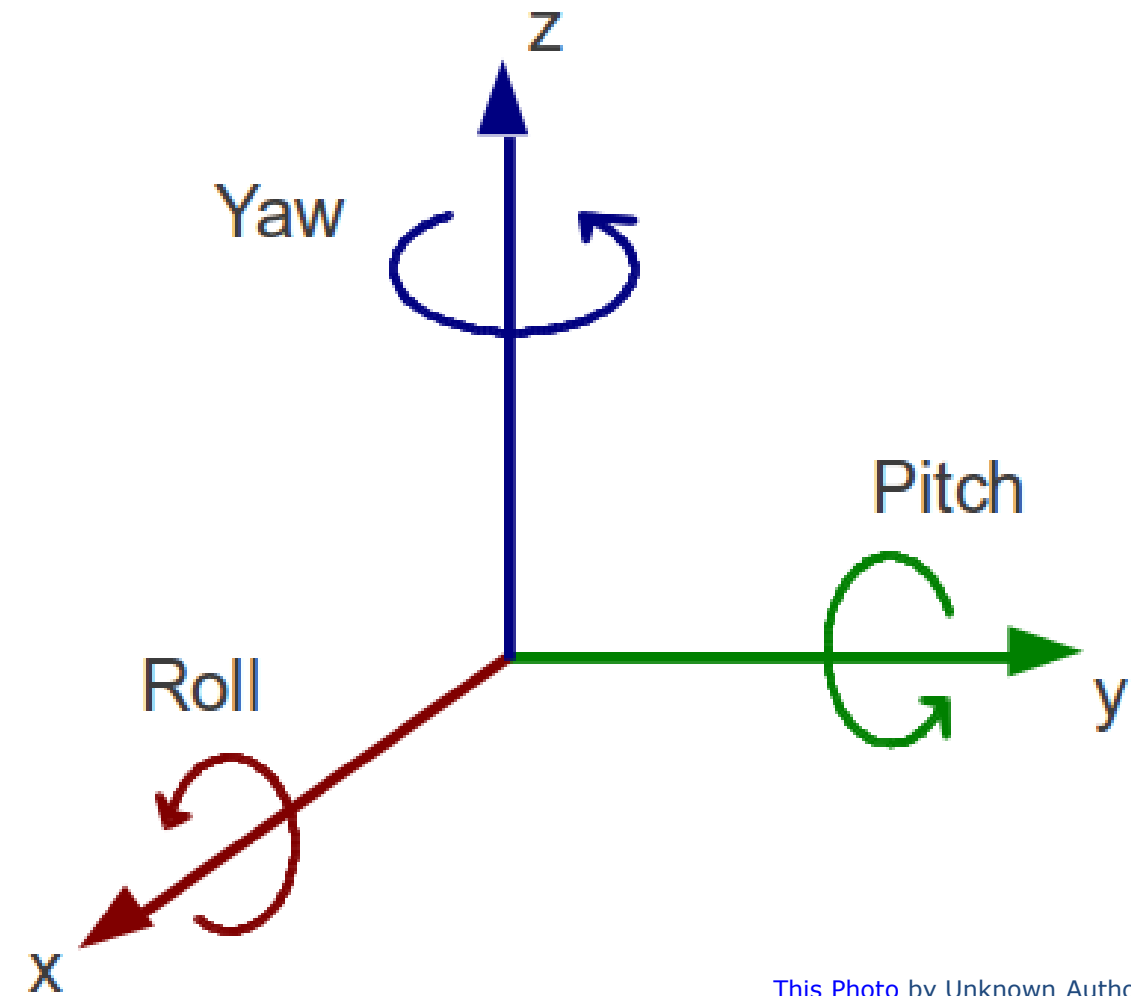
Data Stream



Data Stream - IMU Sample

IMU Sample

- timestamp_us
- acceleration_x
- acceleration_y
- acceleration_z
- angular_velocity_x
- angular_velocity_y
- angular_velocity_z



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Data Stream - Video

Video Frame

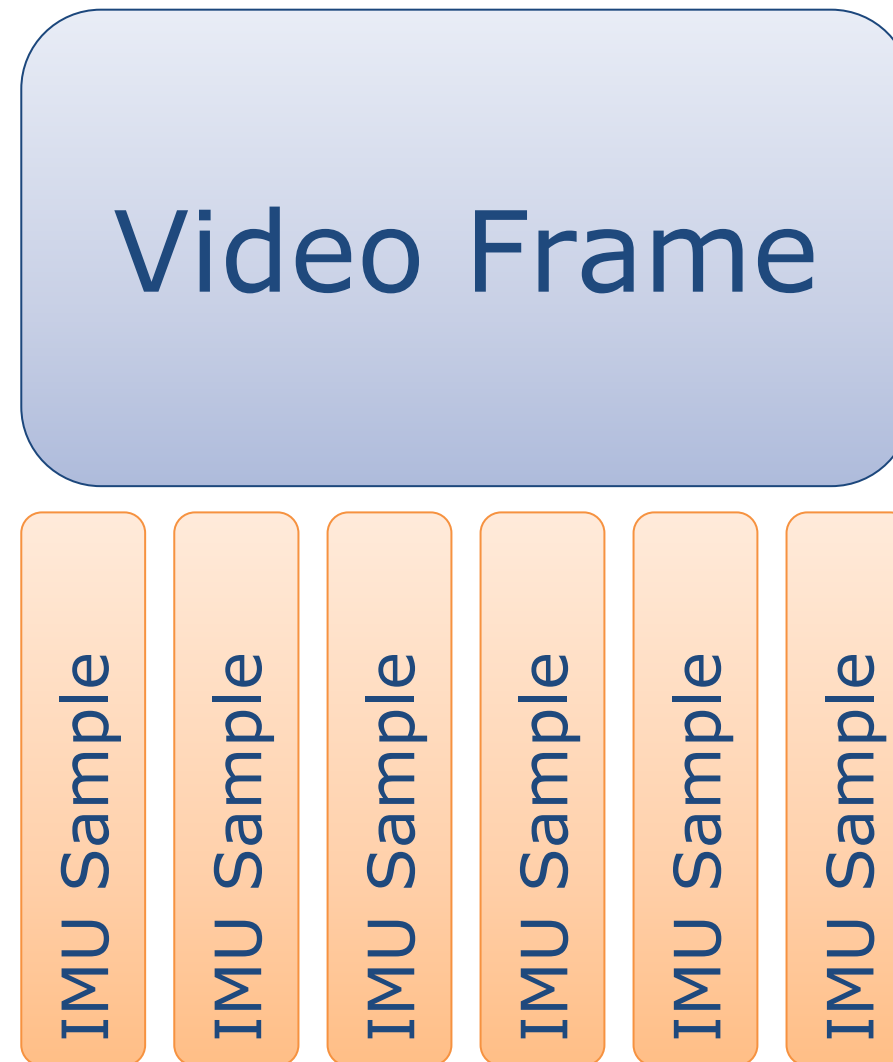
- timestamp_us



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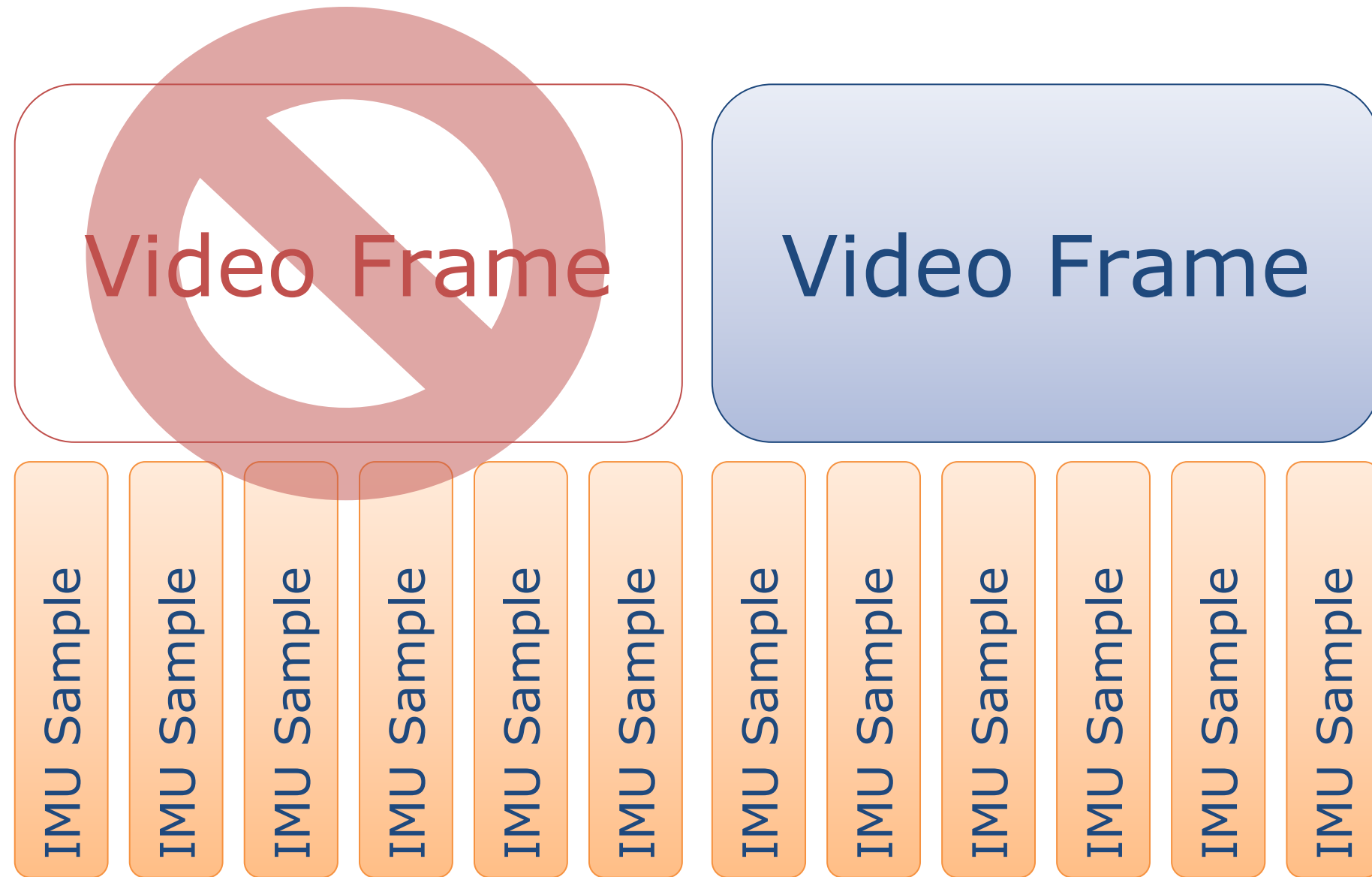
Data Stream



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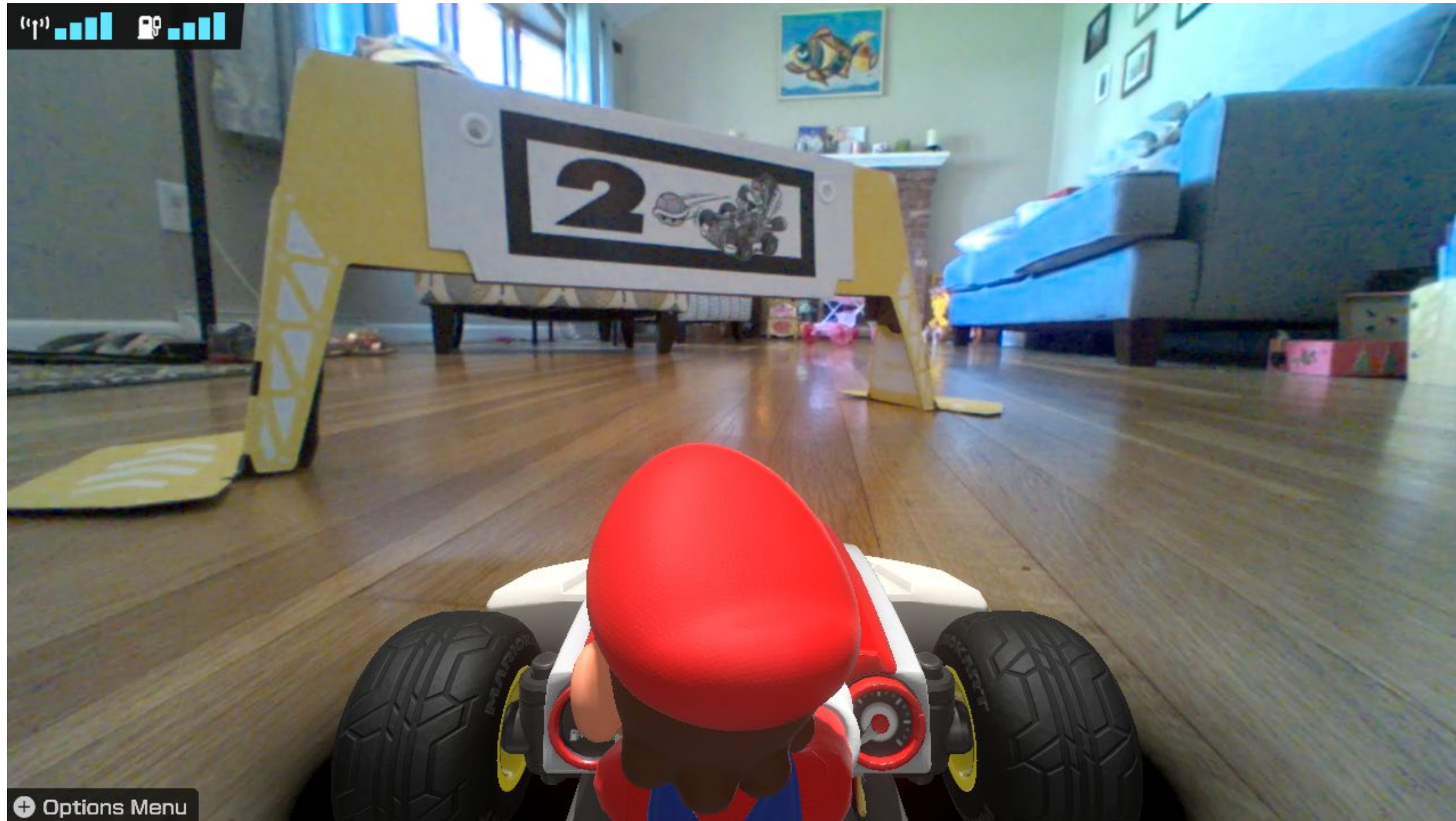
Data Stream



Banner Detection

COMPUTER VISION

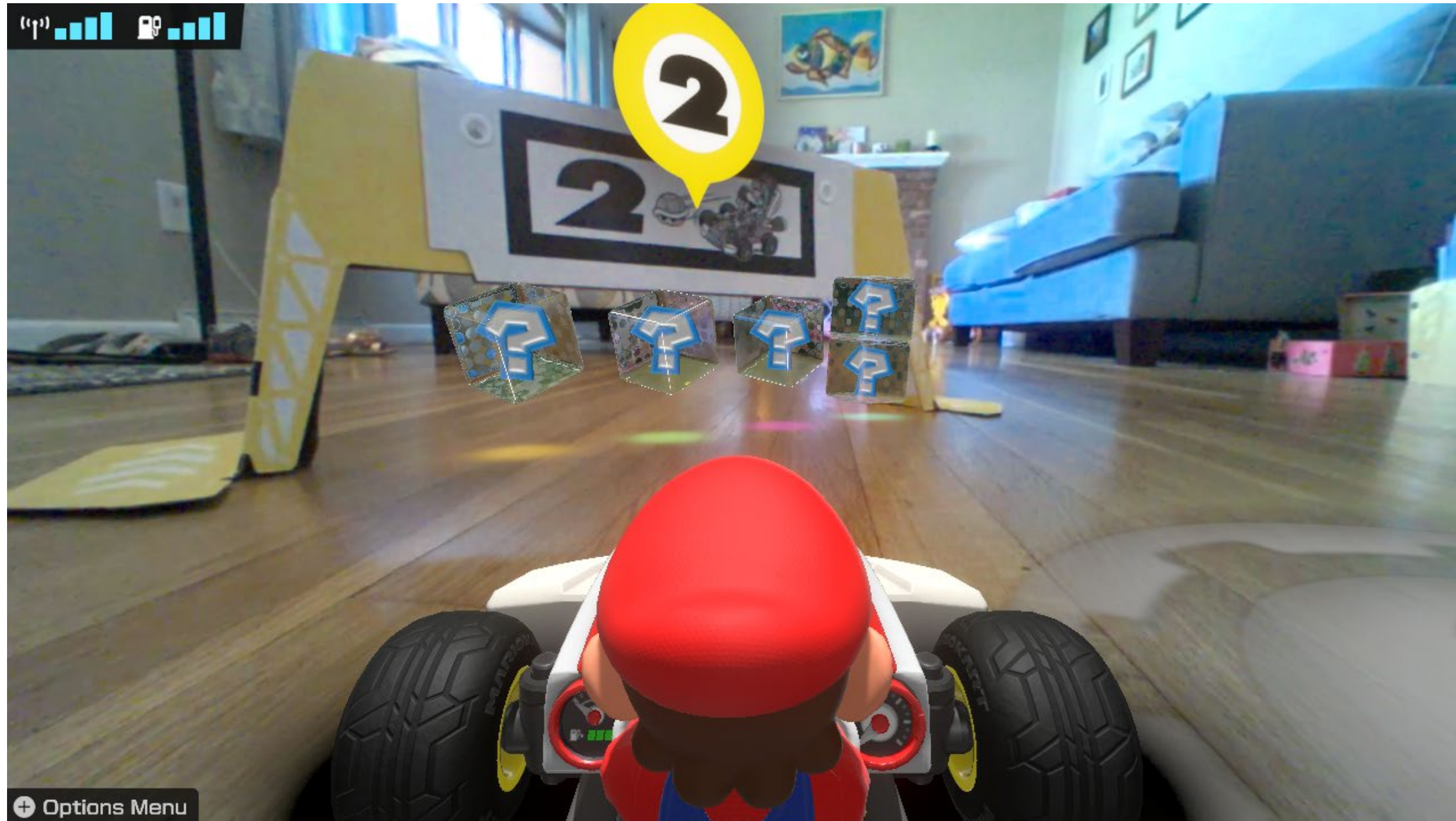
Banner Detection



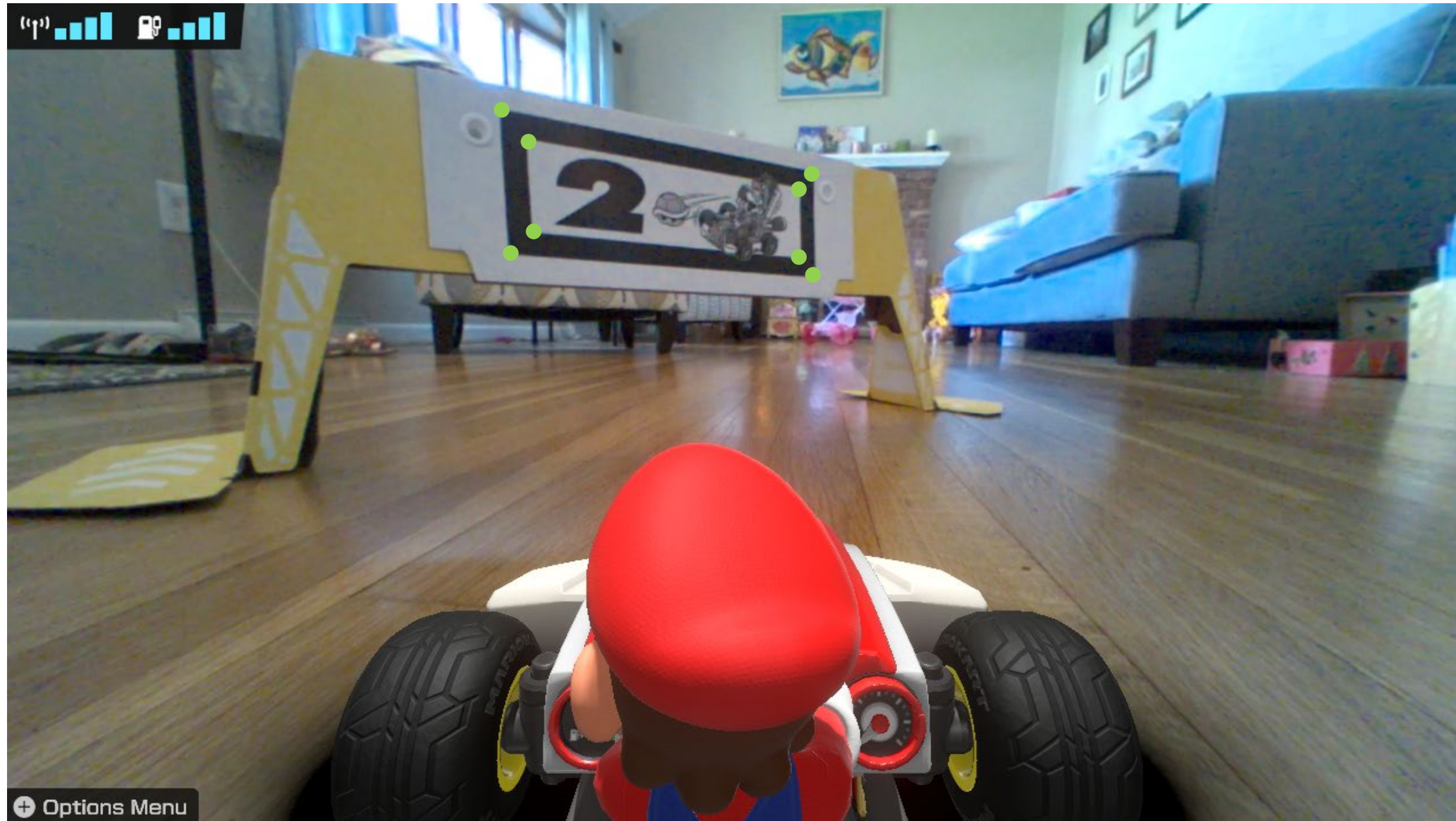
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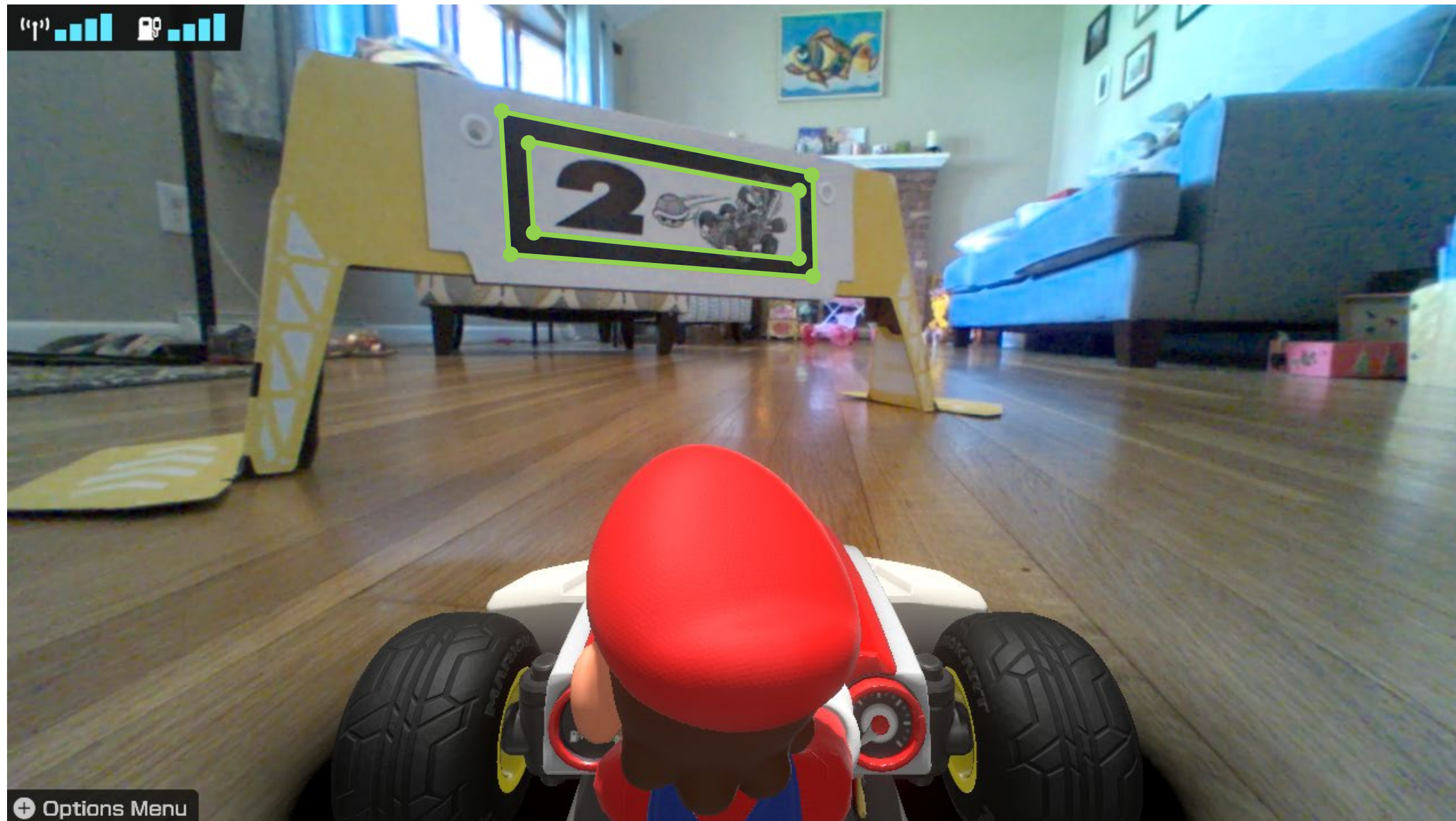
Banner Detection



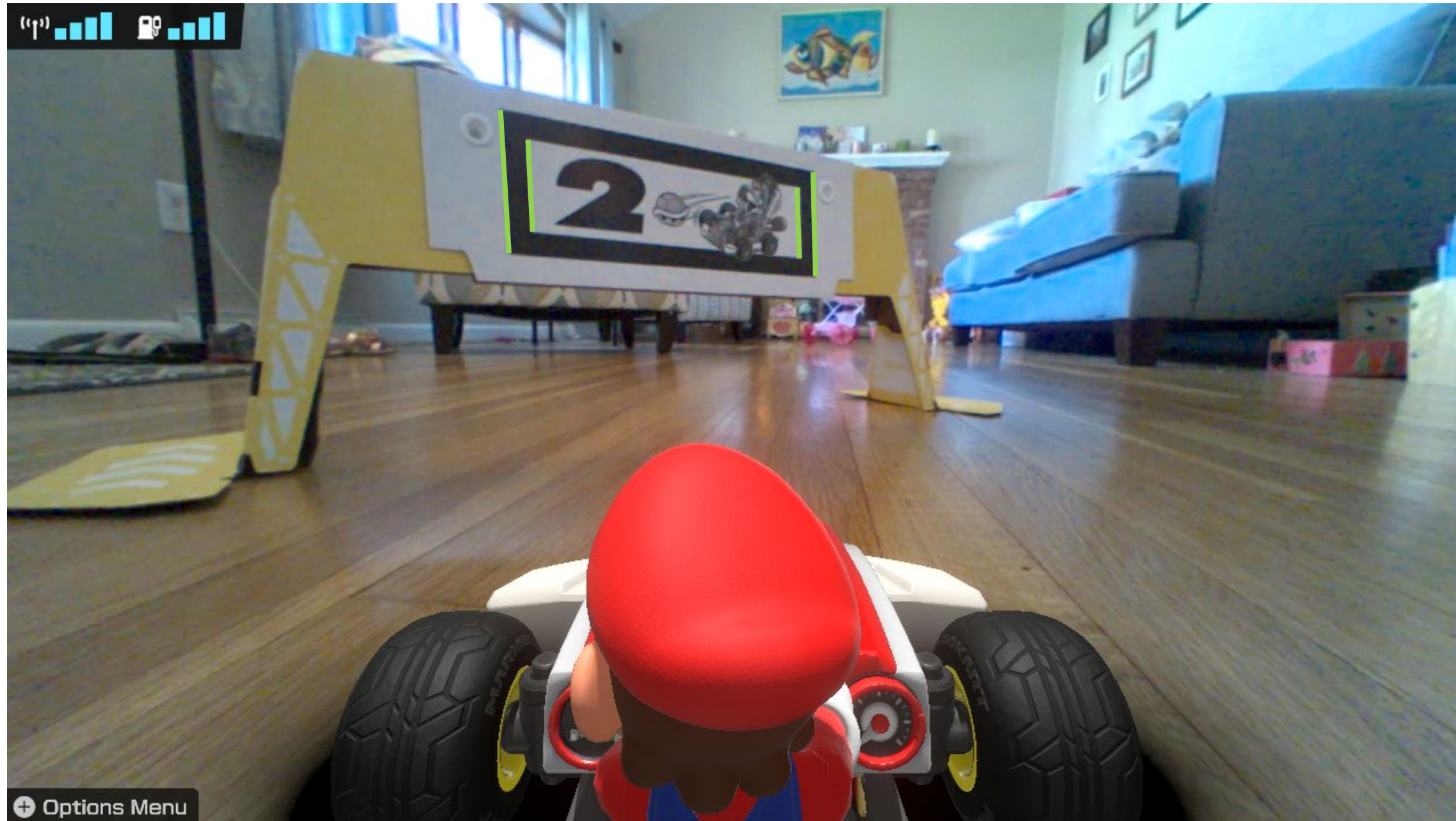
Banner Detection



Banner Detection



Banner Detection



Search For Transitions



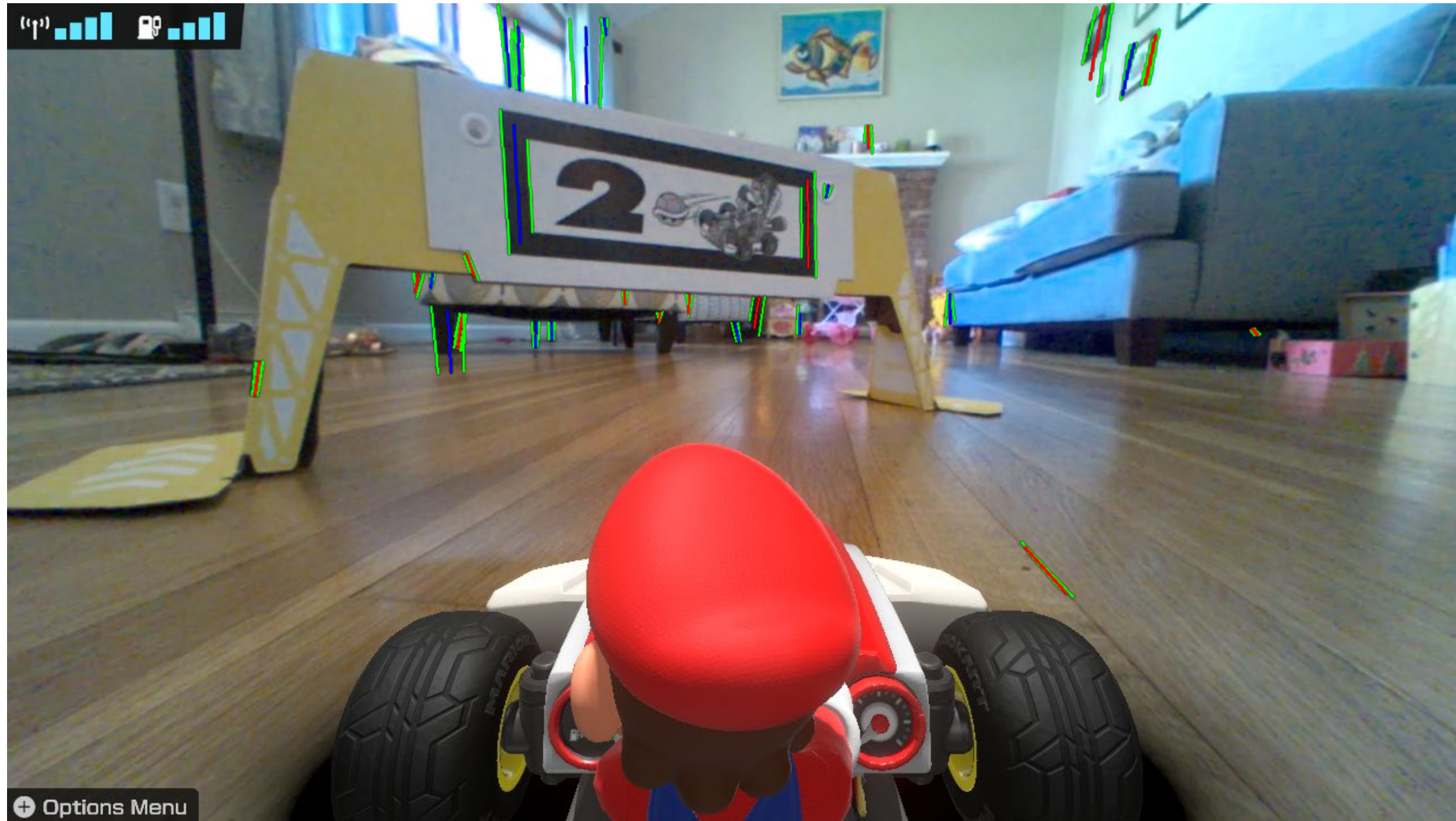
Walk Transitions



Walk Transitions



Find Edges



Pair Edges



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Find Quads



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Refine Quads



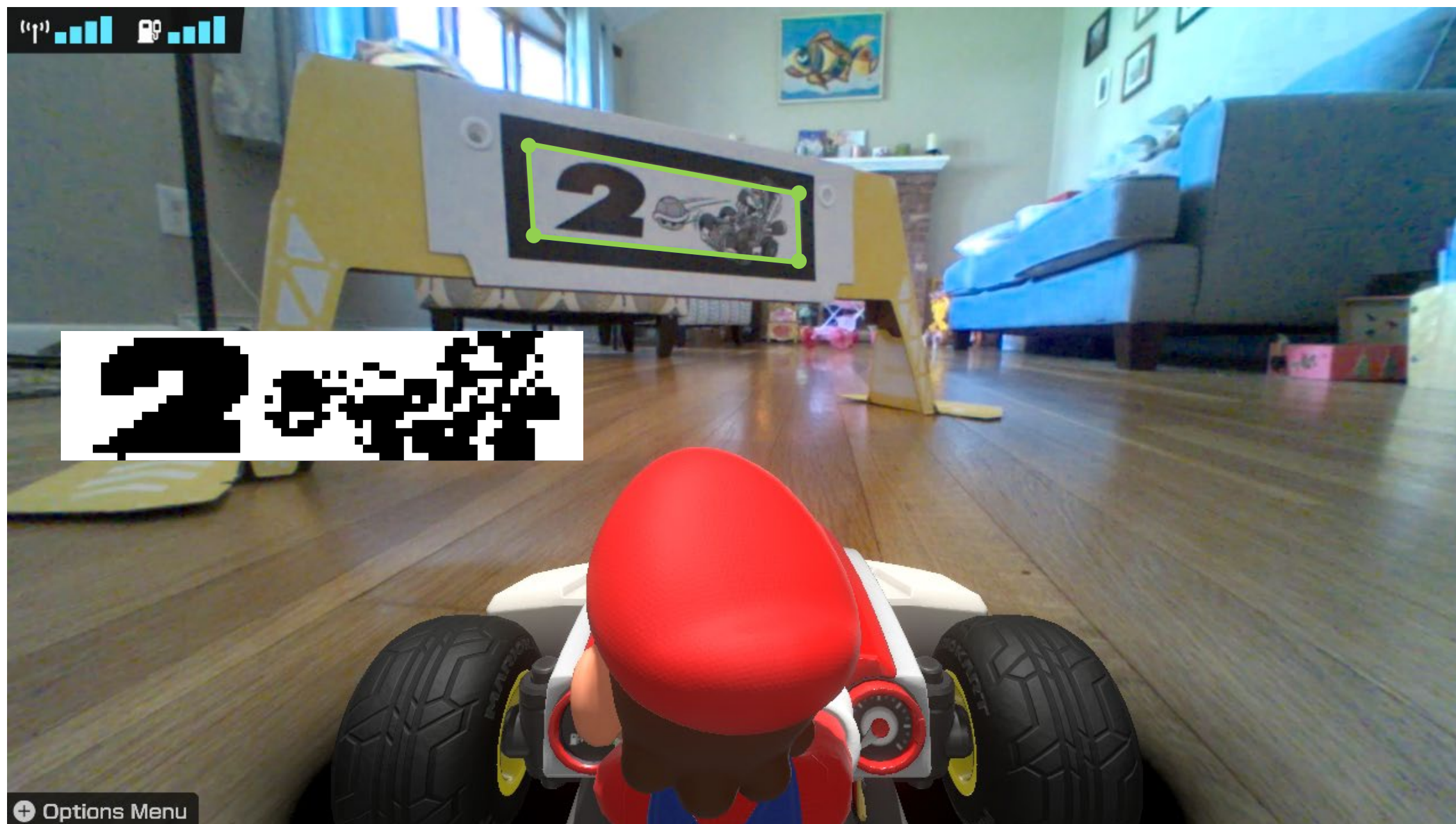
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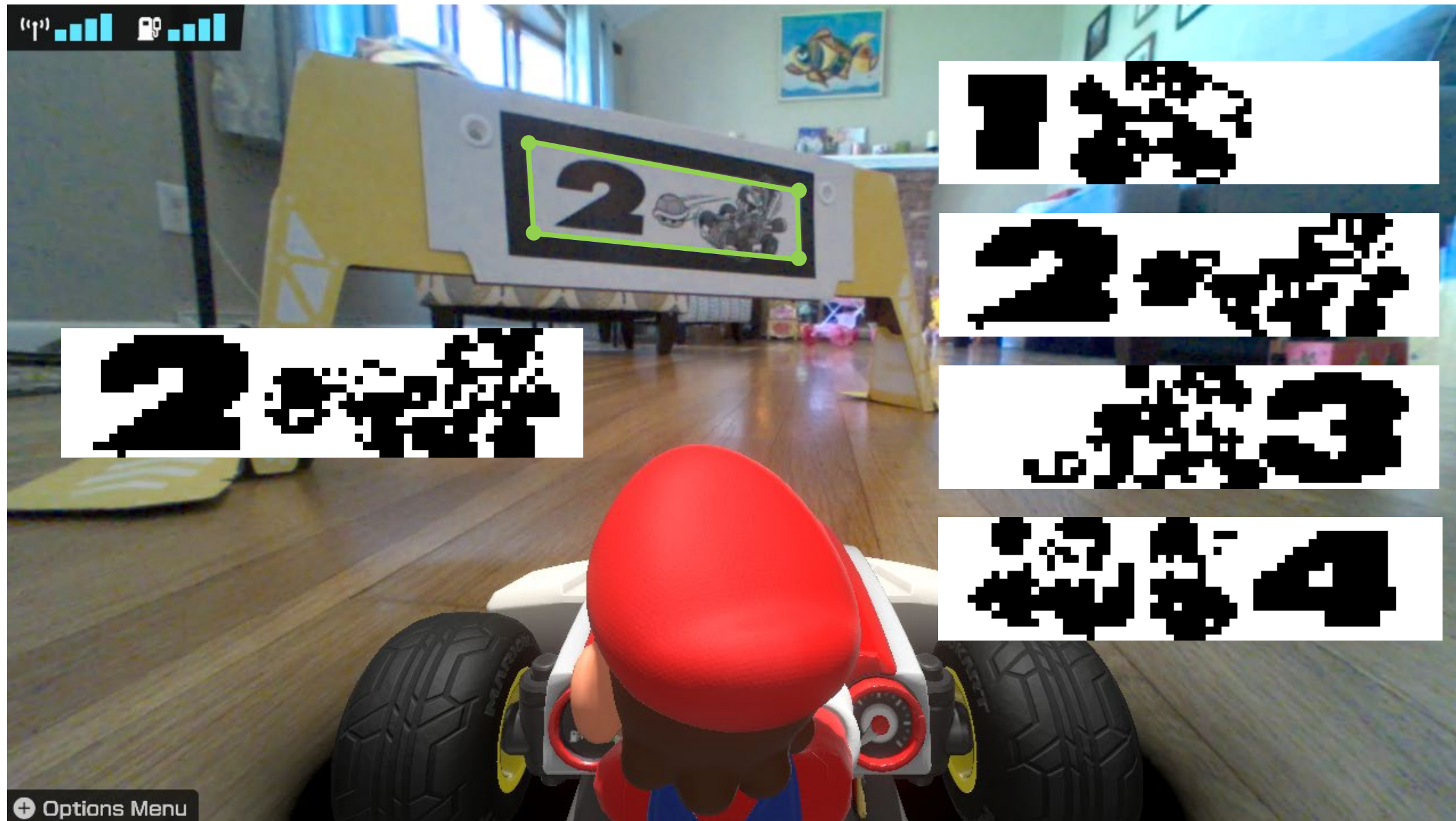
Banner ID



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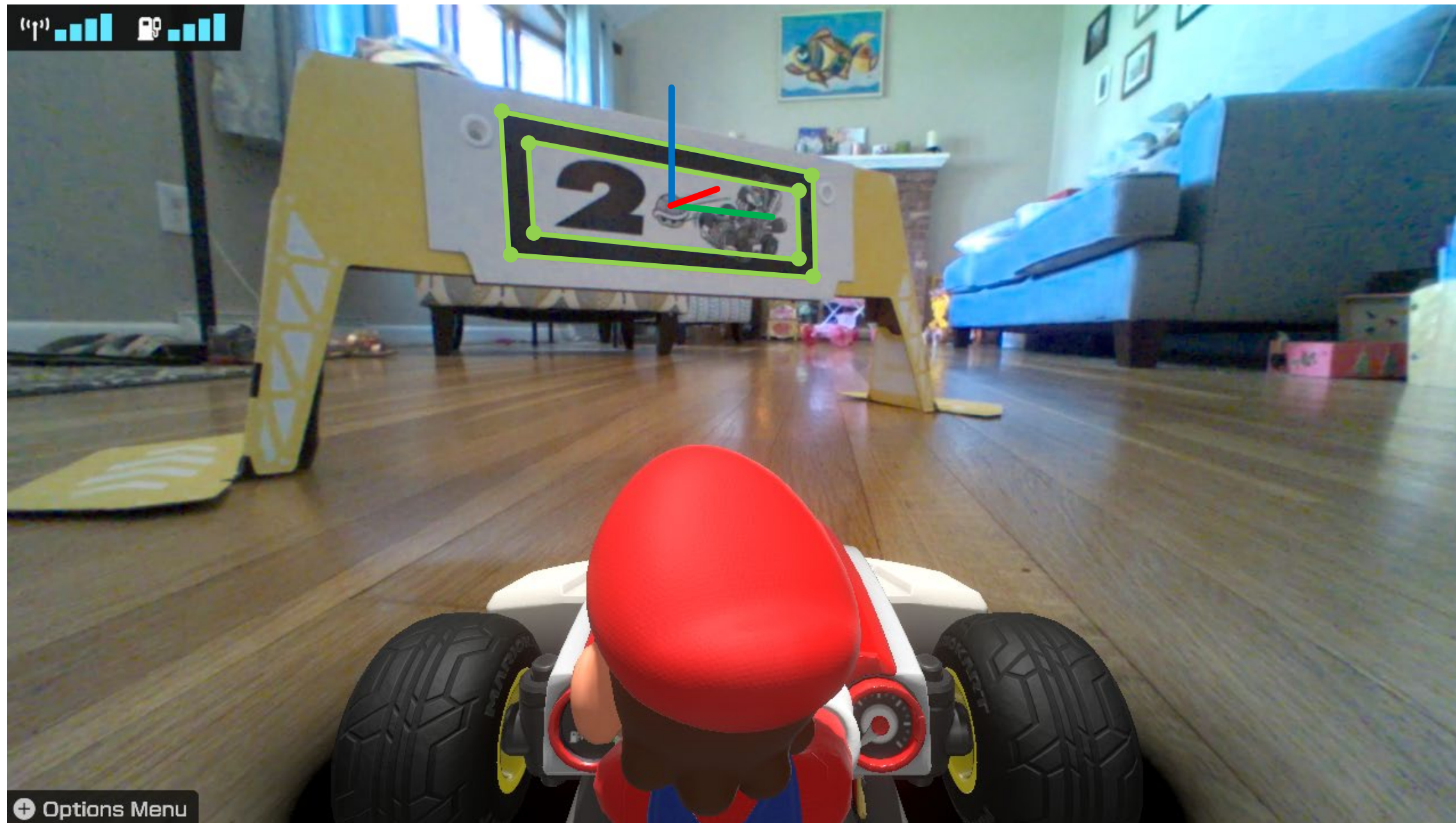
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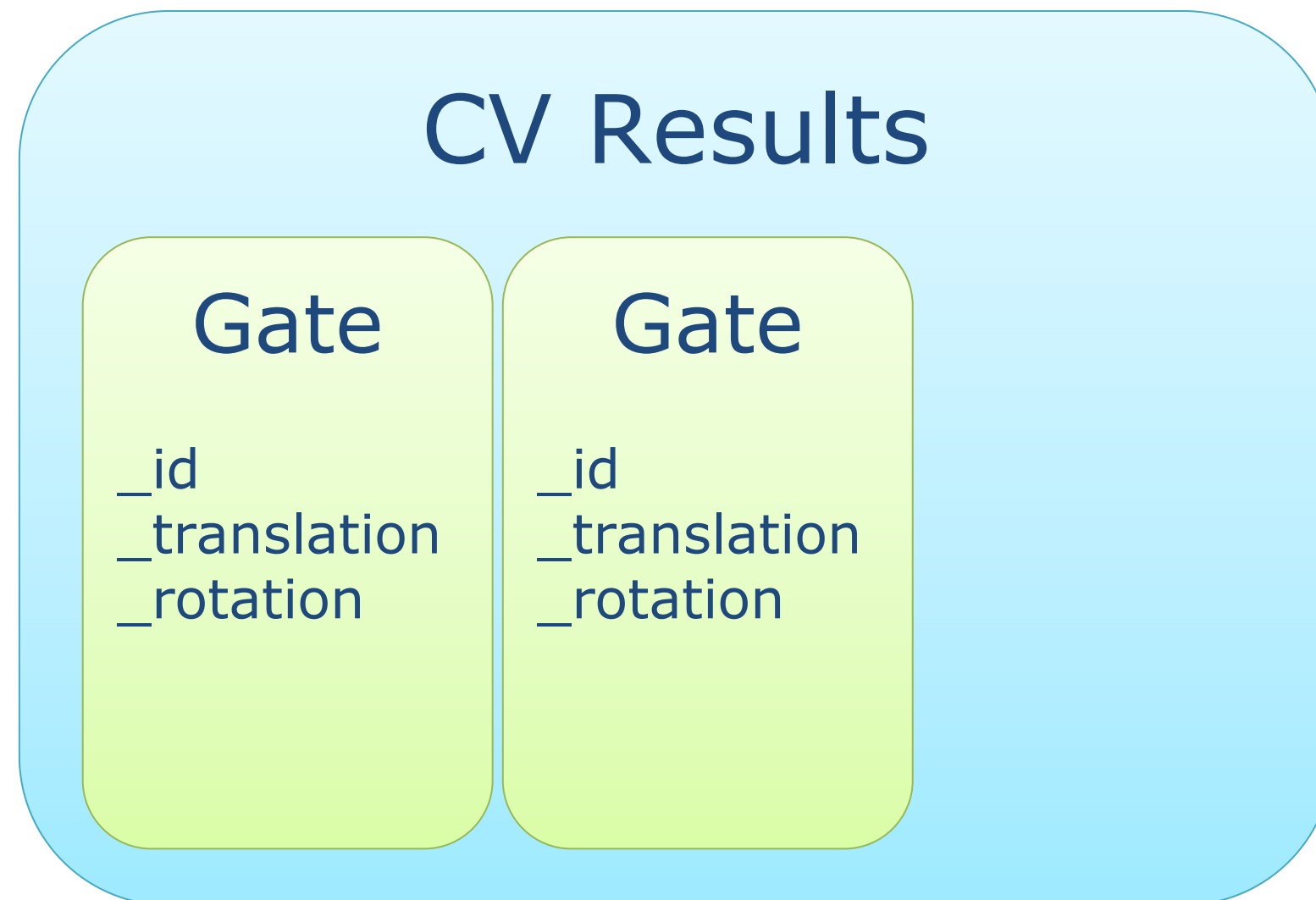
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Pose Estimation



CV Results



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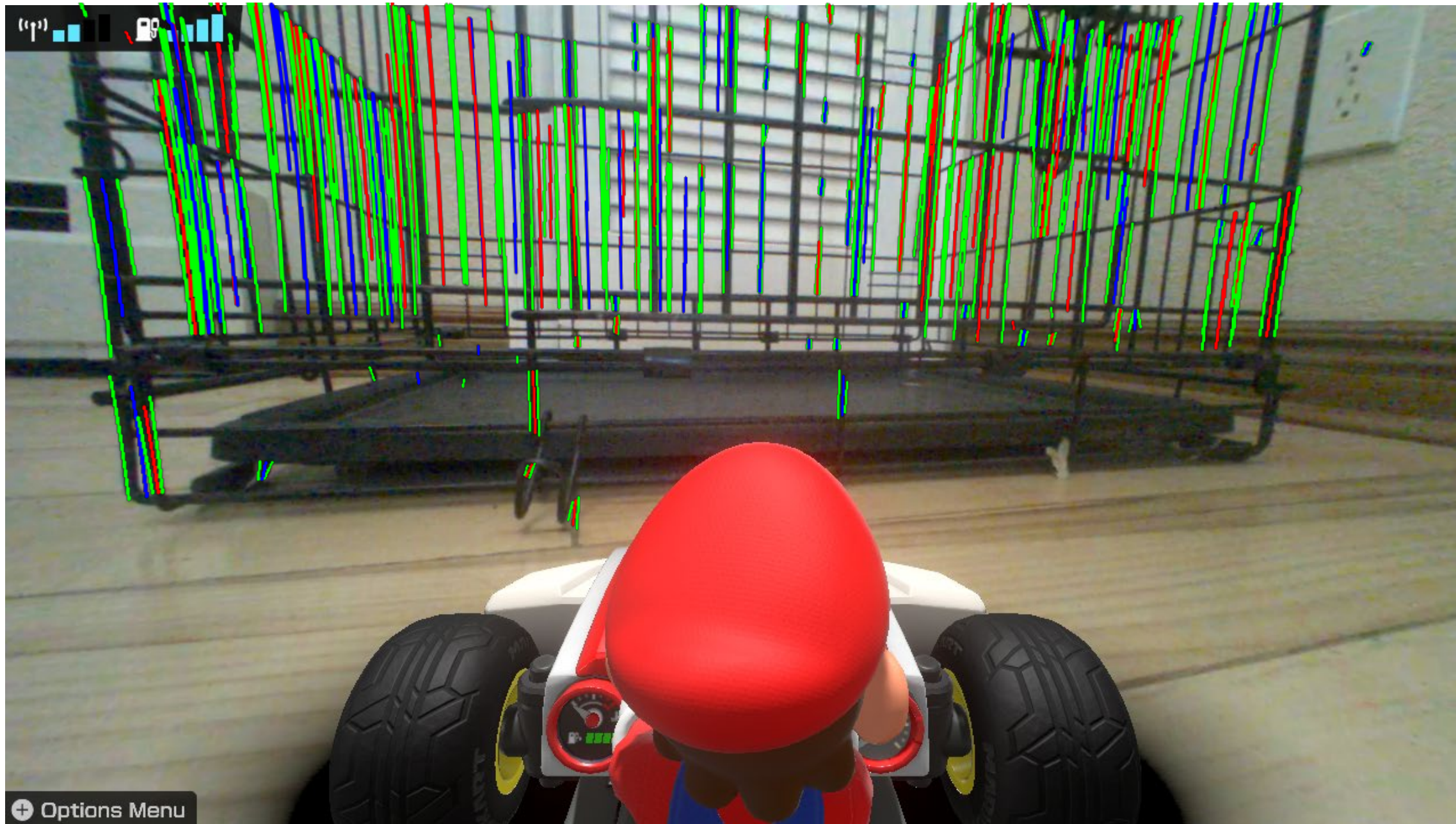
The Enemy



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The Enemy



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The Enemy



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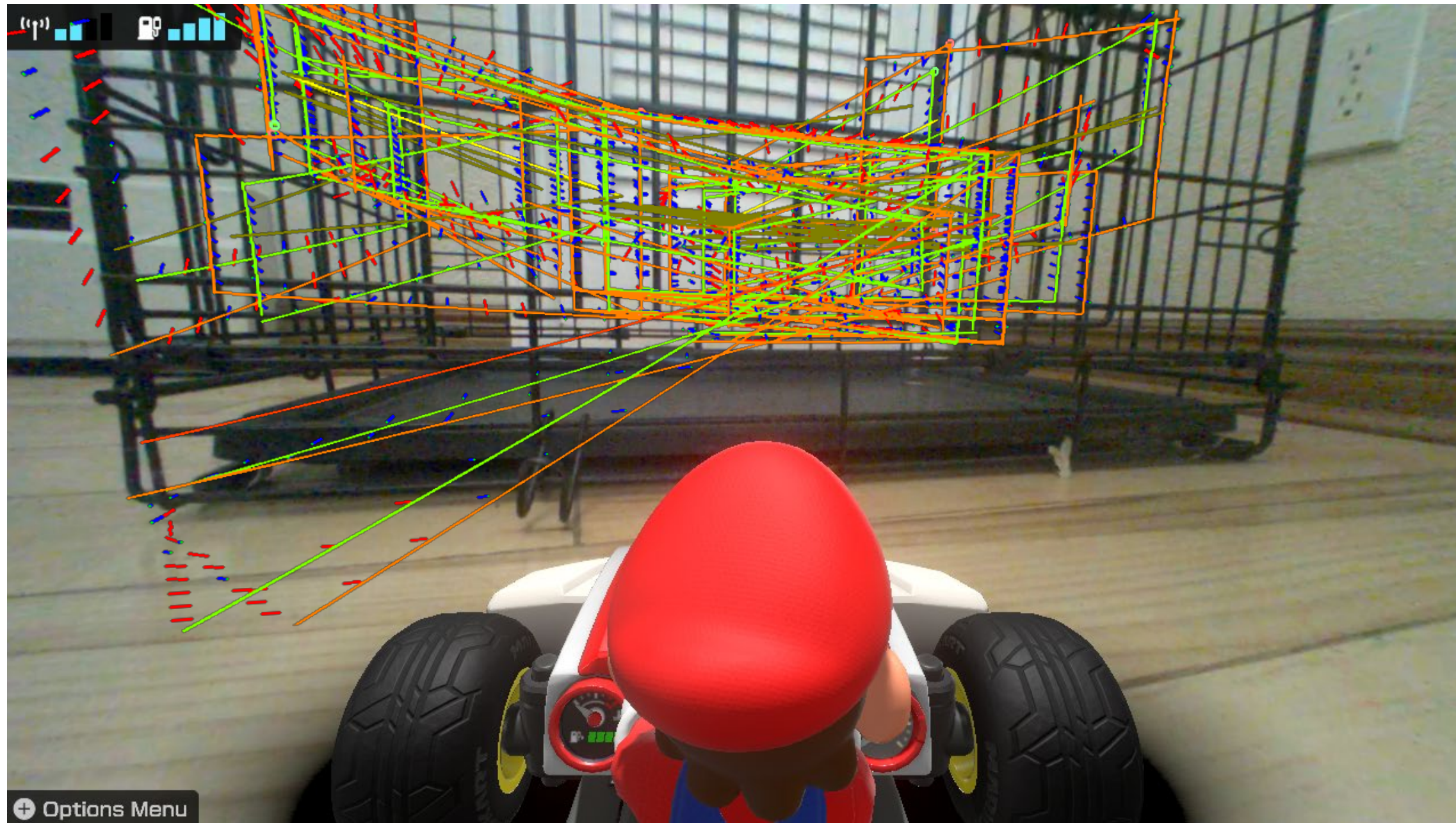
The Enemy



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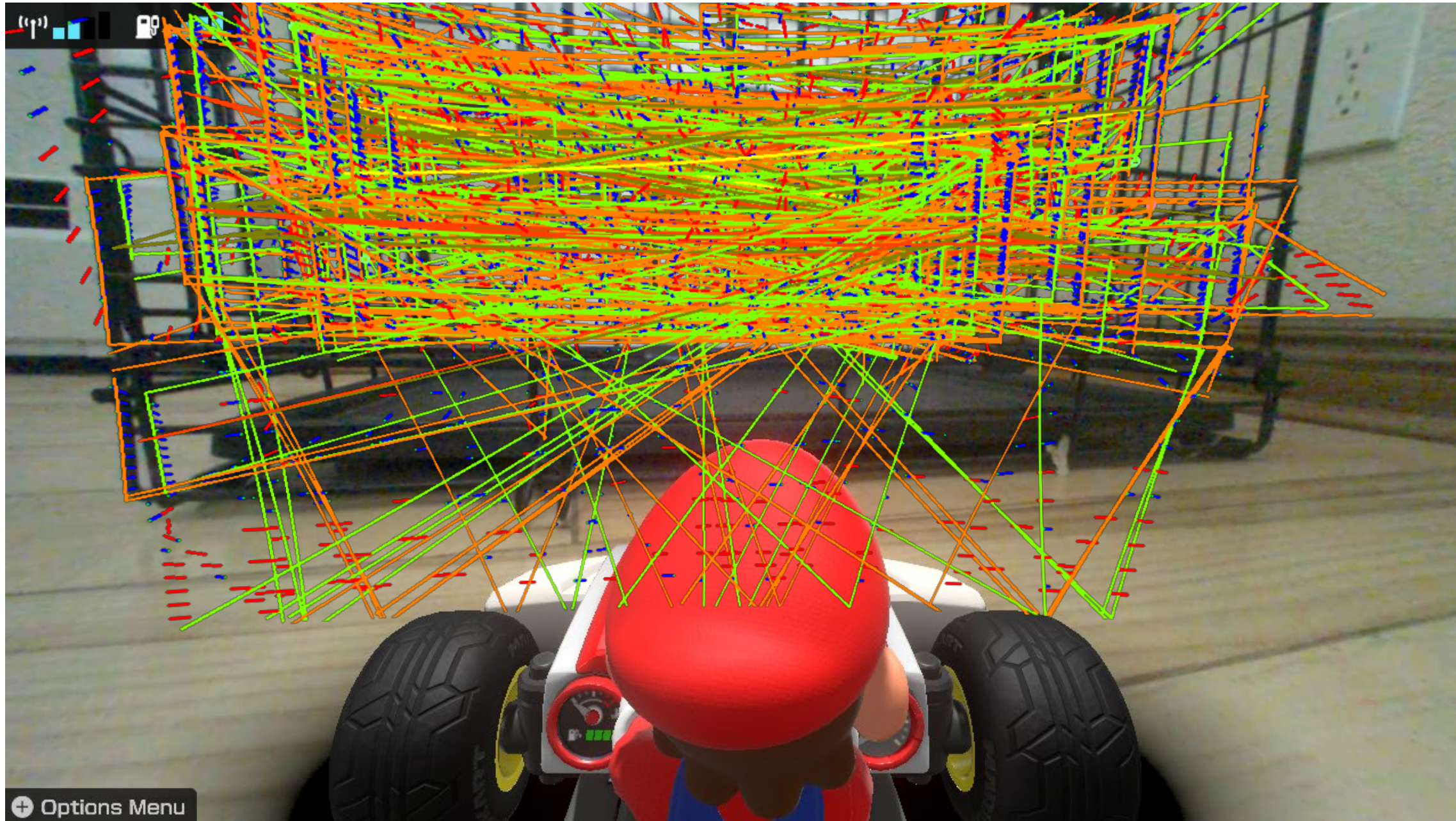
The Enemy



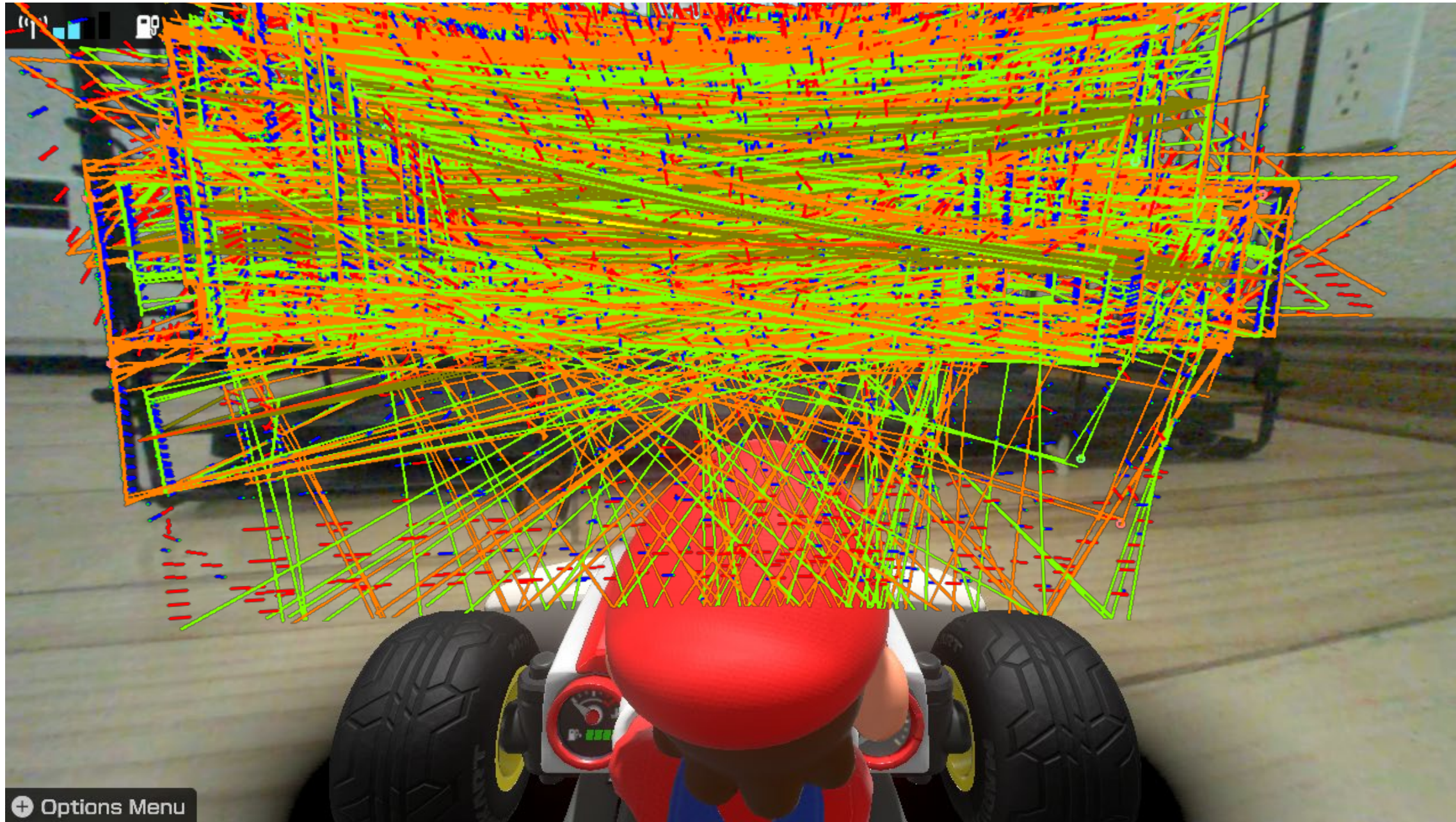
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The Enemy



The Enemy

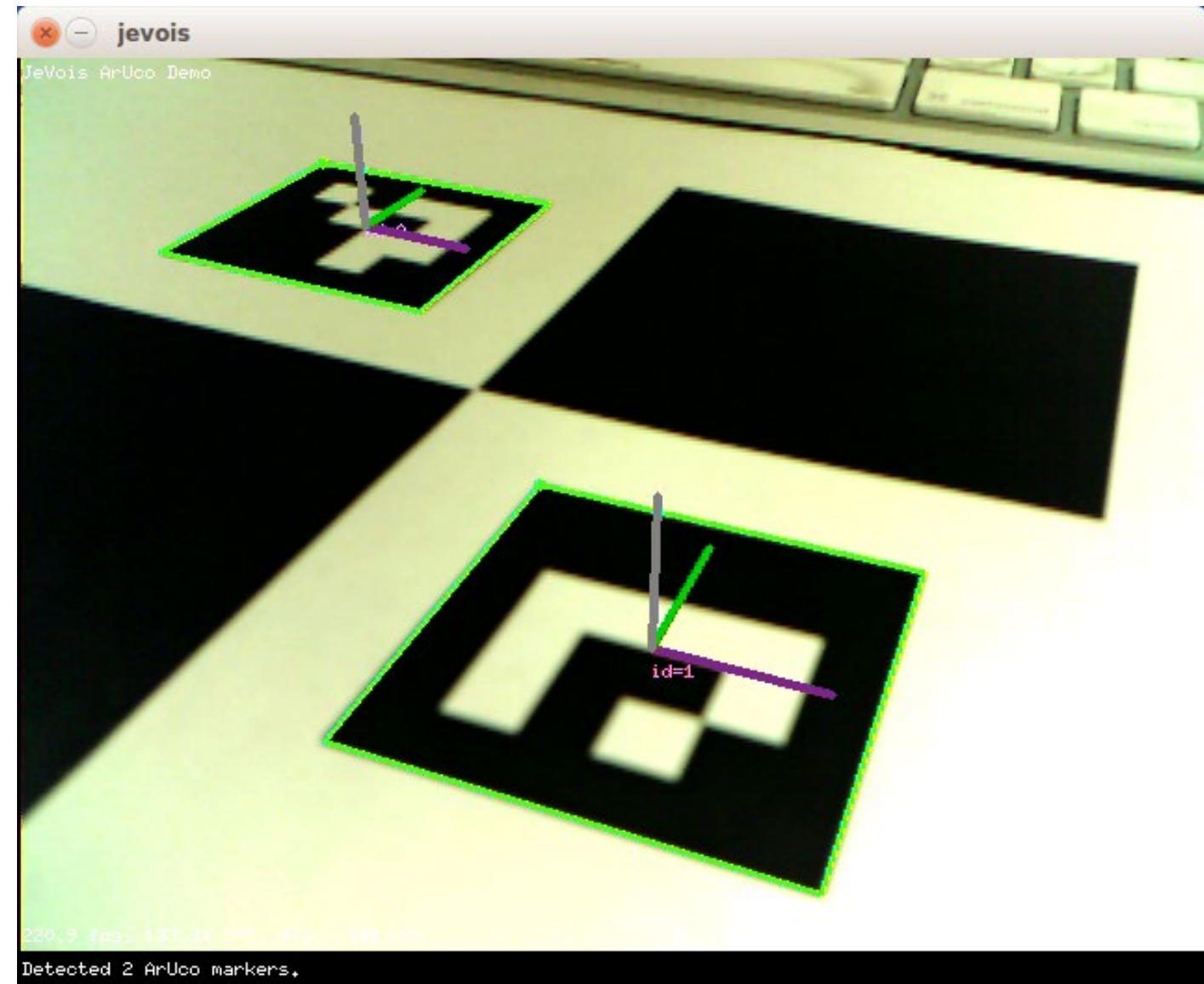


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Marker Resources

- Google: "opencv aruco detection"
- `cv::solvePnP()` – pose estimation



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Gates are good, but...



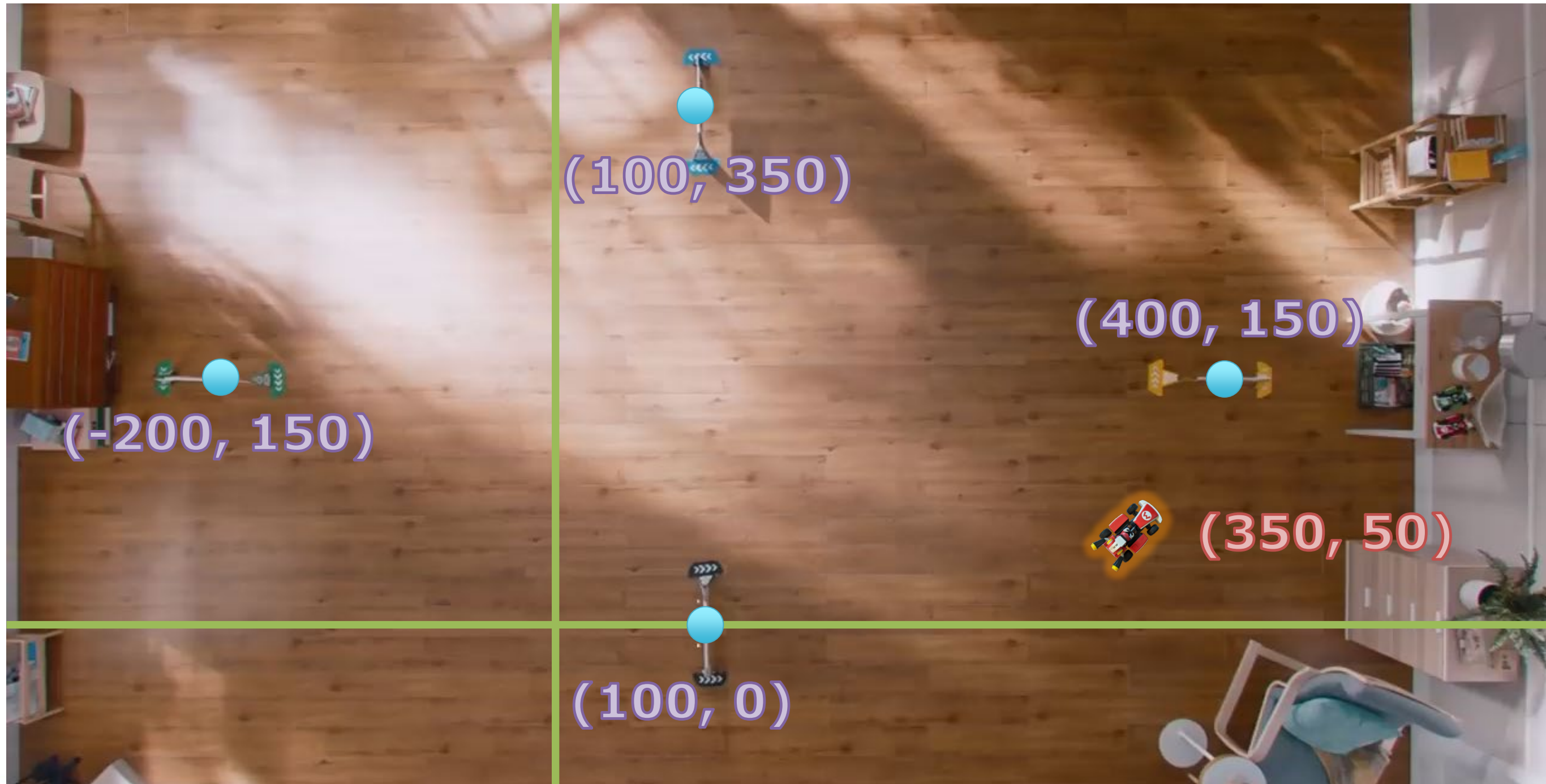
We need SLAM!

SLAM Definition

The computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location with it.

- wikipedia

SLAM

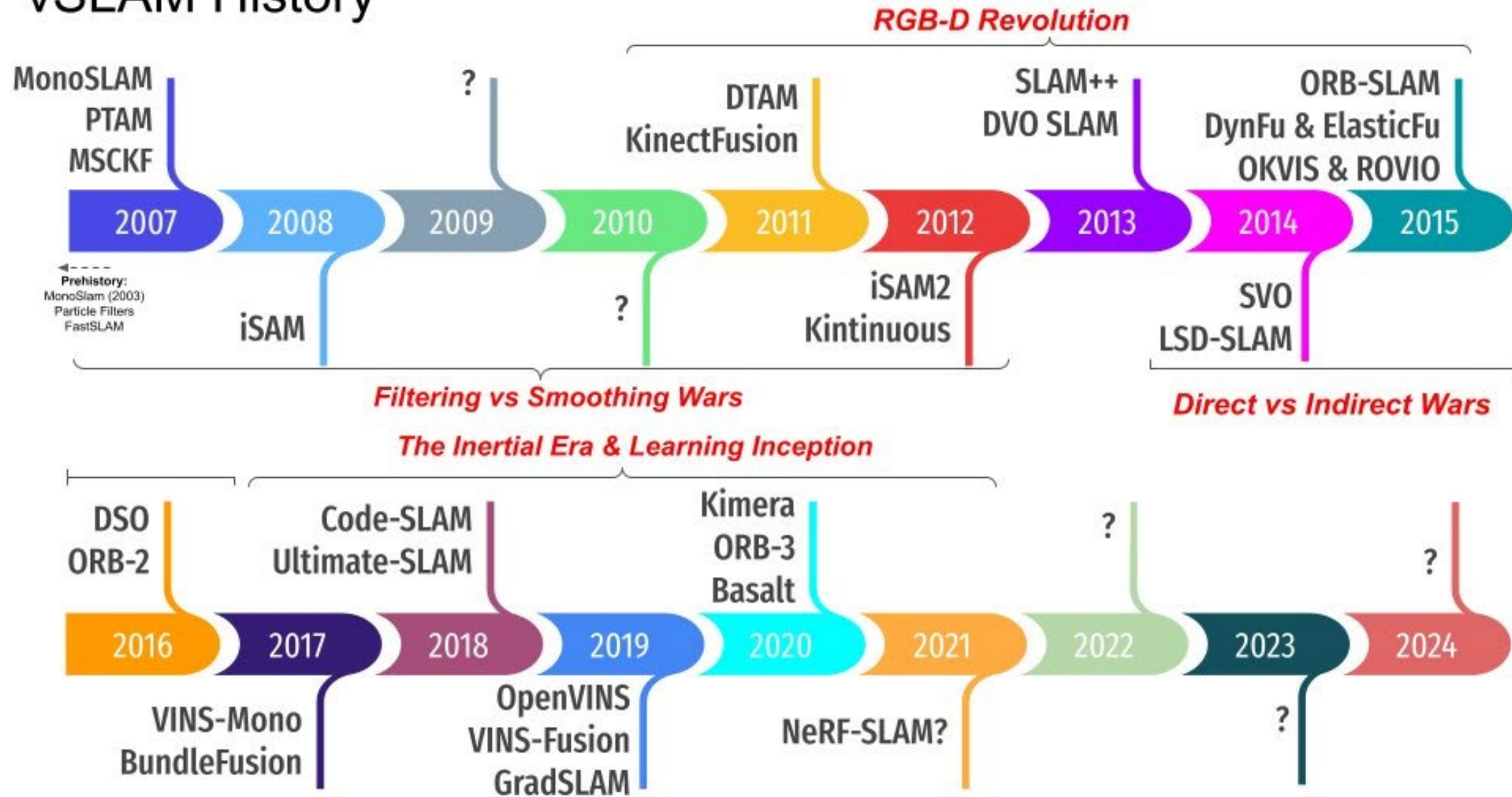


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SLAM Methods

vSLAM History



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EKF SLAM

YouTube

claus brenner slam

SLAM Lectures
Claus Brenner - 1 / 77

SLAM A 00
Claus Brenner
6:37

SLAM A 01
Claus Brenner
4:52

SLAM A 02
Claus Brenner
7:47

SLAM A 03
Claus Brenner
9:39

SLAM A 04
Claus Brenner
3:21

SLAM A 05
Claus Brenner
6:01

SLAM A 06

SLAM A 00

69,786 views • Mar 12, 2013

Claus Brenner
2.45K subscribers

Python code: <https://drive.google.com/open?id=0Bxw...>

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Velan Slam - vSLAM?

- SLI-EKF-SLAM



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Velan Slam - vSLAM?

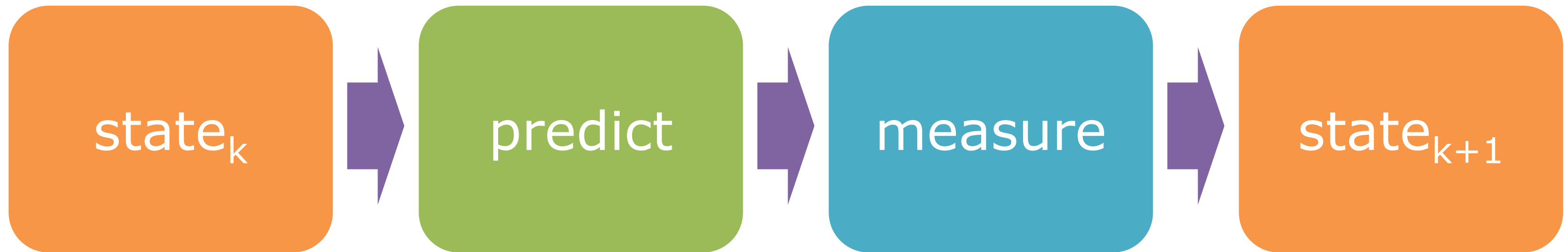
- SLI-EKF-SLAM
 - Sparse Landmark
 - Inertial
 - Extend Kalman Filter
 - Simultaneous Localization and Mapping



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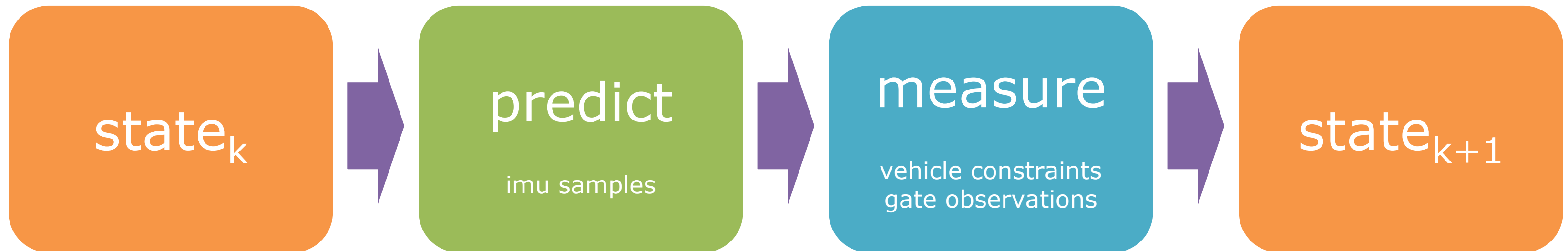
EKF Update



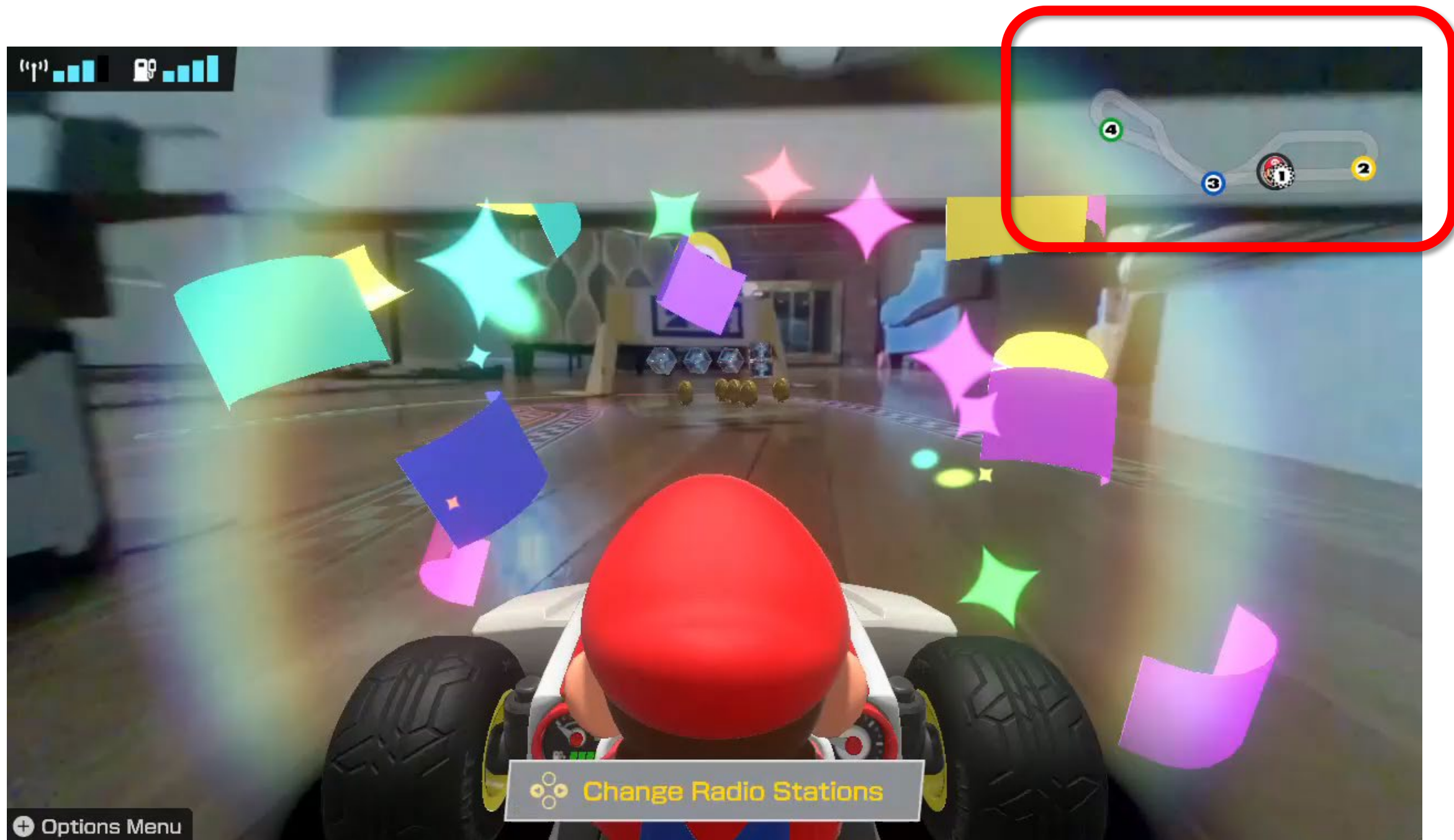
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EKF Update



SLAM – Example Run



Predict With IMU

$$a = accel_x - bias_x$$

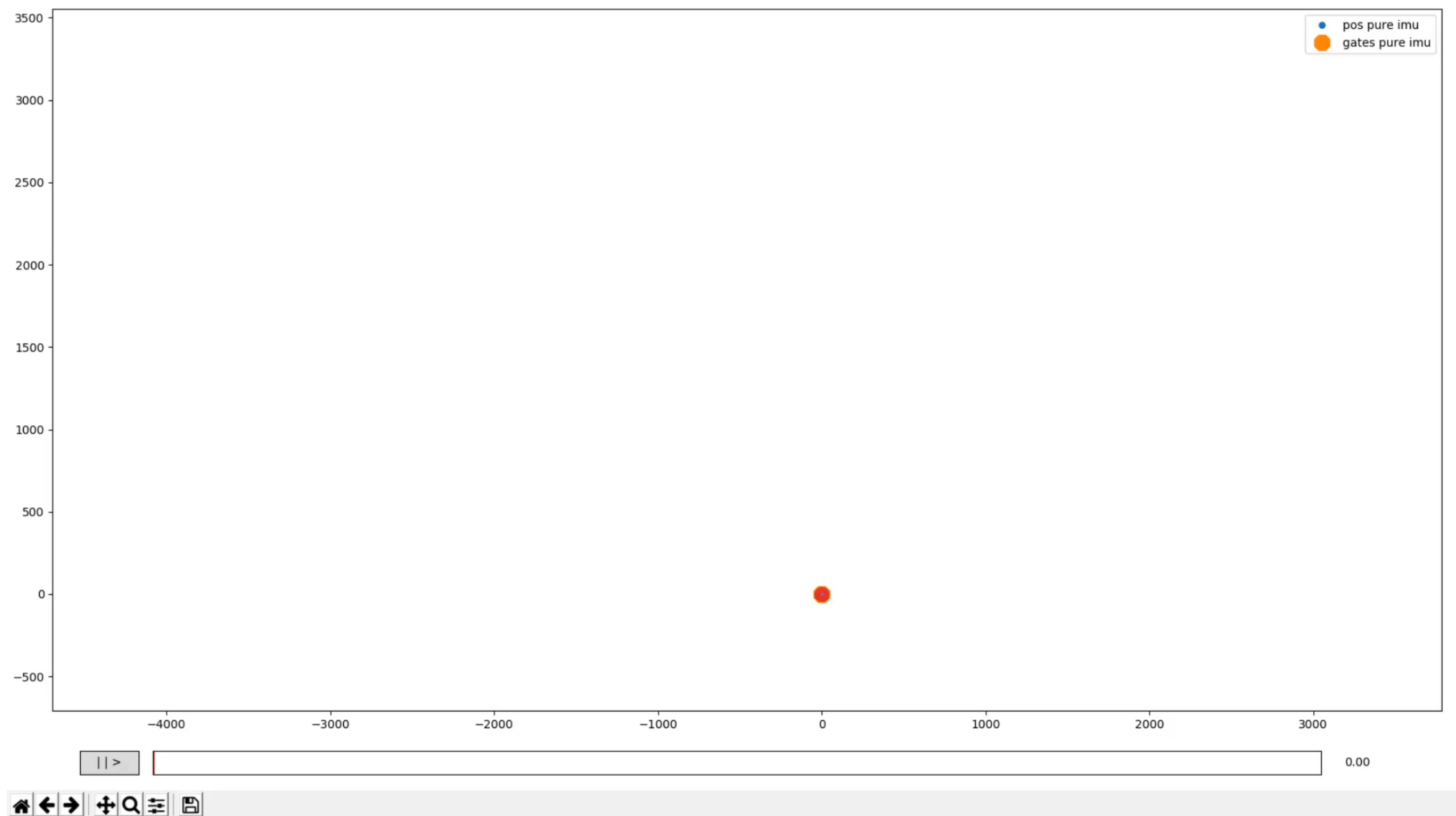
$$v = v_0 + a * dt$$

$$x = x_0 + v_0 * dt + (1/2)a * dt^2$$

IMU Sample

- timestamp_us
- acceleration_x
- acceleration_y
- acceleration_z
- angular_velocity_x
- angular_velocity_y
- angular_velocity_z

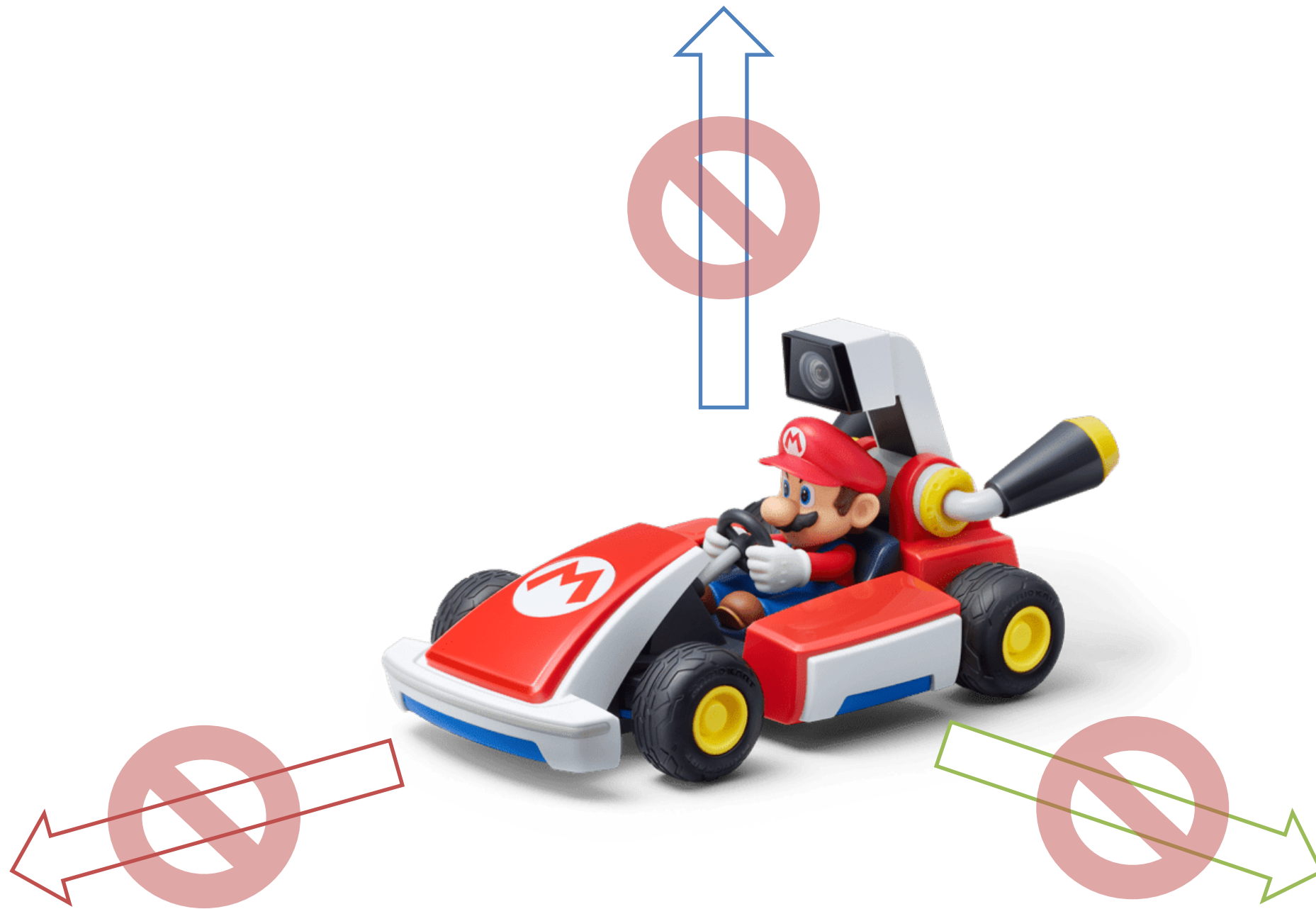
SLAM – Pure Integration



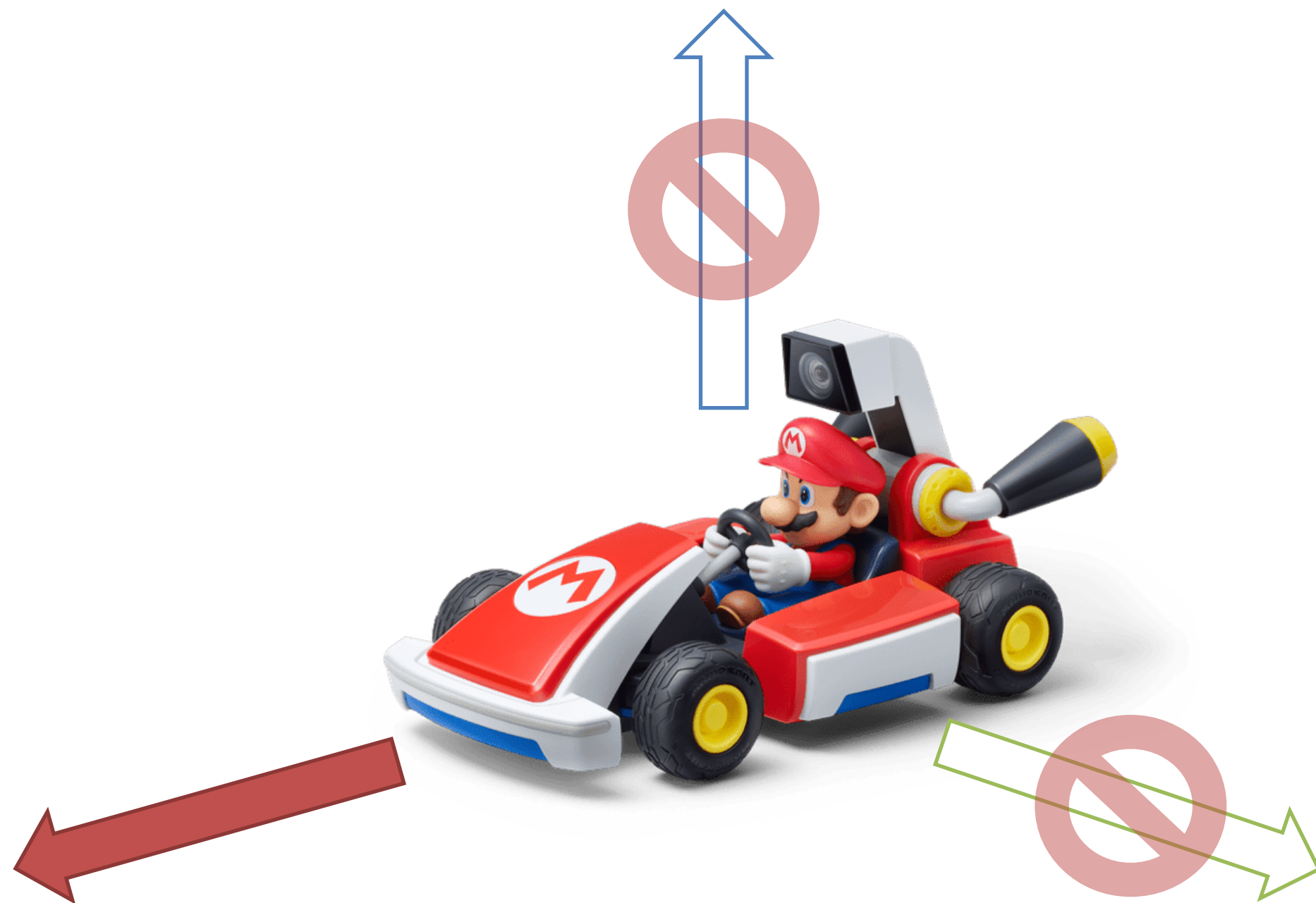
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Measure – Stillness



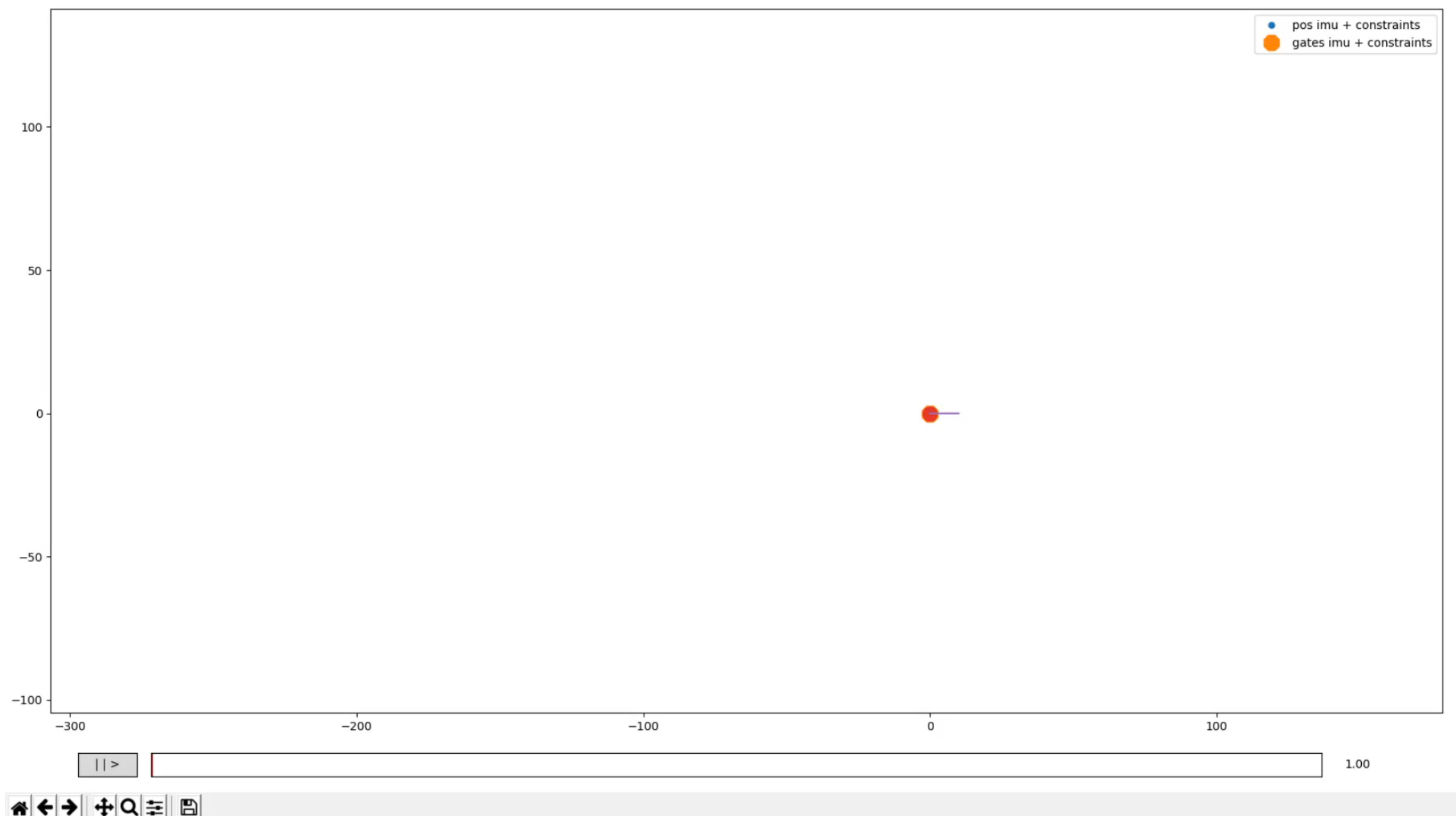
Measure – Driving



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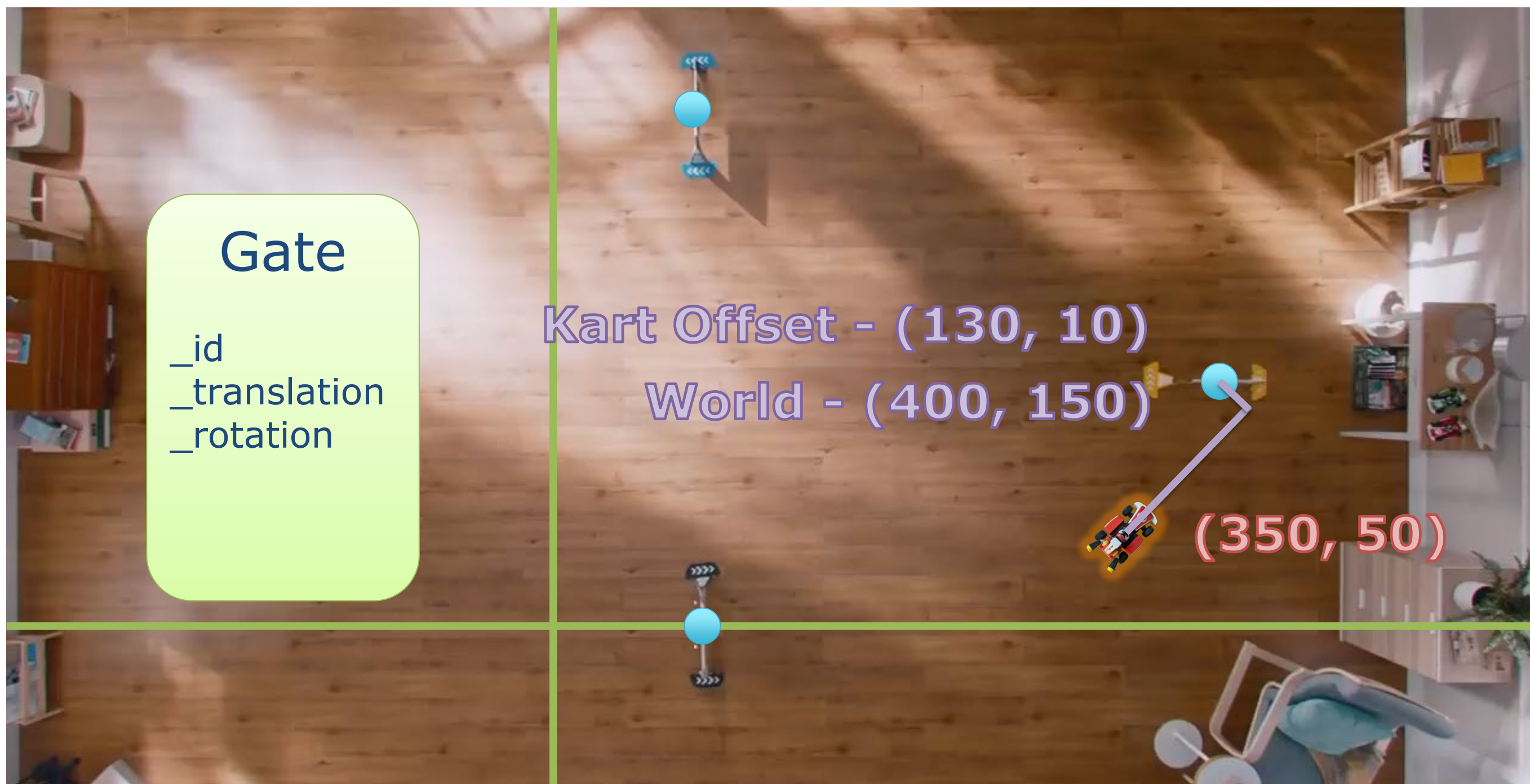
SLAM – IMU + Motion Constraints



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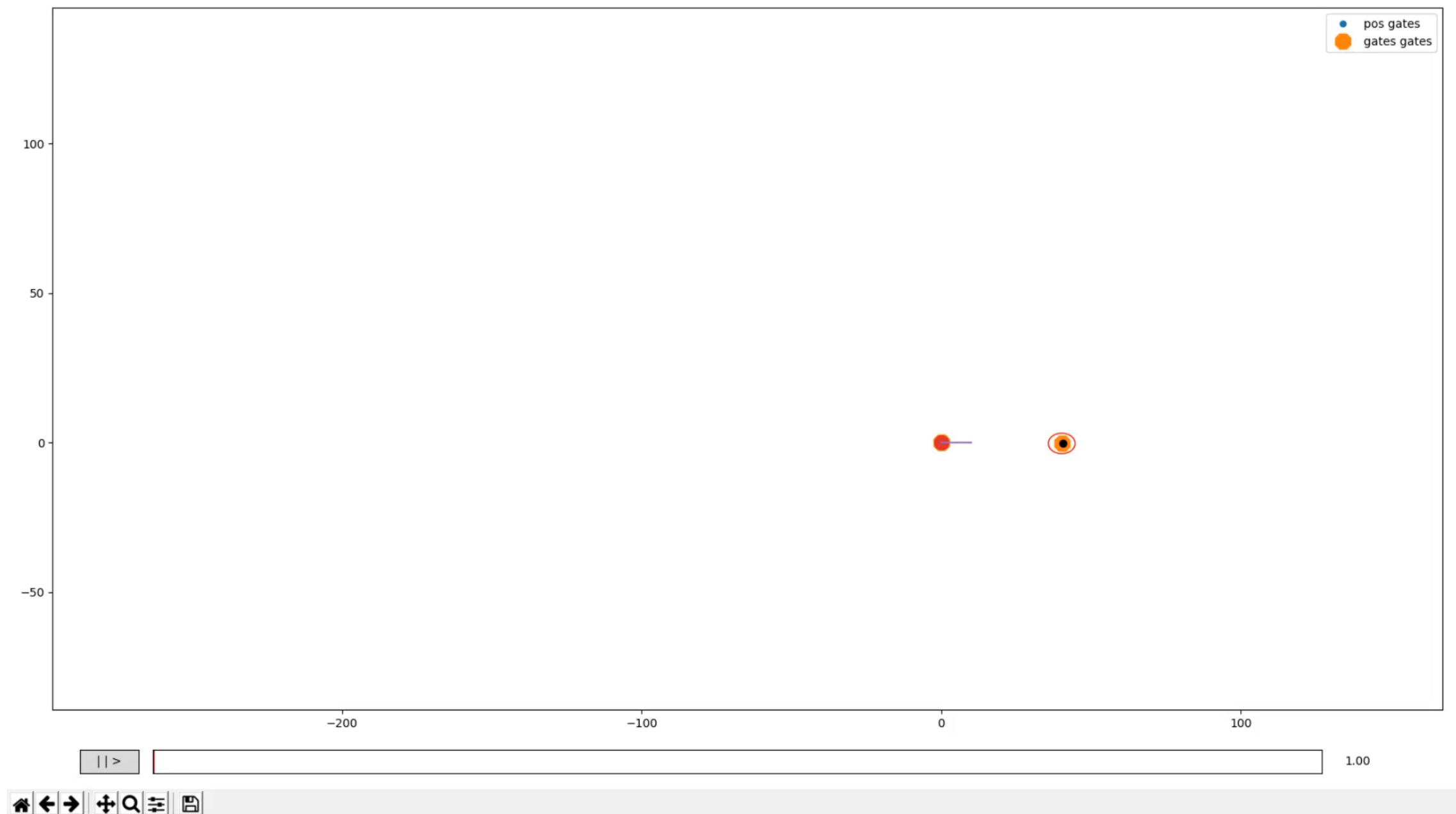
SLAM – Gate Measurement



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SLAM – IMU + Gates



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SLAM - Results

SLAM Results

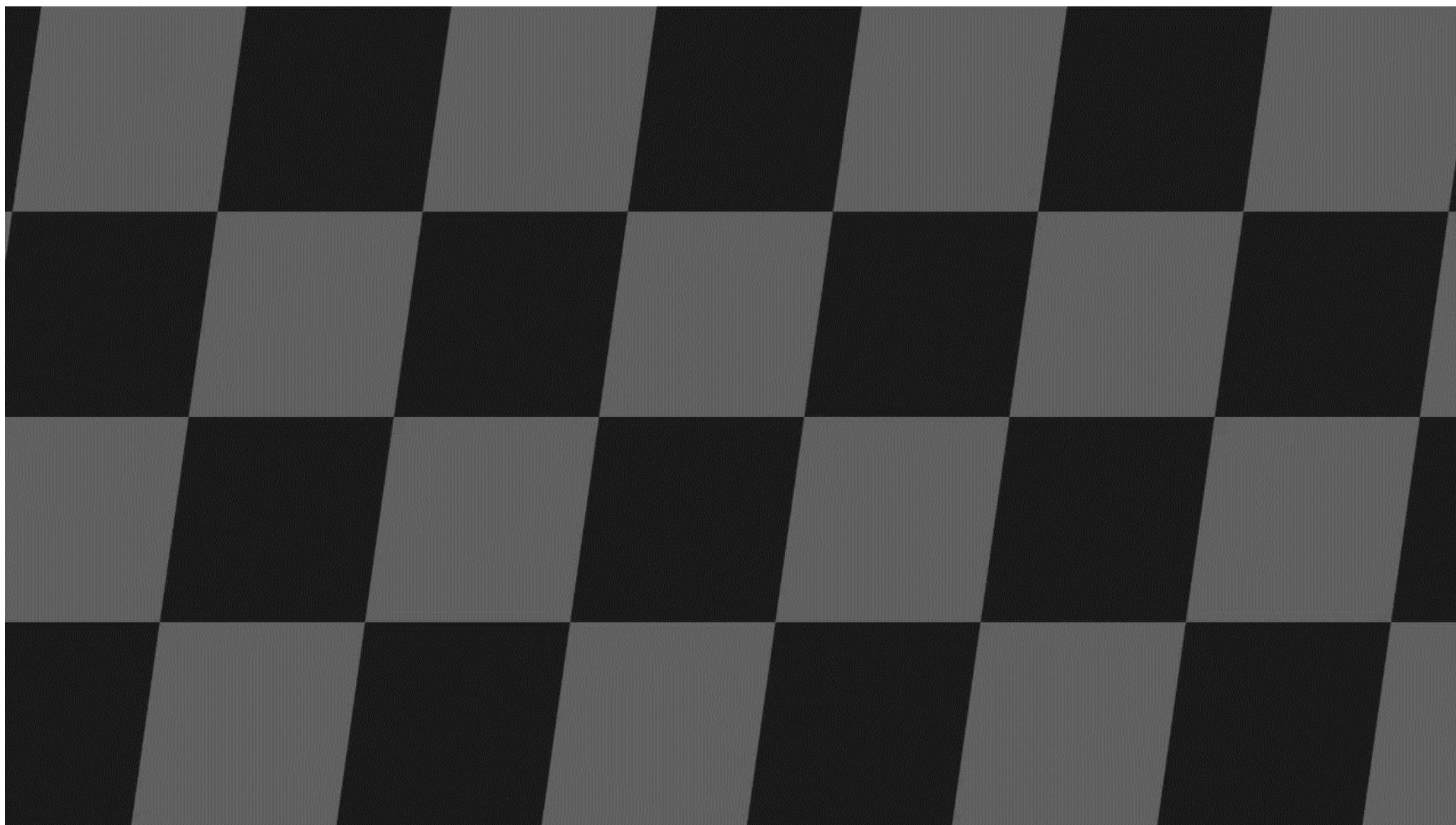
- Position [x, y, z]
- Orientation [quat]
- Velocity [x, y, z]
- Angular Velocity [x, y, x]
- Accelerometer Bias [x, y, z]
- Camera Rotation [x, y, z]
- Gate Positions [x, y, z] x4

SLAM Resources

- YouTube: Claus Brenner – SLAM Lectures
- Udacity Course – “Artificial Intelligence for Robotics”

Trackspace

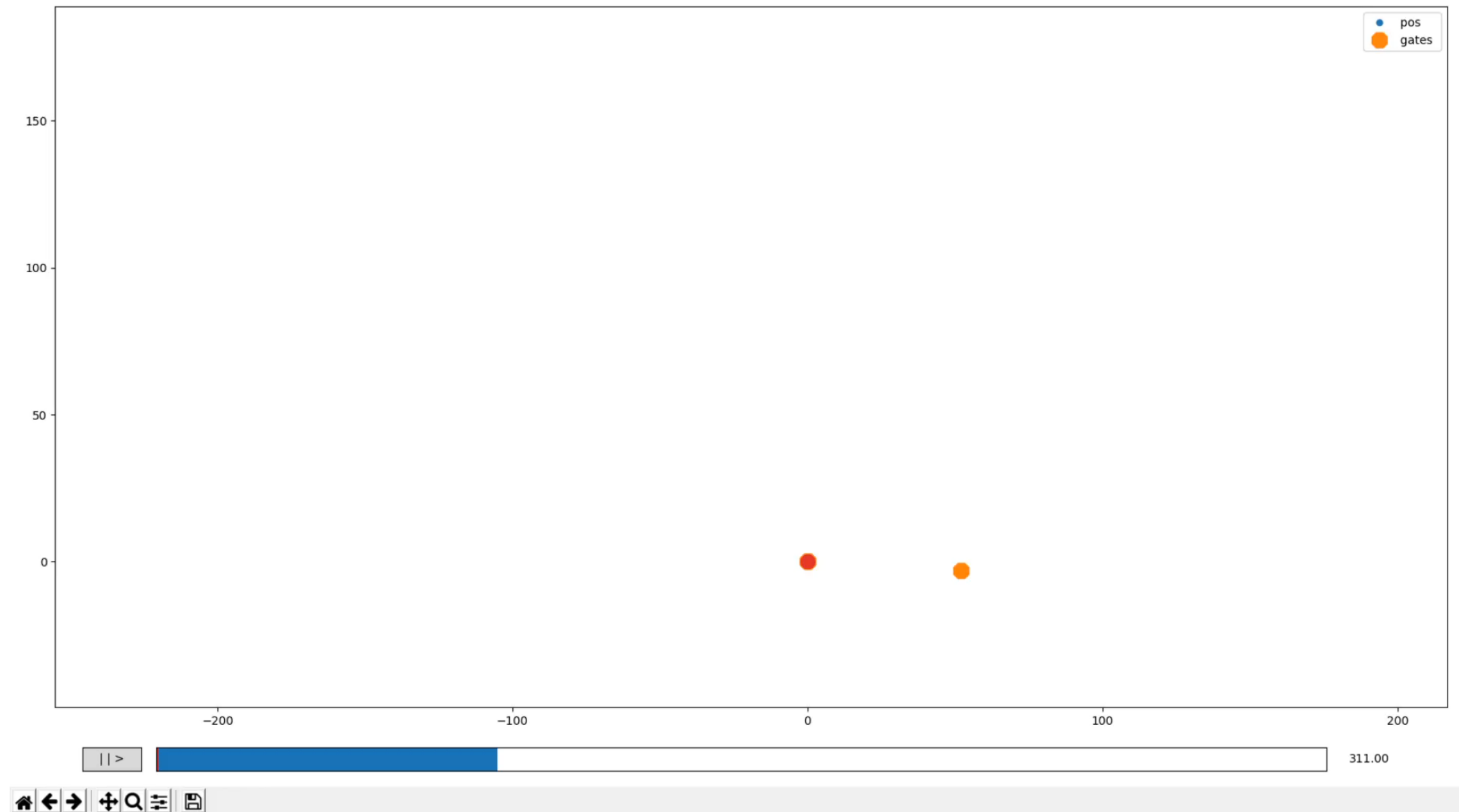
Trackspace – User Experience



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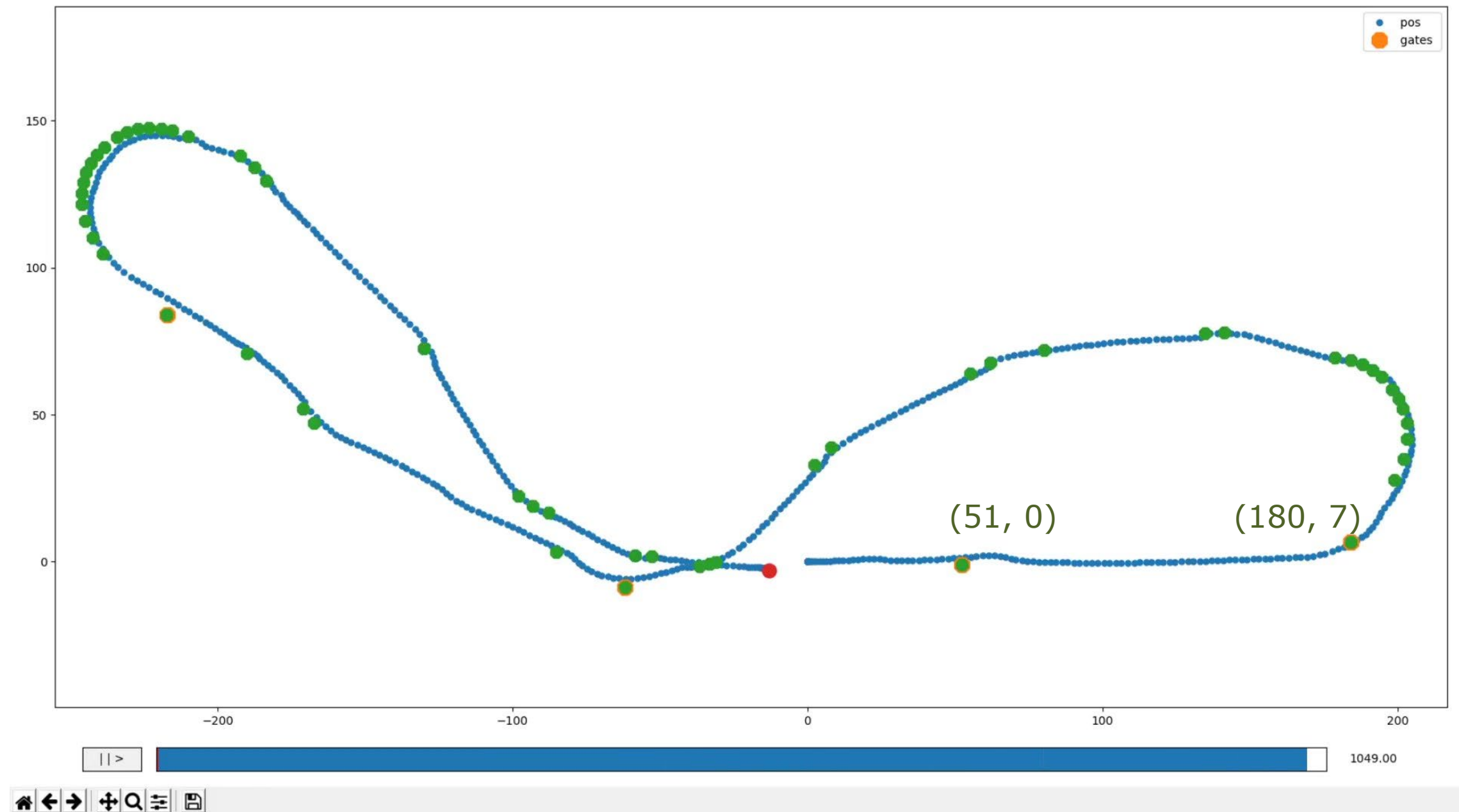
Trackspace - Breadcrumbs



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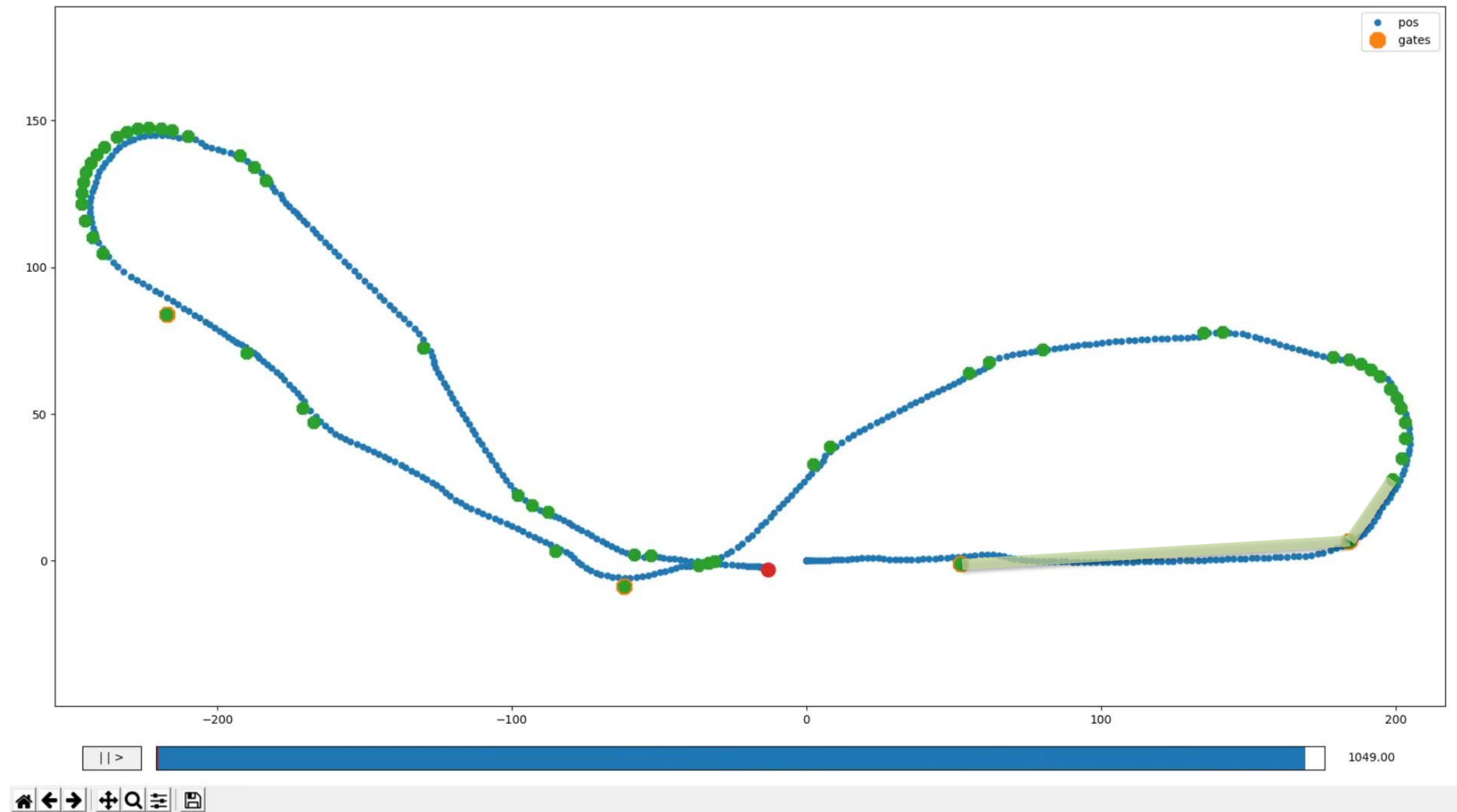
Trackspace - Breadcrumbs



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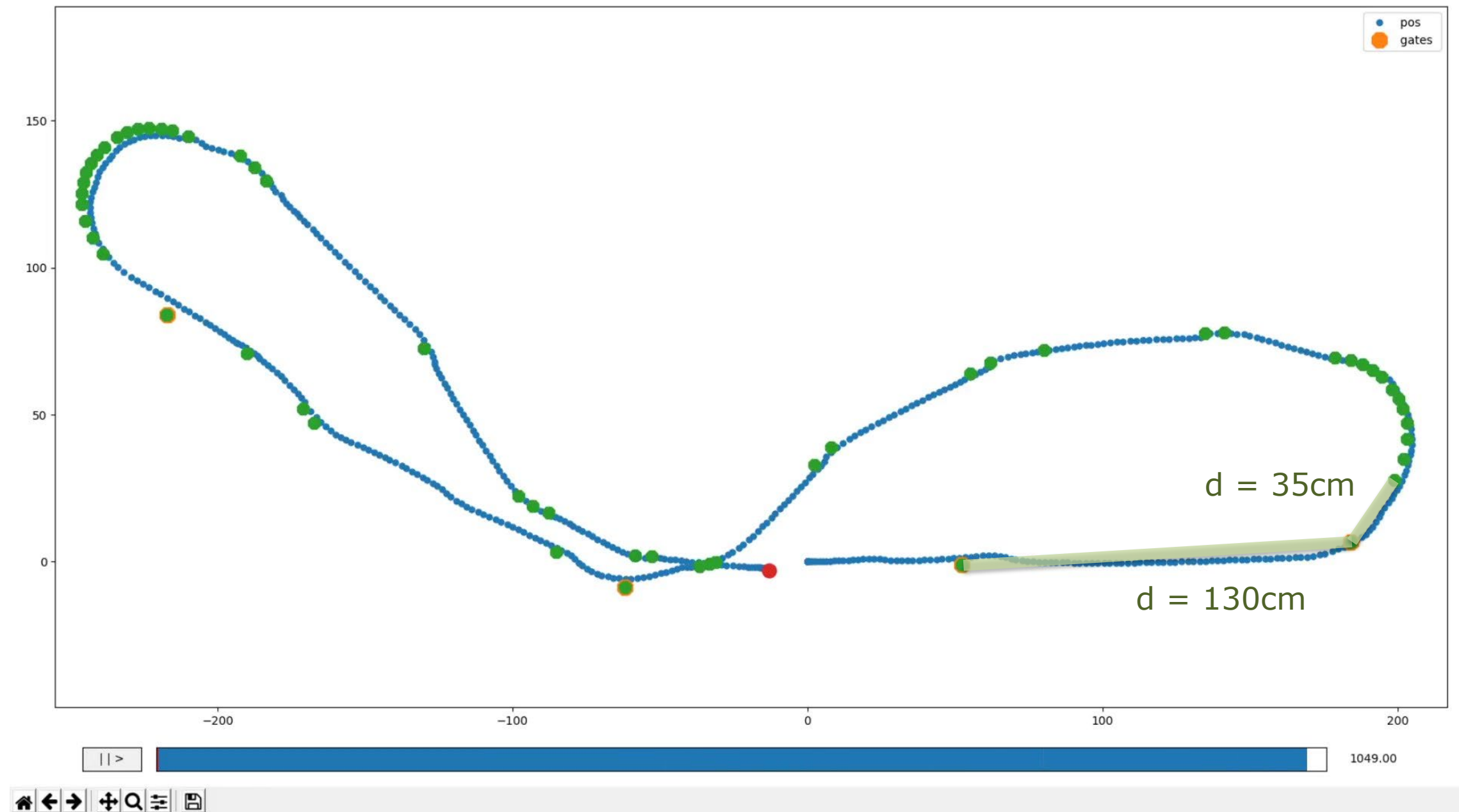
Trackspace - Breadcrumbs



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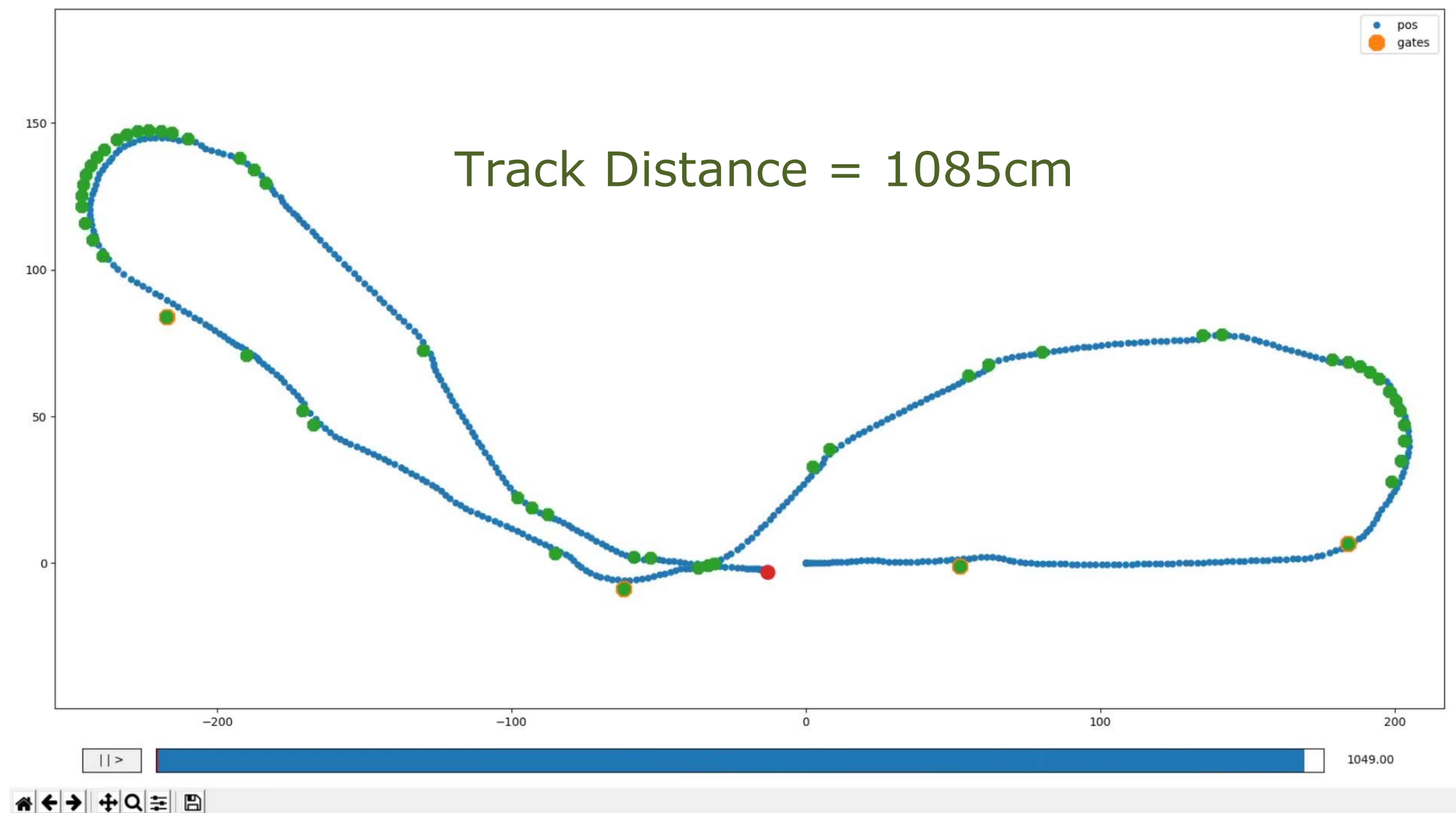
Trackspace - Breadcrumbs



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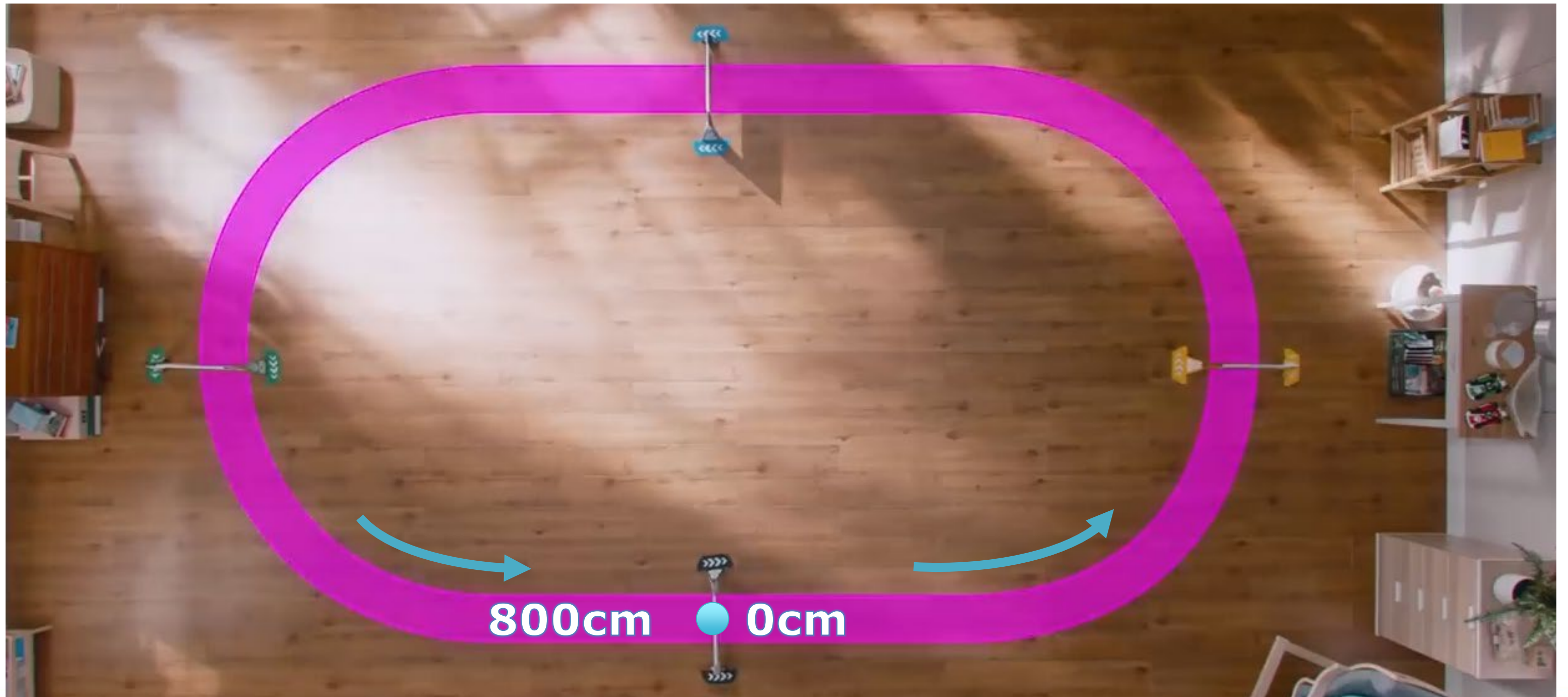
Trackspace - Breadcrumbs



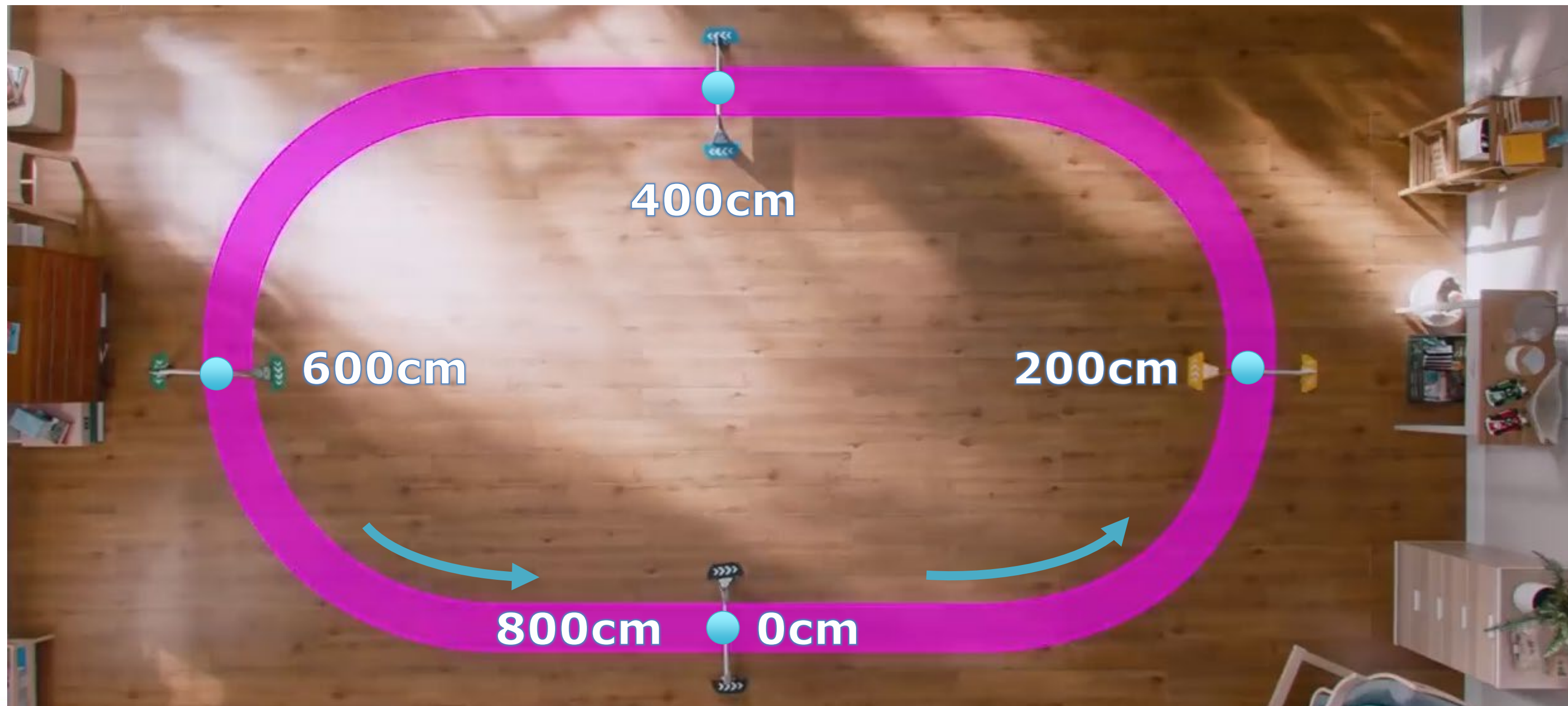
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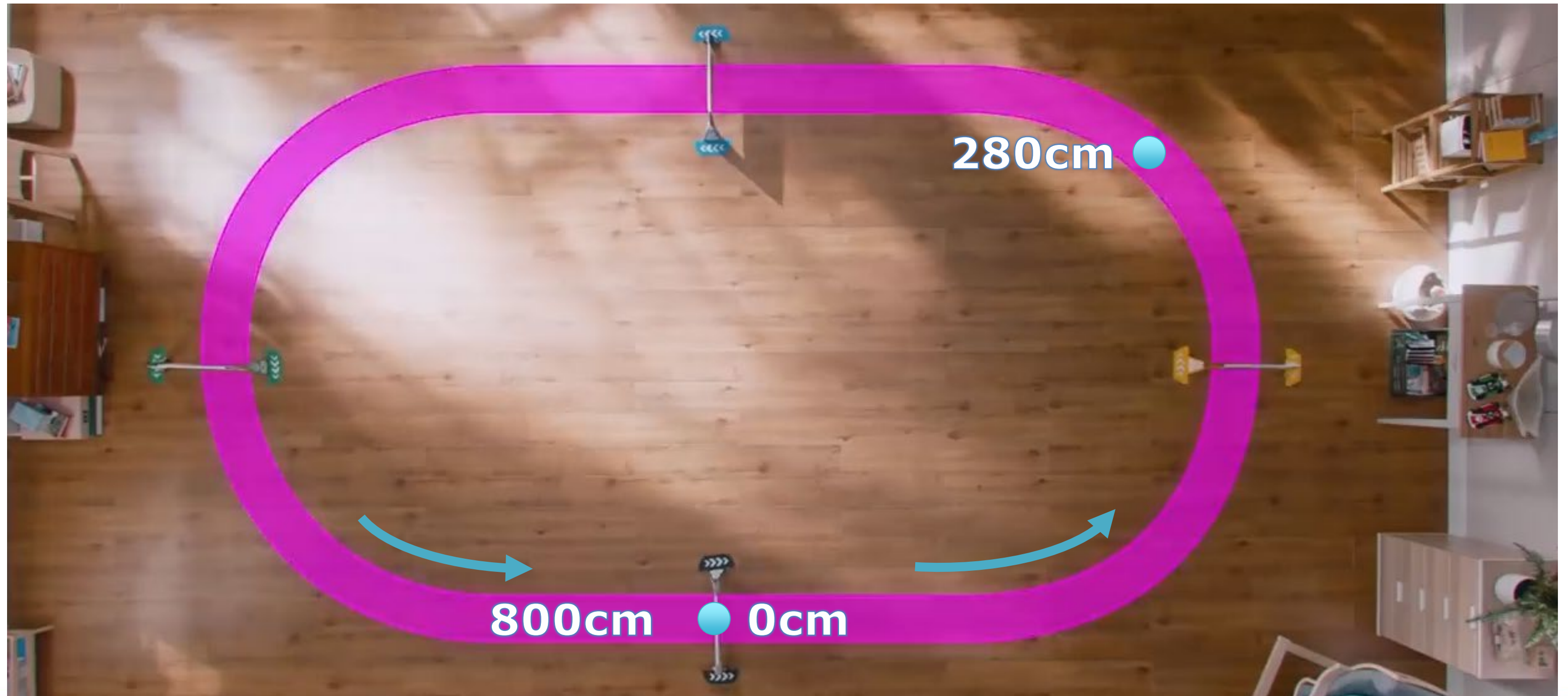
Trackspace Distance



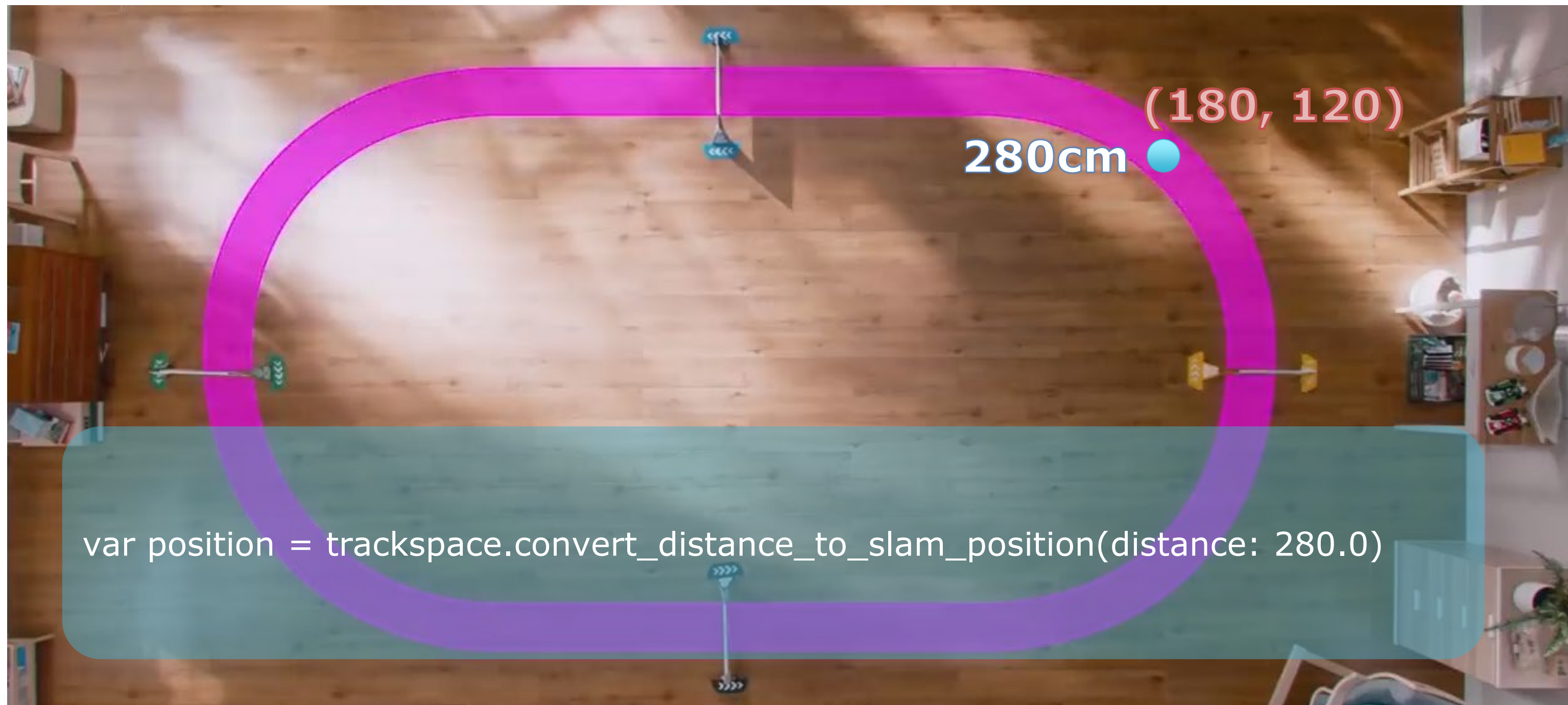
Trackspace Distance



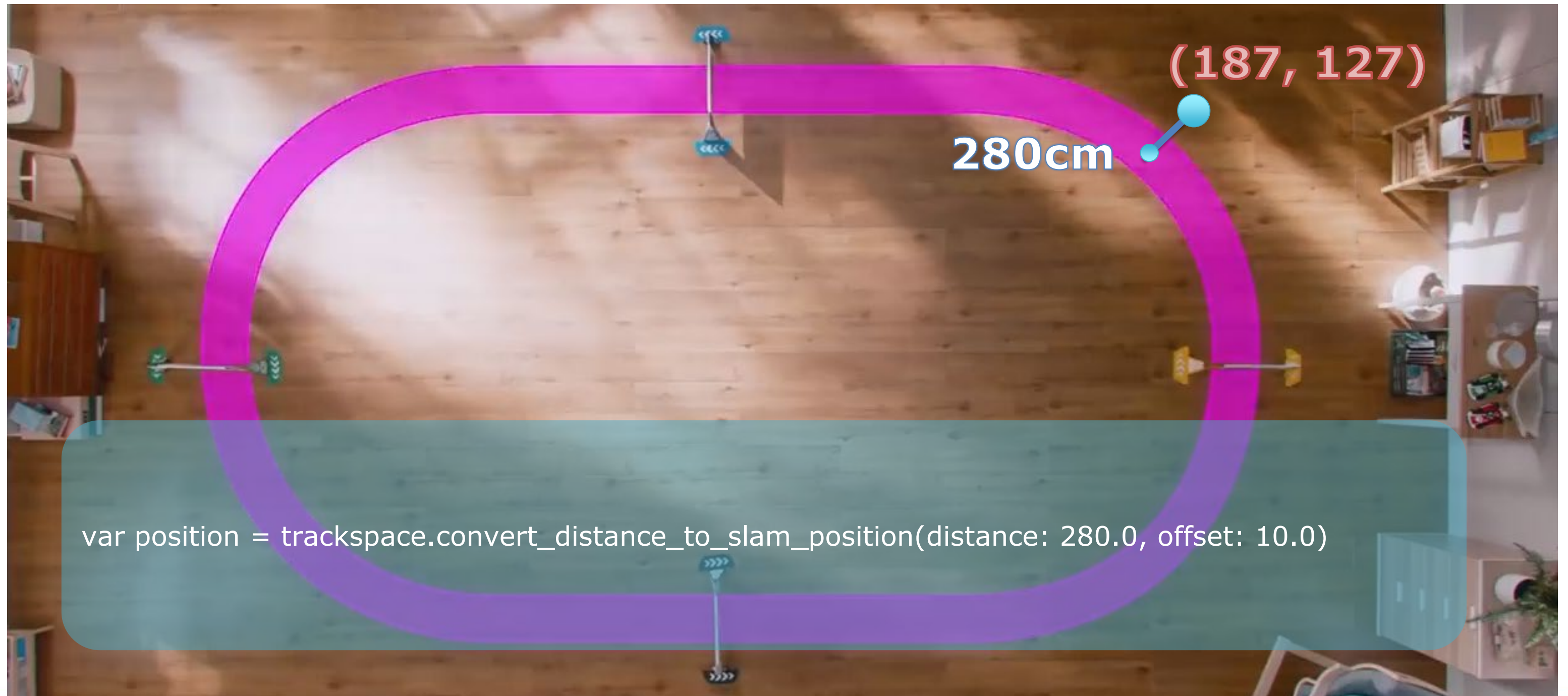
Trackspace Distance



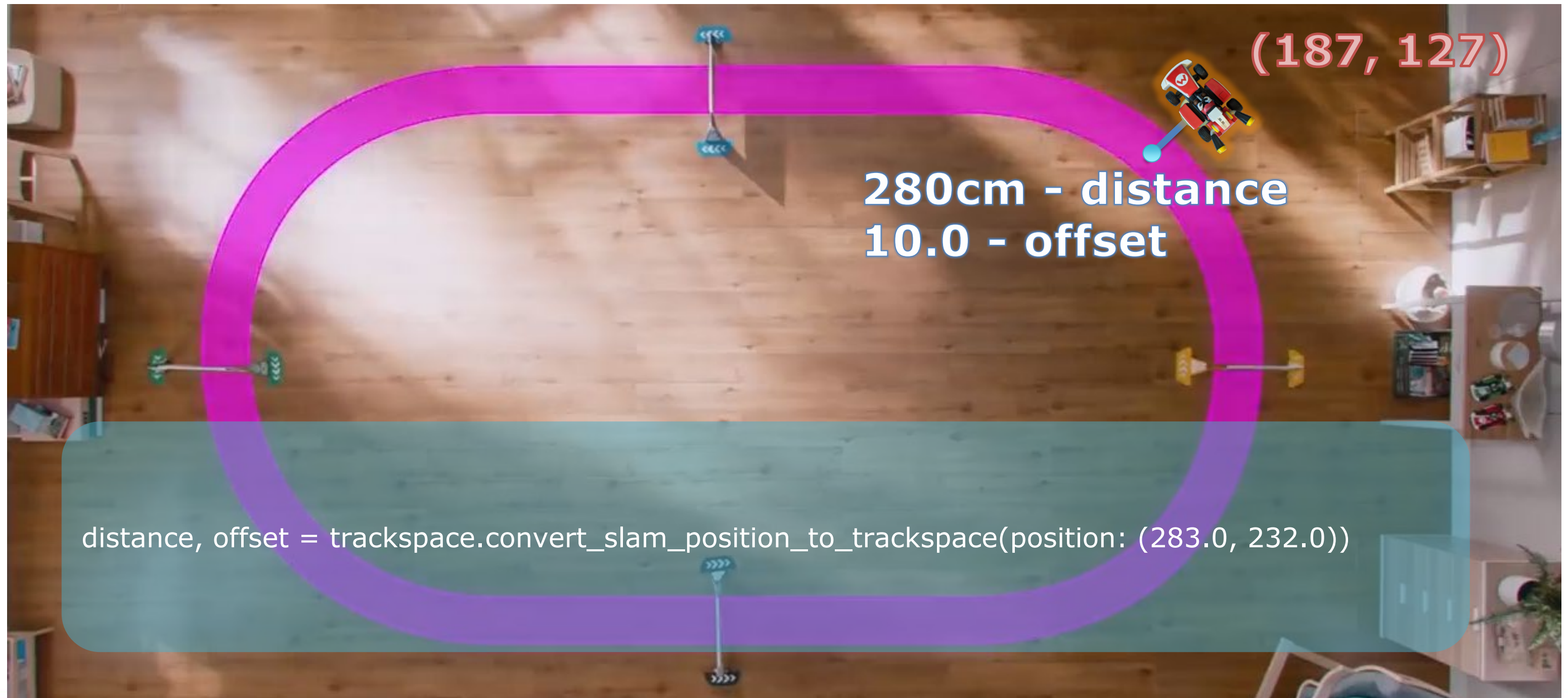
Trackspace Distance



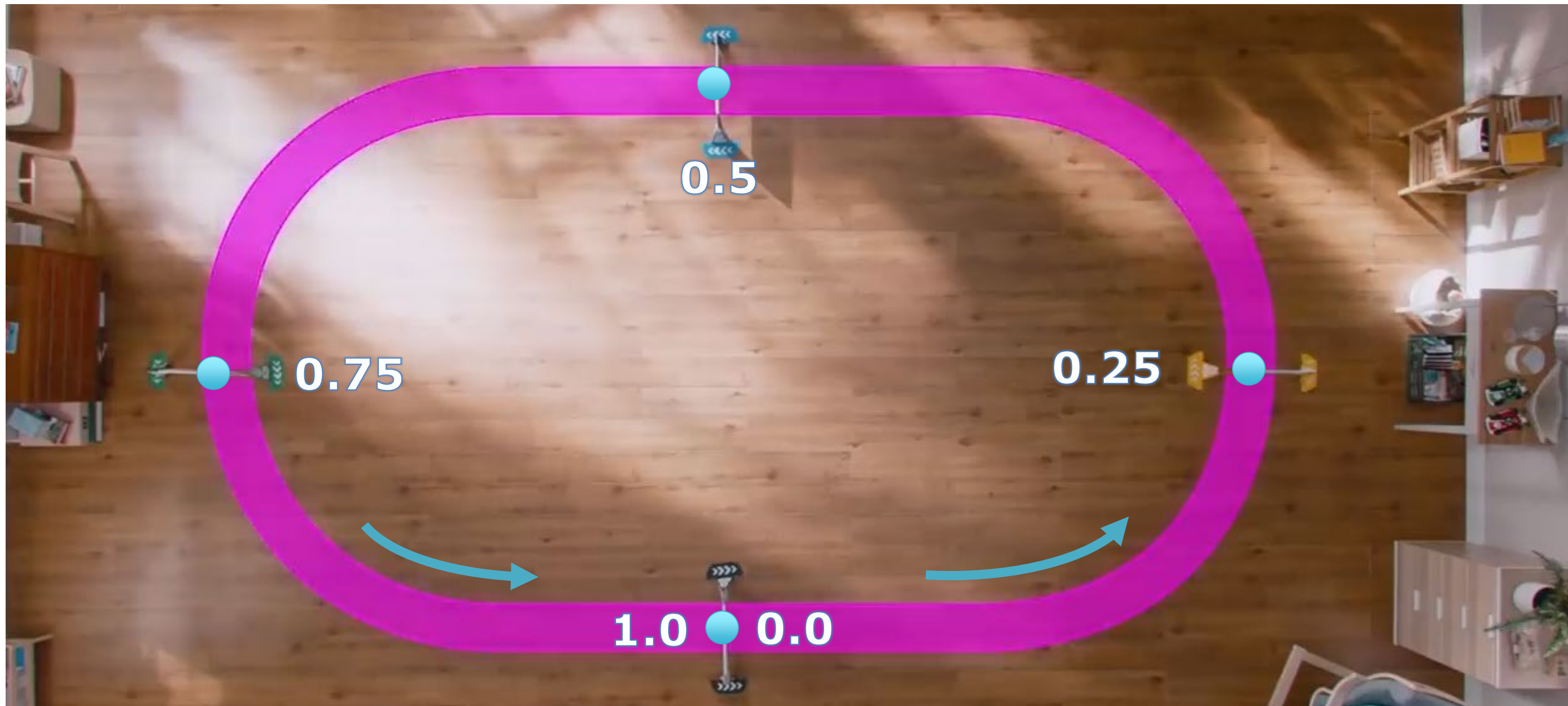
Trackspace Distance



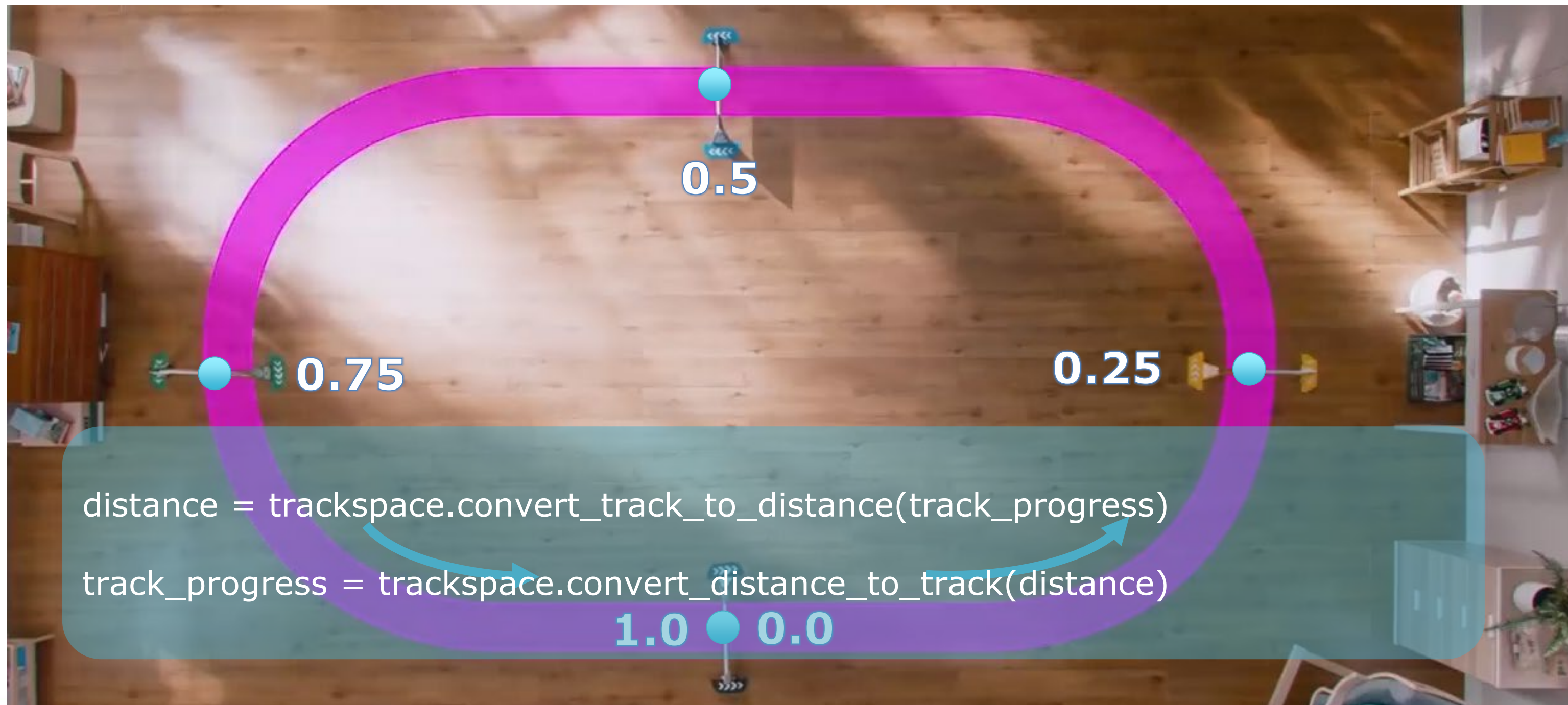
Trackspace Distance



Track Progress



Track Progress



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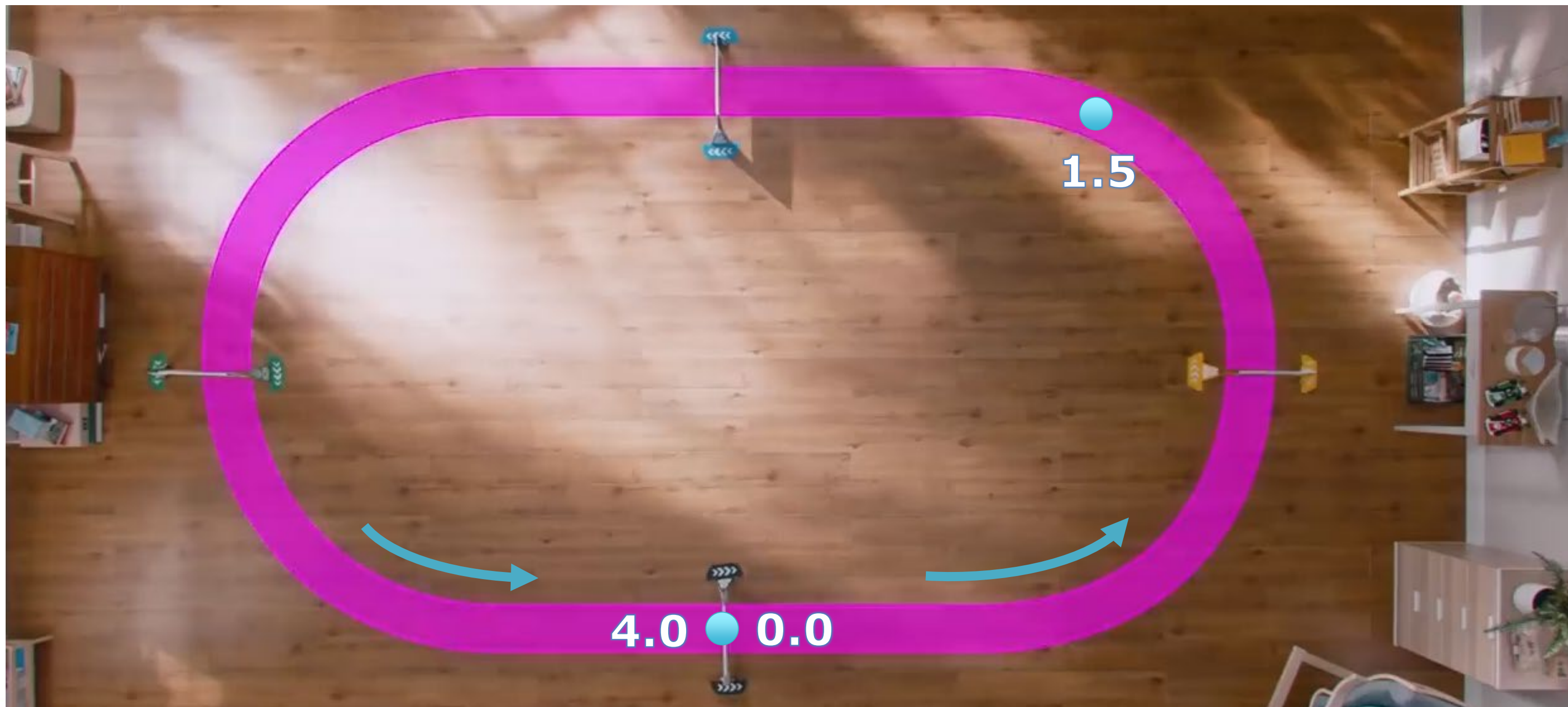
Gate Progress



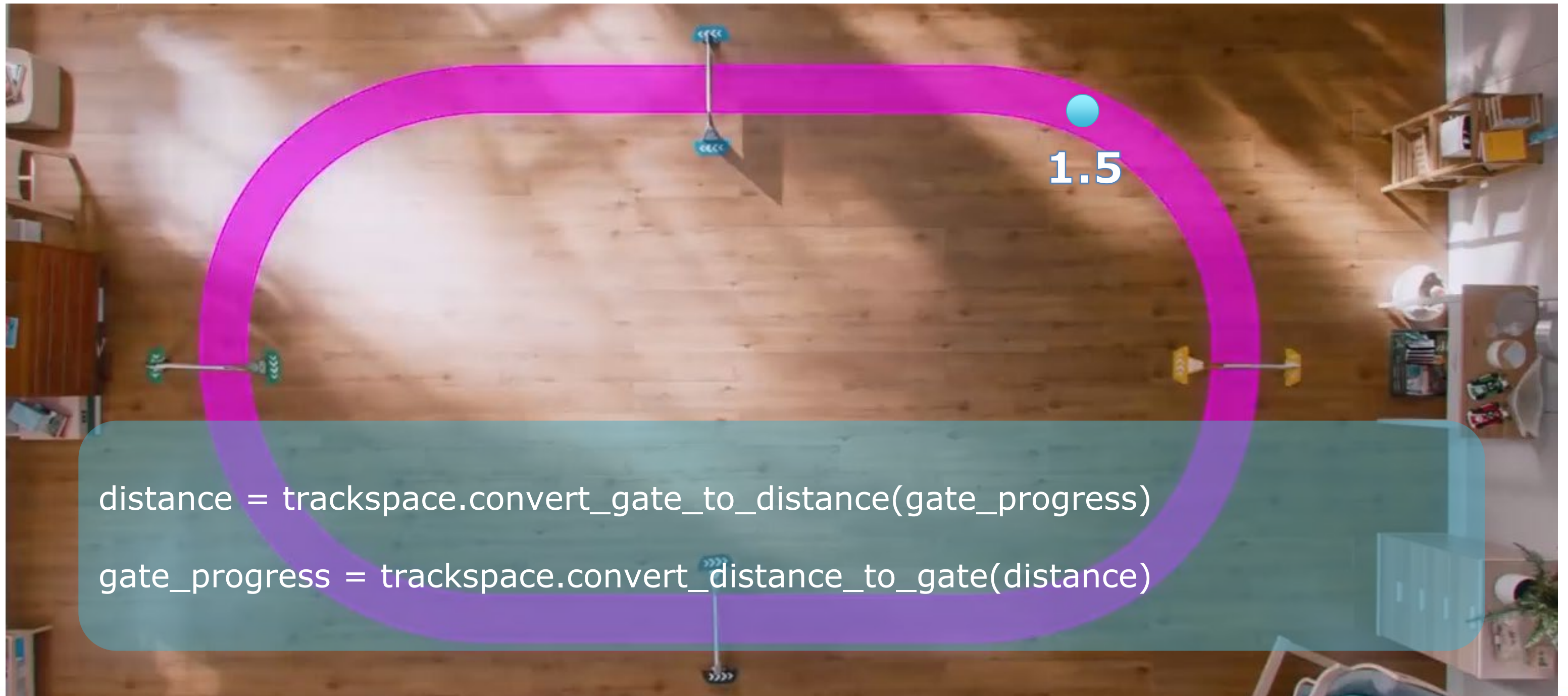
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Gate Progress



Gate Progress

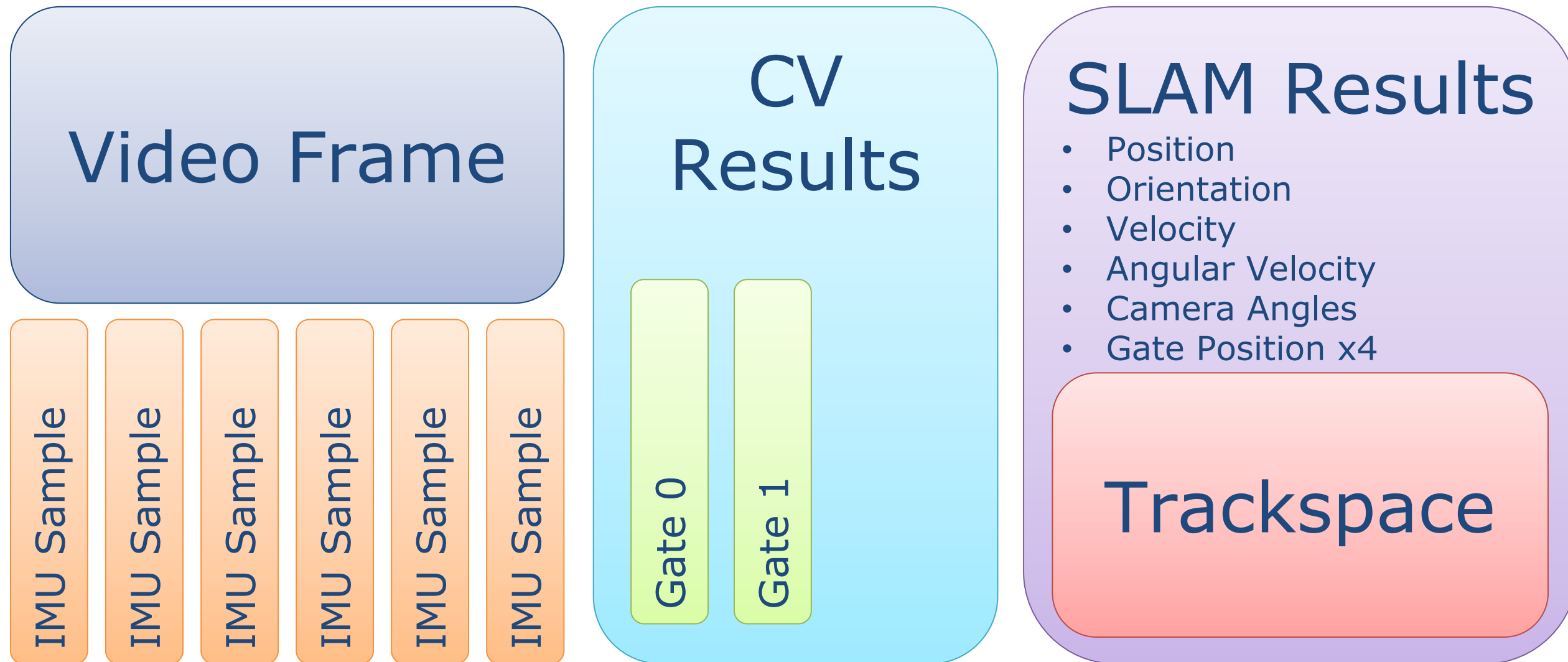


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Putting It All Together

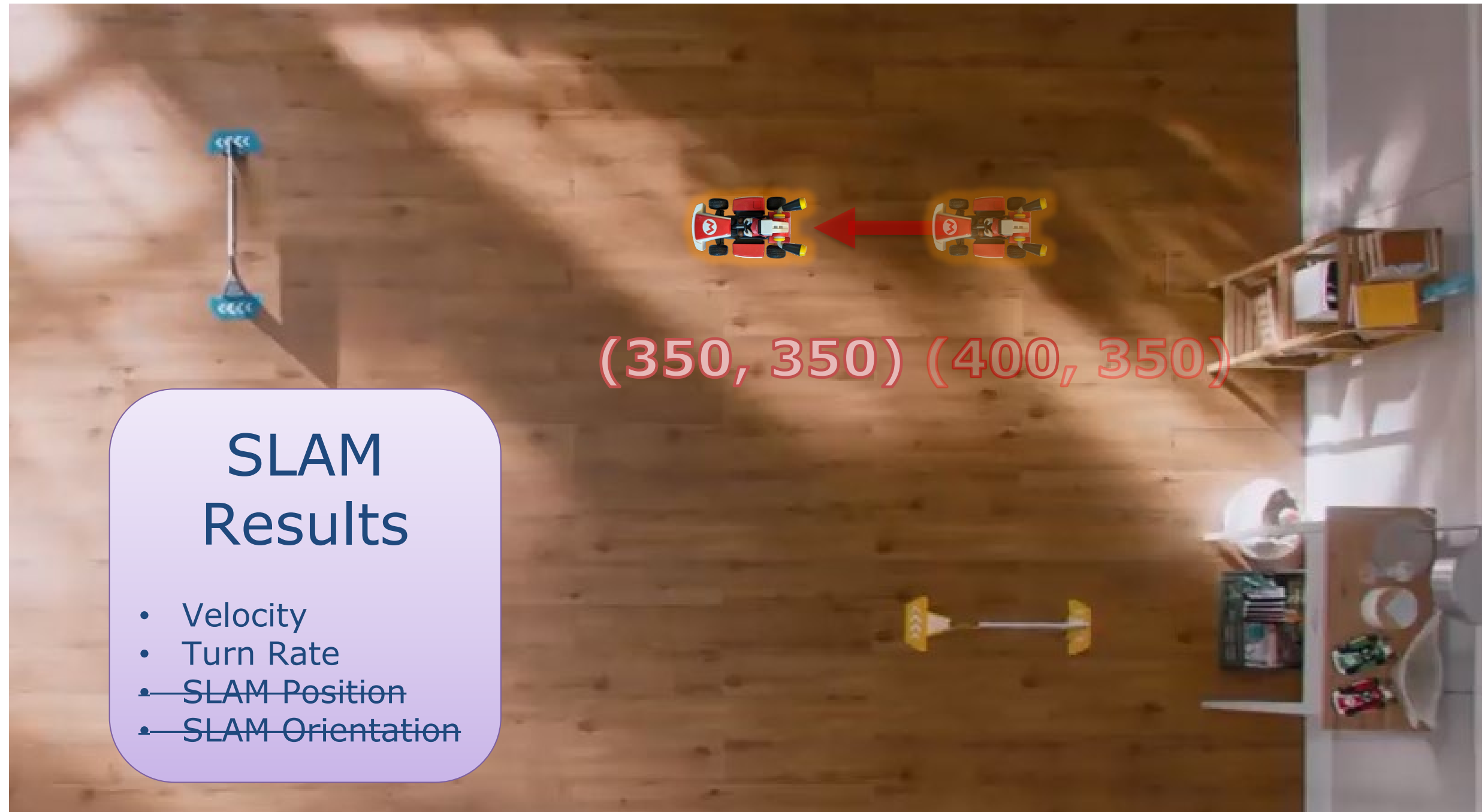
Video Frame + CV + SLAM



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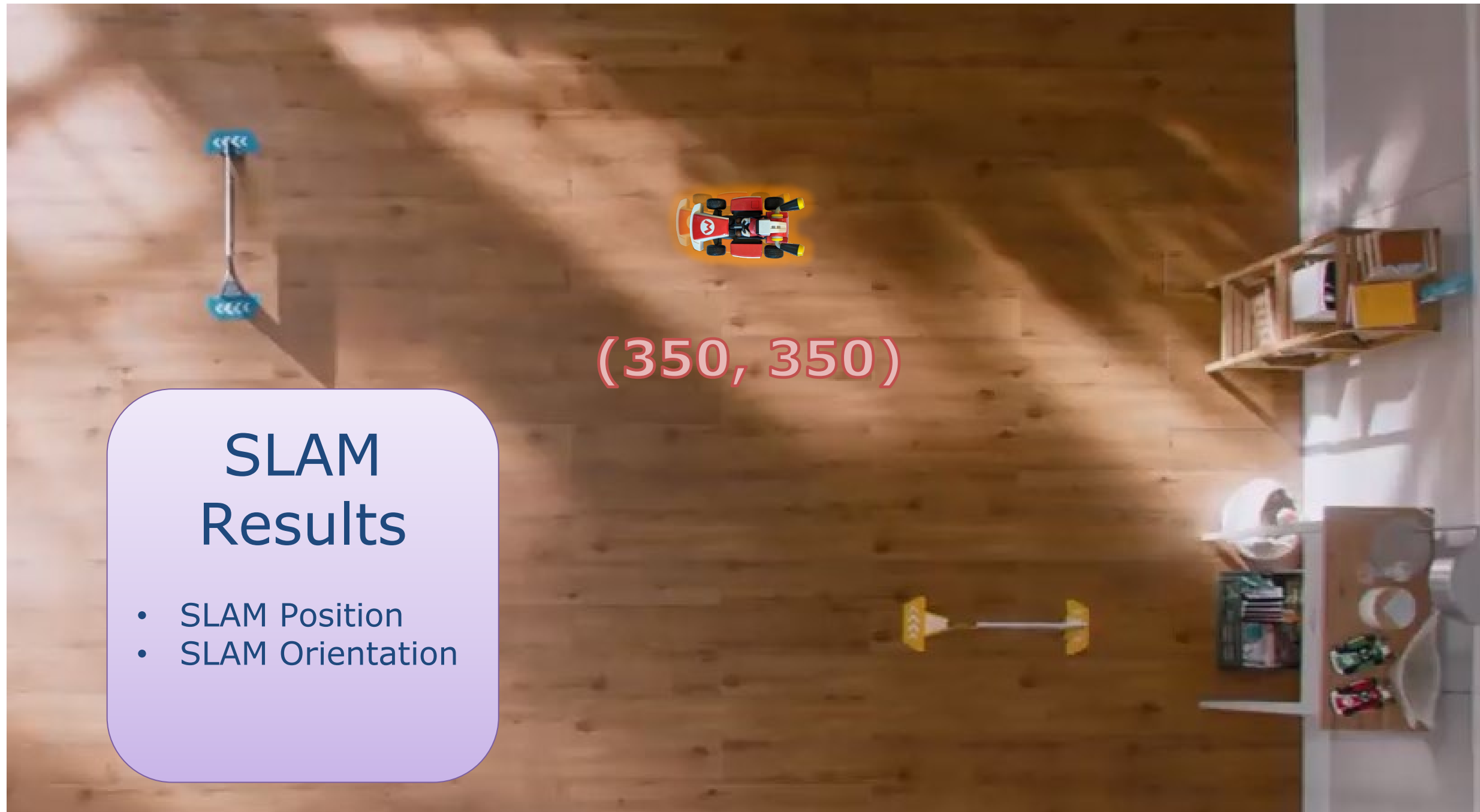
Move the Game Kart



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Interpolate Toward SLAM



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Gate Content

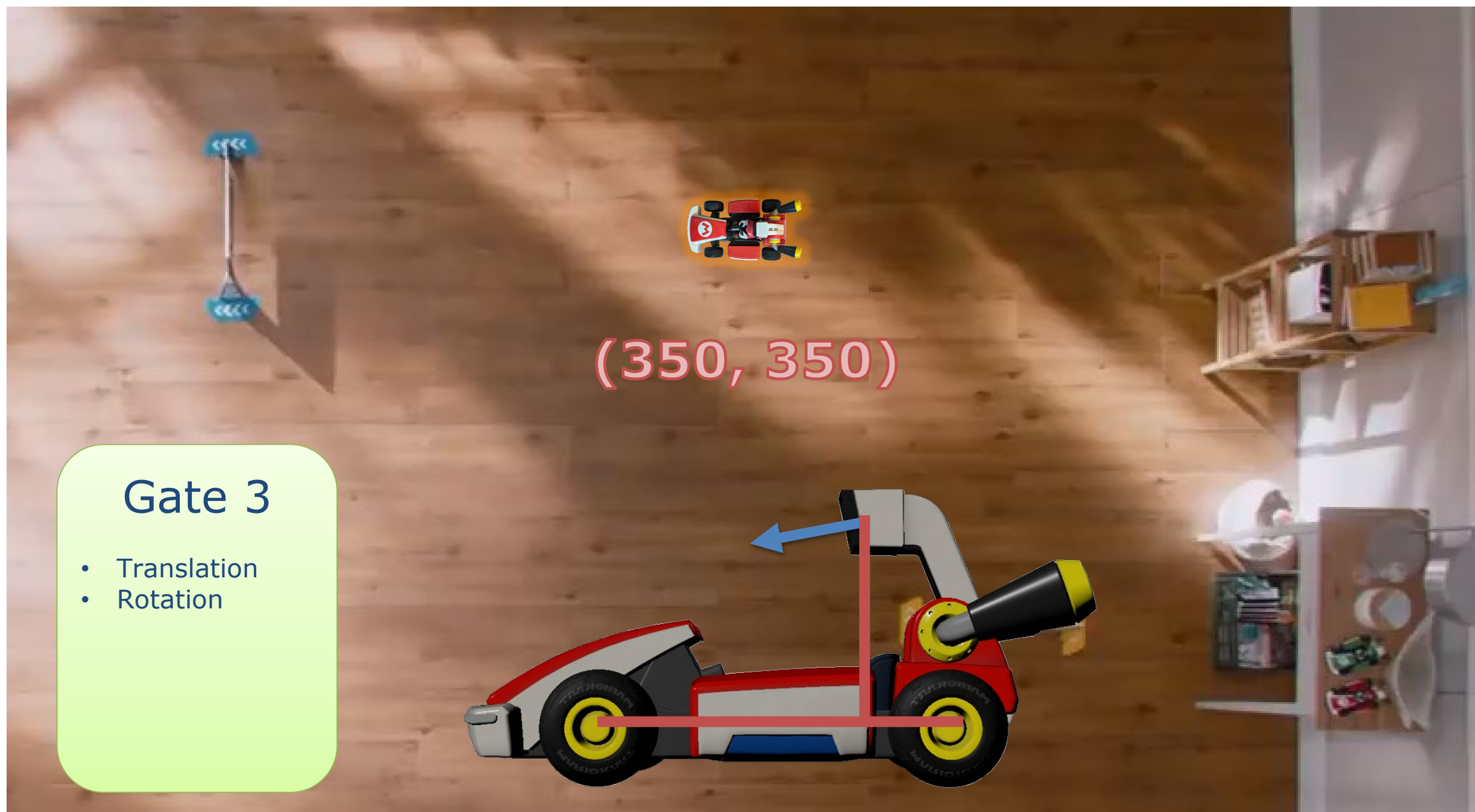
Gate Content



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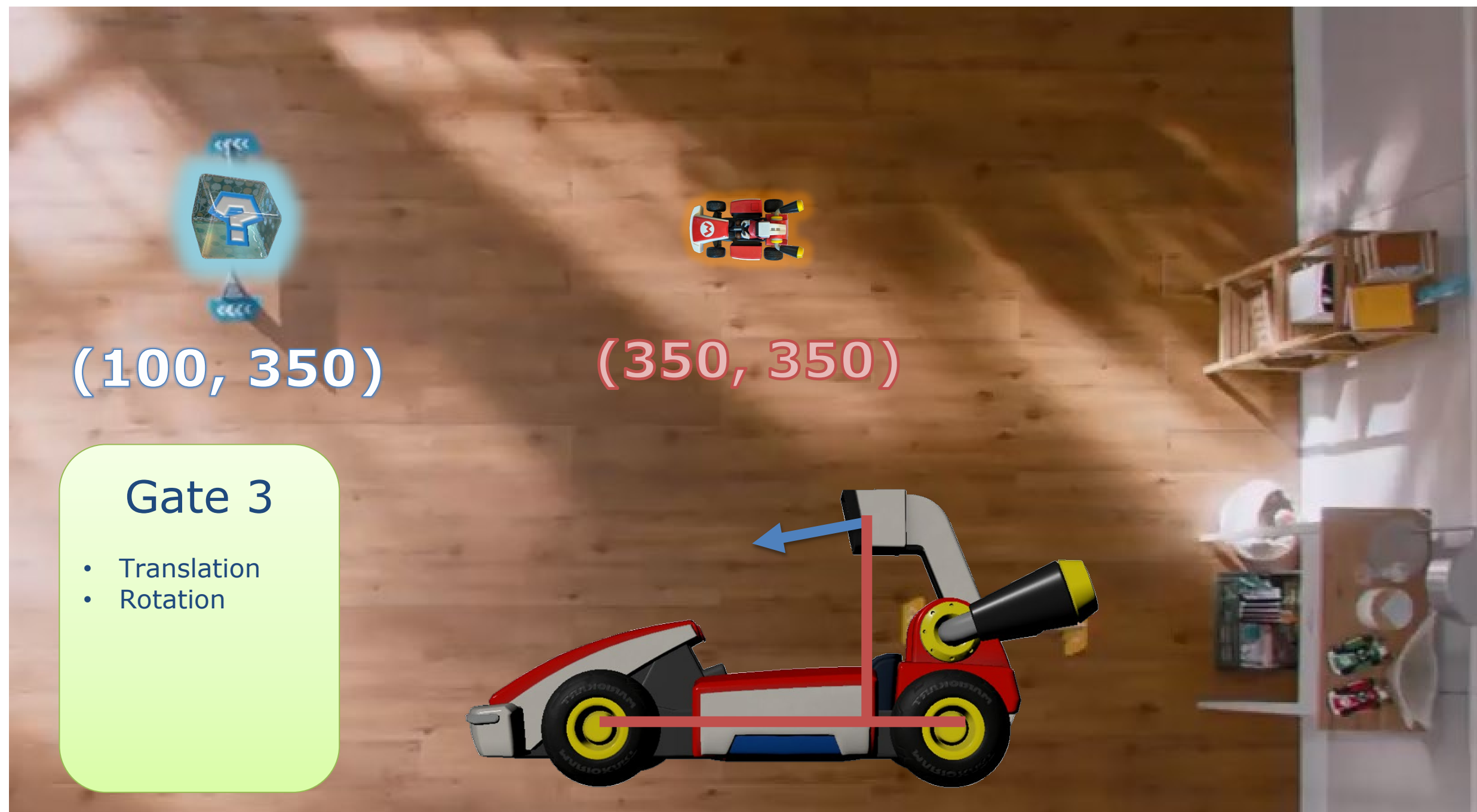
Place Gate Content



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Place Gate Content



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Next Frame - Move Again



Update Gate



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Missing Gate



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Gate Content



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World Items

World Items – Banana Peel



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World Items – Banana Peel



World Items – Banana Peel



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World Items – Banana Peel



Trackspace Items

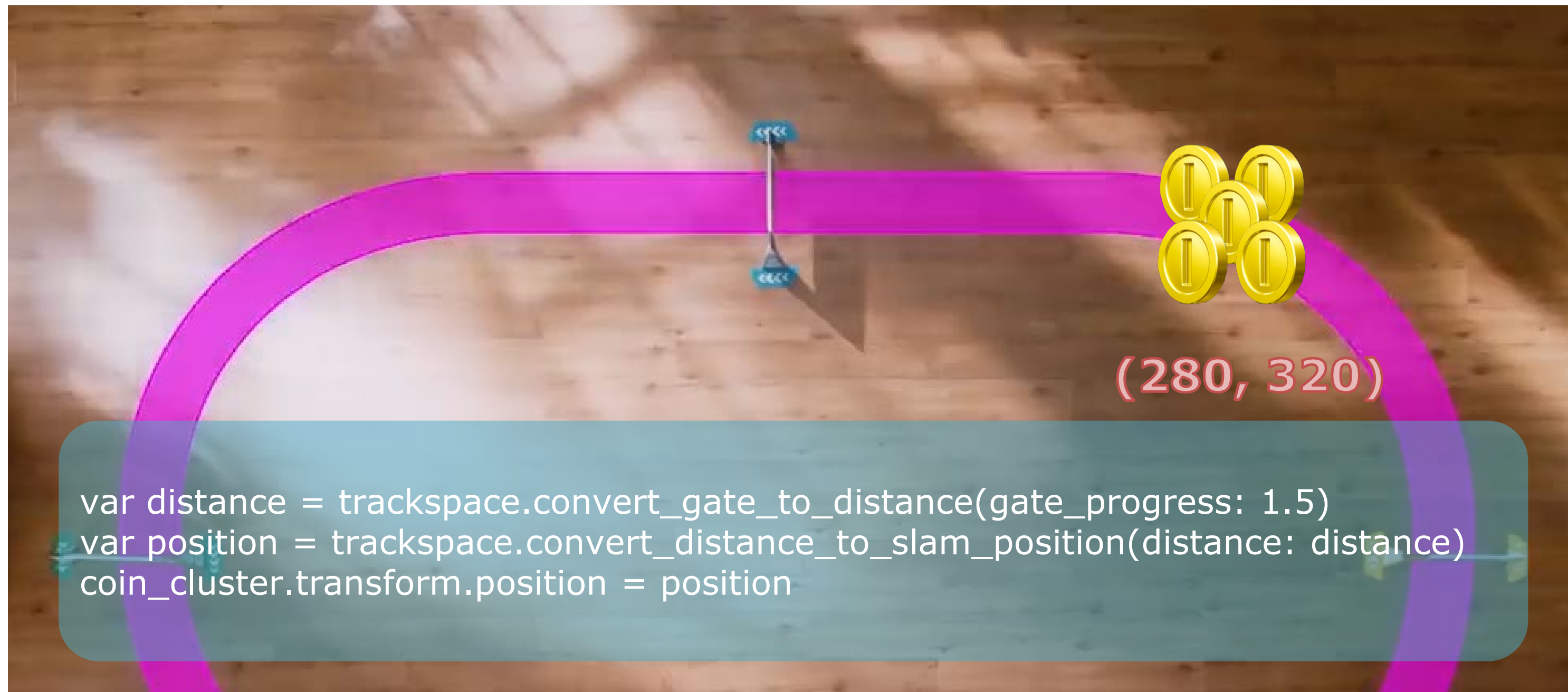
Trackspace Items



Trackspace Items



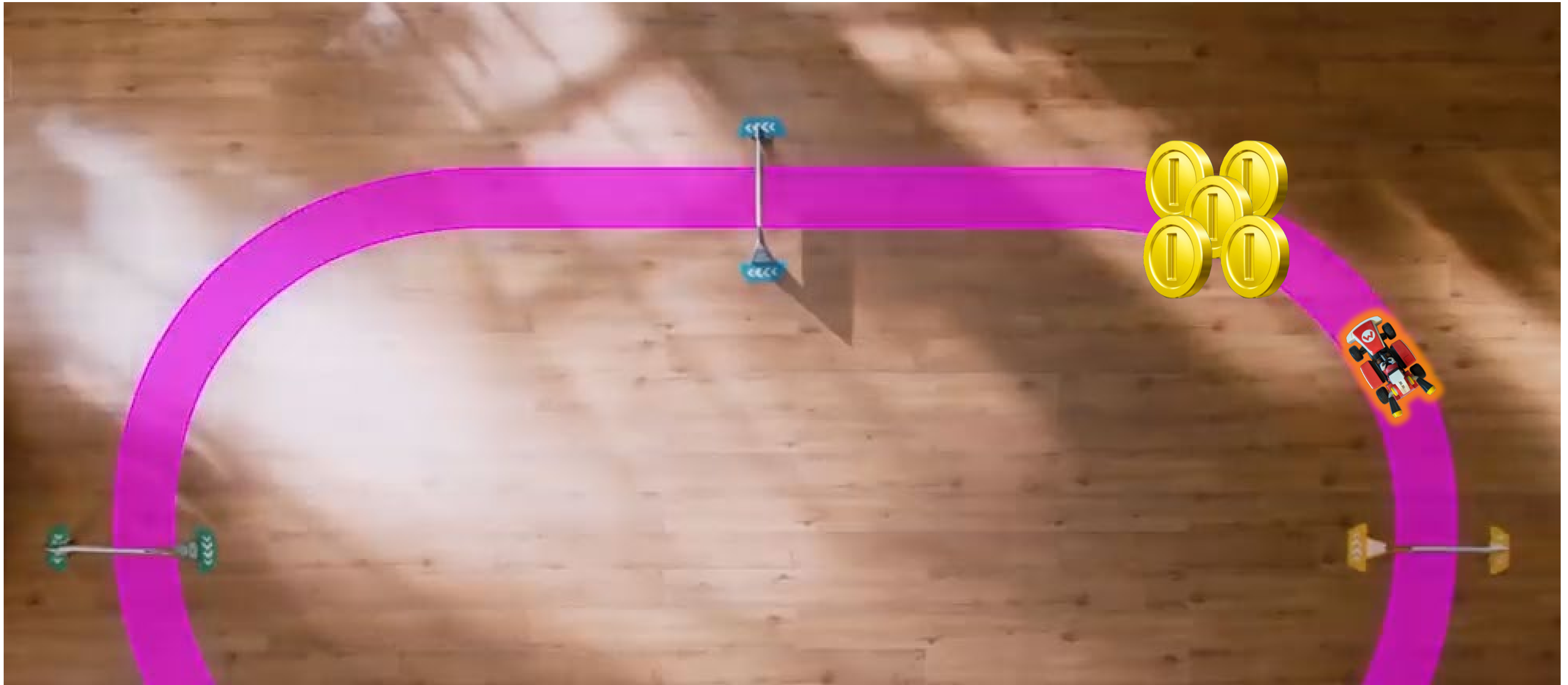
Trackspace Items



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Trackspace Items



Trackspace Items



Dynamic Items

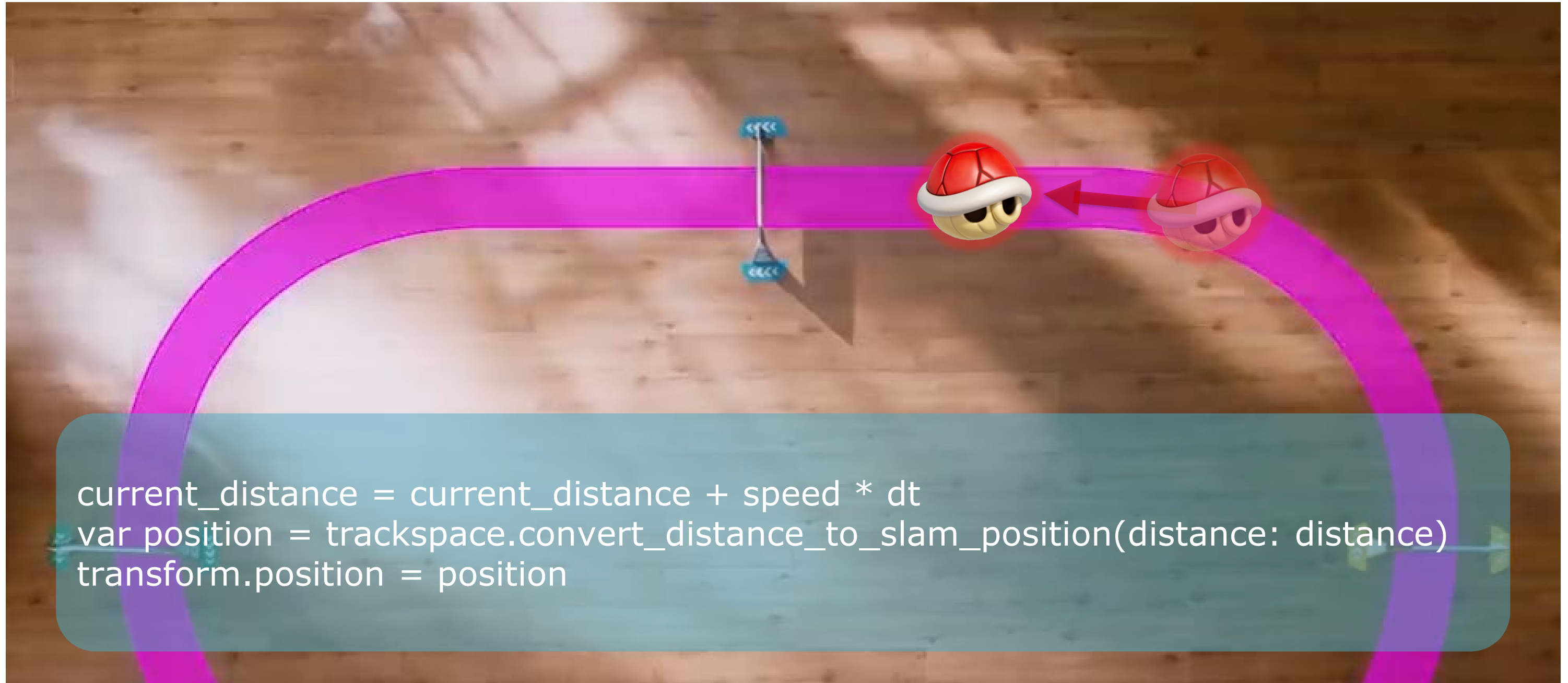
Dynamic Content



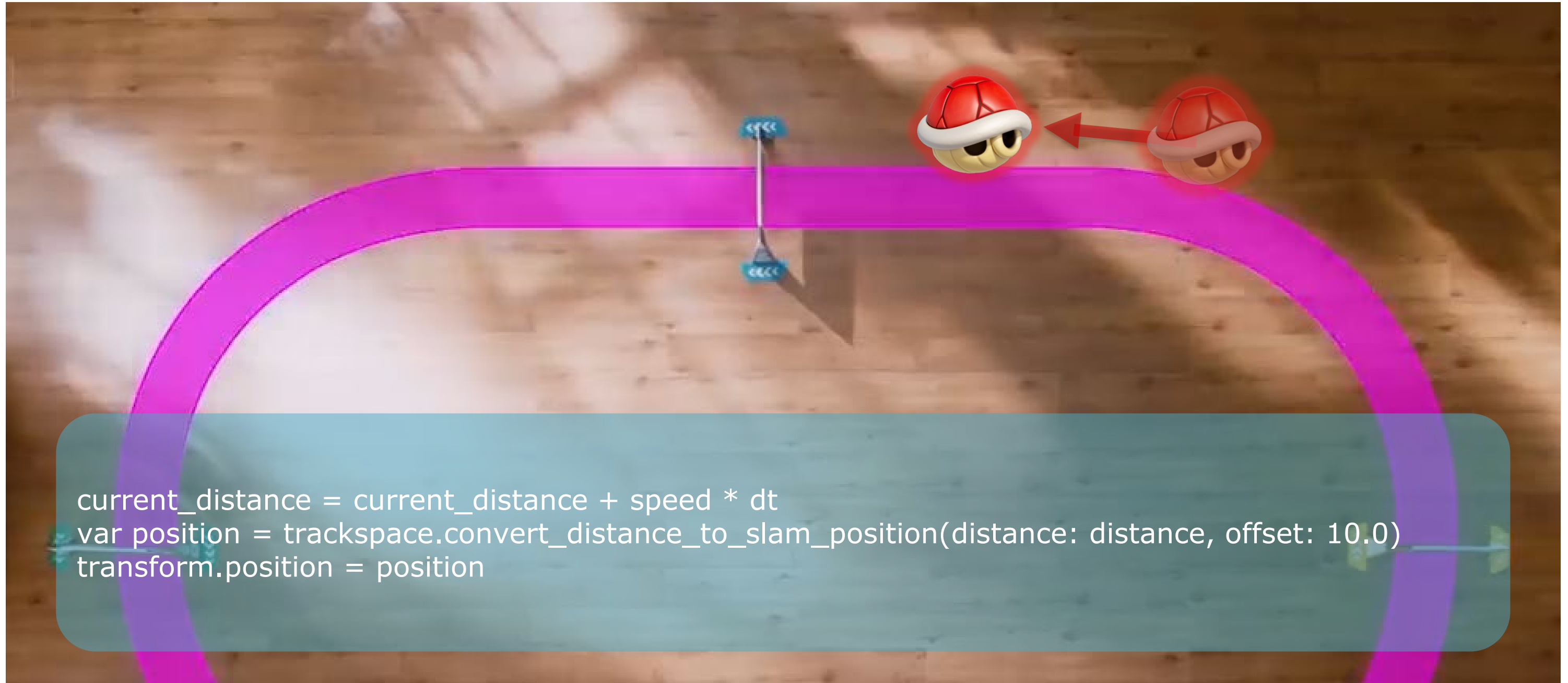
Dynamic Items



Dynamic Items



Dynamic Items



Dynamic Items



Get It On Screen

Render Everything

Video Frame

IMU Sample

IMU Sample

IMU Sample

IMU Sample

IMU Sample

IMU Sample

Gate 0

Gate 1

CV
Results

SLAM Results

- Position
- Orientation
- Velocity
- Angular Velocity
- Camera Angles
- Gate Position x4

Trackspace

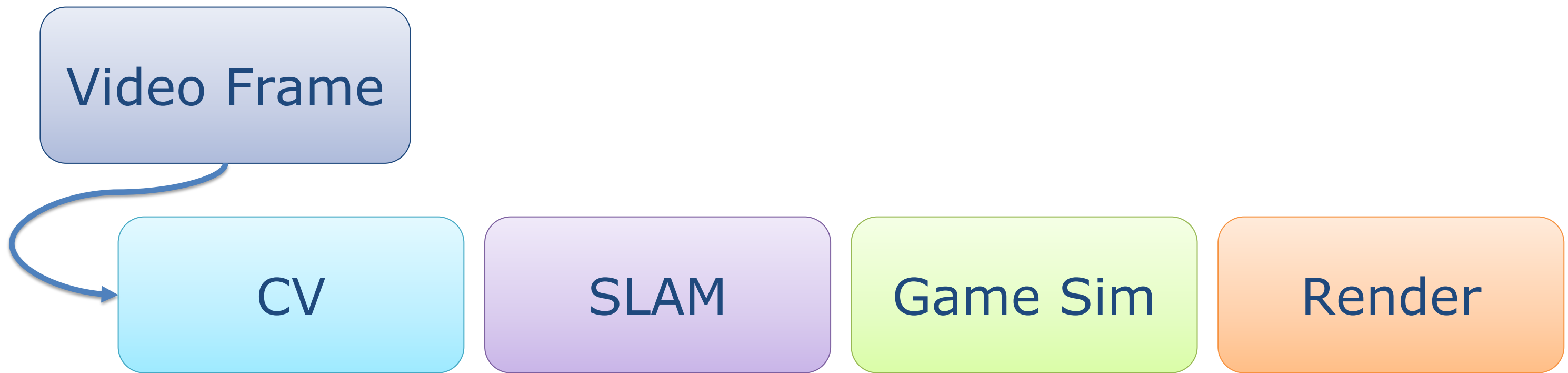
Game
Simulation



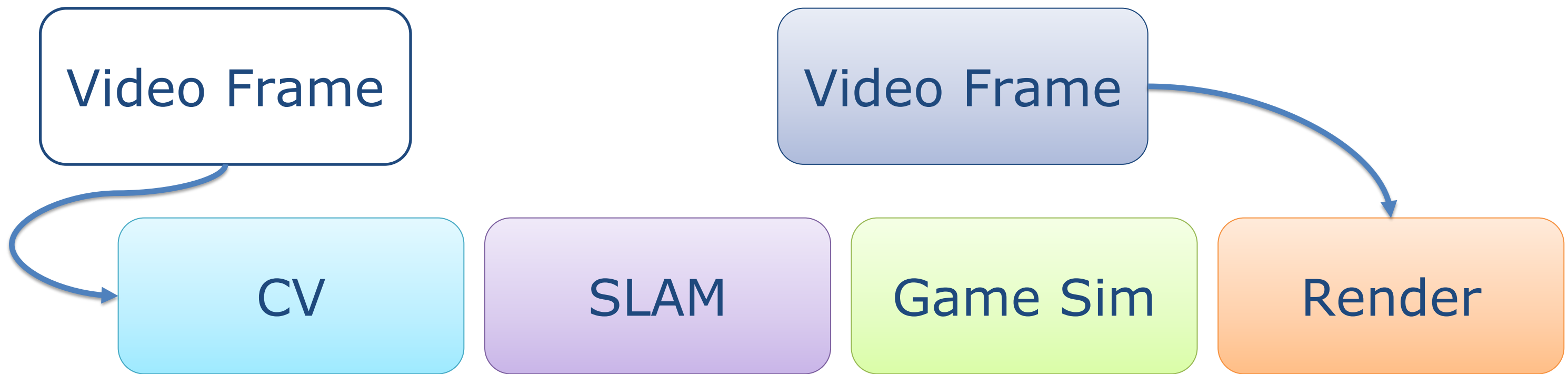
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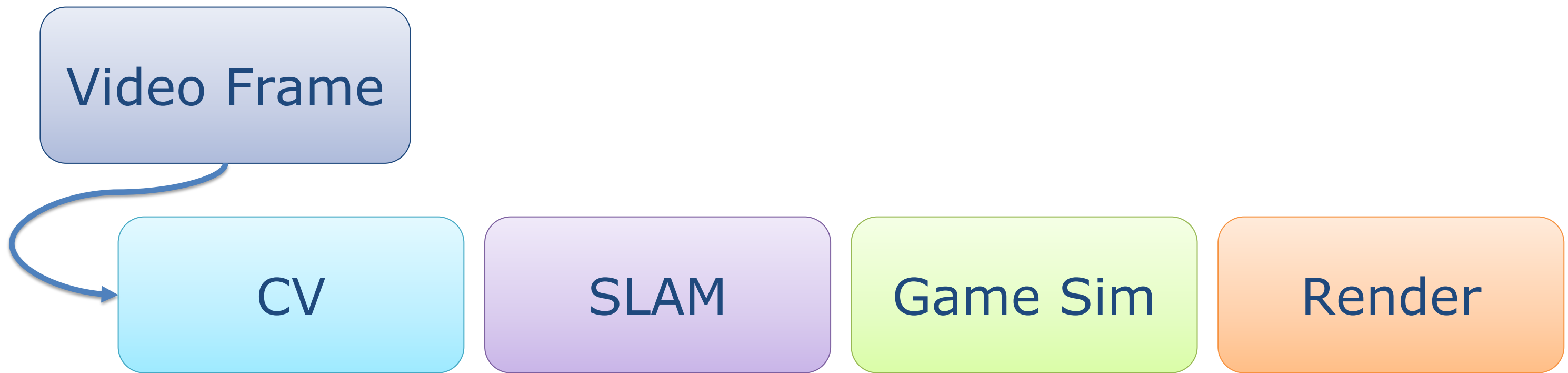
Render Everything



Render Everything



Render Everything



Closing Thoughts

“Lean into our strengths and avoid our weaknesses.”

- Ed Tumbusch

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