

GDC

Cozmo: Animation pipeline for a physical robot

Molly Jameson and Daria Jerjomina
Anki



COZMO®



anki®





Who are we?

Daria Jerjomina

Animation Tools Engineer at Anki

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Molly Jameson

Software Engineer at Anki

Molly@anki.com



What is this talk?



- Why keyframed animation?
- Animation export.
- Software Architecture of Cozmo.
- Accounting for real world uncertainty.
- Testing.





anki®







What is Cozmo?



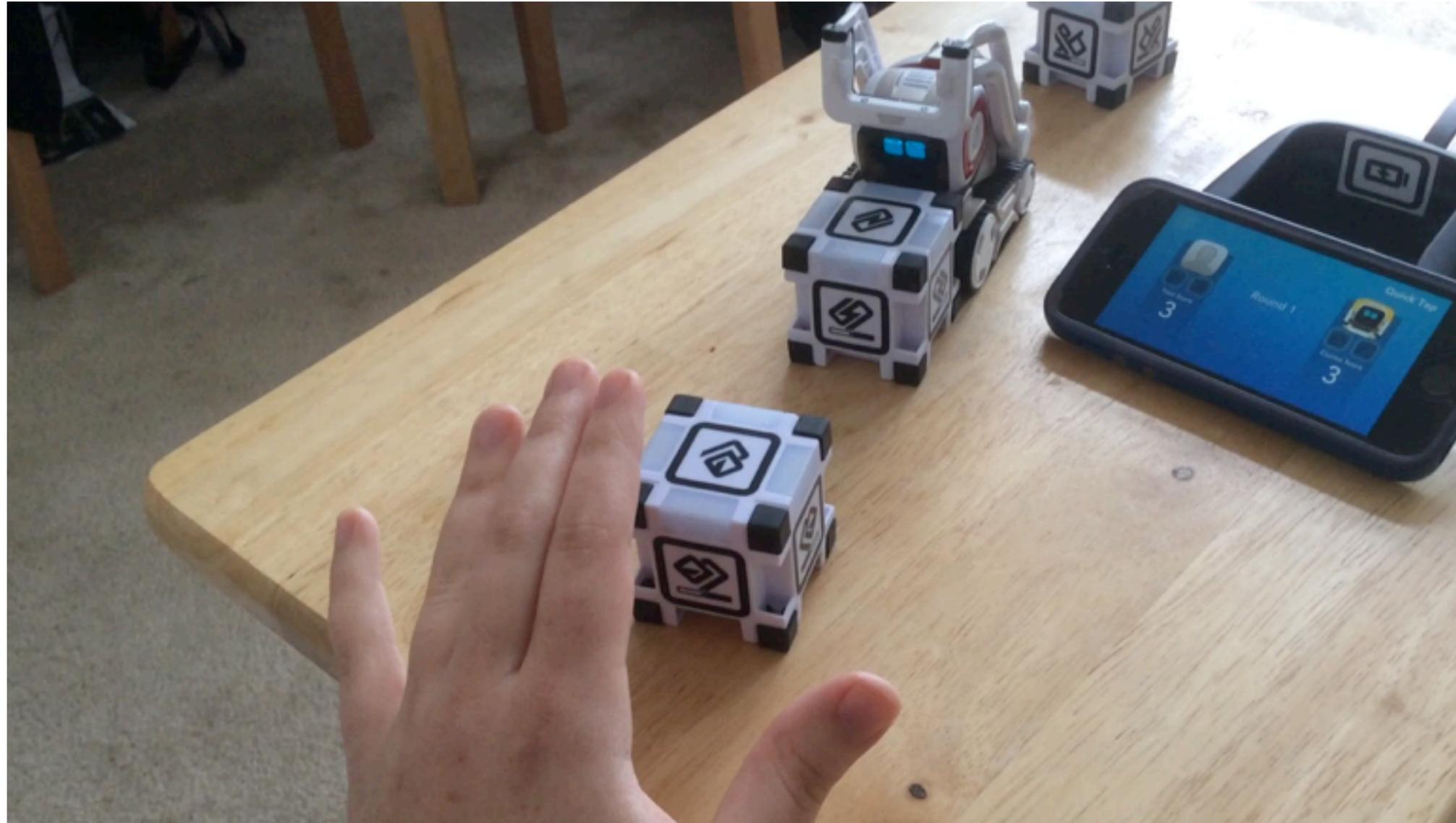
Cozmo the robot pet

The logo for Cozmo, featuring the word "COZMO" in a white, rounded, sans-serif font with a registered trademark symbol (®) to the upper right of the letter "O". The text is centered on a large rectangular background with a blue-to-cyan gradient.

COZMO®



Cozmo plays games





"...showing him off to new people never stops being fun"

- *Polygon*

"He's smarter, cleaner and more lovable than our hamster, plus he doesn't poop and the cat doesn't want to eat him."

- *Kotaku*

" 9/10 [...] the best smart toy of the year"

- *Slashgear*

"The way it moves and emotes is so good that it feels like you're interacting with a Pixar character instead of playing with a toy."

- *Penny-Arcade*





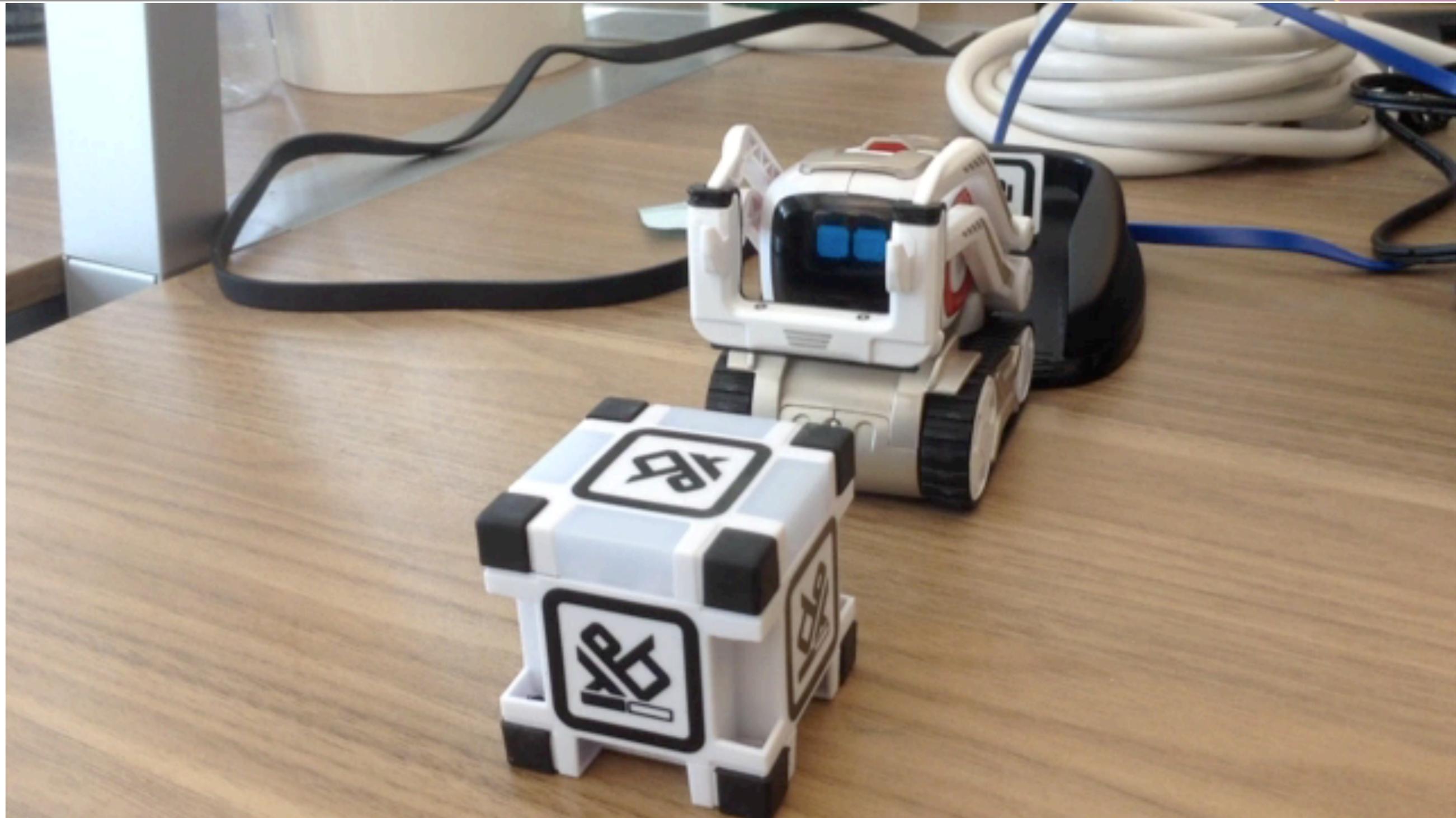
Significance of animation for Cozmo







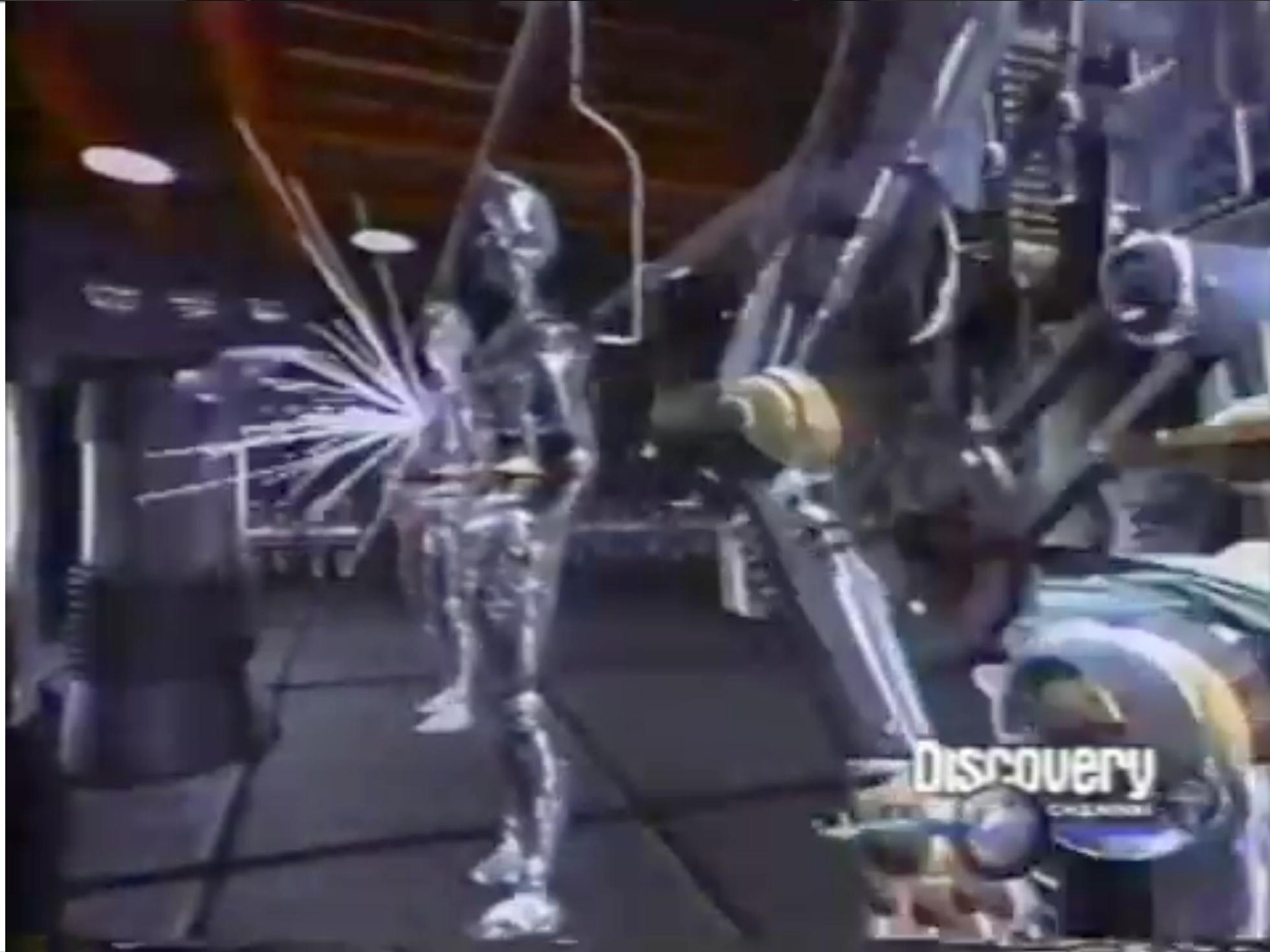




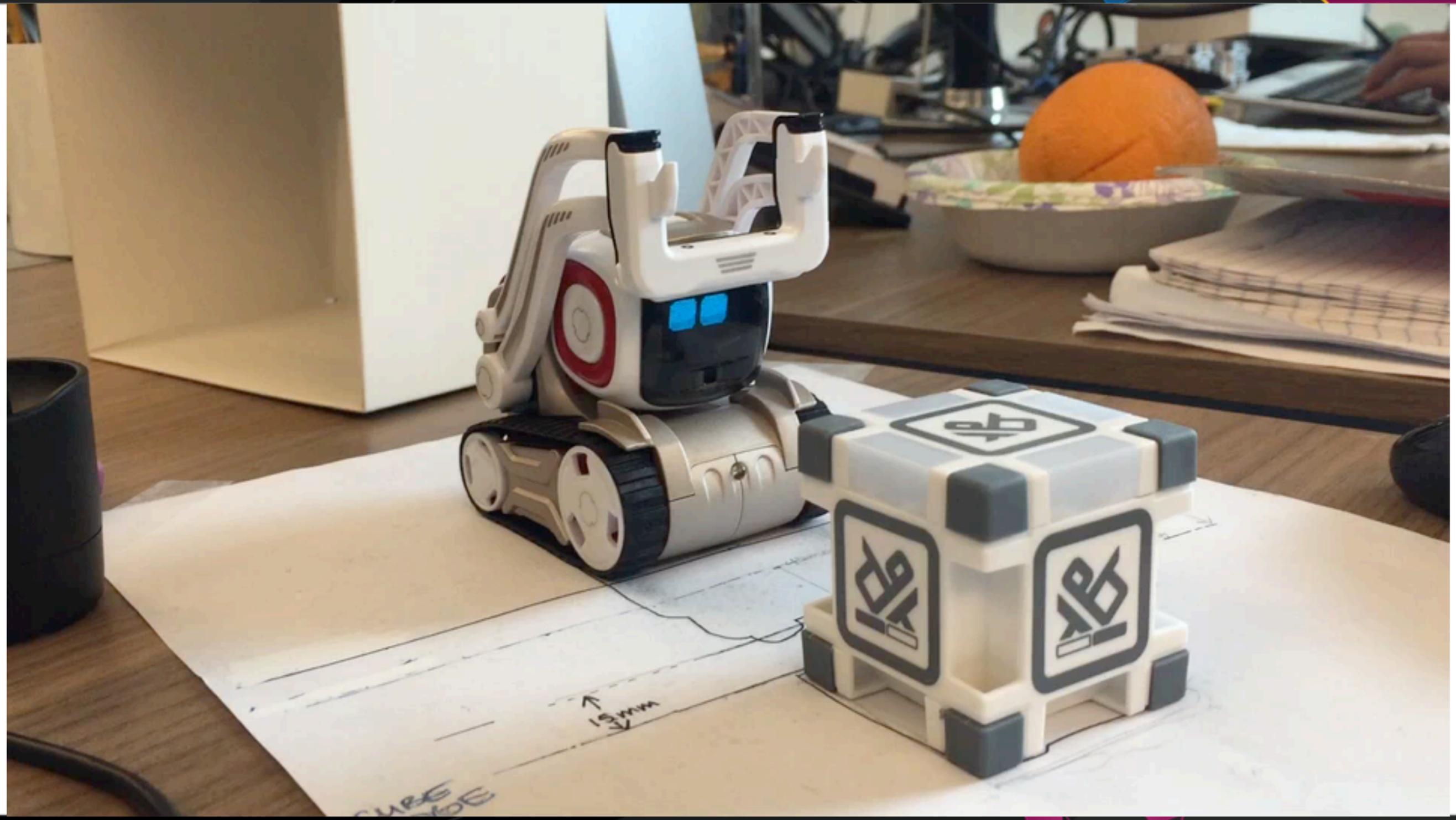


Achieving a natural, appealing motion











Transferring animation to the robot





Data exported from Maya

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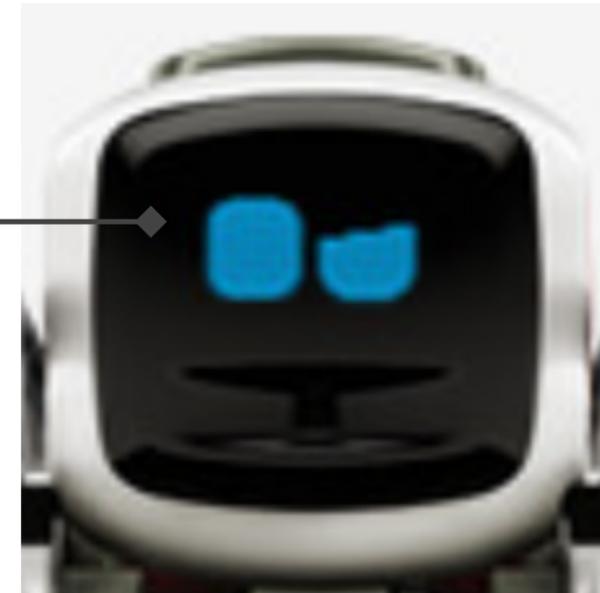


Speaker Head

Face (eyes)

Backpack

Lights



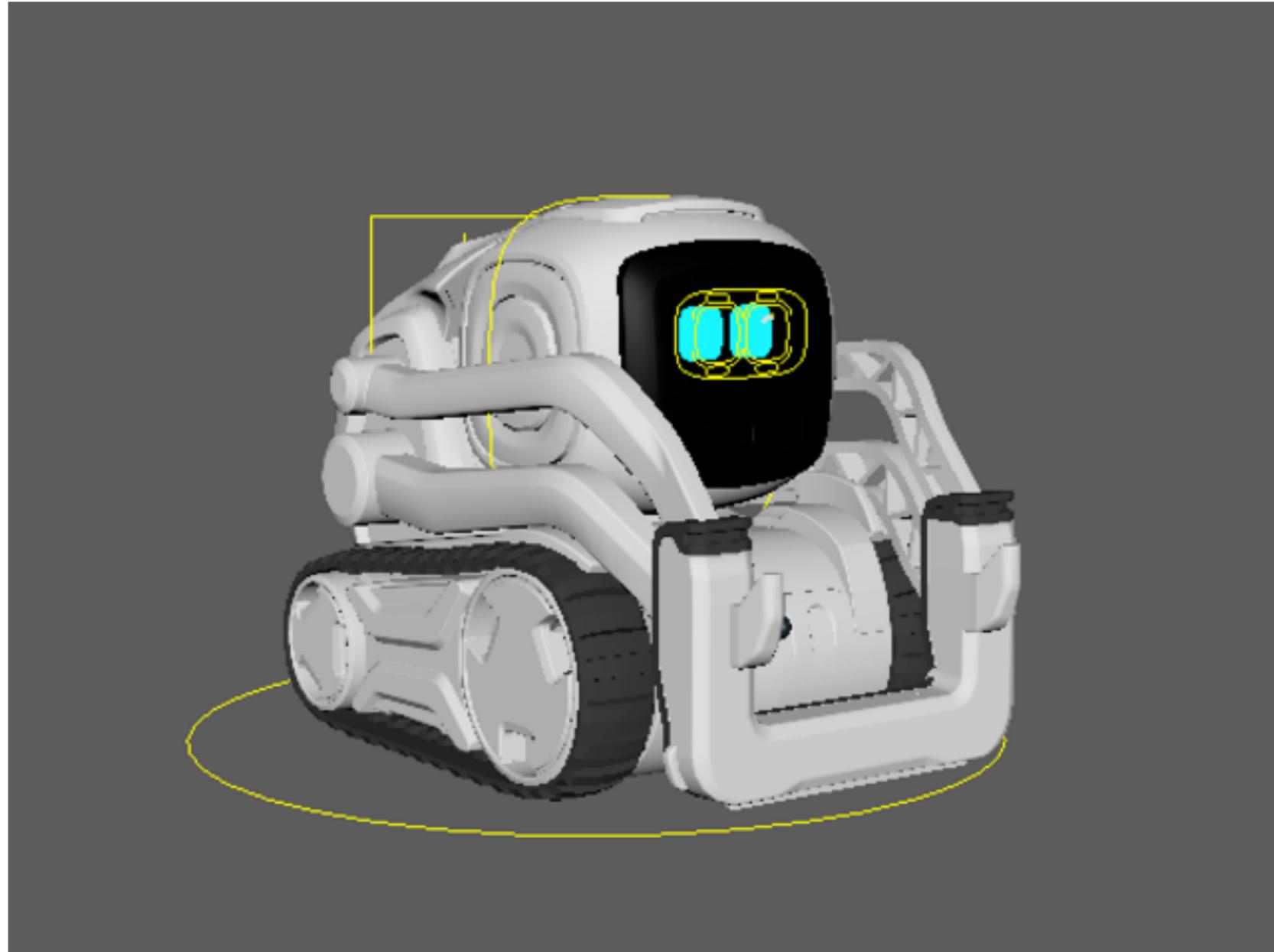
Wheels

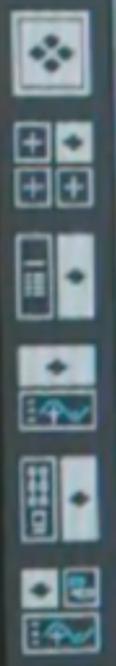
Lift





Cozmo's rig

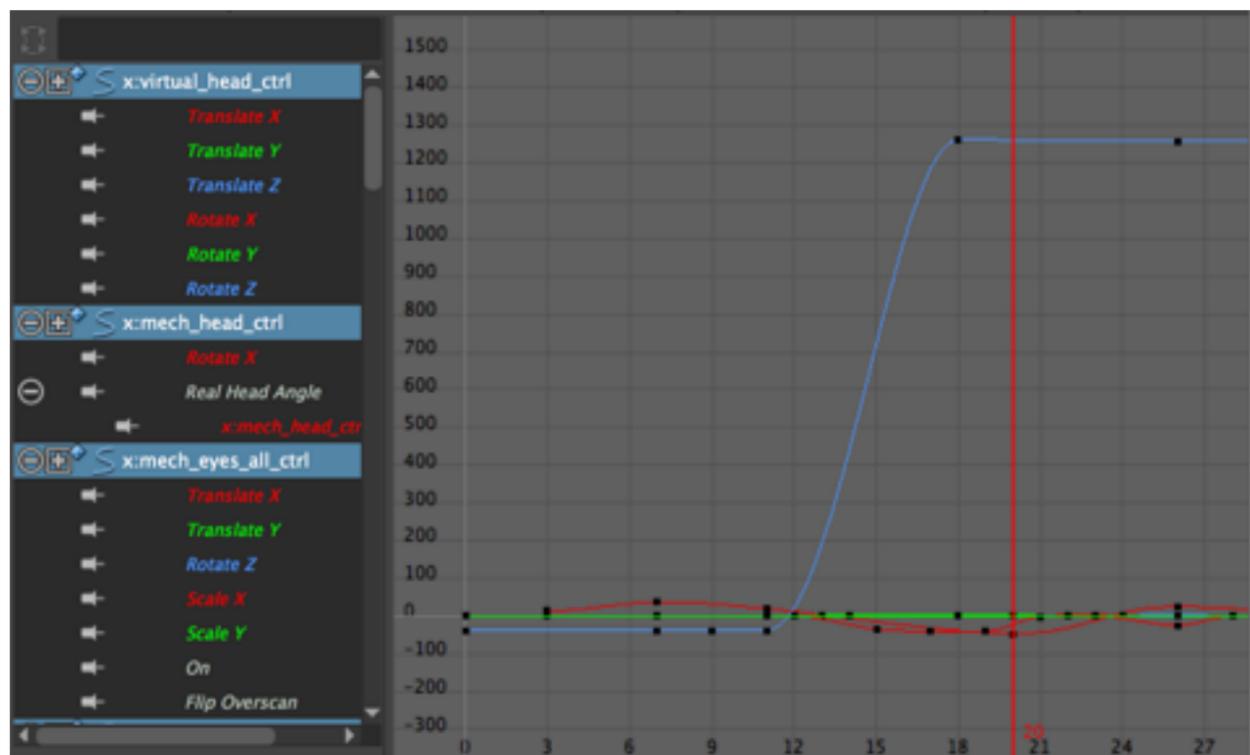




0 0 0

// Result: 1

Data Export

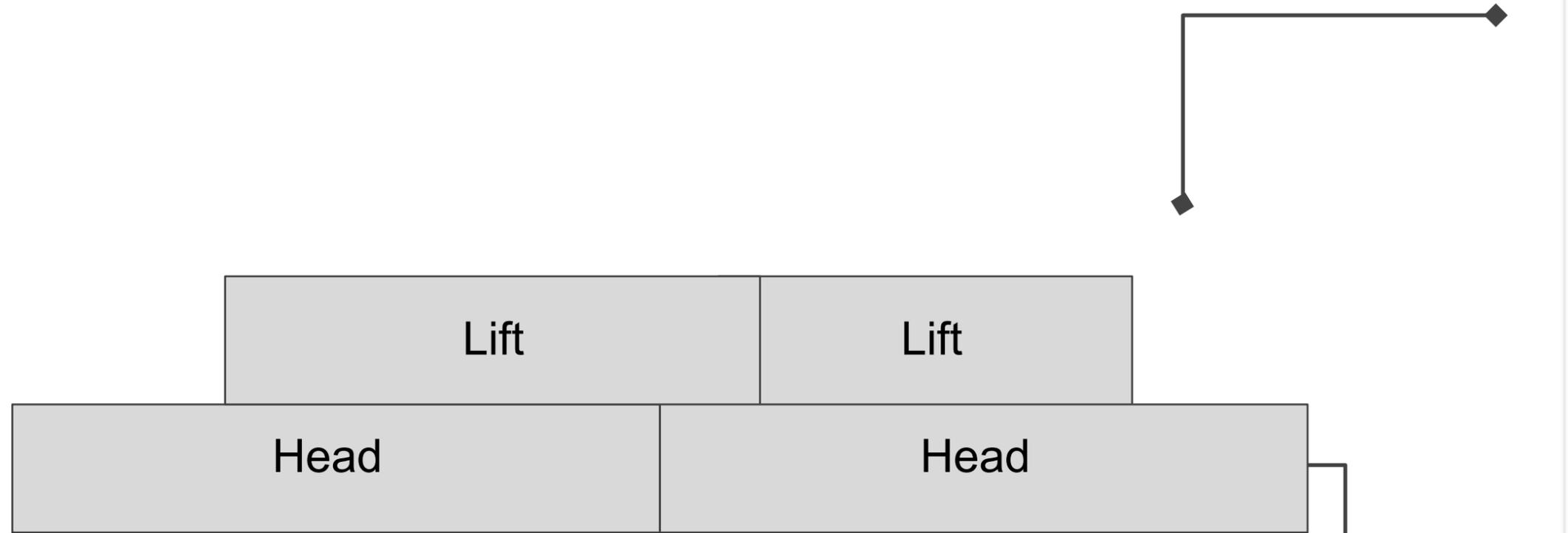


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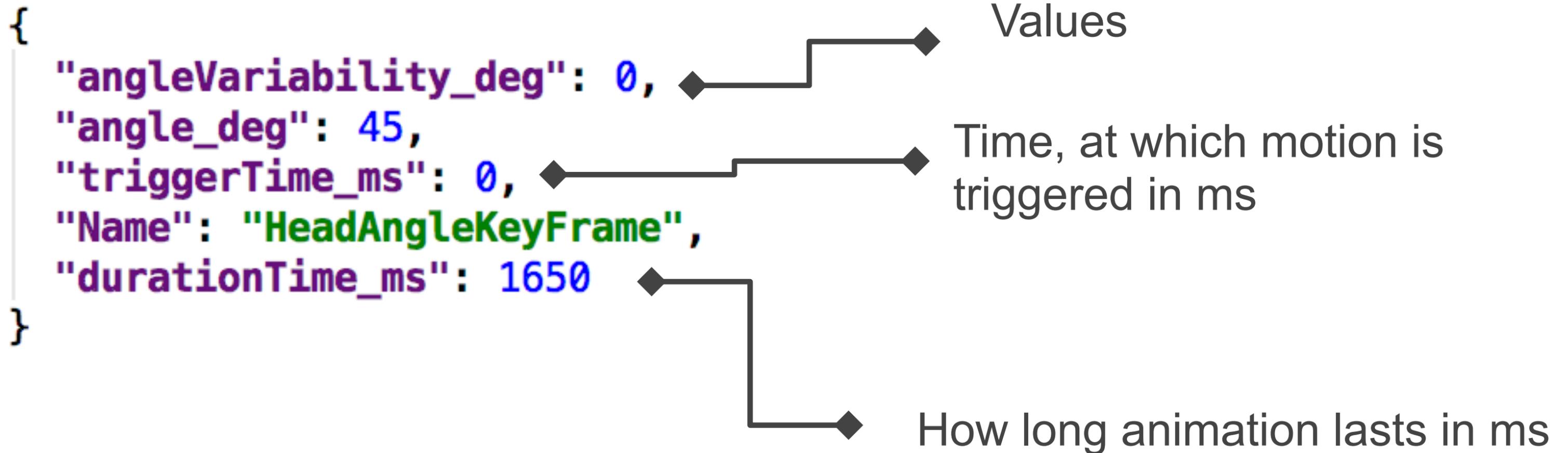


Data Export



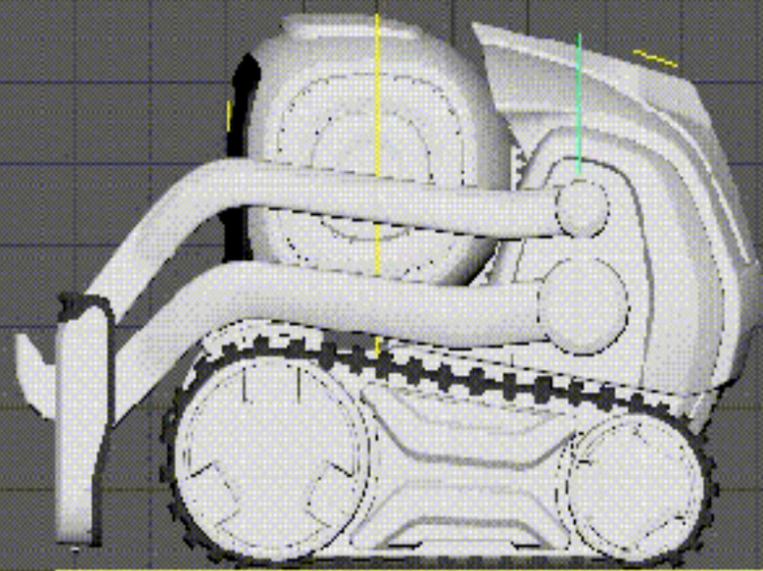


Data in form of a single node

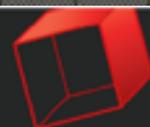




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```



side





Head	Head
------	------

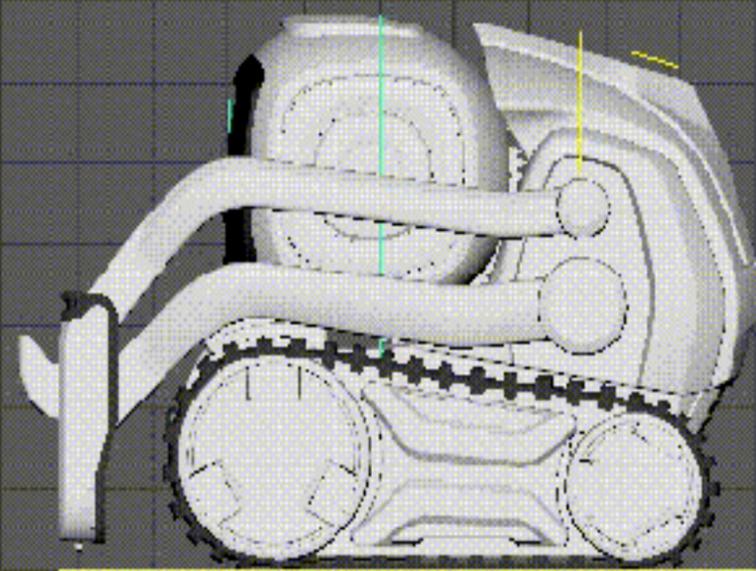
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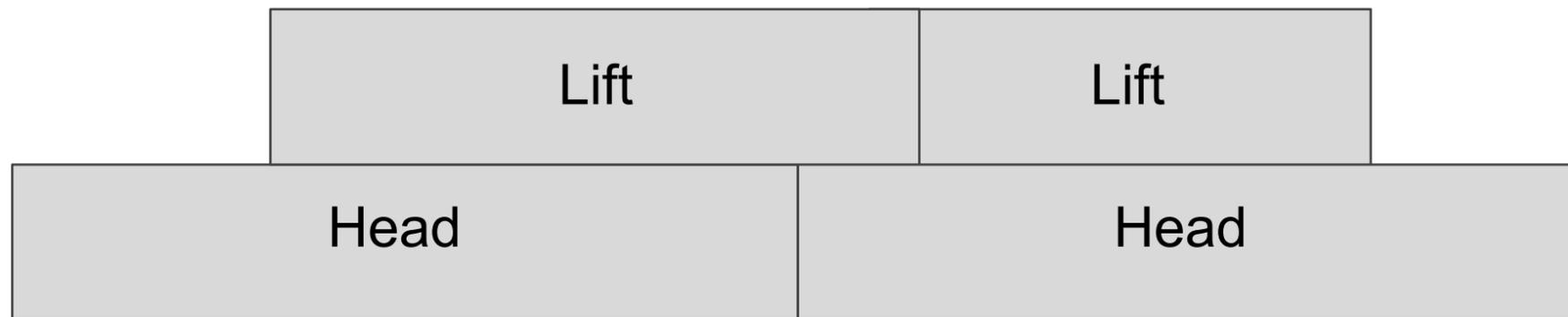
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side

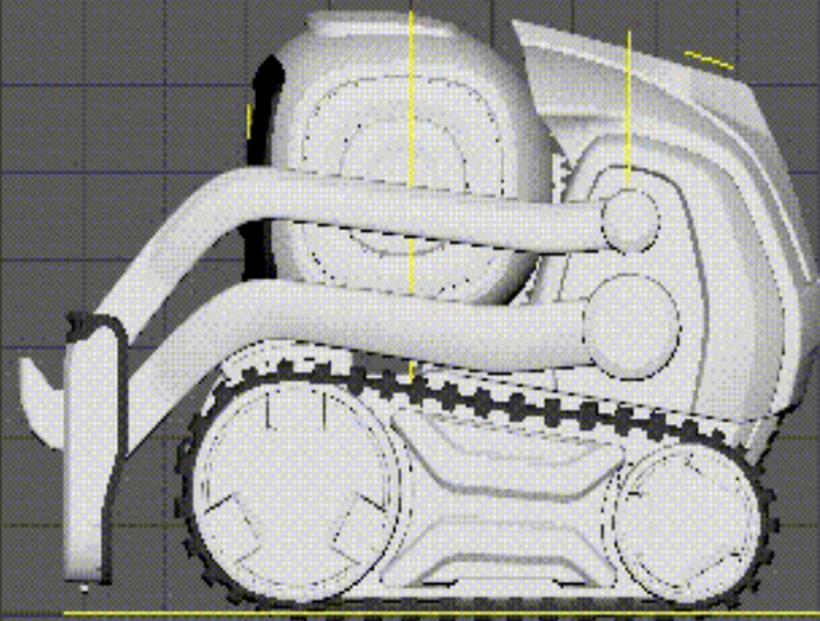




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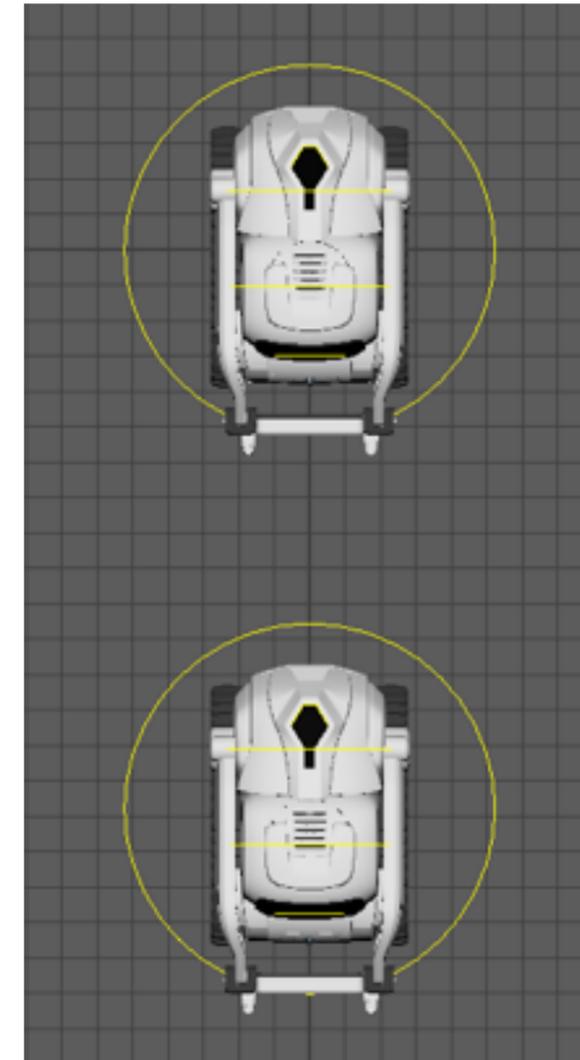
Absolute vs Relative

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```



Velocity vs Position





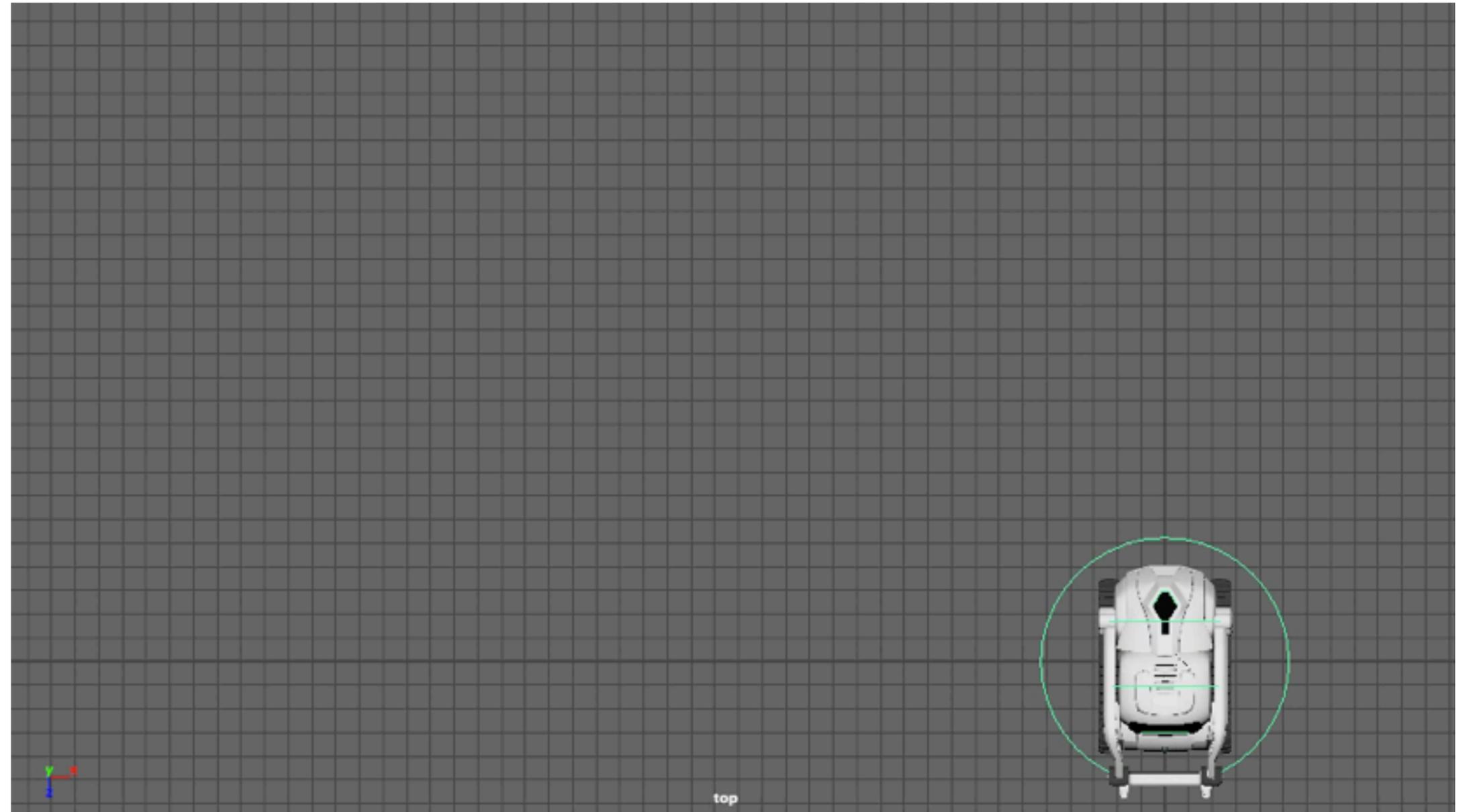
Cozmo's movement





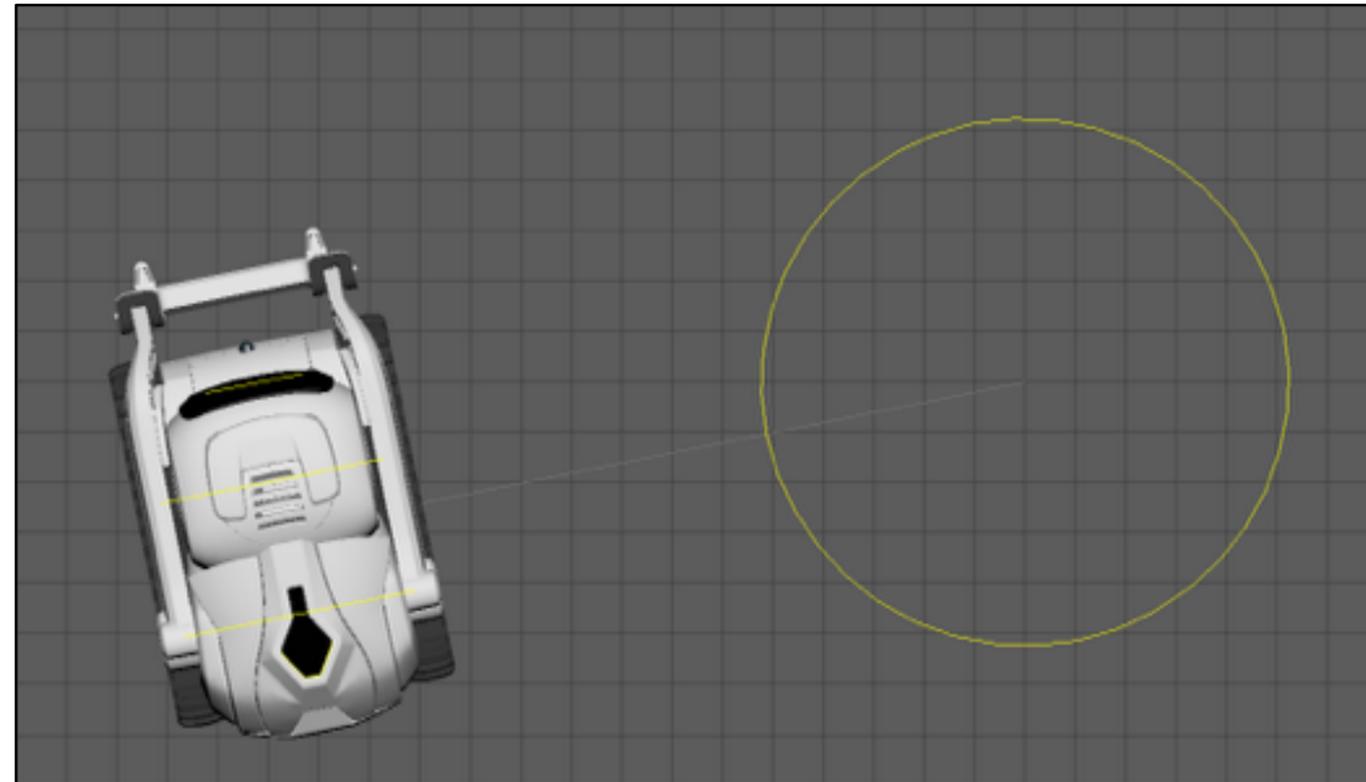
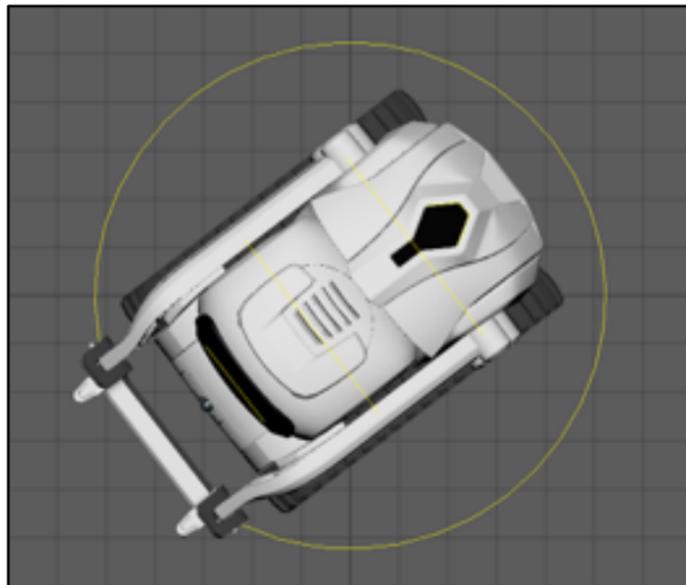
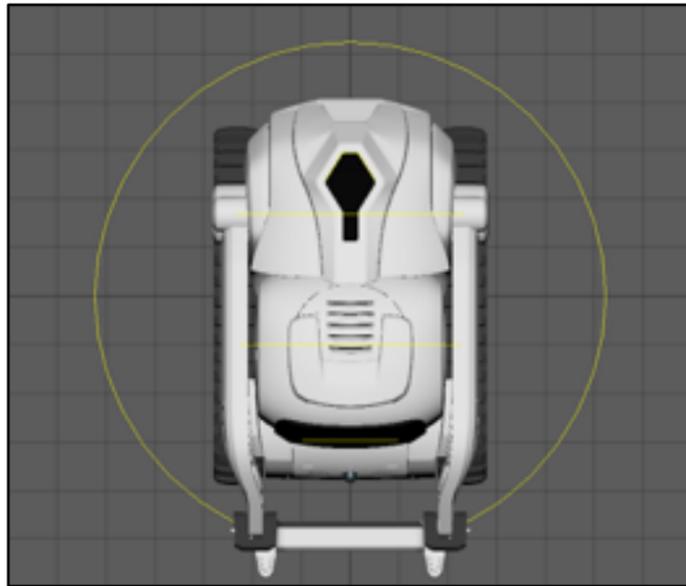
3 types of movement:

Turn in Place
Move Straight
Arc Turn



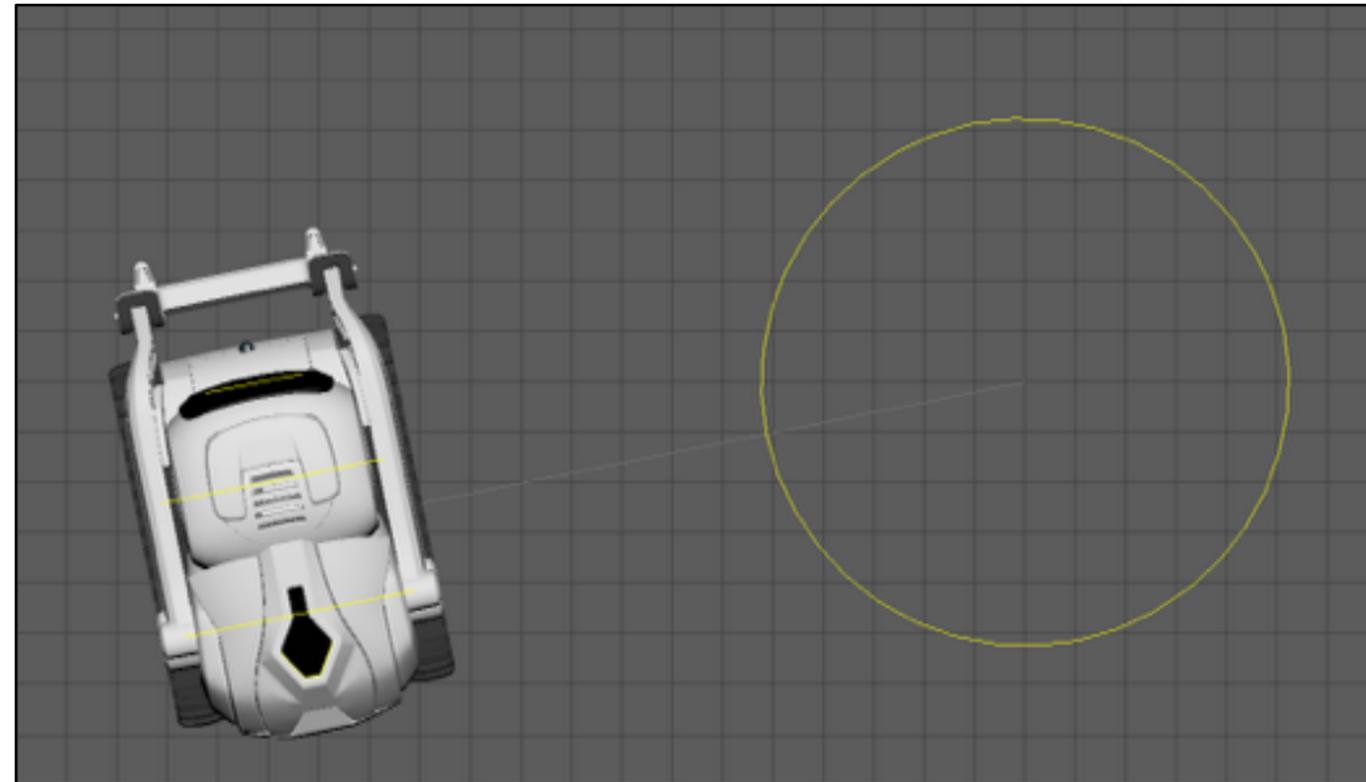
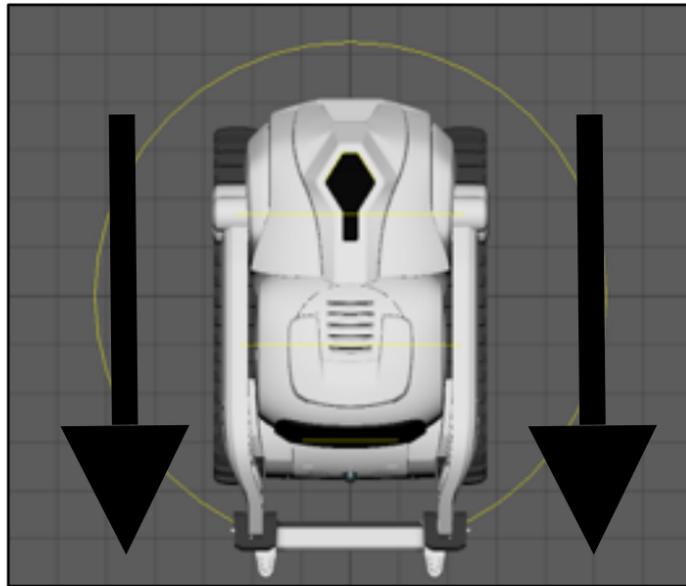


Single Axle Robot Movement



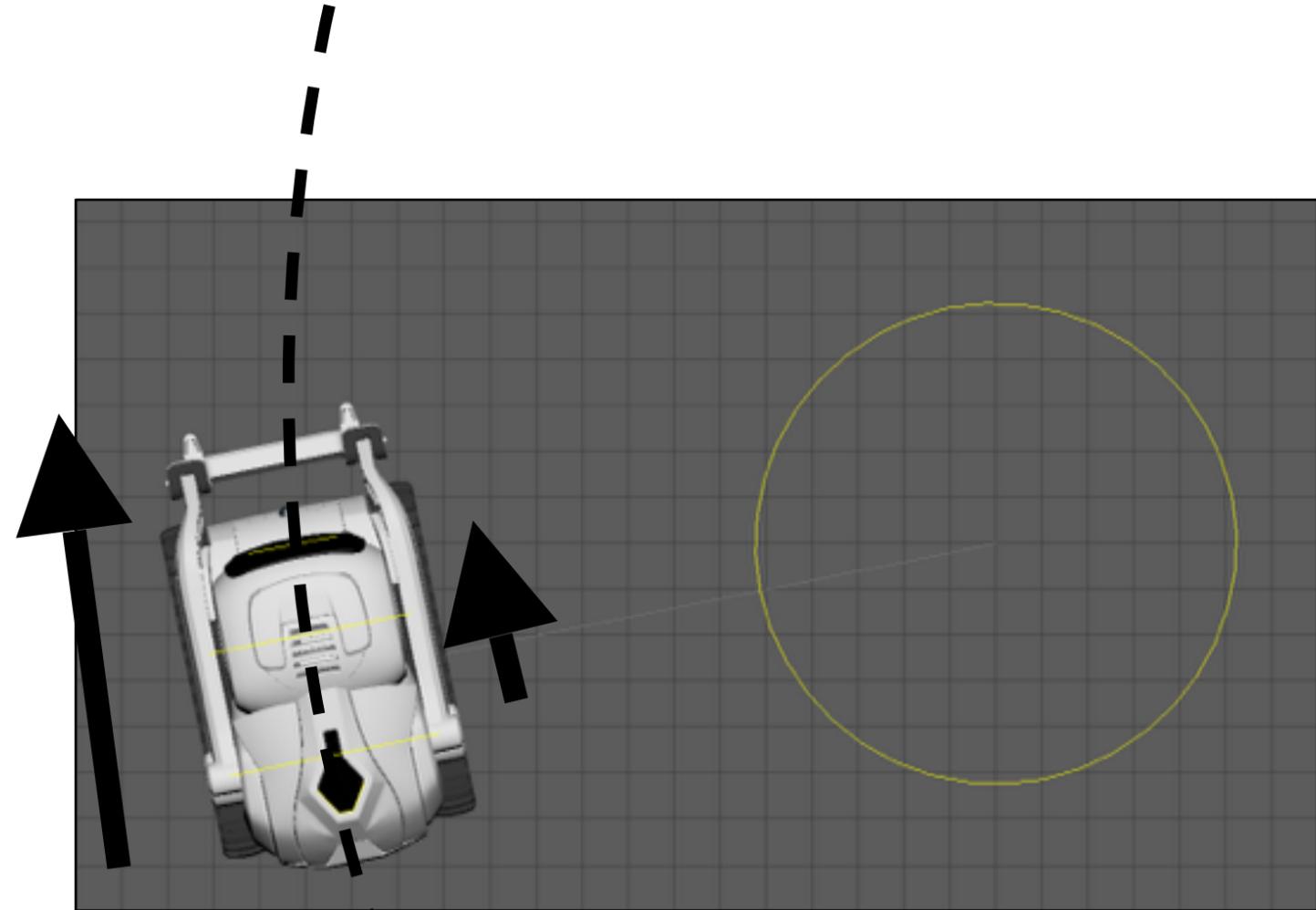
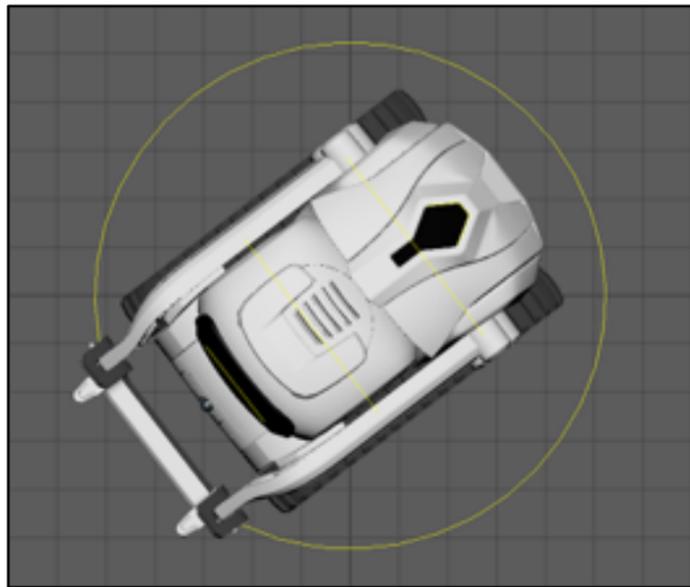
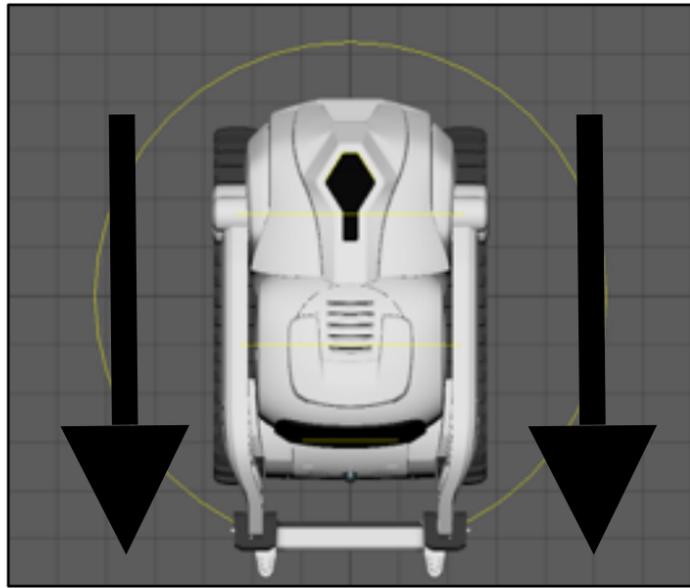


Single Axle Robot Movement



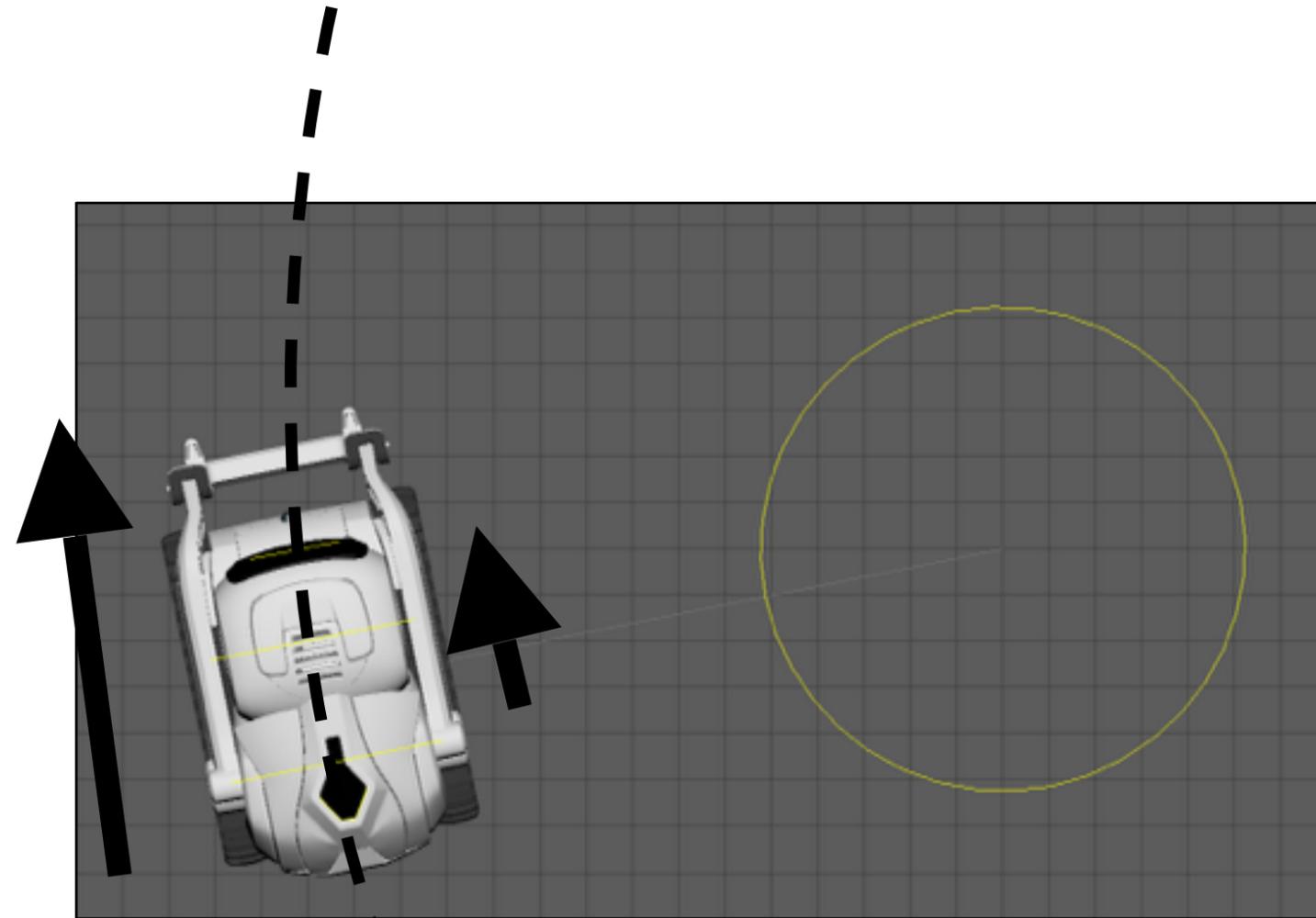
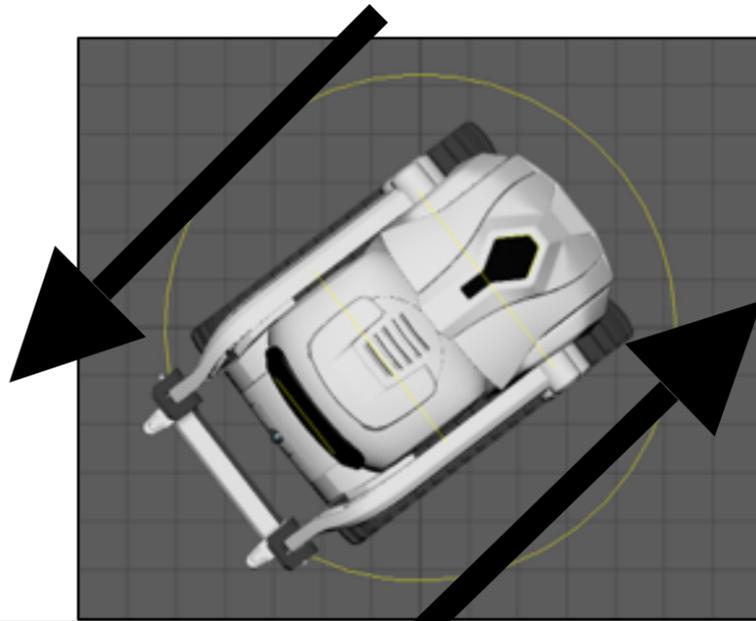
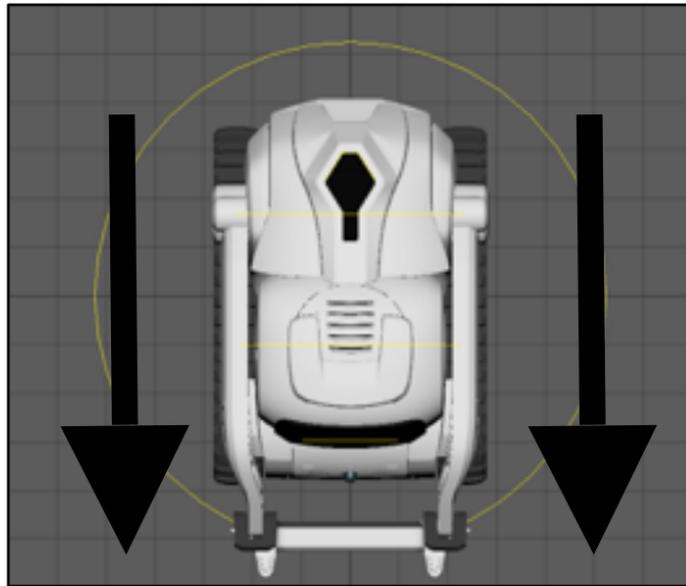


Single Axle Robot Movement





Single Axle Robot Movement

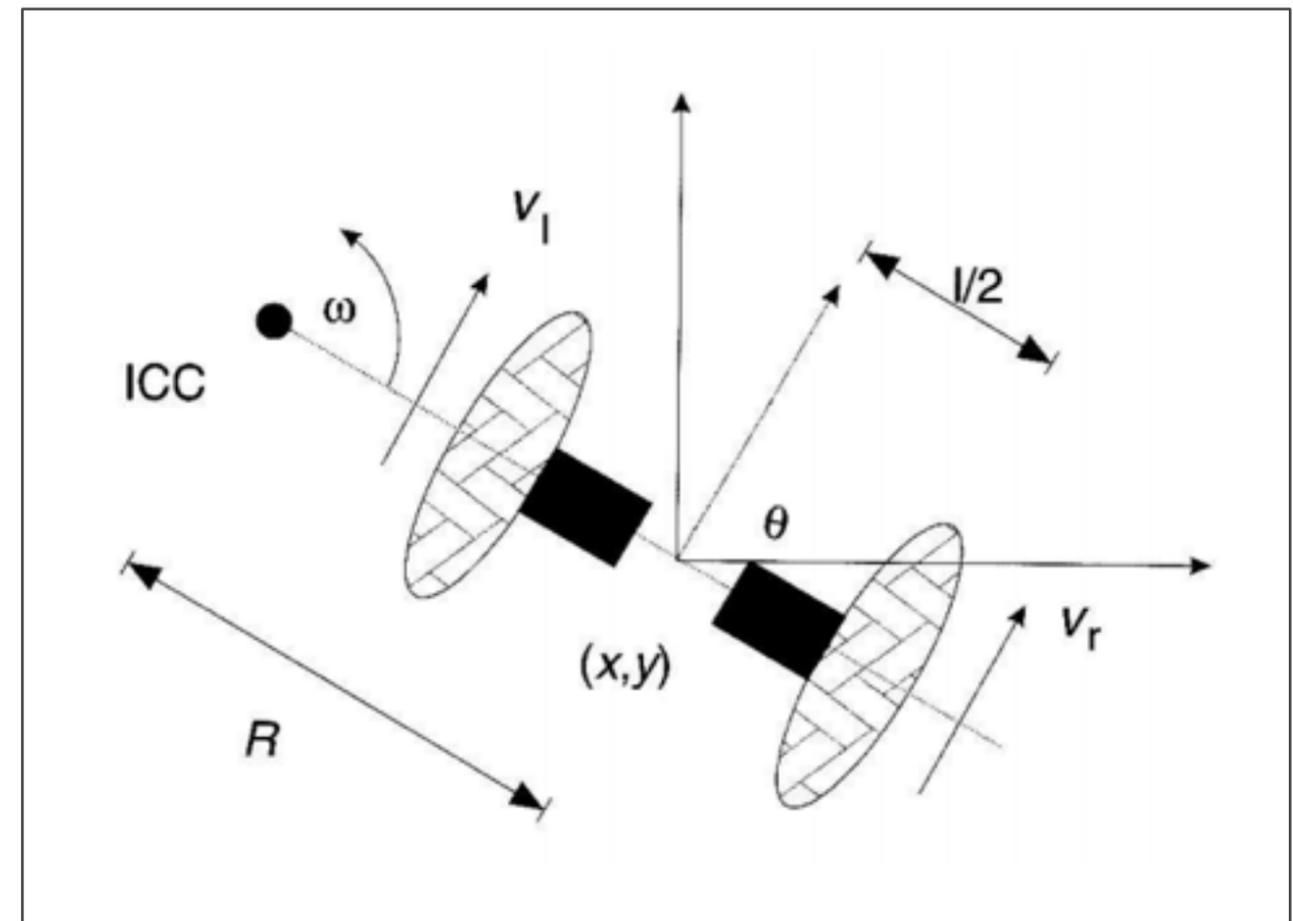
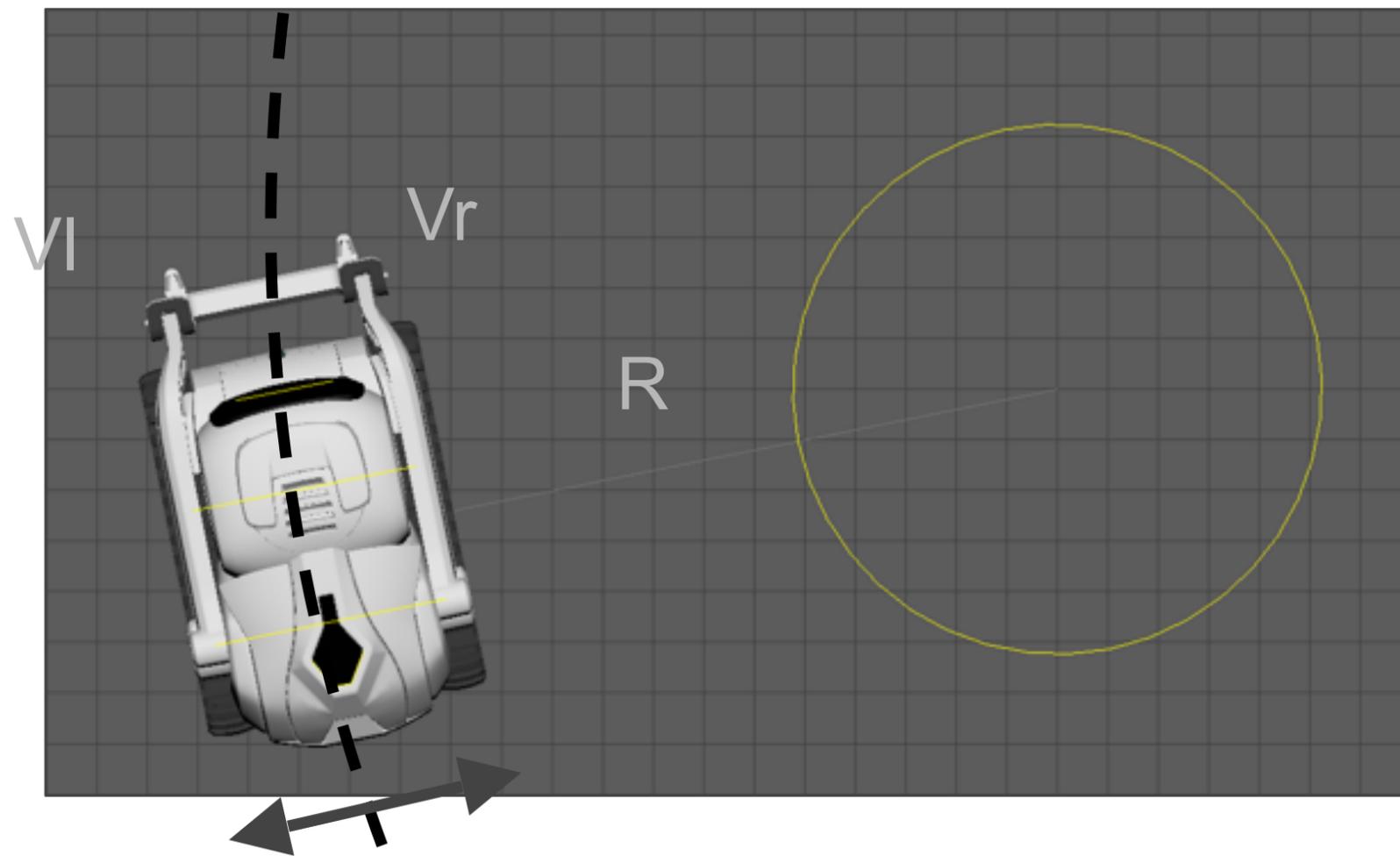




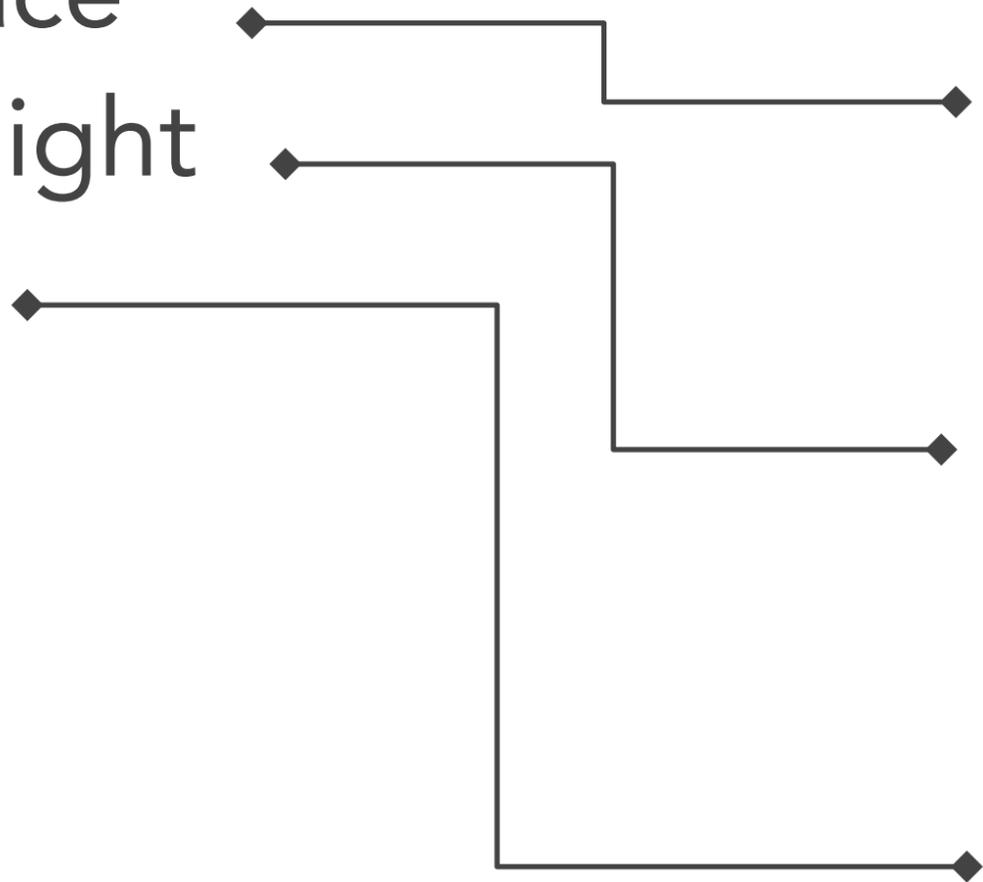
Differential Drive Kinematics

$$\omega (R + l/2) = V_r$$

$$\omega (R - l/2) = V_l$$

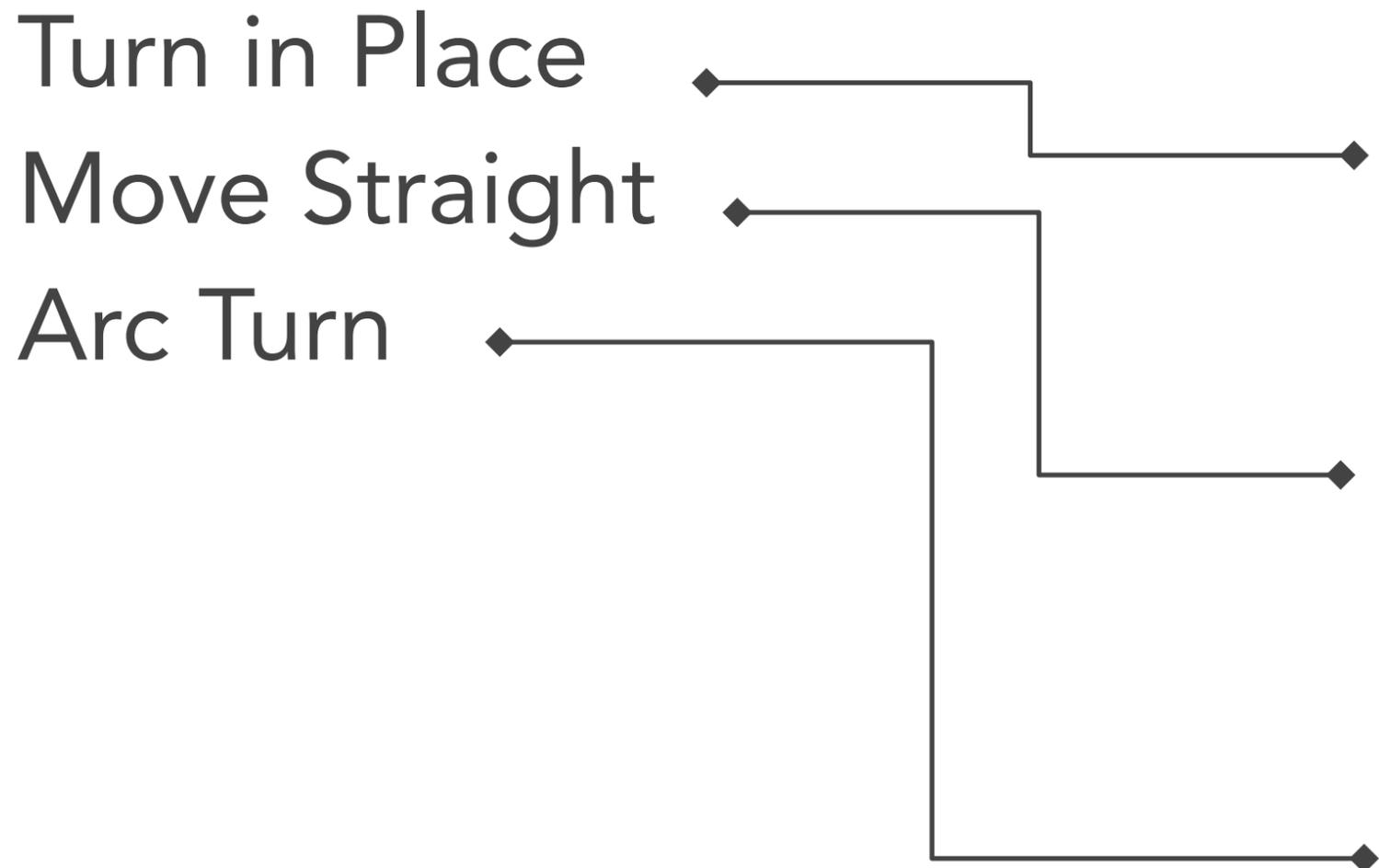


Turn in Place
Move Straight
Arc Turn



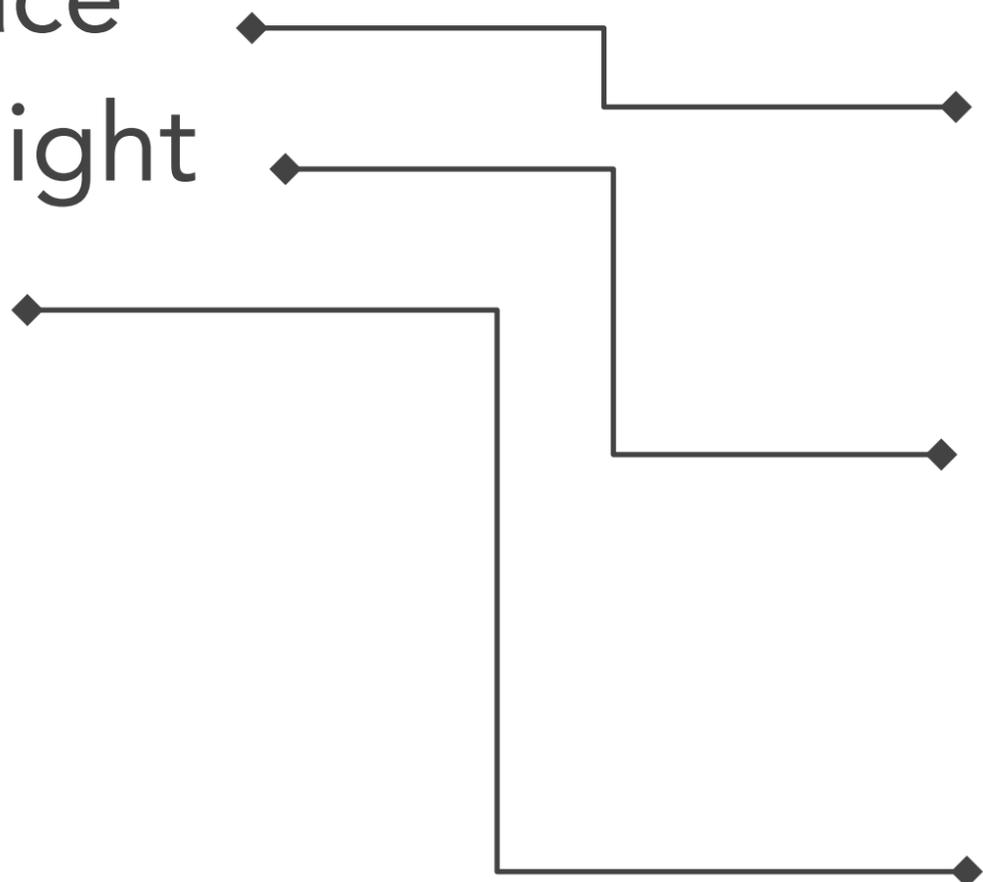
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Turn in Place
Move Straight
Arc Turn

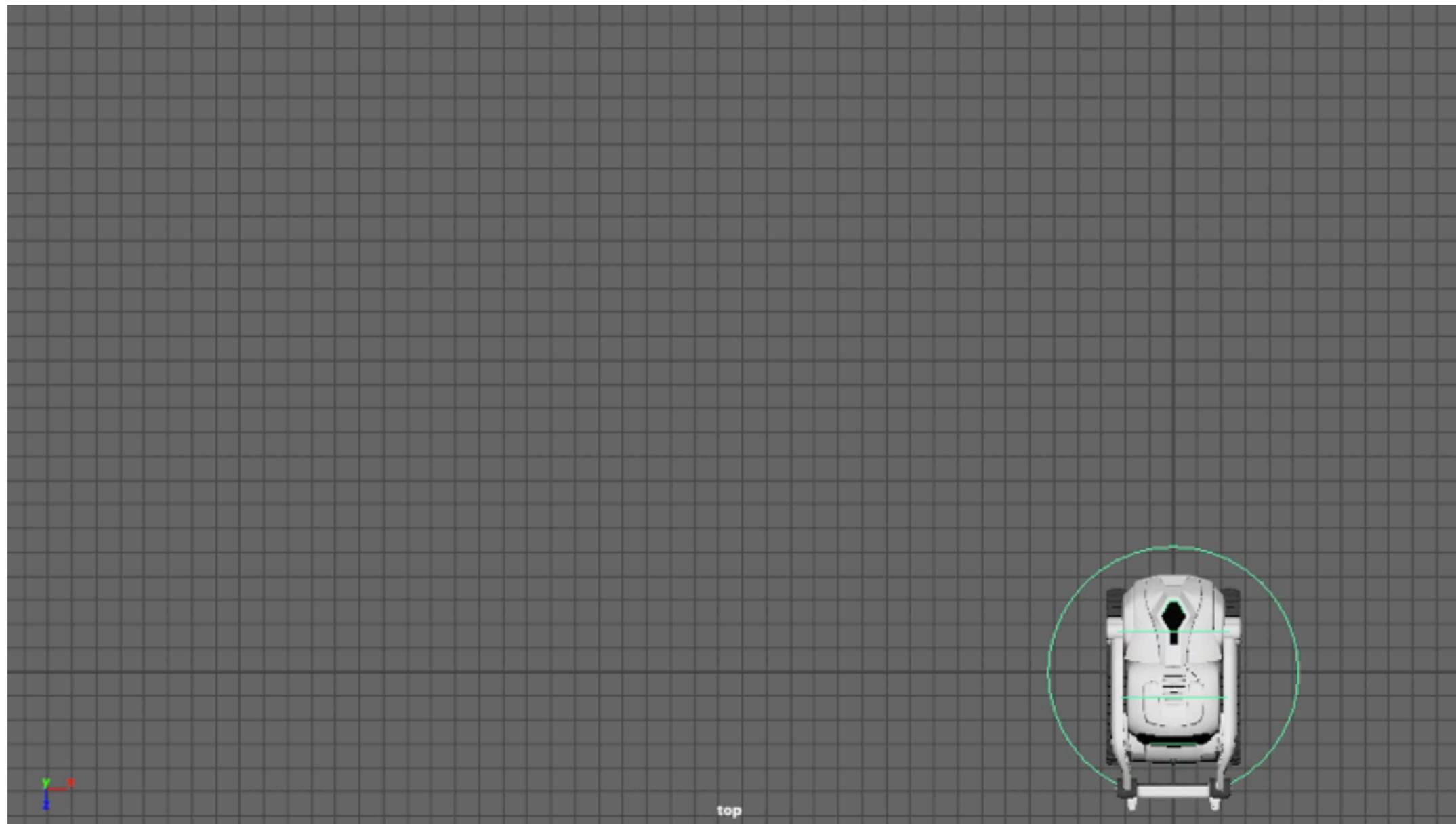


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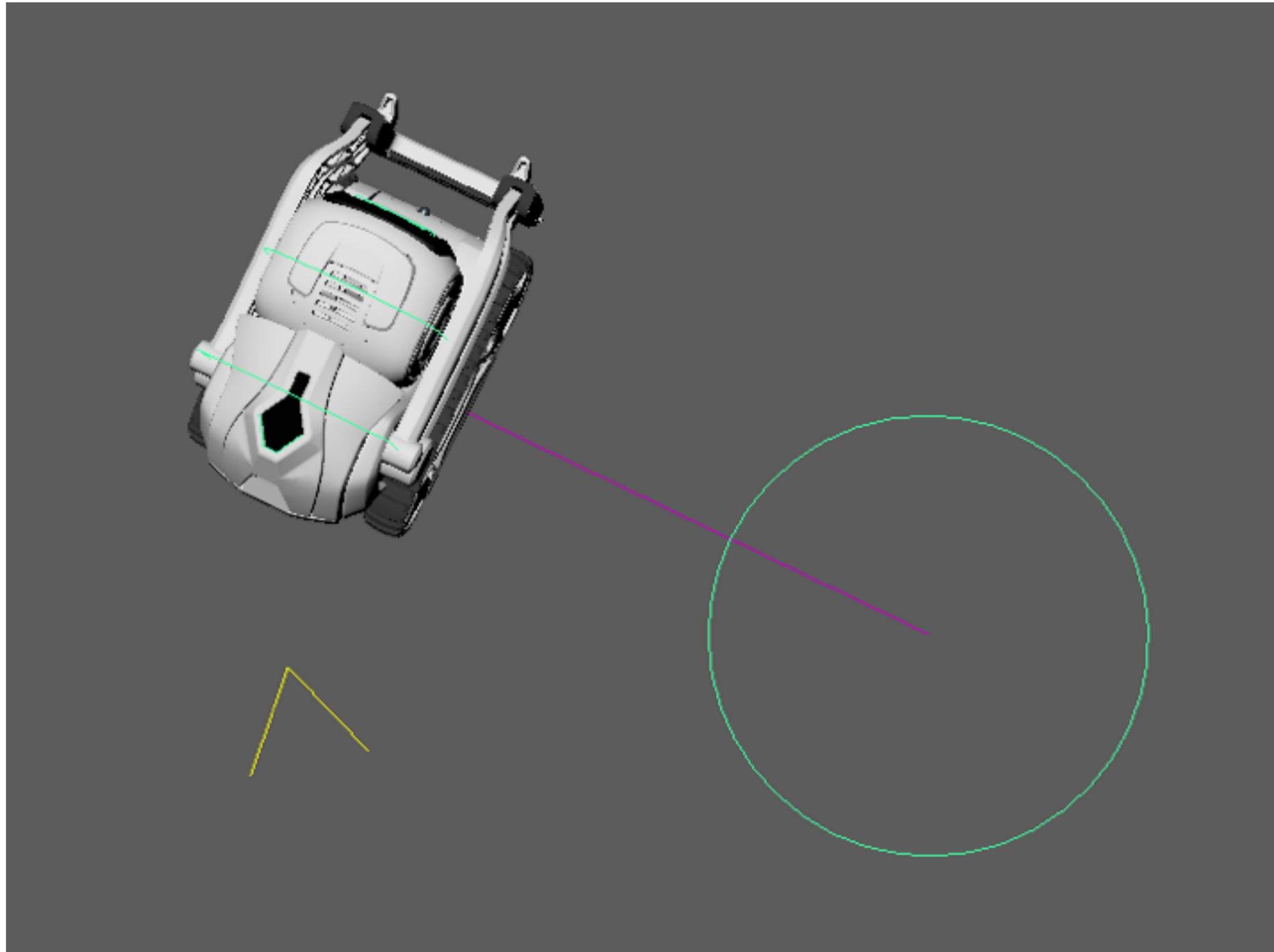
Turn in Place
Move Straight
Arc Turn



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Radius	-15
Forward	0
Turn	-37.531



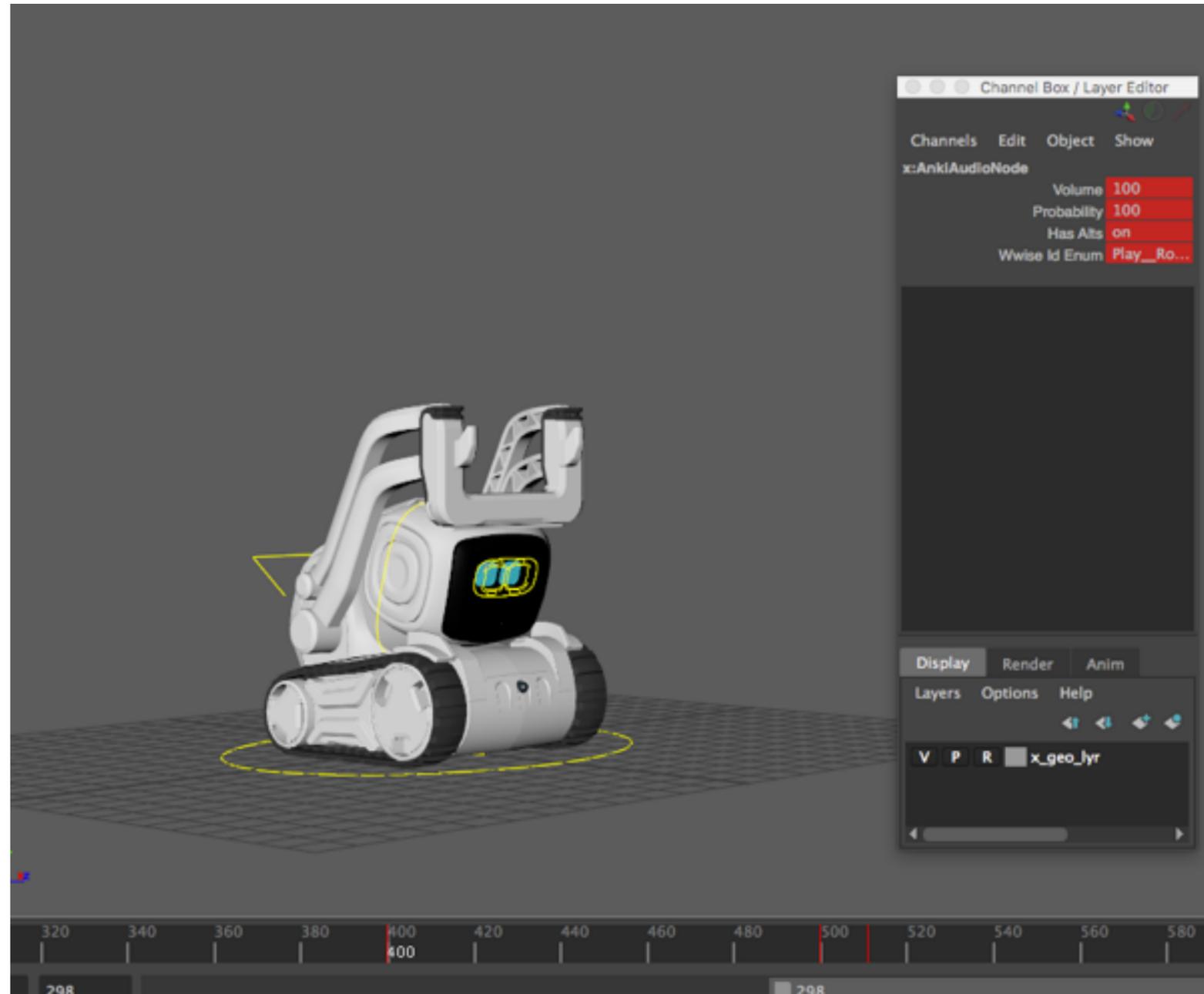


Audio





Audio



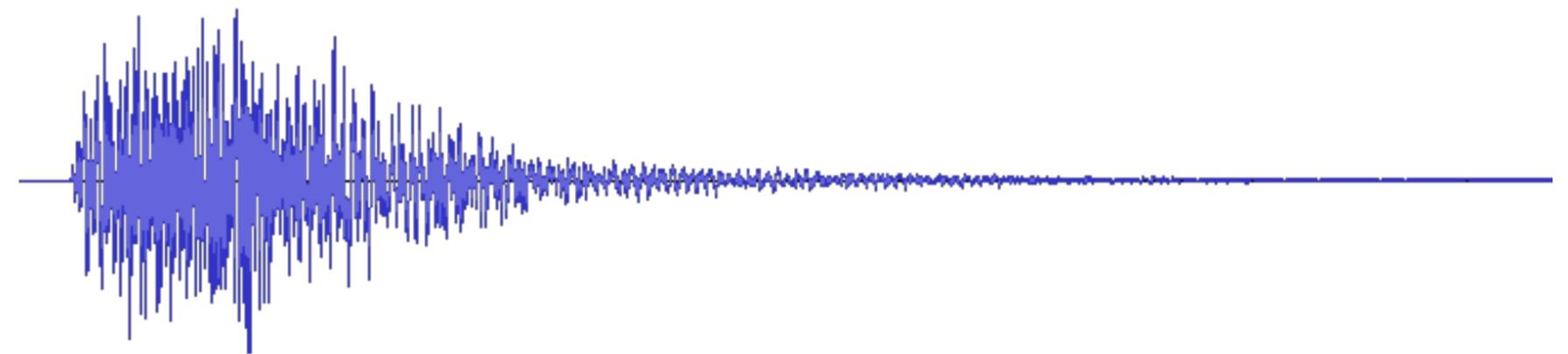
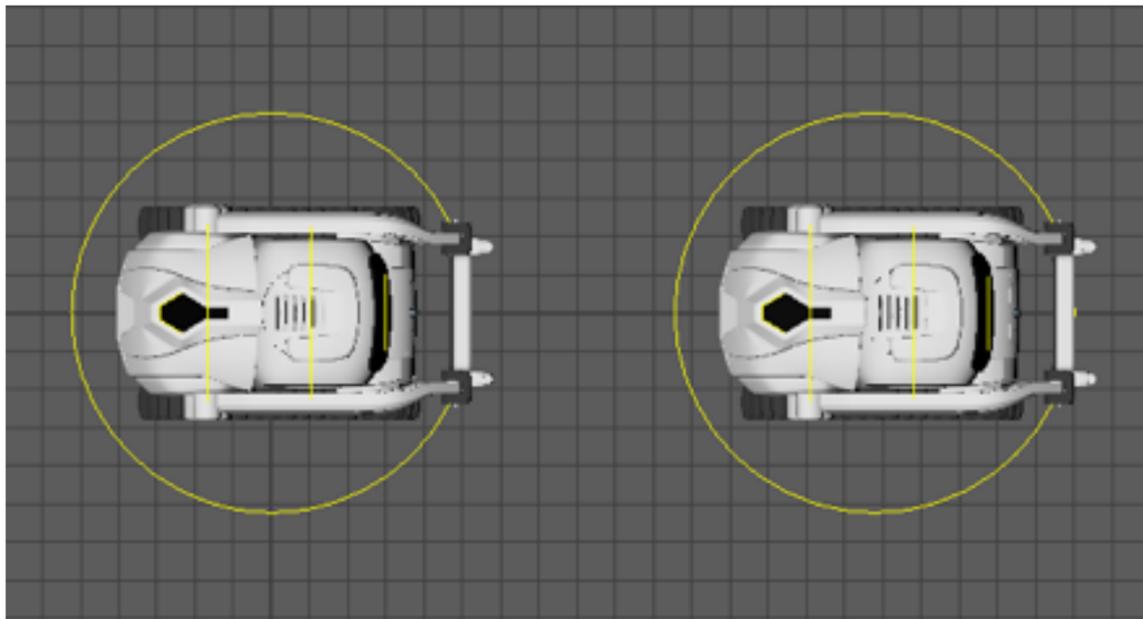
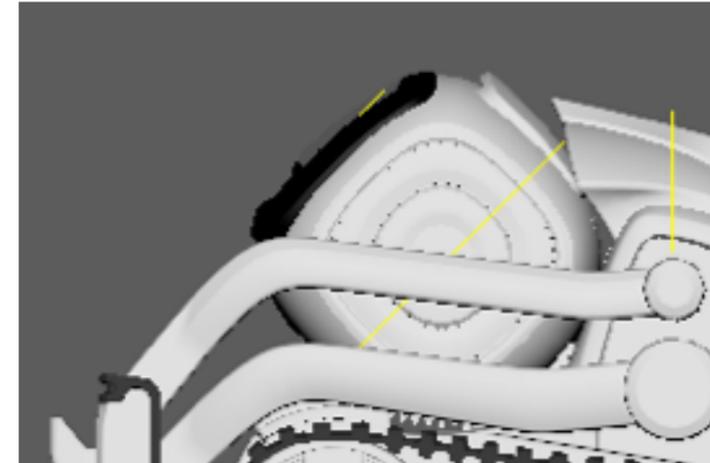


Rig and animation limitations due to physical constraints

Physical limitations

Movement

Audio





Happy accidents









Previewing animation

The screenshot displays a game engine interface with the following components:

- Left Panel (Hierarchy):** A tree view showing the scene's structure, including 'CozmoWorldInfo', 'Viewpoint', 'Background', 'DirectionalLight', 'CozmoMat', and 'WebotsKeyboardController'.
- Center View:** A 3D perspective view of a robot (Cozmo) in a virtual environment with a grey floor and black walls. Several small icons are scattered on the floor.
- Right Panel (Emotion List):** A list of emotion states with corresponding icons: Happy, Calm, Brave, Confident, Charged, Soiled, Social, and Mending.
- Bottom Panel (Console):** A log window showing system messages and warnings, such as 'HandleLoadedKnownFace' and 'EncodedImage.AddChunk.UnexpectedNumberOfChunks'.
- Bottom Left Panel (CozmoMat Properties):** A control panel for the 'CozmoMat' object, featuring tabs for 'Node', 'Mass', and 'Position', along with fields for DEF, Transform, and Proto.





Previewing animation



persp





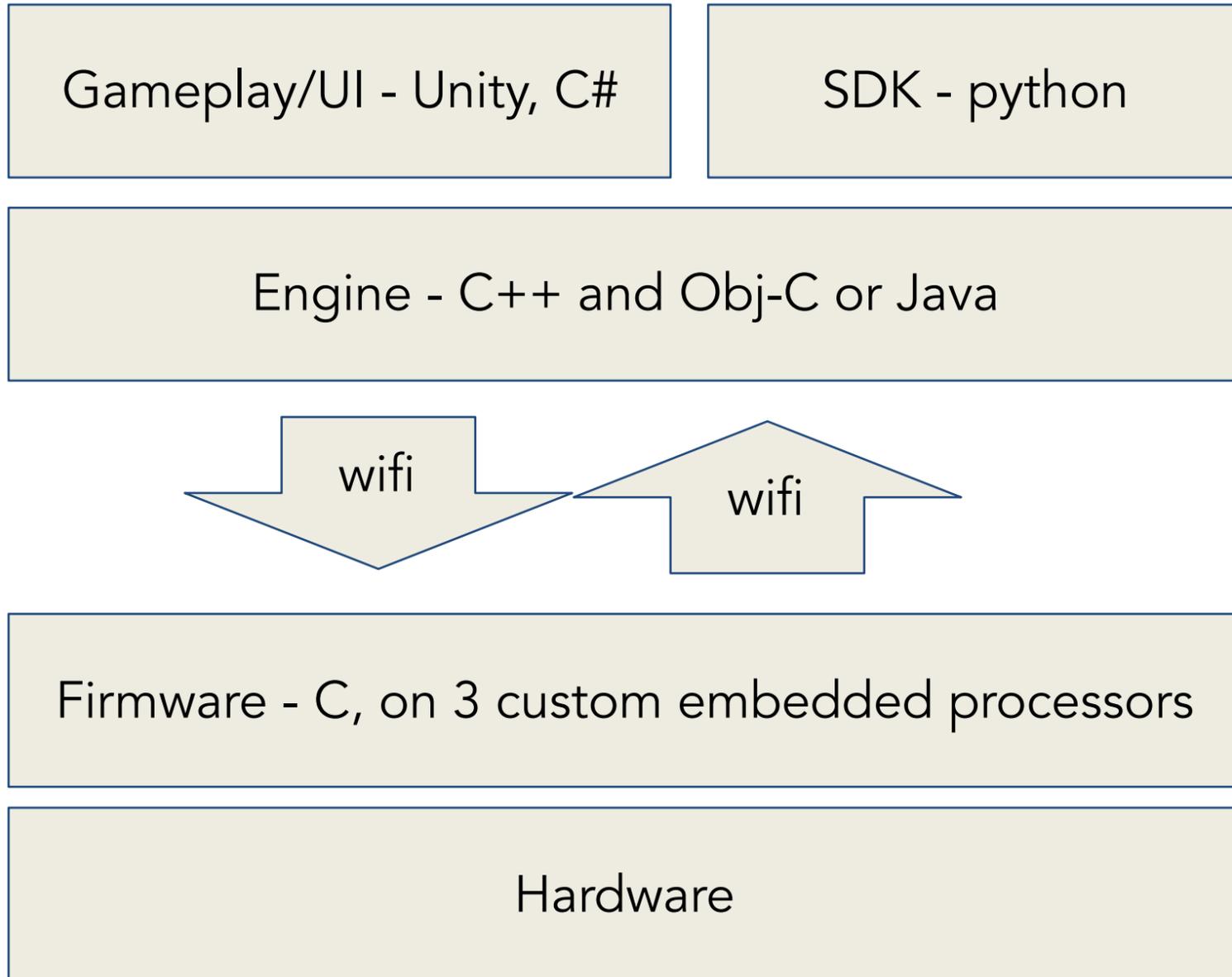
Once we have the animation data created we can then see it in the game as experienced by the player

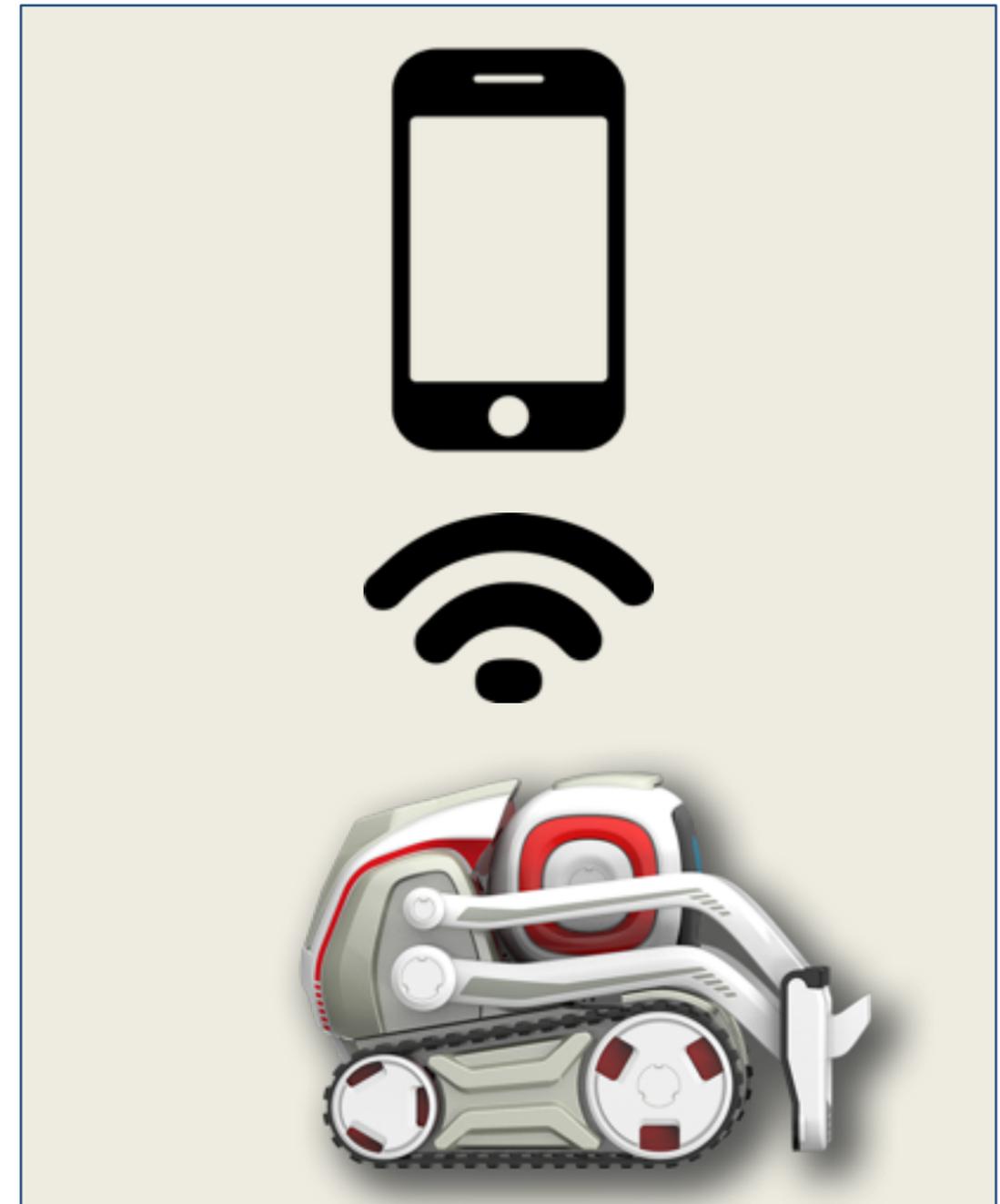
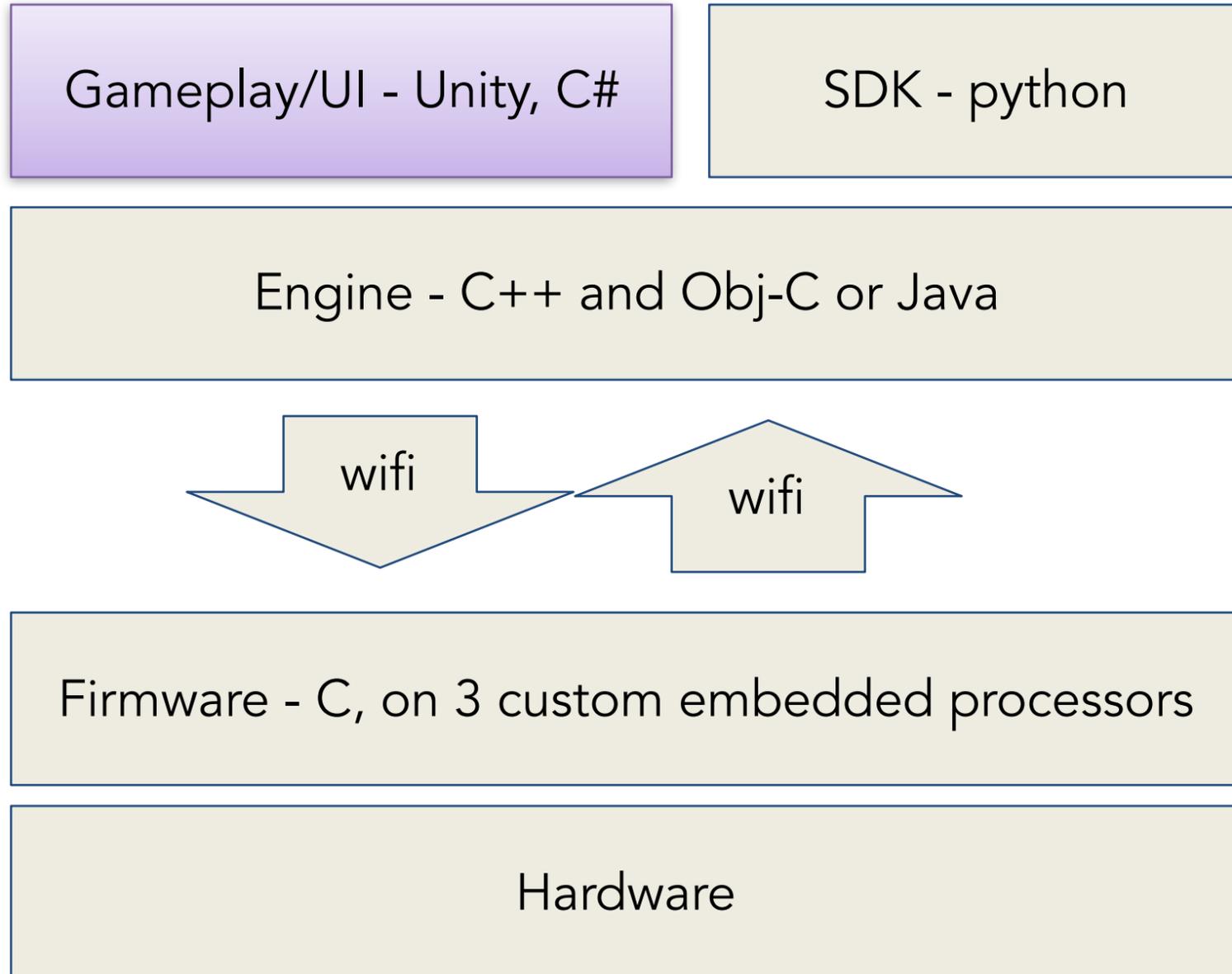


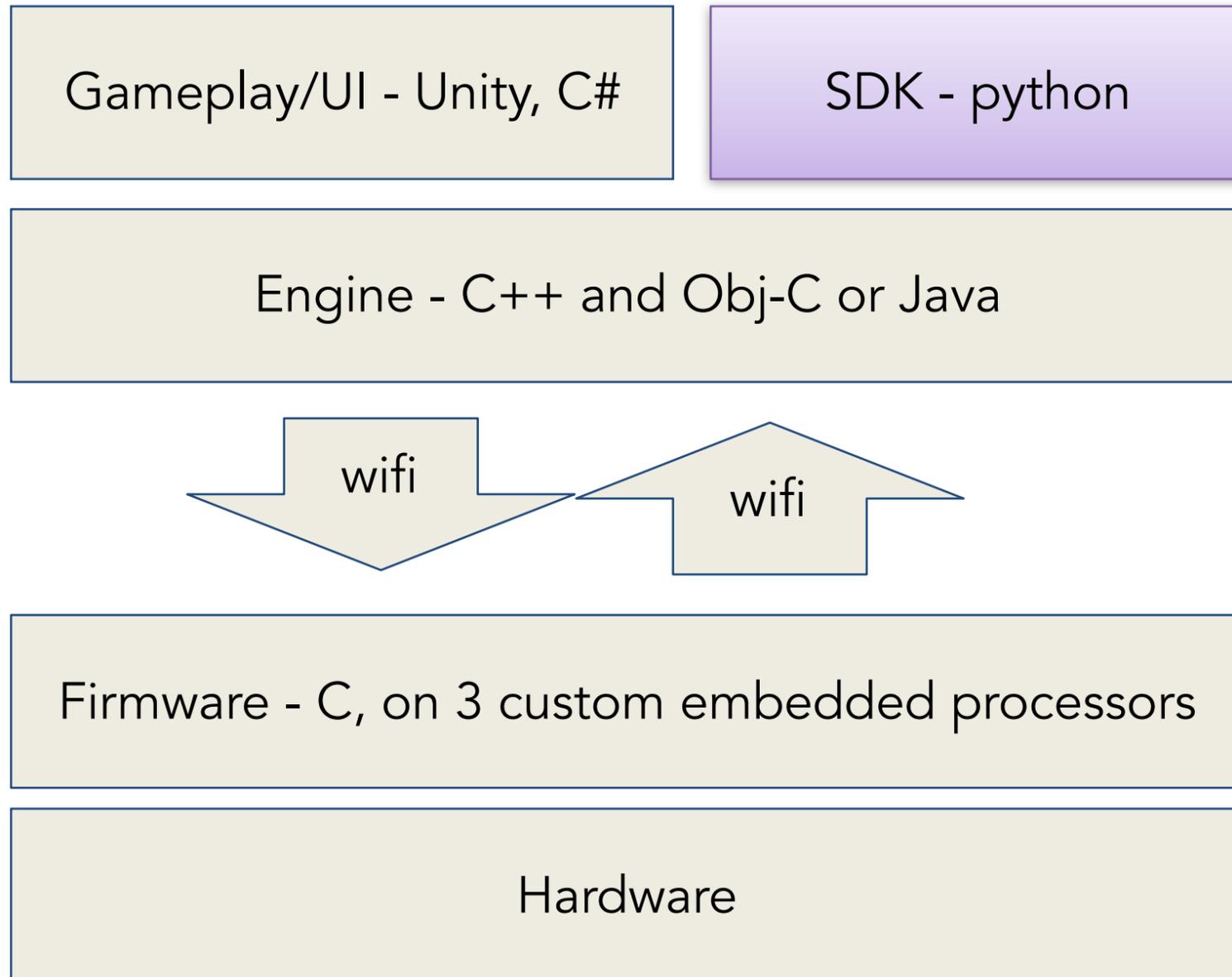


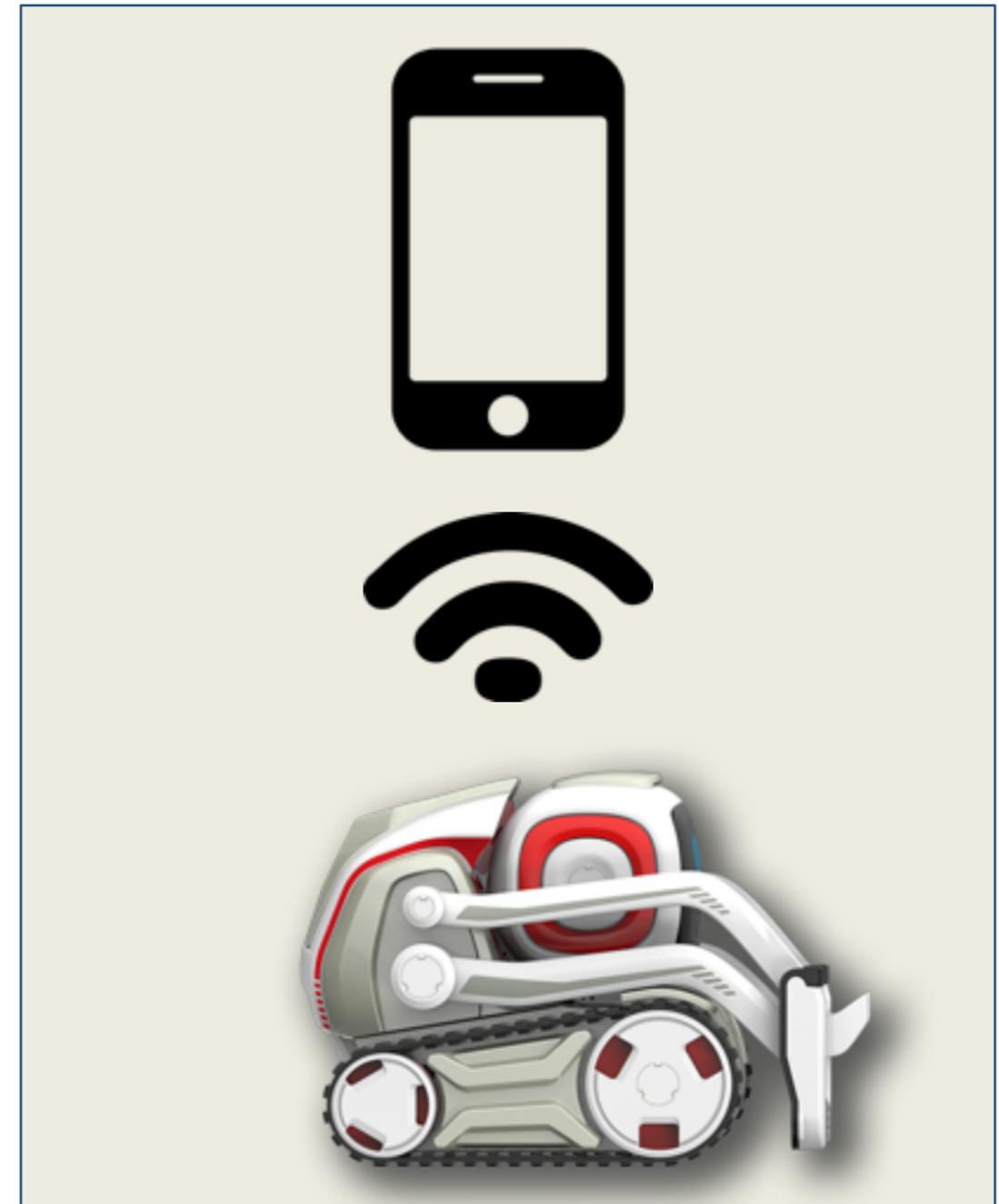
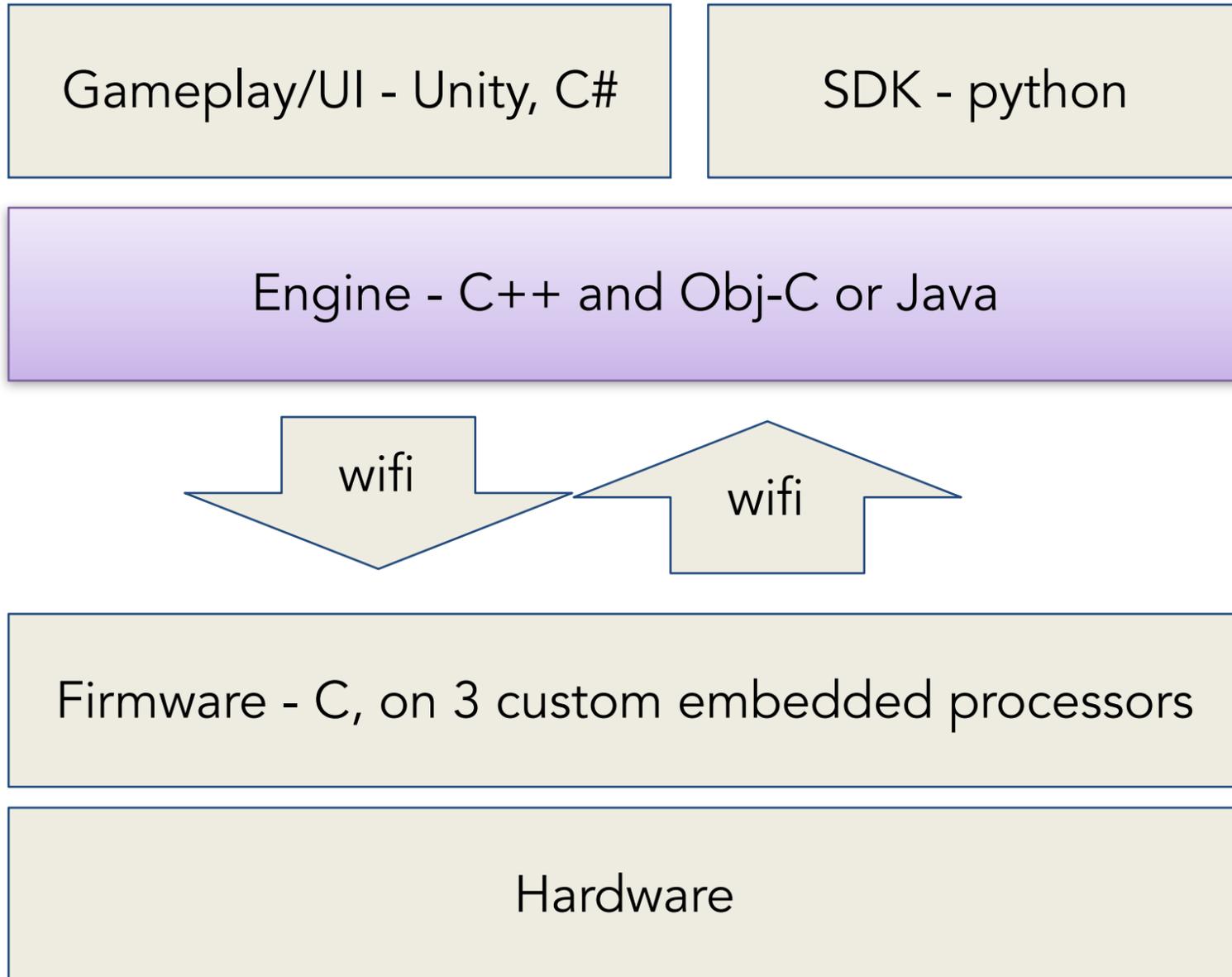
Cozmo's full stack

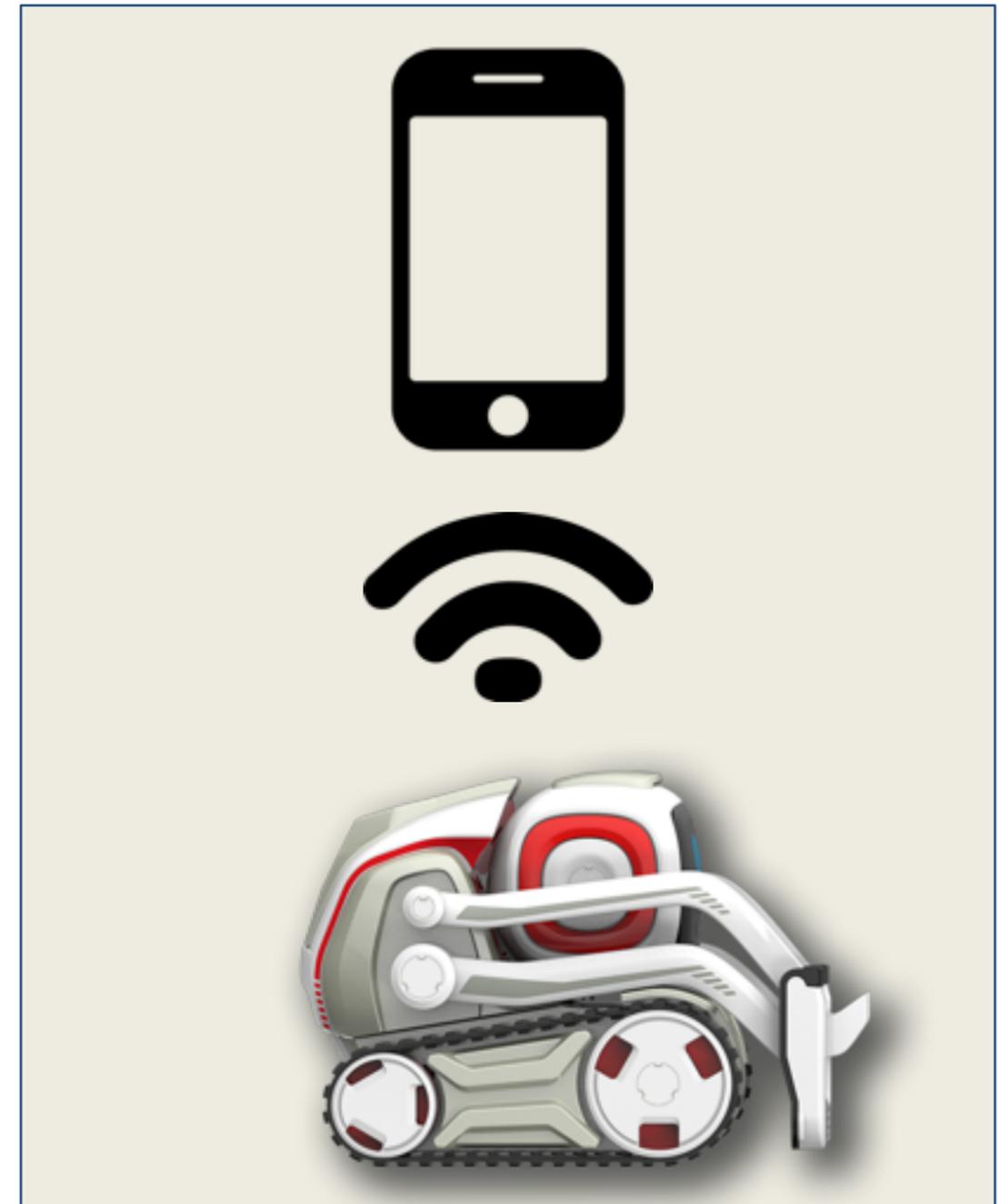
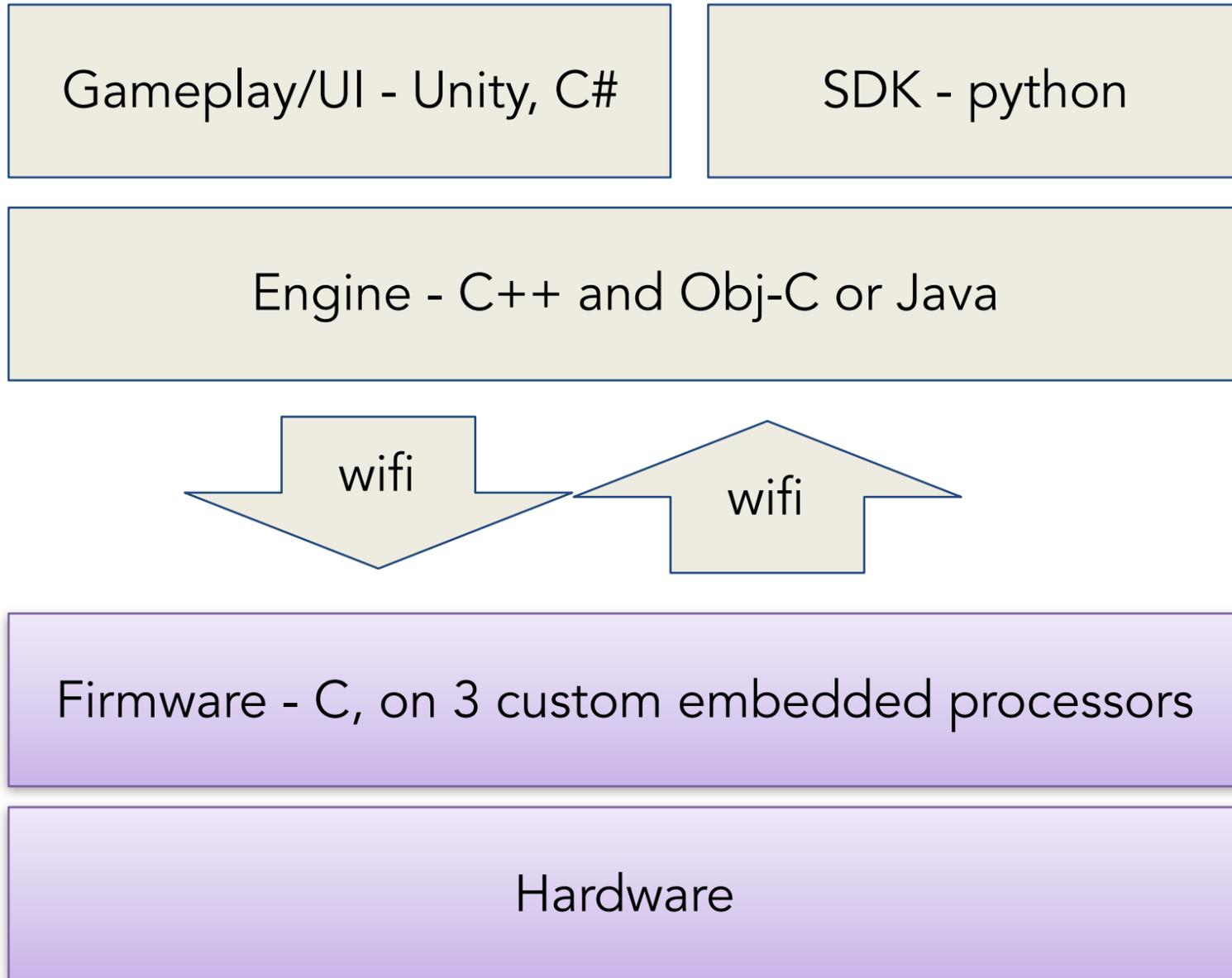




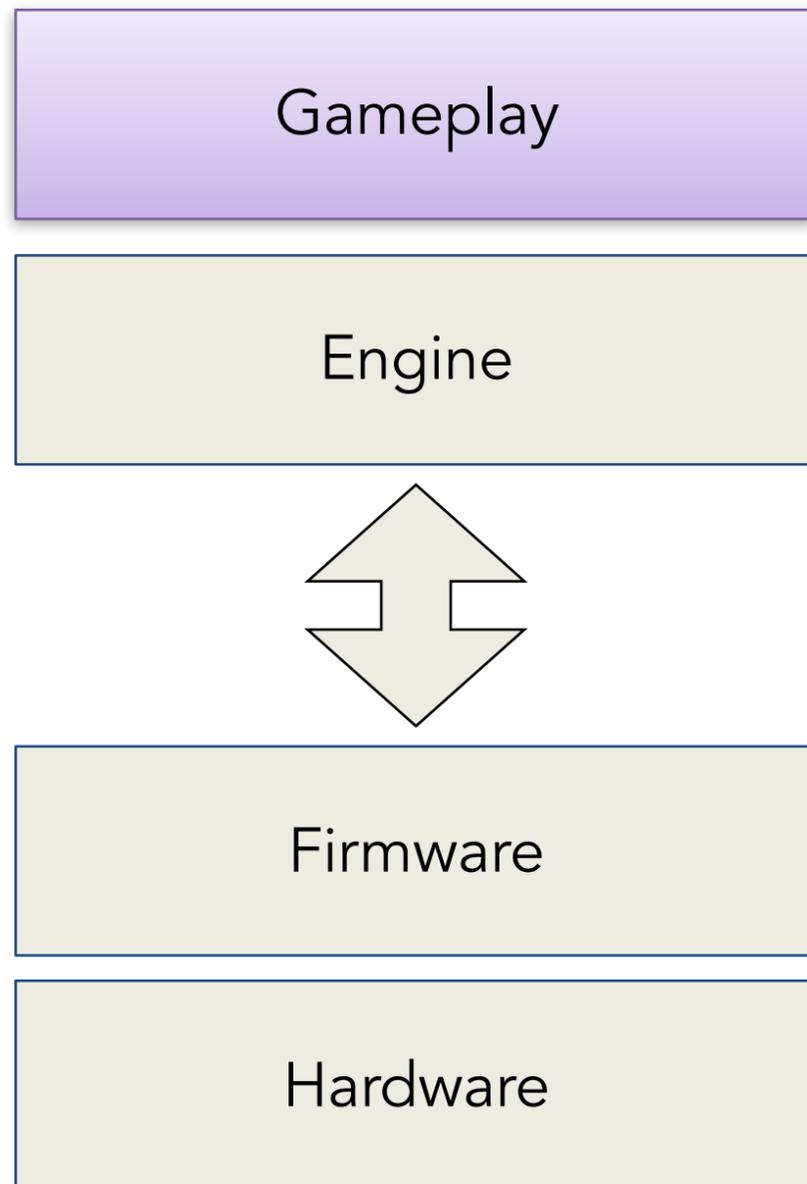








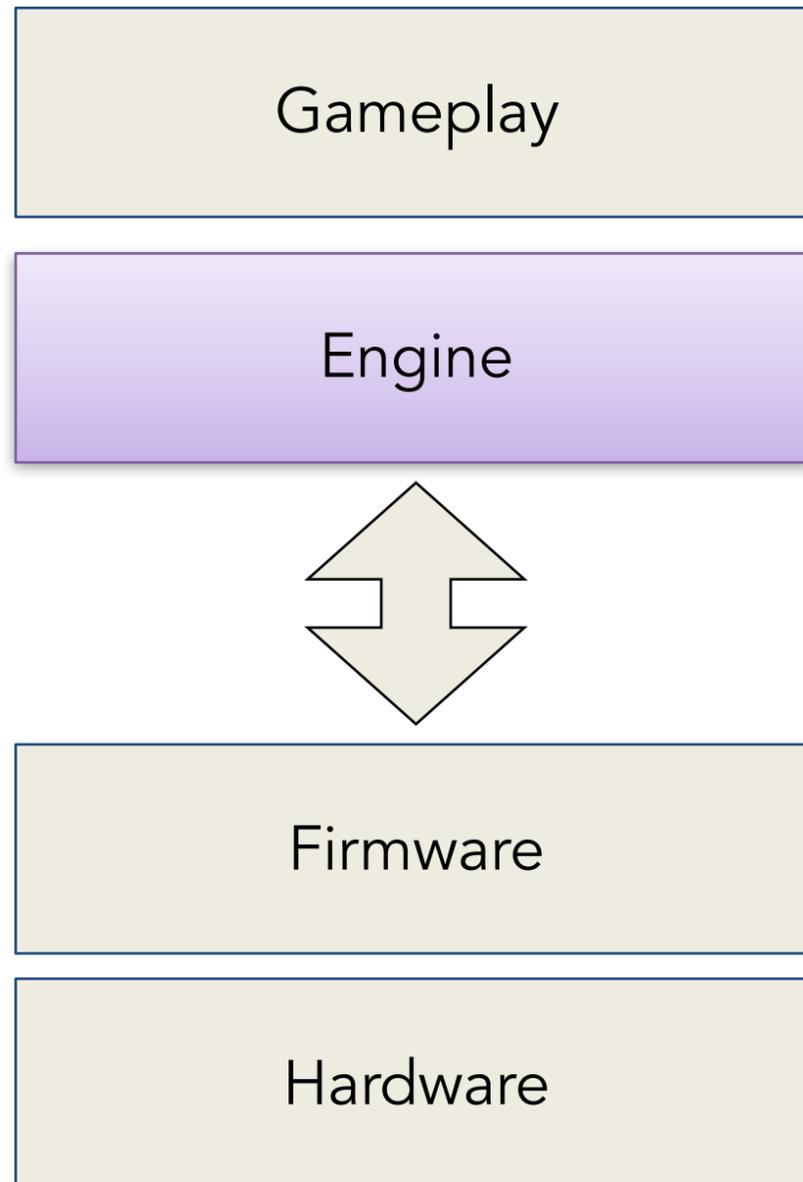
Steps to get animation playing



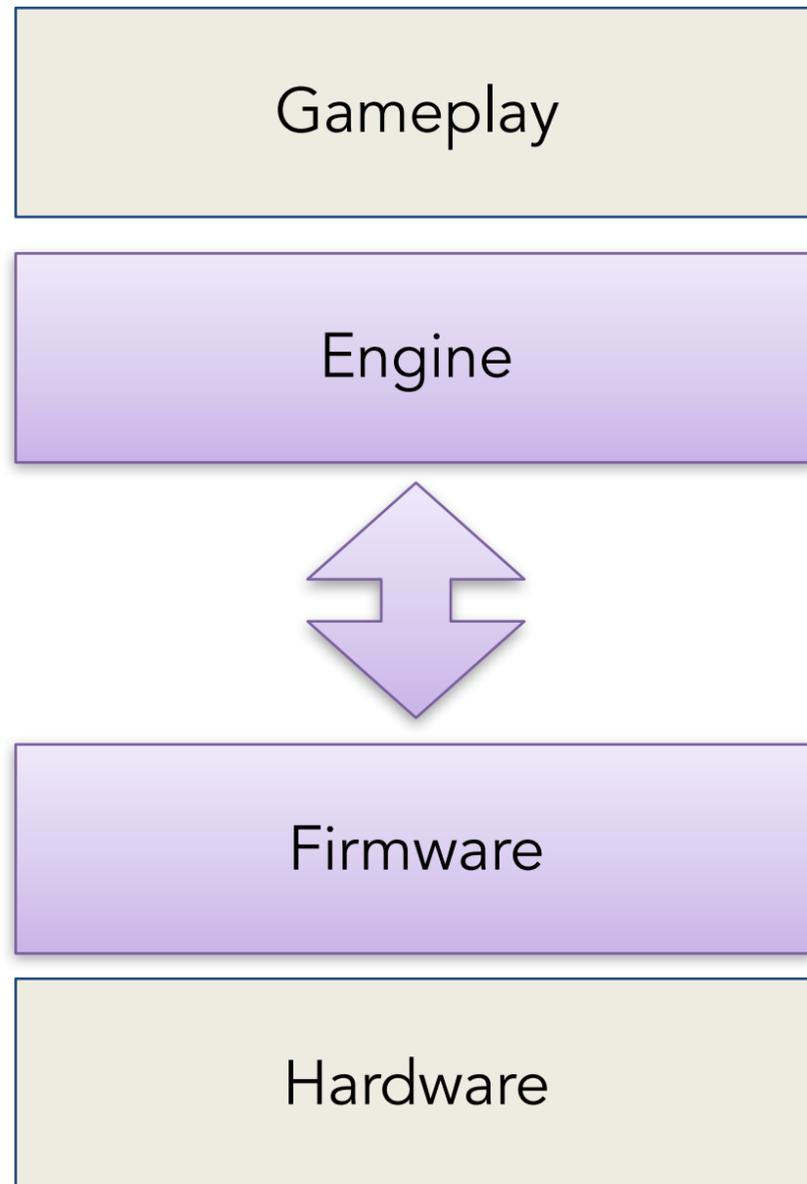
```
robot.play_anim_trigger(  
  cozmo.anim.Triggers.MajorWin)
```



Steps to get animation playing

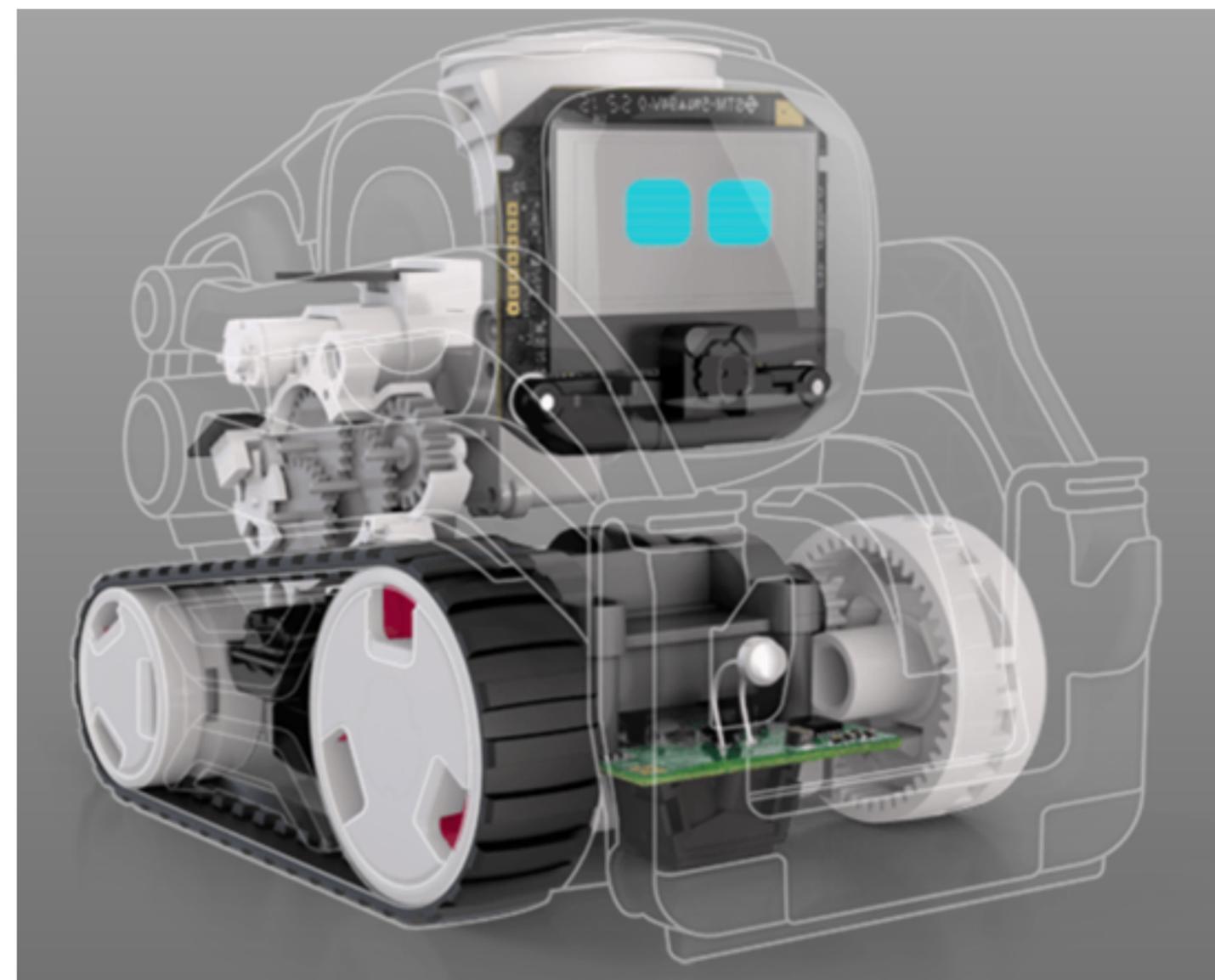
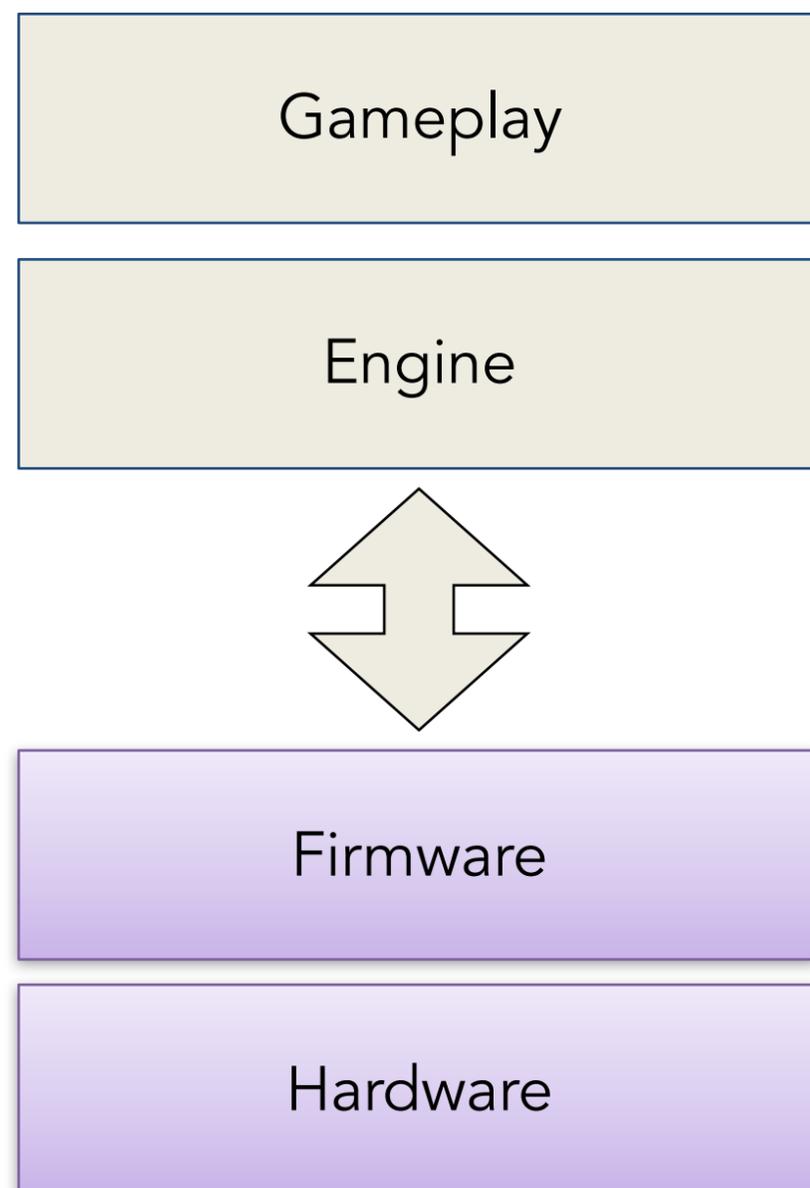


Steps to get animation playing





Steps to get animation playing







Real World Uncertainty And Lessons Learned





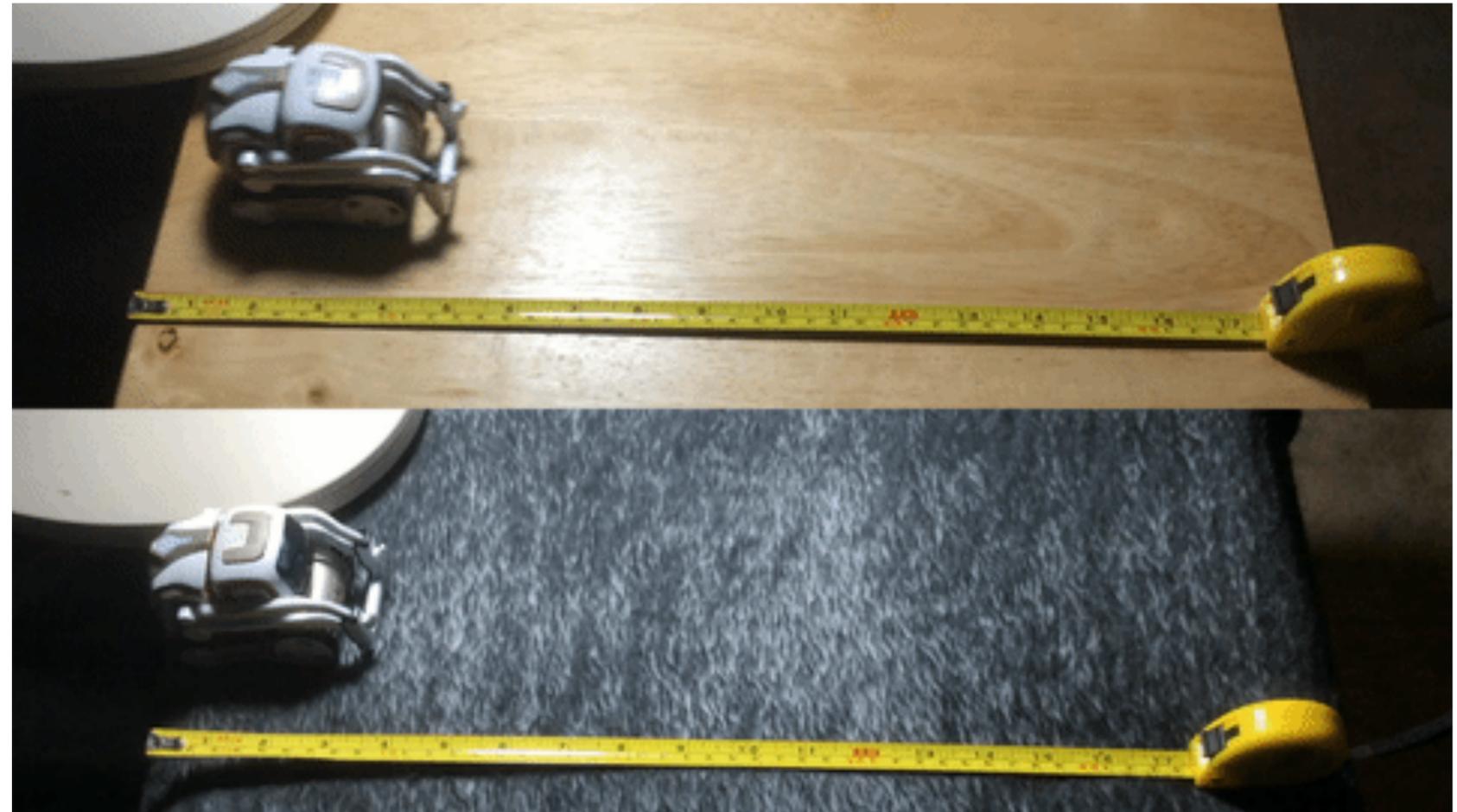
Challenge 1:
Different surfaces make the
robot move differently





Different Surface frictions mean different timing

Challenge: We'd often want things like "Cozmo drives forward for X seconds which should be Y mm at Z speed"





Different Surface frictions mean different timings

Fix: Procedural actions that can dynamically respond to where Cozmo is currently in the world.

How do we know where Cozmo is in the world?



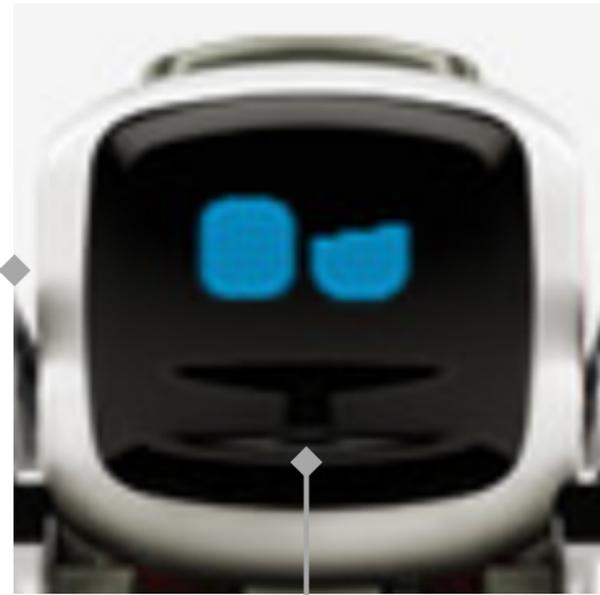


Sensors on Cozmo

wheel encoders

IMU

Cliff Sensor



Camera

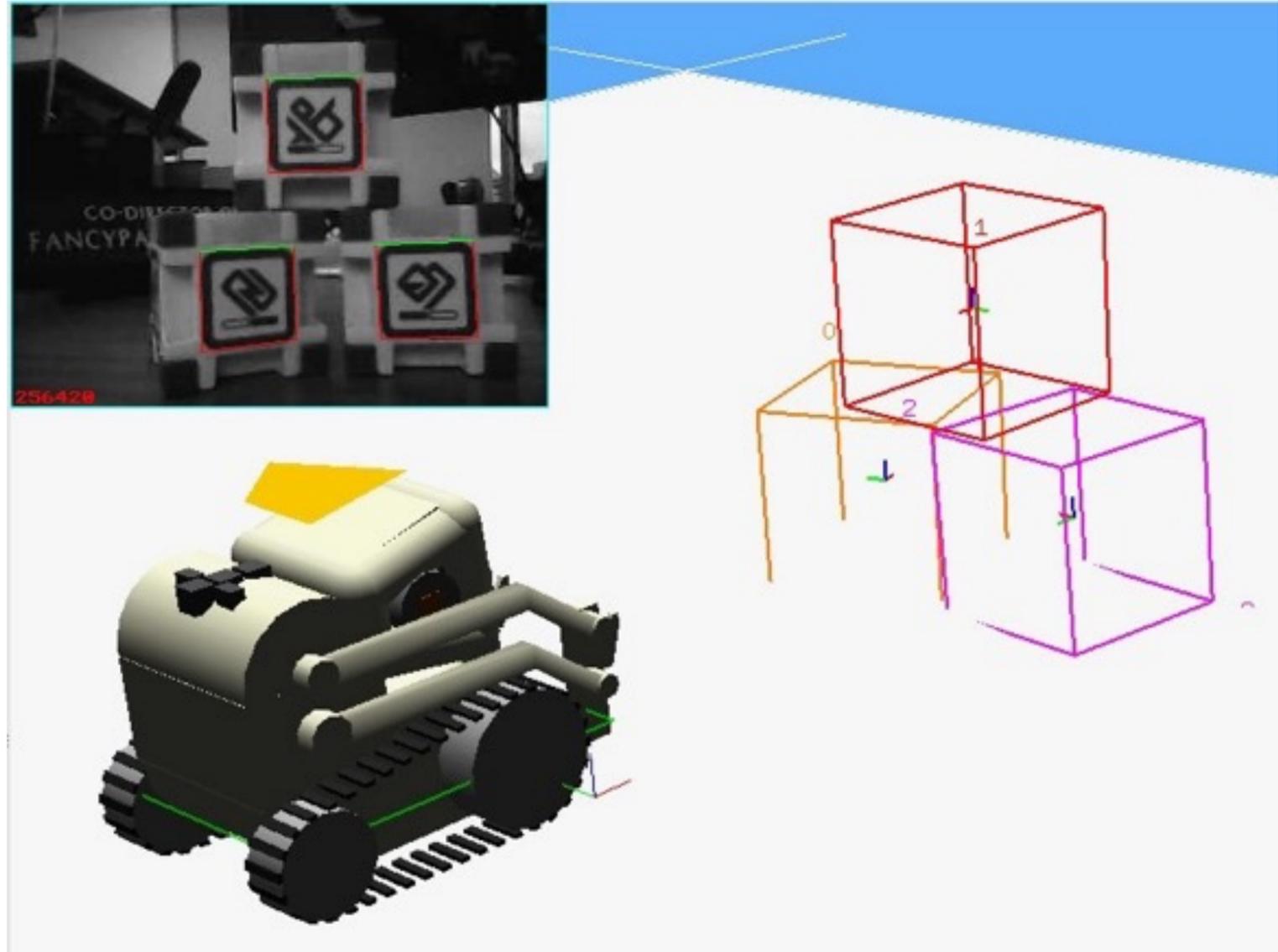




Cozmo Ecosystem

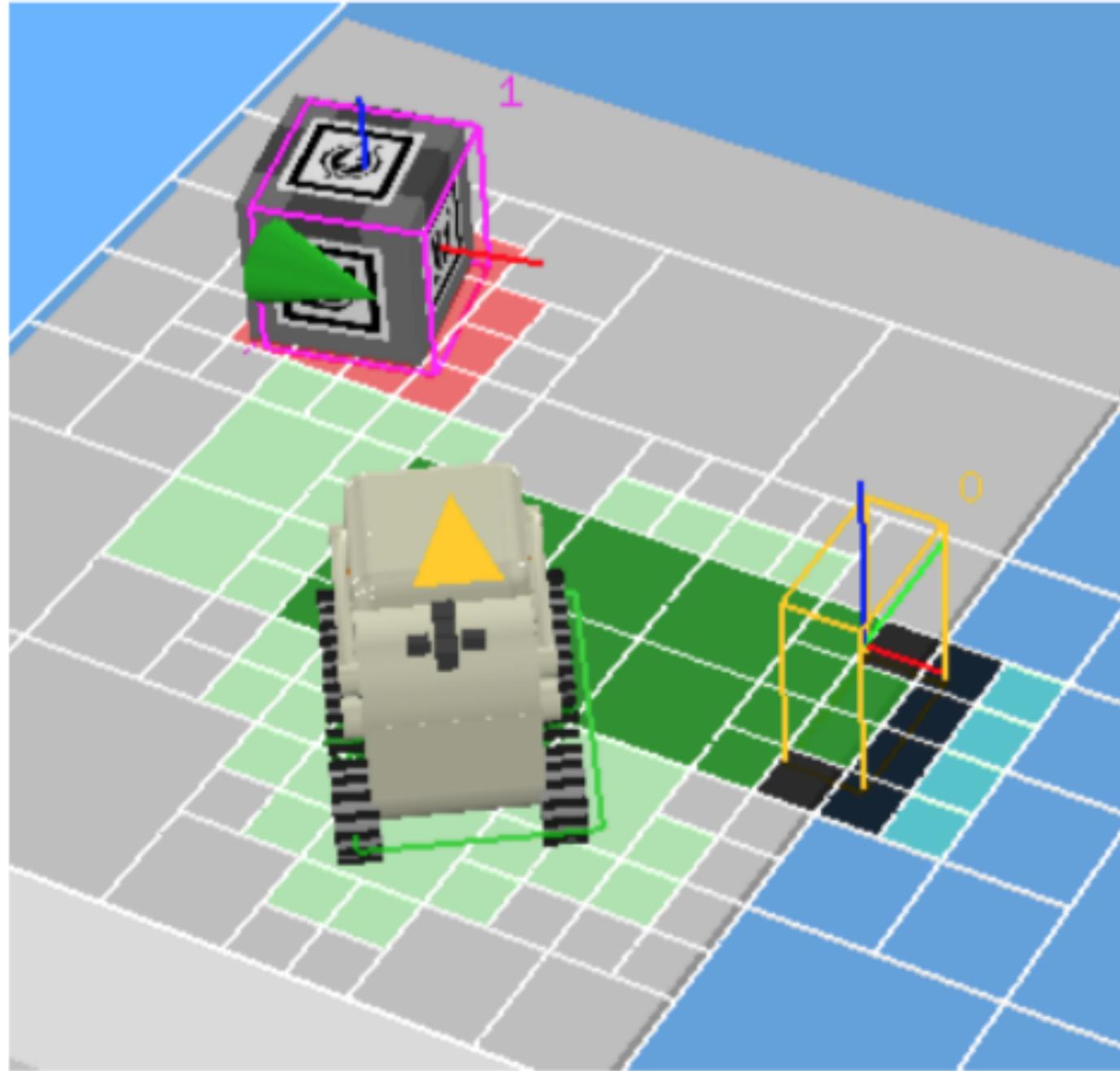


Cozmo's cubes



SLAM (simultaneous localization and mapping)







Robot Localization

How do we know where cozmo is in the world?

- Camera data of seen blocks
- Drive history
- Visible area between camera and cliffs probably obstacle free.
- Gyro + cliff sensor can feel if he's been moved by an outside force





Challenge 2: Making animations work in multiple situations





Making animations work in multiple situations

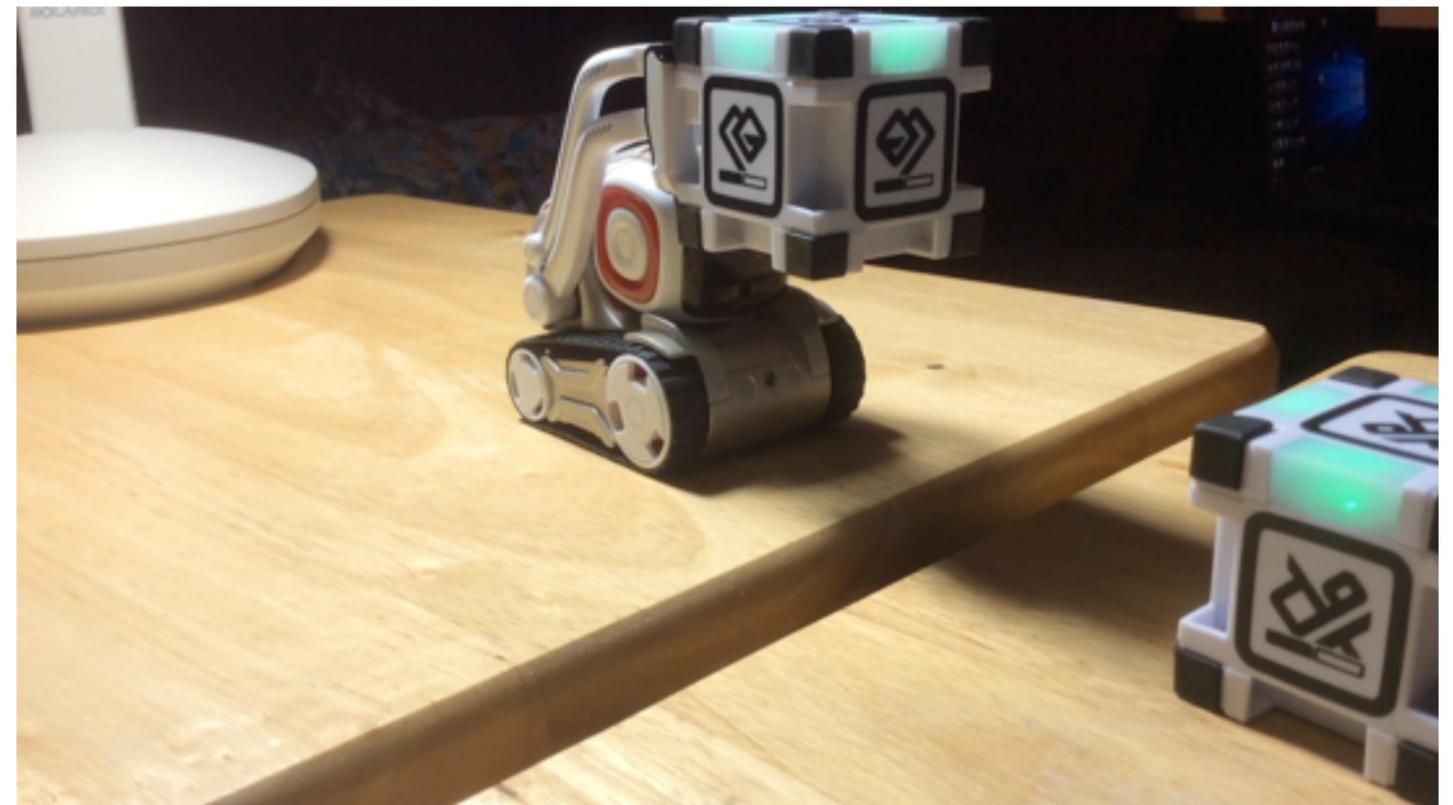
Challenge: Animations need to be flexible to play in different contexts, such as driving and driving while holding a cube.





Making animations work in multiple situations

Fix: locking important tracks we don't want to move if they are occupied





Challenge 3:

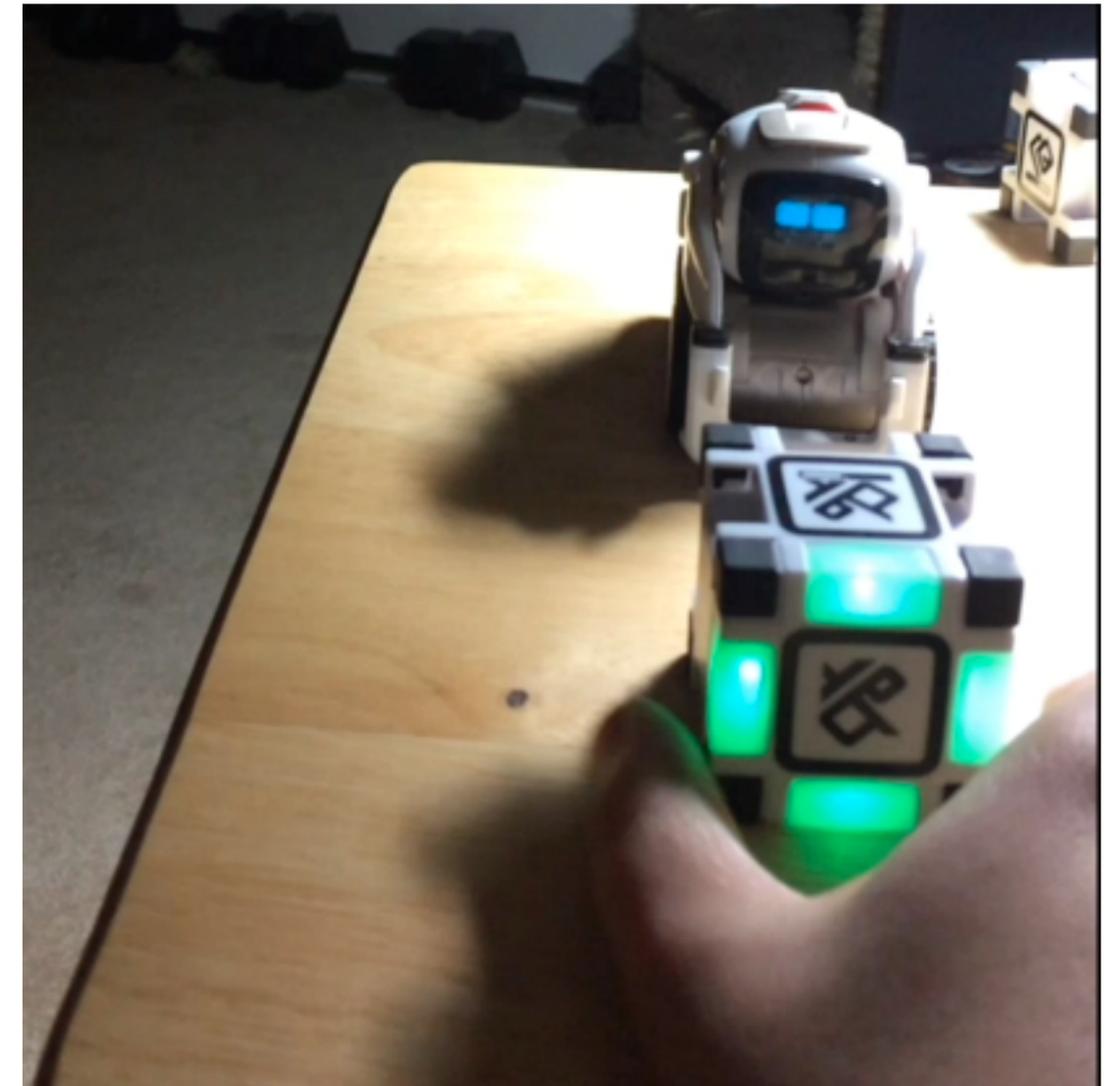
Recovering if actions unexpectedly fail





Sometimes actions fail

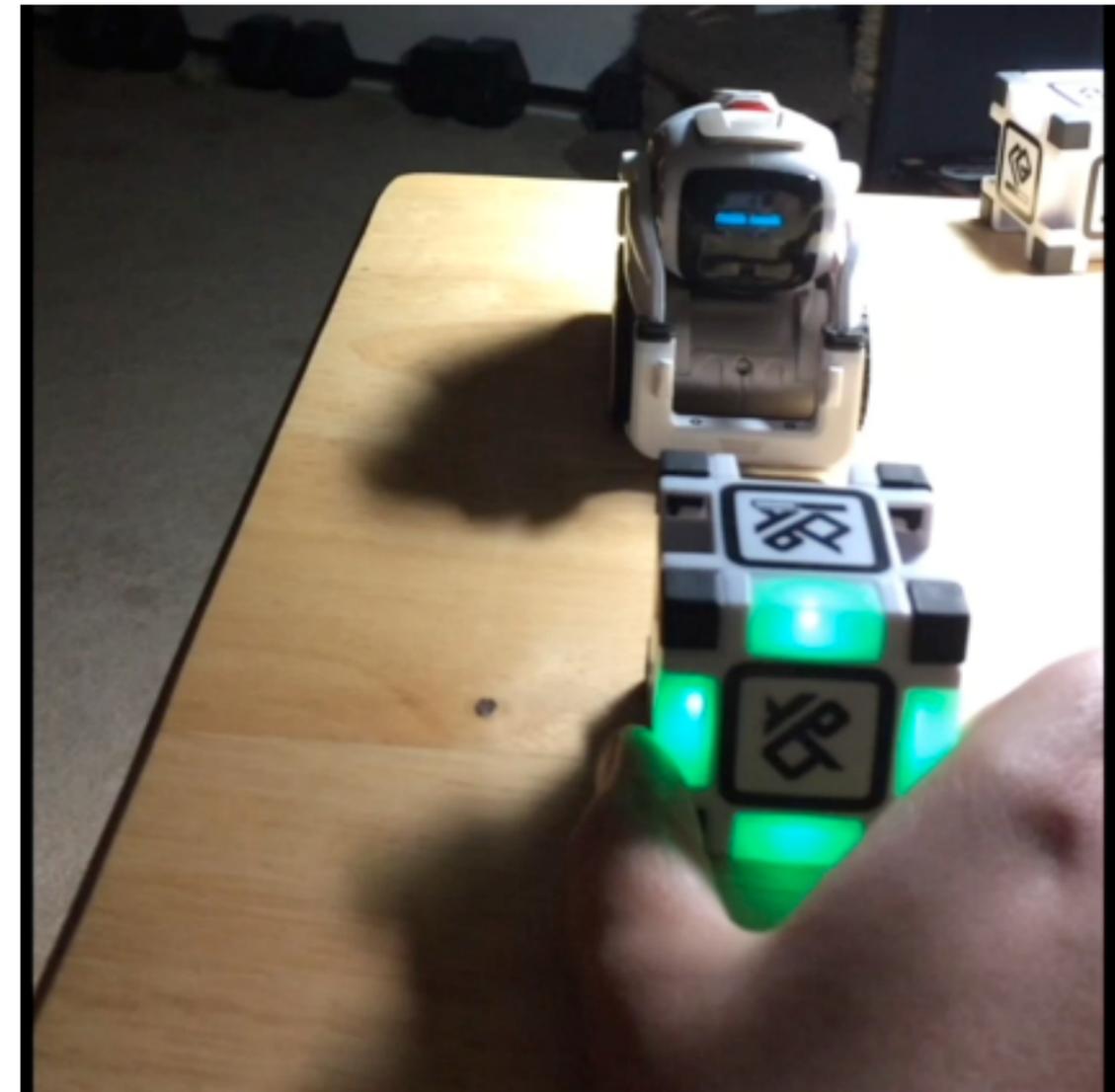
Challenge: Cozmo only has a simulated version of the world and often the real world doesn't match meaning actions can fail if something isn't where he thinks it should be.





When actions will fail, communicate a retry

Fix: Animators made failure states that demonstrated Cozmo was confused by the frustrating world making behaviors robust enough to handle several retries





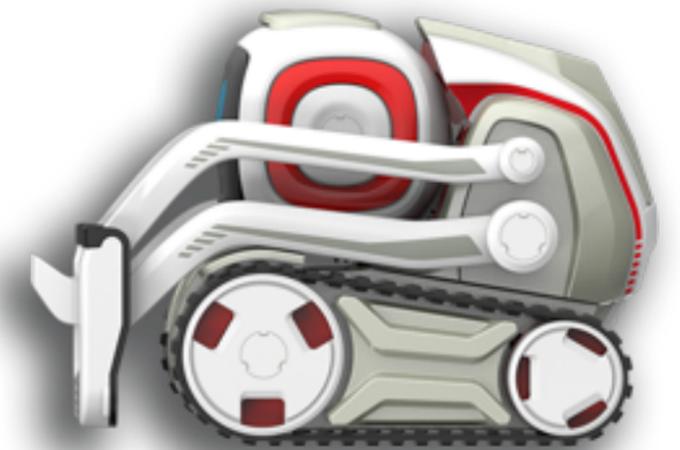
Challenge 4: Directing the user's focus





Where is the user's focus?

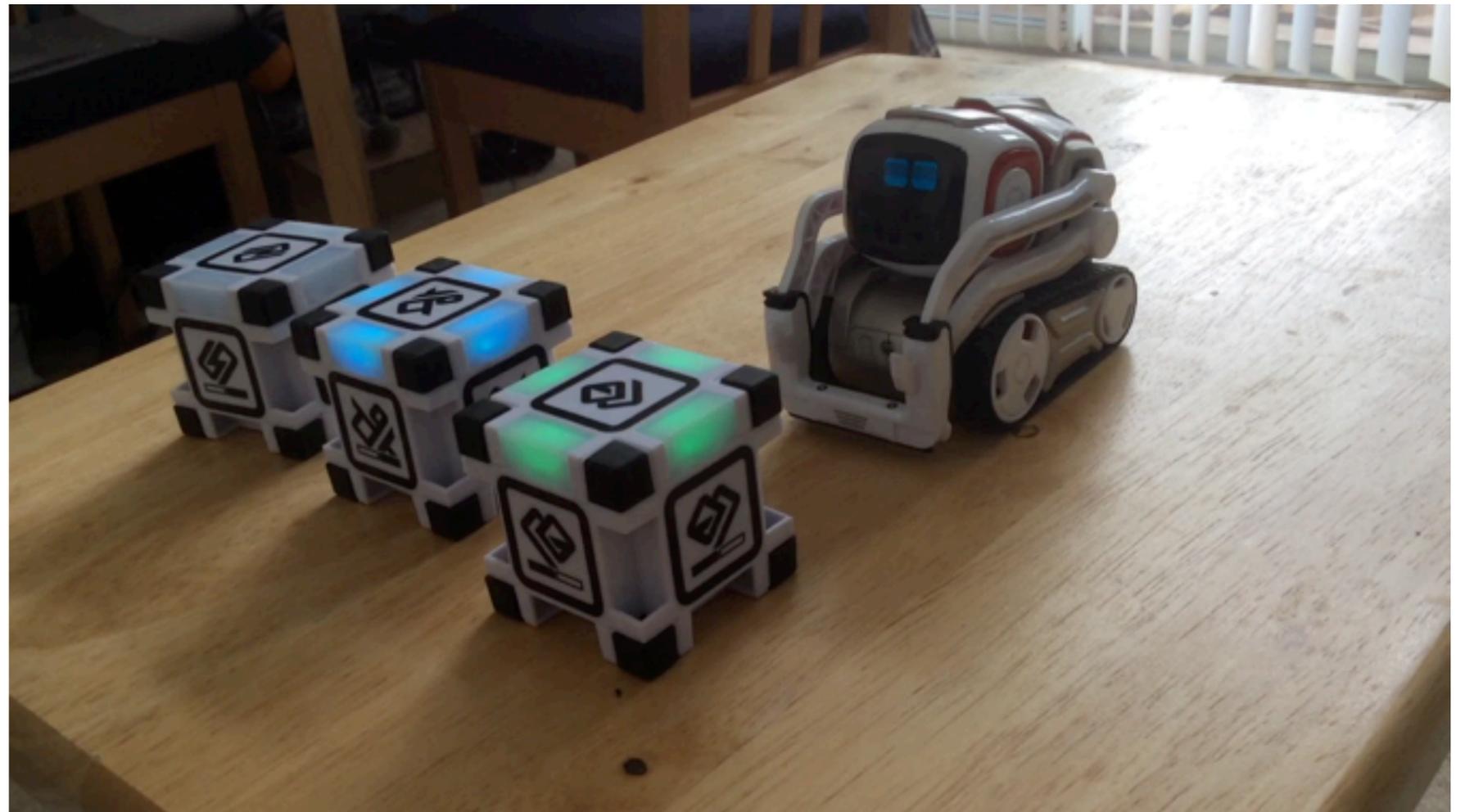
Challenge: Because we have an App with UI and a robot that can do cool stuff, the user might not be looking where we need them.





Where is the user's focus?

Fix: "Hey look at me!" behavior when Cozmo was about to do something interesting on his own



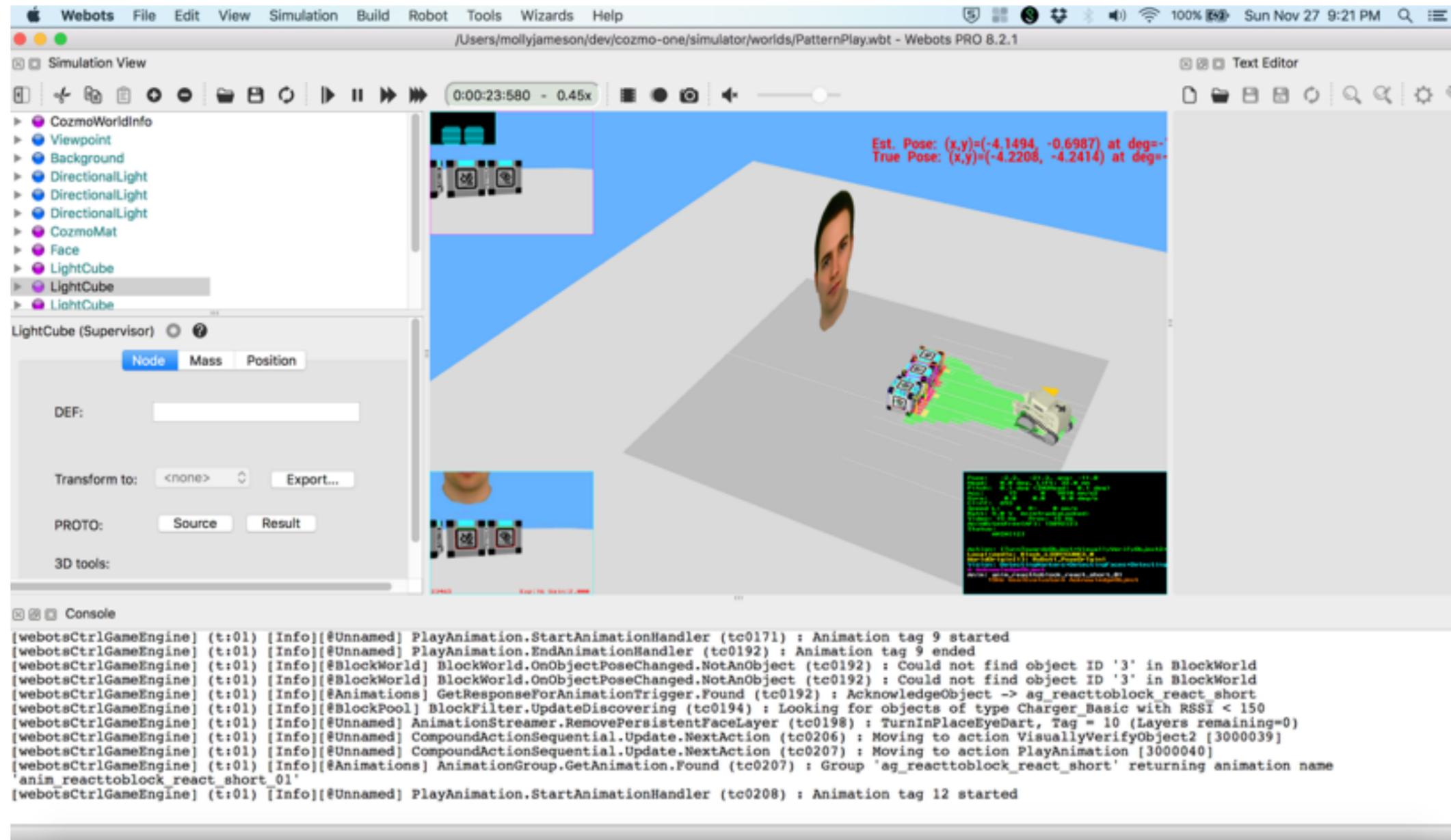
Challenges Overcome!



it!

... After testing

Automated Testing



The screenshot displays the Webots PRO 8.2.1 interface. The main window shows a 3D simulation of a robot on a grey floor with a blue sky background. A person's head is visible in the scene. The left sidebar contains a hierarchy of objects: CozmoWorldInfo, Viewpoint, Background, DirectionalLight, CozmoMat, Face, LightCube, and LiqhtCube. Below this is the 'LightCube (Supervisor)' panel with tabs for Node, Mass, and Position. The bottom panel is the Console, showing log messages from the game engine and animation handlers.

Simulation View

0:00:23:580 - 0.45x

Est. Pose: (x,y)=(-4.1494, -0.6987) at deg=
True Pose: (x,y)=(-4.2206, -4.2414) at deg=

LightCube (Supervisor)

Node Mass Position

DEF:

Transform to: <none> Export...

PROTO: Source Result

3D tools:

Console

```
[webotsCtrlGameEngine] (t:01) [Info][@Unamed] PlayAnimation.StartAnimationHandler (tc0171) : Animation tag 9 started
[webotsCtrlGameEngine] (t:01) [Info][@Unamed] PlayAnimation.EndAnimationHandler (tc0192) : Animation tag 9 ended
[webotsCtrlGameEngine] (t:01) [Info][@BlockWorld] BlockWorld.OnObjectPoseChanged.NotAnObject (tc0192) : Could not find object ID '3' in BlockWorld
[webotsCtrlGameEngine] (t:01) [Info][@BlockWorld] BlockWorld.OnObjectPoseChanged.NotAnObject (tc0192) : Could not find object ID '3' in BlockWorld
[webotsCtrlGameEngine] (t:01) [Info][@Animations] GetResponseForAnimationTrigger.Found (tc0192) : AcknowledgeObject -> ag_reacttoblock_react_short
[webotsCtrlGameEngine] (t:01) [Info][@BlockPool] BlockFilter.UpdateDiscovering (tc0194) : Looking for objects of type Charger_Basic with RSSI < 150
[webotsCtrlGameEngine] (t:01) [Info][@Unamed] AnimationStreamer.RemovePersistentFaceLayer (tc0198) : TurnInPlaceEyeDart, Tag = 10 (Layers remaining=0)
[webotsCtrlGameEngine] (t:01) [Info][@Unamed] CompoundActionSequential.Update.NextAction (tc0206) : Moving to action VisuallyVerifyObject2 [3000039]
[webotsCtrlGameEngine] (t:01) [Info][@Unamed] CompoundActionSequential.Update.NextAction (tc0207) : Moving to action PlayAnimation [3000040]
[webotsCtrlGameEngine] (t:01) [Info][@Animations] AnimationGroup.GetAnimation.Found (tc0207) : Group 'ag_reacttoblock_react_short' returning animation name
'anin_reacttoblock_react_short_01'
[webotsCtrlGameEngine] (t:01) [Info][@Unamed] PlayAnimation.StartAnimationHandler (tc0208) : Animation tag 12 started
```



Lesson Learned:

Programmers from robotics backgrounds are way more serious about automated testing than most games programmers.





Manual Testing



Message your users when in trouble





Sometimes the key to testing is getting creative



Factory Testing

2016-8-9 / K6 + V05cm + V06CF
2016-8-10 / K6 + V06cm + V07CF
2016-8-11 / K6 + V16cm + V18CF
2016-8-12 / K6 + V18cm + V19CF

Afix05

Afix05

FULL SYSTEM TEST + SENSOR CALIBRATION

Testing

- Hardware is finalized long before software (~1 year in our case) to go to factory. QA needs to be testing way sooner as a result.
- Features need to be tested across multiple robots, multiple devices, multiple environments.
- Drop testing, temperature and humidity testing.



Thanks

Nishkar Grover

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Meghan McDowell

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Mooly Segal

Mark Wesley

David Cerpa

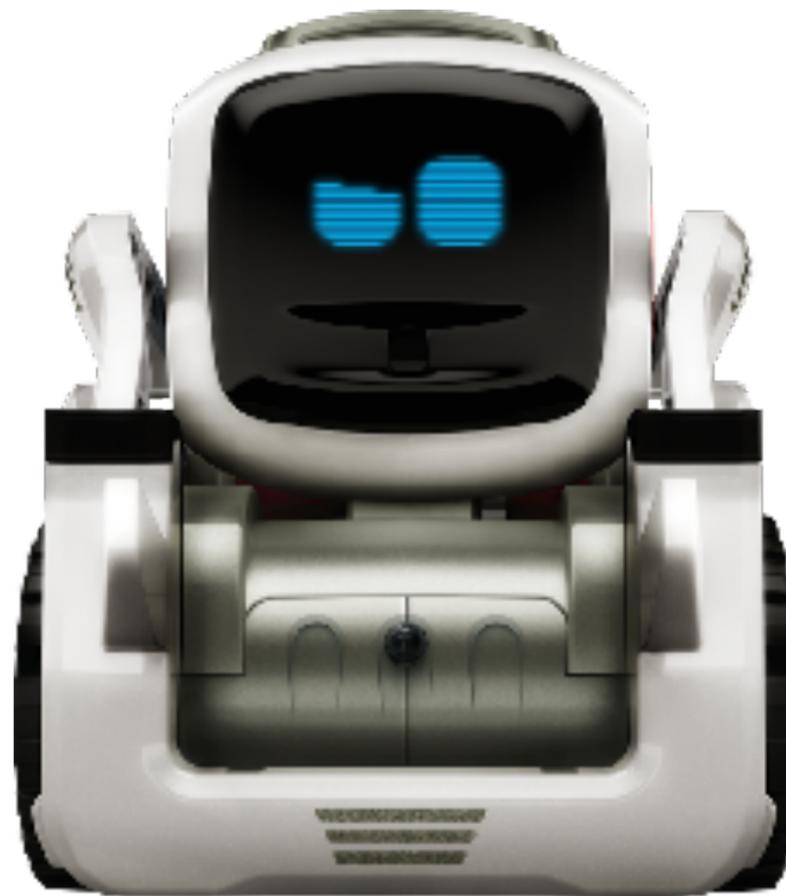
Kevin Yoon

Brad Neuman





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