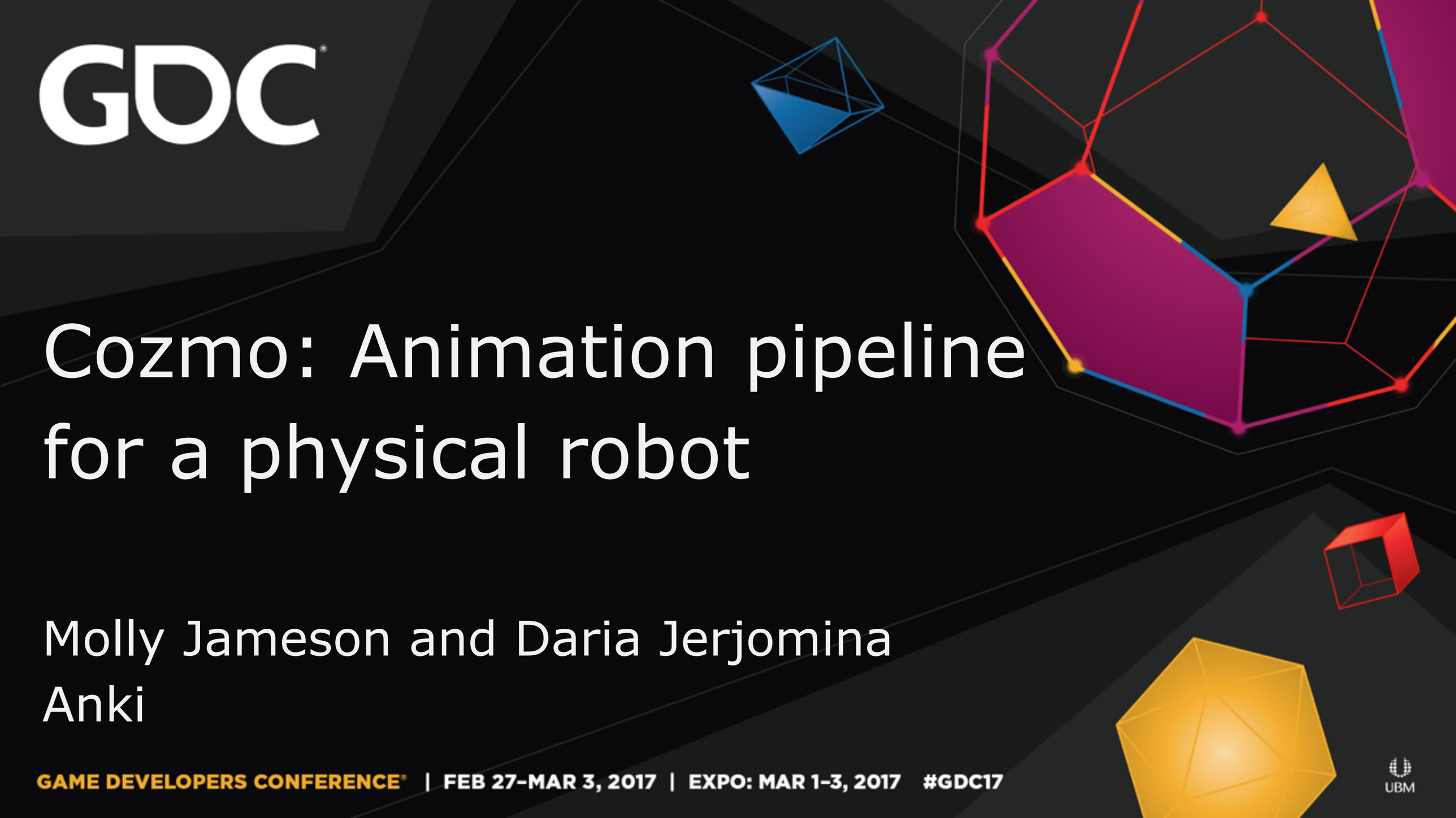


Cozmo: Animation pipeline for a physical robot

Molly Jameson and Daria Jerjomina
Anki

GAME DEVELOPERS CONFERENCE® | FEB 27–MAR 3, 2017 | EXPO: MAR 1–3, 2017 #GDC17

UBM

COZMO®

anki®

Who are we?

Daria Jerjomina
Animation Tools Engineer at Anki
daria.jerjomina@anki.com

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.

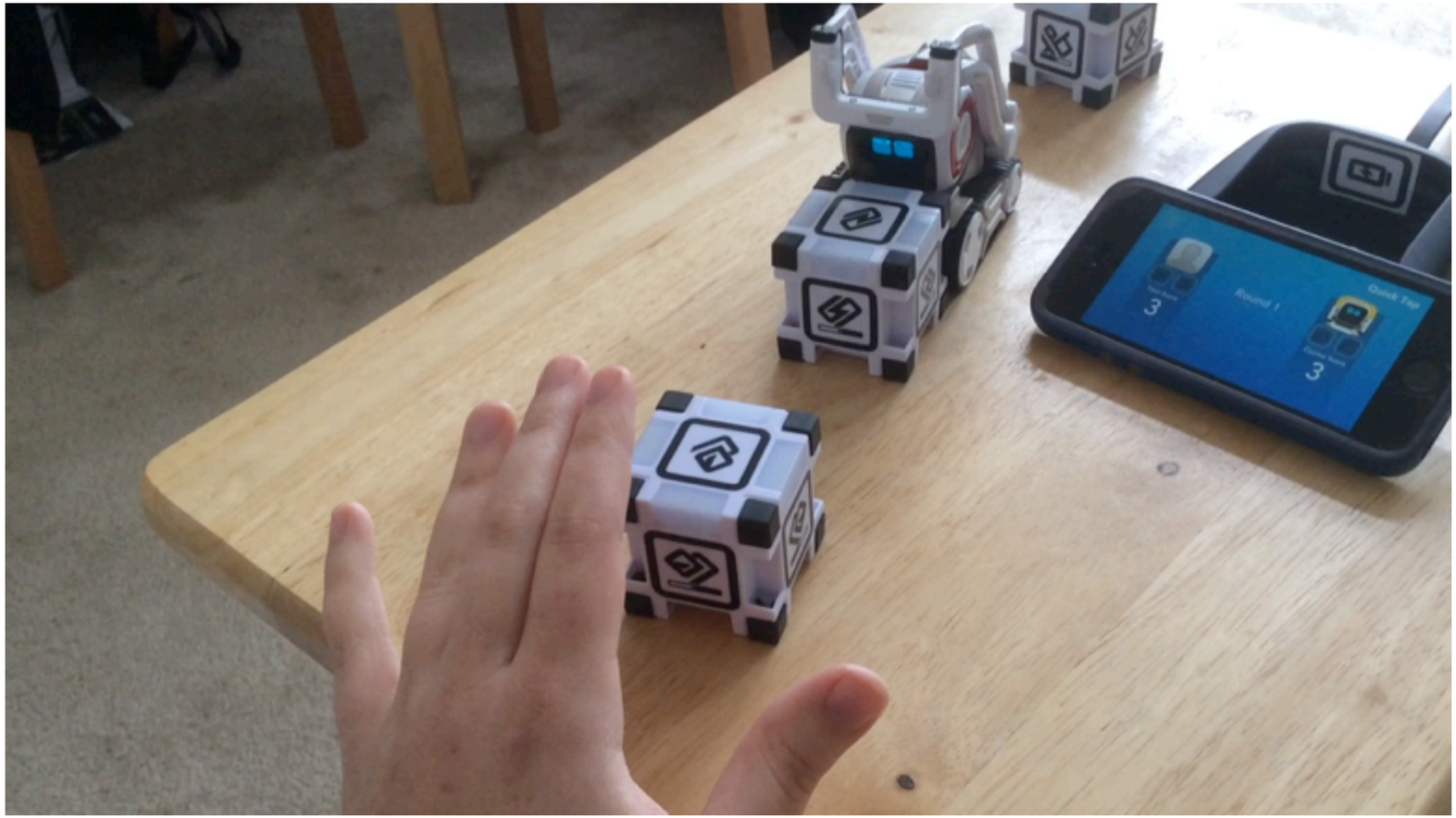
anki®

anki OVERDRIVE

What is Cozmo?

Cozmo the robot pet

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."

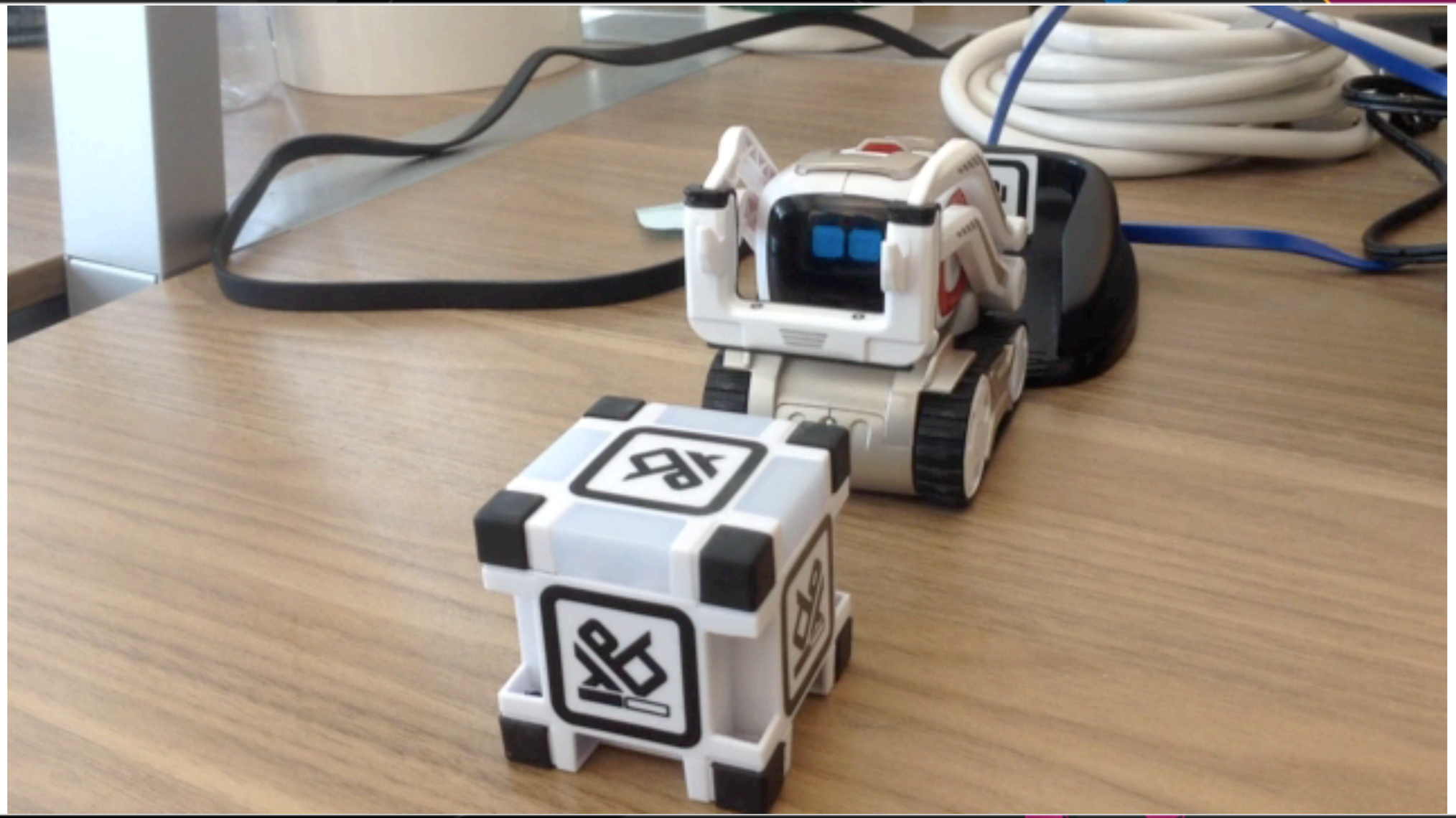
- *Penny-Arcade*

Significance of animation for Cozmo

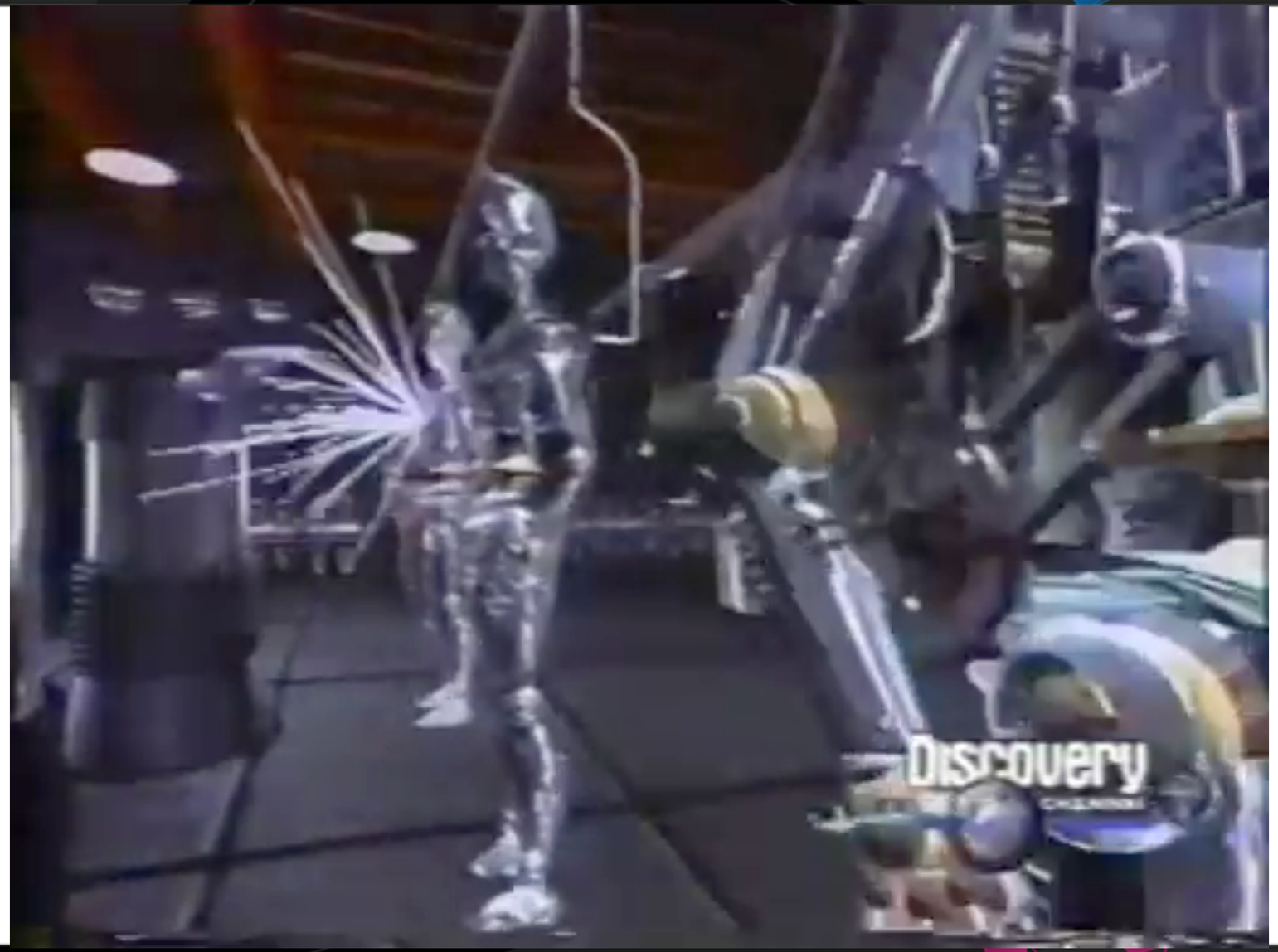
T02

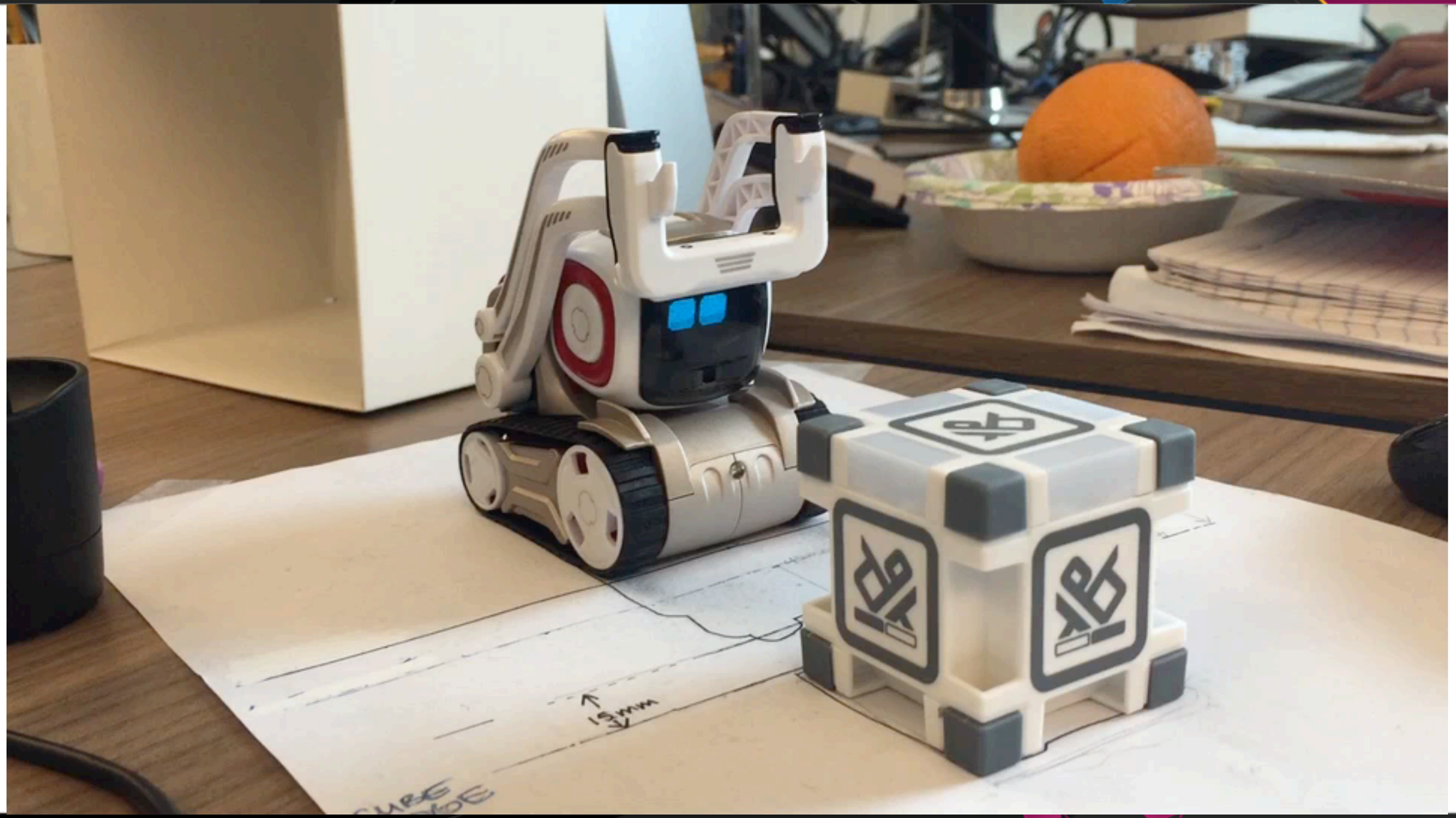
DANGER
ACID
DANGER
ROBOT MOVES WITHOUT WARNING
KEEP AWAY
ARGON

6X



Achieving a natural, appealing motion


Discovery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Transferring animation to the robot

MAYA

Data exported from Maya


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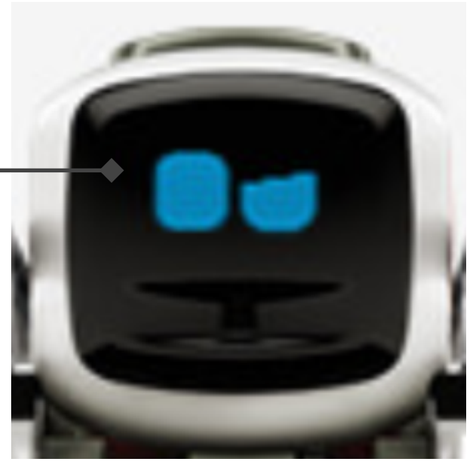
Speaker

Head

Face (eyes)

Backpack

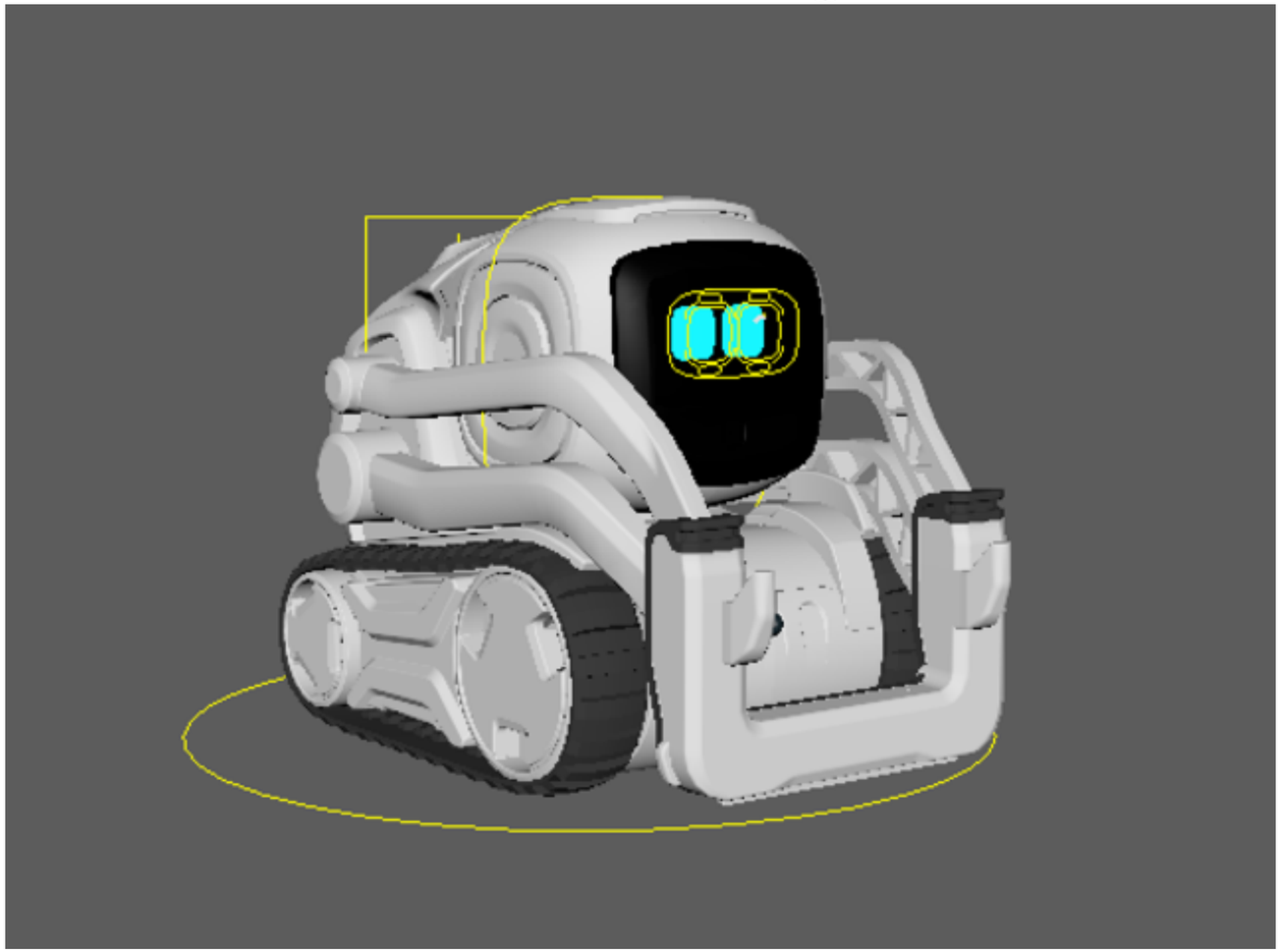
Lights



Wheels

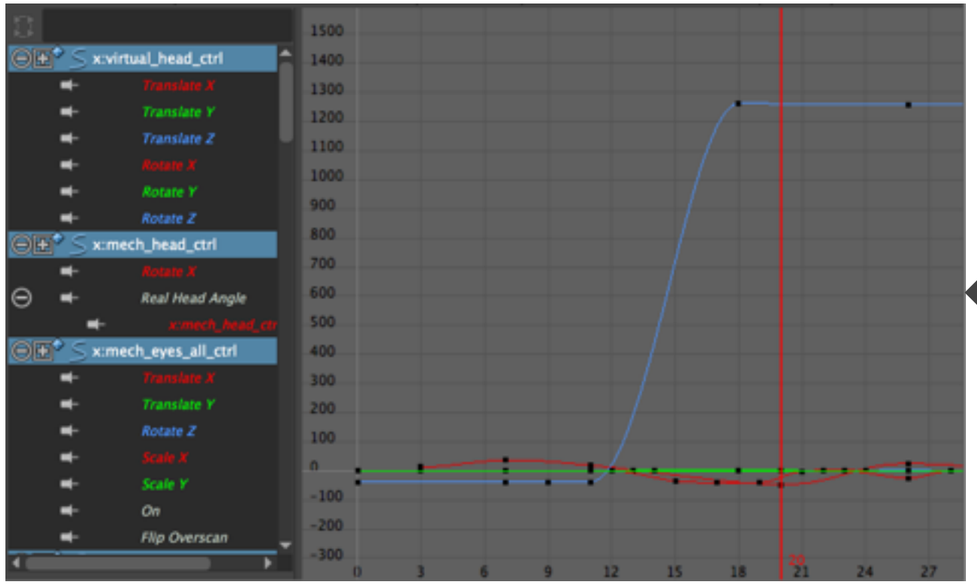
Lift

Cozmo's rig



persp
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
50
150
0
0
0
// Result: 1
anki

Data Export

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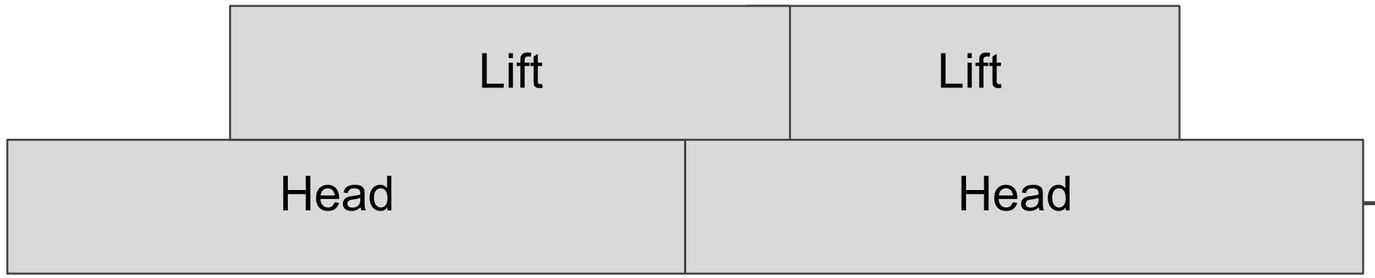


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}
```

Data Export

Data in form of a single node

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{
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  "angle_deg": 45,
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```

Values

Time, at which motion is triggered in ms

How long animation lasts in ms

```
{
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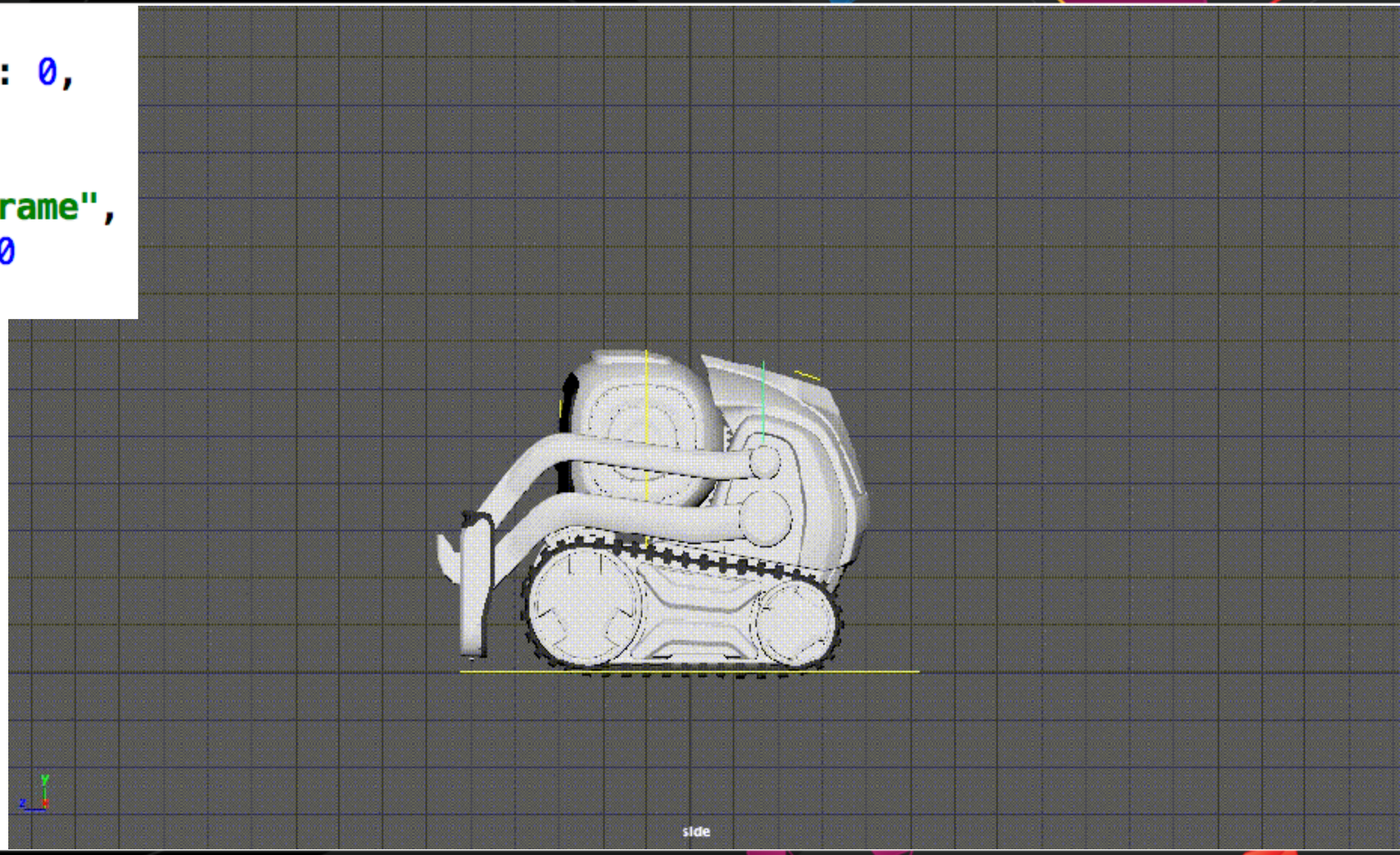

Head	Head

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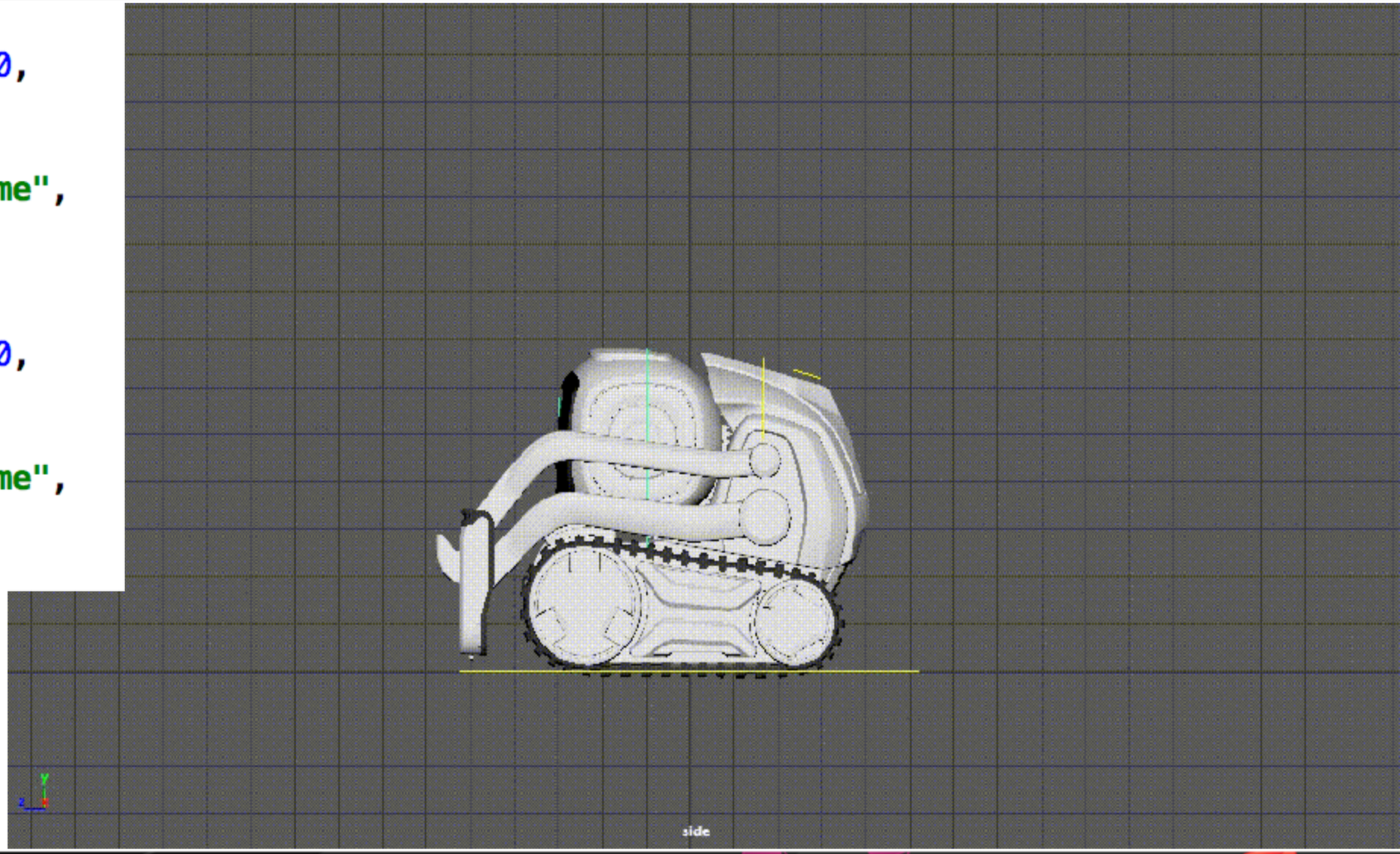

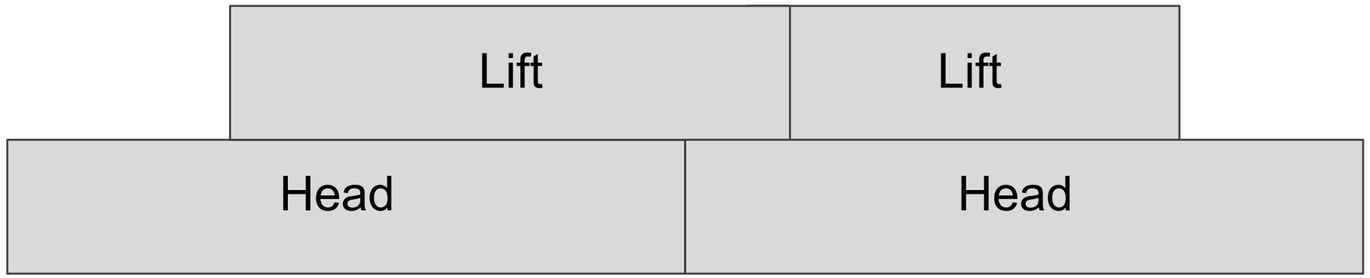


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```

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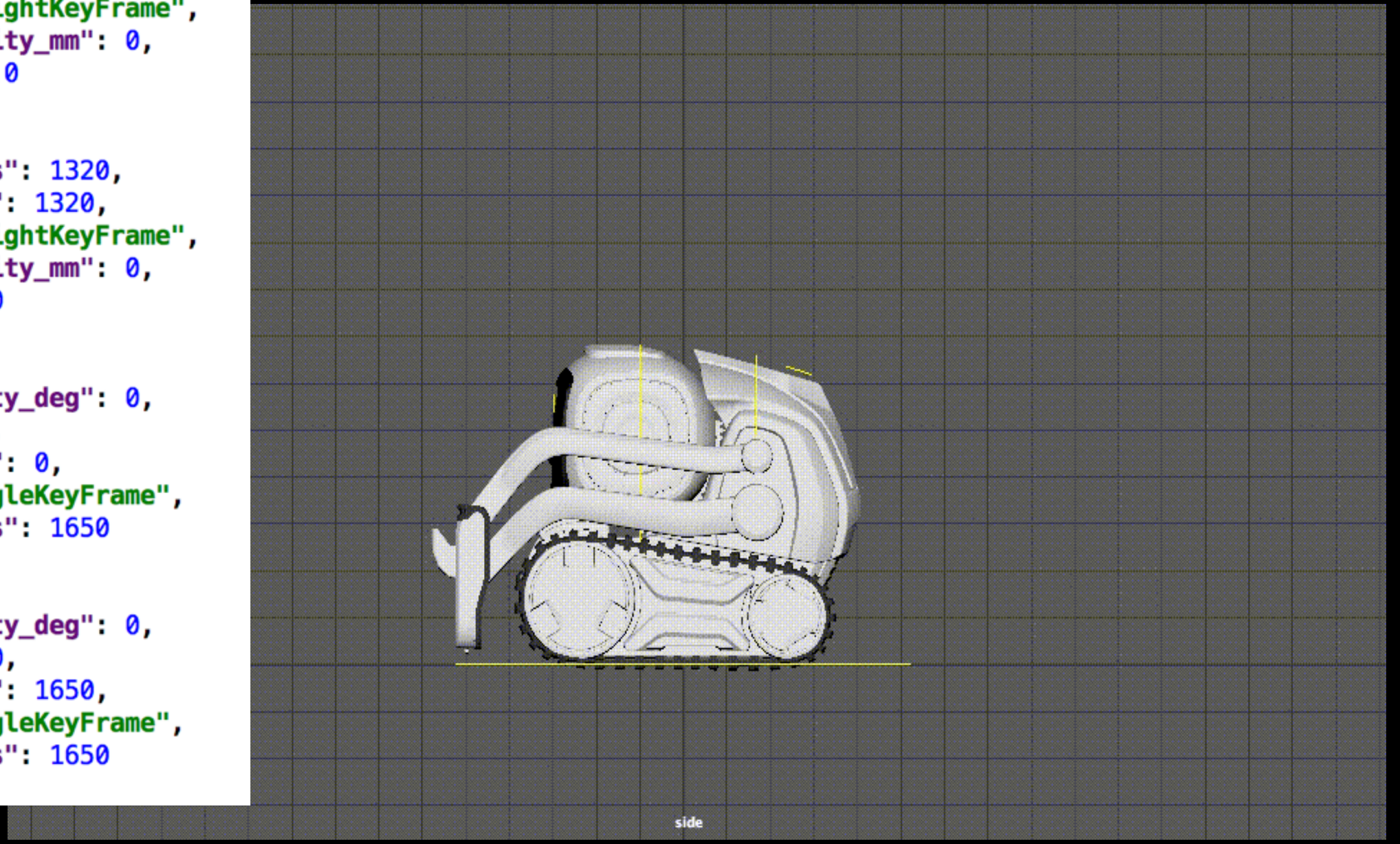

Absolute vs Relative

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```

```
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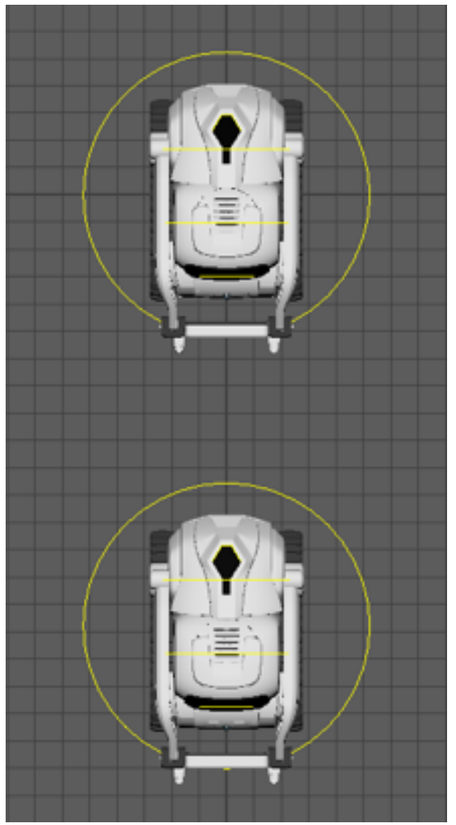
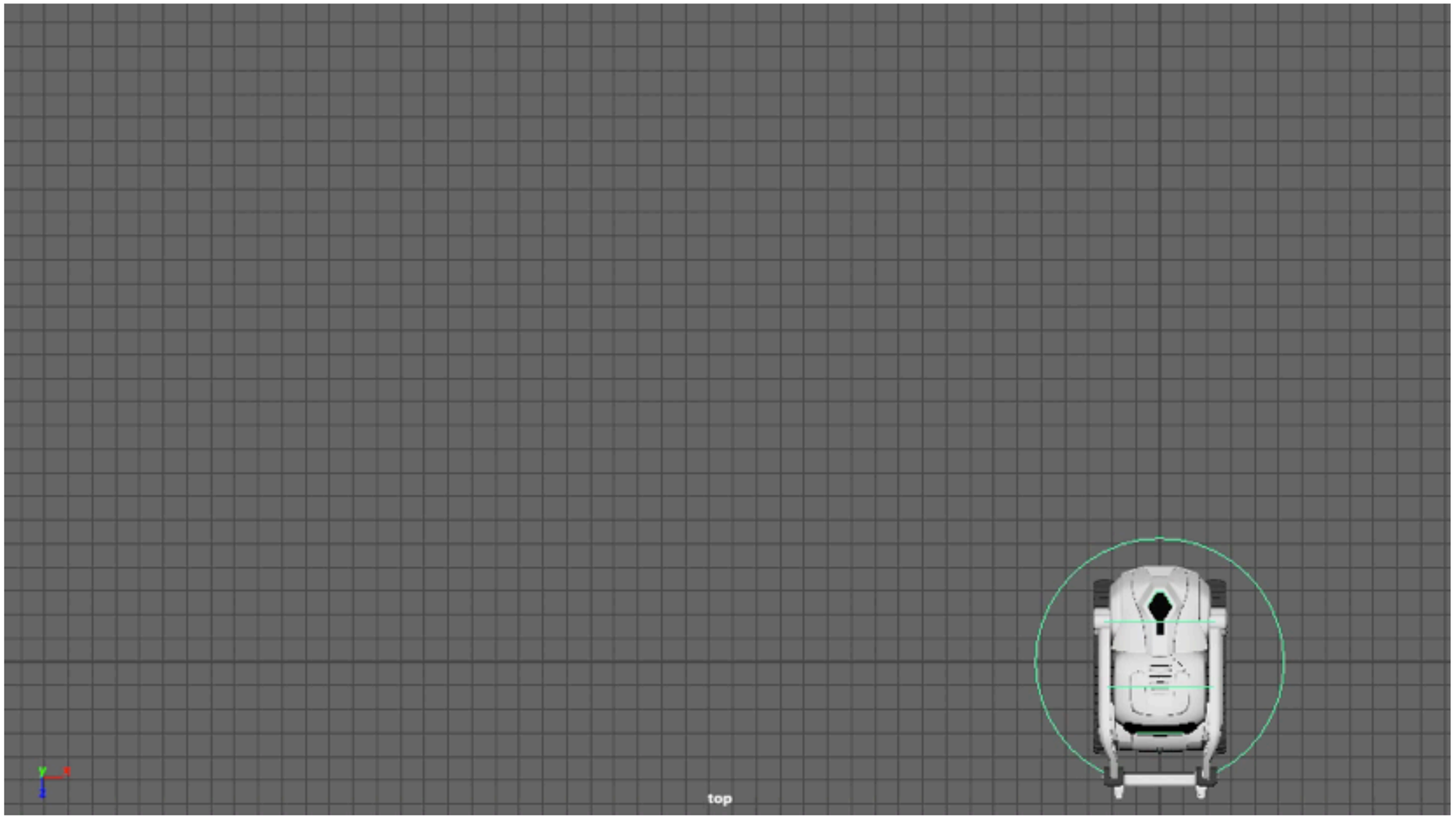
Velocity vs Position



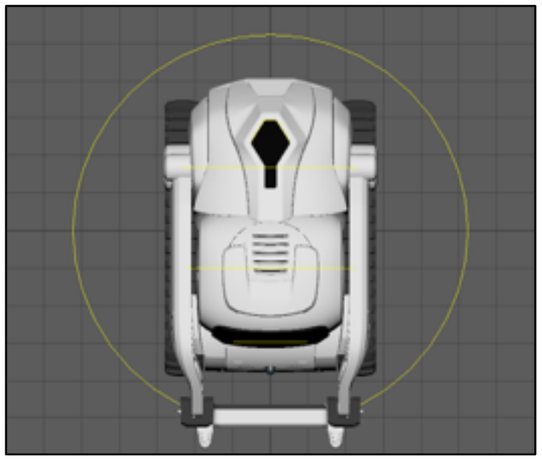
Cozmo's movement

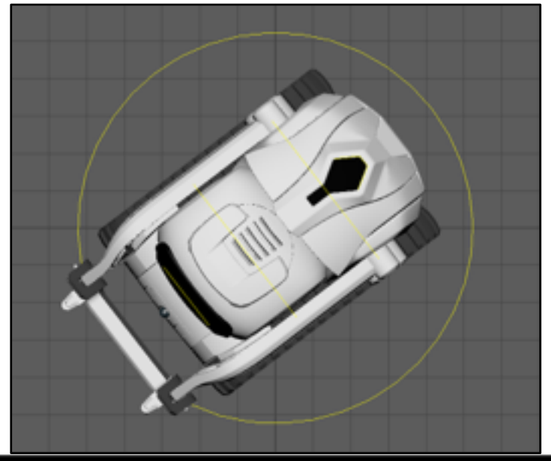
3 types of movement:

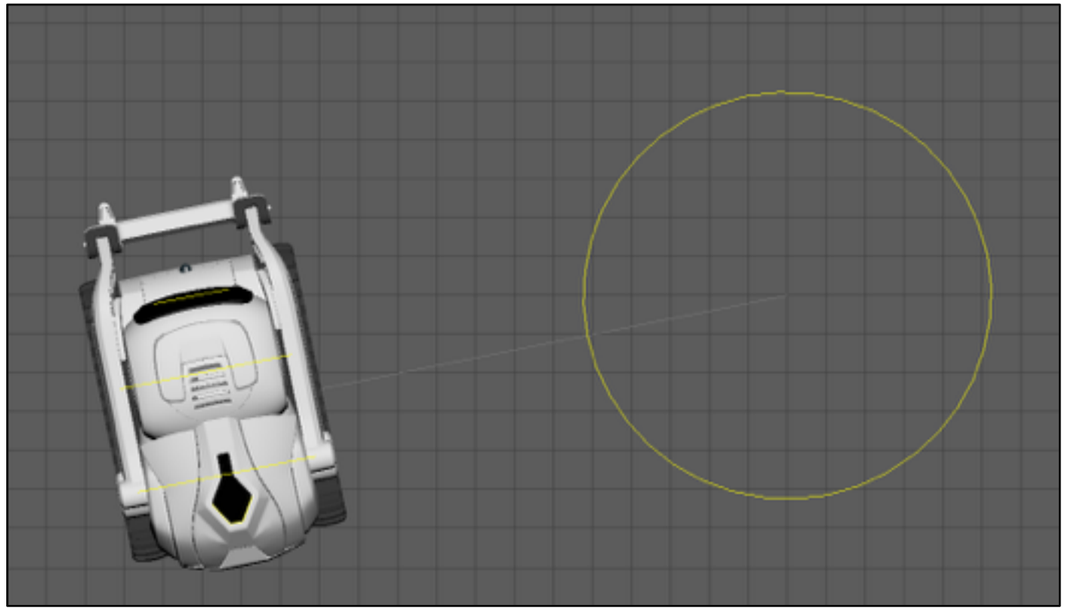
Turn in Place
Move Straight
Arc Turn



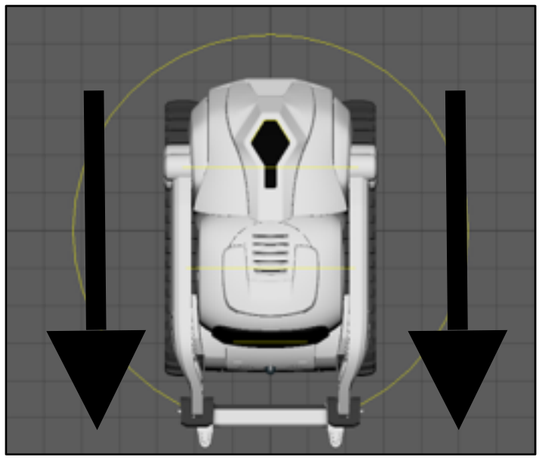
Single Axle Robot Movement

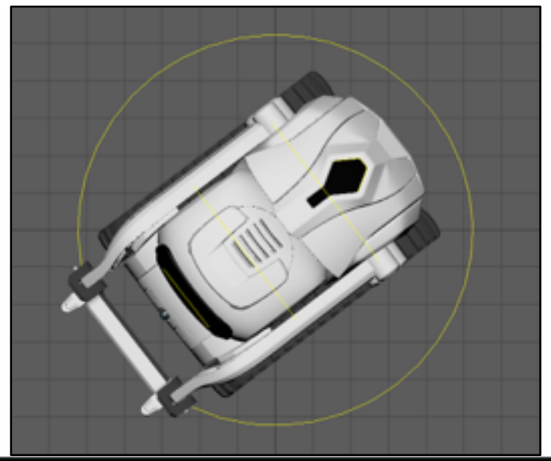


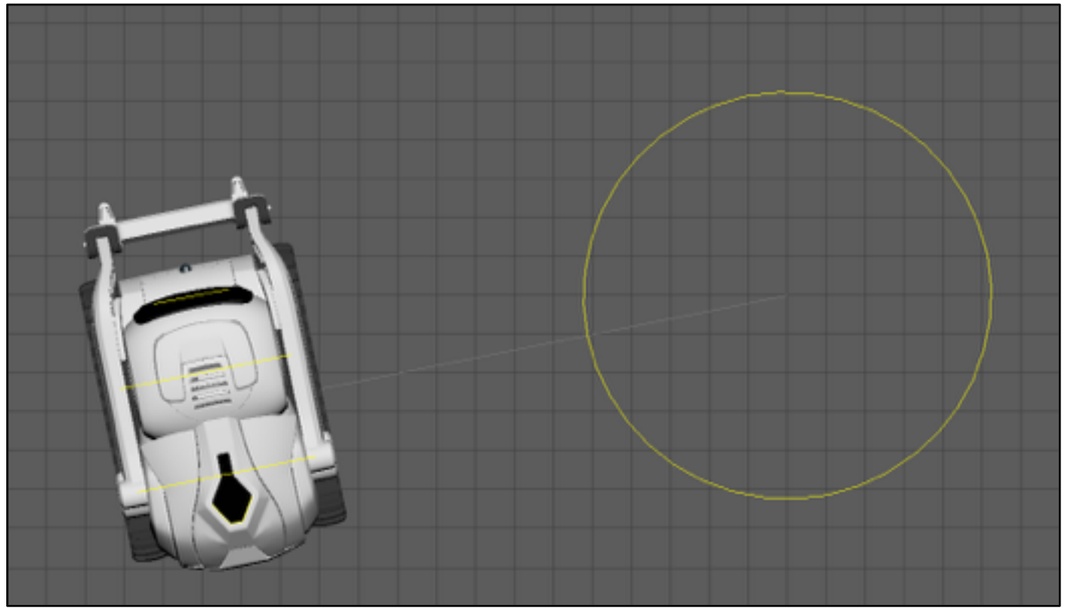




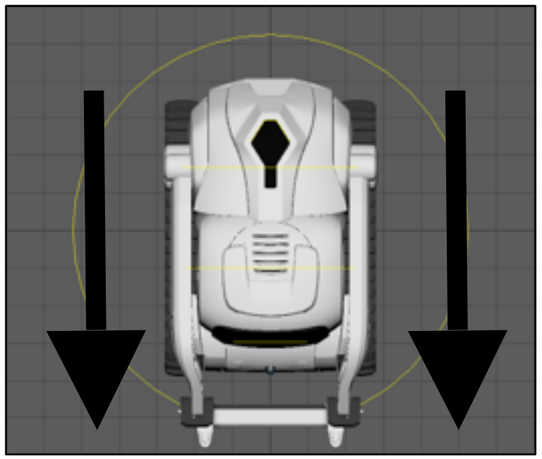
Single Axle Robot Movement

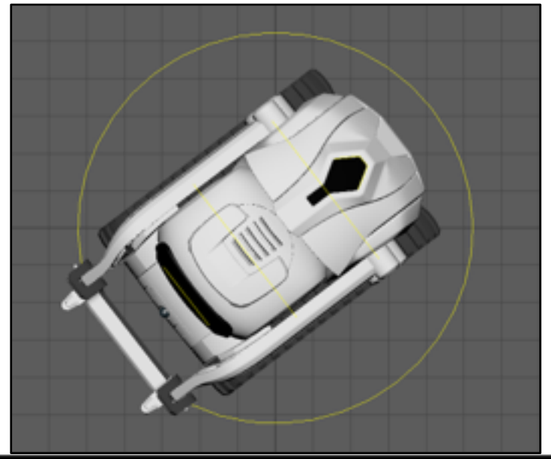


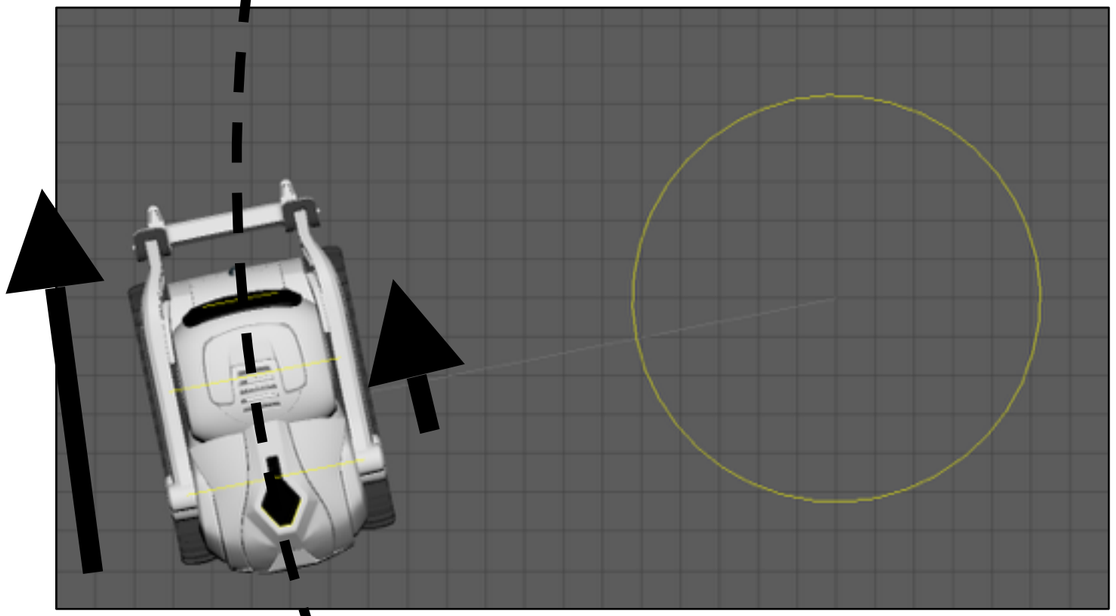




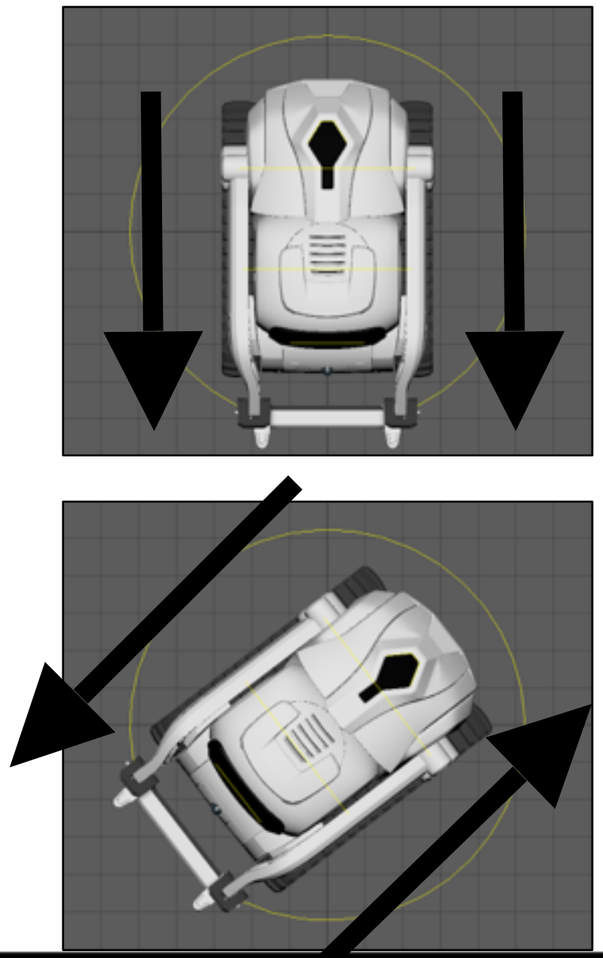
Single Axle Robot Movement

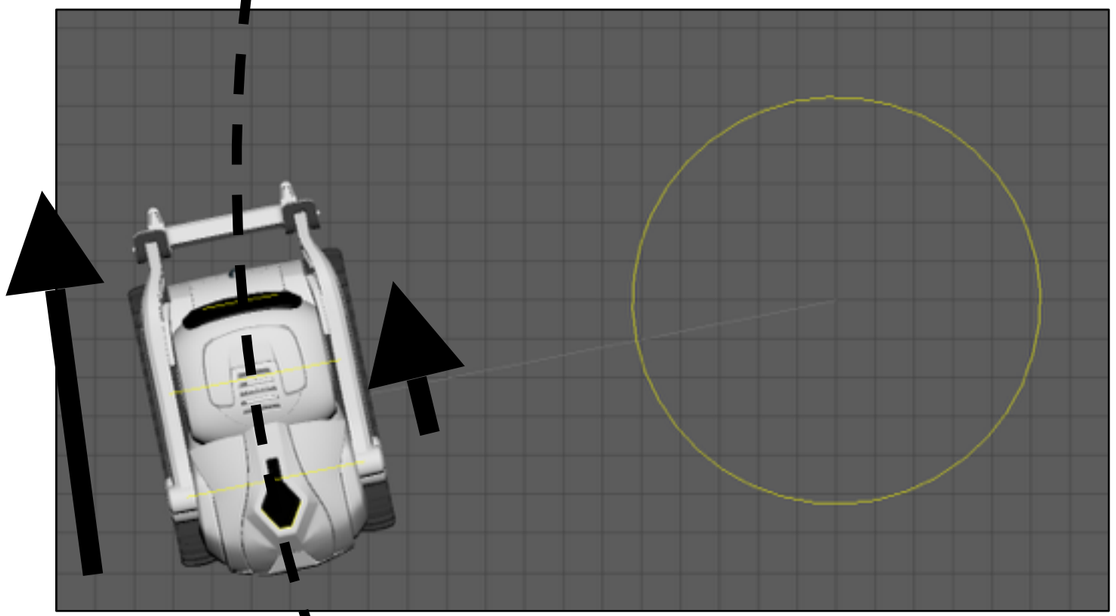






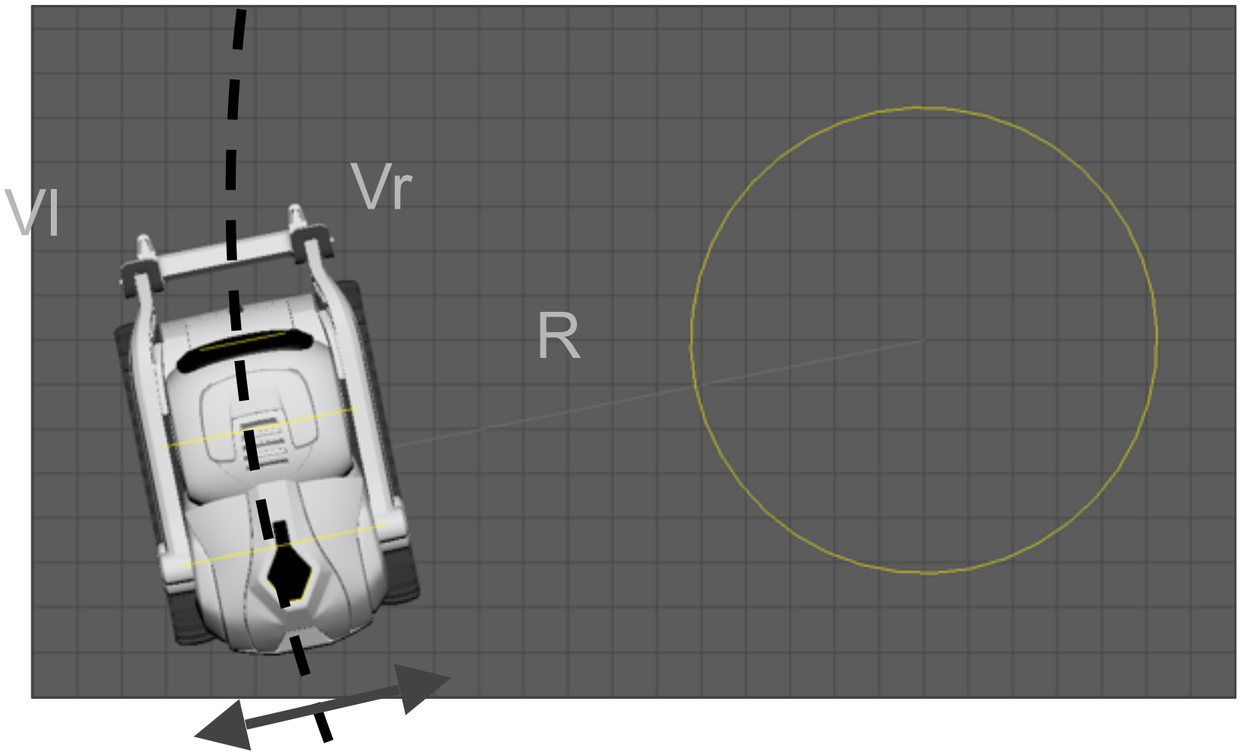
Single Axle Robot Movement

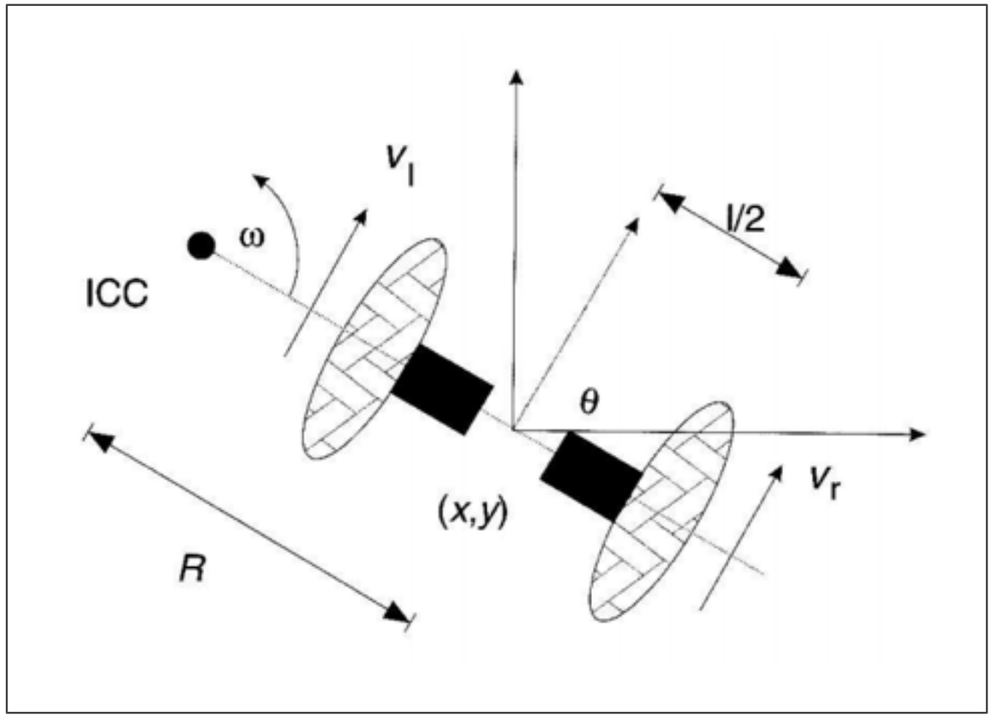




Differential Drive Kinematics

$$\omega\,(R + l/2) = Vr$$
$$\omega\,(R - l/2) = Vl$$

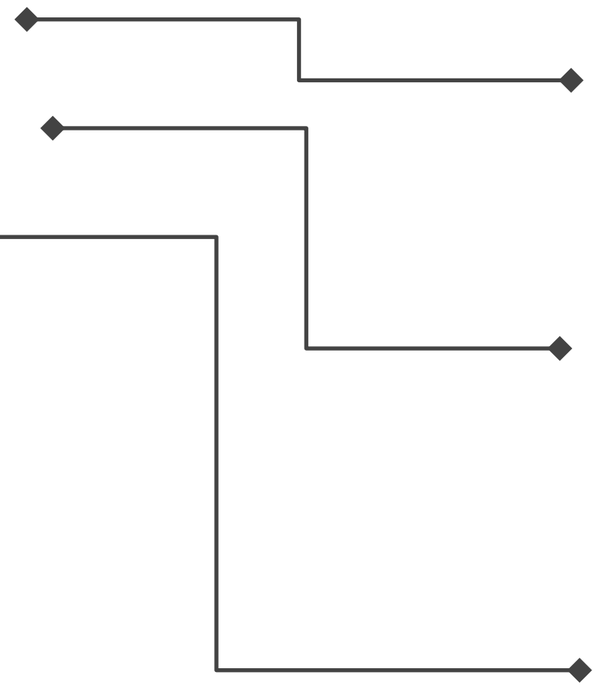




Turn in Place

Move Straight

Arc Turn



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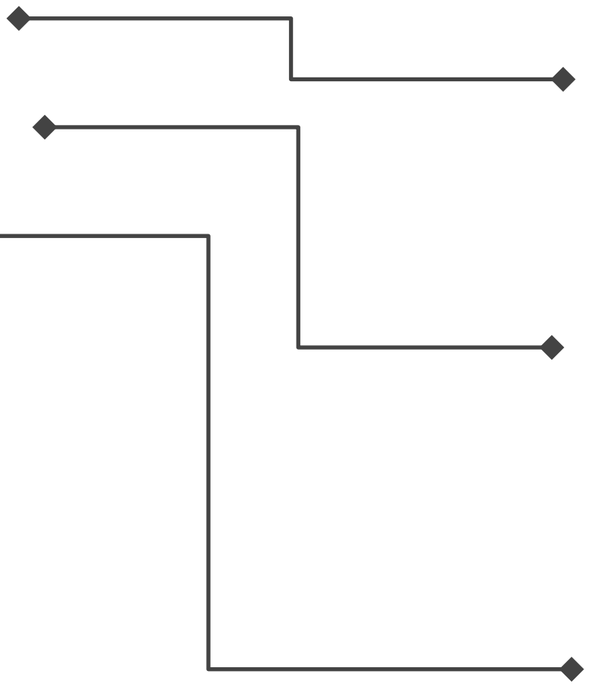
```

Turn in Place

Move Straight

Arc Turn



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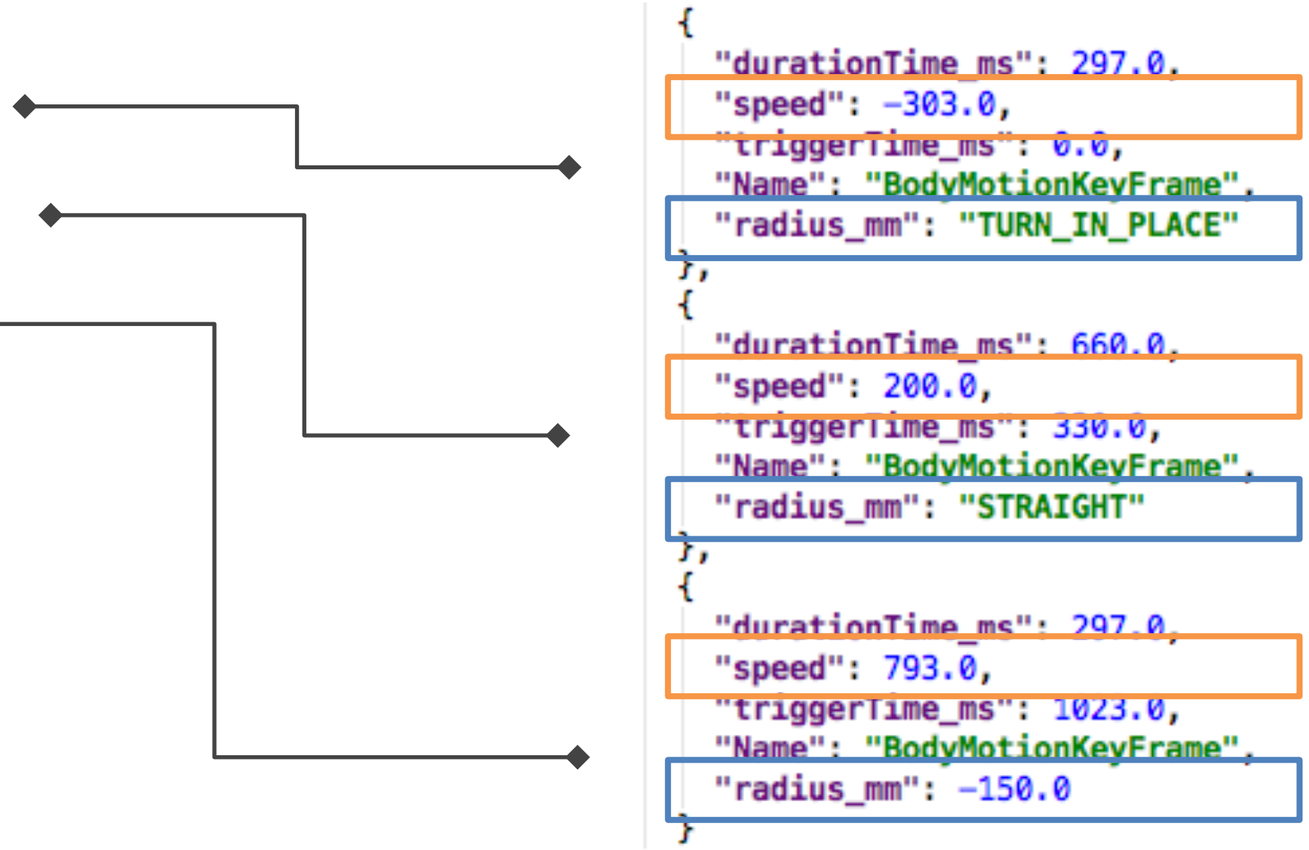
Turn in Place

Move Straight

Arc Turn



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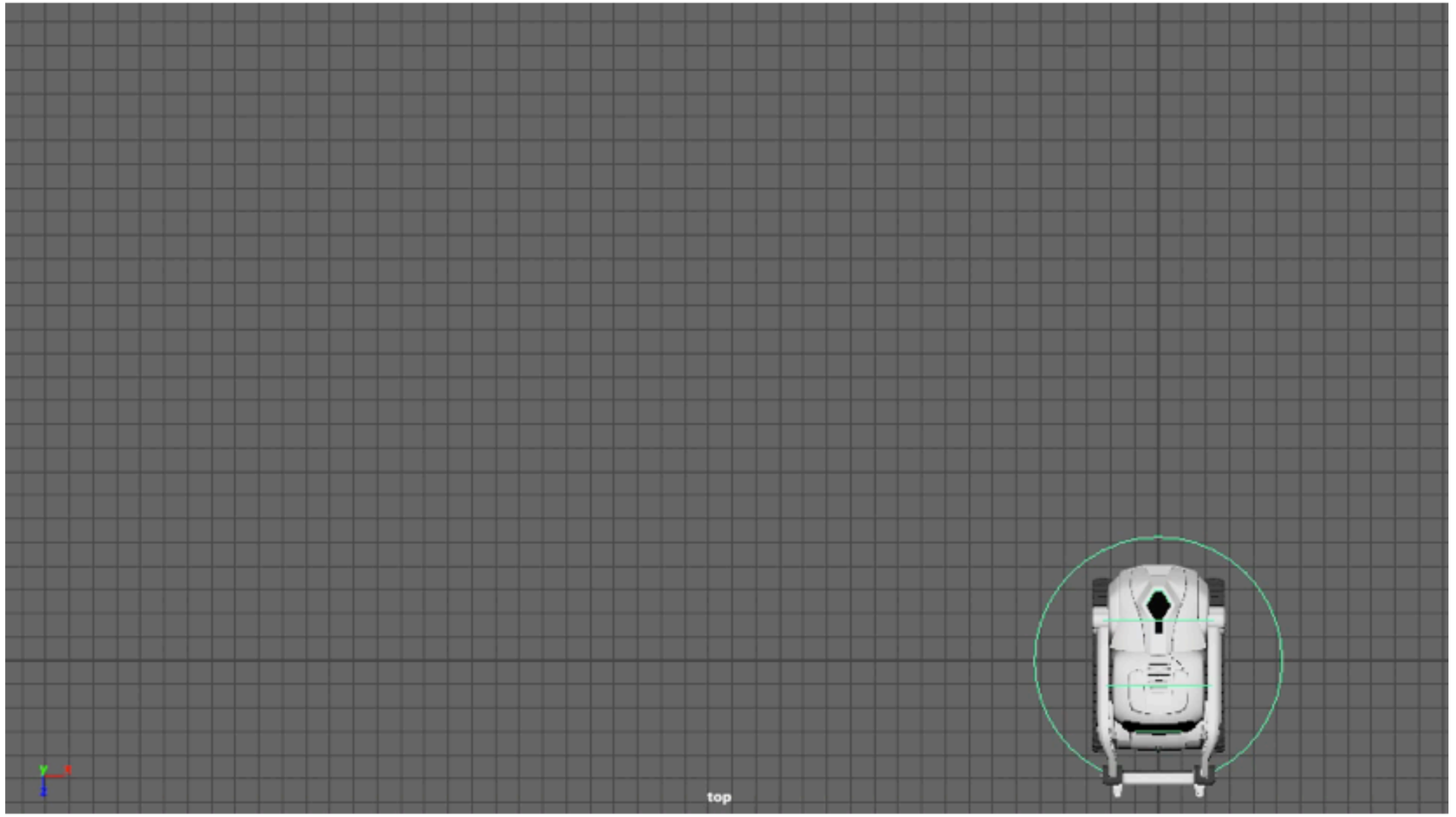


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{
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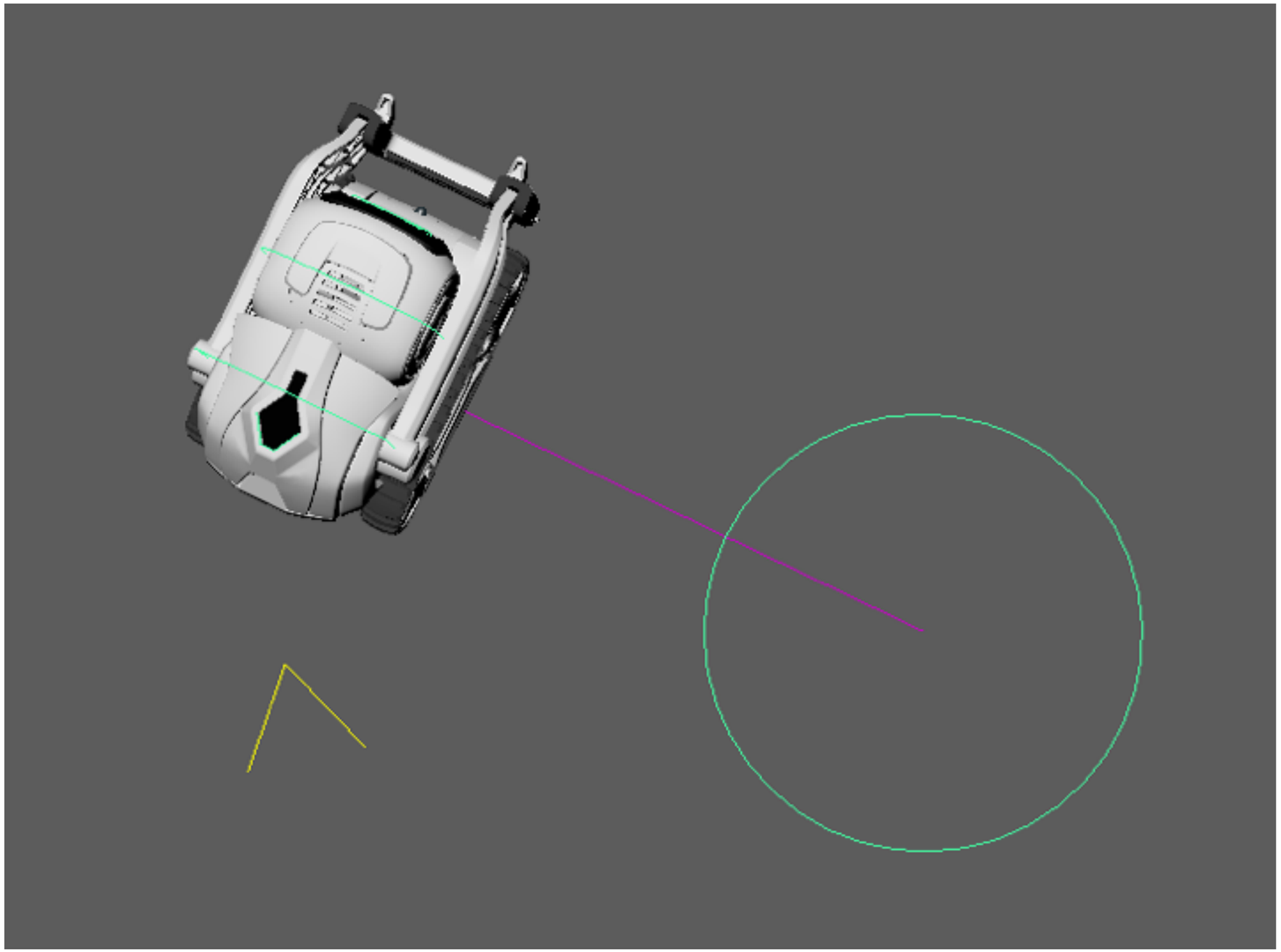
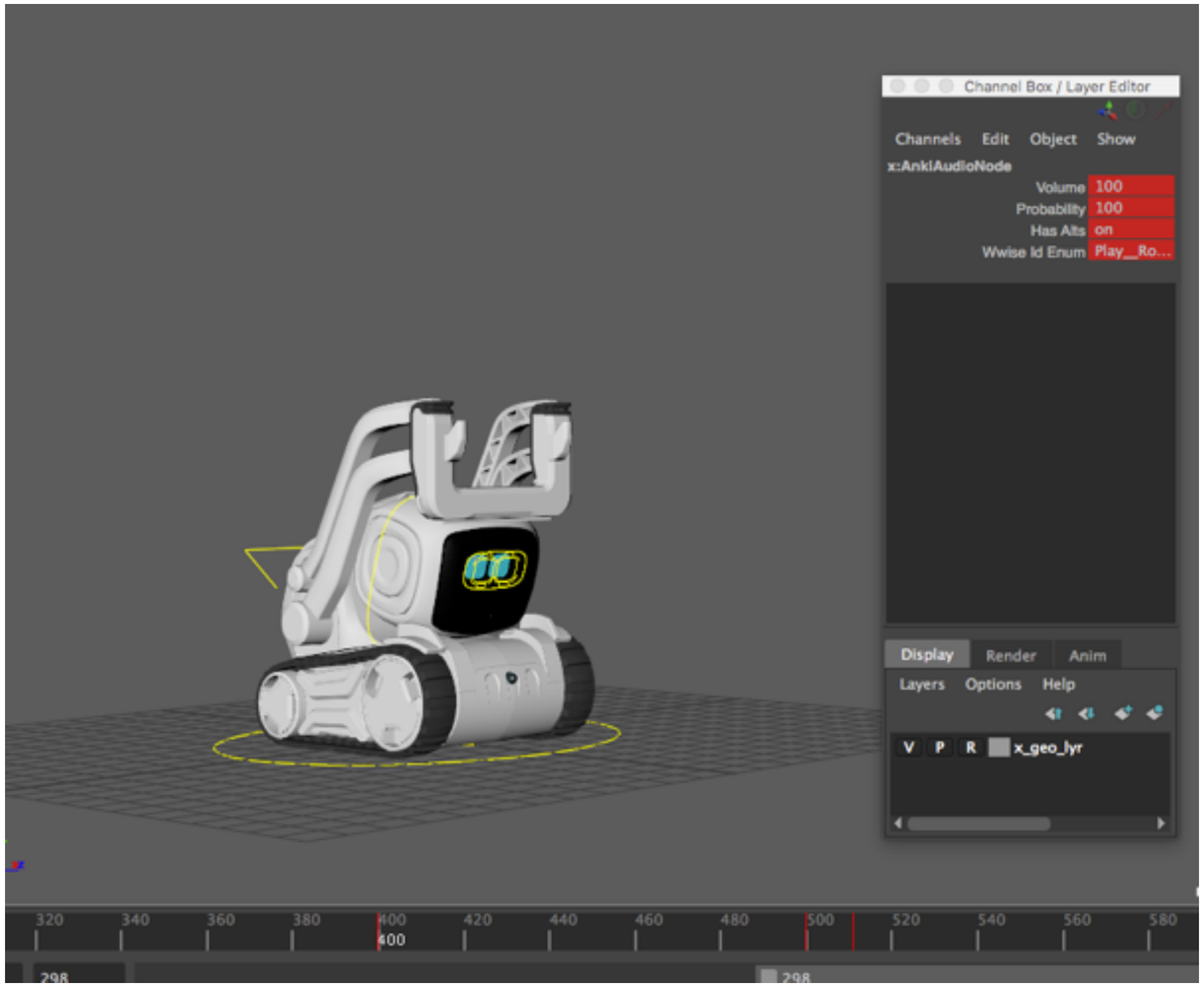


Radius	-15
Forward	0
Turn	-37.531

Audio

Audio

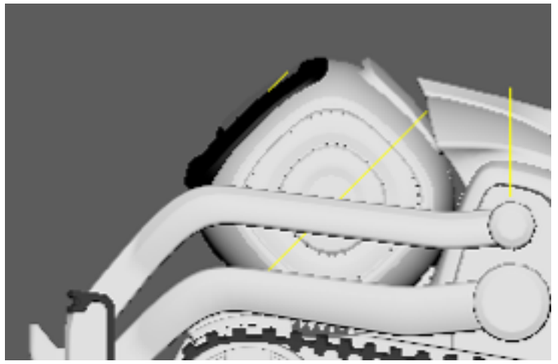

Channel Box / Layer Editor
Channels Edit Object Show
x:AnkiAudioNode
Volume 100
Probability 100
Has Alts on
Wwise Id Enum Play__Ro...
Display Render Anim
Layers Options Help
V P R x_geo_lyr
320 340 360 380 400 420 440 460 480 500 520 540 560 580
400
298
298

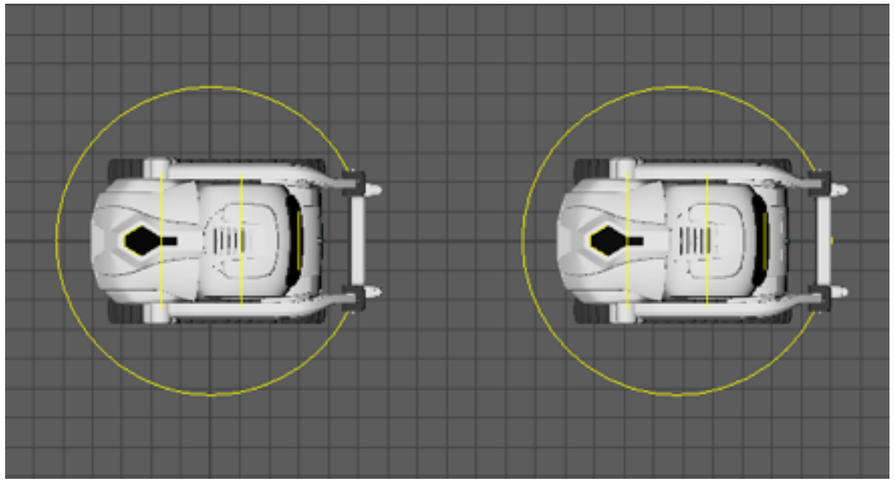
Rig and animation limitations due to physical constraints

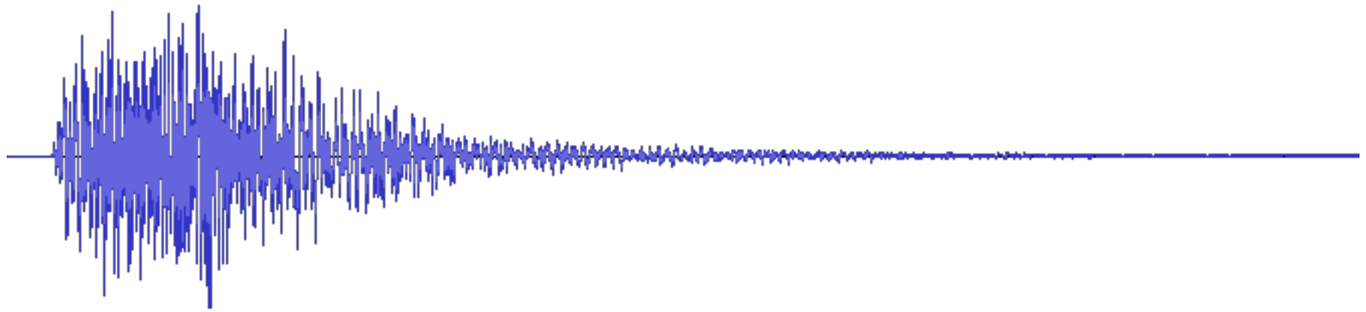
Physical limitations

Movement

Audio

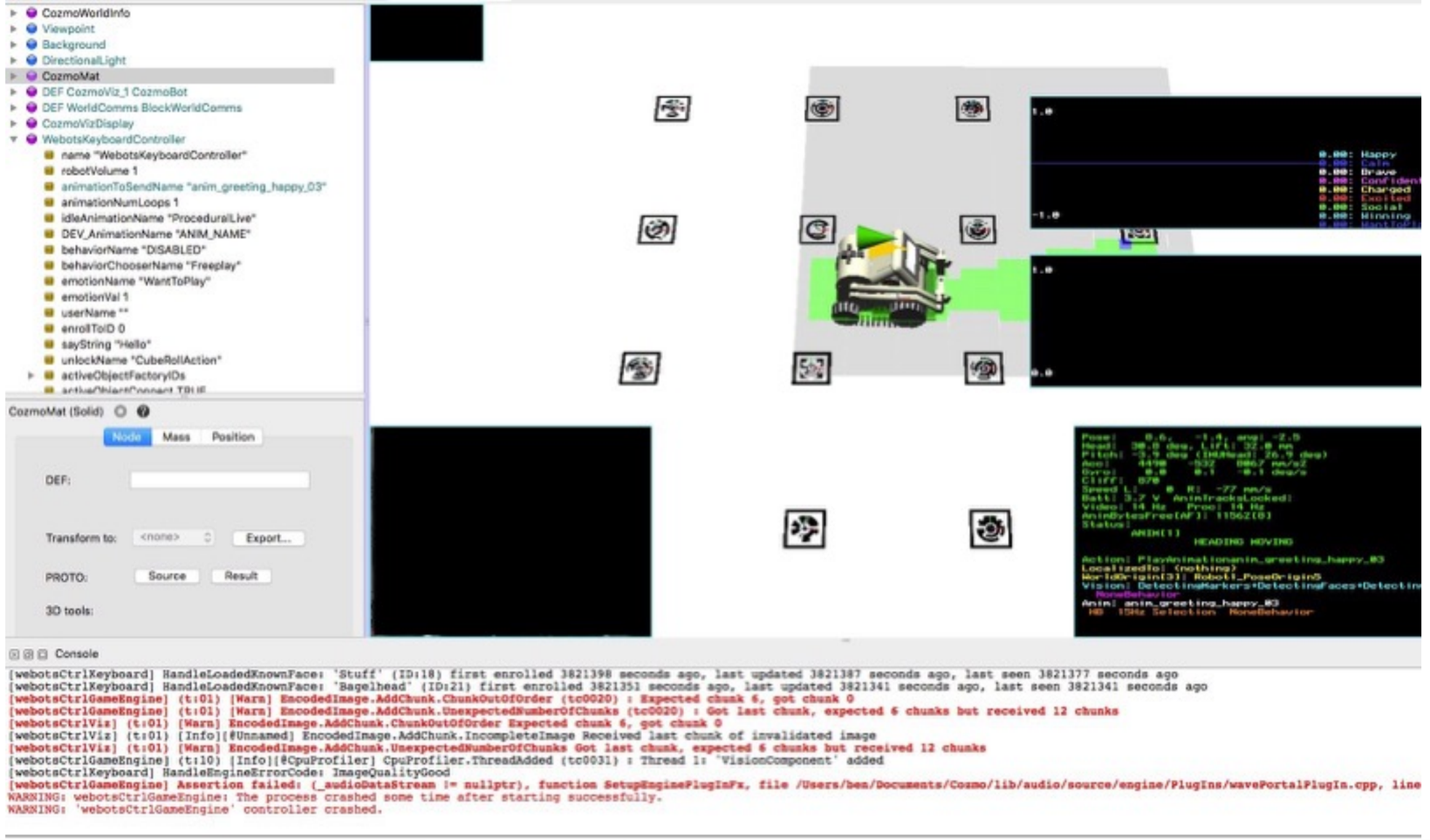




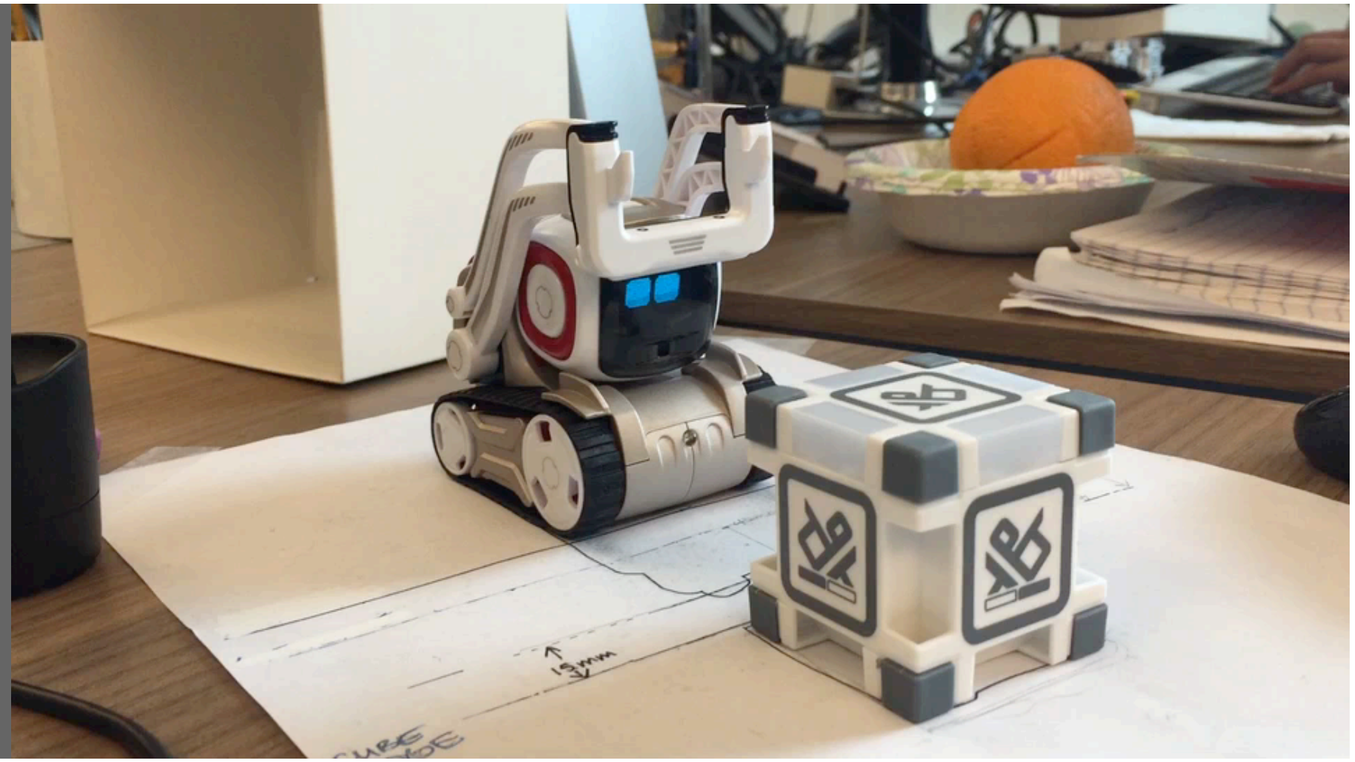


Happy accidents

Previewing animation



Previewing animation



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

Cozmo's full stack

Gameplay/UI - Unity, C#

SDK - python

Engine - C++ and Obj-C or Java

wifi

wifi

Firmware - C, on 3 custom embedded processors

Hardware

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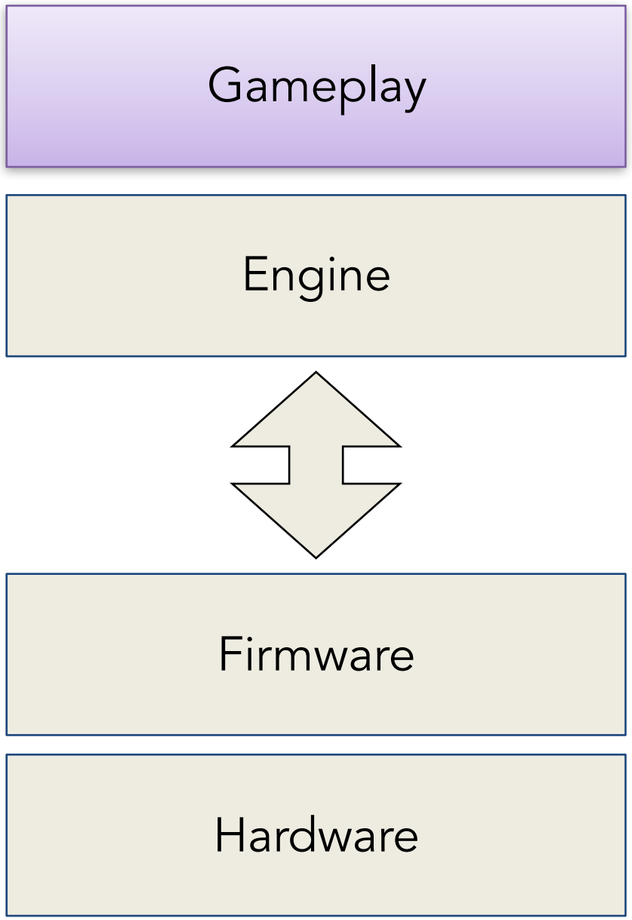
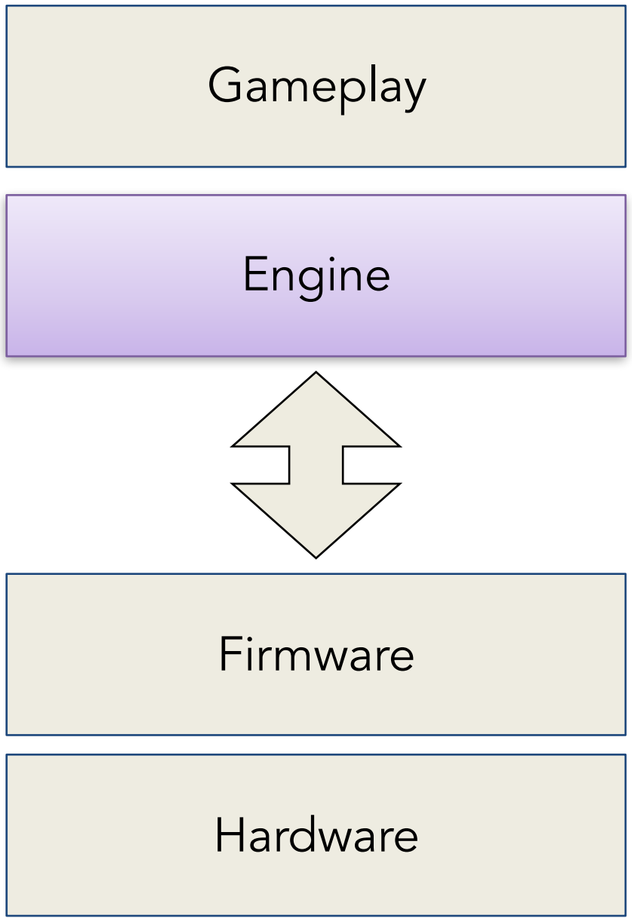
Hardware

Steps to get animation playing

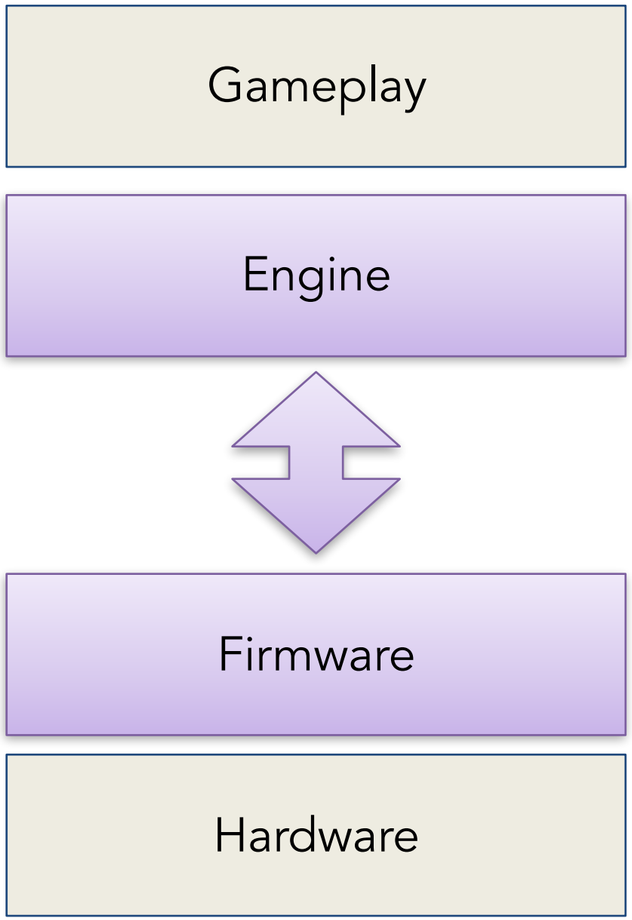


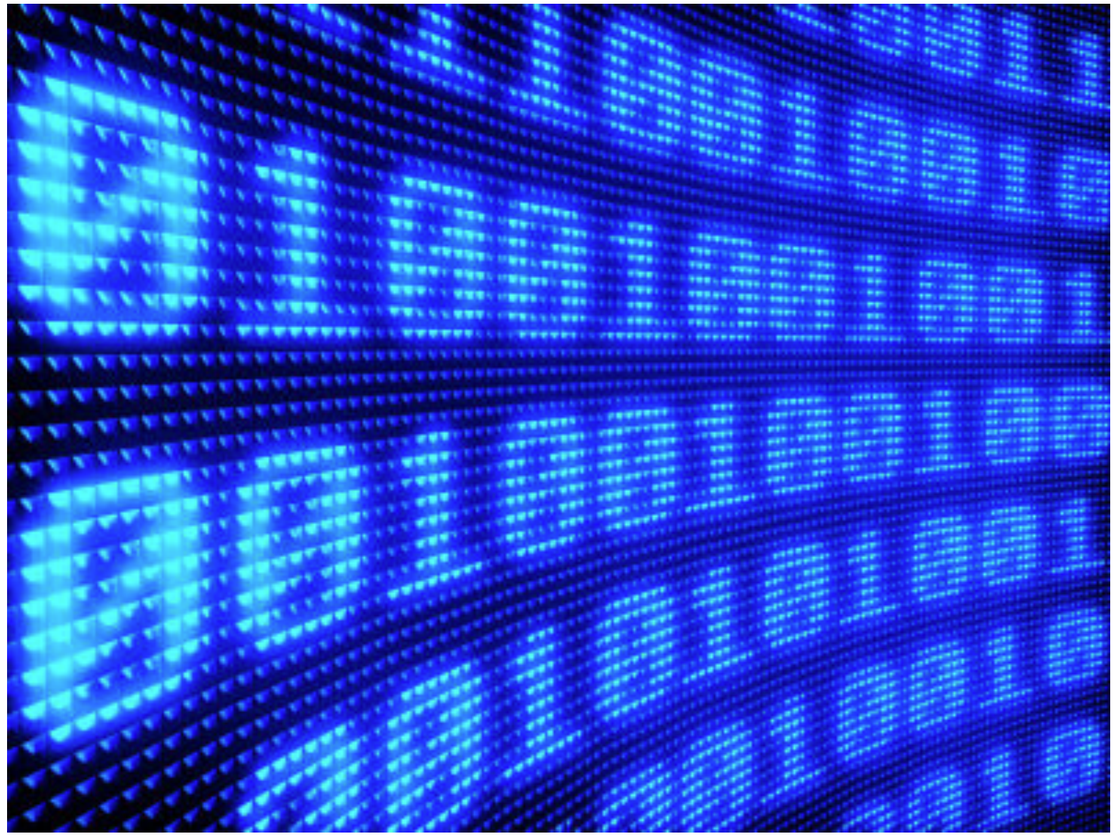

```
robot.play_anim_trigger(
cozmo.anim.Triggers.MajorWin)
```

Steps to get animation playing

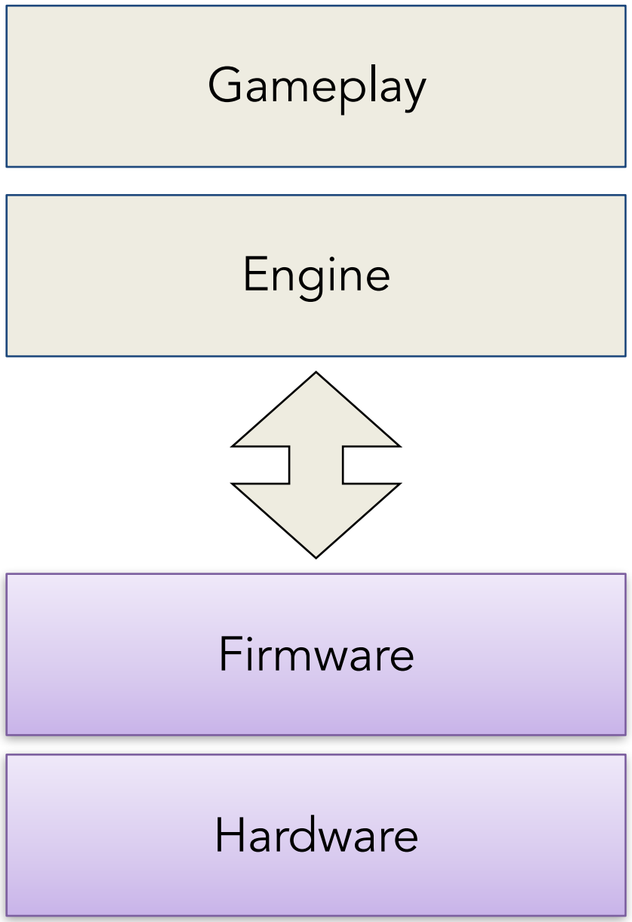


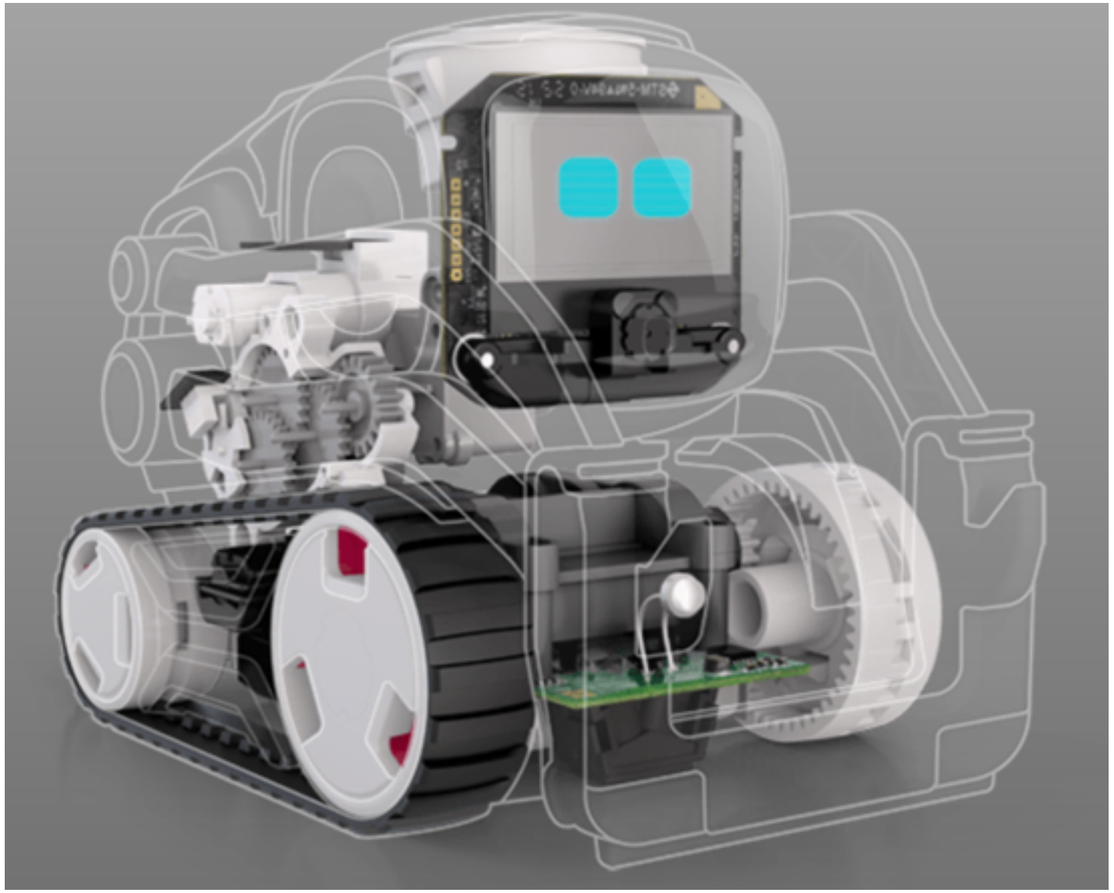
Steps to get animation playing





Steps to get animation playing



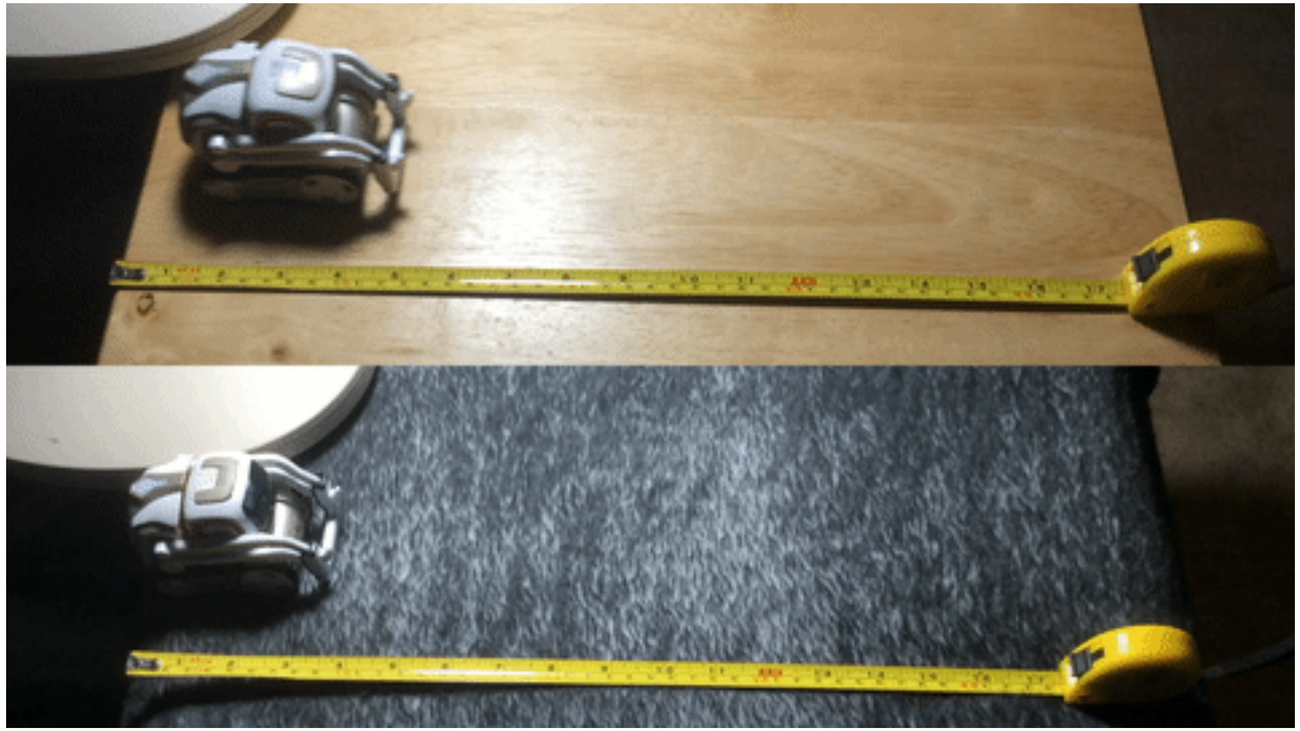


Real World Uncertainty And Lessons Learned

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"



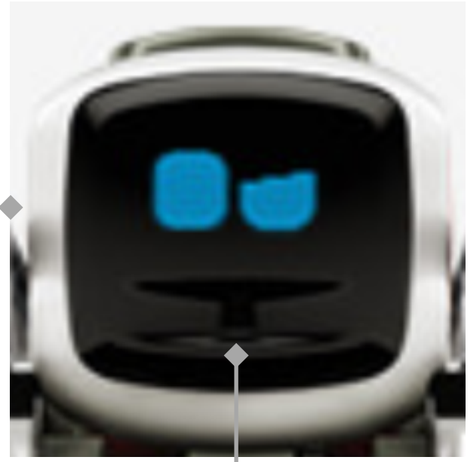
Different Surface frictions mean different timings

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



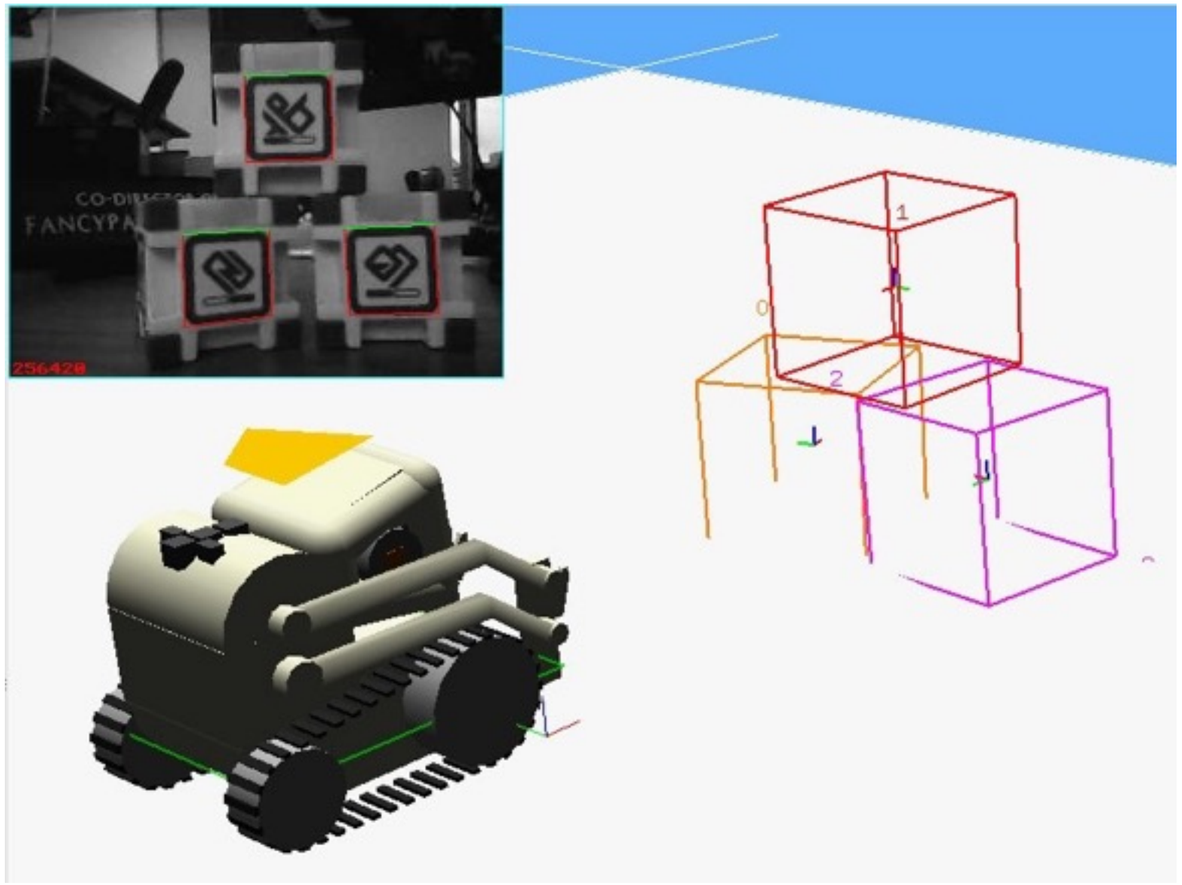
IMU

Cliff Sensor

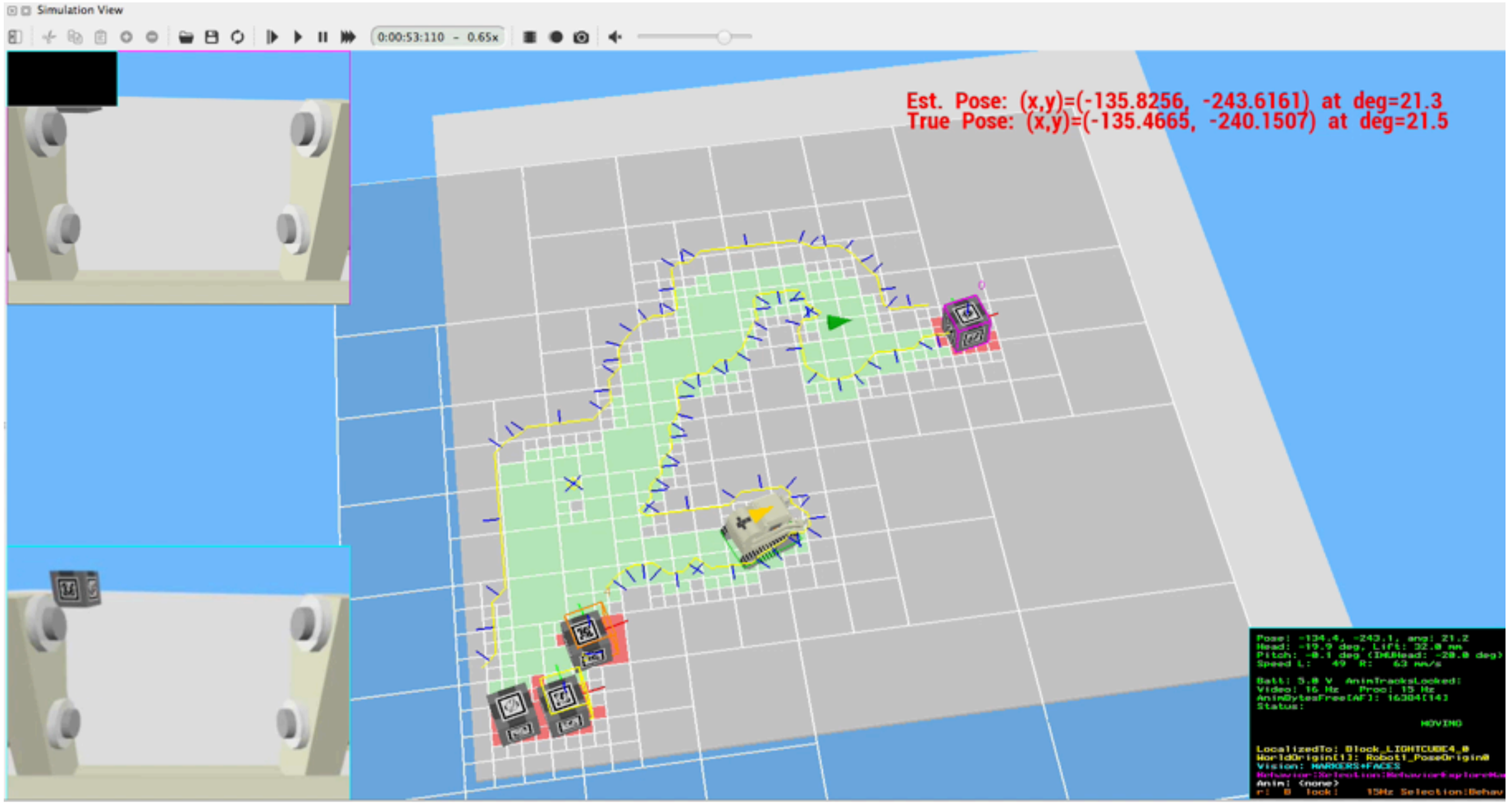
Camera

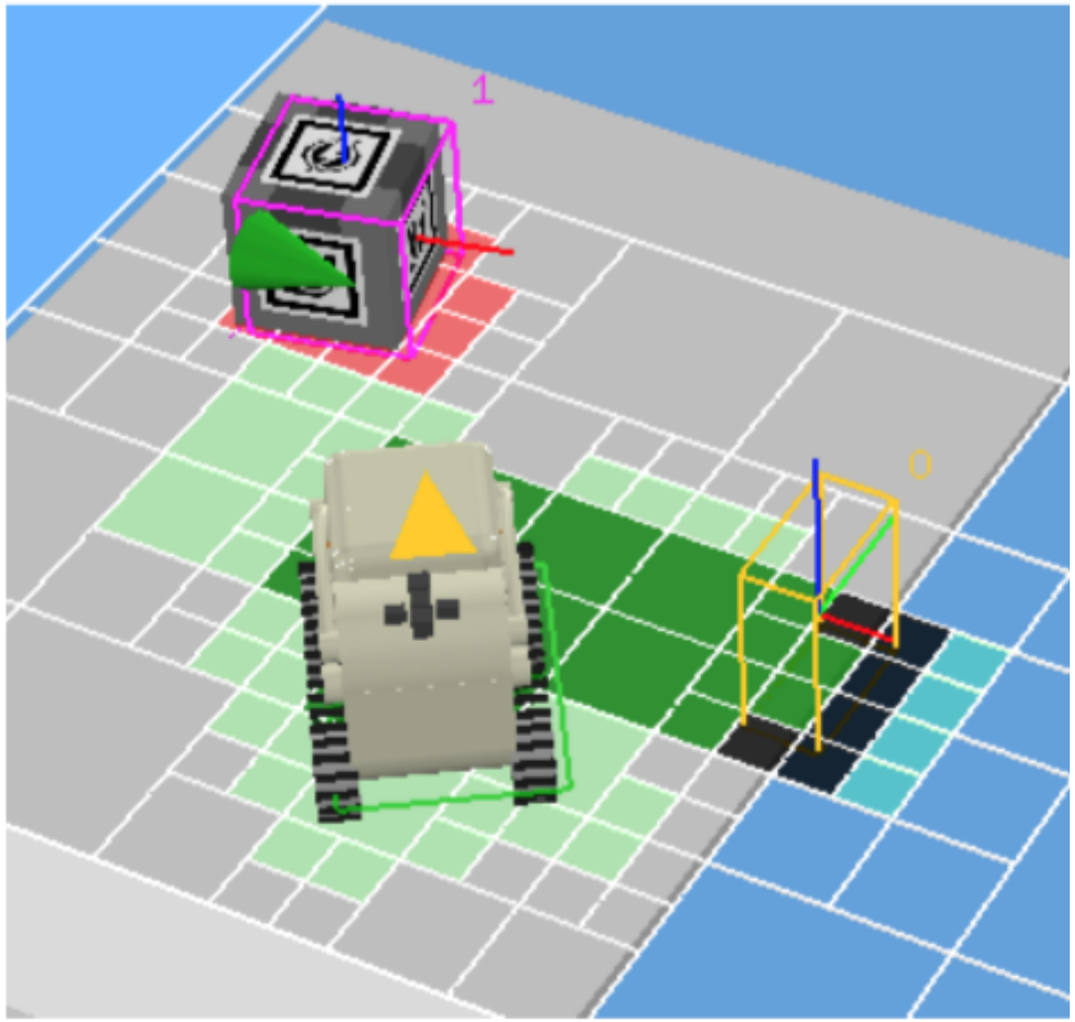
Cozmo Ecosystem

Cozmo's cubes



SLAM (simultaneous localization and mapping)

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0

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

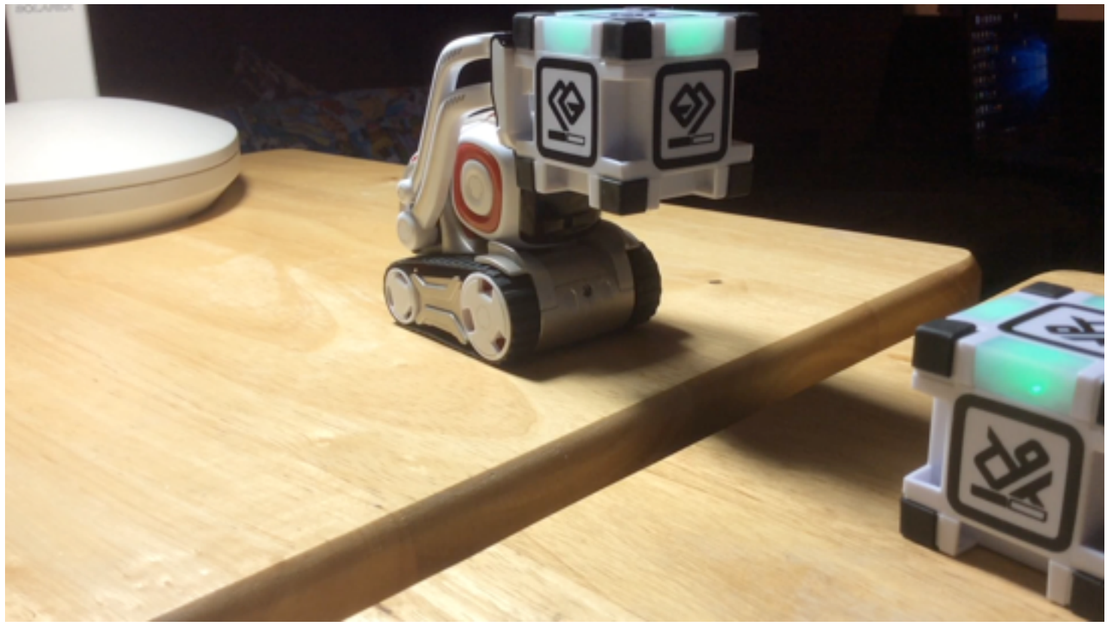
Challenge 2:
Making animations work in multiple situations

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

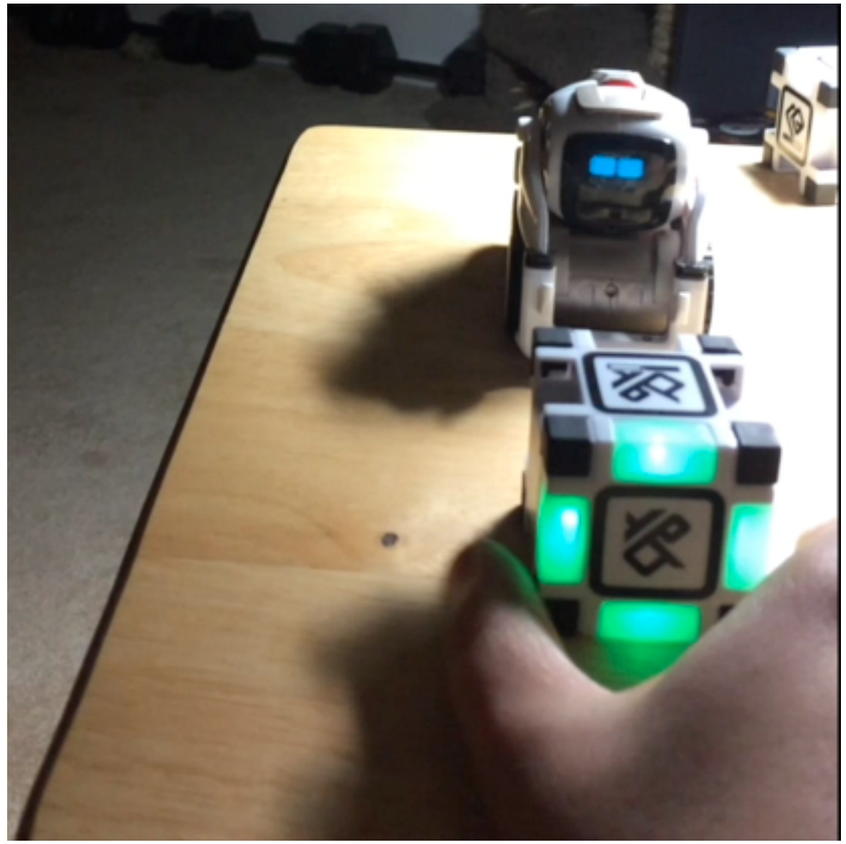


Challenge 3:

Recovering if actions unexpectedly fail

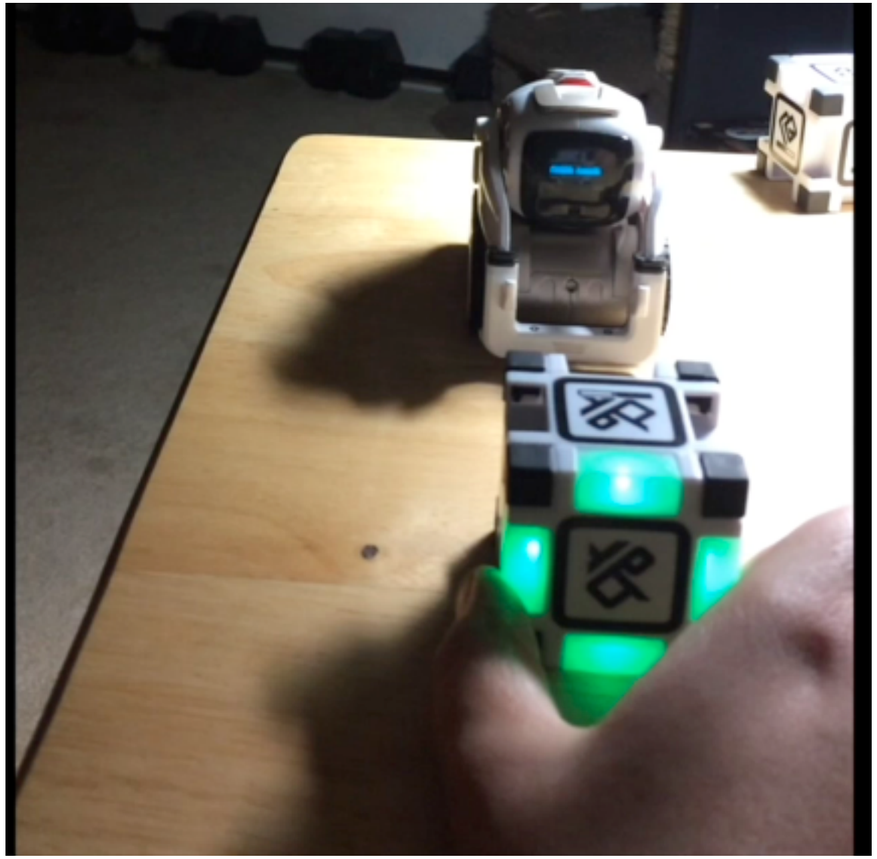
Sometimes actions fail

Challenge: Cozmo only has a simulated version of the world and often the real word doesn't match meaning actions can fail if something isn't where he think 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



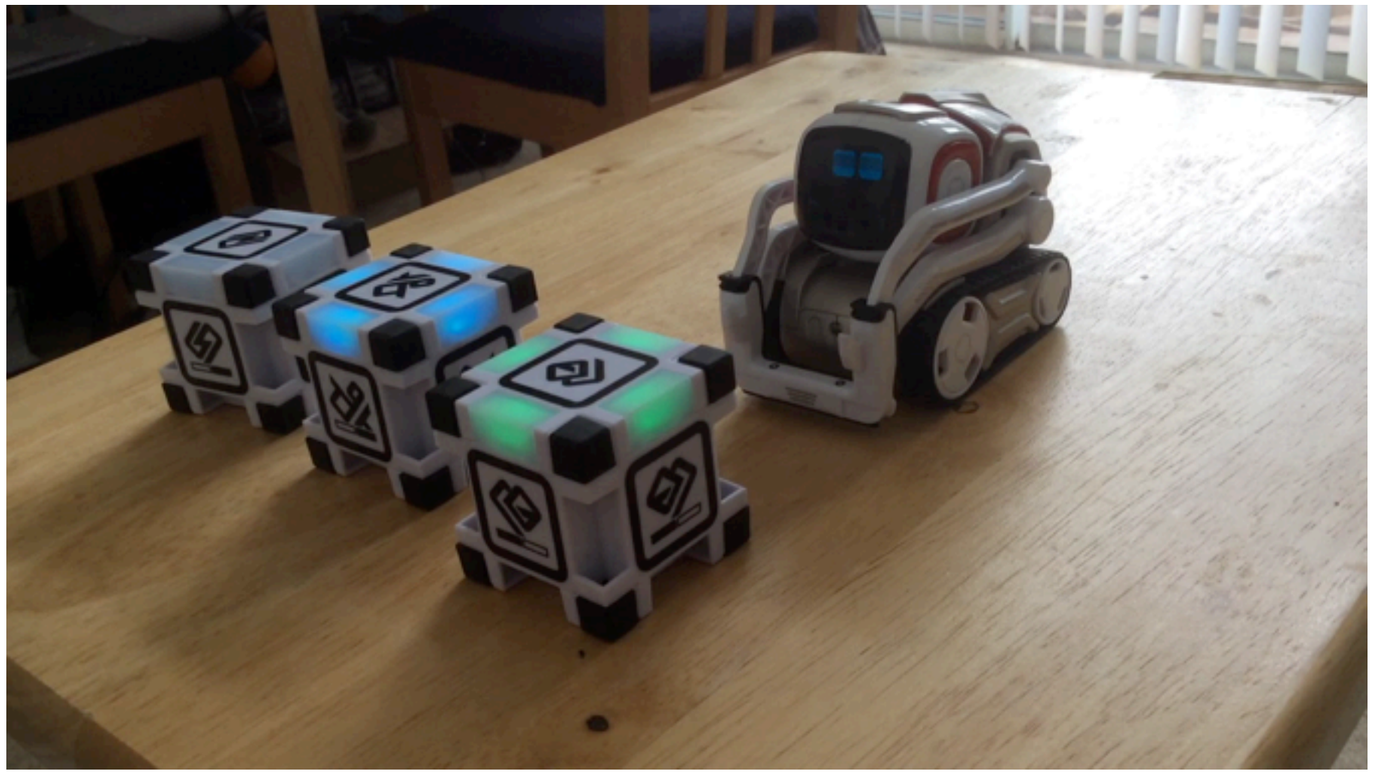
Challenge 4:
Directing the user's focus

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

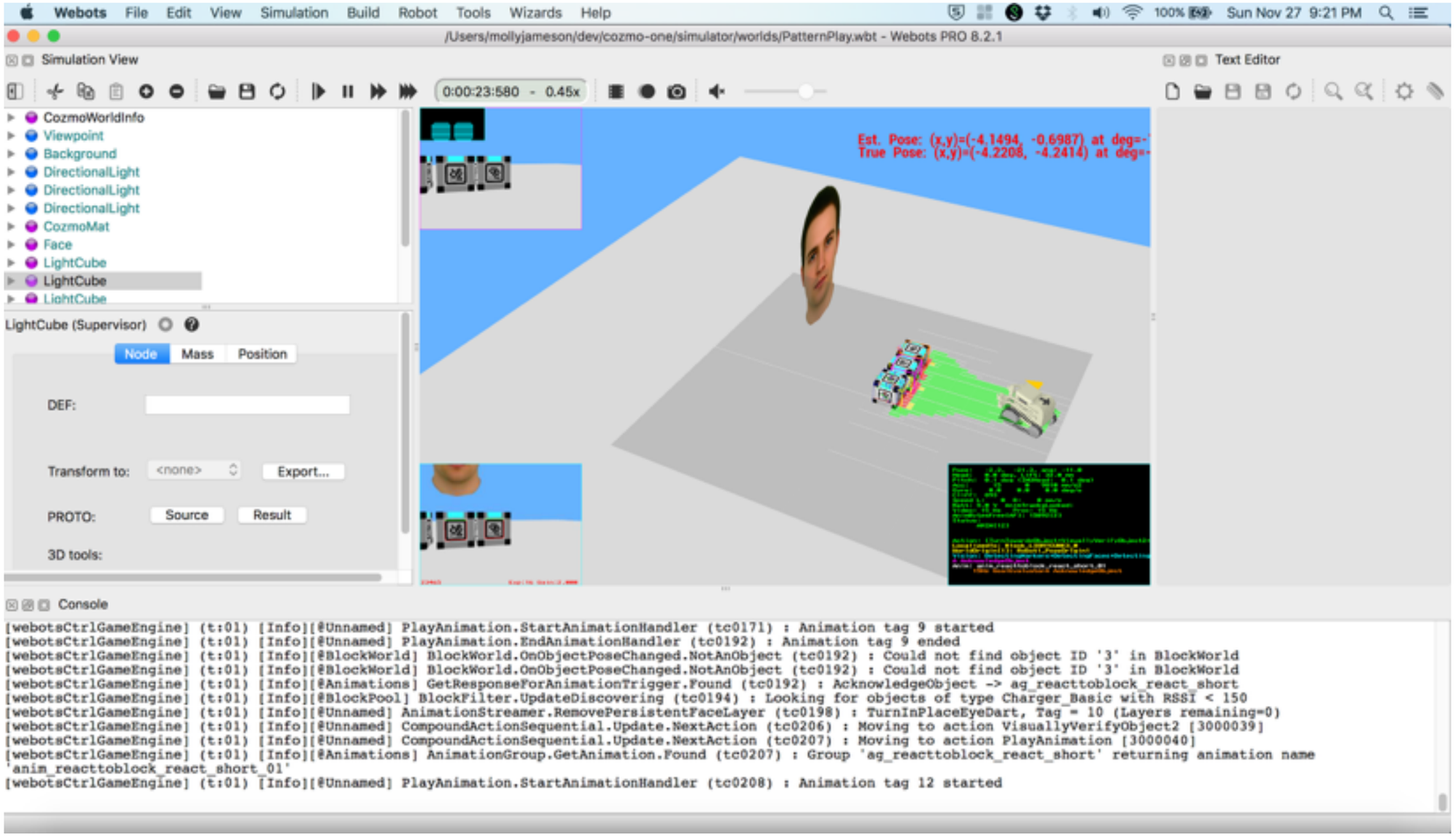


Challenges Overcome!

it!

… After testing

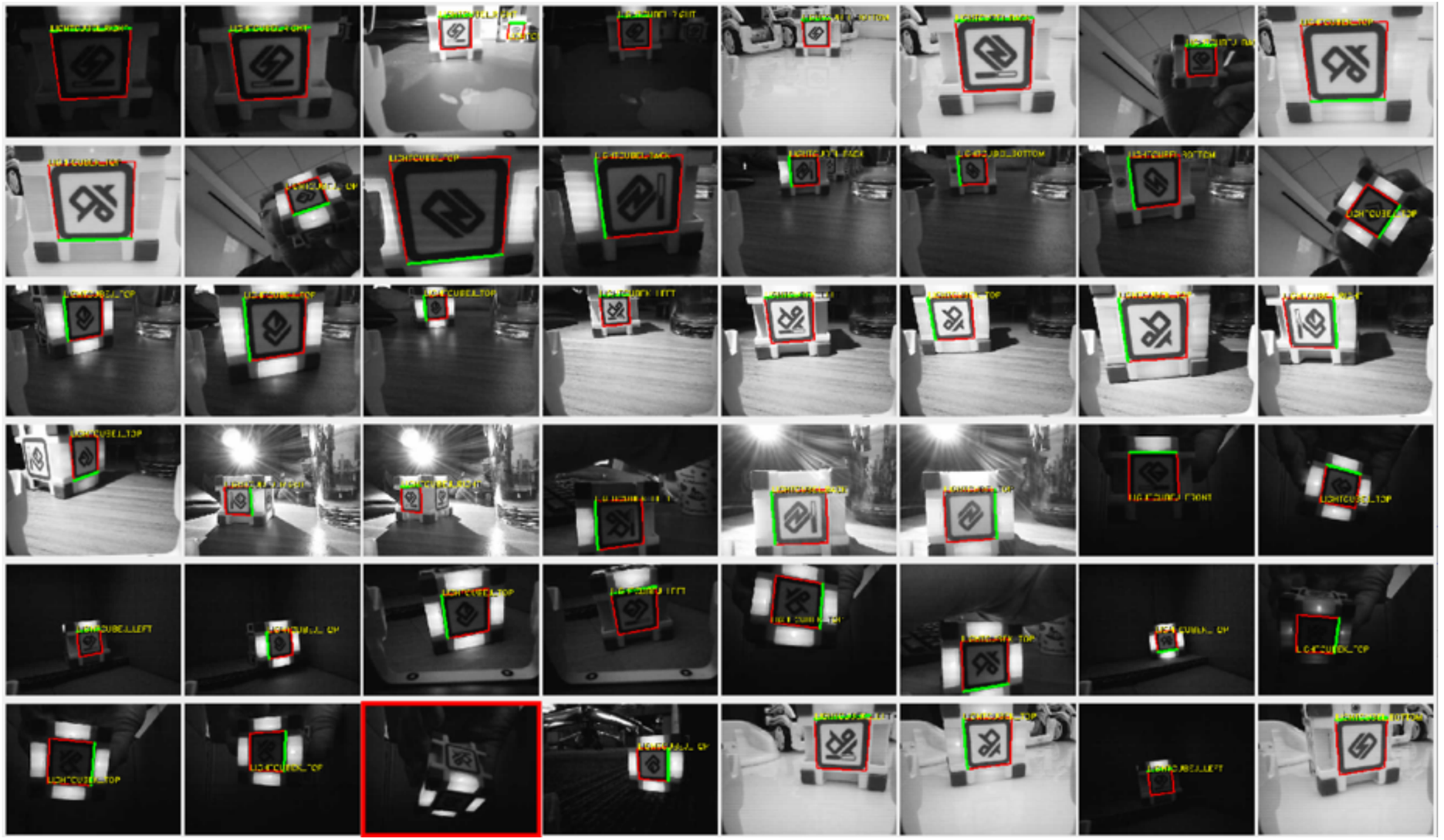
Automated Testing



Lesson Learned:

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

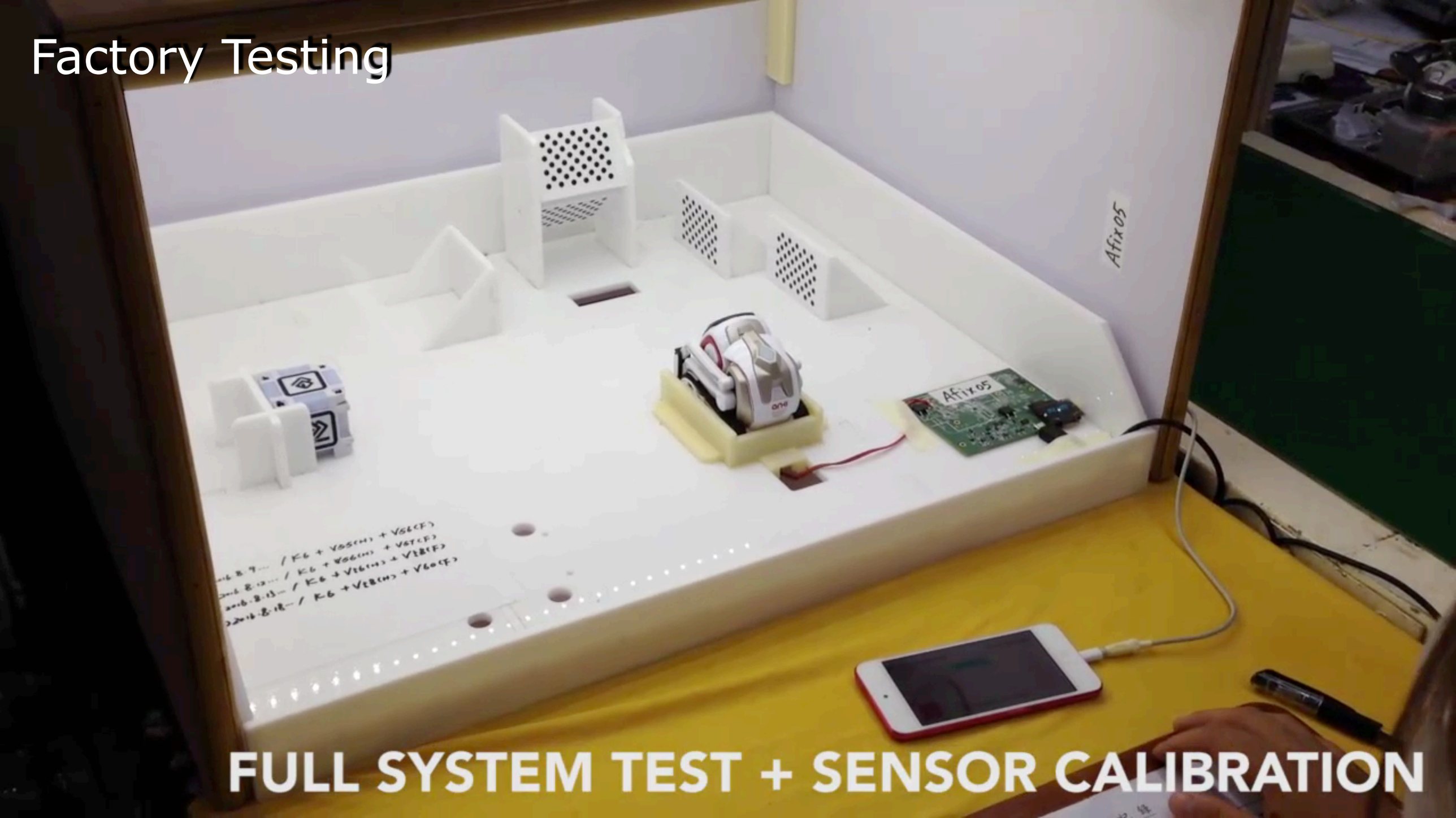
Manual Testing



Message your users when in trouble

Sometimes the key to testing is getting creative

Factory Testing



Testing

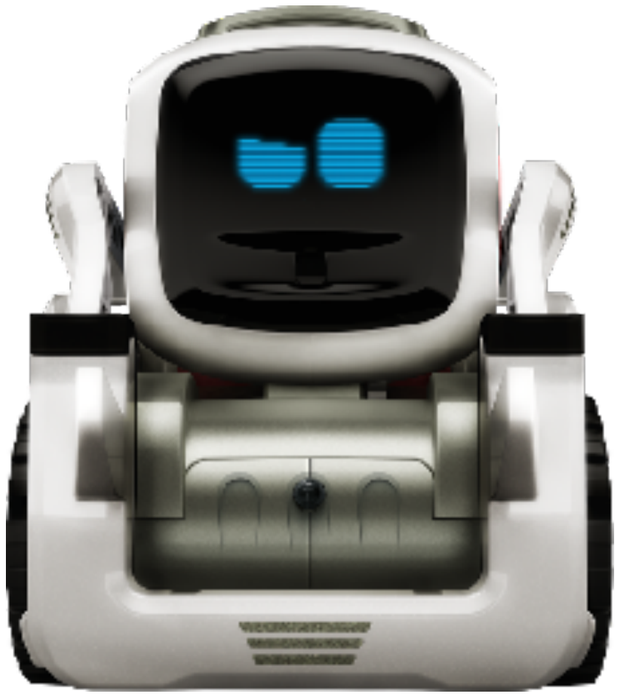
- Hardware is finalized long before software (~1 year in our case) to go to factory. QA needs to be testing way sooner as a result.
- Features need to be tested across multiple robots, multiple devices, multiple environments.
- Drop testing, temperature and humidity testing.

Thanks

Nishkar Grover
Damjan Stulic
Jordan Rivas
Andrew Stein
Meghan McDowell
Carlos Baena

Mooly Segal
Mark Wesley
David Cerpa
Kevin Yoon
Brad Neuman

Questions?



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