Automatic Test Generation for Physical Systems

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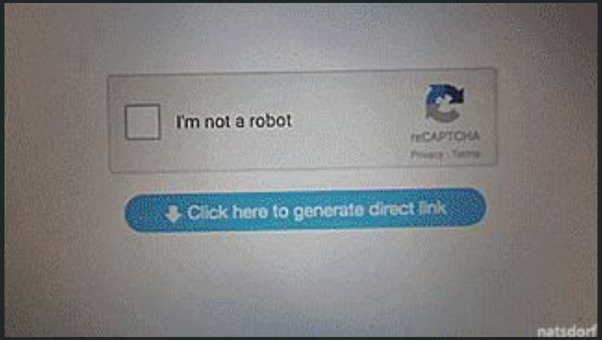
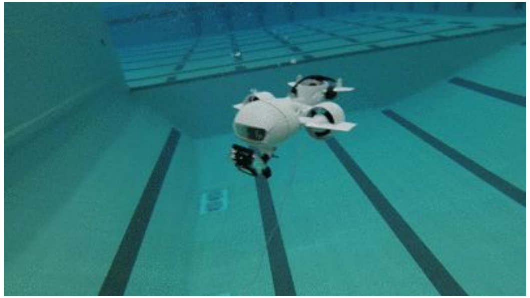


Motivation

Autonomous vehicles are becoming a **reality** in society

Amazon Drone-Releasing Blimp

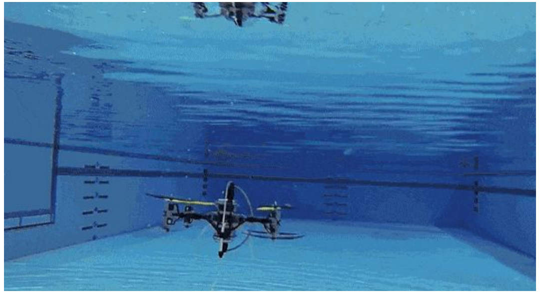
Amazon Warehouse Robots



Autonomous Aquatic Vehicles

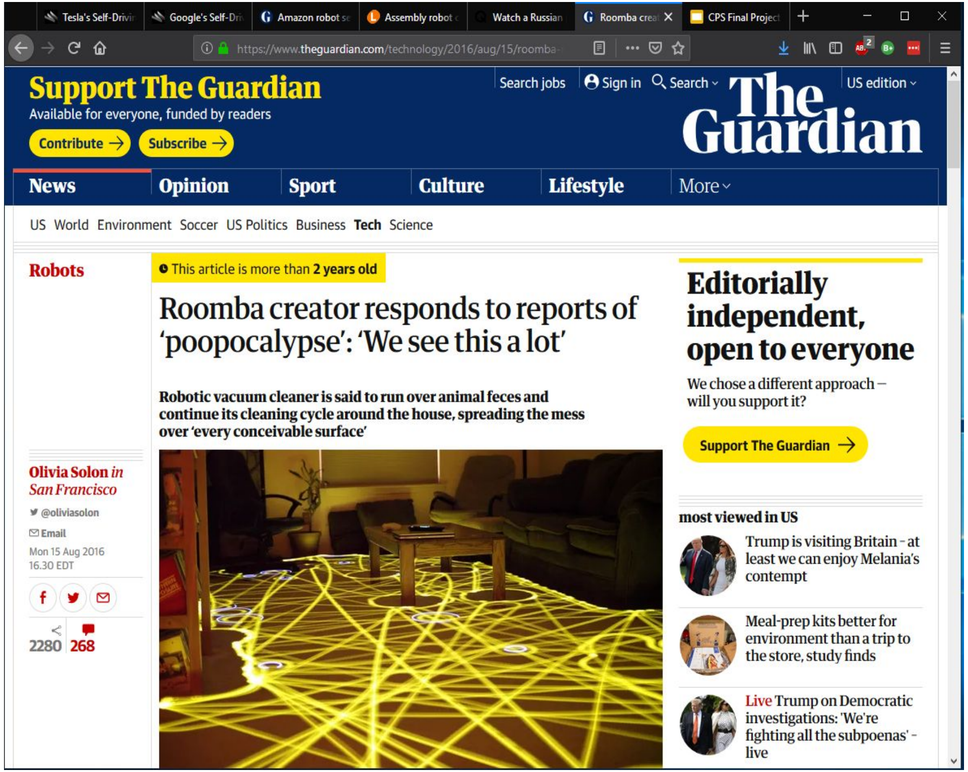
Autonomous Differential Drive Robots

Self Driving Cars



Arial-Aquatic Vehicles

Traditional testing is **not** enough.



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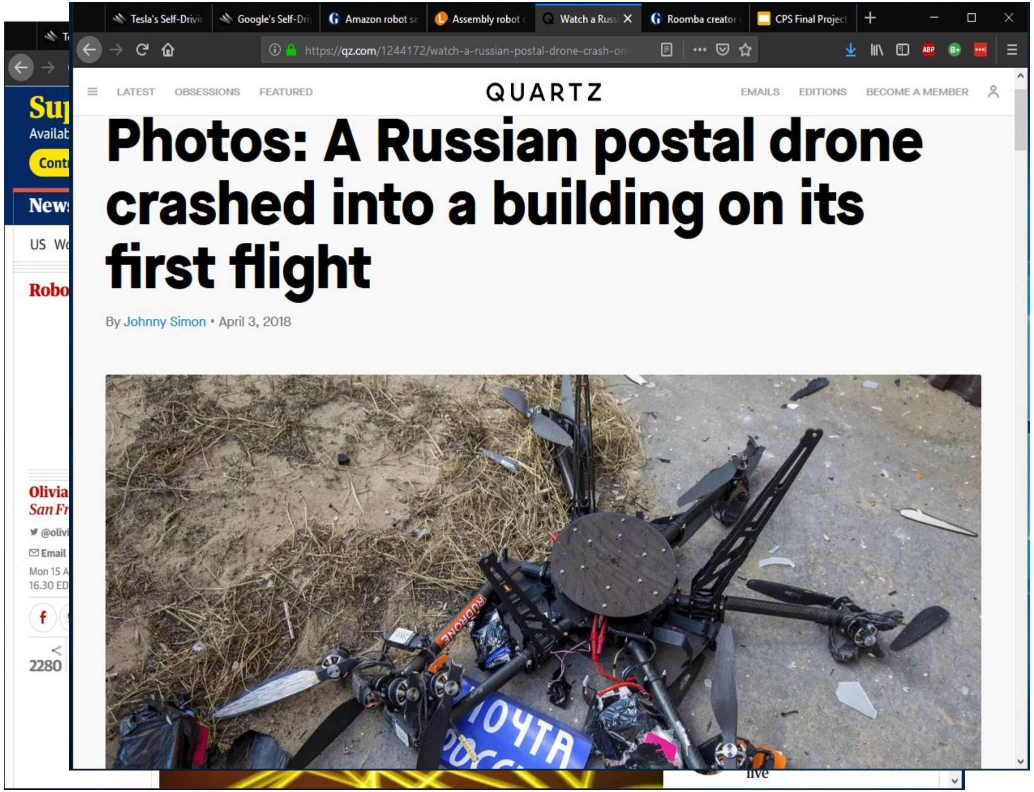

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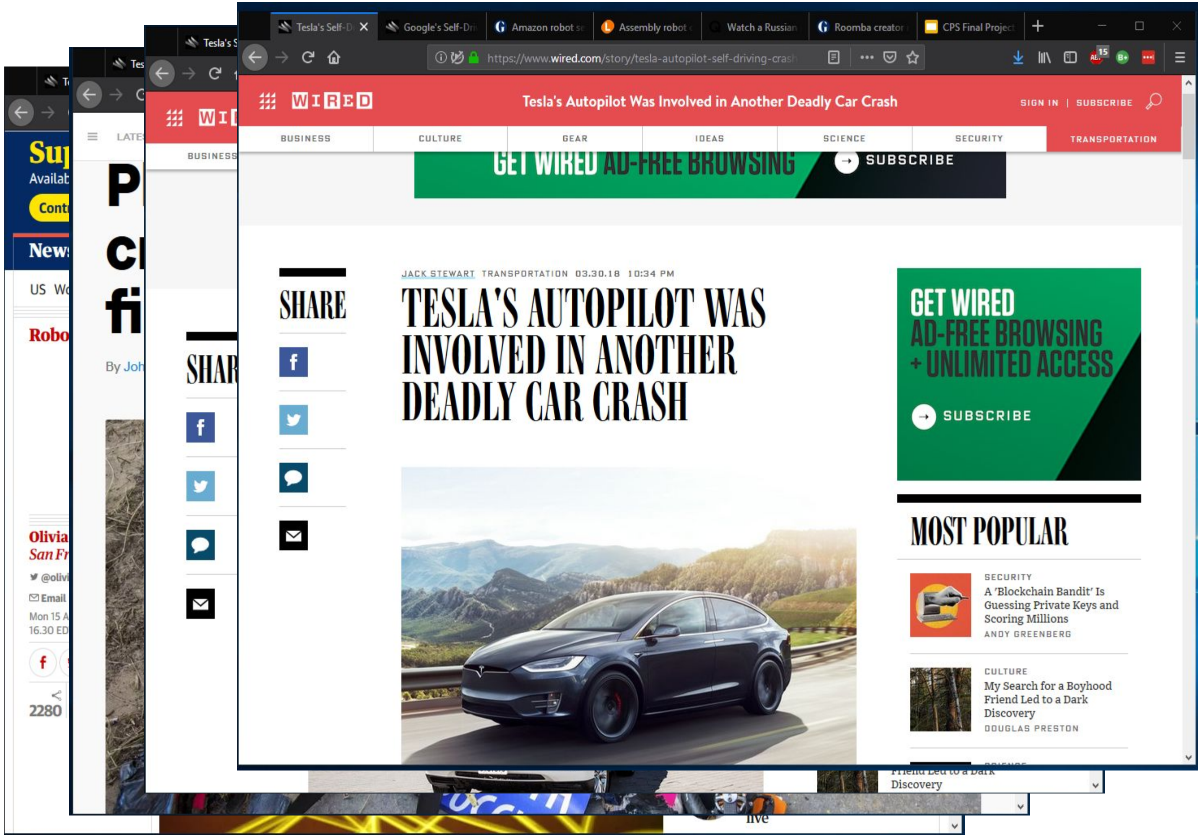

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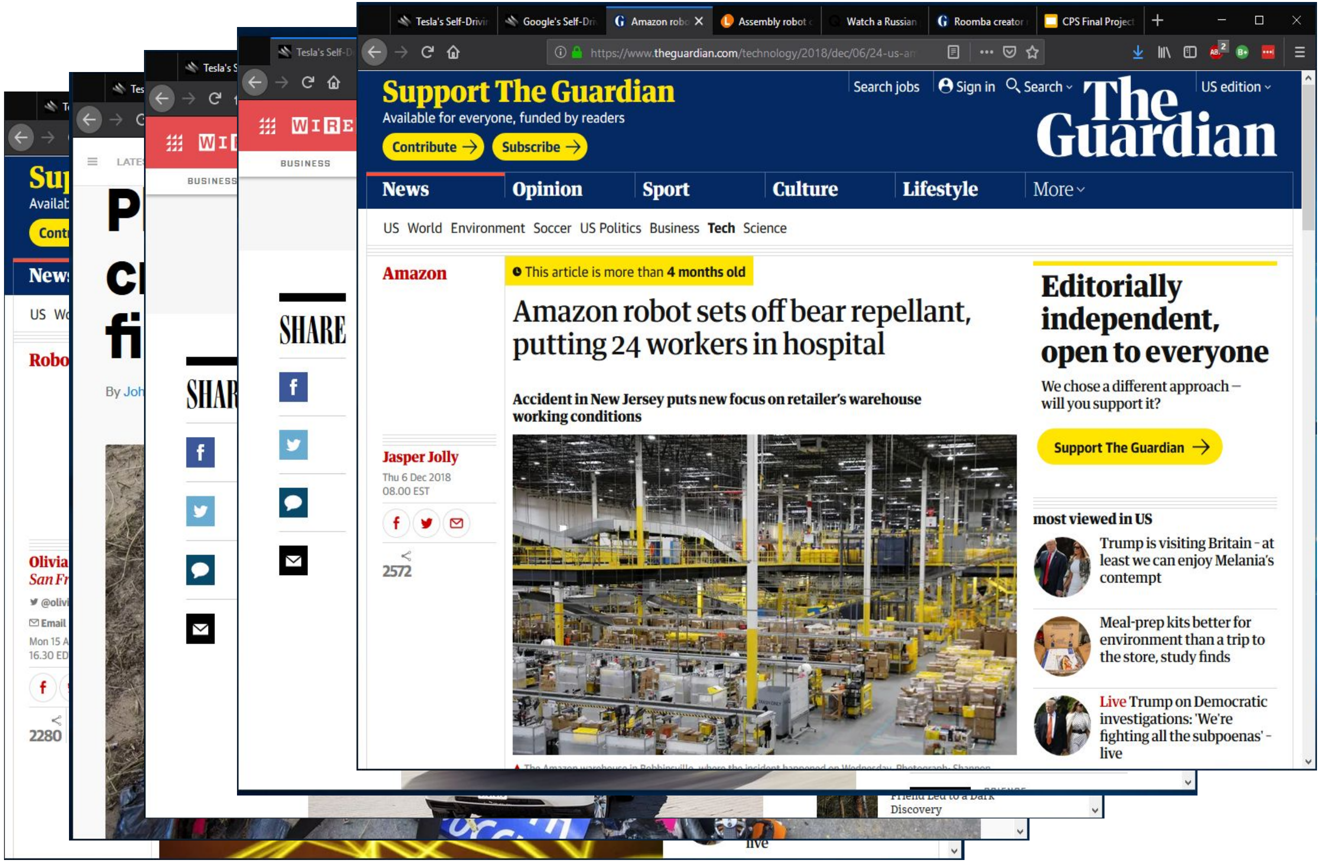

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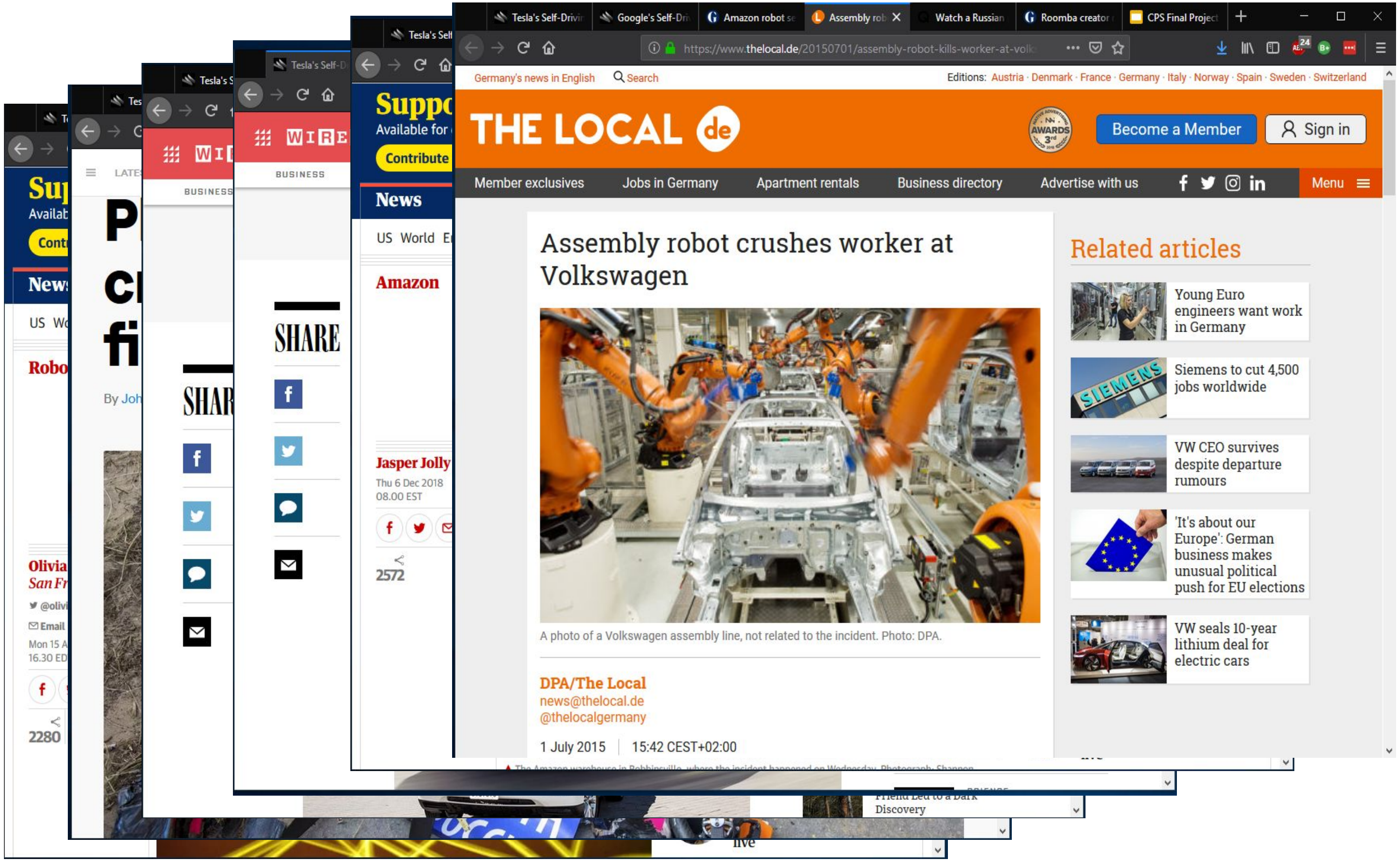

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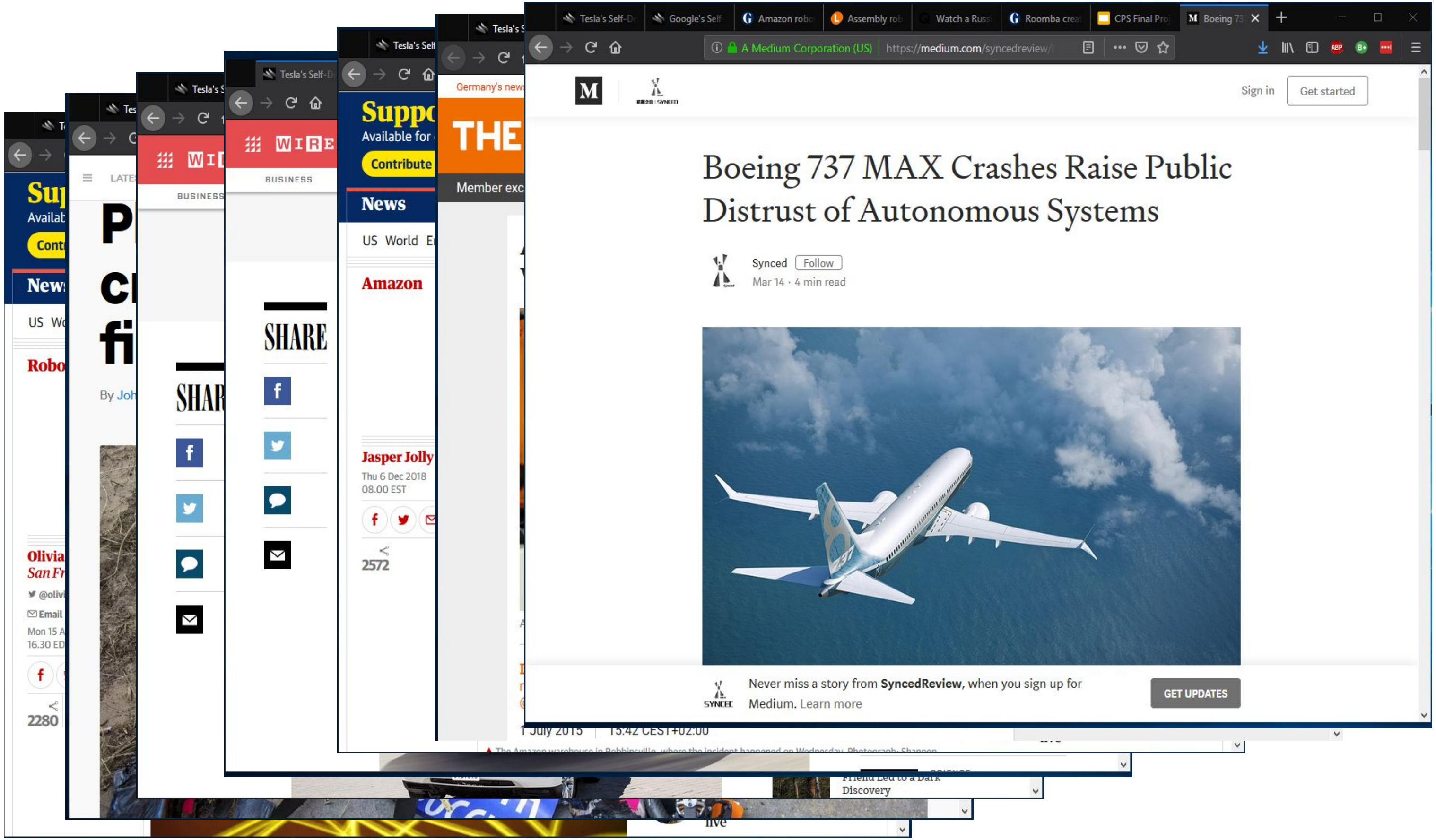
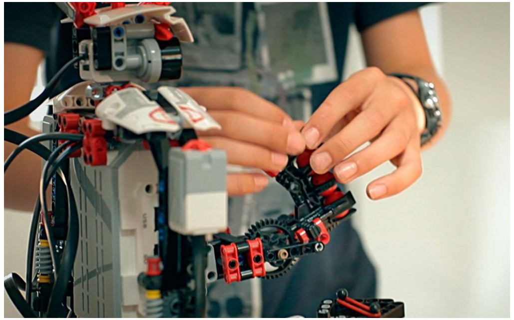
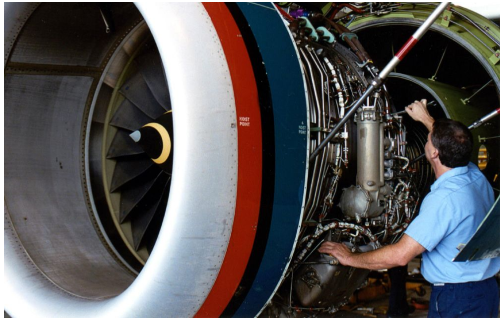


Problem

- Faults occur when system changes
- Errors come from incompatibilities between:
  - Hardware and other hardware
  - Hardware and software
- Isolating the differences caused by hardware changes is difficult





Is it possible to create **test cases** that **identify differences** in robot behavior brought about by **hardware changes**?

Goals

- Devise technique to formally model differences spurred by hardware changes.
- Construct test cases that identifies and isolates differences.
- (Bonus) Uncover existing bugs in legacy code.

Method

- Clearpath Husky Robot
    - Well-known autonomous ground vehicle
    - Very customizable
- What do you notice about the Husky Robots?

Customers of Clearpath Robotics

Examples of Husky Robot

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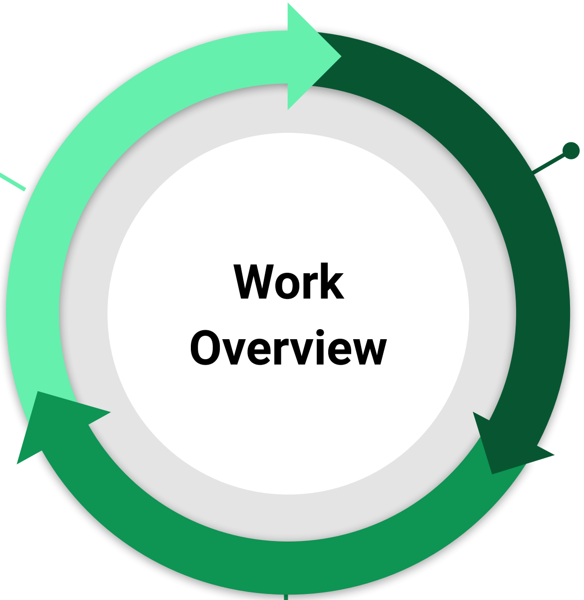
Examples of Husky Robot

Method

Test Generation

Constraints containing information about the both laser scanners were used to generate tests.



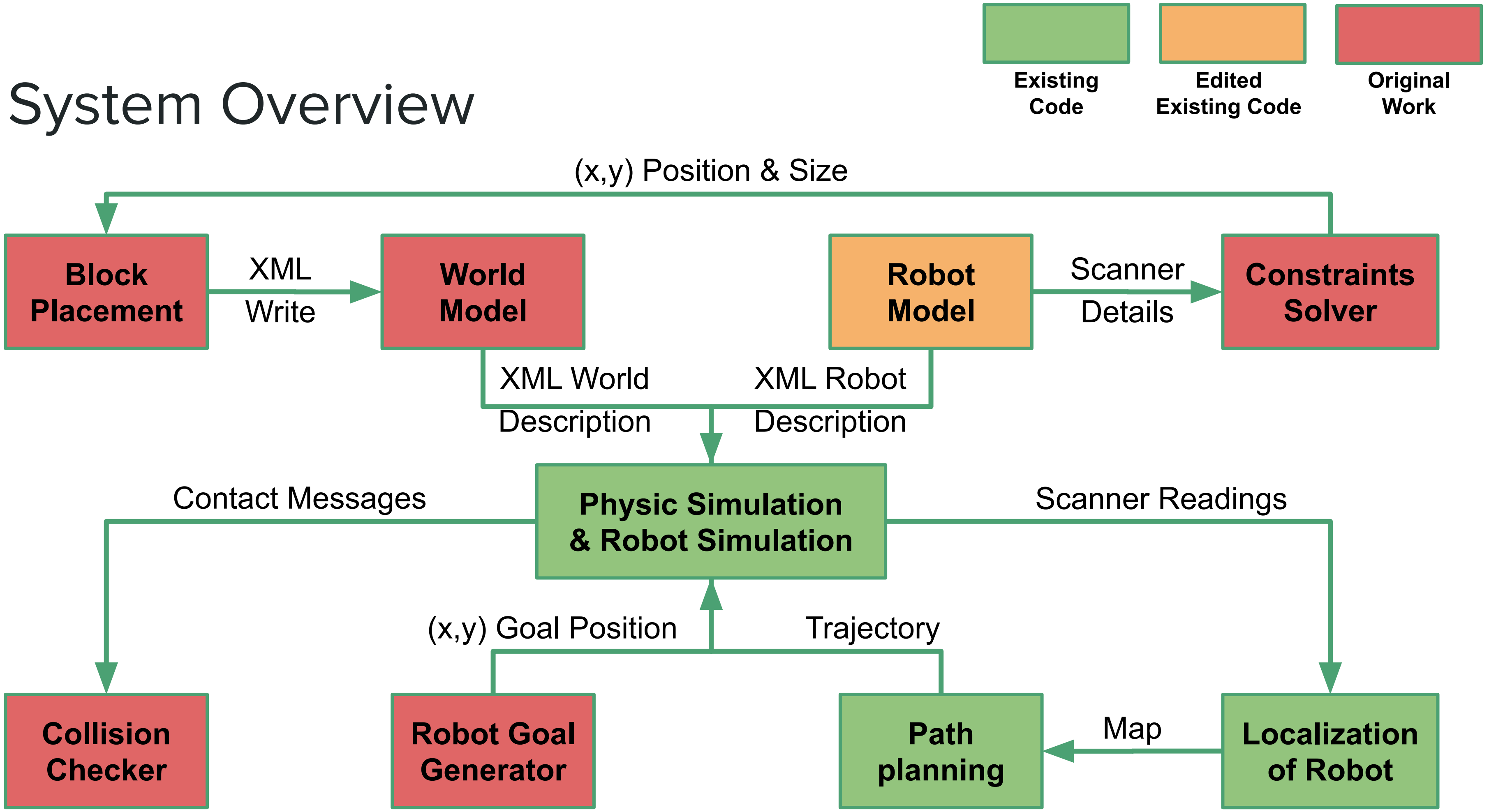
World Generation

The world was generated using a ground plane and cube(s). The robot was placed. A goal was set.

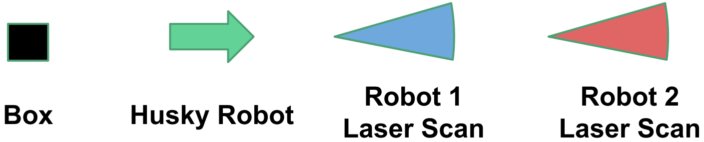
Robot Simulation

The robot was allowed to navigate autonomously to the goal. Collisions were monitored.

System Overview

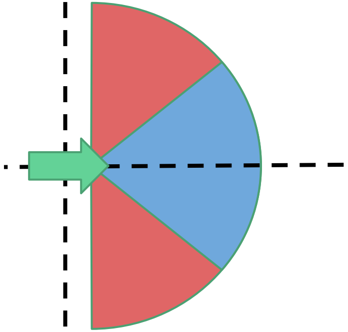


Constraints



Blind Spot Constraint

$$\text{Block Angle} > \text{Max\_Angle}_{\text{robot1}}$$
$$\text{Block Angle} < \text{Max\_Angle}_{\text{robot2}}$$
$$0 \leq x \leq \text{Beam Length}$$
$$y = tan(\text{Block Angle}) \times x$$



Distance Constraint

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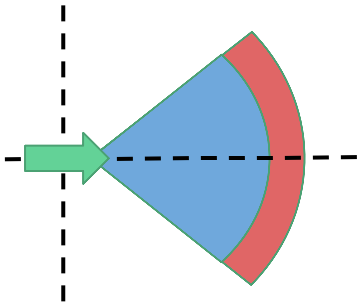

Size Constraint

$$x = \text{Beam Length} \; ; y = 0$$
$$\text{Range} = |\text{Max\_Angle}| + |\text{Min\_Angle}|$$
$$\text{Sectors} = max(\text{Number beams}) - 1$$
$$\text{Sector Angle} = \frac{\text{Range}}{\text{Sectors}}$$
$$\text{Sector Size} = tan(\text{Sector Angle} \div 2) \times x$$
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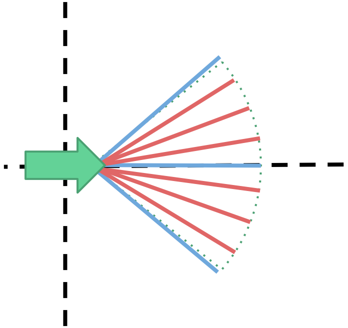

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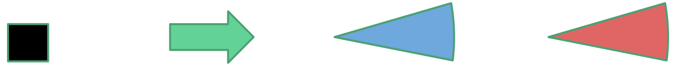

Box

Husky Robot

Robot 1 Laser Scan

Robot 2 Laser Scan

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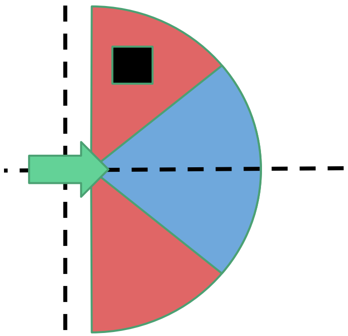

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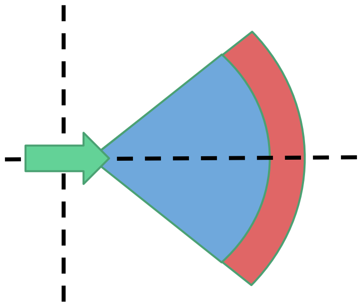

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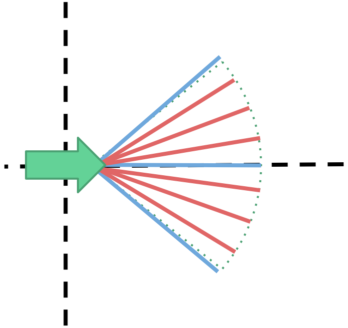

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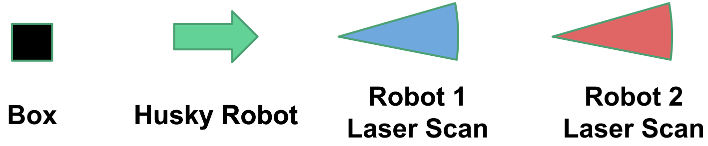

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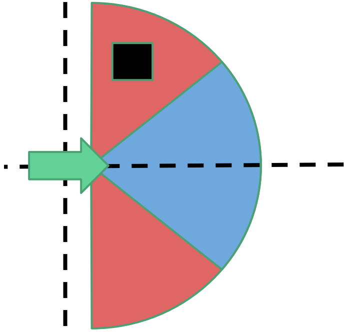

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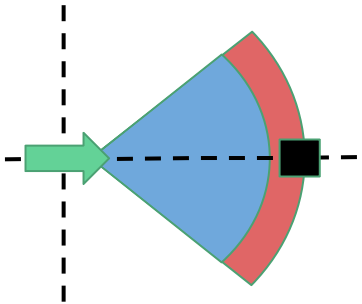

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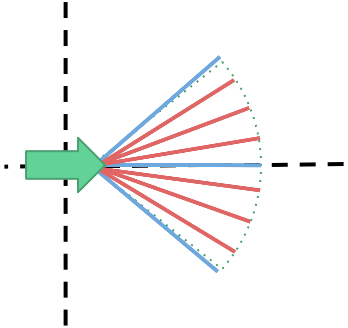

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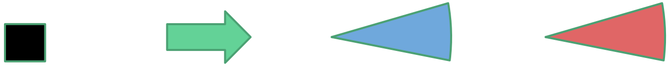

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Husky Robot

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Laser Scan

Robot 2
Laser Scan

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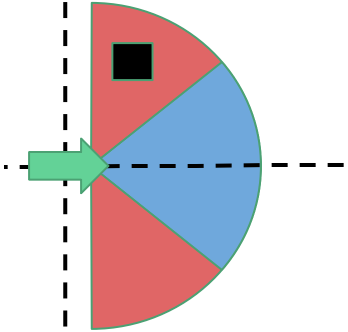

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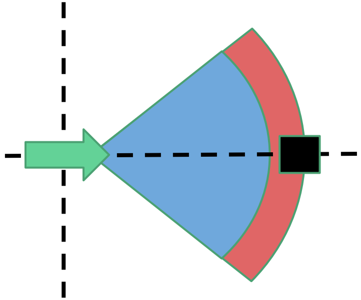

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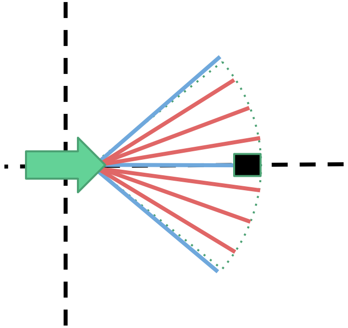


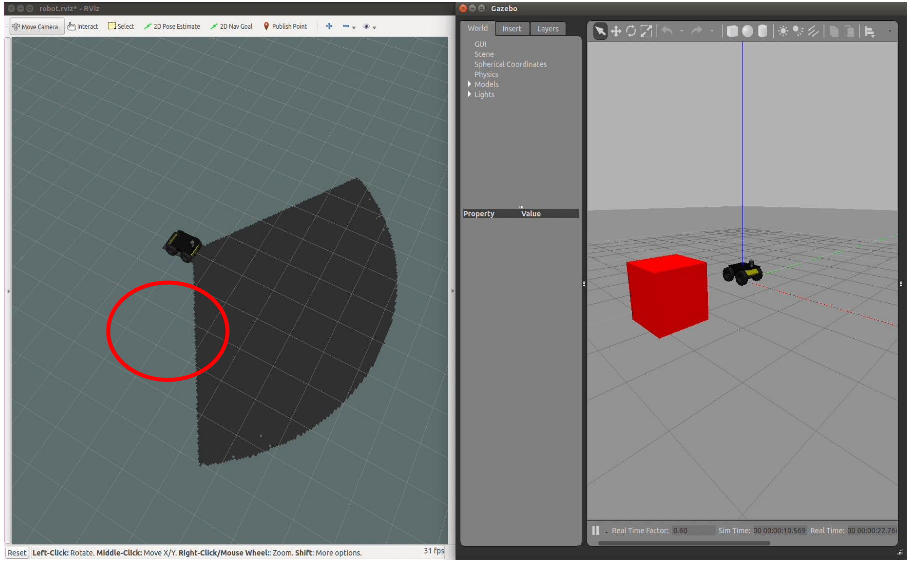
Results - Blind Constraint

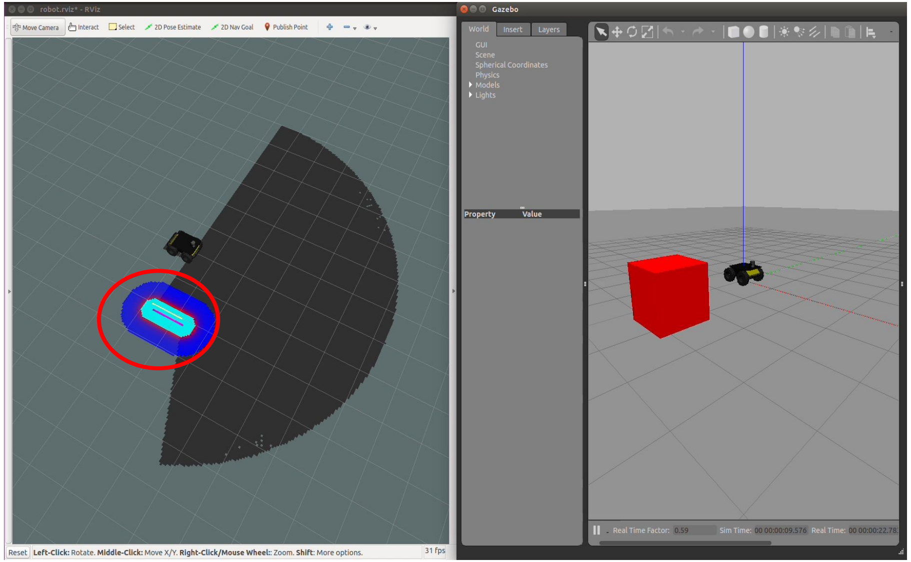
Robot 1:

- Minimum Angle: -1 rad
- Maximum Angle: 1 rad

Robot 2:

- Minimum Angle: $-\pi/2$ rad
- Maximum Angle: $\pi/2$ rad





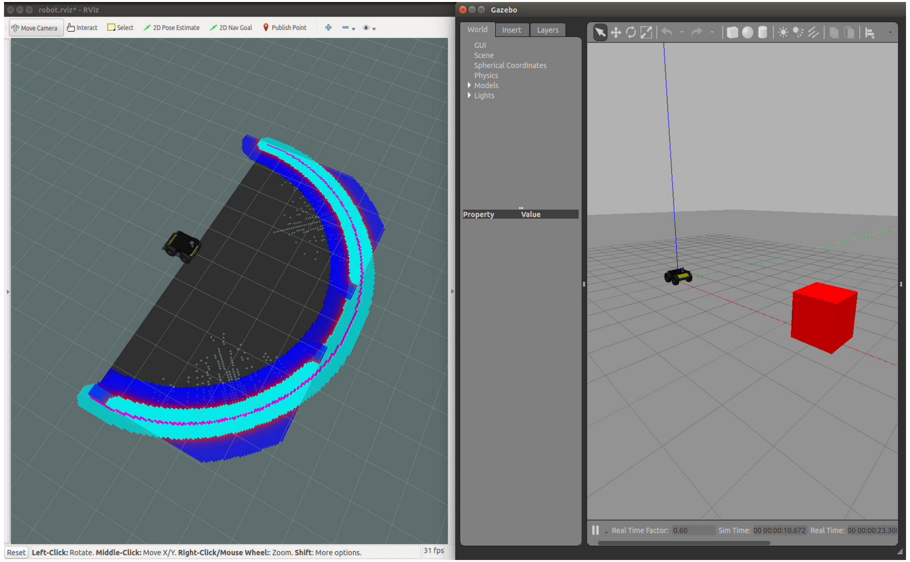
Results - Distance Constraint

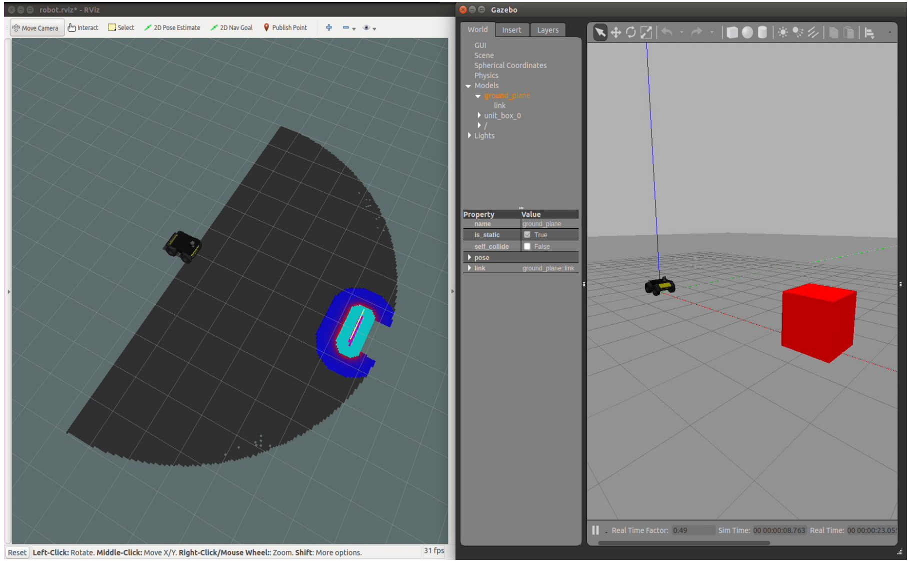
Robot 1:

- Max Range: 5m

Robot 2:

- Max Range: 10m





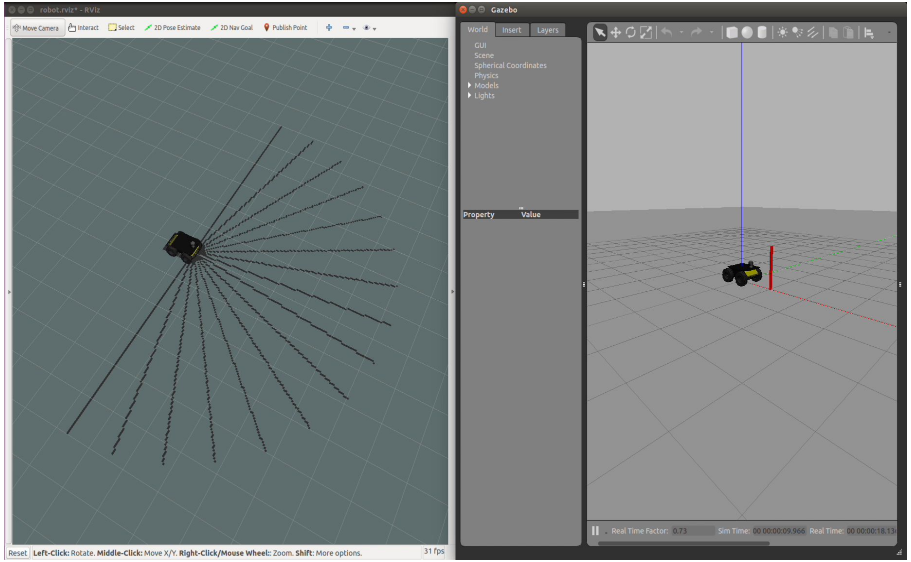
Results - Size Constraint

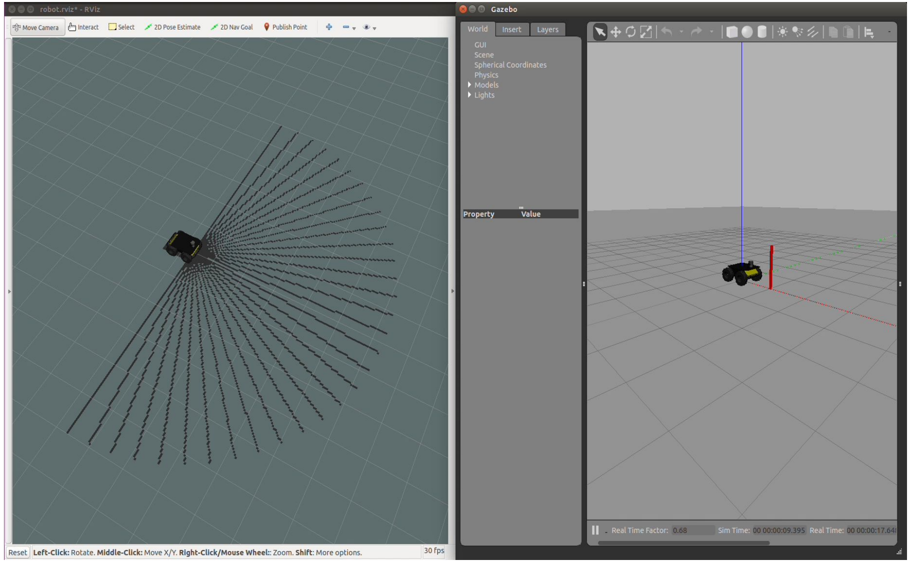
Robot 1:

- Resolution: 16 samples

Robot 2:

- Resolution: 32 samples





Questions