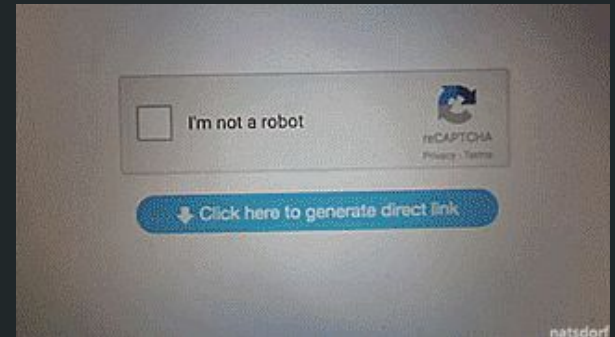


Automatic Test Generation for Physical Systems

Melony Bennis (mmb4vu)
Carl Hildebrandt (ch6wd)



Motivation

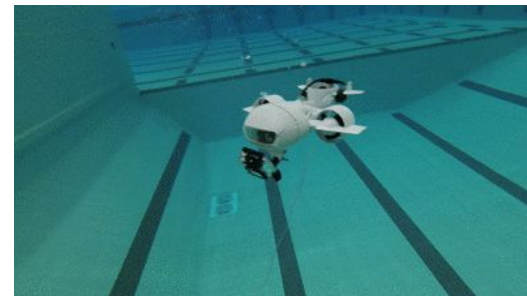
Autonomous vehicles are becoming a **reality** in society



Amazon Drone-Releasing Blimp



Amazon Warehouse Robots



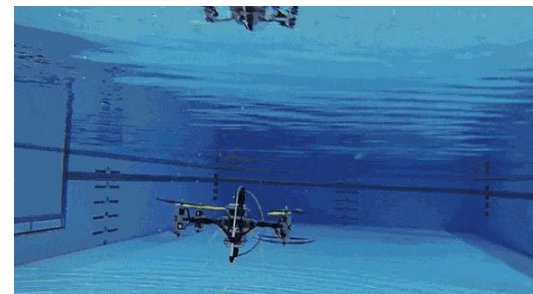
Autonomous Aquatic Vehicles



Autonomous Differential Drive Robots



Self Driving Cars



Aerial-Aquatic Vehicles

Traditional testing is **not** enough.

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Robots

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Robotic vacuum cleaner is said to run over animal feces and continue its cleaning cycle around the house, spreading the mess over 'every conceivable surface'

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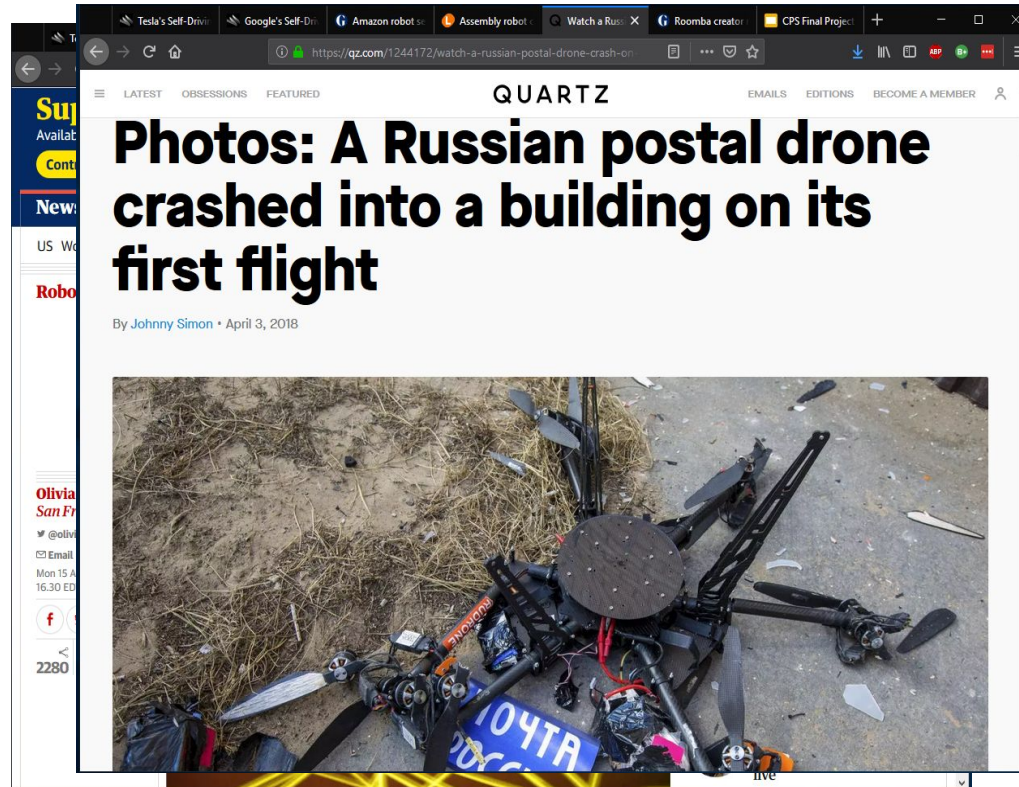
- Trump is visiting Britain - at least we can enjoy Melania's contempt
- Meal-prep kits better for environment than a trip to the store, study finds
- Live Trump on Democratic investigations: 'We're fighting all the subpoenas' - live

Olivia Solon in San Francisco
@oliviasolon
Mon 15 Aug 2016 16:30 EDT

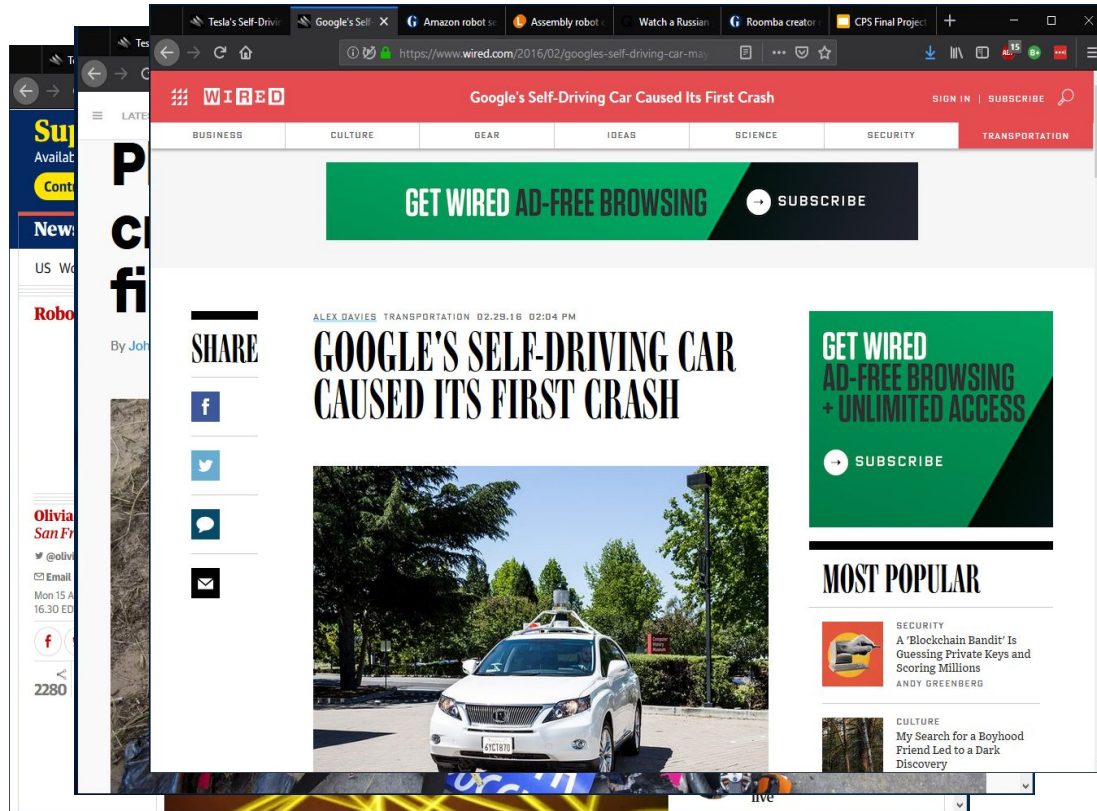
2280 268



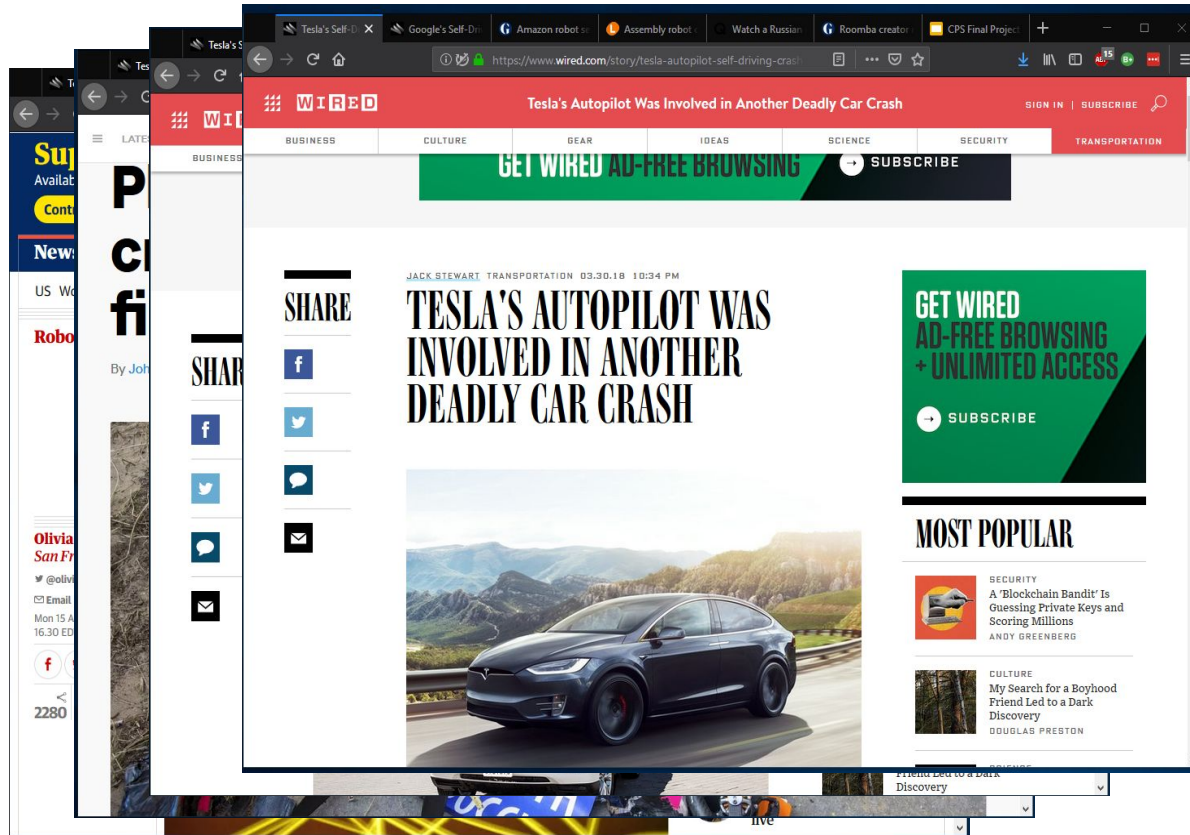
Traditional testing is **not** enough.



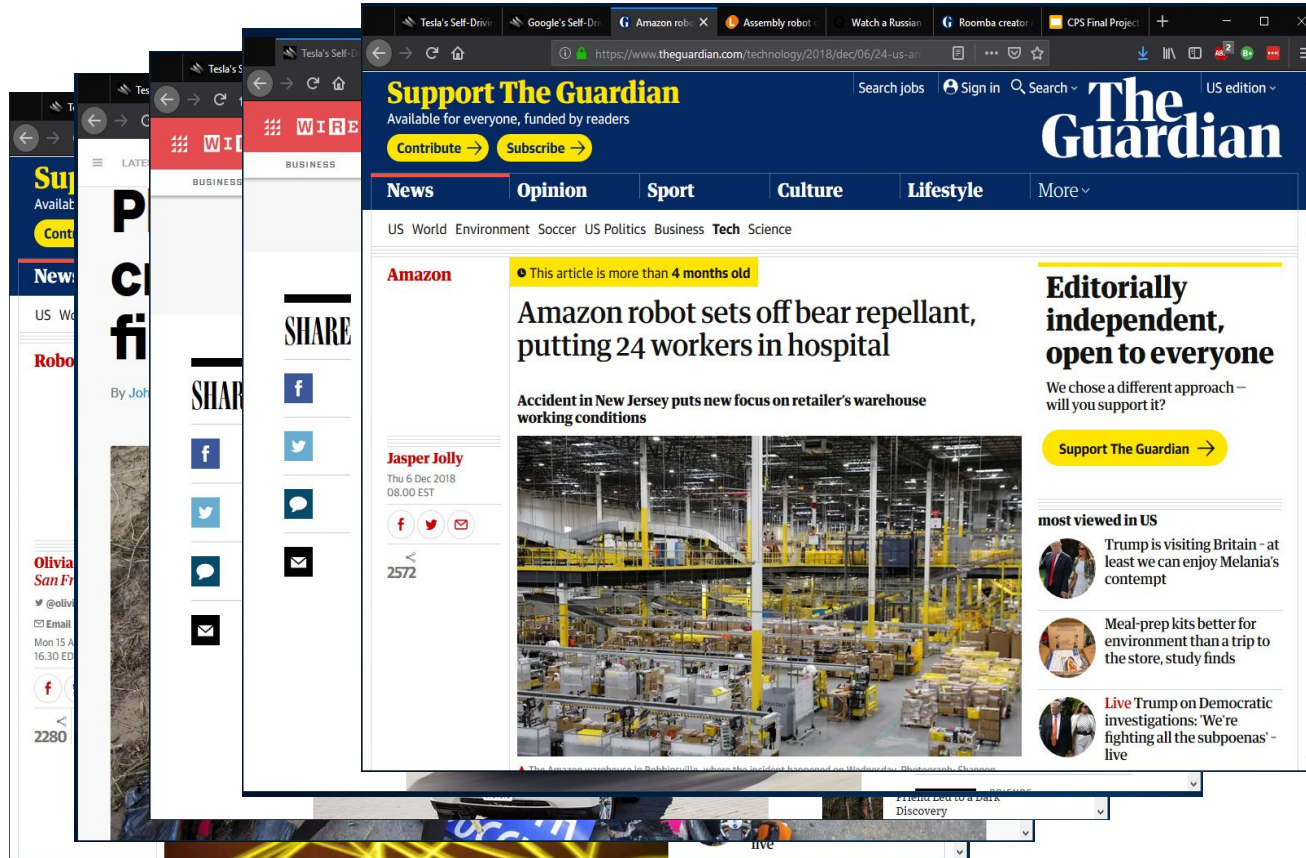
Traditional testing is **not** enough.



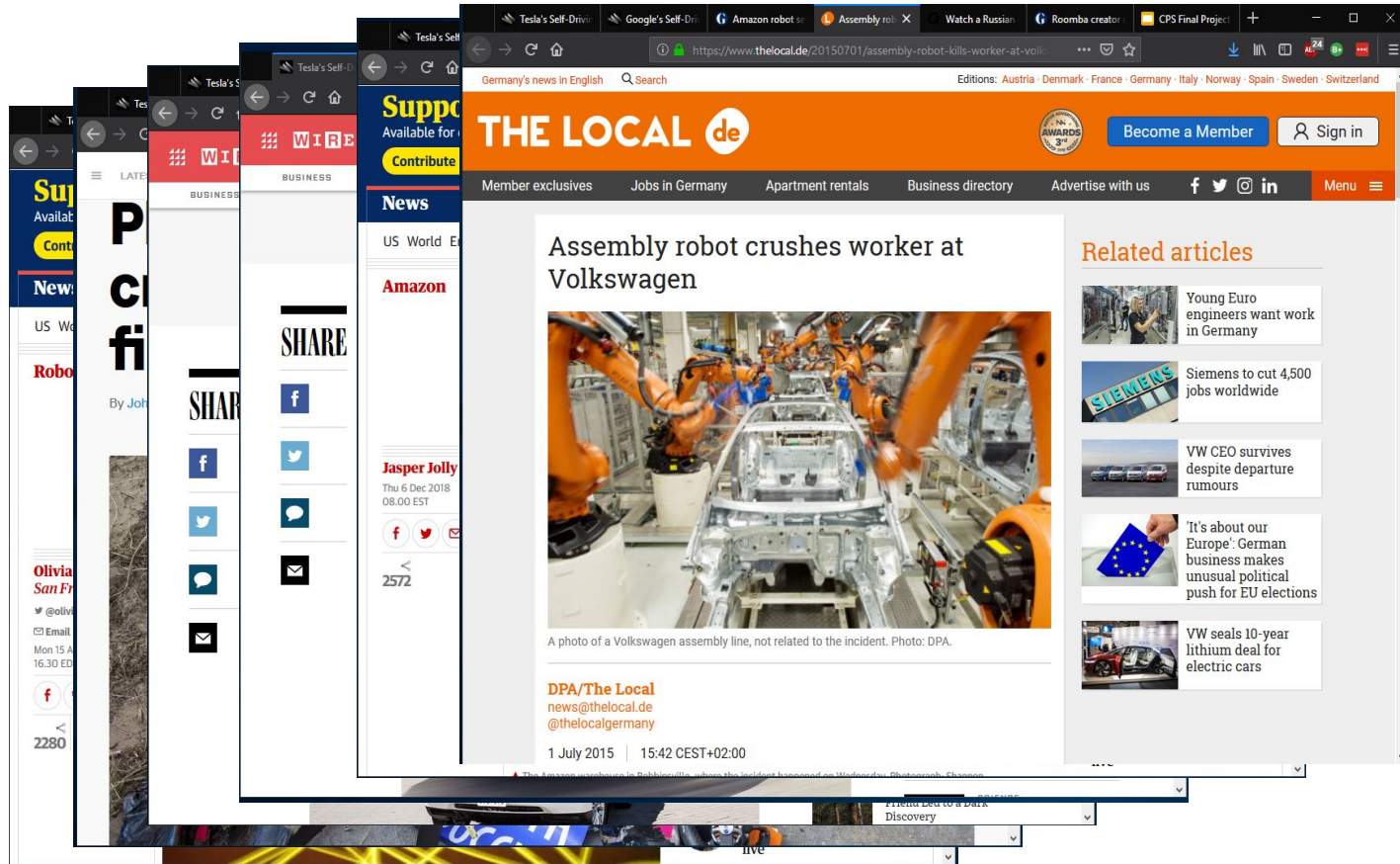
Traditional testing is **not** enough.



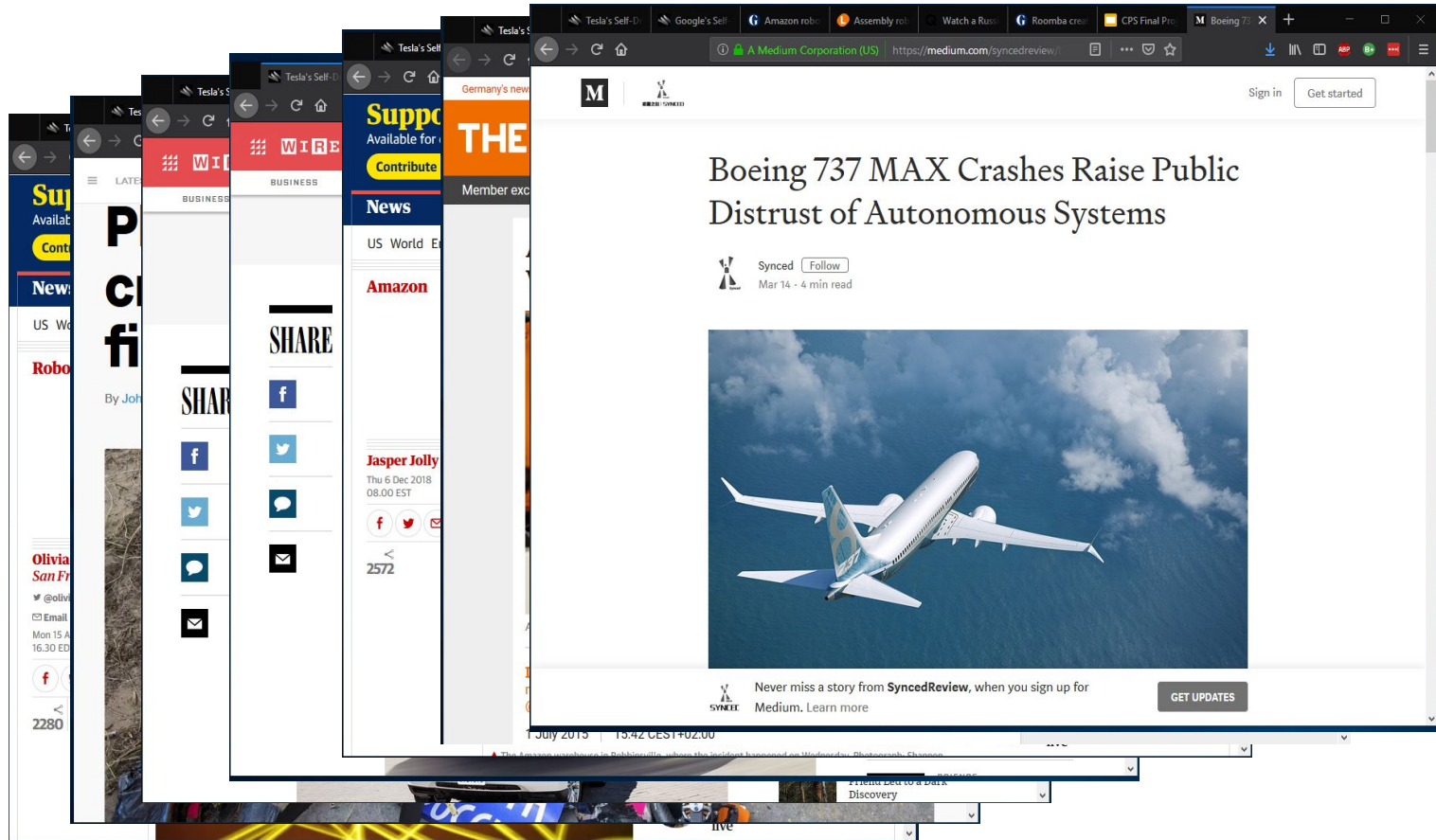
Traditional testing is **not** enough.



Traditional testing is **not** enough.

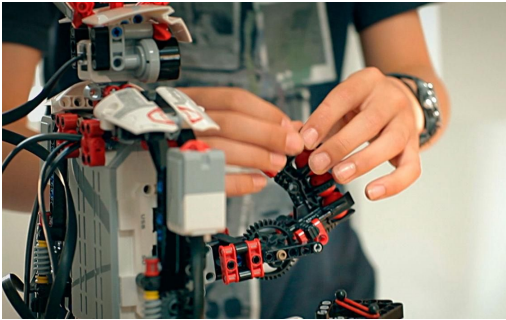


Traditional testing is **not** enough.



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

Method

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

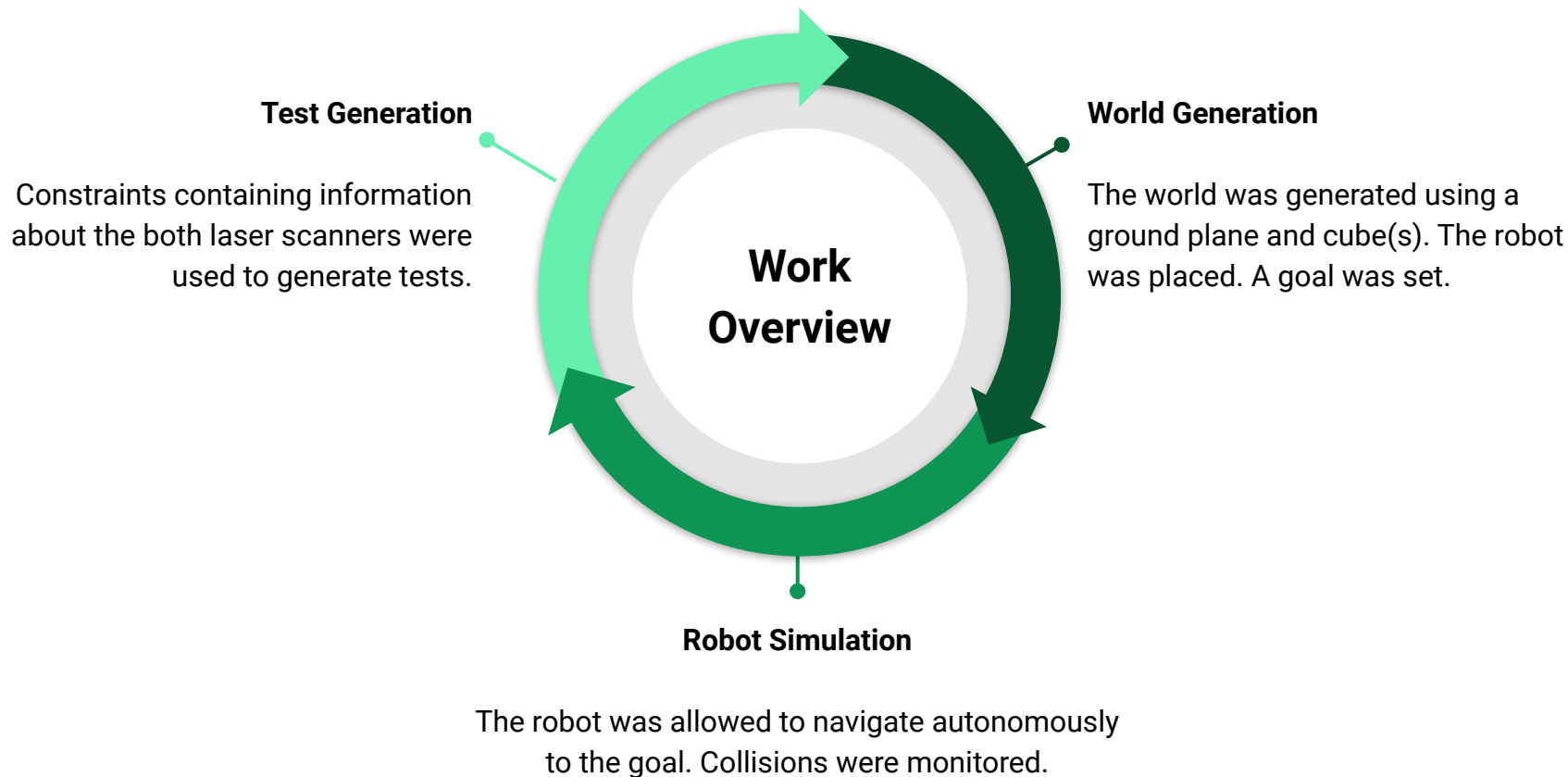


Customers of Clearpath Robotics

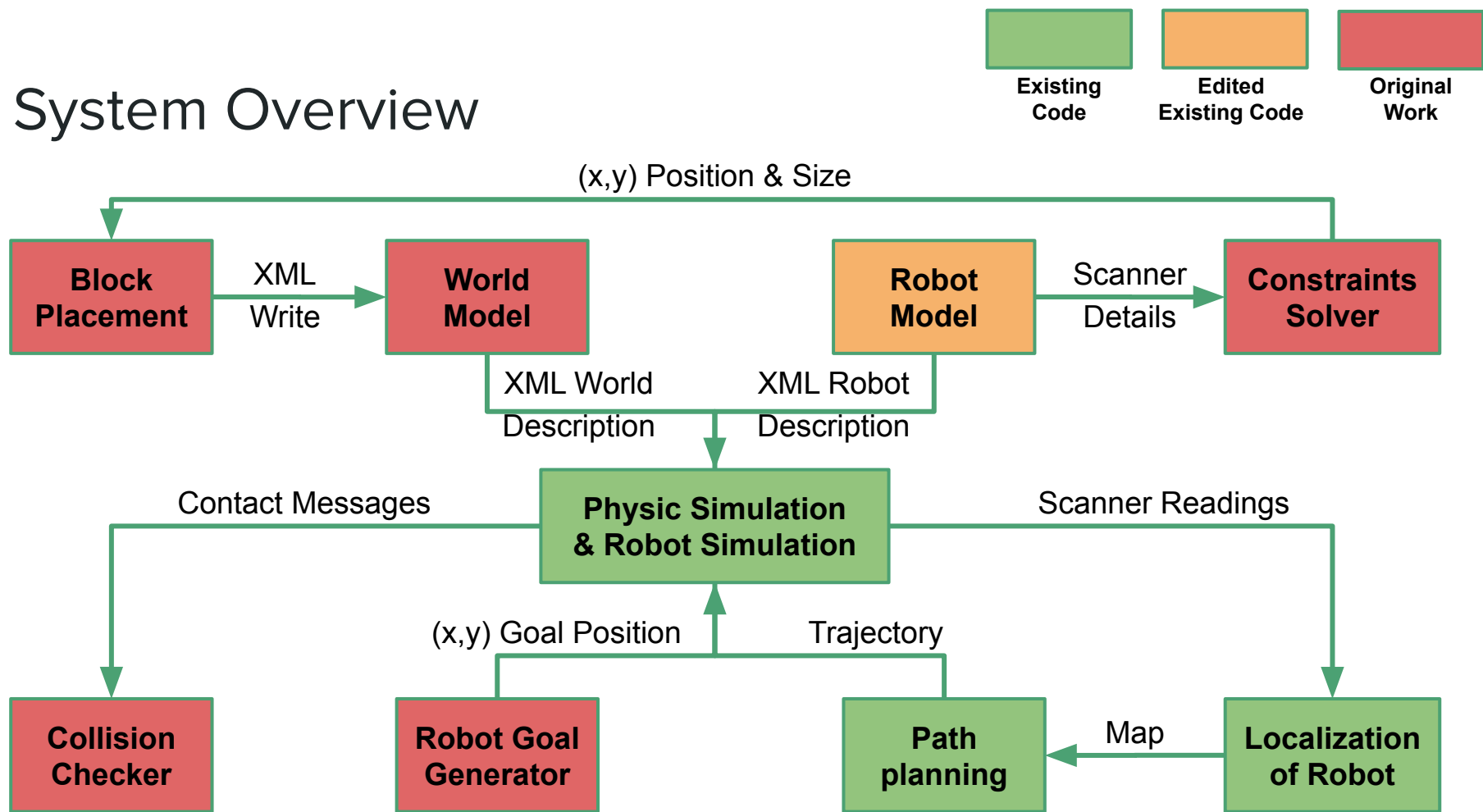


Examples of Husky Robot

Method



System Overview



Constraints



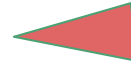
Box



Husky Robot



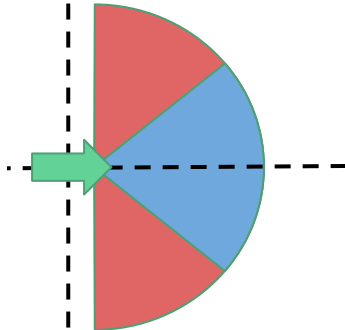
Robot 1
Laser Scan



Robot 2
Laser Scan

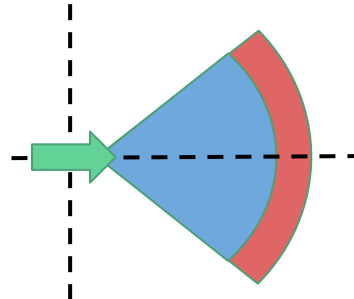
Blind Spot Constraint

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



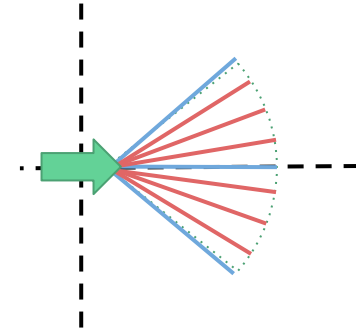
Distance Constraint

$\text{Block Angle} > \text{Min_Angle}_{\text{robot1}}$
 $\text{Block Angle} < \text{Max_Angle}_{\text{robot2}}$
 $x < \text{Beam Length}_{\text{robot1}}$
 $x > \text{Beam Length}_{\text{robot2}}$
 $y = \tan(\text{Block Angle}) \times x$



Size Constraint

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



Constraints



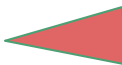
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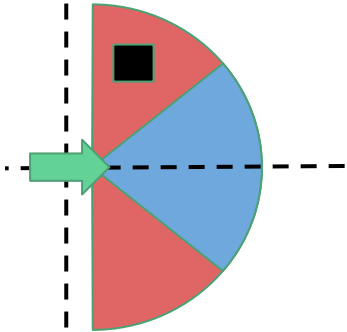
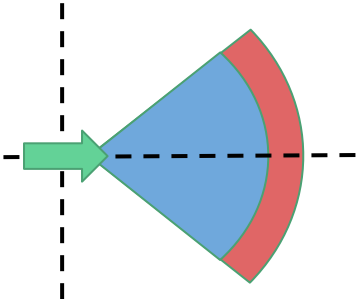
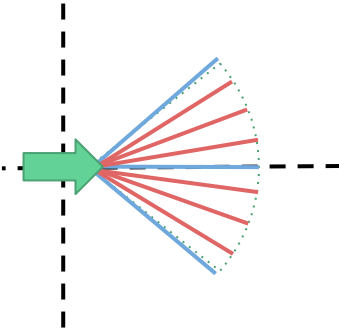
Husky Robot



Robot 1
Laser Scan



Robot 2
Laser Scan

Blind Spot Constraint	Distance Constraint	Size Constraint
<p>Block Angle $>$ $\text{Max_Angle}_{\text{robot1}}$</p> <p>Block Angle $<$ $\text{Max_Angle}_{\text{robot2}}$</p> <p>$0 \leq x \leq \text{Beam Length}$</p> <p>$y = \tan(\text{Block Angle}) \times x$</p> 	<p>Block Angle $>$ $\text{Min_Angle}_{\text{robot1}}$</p> <p>Block Angle $<$ $\text{Max_Angle}_{\text{robot2}}$</p> <p>$x < \text{Beam Length}_{\text{robot1}}$</p> <p>$x > \text{Beam Length}_{\text{robot2}}$</p> <p>$y = \tan(\text{Block Angle}) \times x$</p> 	<p>$x = \text{Beam Length} ; y = 0$</p> <p>$\text{Range} = \text{Max_Angle} + \text{Min_Angle}$</p> <p>$\text{Sectors} = \max(\text{Number beams}) - 1$</p> <p>$\text{Sector Angle} = \frac{\text{Range}}{\text{Sectors}}$</p> <p>$\text{Sector Size} = \tan(\text{Sector Angle} \div 2) \times x$</p> <p>$0 < \text{Size} \leq \text{Sector Size}$</p> 

Constraints



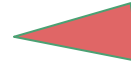
Box



Husky Robot



Robot 1
Laser Scan



Robot 2
Laser Scan

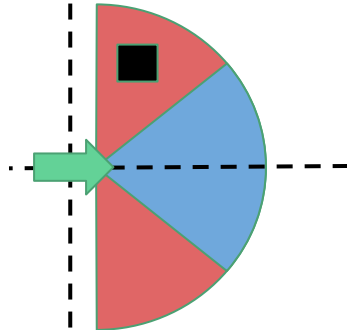
Blind Spot Constraint

$$\text{Block Angle} > \text{Max_Angle}_{\text{robot1}}$$

$$\text{Block Angle} < \text{Max_Angle}_{\text{robot2}}$$

$$0 \leq x \leq \text{Beam Length}$$

$$y = \tan(\text{Block Angle}) \times x$$



Distance Constraint

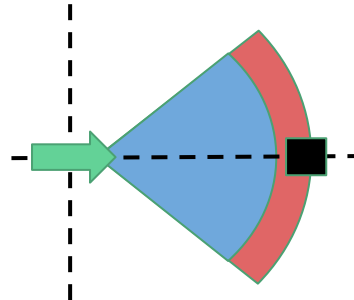
$$\text{Block Angle} > \text{Min_Angle}_{\text{robot1}}$$

$$\text{Block Angle} < \text{Max_Angle}_{\text{robot2}}$$

$$x < \text{Beam Length}_{\text{robot1}}$$

$$x > \text{Beam Length}_{\text{robot2}}$$

$$y = \tan(\text{Block Angle}) \times x$$



Size Constraint

$$x = \text{Beam Length} ; y = 0$$

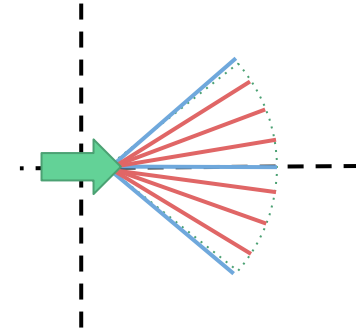
$$\text{Range} = |\text{Max_Angle}| + |\text{Min_Angle}|$$

$$\text{Sectors} = \max(\text{Number beams}) - 1$$

$$\text{Sector Angle} = \frac{\text{Range}}{\text{Sectors}}$$

$$\text{Sector Size} = \tan(\text{Sector Angle} \div 2) \times x$$

$$0 < \text{Size} \leq \text{Sector Size}$$



Constraints



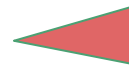
Box



Husky Robot



Robot 1
Laser Scan



Robot 2
Laser Scan

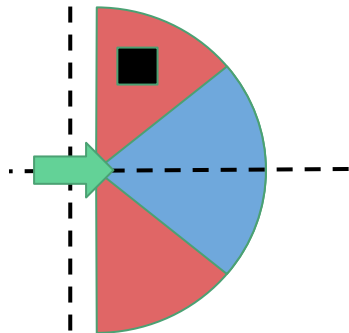
Blind Spot Constraint

$$\text{Block Angle} > \text{Max_Angle}_{\text{robot1}}$$

$$\text{Block Angle} < \text{Max_Angle}_{\text{robot2}}$$

$$0 \leq x \leq \text{Beam Length}$$

$$y = \tan(\text{Block Angle}) \times x$$



Distance Constraint

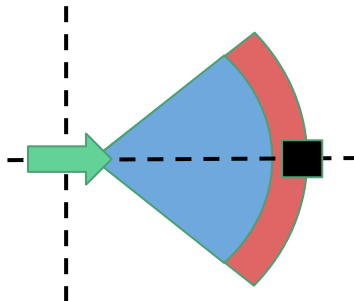
$$\text{Block Angle} > \text{Min_Angle}_{\text{robot1}}$$

$$\text{Block Angle} < \text{Max_Angle}_{\text{robot2}}$$

$$x < \text{Beam Length}_{\text{robot1}}$$

$$x > \text{Beam Length}_{\text{robot2}}$$

$$y = \tan(\text{Block Angle}) \times x$$



Size Constraint

$$x = \text{Beam Length} ; y = 0$$

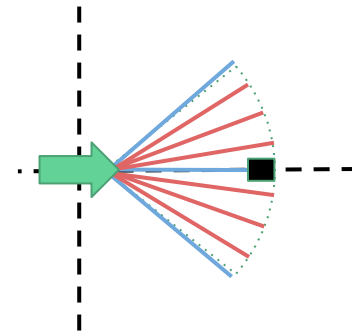
$$\text{Range} = |\text{Max_Angle}| + |\text{Min_Angle}|$$

$$\text{Sectors} = \max(\text{Number beams}) - 1$$

$$\text{Sector Angle} = \frac{\text{Range}}{\text{Sectors}}$$

$$\text{Sector Size} = \tan(\text{Sector Angle} \div 2) \times x$$

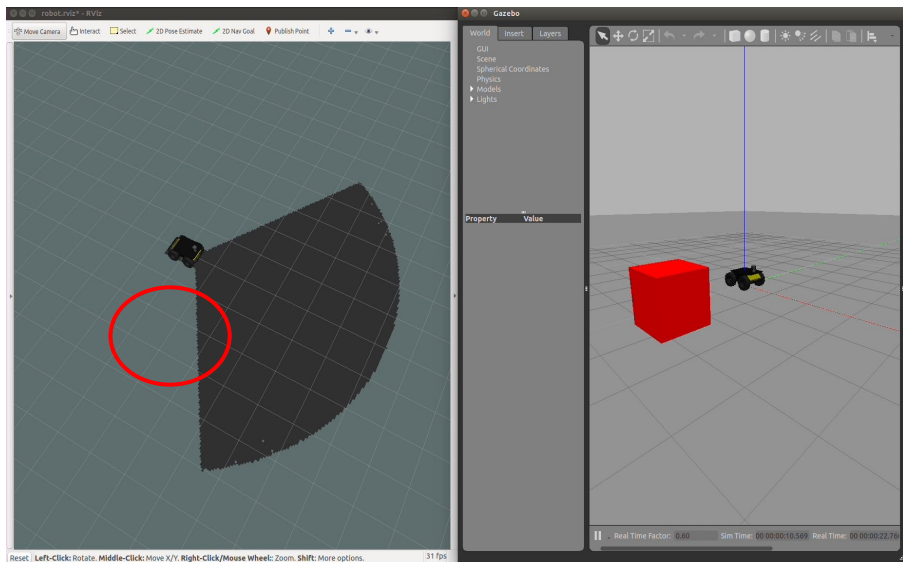
$$0 < \text{Size} \leq \text{Sector Size}$$



Results - Blind Constraint

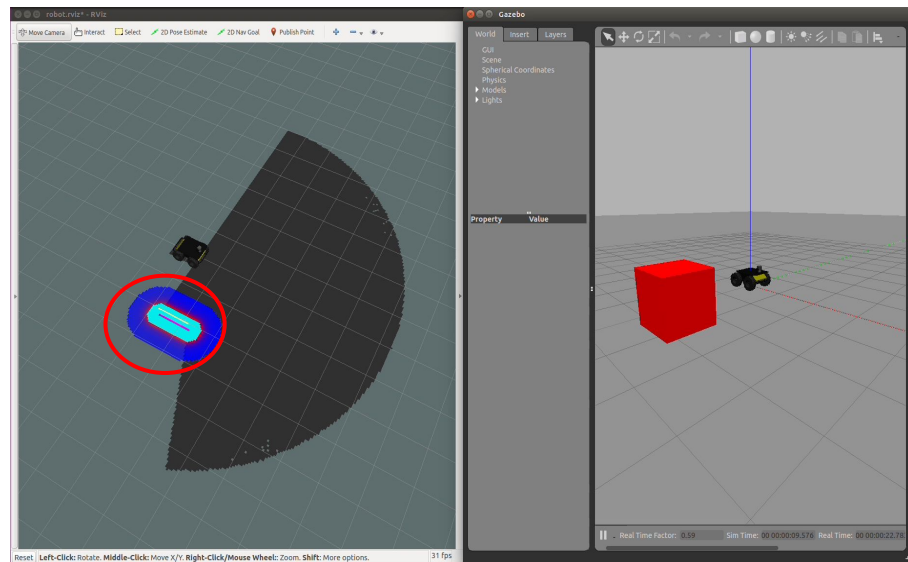
Robot 1:

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



Robot 2:

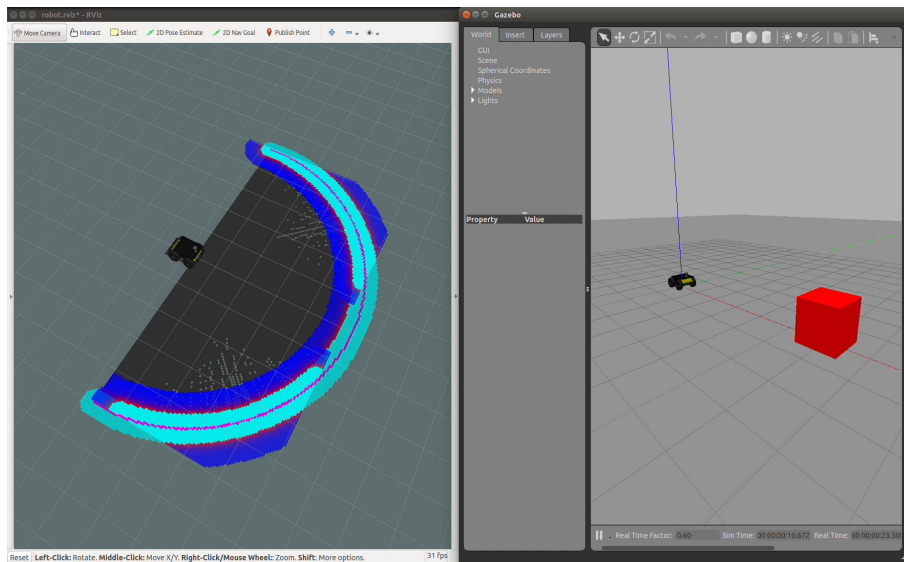
- Minimum Angle: $-\pi/2$ rad
- Maximum Angle: $\pi/2$ rad



Results - Distance Constraint

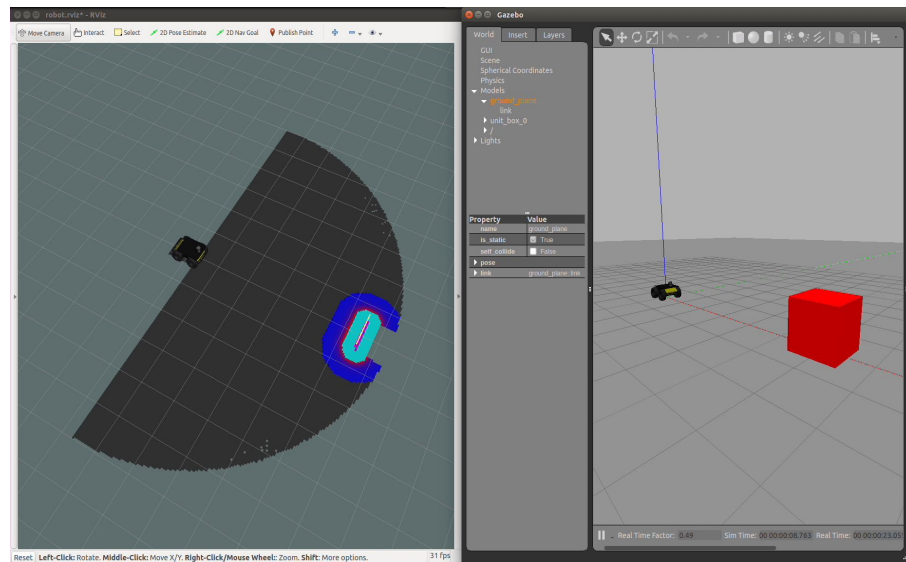
Robot 1:

- Max Range: 5m



Robot 2:

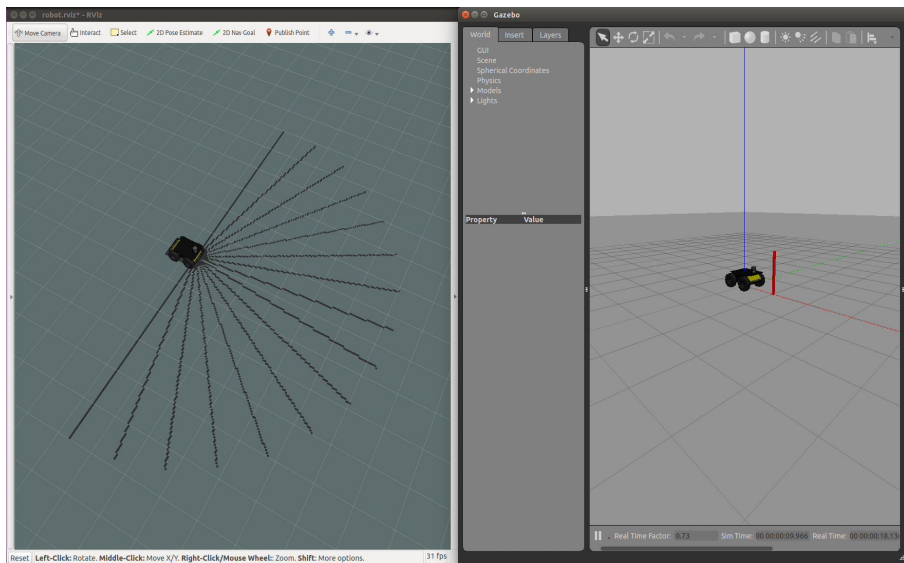
- Max Range: 10m



Results - Size Constraint

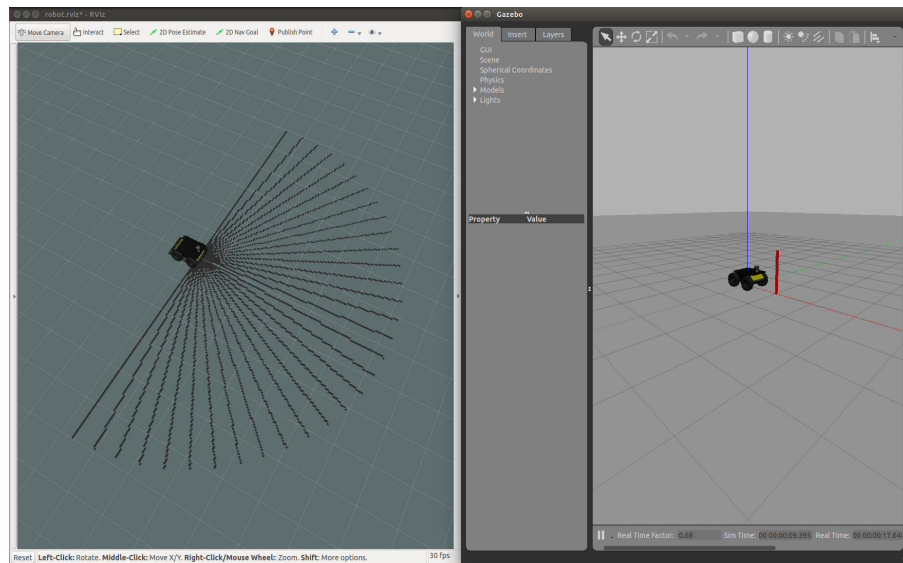
Robot 1:

- Resolution: 16 samples



Robot 2:

- Resolution: 32 samples



Questions

