Junior Robots at the Rescue

Arnoud Visser

Bridging the cap to CoSpace workshop
Cambridge, March 20, 2019

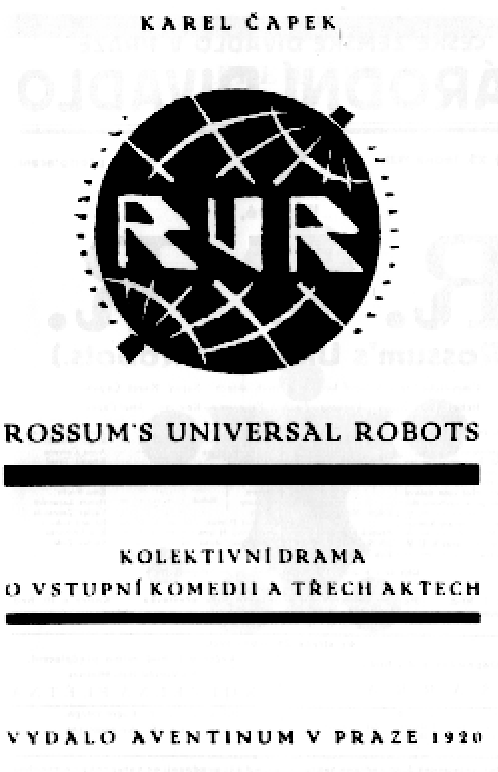
UNIVERSITY OF CAMBRIDGE

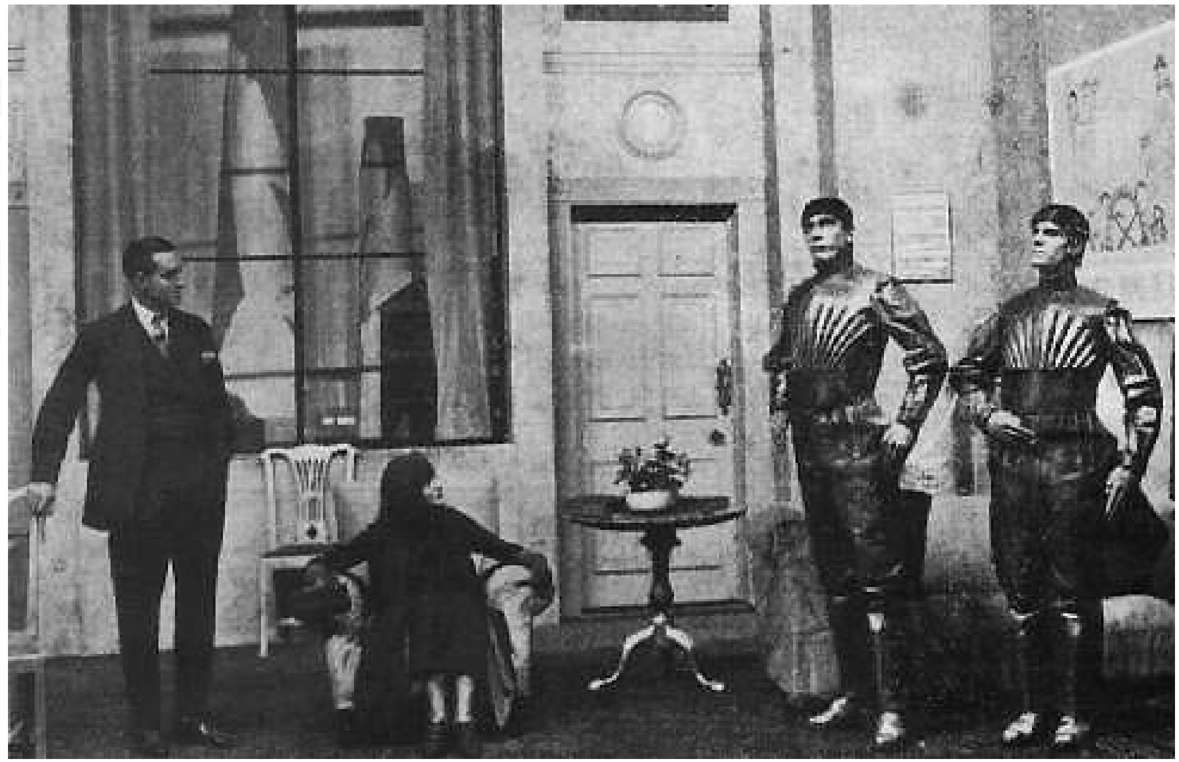
Universiteit van Amsterdam

In close cooperation with

中京大学
CHUKYO UNIVERSITY

The Robot





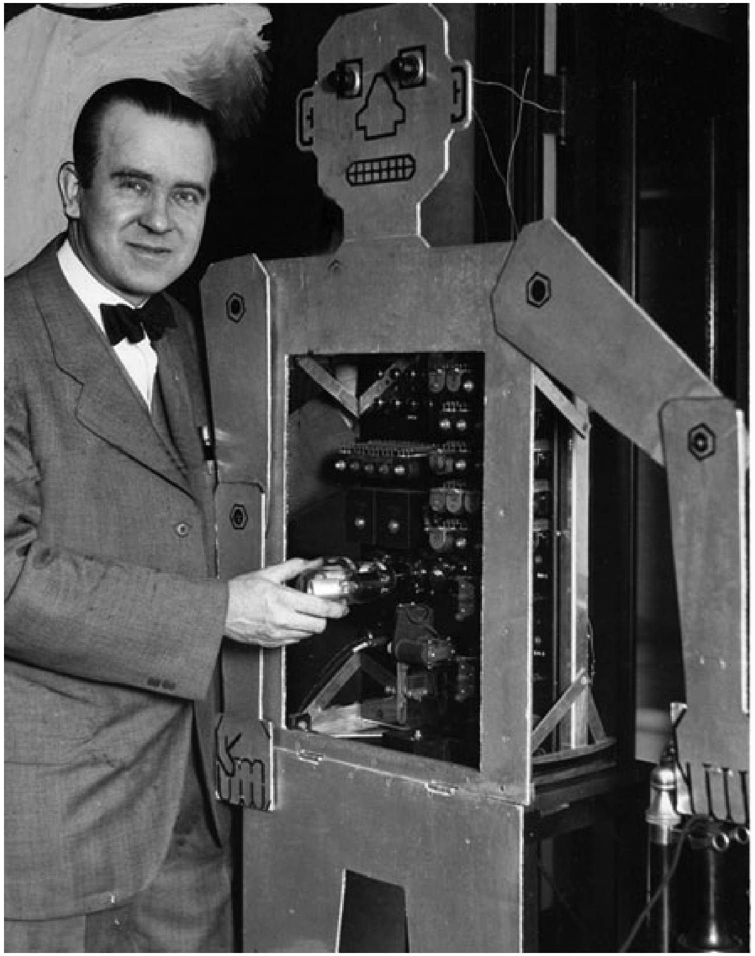
The word *robot* was introduced in 1920 in a play by Karel Capek called R.U.R

Electro

Westinghouse Motor Man, 1939

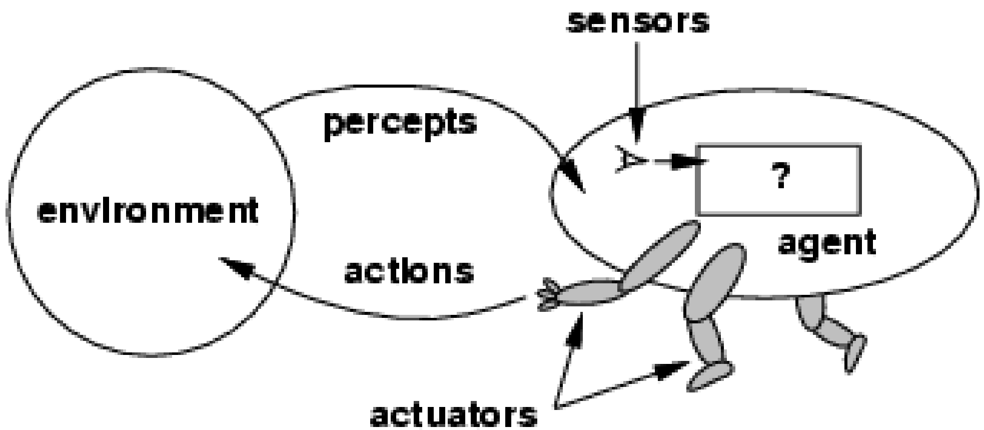
youtube

Herbert Televox



Controlled by analog switches

Physical situated agent



An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators†

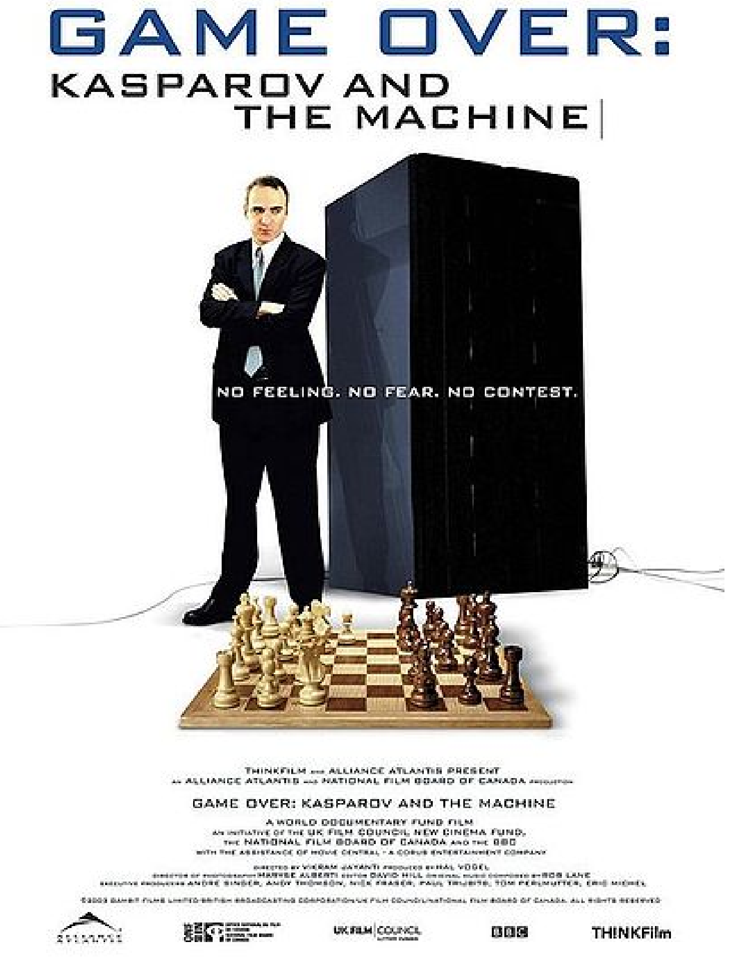
† Russell & Norvig, 'Artificial Intelligence – A modern approach', Prentice Hall, 2003

AIMA p. 32

Anthropic principle

To replace a human worker,
a robot needs the equivalent of

- ✓ Human knowledge
- ✓ Human rational
- Human perception
- Human actuators
- Human communication



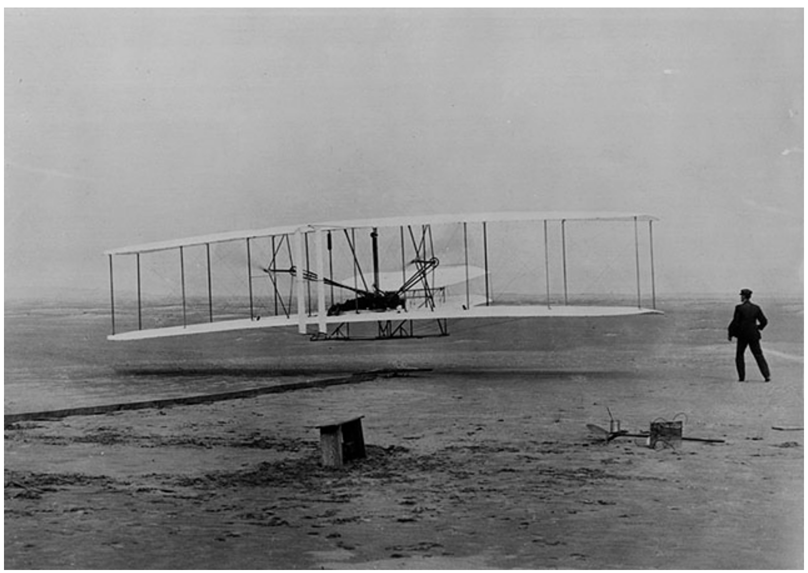
RoboCup

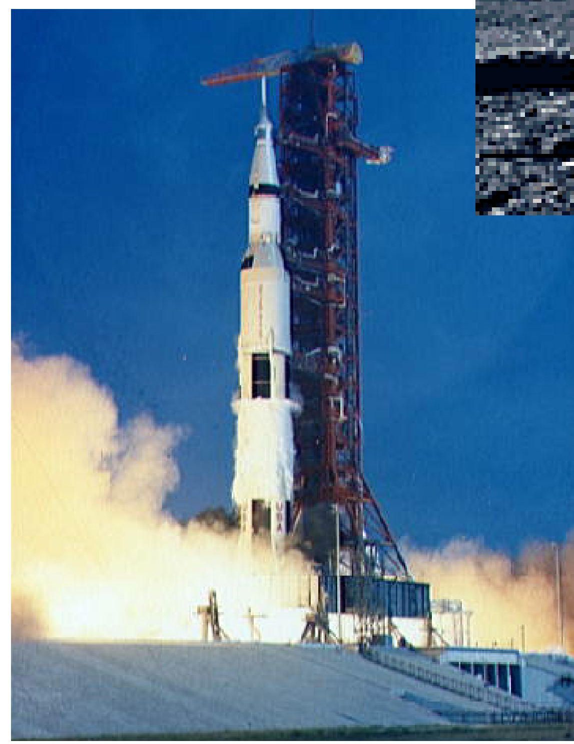
By 2050, build a team of fully autonomous humanoids which can win against the human world champion under the official regulation of FIFA

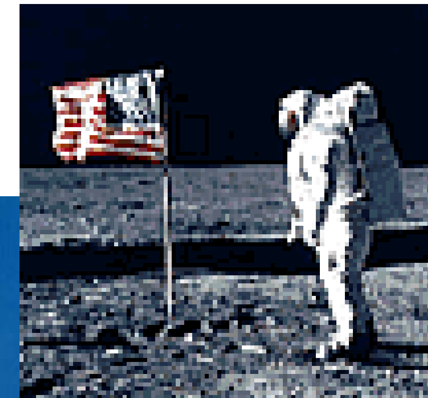
Courtesy Prof. Nardi, RoboCup Soccer Overview, RomeCup 2011

Can we accomplish the goal?

1903 → **1969**







© NASA

Courtesy Prof. Nardi, RoboCup Soccer Overview, RomeCup 2011

Computer Chess

ENIAC
1946

Deep Blue
1997

© IBM

Courtesy Prof. Nardi, RoboCup Soccer Overview, RomeCup 2011

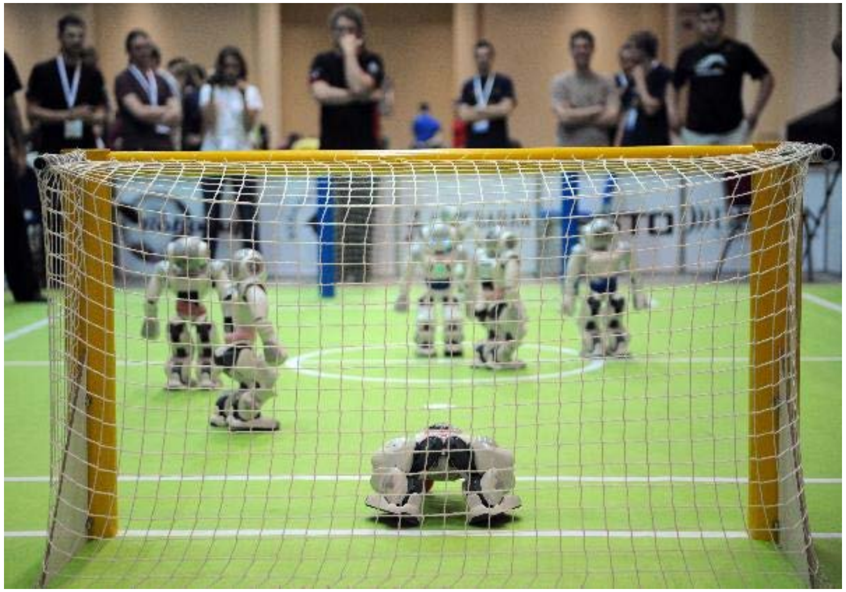
RoboCup-97 Nagoya

35 teams from 12 countries

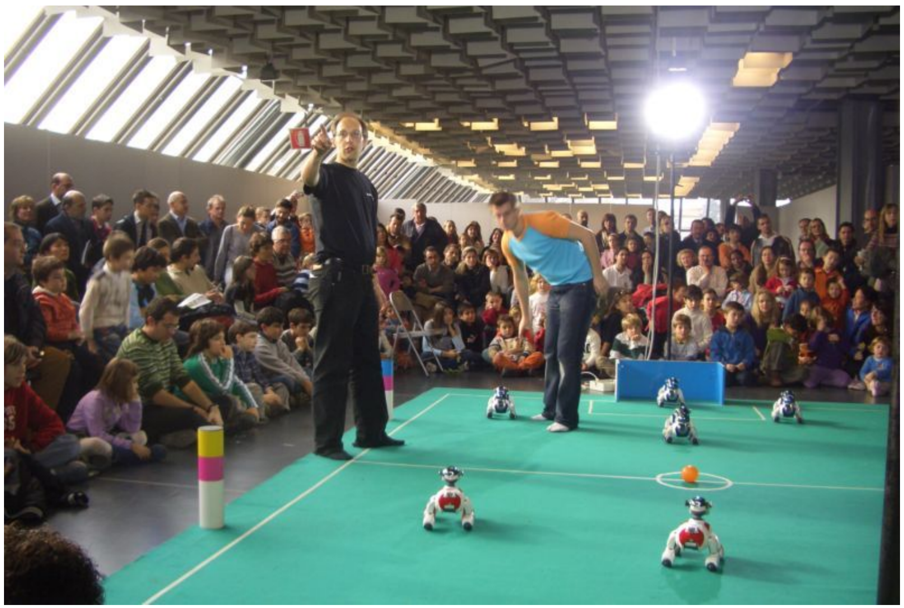
Courtesy Prof. Nardi, RoboCup Soccer Overview, RomeCup 2011

RoboCup Events

1997 Nagoya
1998 Paris
1999 Stockholm
2000 Melbourne
2001 Seattle
2002 Fukuoka
2003 Padua
2004 Lisboa
2005 Osaka
2006 Bremen
2007 Atlanta
2008 Suzhou
2009 Graz
2010 Singapur
2011 Istanbul
2012 Mexico
2013 Eindhoven
2014 João Pessoa
2015 Hefei
2016 Leipzig
2017 Nagoya
2018 Montréal



RoboCup



Very popular yearly event,
with typically 400 participating teams

Urban Search & Rescue (USAR)

- Research in USAR robotics is a vigorous research area
- Offers unique challenges that are difficult to create in a lab environment

Image from CMU biorobotics

Applications of rescue robots

- After the Oklahoma City bombing (1995),
  J. Blitch took notes as to how robots might have been applied.

- The trigger for the RoboCup Rescue initiative was the Hanshi-Awaji earthquake which hit Kobe City on the same year.

- Rescue robots were first used at the WTC 9/11 (2001).
  M. Micire analyzed the operations and identified
  seven research topics for the robotics community.

World Trade Center 9/11

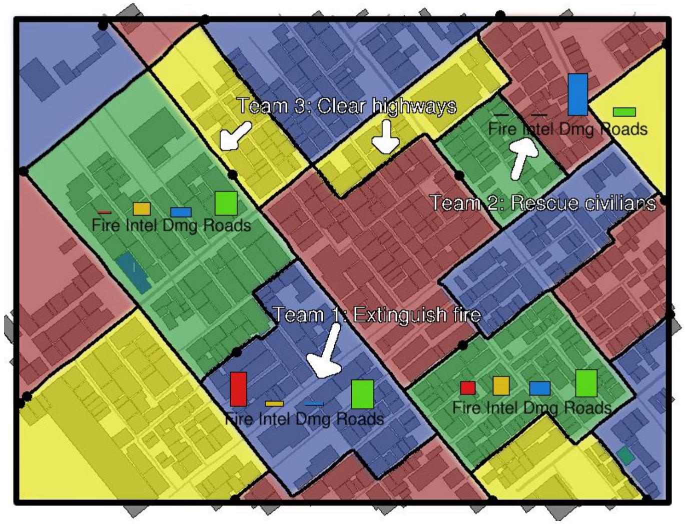
University of South Florida engineering professor Robin Murphy and three graduate students took six urban search and rescue robots to "ground zero" in New York in September 2001 to look for survivors. Murphy's 11-day mission was part of a larger team effort that recovered the remains of six victims

Applications of rescue robots

- After 2001, rescue robots were applied in several occasions:
  - Aerial robots were used after hurricane Katrina and Rita
  - Boat robots after hurricane Wilma
  - Snake robots after Bonn’s city archive collapse
  - iRobot, BobCat and Talon at Fukushima Nuclear Power Plant

RoboCup Rescue Competitions

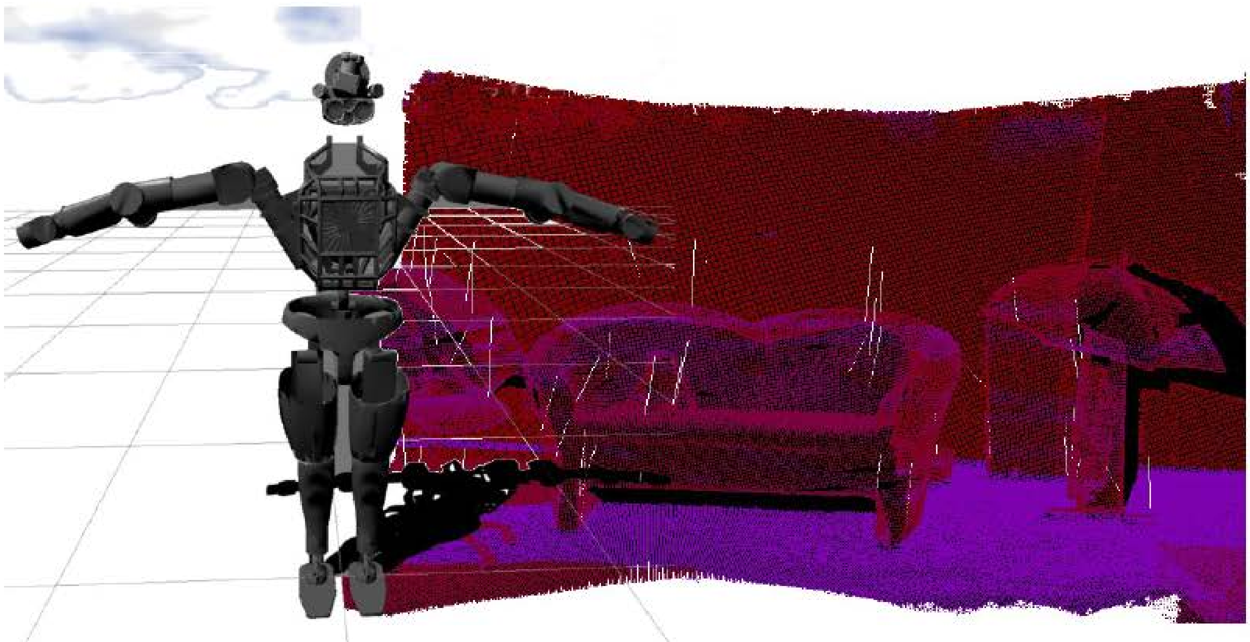
- Rescue Agent simulation
  - Distributed decision making
  - Cooperation
  - Simulations of:
    - Building collapses
    - Road Blockages
    - Spreading fire
    - Traffic
- Real Robots
  - Single collapsed structure
  - Autonomous navigation
  - Victim location and assessment



Virtual Robot Competition

- Autonomous multi-robot control
- Human, multi-robot interfaces
- 3D mapping and exploration by fusing information from multiple robots
- Development of novel mobility modes and sensor processing skills
- Lower entry barriers for developers
- Competition based upon a realistic simulation

Analysis of flat terrain for the Atlas robot



UvA Rescue

RoboCup IranOpen 2013 competition
Tehran, April , 2013

Universiteit van Amsterdam

ISLA
Intelligent Systems Laboratory

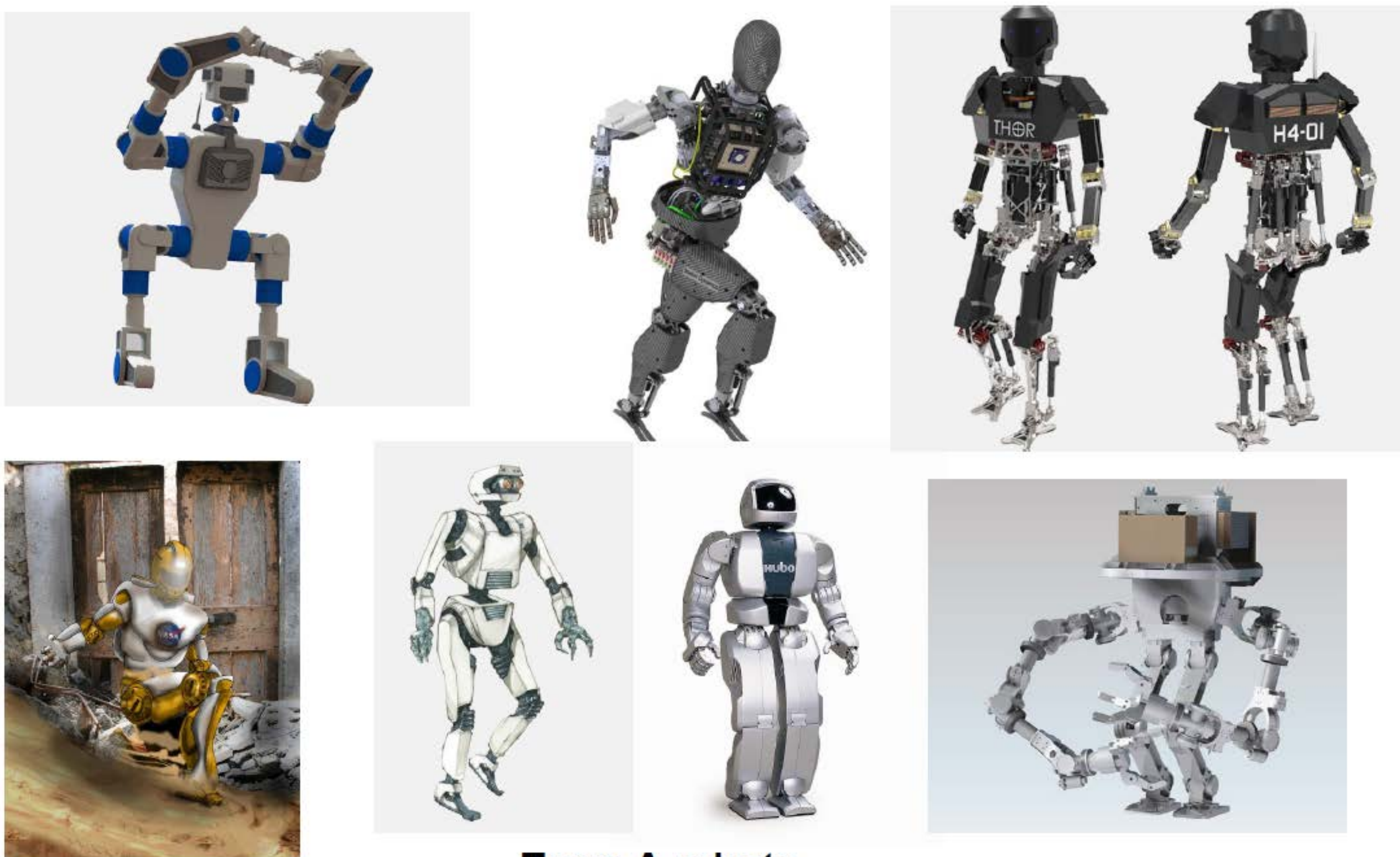
DARPA Urban Challenge

Urmson, C.; Whittaker, W., "Self-Driving Cars and the Urban Challenge," *Intelligent Systems, IEEE* , vol.23, no.2, pp.66,68, March-April 2008

DARPA Challenge 2013

http://www.theroboticschallenge.org/

DARPA Challenge 2013



Team A robots

[Meet the teams]

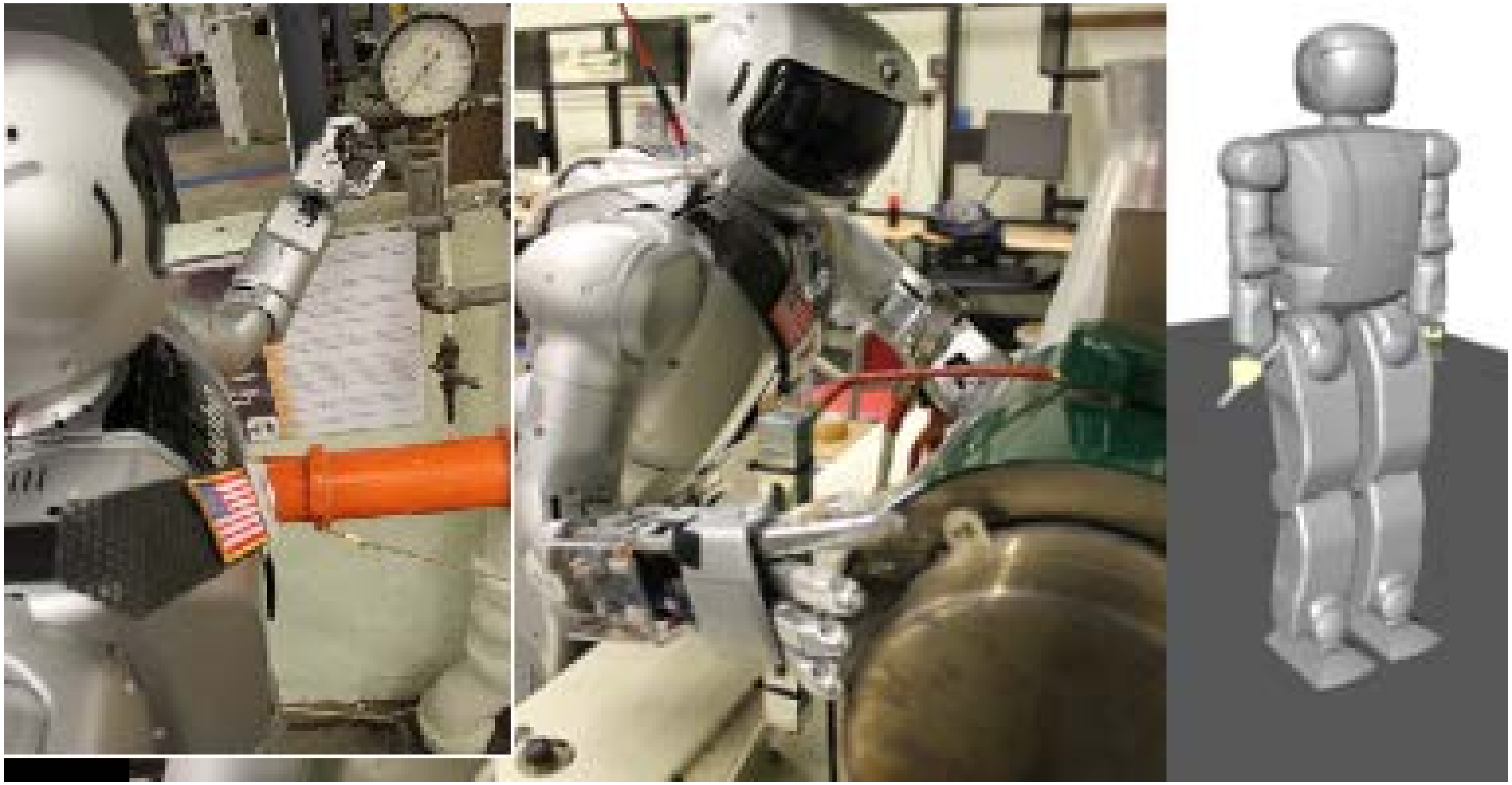
DARPA Challenge 2013

- [Hubo Vision on competition]

DARPA Challenge 2013

- [Hubo Vision on competition]

DARPA Challenge 2013



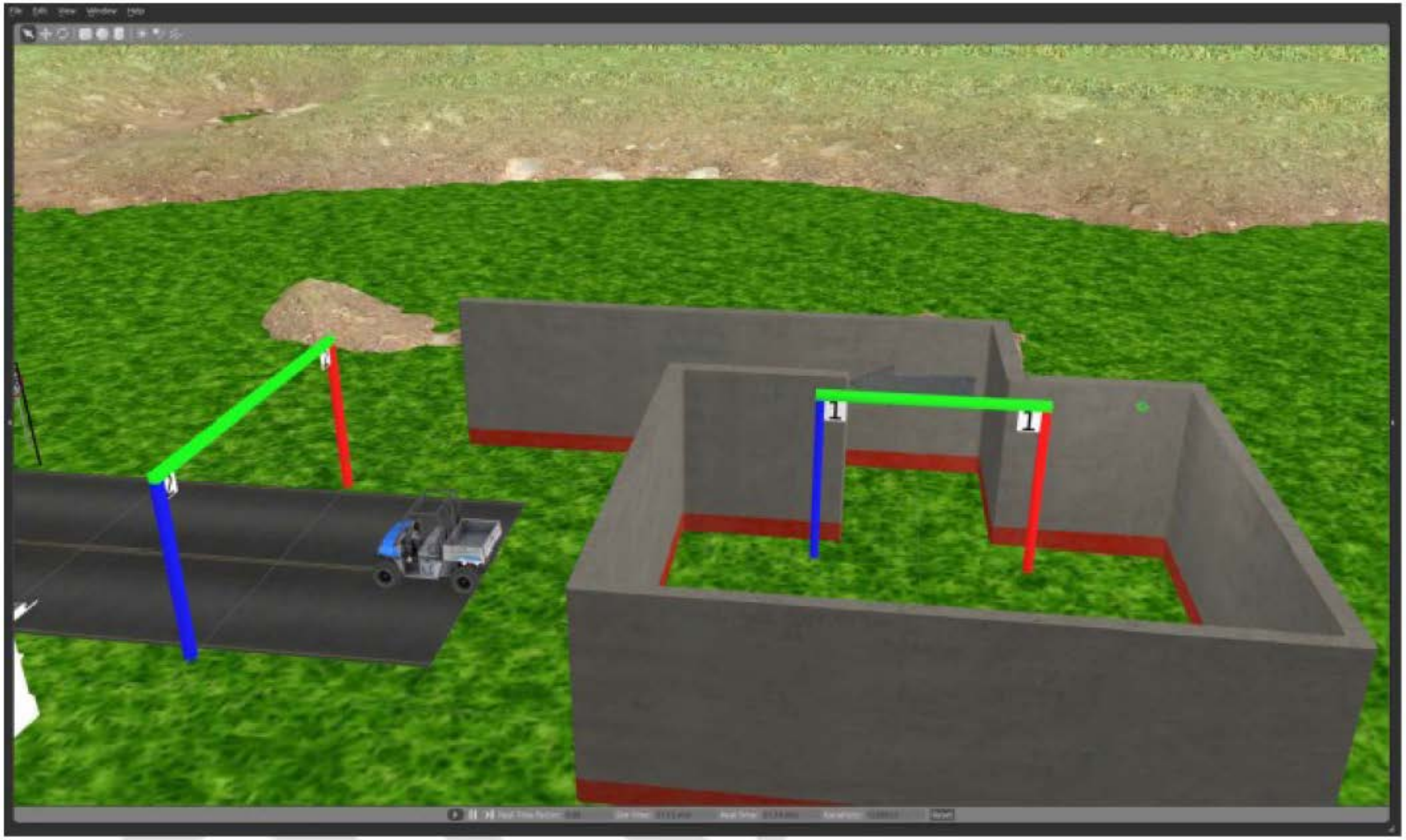
- [Hubo Vision on competition]

DARPA Robotics Challenge
Task 1

http://www.theroboticschallenge.org/

Challenge Overview

DARPA Robotics Challenge
Task 1



http://www.theroboticschallenge.org/

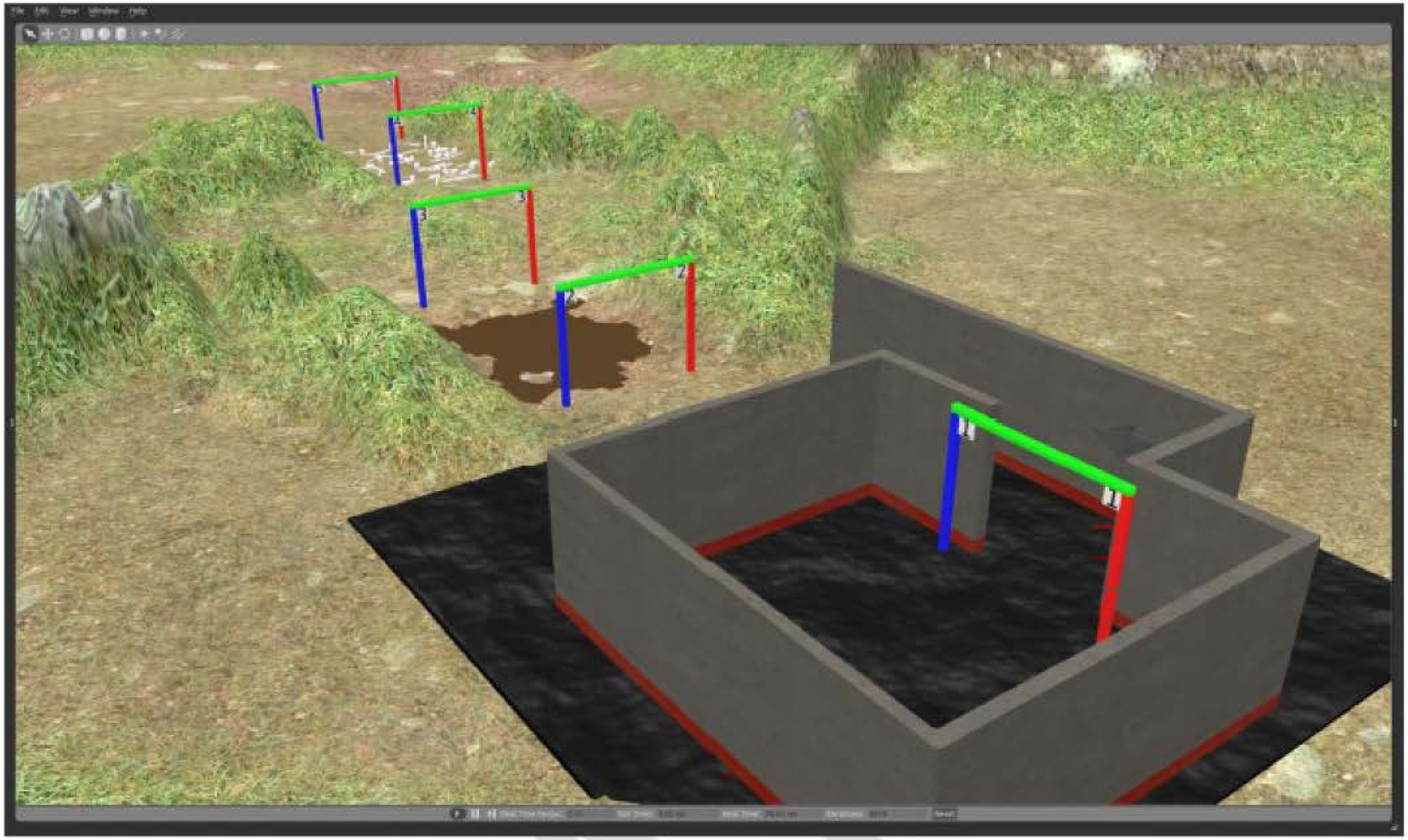
DARPA Robotics Challenge
Task 1

http://www.theroboticschallenge.org/

DARPA Robotics Challenge
Task 1

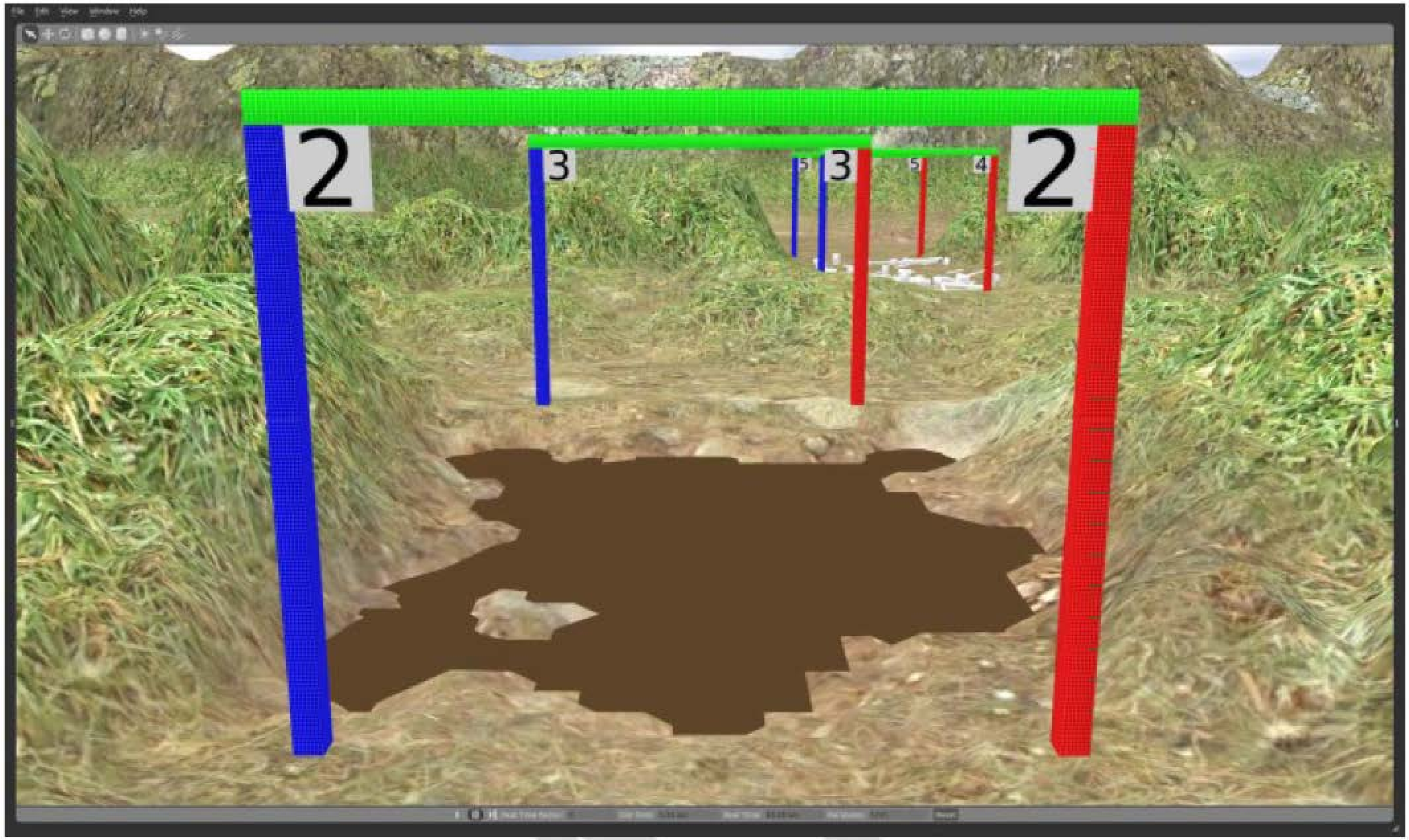
http://www.theroboticschallenge.org/

DARPA Robotics Challenge
Task 2



http://www.theroboticschallenge.org/

DARPA Robotics Challenge
Task 2



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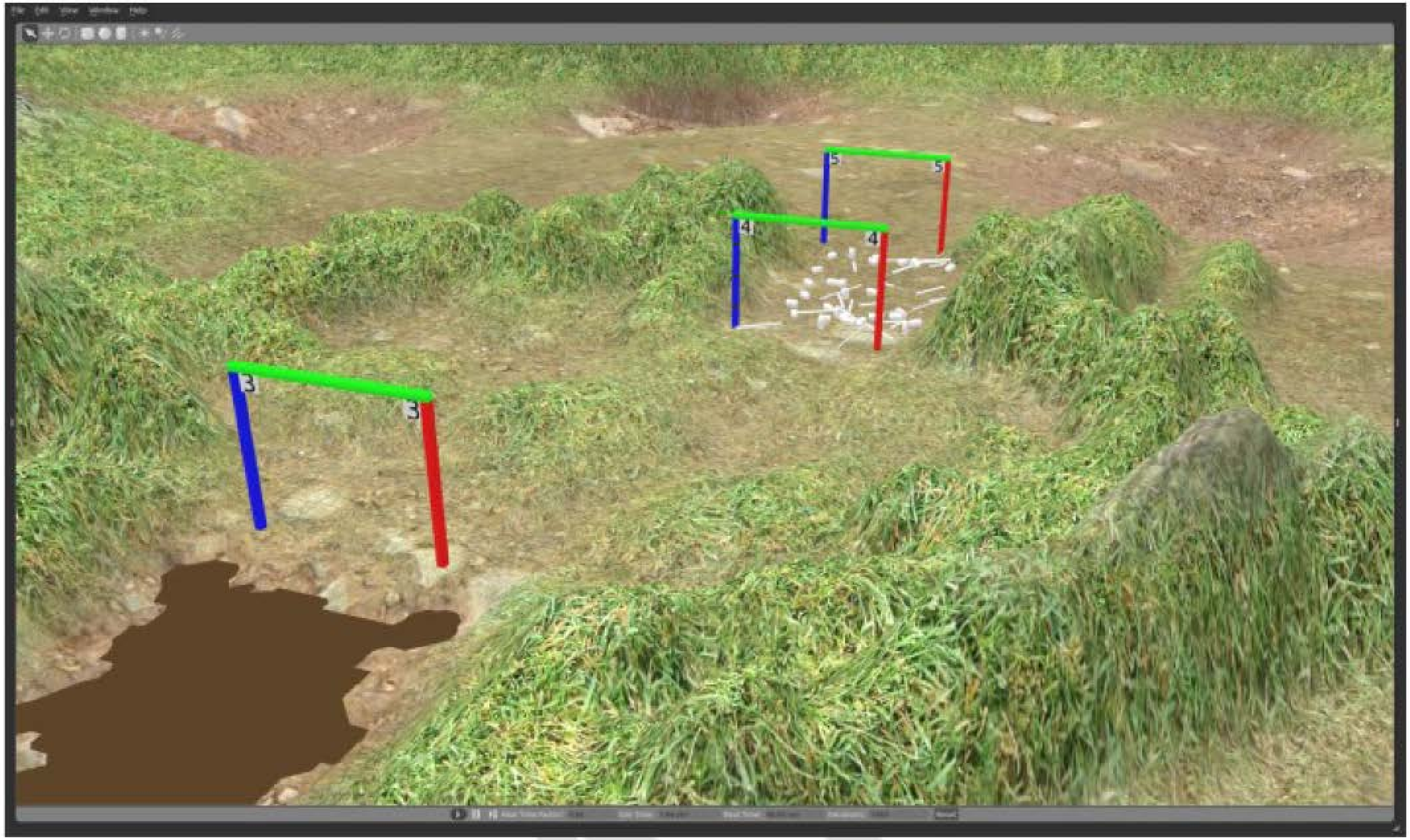
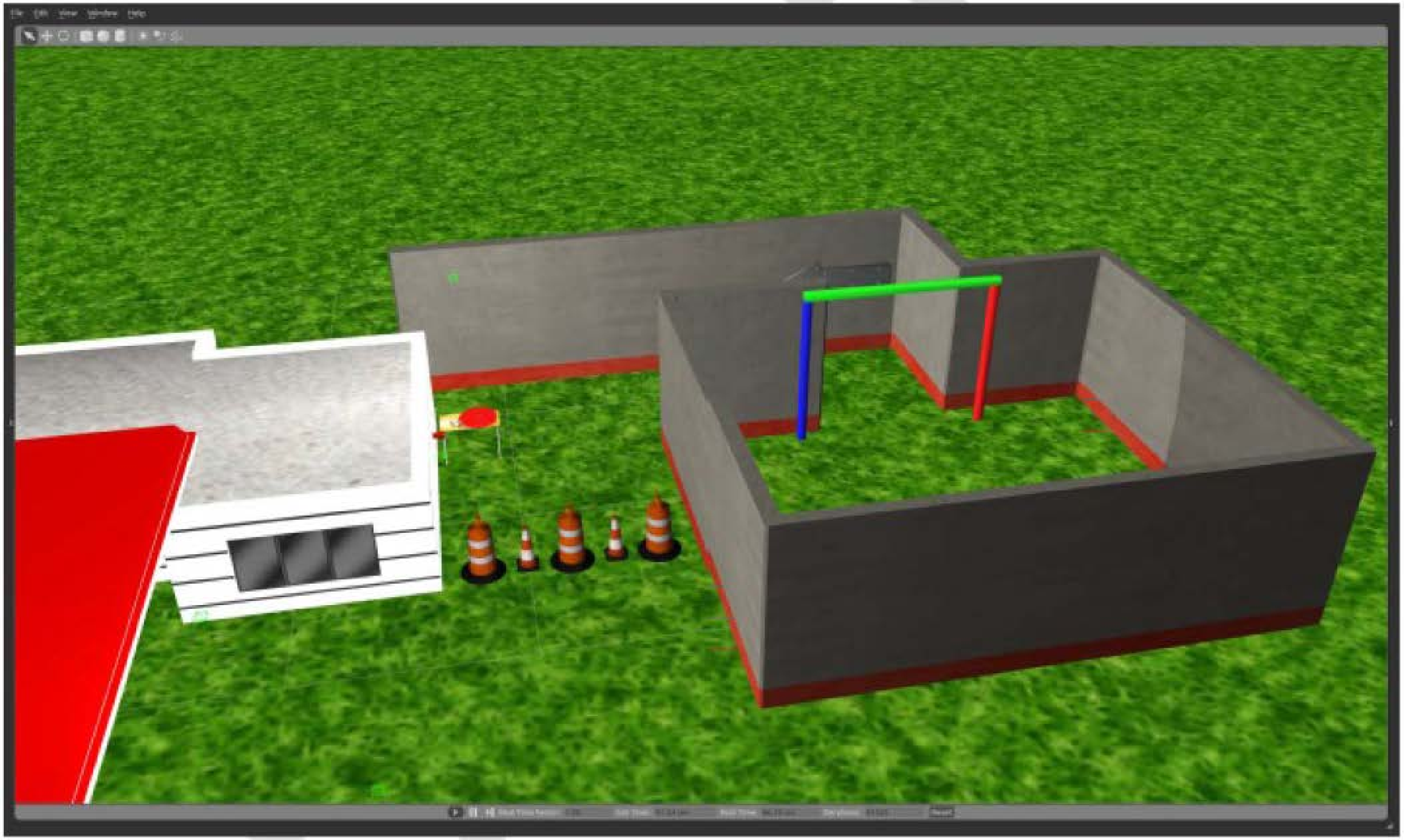
DARPA Robotics Challenge
Task 2



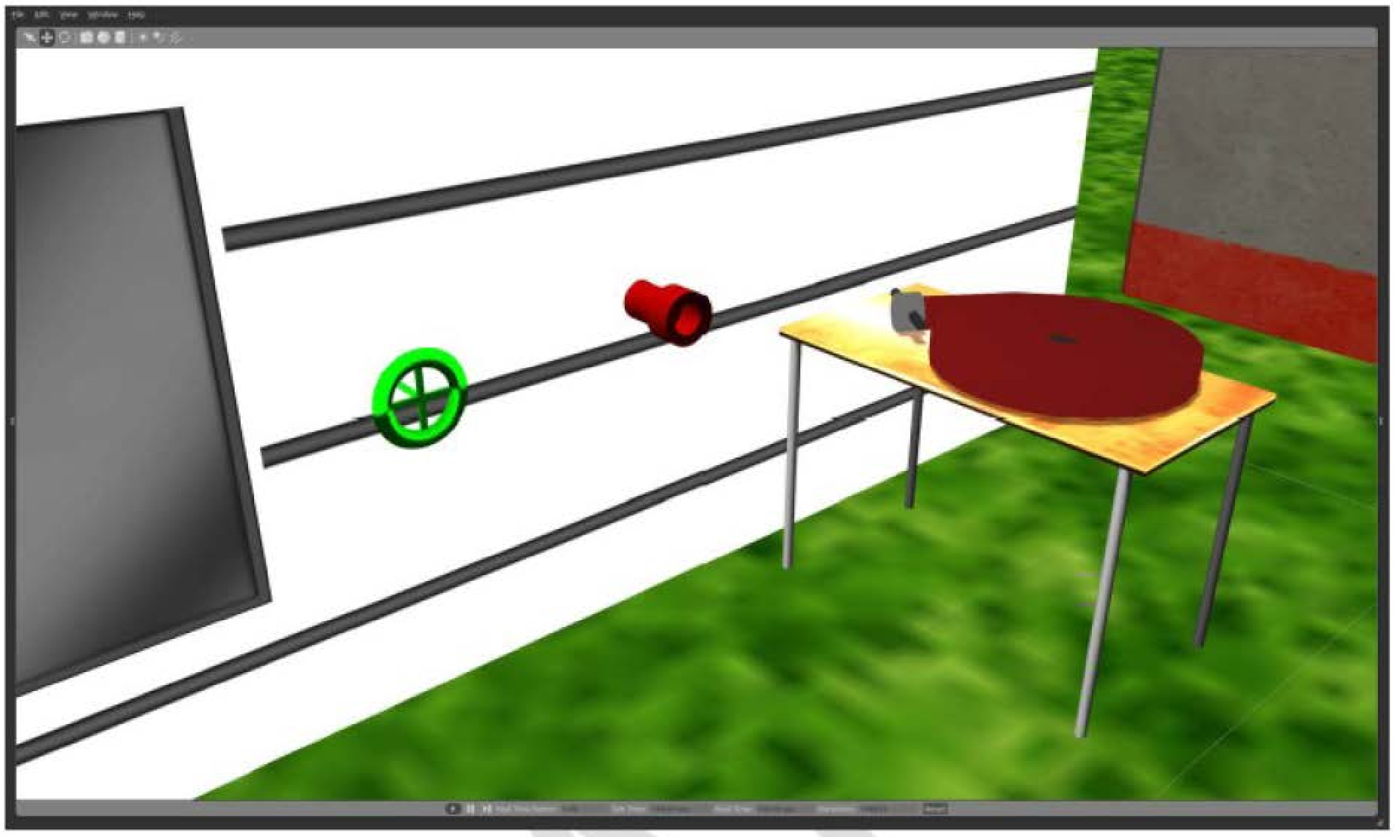
http://www.theroboticschallenge.org/

DARPA Robotics Challenge
Task 3



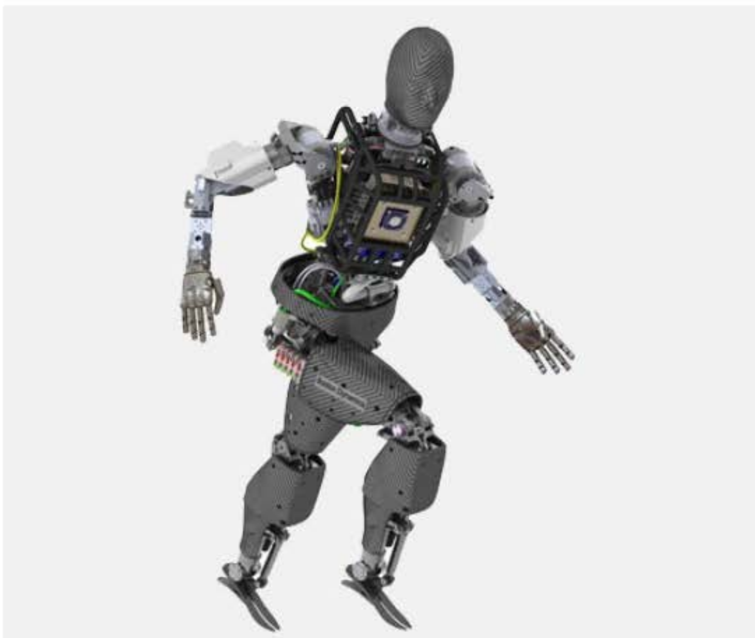
http://www.theroboticschallenge.org/

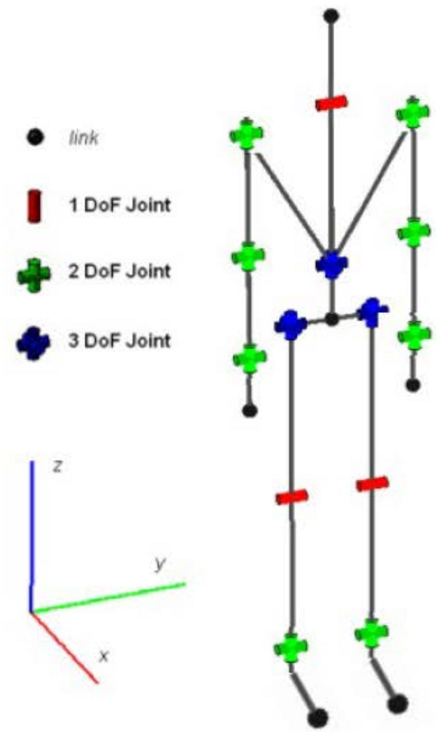
DARPA Robotics Challenge
Task 3



http://www.theroboticschallenge.org/ Challenge Overview

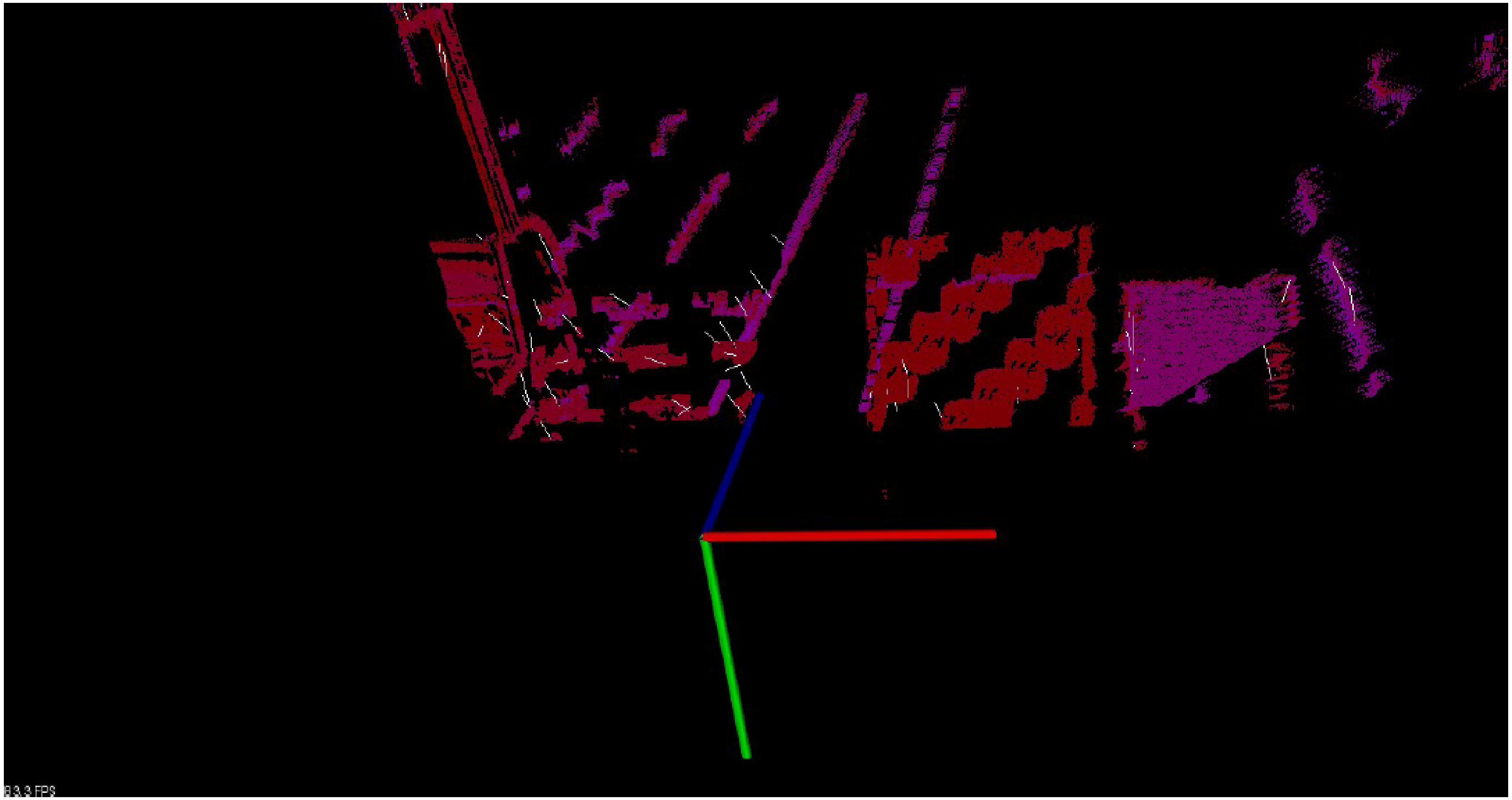
Walking over uneven terrain





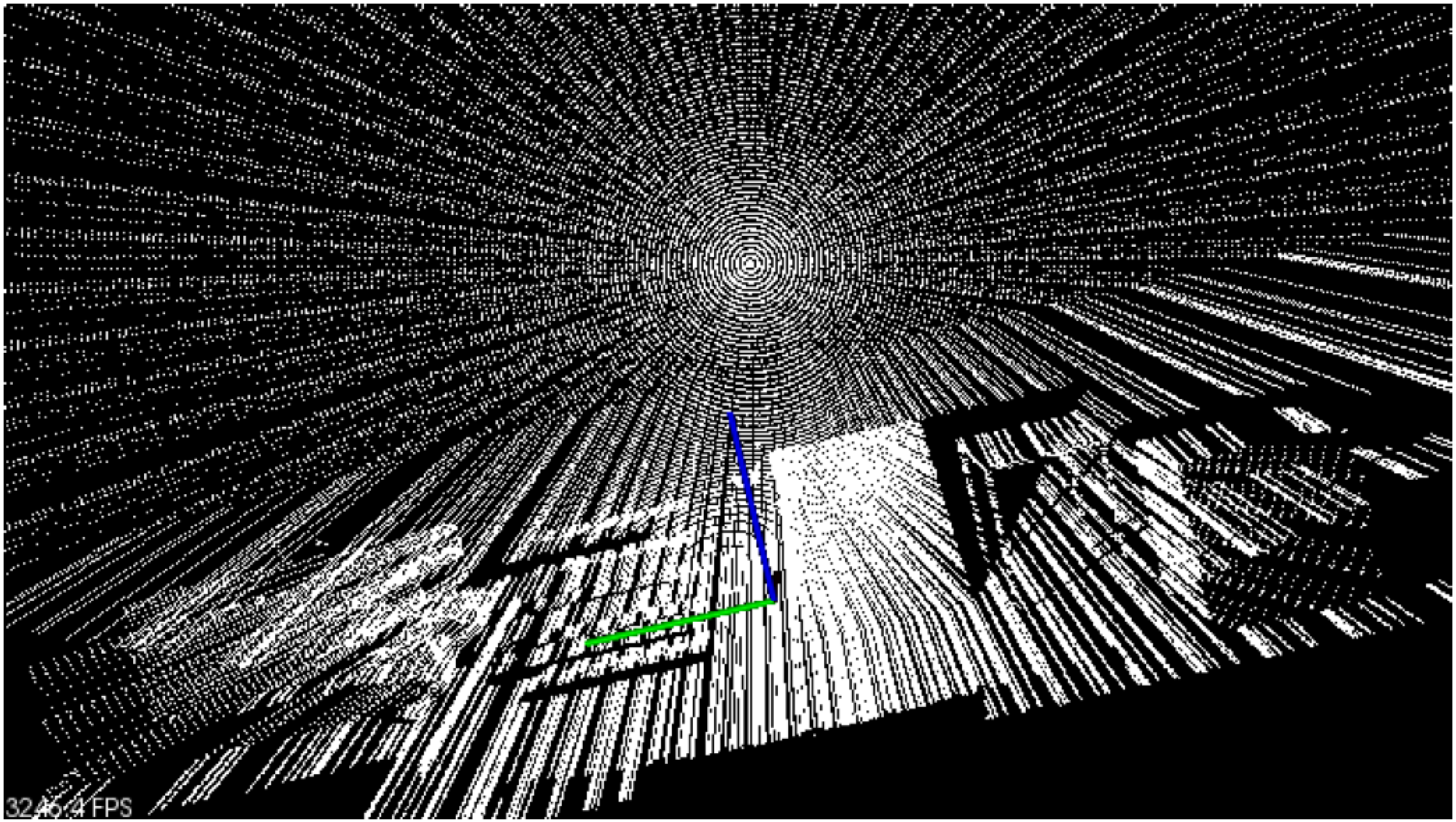
Atlas robot from Boston Dynamics: 28 Degrees of Freedom

Point Cloud sensor



The result: a sparse grid of points

Rotary laser sensor



The result: dense lines of points

The algorithm

Find Planes:

1) Plane Segmentation:

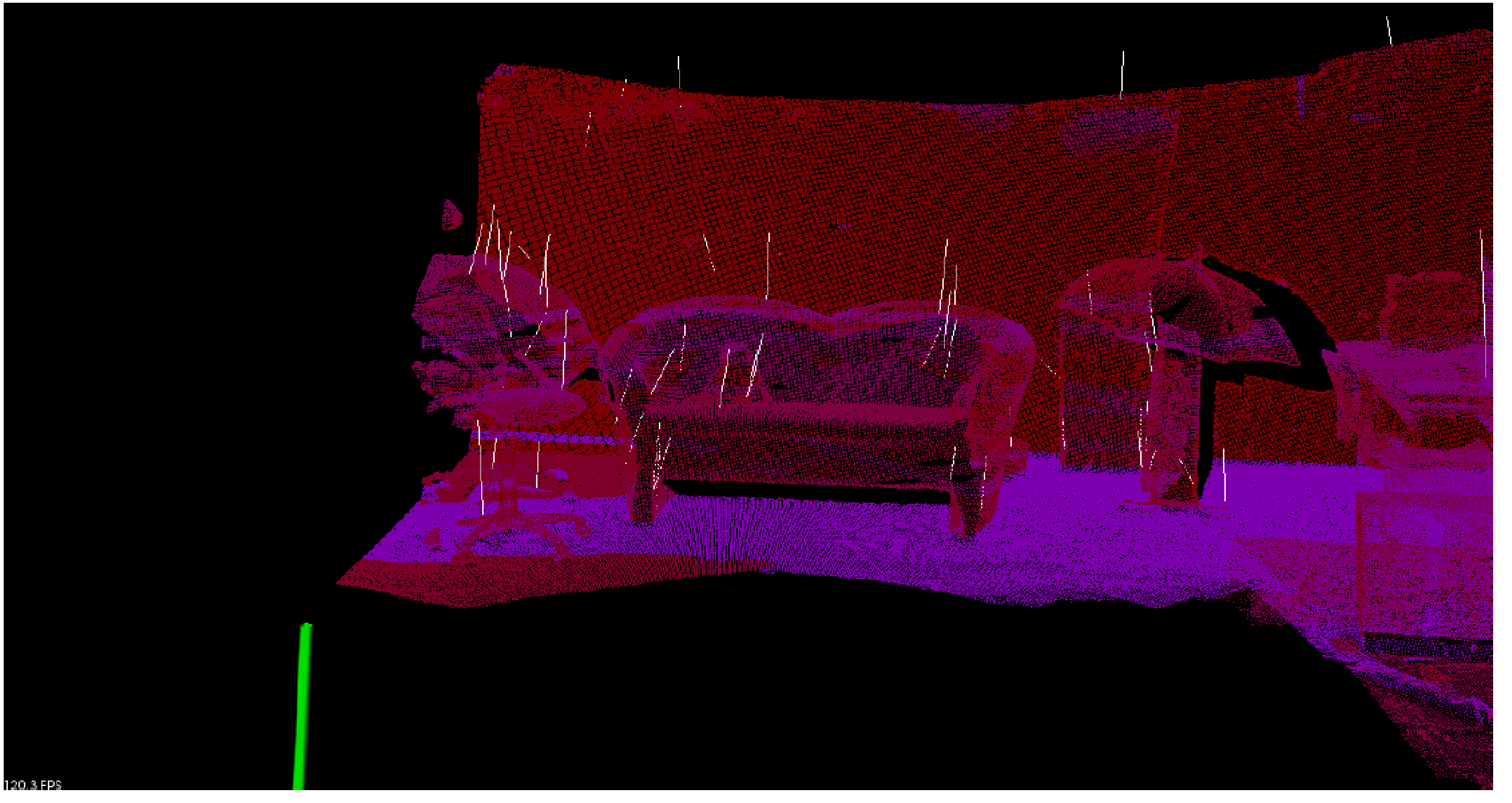
The RANSAC algorithm informally goes as followed:

- Randomly select a subset of the point cloud and estimate the free model parameters
- Other data is considered, if a point fits the model a point is added (considered an inlier)
- The model is re-estimated considering all the inliers
- The model is evaluated by estimating the error relative to the model

2) Calculate normal for plane

3) Plane Evaluation: distance to ideal normal $[0, 0, 1]$

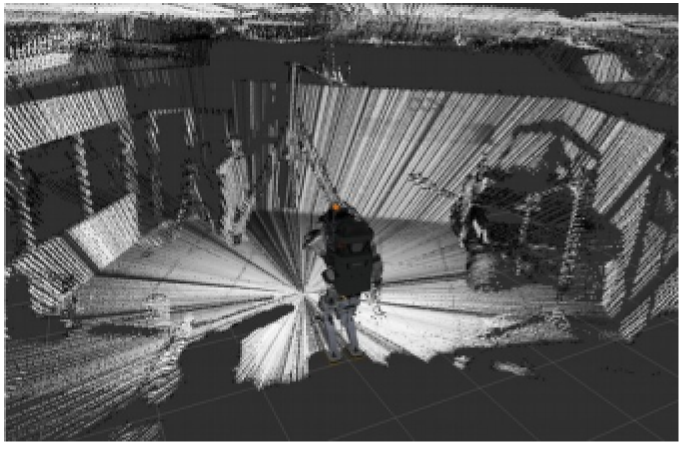
Results

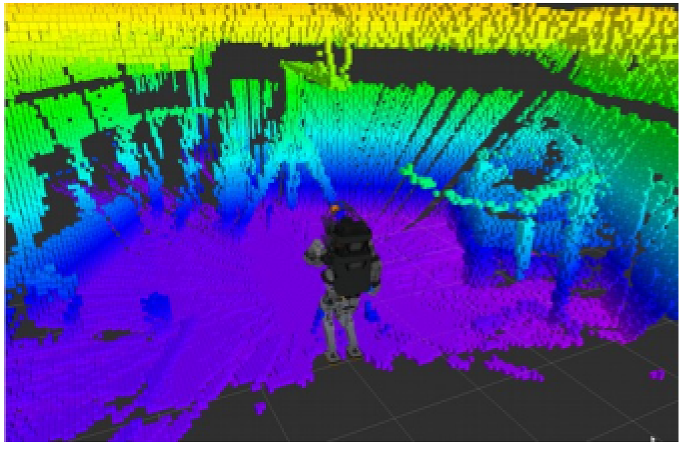


Artificial color: indication for equality: *$equality^5 * 255 = color$*

Perception

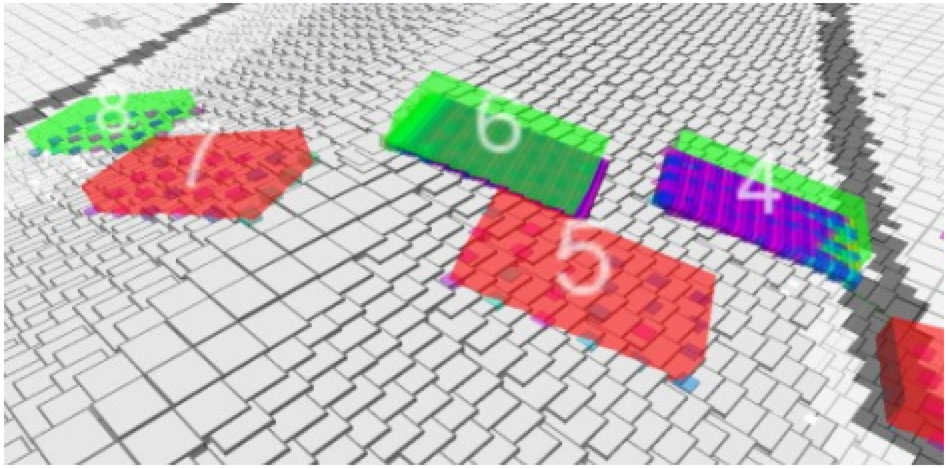
- Provide situational awareness for operator(s)
- Provide world state estimate for robot
  - Footstep planning
  - Manipulation





Footstep Planner: 3D Planning

- Extension to 3D

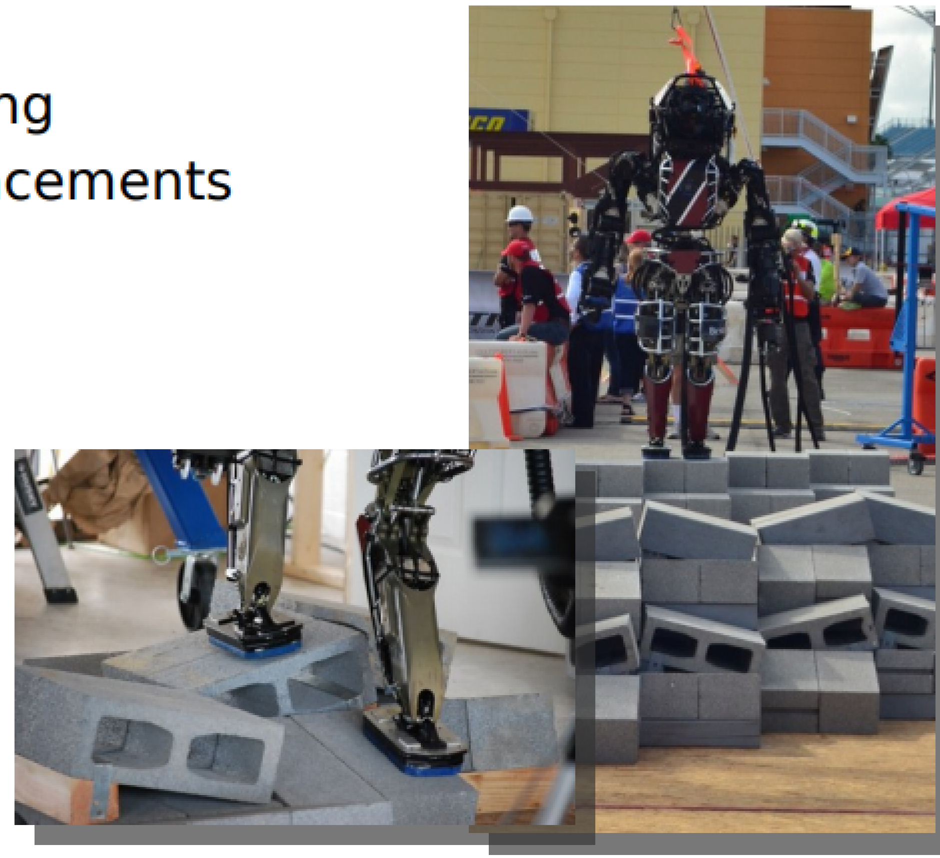


- States: Become full 6 DOF
- Actions: Remain the same
- Roll, pitch and step height are constrained by underlying terrain
- Search space does not enlarge
- No expensive branching tree!

Footstep Planner

TECHNISCHE UNIVERSITÄT DARMSTADT

- Complex Locomotion:
  - 3D perception and modeling
  - Safe sequences of foot placements
  - 6DOF foot placements
  - Obstacle avoidance
  - Balance control
- Divide and conquer
  - Terrain Model Generator
  - 3D Footstep Planning
  - Robot Controller



github.com/team-vigir/vigir_footstep_planning_core

VIGIR sim

DARPA Challenge Terrain Task: Pitch Ramp

Conclusion

It is possible to find planes in the environment that can be stepped on by the Atlas robot.

RoboCup 2006 Bremen · Germany
3rd place

RoboCup Atlanta 2007
4th place

RoboCup German Open
2nd place

Brazil Open
1st place

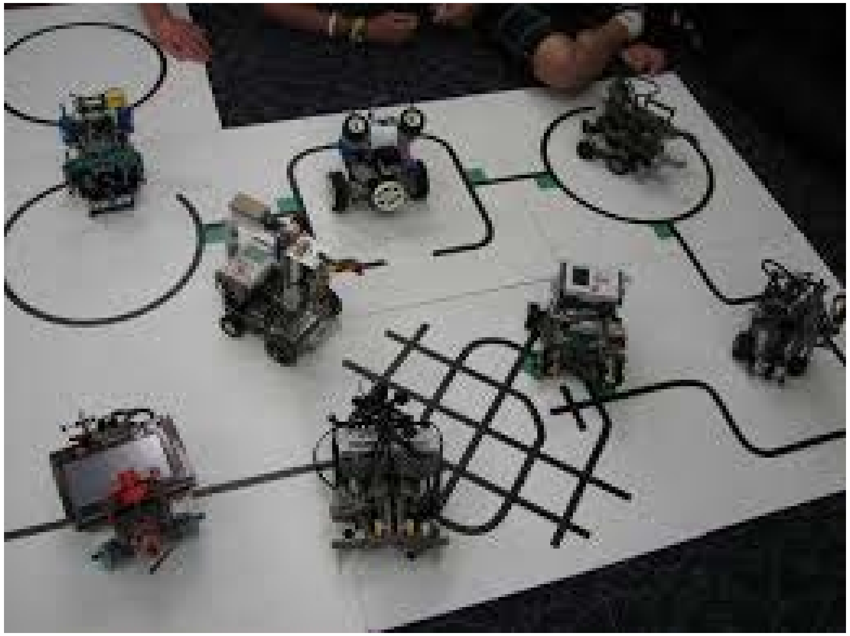
RoboCup 2009 Graz · Austria
3rd place

RoboCup 2012 18 - 24 June Mexico City
Infrastructure price

RoboCup 2018 Montréal · Canada
Infrastructure price

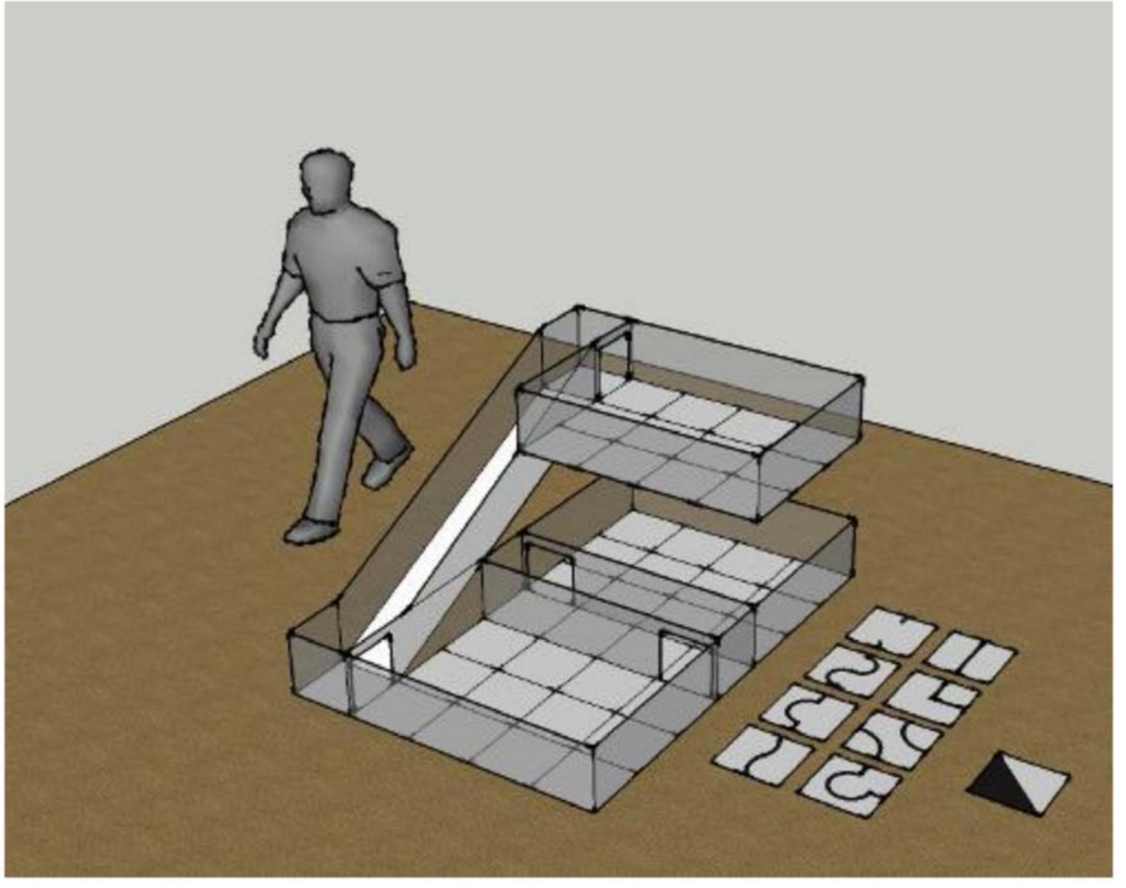
RoboCup Junior

Since 2008, there is also a Rescue League inside the RoboCup Junior



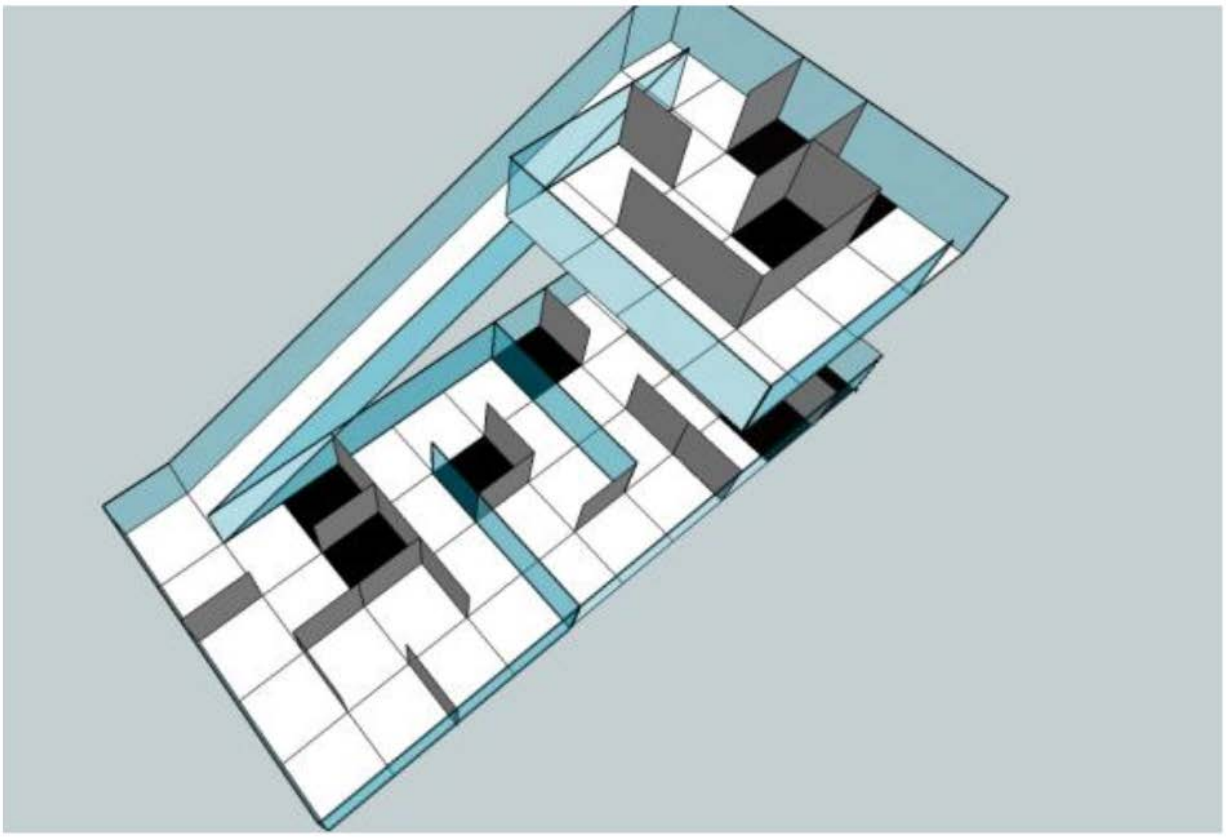
Courtesy Australian RoboCup Junior teams

Rescue A



Modular line following
(including ramp, no longer optional in 2010)

Rescue B



Wall following,
cul-de-sacs will have a dark floor

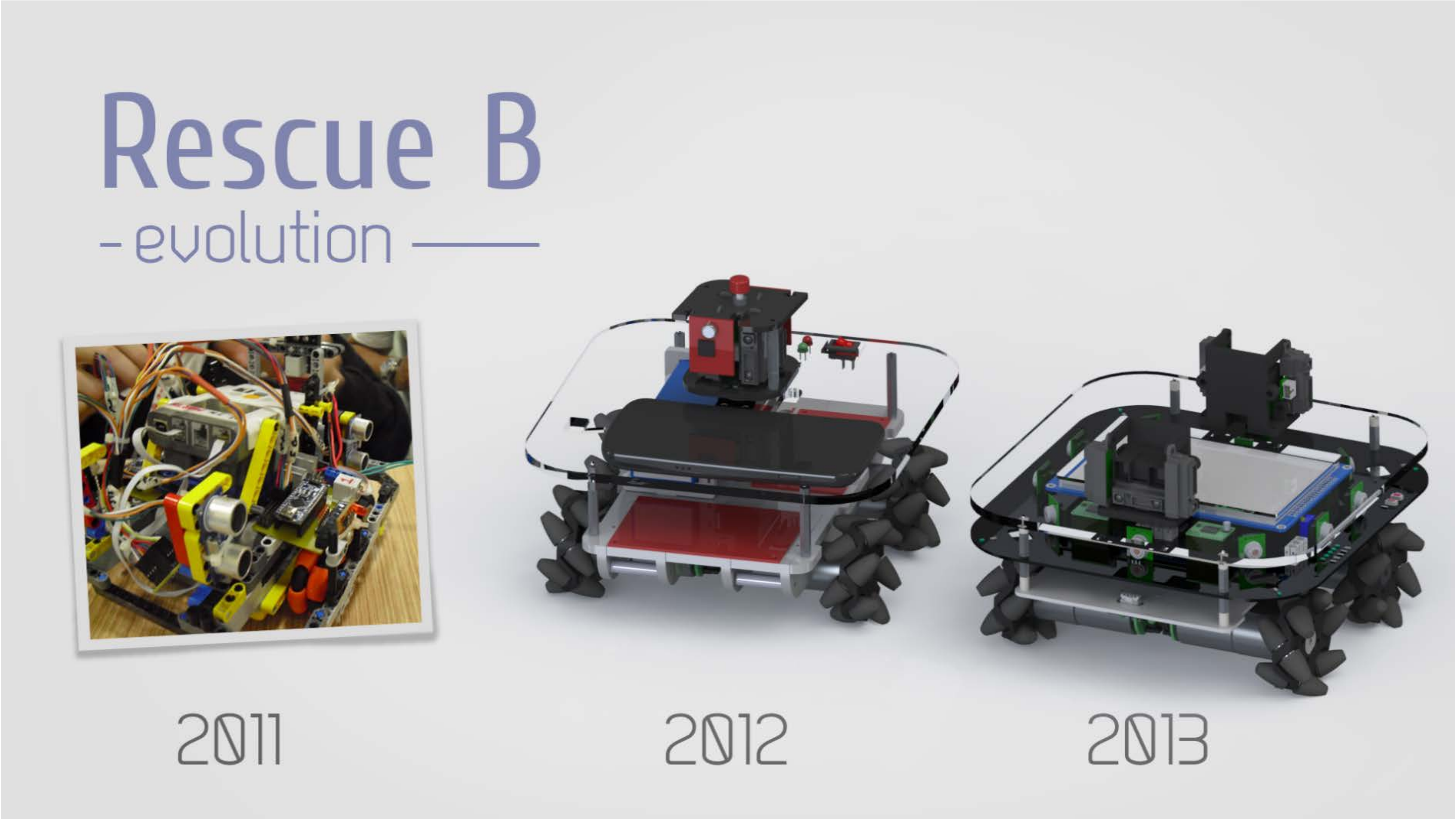
Rules 2010

Simulation (formally CoSpace)

Collect red / blue victims

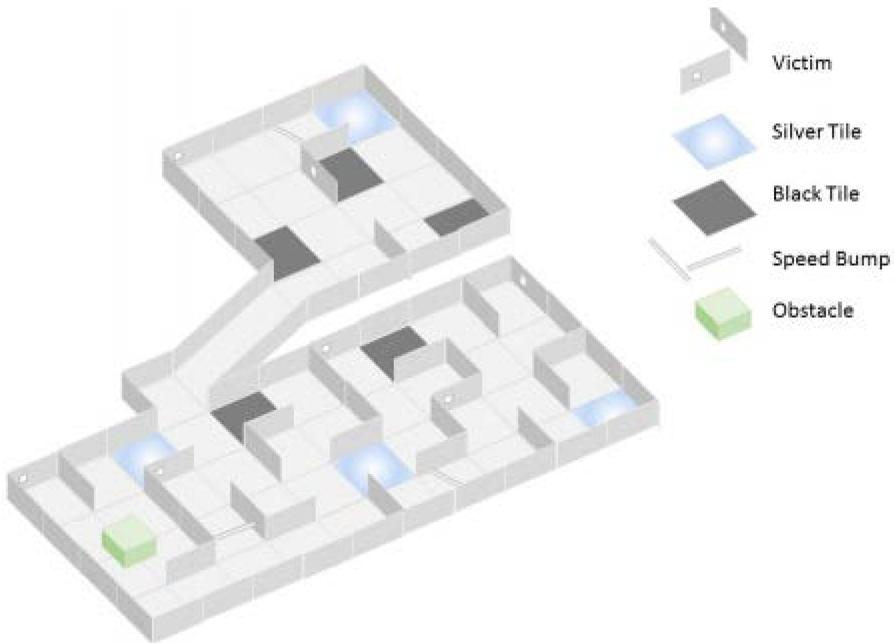
Since 2011

Developments



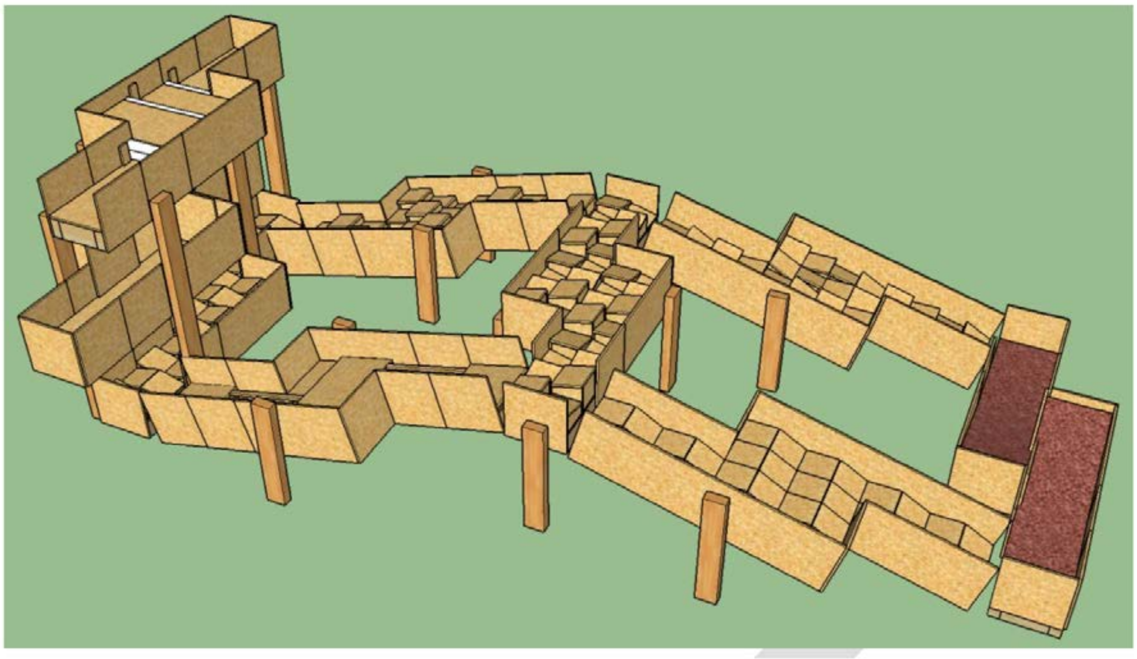
Courtesy Ivan Seidel

Junior Rescue B 2019



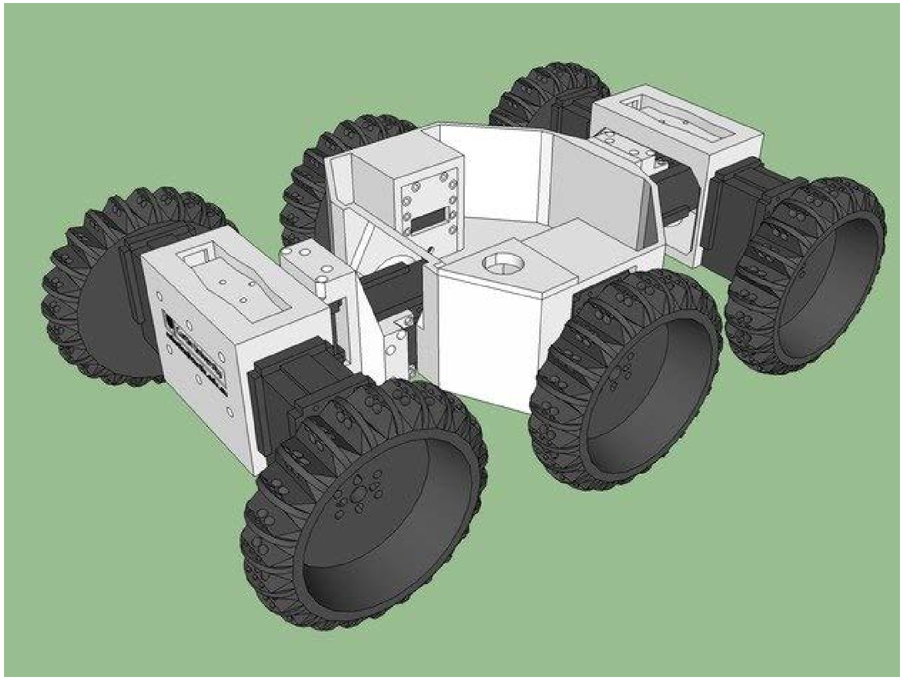
Courtesy Josie Hughes *et al*

Rapid Manufacturing Challenge



3D printing, laser cutting and low cost, common sensors, computation and other electronics lower the barrier of entry

Open Academic Robot Kit

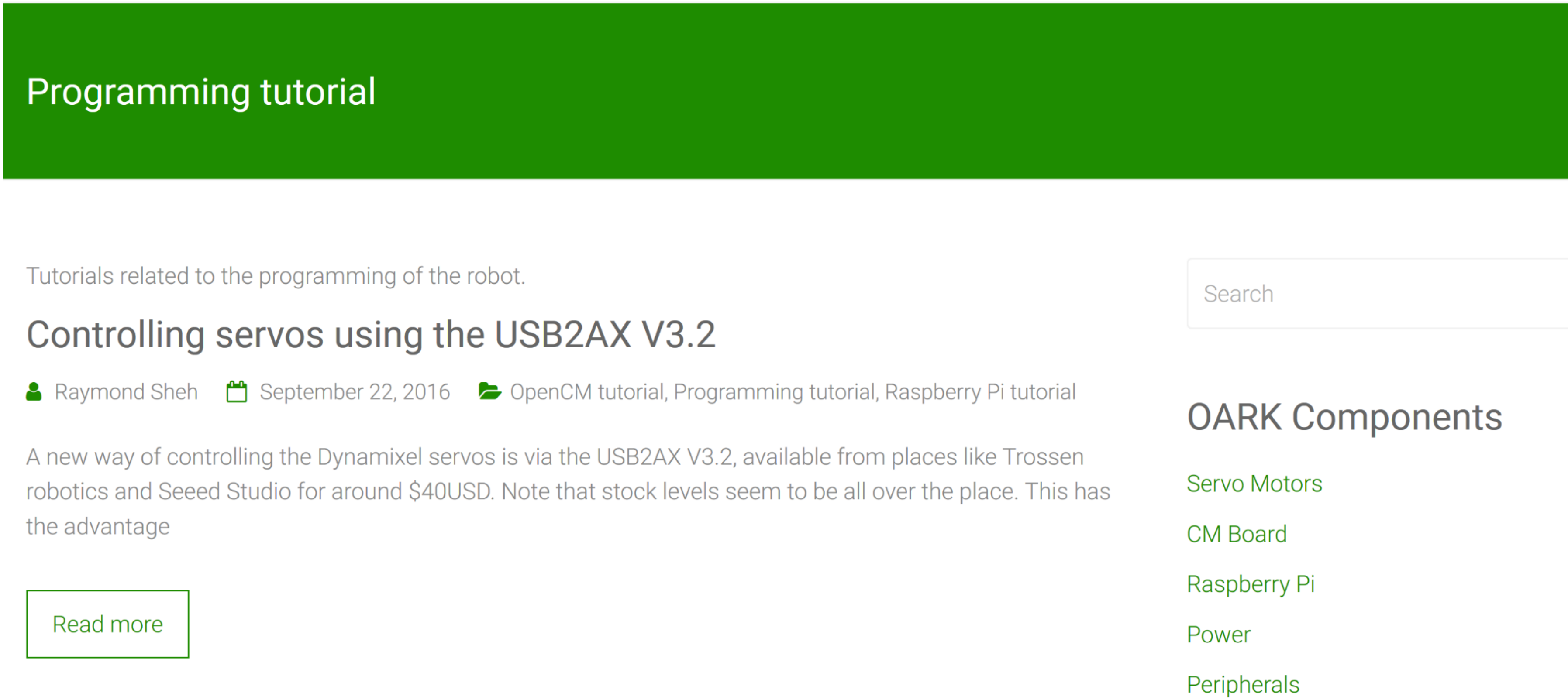


Example designs (stl, which could be converted to dae with Blender)
http://oarkit.intelligentrobots.org/wiki/doku.php?id=designs:home

Sensor tests

For instance:
Visual/Thermal Activity, Motion, Colour, Hazmat tests

Including Tutorials


Programming tutorial

Tutorials related to the programming of the robot.

Controlling servos using the USB2AX V3.2

Raymond Sheh September 22, 2016 OpenCM tutorial, Programming tutorial, Raspberry Pi tutorial

A new way of controlling the Dynamixel servos is via the USB2AX V3.2, available from places like Trossen robotics and Seeed Studio for around $40USD. Note that stock levels seem to be all over the place. This has the advantage

Read more

Search

OARK Components

Servo Motors

CM Board

Raspberry Pi

Power

Peripherals

http://oarkit.intelligentrobots.org/home/category/programming/

Conclusion

- Much can be learned from the RoboCup Junior

Quite some robots were hurt by this research