Tutorial - Versatile Autonomous Urban Search and Rescue Robots

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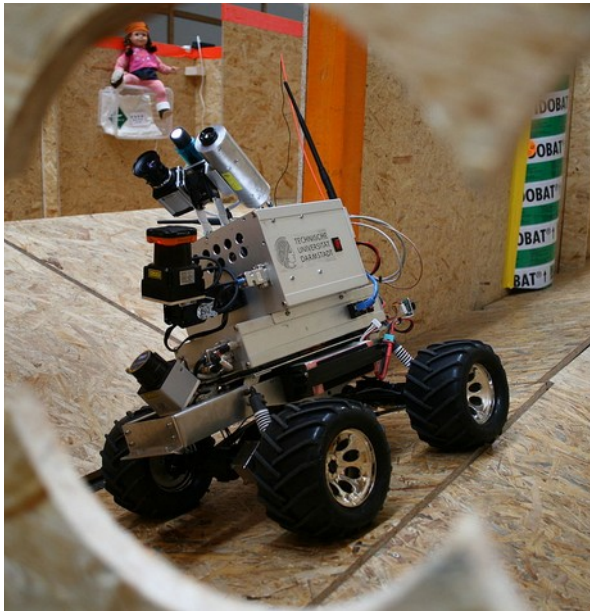

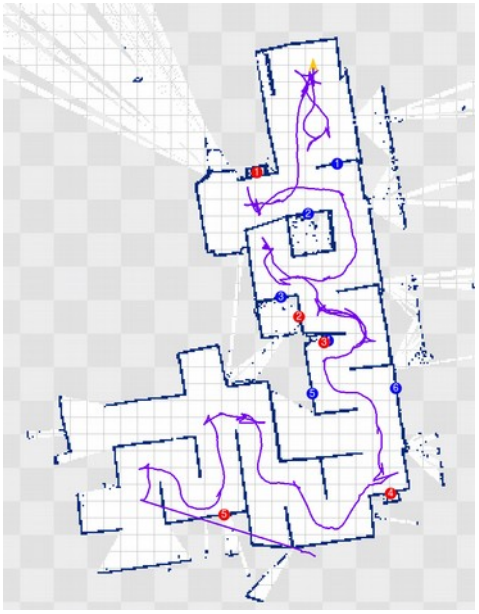

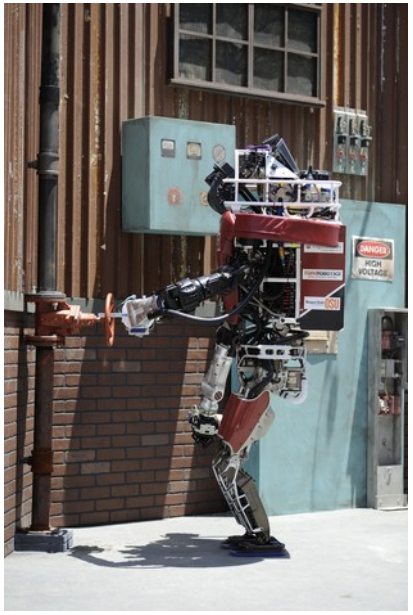

Motivation – Urban Search and Rescue and Disaster Response

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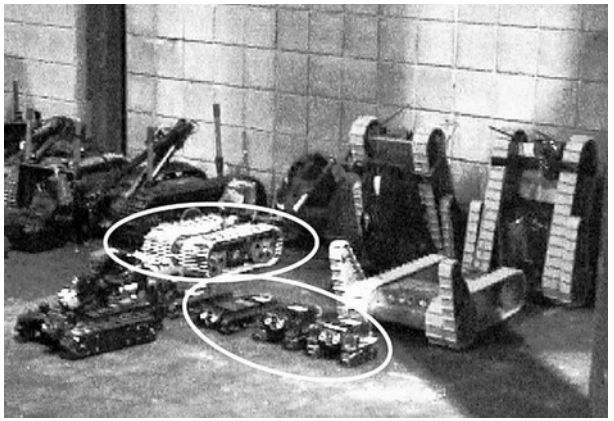
[Chuck Simmins, Flickr]



WTC [Casper et al. SMC 2003]

Fukushima [Yoshida et al. FSR 2014]

Motivation - Exploration and Search for Victims

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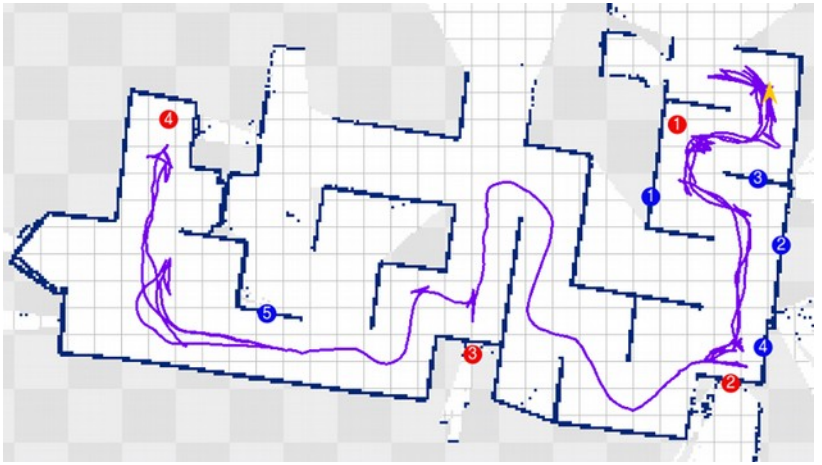
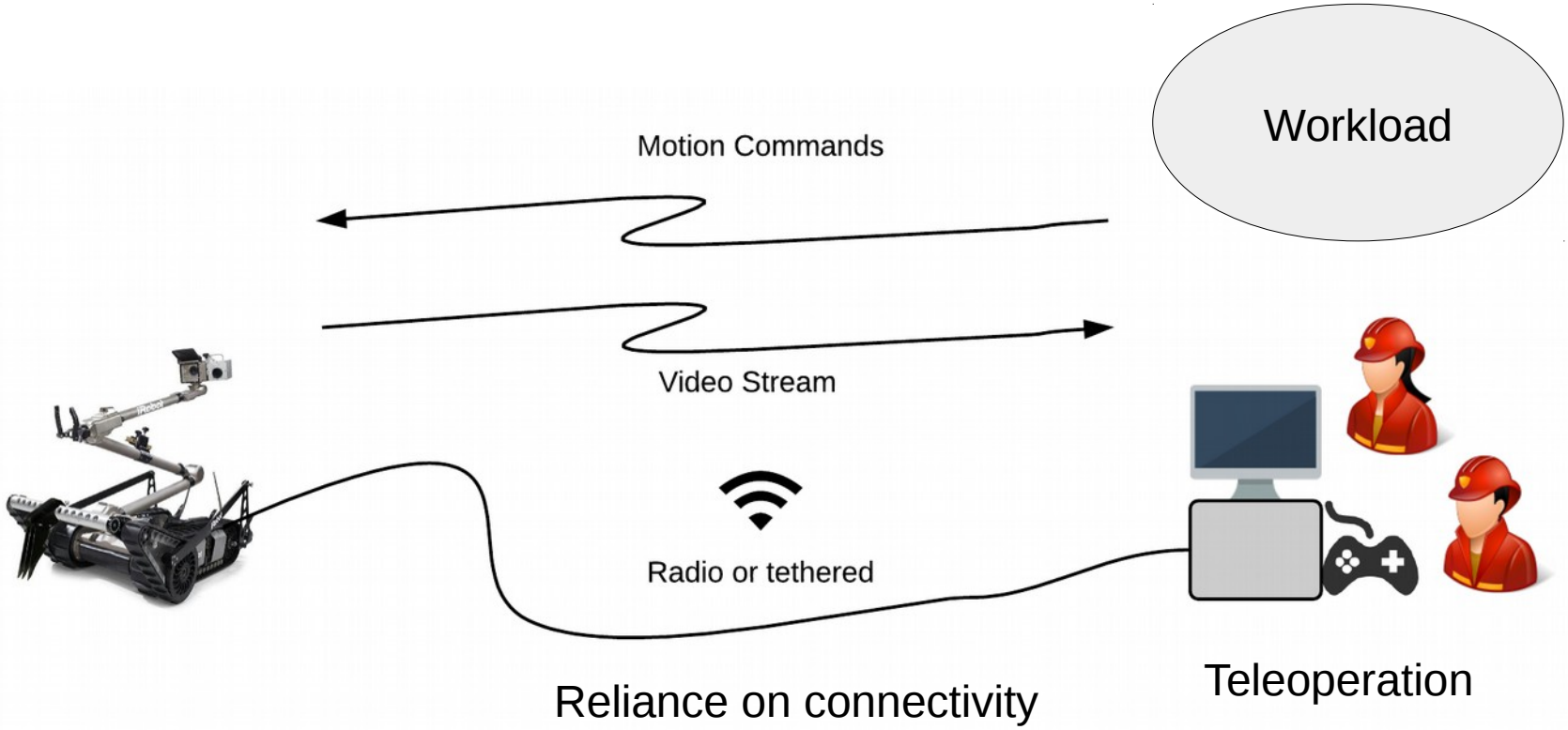
[Brian Gauvin 2005]

[Richard Campanella 2005]



State of the Art



Improving Capabilities leveraging Autonomy

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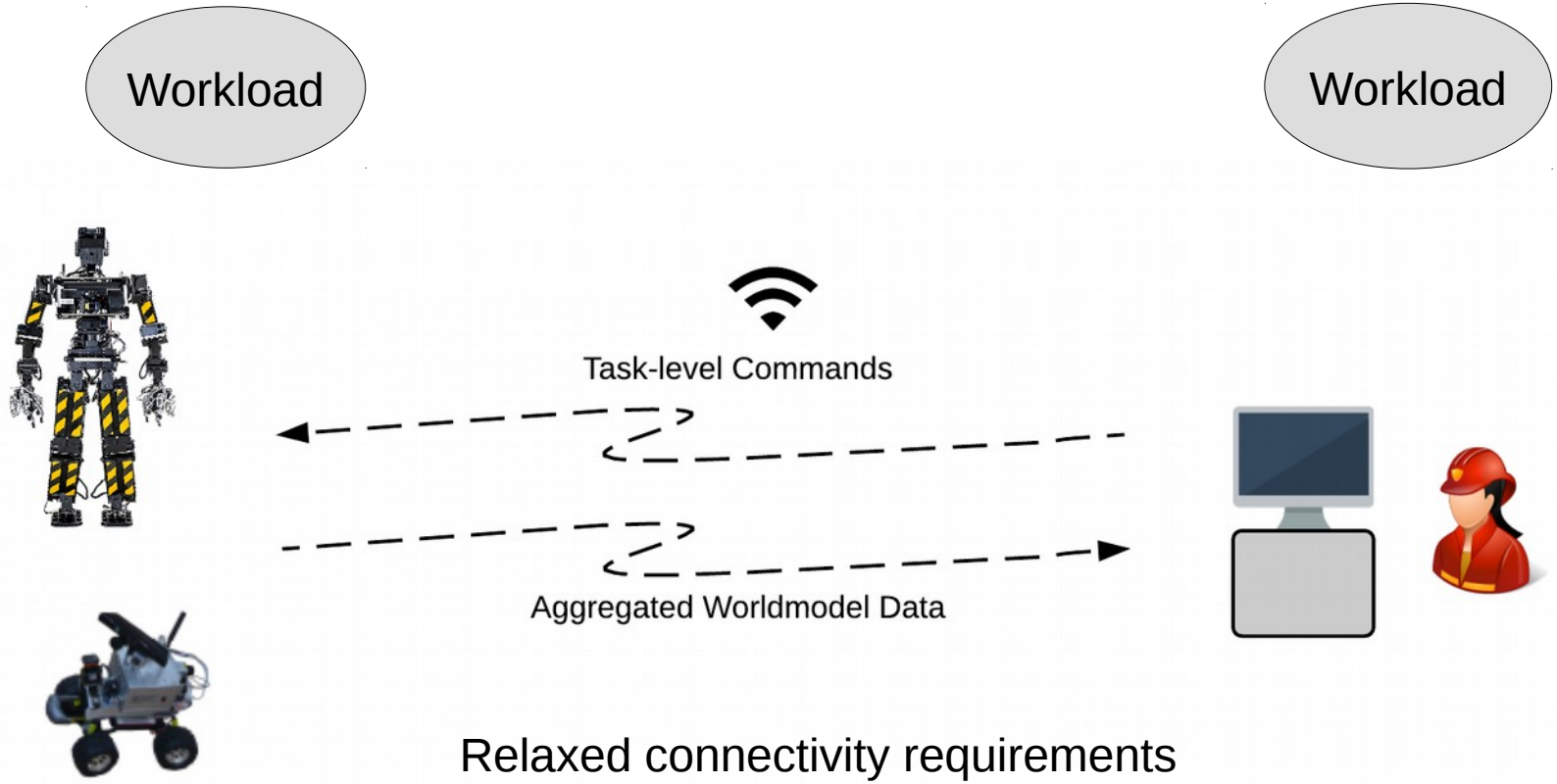

Example Hardware
Hector UGV

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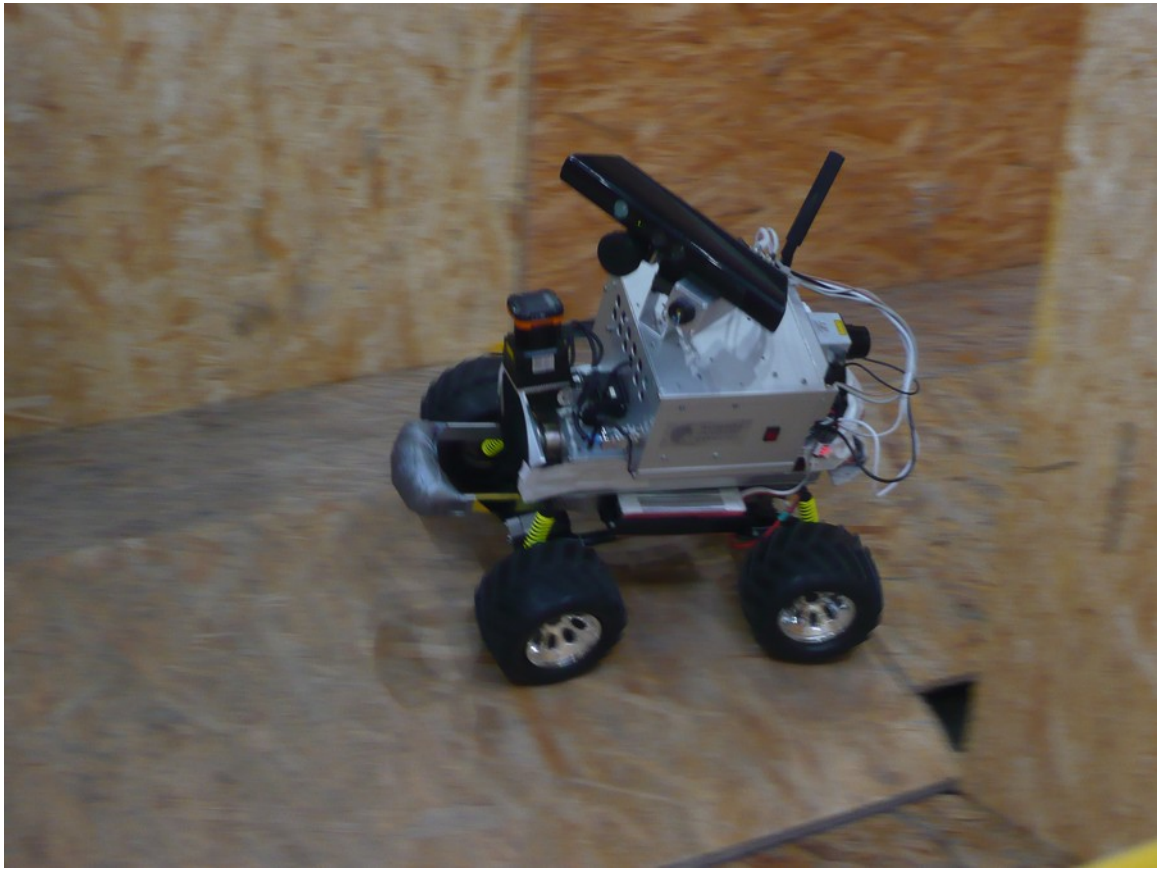

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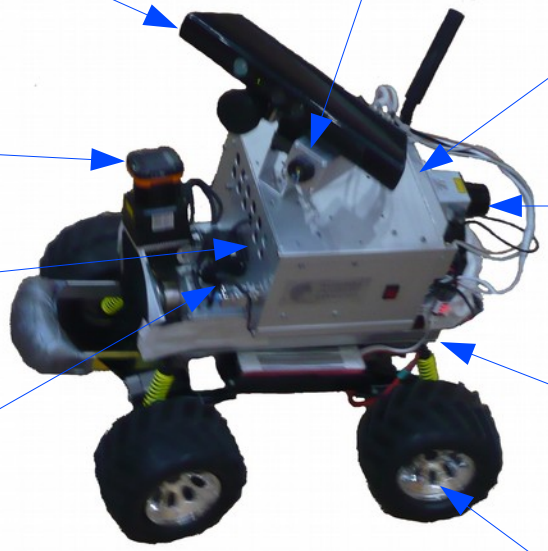

RGB-D Camera
-4m range
-30Hz

Thermal Camera
-10Hz
-160x120 resolution

2 x PS Eye Camera
(not pictured)
-up to 60Hz
-640x480

Hokuyo UTM-30LX LIDAR
-30m range
-40Hz scan rate
-roll-/pitch-stabilized

Hokuyo URG-04LX LIDAR
-4m range
-10Hz scan rate

CO2 Sensor

Navigation & Control Unit
-3 Axis Accelerometer
-3 Axis Gyroscope
-2 Axis Magnetometer
-Barometer

Bi-Directional Audio

Wheel Encoders
(one per wheel)

Processing:
-Geode 500 MHz (low level control)
-Core i7 2.6 GHz Mini-ITX
-Nvidia CUDA GPU optional

Onboard Network
Hector UGV

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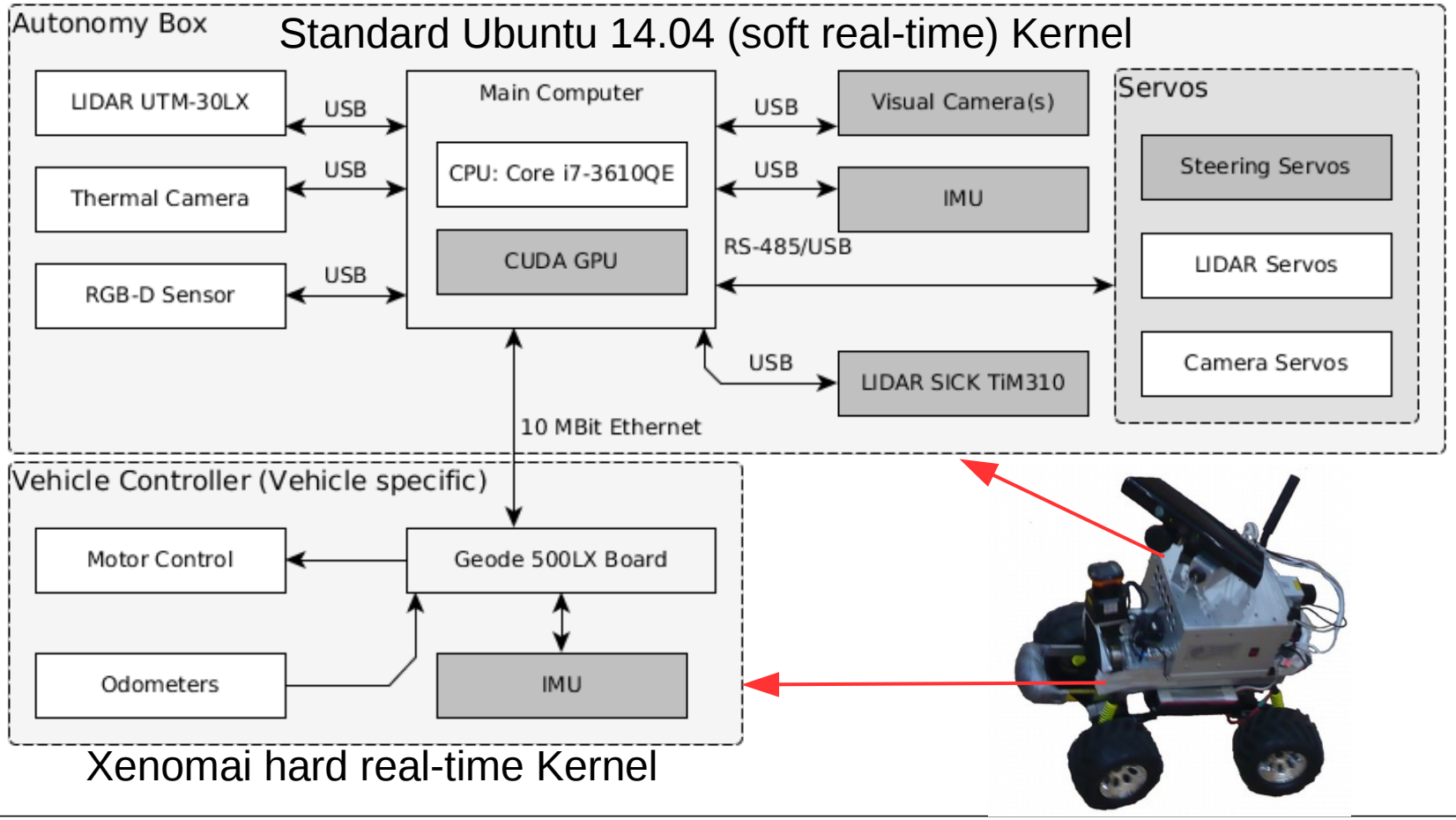

System Computation Graph

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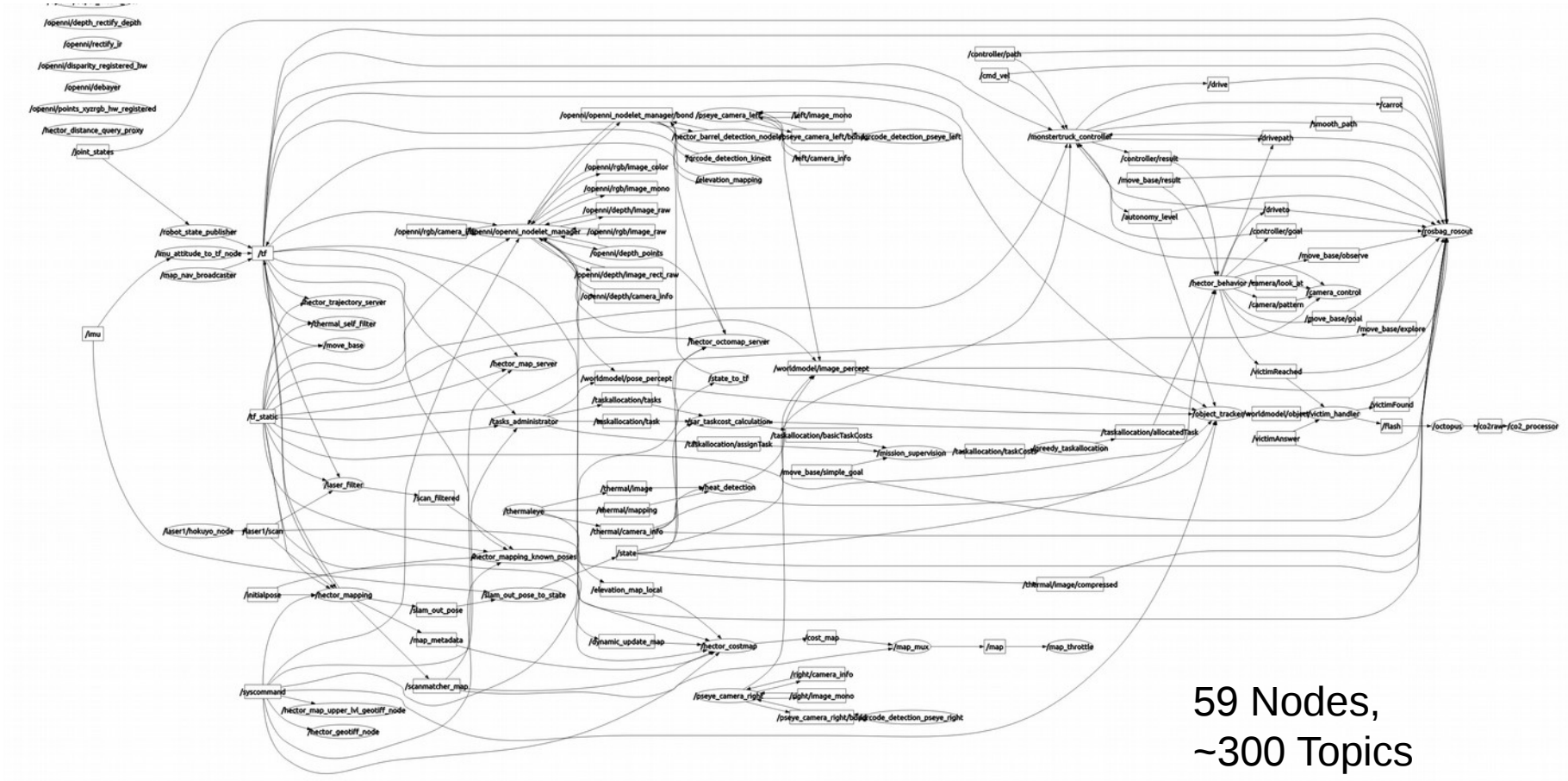

59 Nodes,
~300 Topics

Robust Communication

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- Integration with Serval Mesh Extender
  - Automated multi-hop routing
  - Delay tolerant communication
    - Automatic sync with devices in range
- Integration with MiniWorld simulator upcoming
  - Simulation
  - Hardware in the loop
- Research as part of the NICER (Networked Infrastructureless Cooperation for Emergency Response) project

Multi Robot Map Merging – RoboCup 2015

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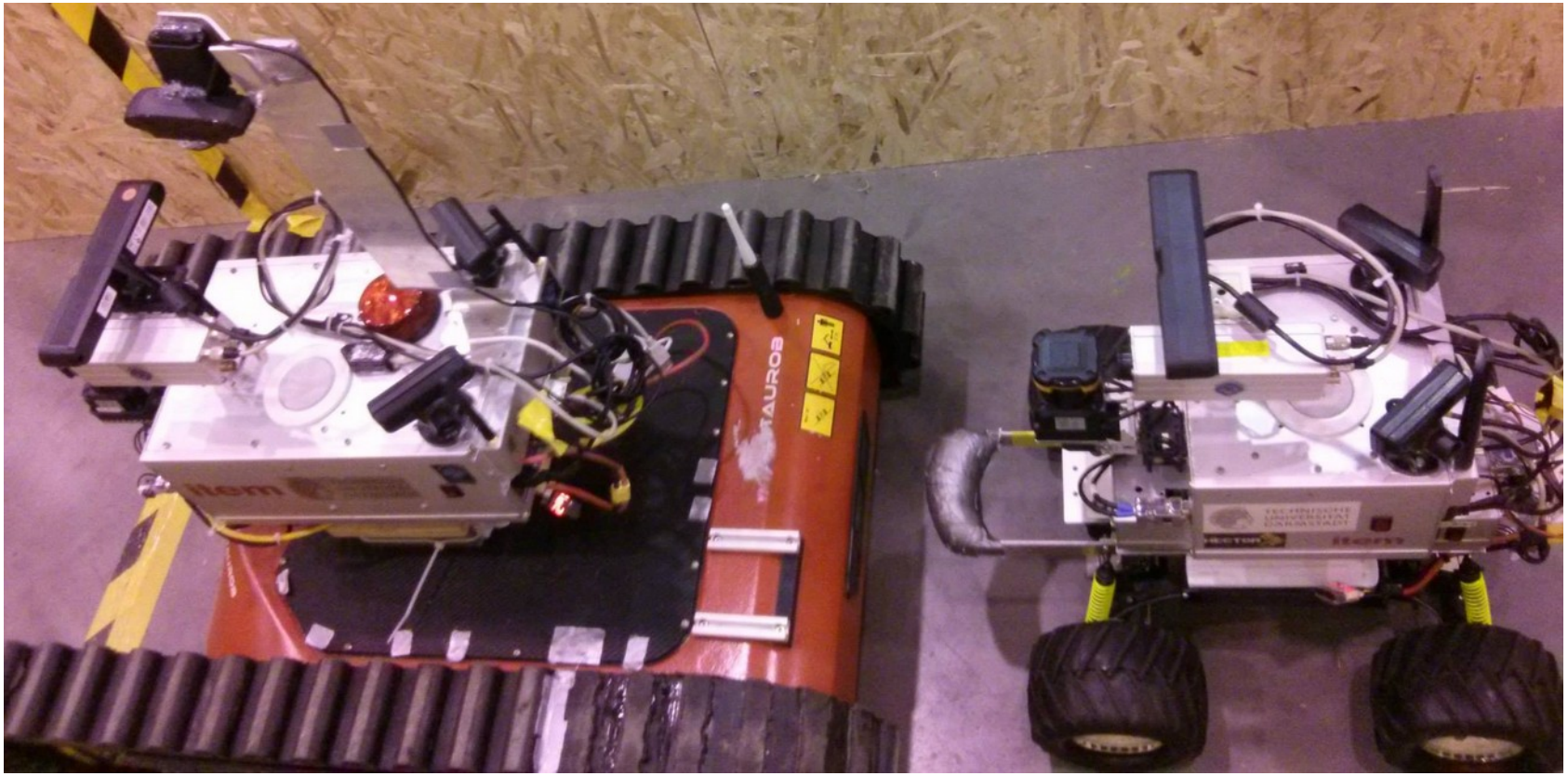

Multi Robot Map Merging – RoboCup 2015

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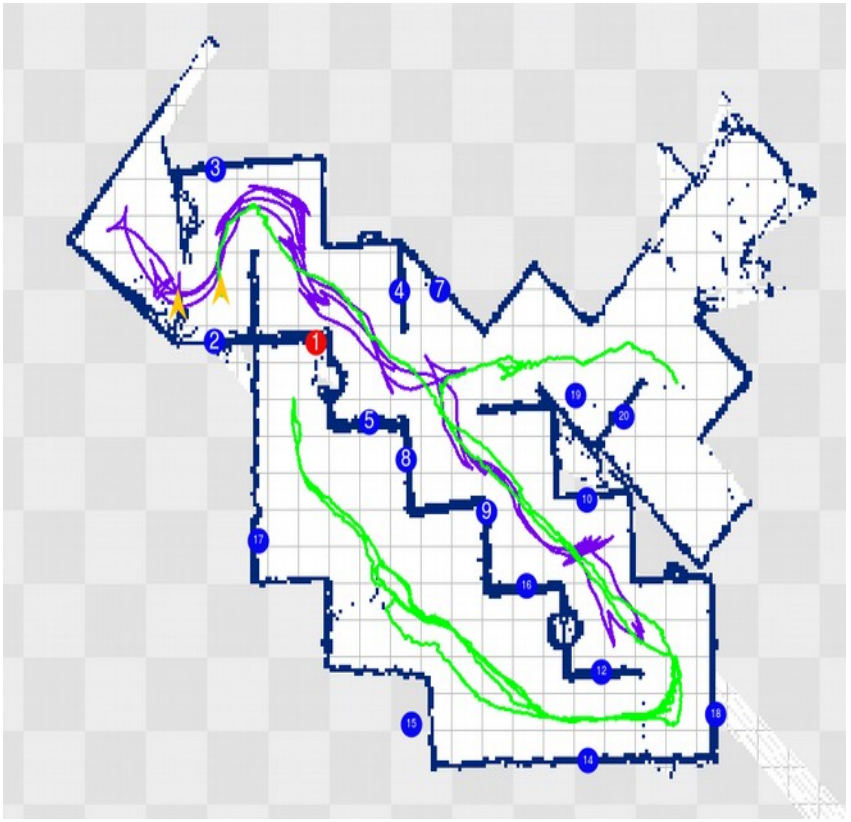

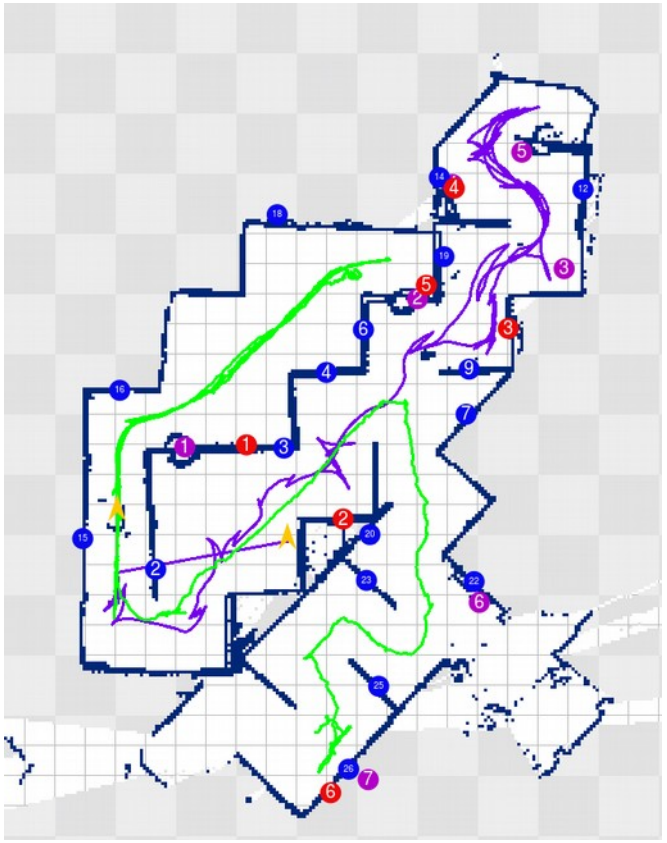

Simulation

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- First class tool
  - Especially when focusing on autonomy
- Find bugs early
- Ubiquitous testing capability
- RoboCup Rescue:
  - 2008-2011: MuroSimF
  - From 2012: Gazebo

Customizing Gazebo

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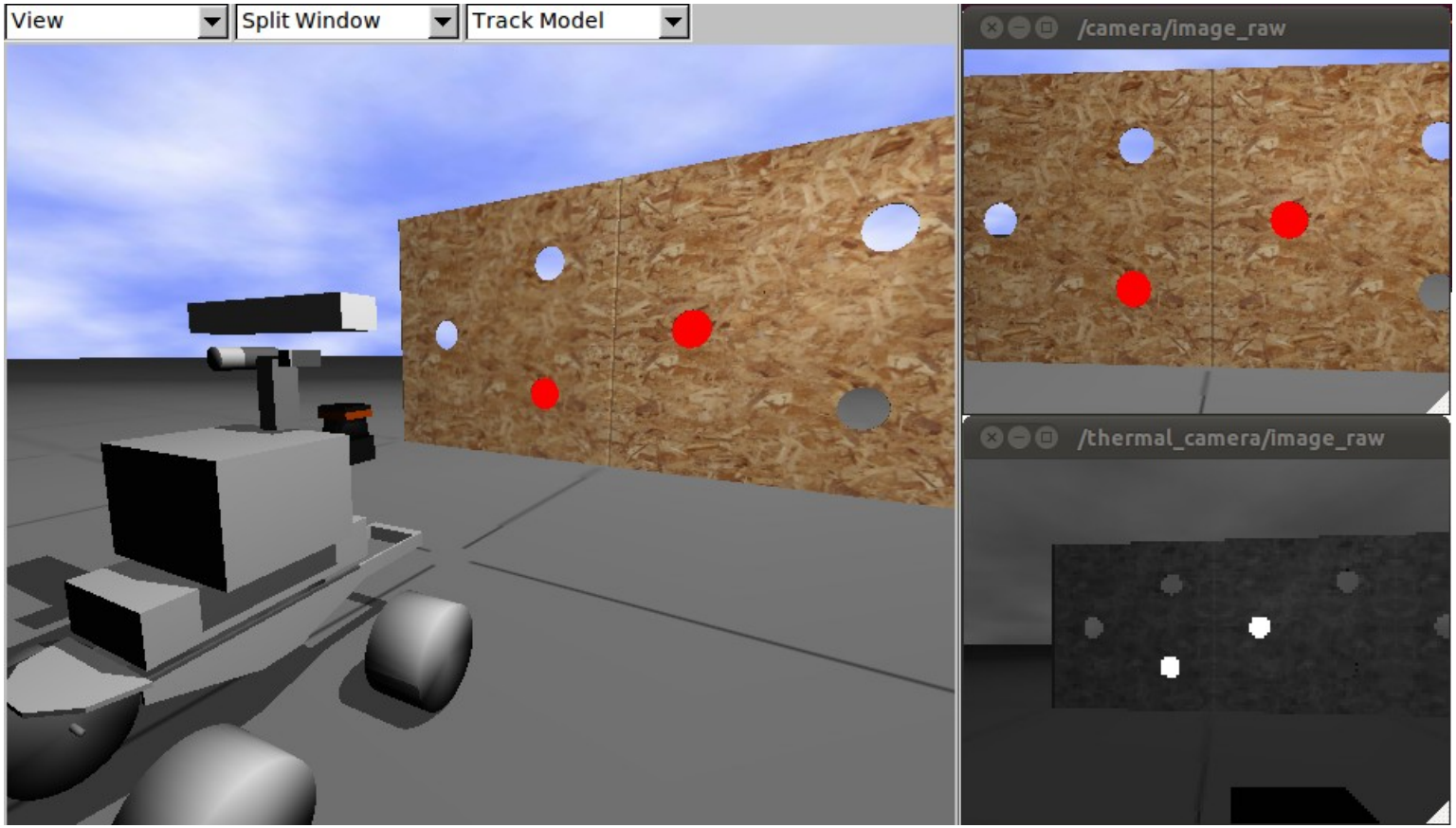
- hector_gazebo_thermal_camera



Customizing Gazebo

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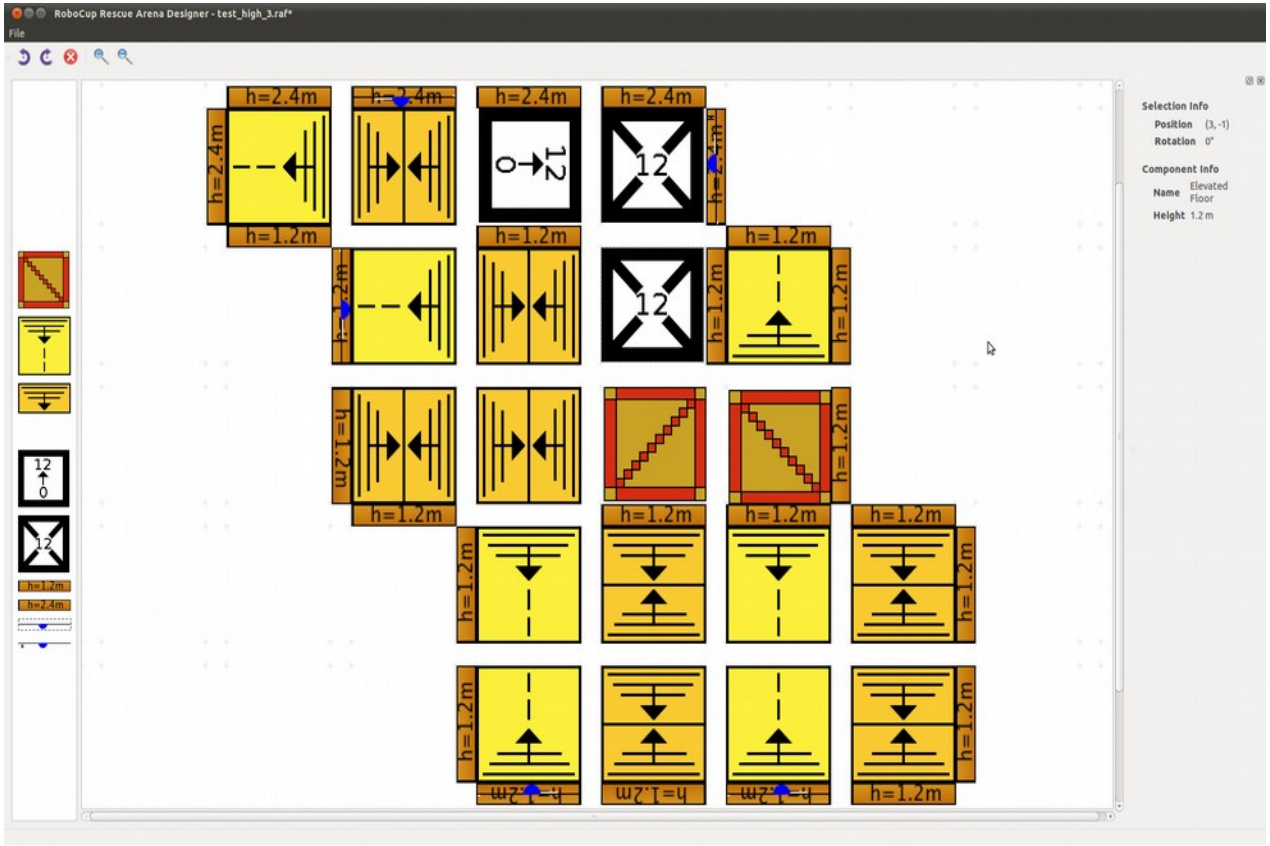

Customizing Gazebo

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- hector_nist_arenas_gazebo

Customizing Gazebo

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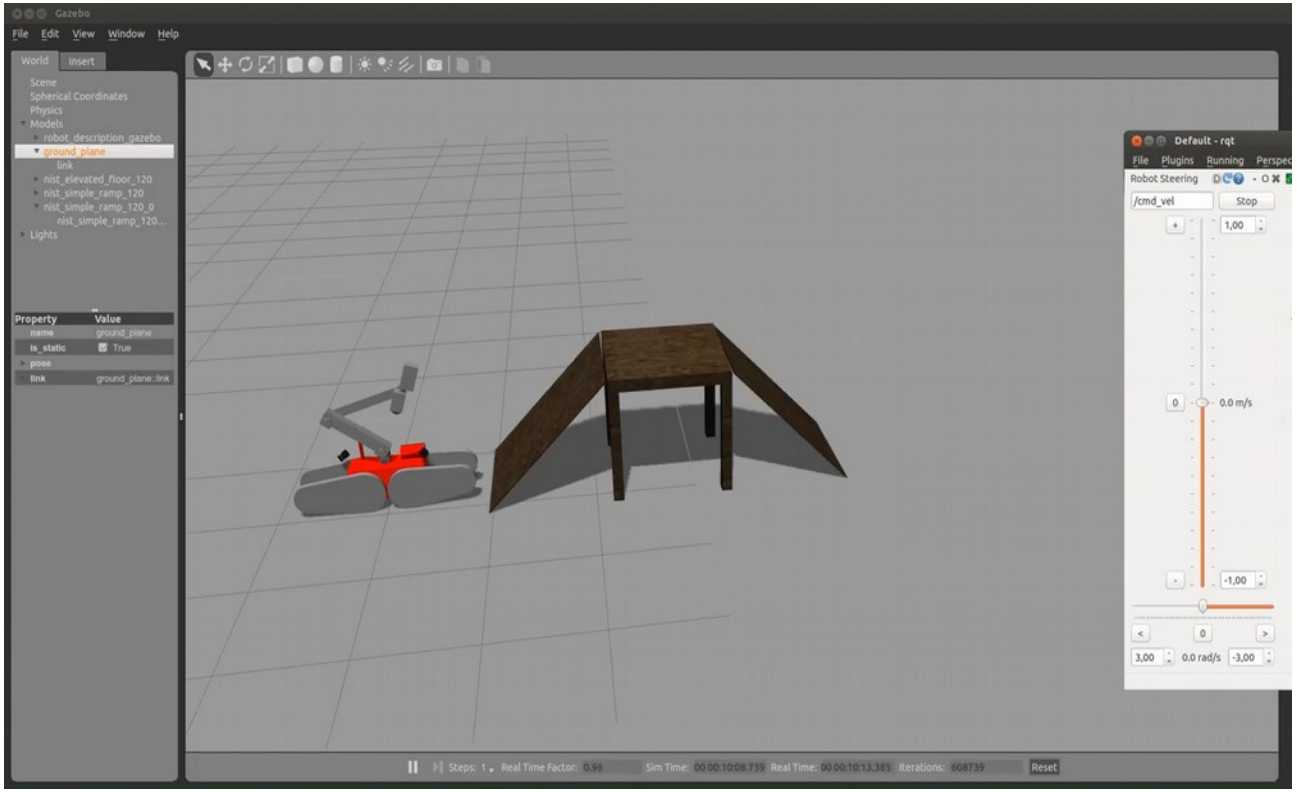
- hector_gazebo_plugins



Customizing Gazebo

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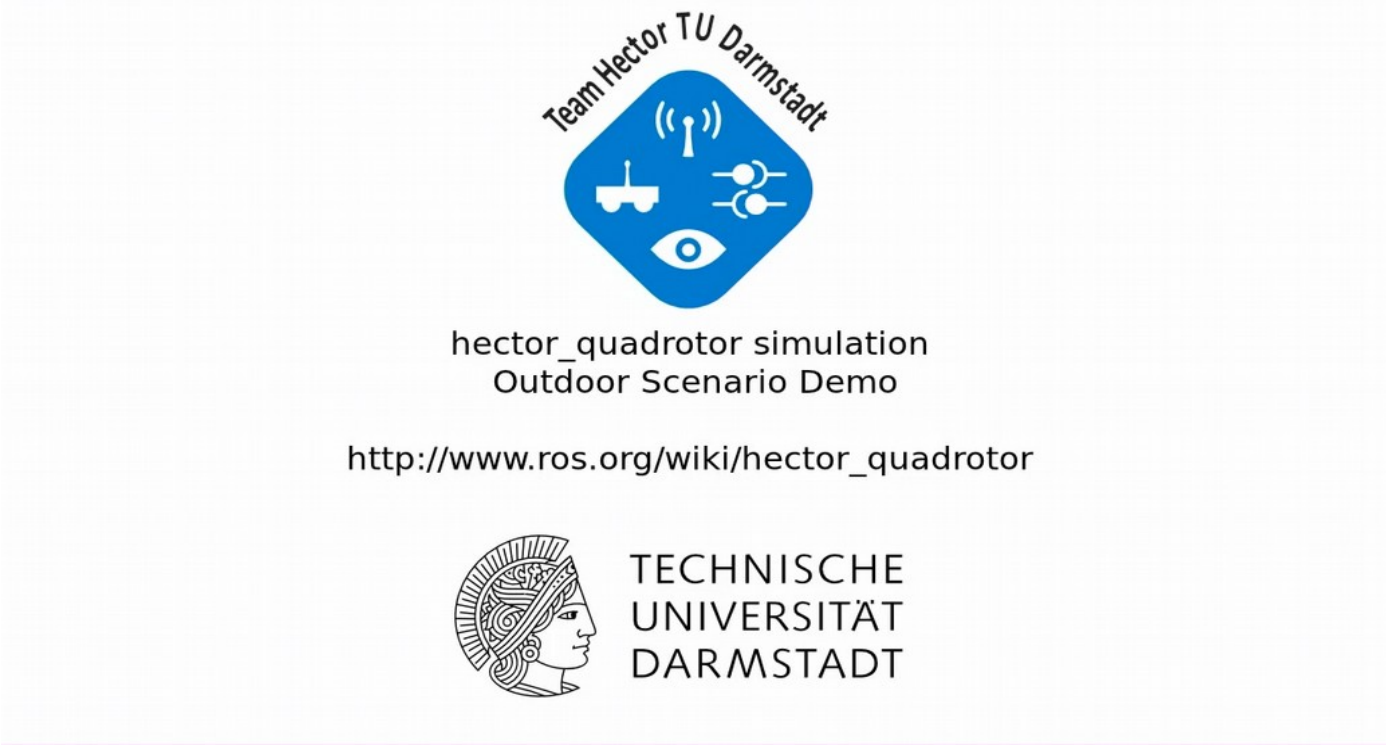
- hector_quadrotor



Customizing Gazebo

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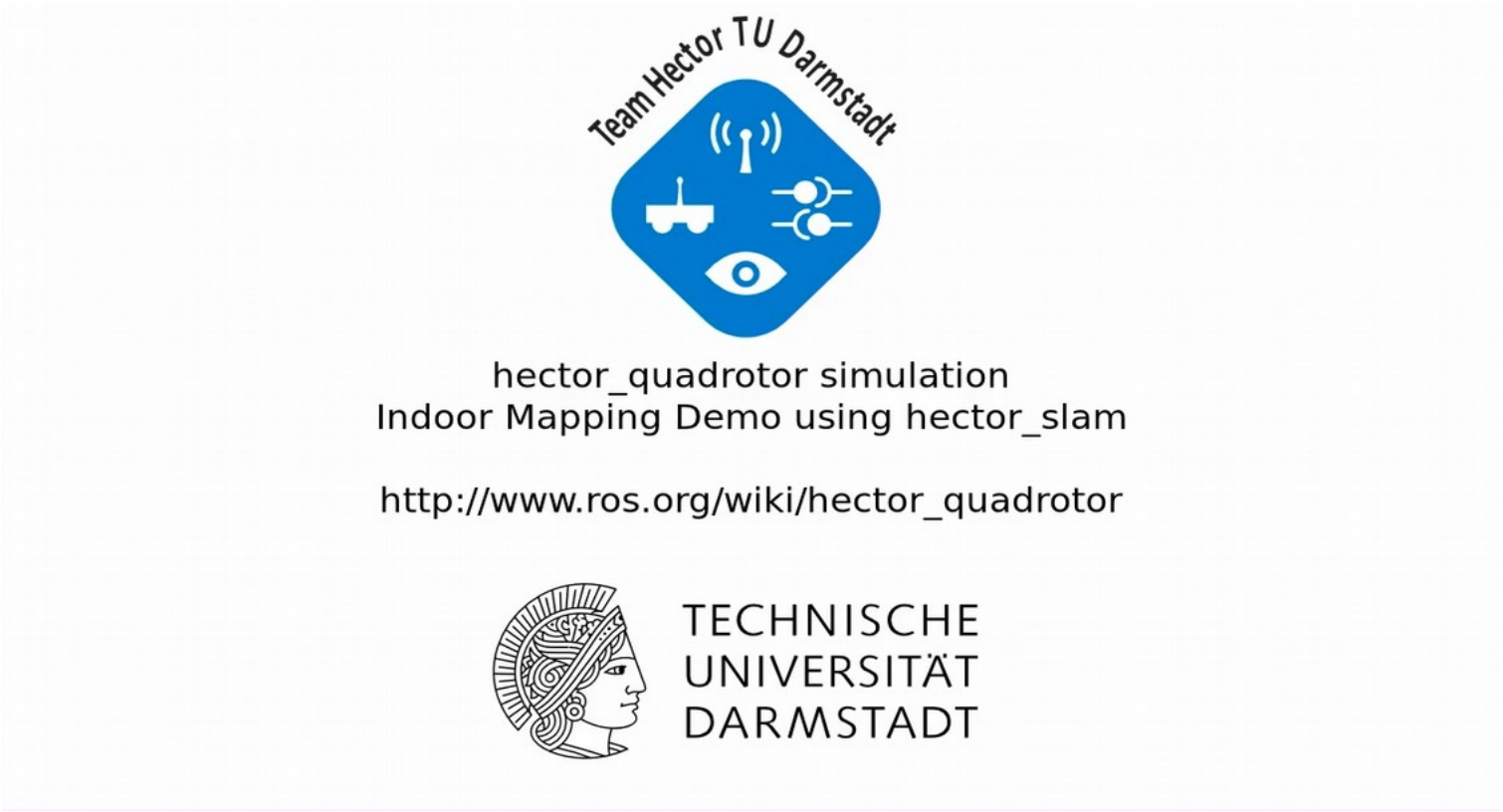

Search for Victims - Evaluation

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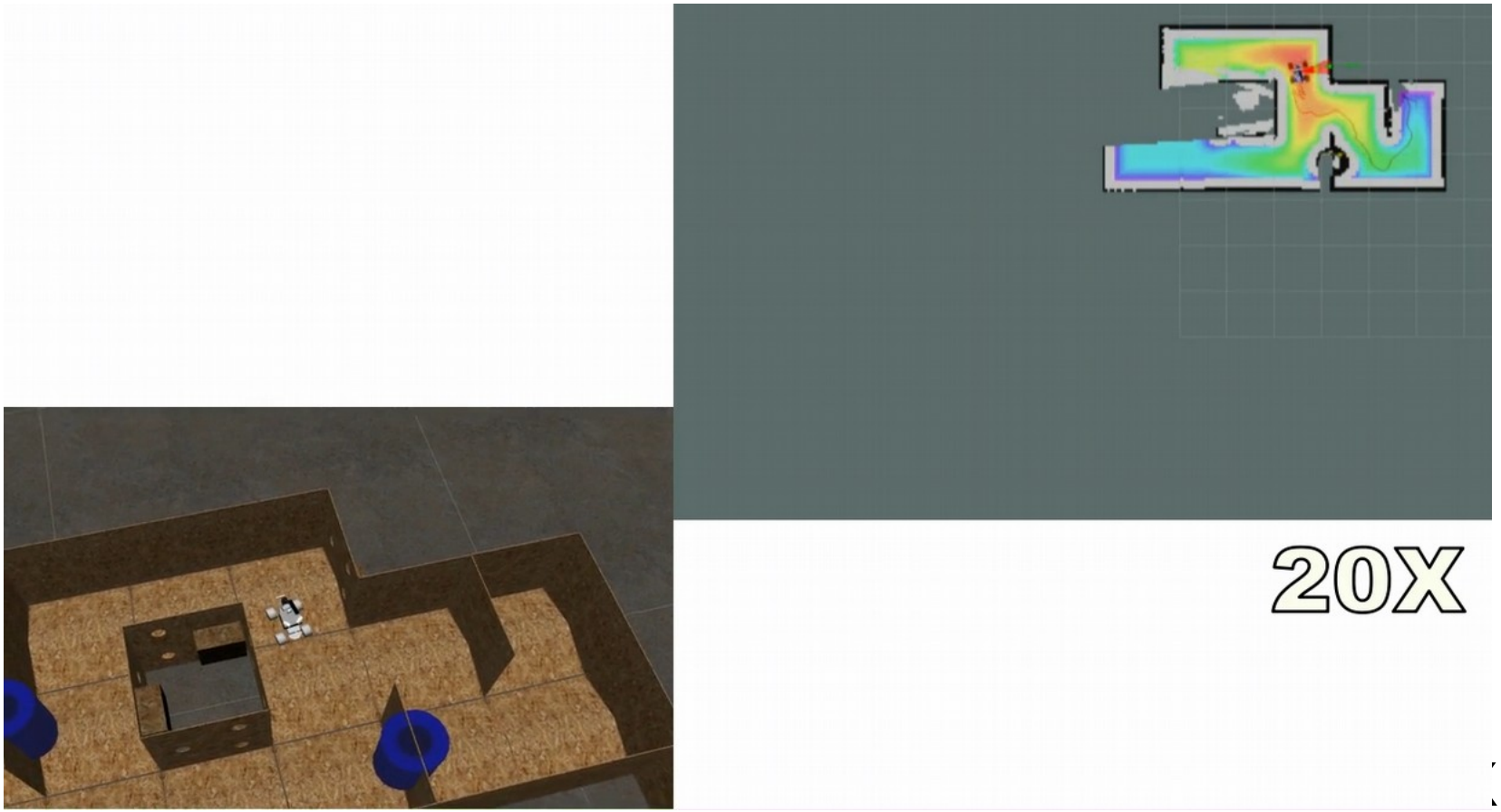

Search for Victims - Evaluation

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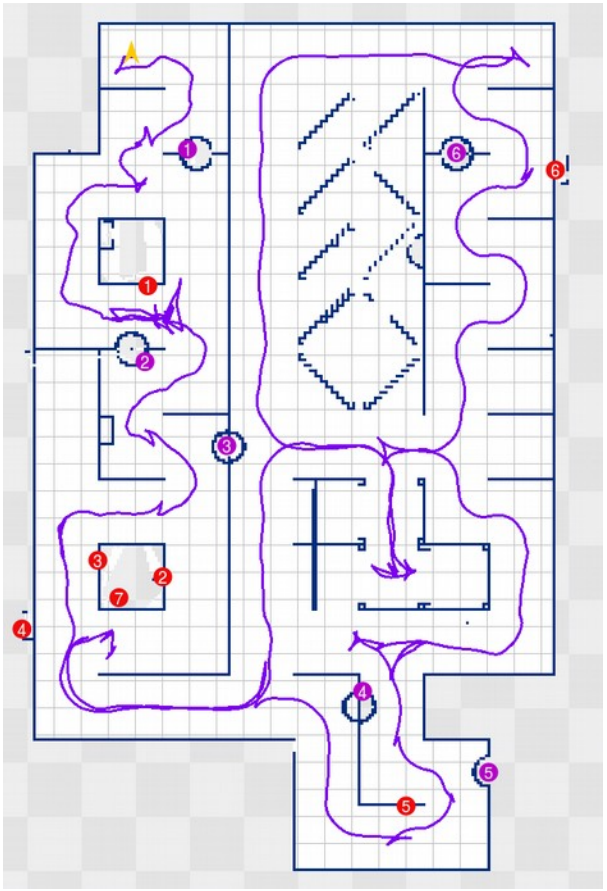
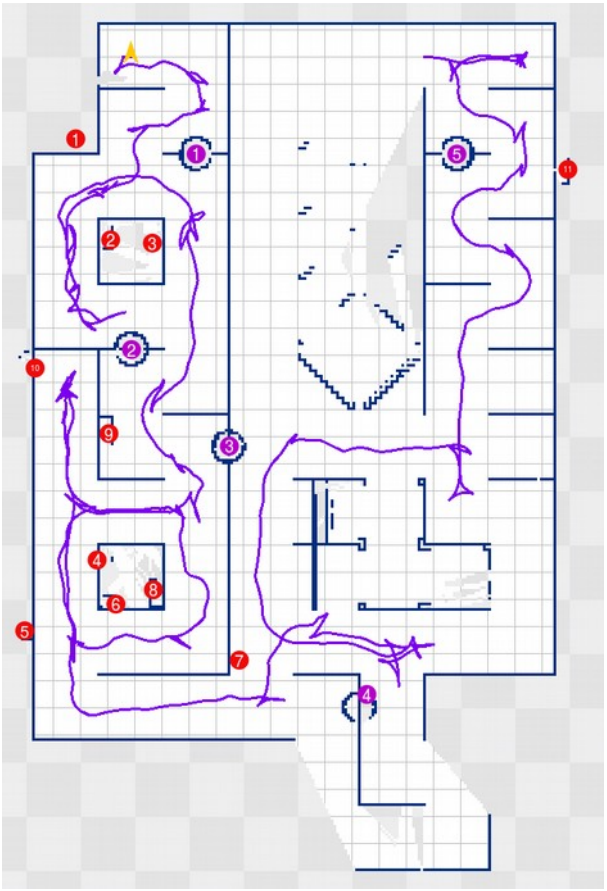
Exploration Transform



Victim Exploration



Search for Victims - Evaluation

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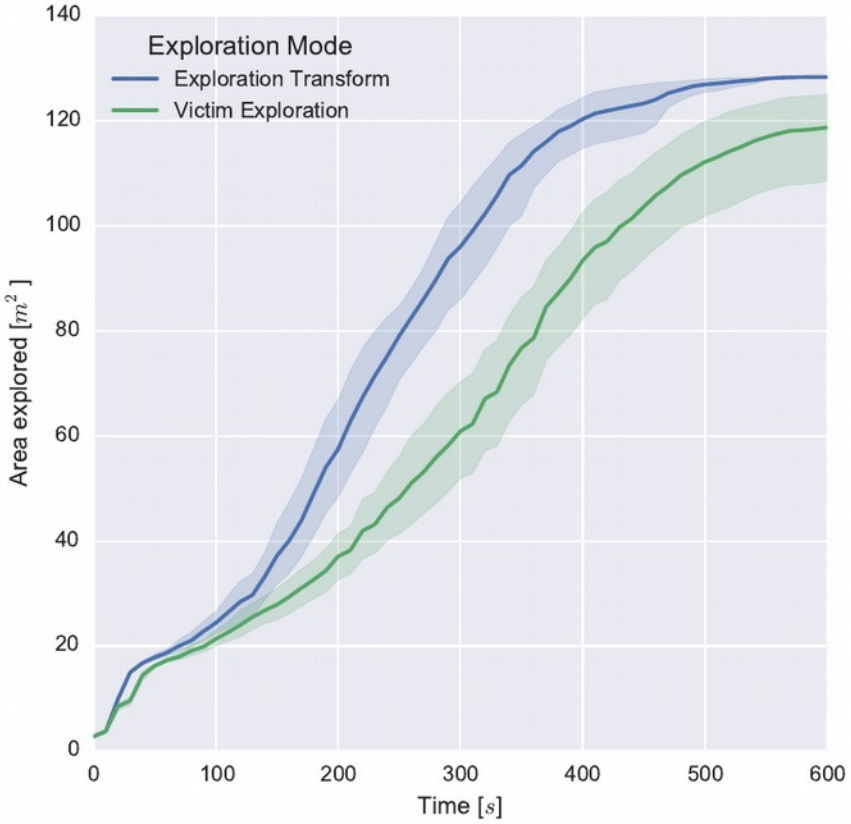

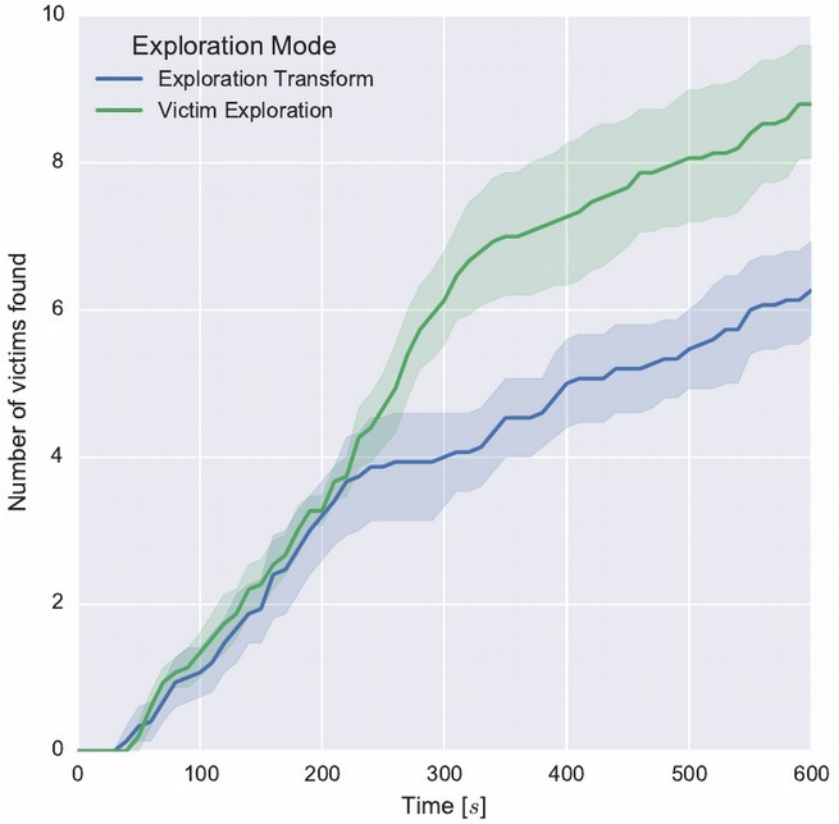

Search for Victims - Evaluation

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- Reproduce experiments
  - exploration_test_node.py - rospy node controlling a evaluation run
    - Auto confirm victims
    - End after 10 minutes
    - Log data
  - launch_eval_complete.launch - Launch setup
  - run_looped.sh - Script runs launch setup in loop
- Steps:
  - Start script on server (or for instance your own machine overnight)
  - Wait
  - Profit

Gazebo Wishlist :)

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- Features
  - Open source humanoid robot example
  - Tracked vehicle plugin
  - Multi-robot support (more a ROS issue really)
  - Rendering improvements
    - Higher fidelity
    - Less GPU driver sensitivity
- Bugfixes
  - Camera timestamp issue introduced with Gazebo4

Overall Performance – RoboCup 2014

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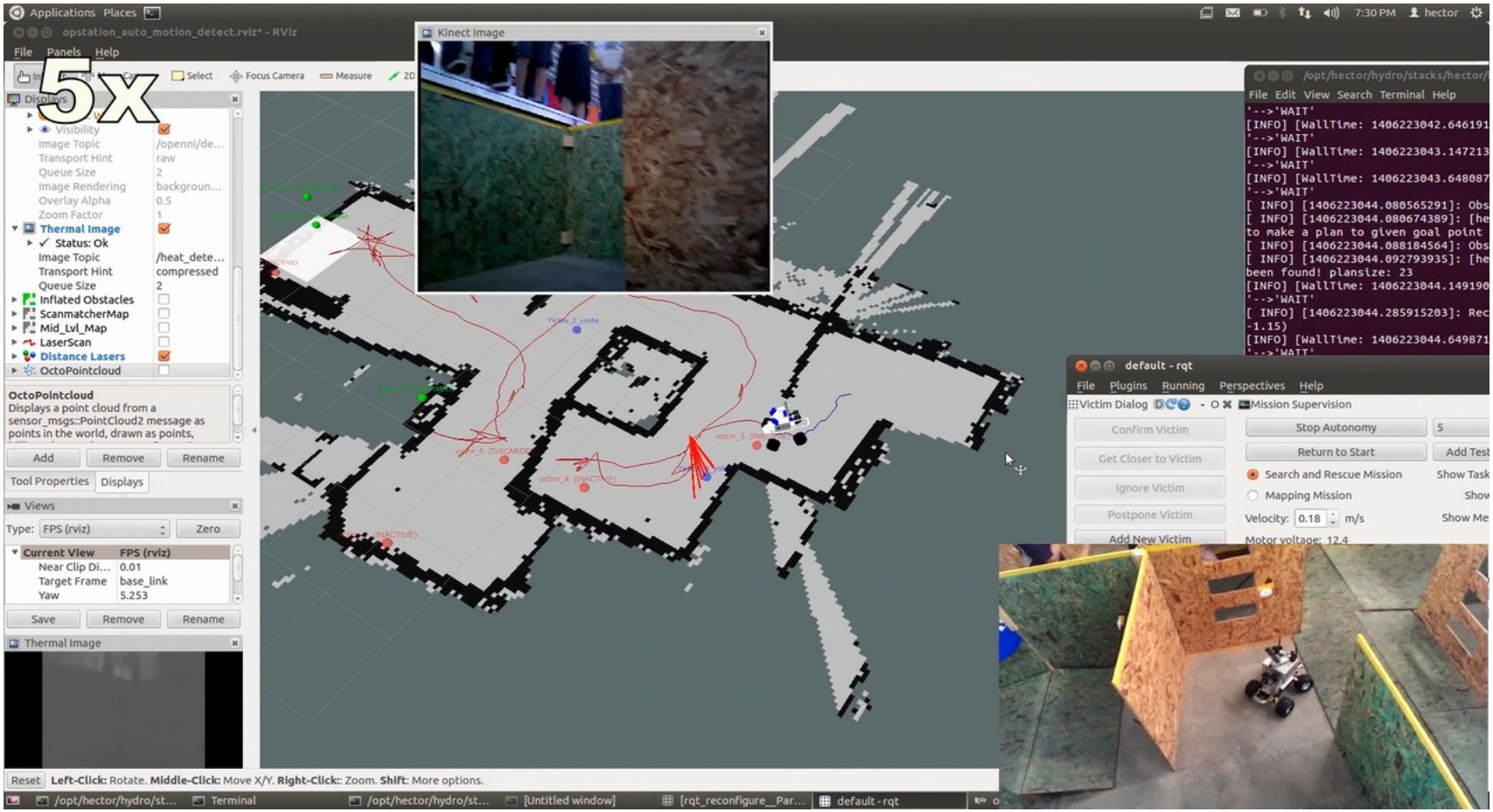

Team Hector Darmstadt - Awards

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- Best in Class Autonomy
  - RoboCup German Open 2011 – 2015
  - RoboCup 2012 – 2015
- Winner RoboCup German Open 2011 - 2014
- RoboCup 2014 World Champions

Ongoing Research – Robot Capabilities

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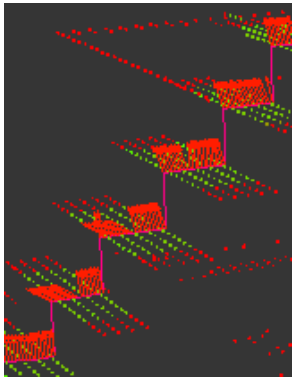
- SLAM
  - Robust 3D Simultaneous Localization and Mapping
- Locomotion
  - 3D Motion Planning in challenging terrain
- Semantic Mapping
  - Detection of victims
- **From Exploration and Observation to Manipulation**
  - Picking up objects
  - Removing debris
  - Manipulating valves
  - Using human tools
- Flexible Supervisory Control
- Coordination of Heterogenous Robot Teams



Centaur Robot

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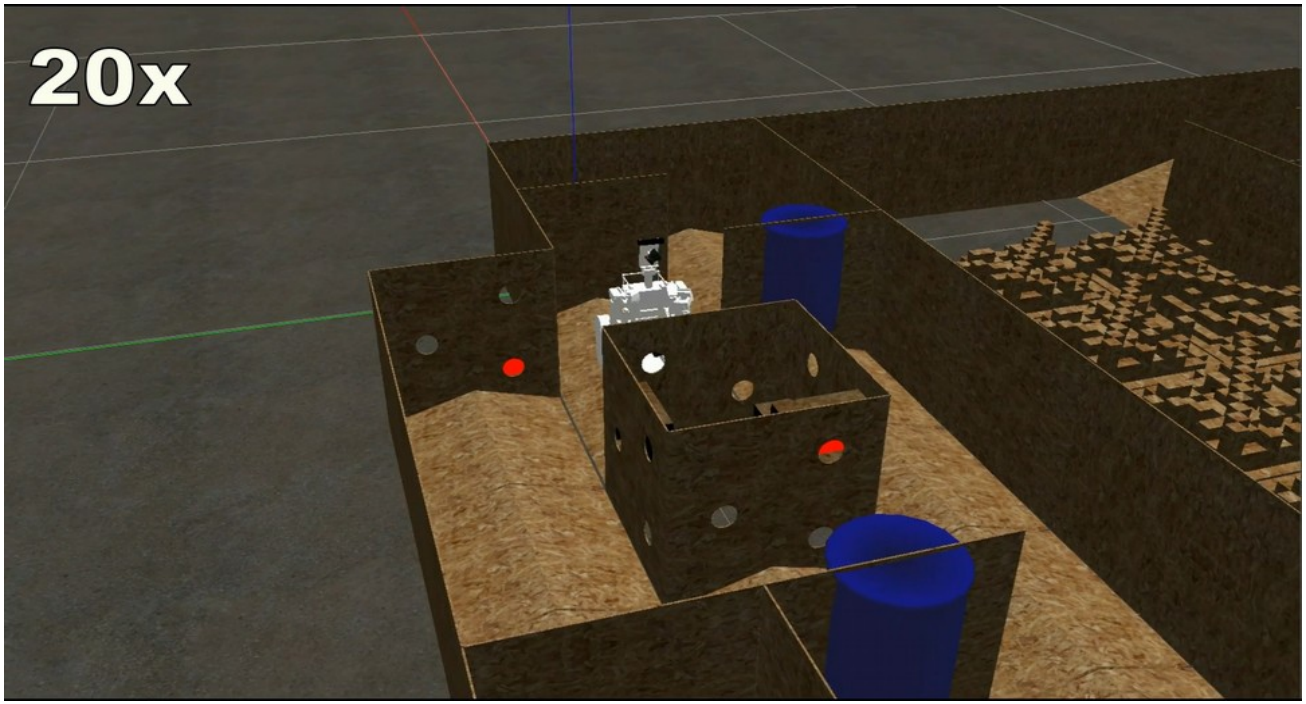
- Leverage
  - Stability of conventional robot base
  - Versatility and dexterity of humanoid upper body



Centaur Robot

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- Comprehensive simulated setup available:
  https://github.com/tu-darmstadt-ros-pkg/centaur_robot_tutorial

- Hands-On!

Hands-On Ideas

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- Apply the LIDAR obstacle avoidance developed yesterday to Centaur
- Track green blocks and move toward them
  - Possibly move them out of the way
- Use simulated thermal camera for victim detection
- Add camera in hand and look for and detect QR codes
- Open a door using MoveIt! Motion planning

References

TECHNISCHE UNIVERSITÄT DARMSTADT

- RoboCup Rescue wiki page on ros.org
- tu-darmstadt-ros-pkg on ros.org
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