Tutorial - Versatile Autonomous Urban Search and Rescue Robots
Motivation – Urban Search and Rescue and Disaster Response

WTC [Casper et al. SMC 2003]

Fukushima [Yoshida et al. FSR 2014]
Motivation - Exploration and Search for Victims

[Brian Gauvin 2005]

[Richard Campanella 2005]
State of the Art

Reliance on connectivity

Motion Commands

Video Stream

Radio or tethered

Workload

Teleoperation
Improving Capabilities leveraging Autonomy

Workload

Task-level Commands

Aggregated Worldmodel Data

Relaxed connectivity requirements
Example Hardware
Hector UGV
Example Hardware
Hector UGV

RGB-D Camera
- 4m range
- 30Hz

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

CO2 Sensor

Bi-Directional Audio

Thermal Camera
- 10Hz
- 160x120 resolution

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

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

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

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

Standard Ubuntu 14.04 (soft real-time) Kernel

Xenomai hard real-time Kernel
System Computation Graph

59 Nodes, ~300 Topics
Robust Communication

- 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
Multi Robot Map Merging - RoboCup 2015
Simulation

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

- hector_gazebo_thermal_camera
Customizing Gazebo

- hector_nist_arenas_gazebo
Customizing Gazebo

- hector_nist_arenas_gazebo
Customizing Gazebo

- `hector_gazebo_plugins`
Customizing Gazebo

- hector_quadrotor

http://www.ros.org/wiki/hector_quadrotor
Customizing Gazebo

- hector_quadrotor

hector_quadrotor simulation
Indoor Mapping Demo using hector_slam

http://www.ros.org/wiki/hector_quadrotor
Search for Victims - Evaluation
Search for Victims - Evaluation

Exploration Transform

Victim Exploration
Search for Victims - Evaluation

![Graphs showing area explored and number of victims found over time in Exploration Mode.](image)
Search for Victims - Evaluation

- **Reproduce experiments**
  - `exploration_test_node.py` - rospy node controlling an 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 :) 

- **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
Team Hector Darmstadt - Awards

- **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

- **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

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

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

- Hands-On!
Hands-On Ideas

- 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

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