Realistic simulations of advanced robot control algorithms

Arnoud Visser

Technical Committee
Simulation League

In close cooperation with

Mediterranean Open Workshop on RoboCup Research,
Universita di Roma, "La Sapienza", Roma, Italy, March 15th, 2011.

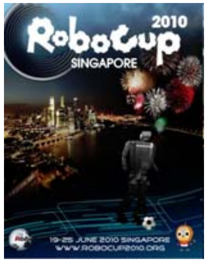
Universiteit van Amsterdam
Intelligent Systems Laboratory

University of Oxford
Computing Laboratory

Realistic Testbeds

At the Intelligent System Laboratory Amsterdam we prefer to study scientific problems based on real data. Our groups are active in:

- TRECvideo competition
- IMMIX query – answer text competitions
- Reinforcement Learning competition
- Indoor Micro Air Vehicle Flight Competition
- RoboCup competition



RoboCup

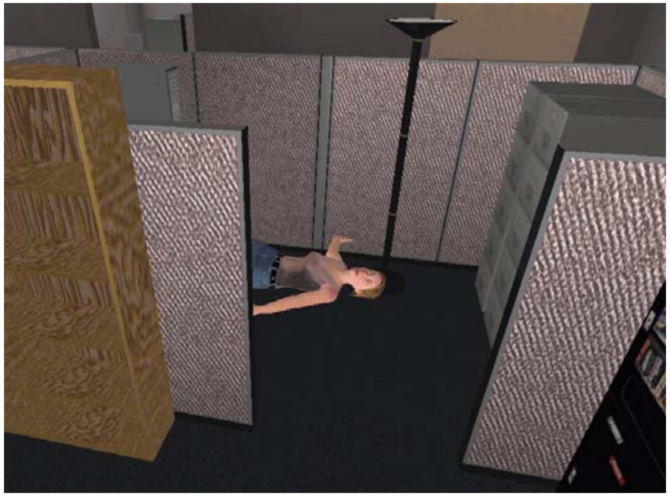
Universiteit van Amsterdam has been active since 1998 in both Soccer and Rescue League

RoboCup Rescue Competitions

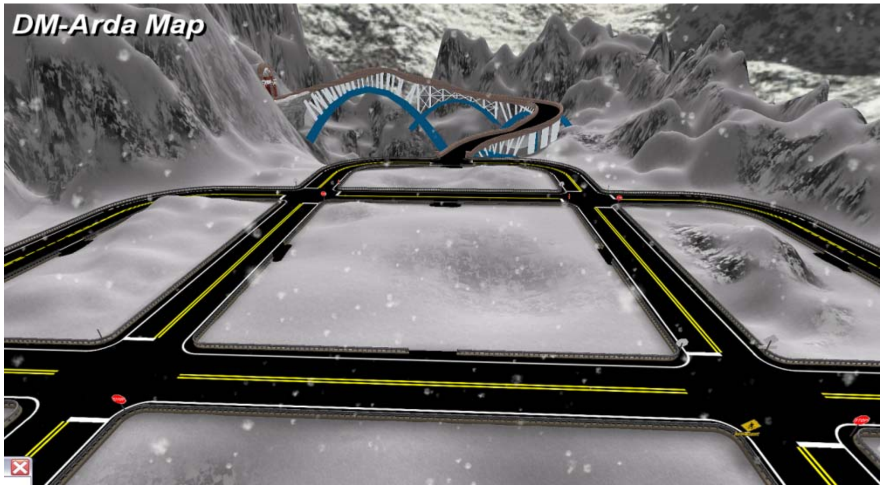
- Rescue Agent simulation
  - Distributed decision making
  - Cooperation
  - Simulations of:
    - Building collapses
    - Road Blockages
    - Spreading fire
    - Traffic
- Real Robots
  - Single collapsed structure
  - Autonomous navigation
  - Victim location and assessment

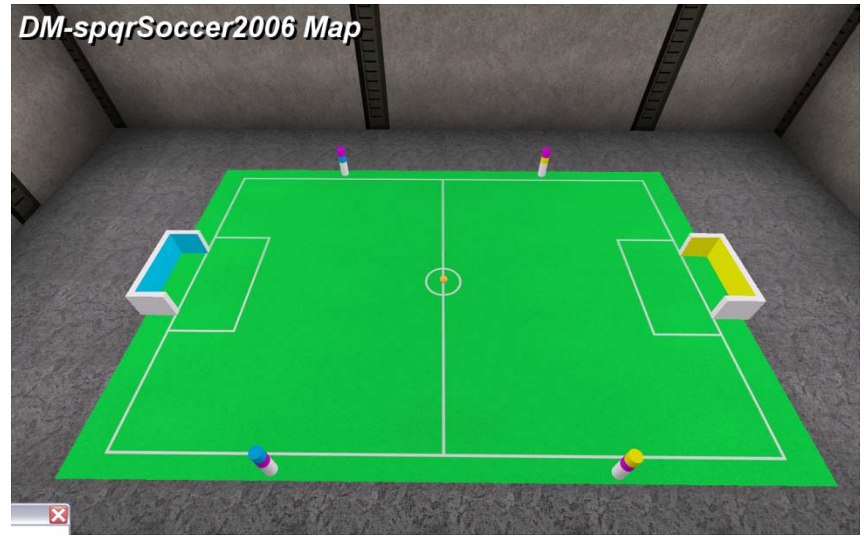
Virtual Robot Competition

- 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

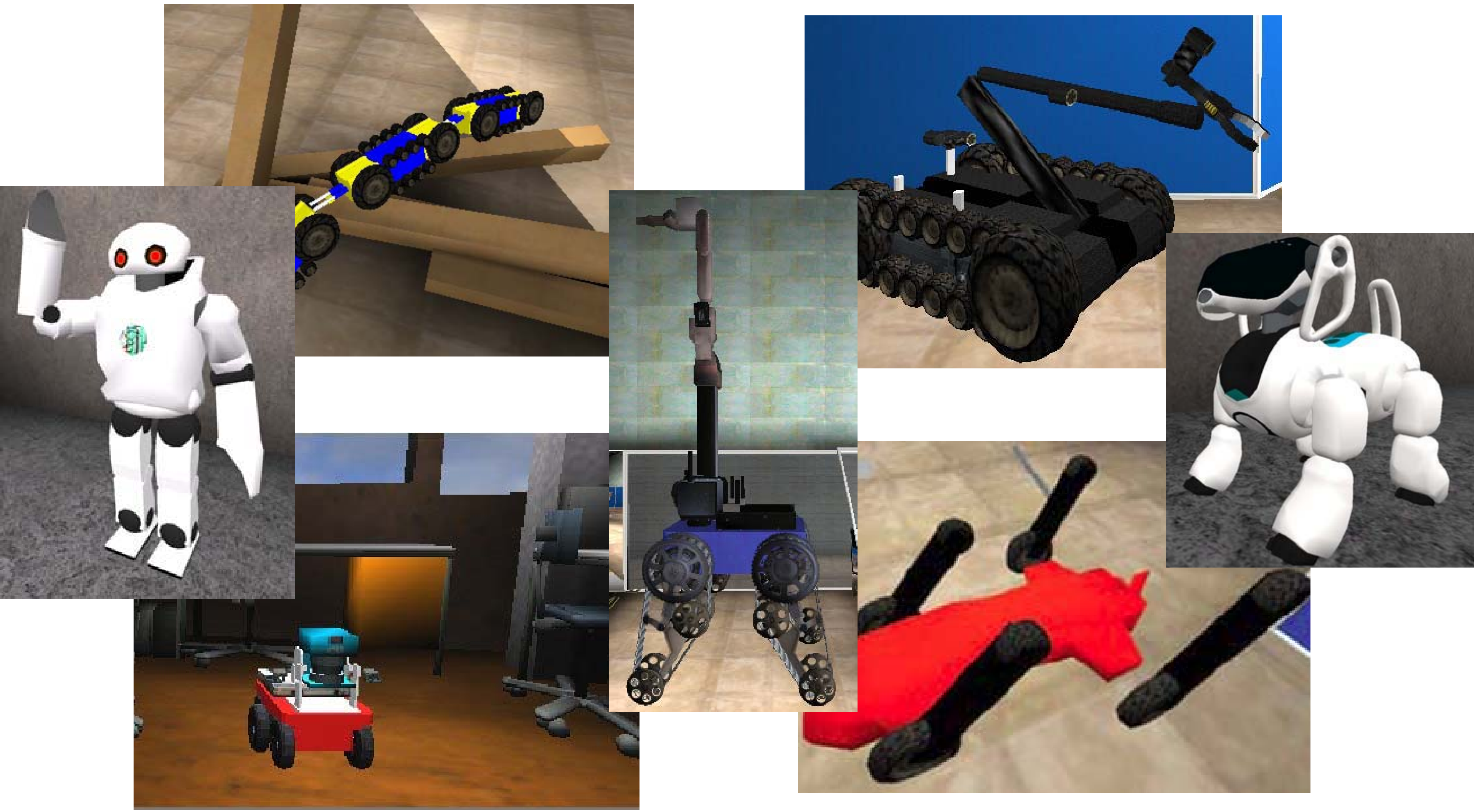


A wide variety of simulated worlds





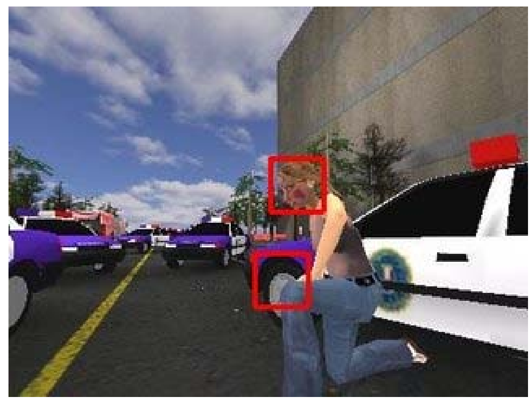
A wide variety of Robotic platforms

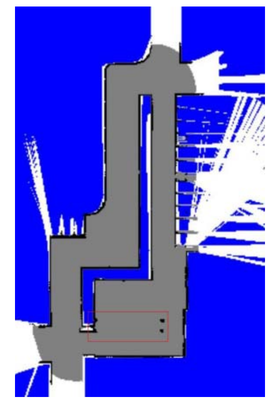


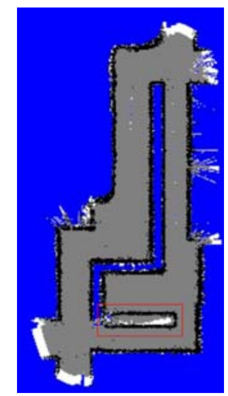
Amsterdam Oxford Joint Rescue Forces

Innovations in 2009 (i.e.)

- Using the Kenaf-robot
- Camera is used to learn victims and landmarks
- Landmarks stay in view
- Camera is used to build visual maps







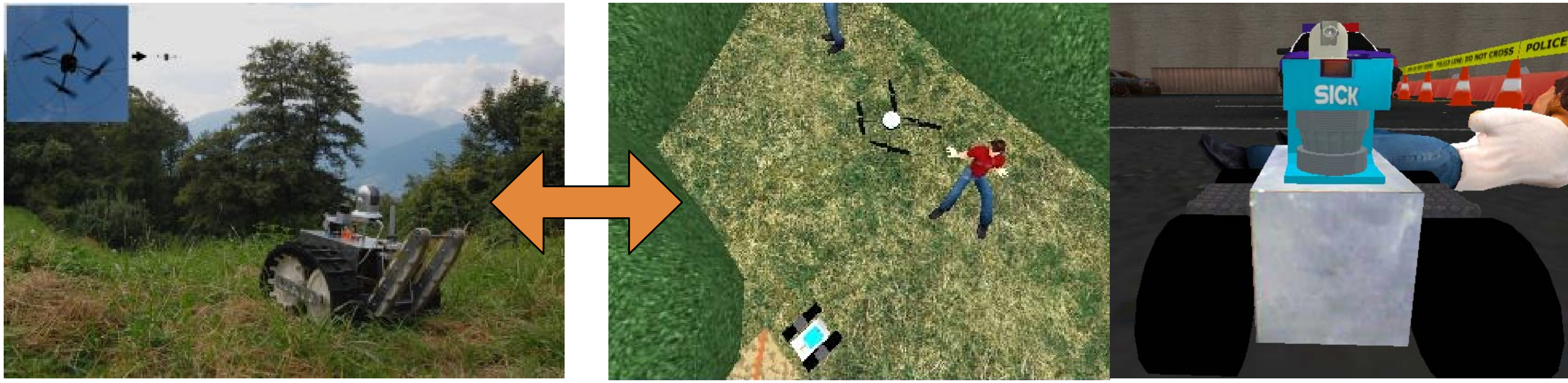
Other assets:

- Can control many robots (Matilda, Element, Talon, AirRobot, ATRVJr, Zerg. Etc.)
- Graph based map, which can be easily shared and corrected
- Smooth transition from teleoperated to fully autonomous behavior

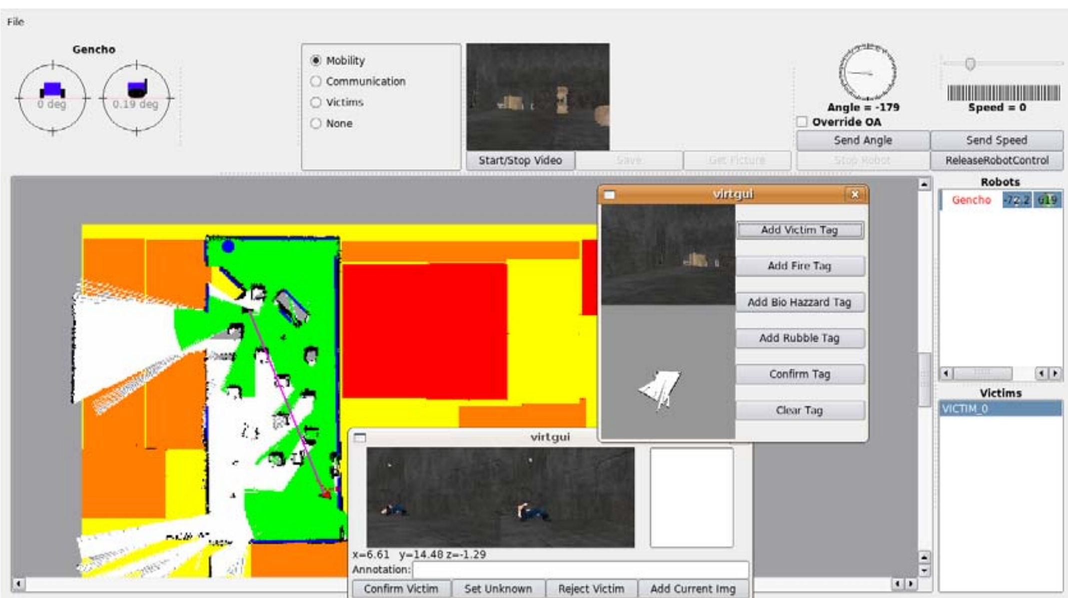
www.jointrescueforces.eu

Robotics
JACOBS UNIVERSITY

Jacobs Virtual Rescue



Transfer between real and simulated leagues.



Major Features:

- Heterogeneous Multi-Robot Mapping and Exploration
- Adjustable Autonomy
- Semantic Mapping
- Sensor Fusion

Max Pfingsthorn, Ravi Rathnam,
Todor Styanov, Yashodhan Nevatia, Rares Ambrus

POLITÉCNICA
Ingeniamos el futuro

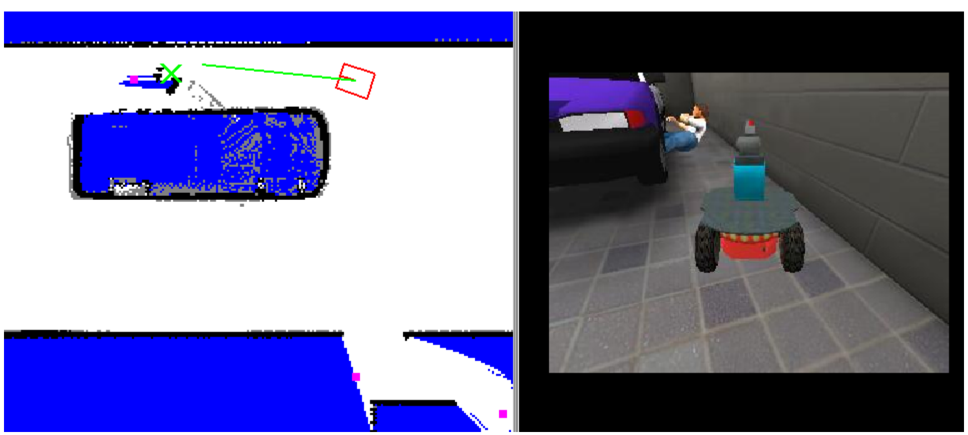
UPM - SPQR

Spain - Italy

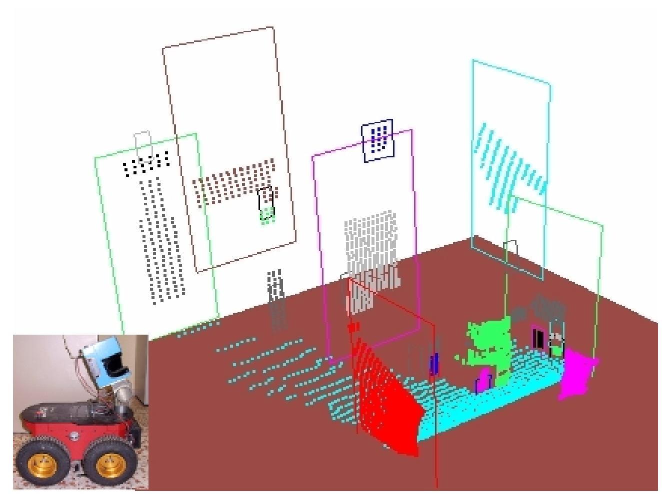
Dipartimento di Informatica e Sistemistica Antonio Ruberti
Sapienza Università di Roma

Heterogeneous team

Multi-Robot 3D Interface



Autonomous exploration and navigation

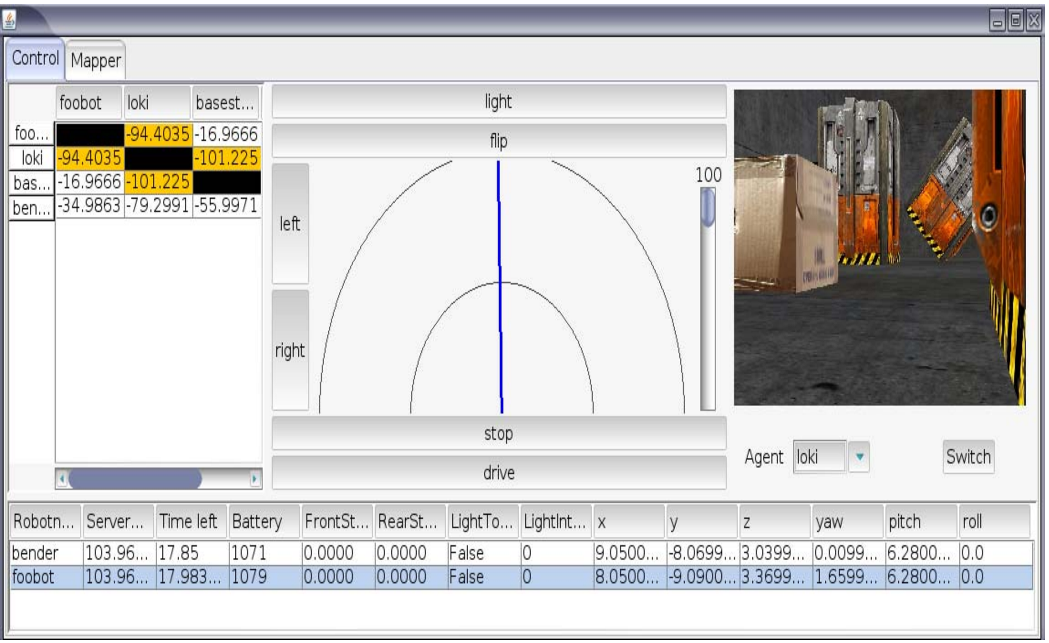


3D point cloud segmentation

npsolvers.wootstube.de

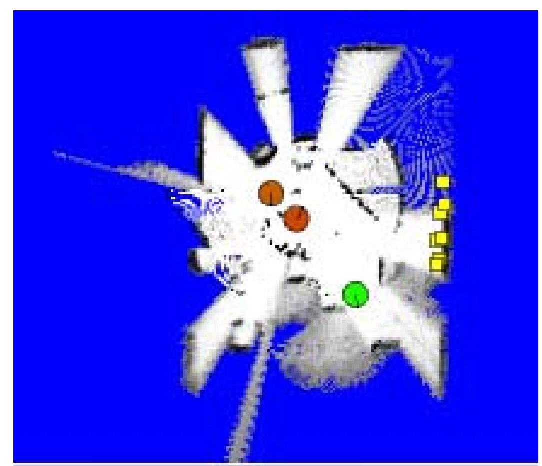
Teamleader: Patrick Sturm

Team members:Emanuel Plochberger, Leonhard Pfeiffer-Vogl



Main Features:

- High modularity
- Well documented
- Implemented in Java :)
- Simple Userinterface
- Multi Robot Mapping and Exploration
- Autonomous movement

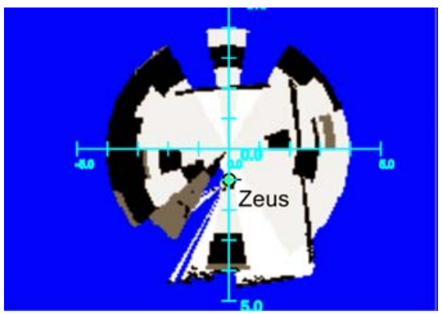


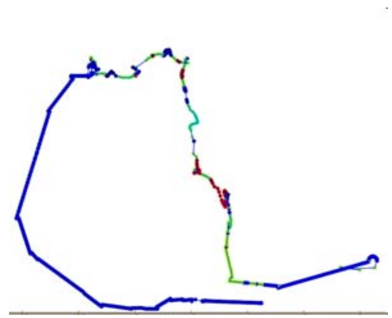
FACHHOCHSCHULE TECHNIKUM WIEN

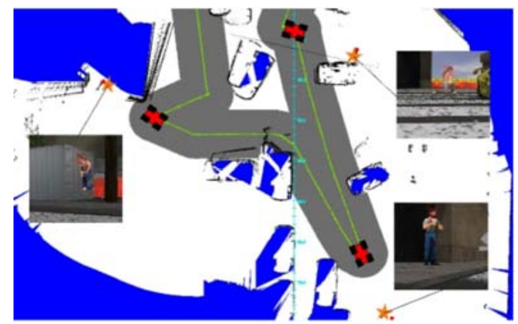
Amsterdam Oxford Joint Rescue Forces

Innovations in 2010 (i.e.)

- Local sonar maps
- Confidence selection inside maps
- Victim detection based on shape

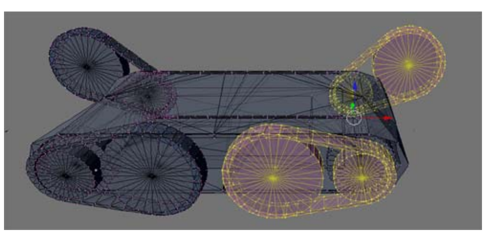






Infrastructure contributions:

- Kenaf model

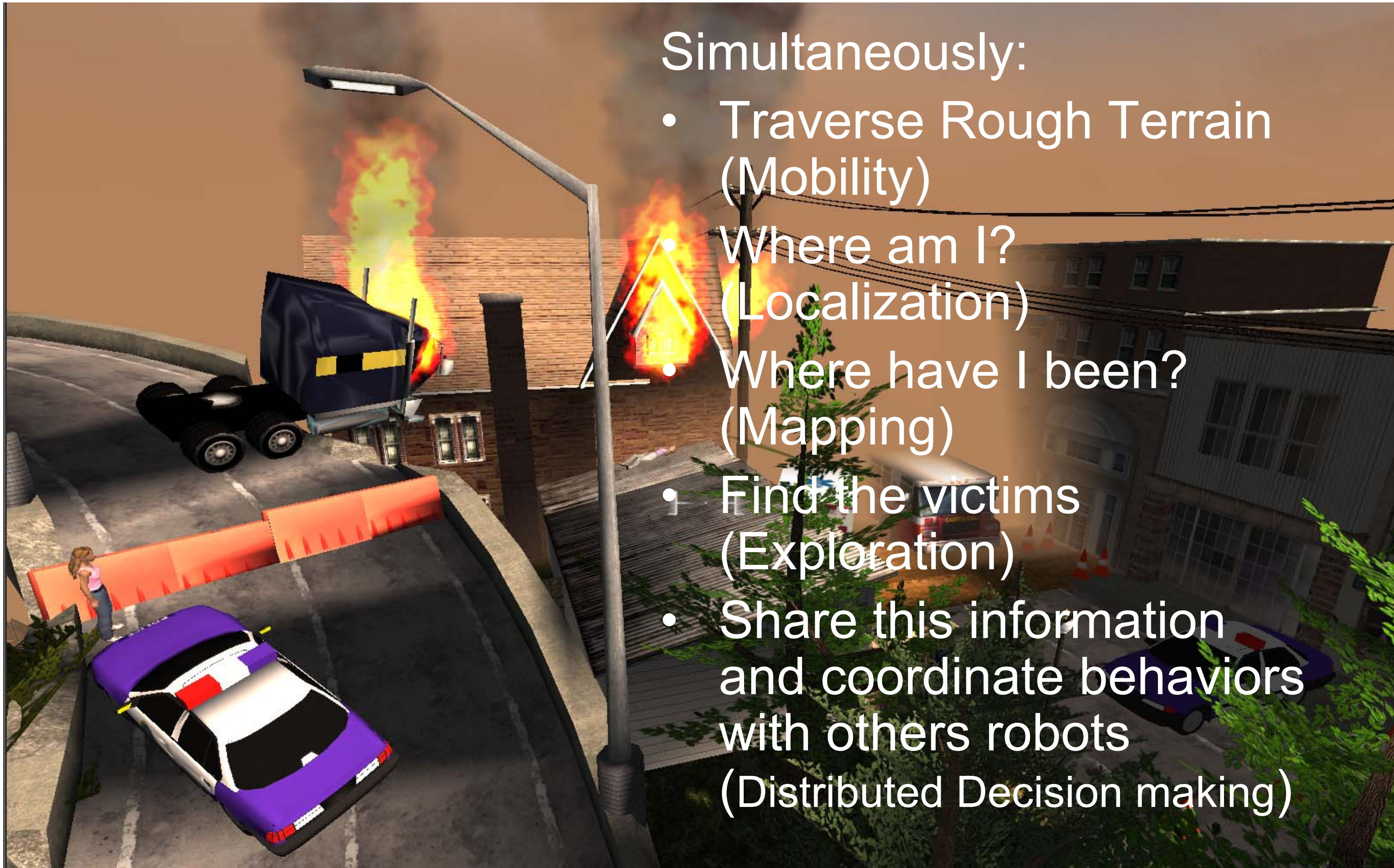


- Lasers sensitive for smoke

- Victim behaviour

www.jointrescueforces.eu

Virtual Rescue League



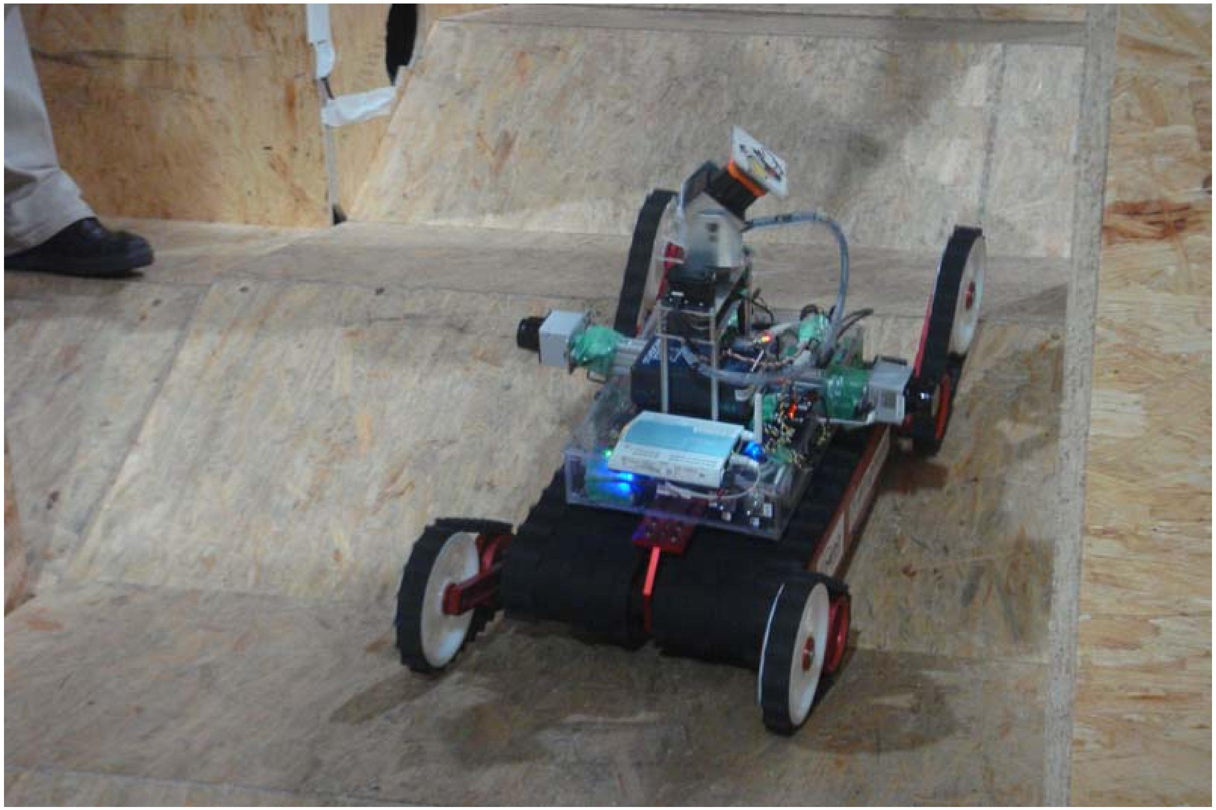
Mobility challenge:

Machine Learning for Automated Robot Navigation in Rough Terrain

Radoslaw Sobolewski and Julian de Hoog

University of Oxford
Computing Laboratory

Traversal of Rough Terrain



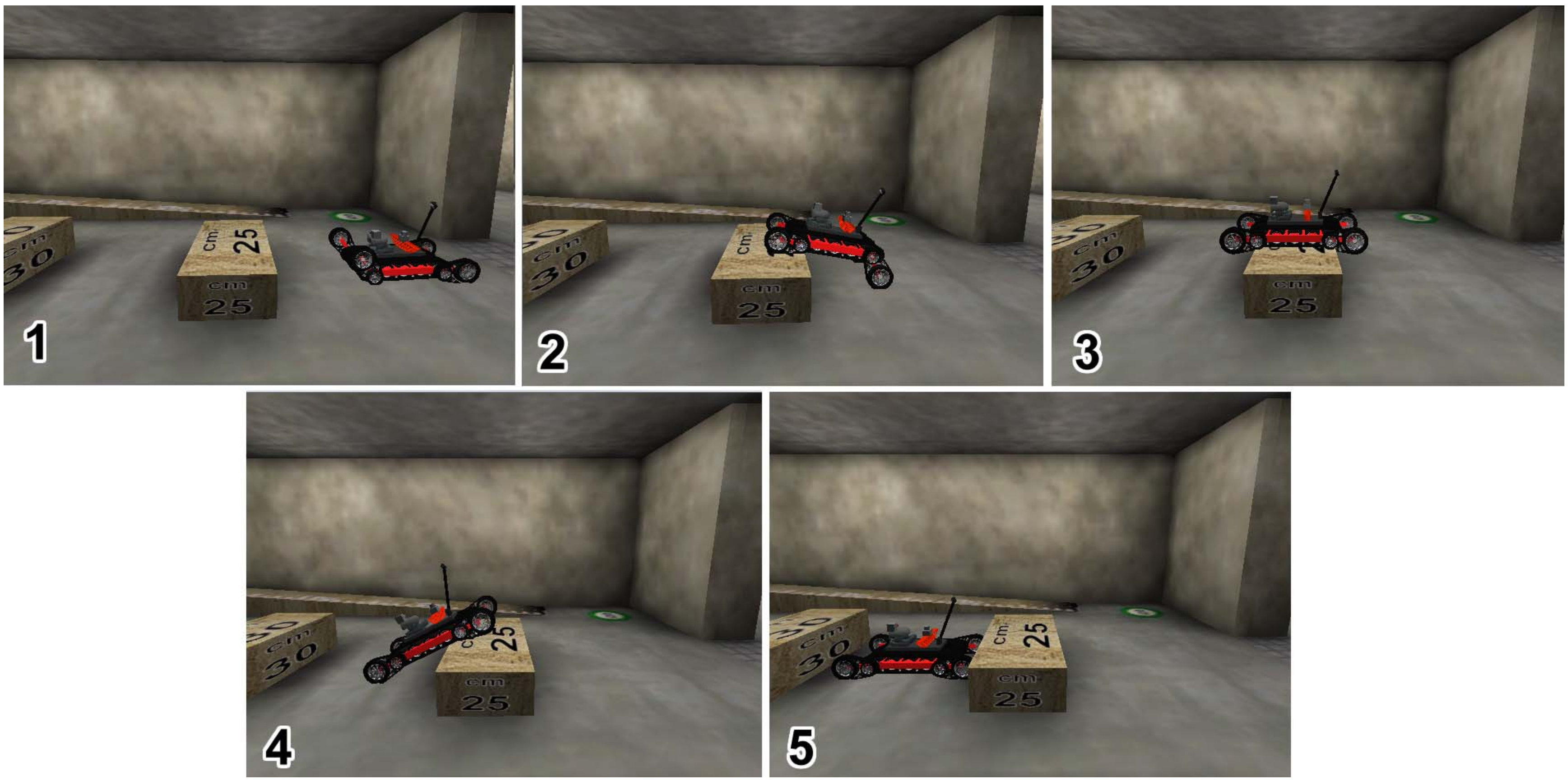
- Kenaf, designed by the University of Tohoku, is the winner of the 2007 Mobility Challenge

USARSim as design tool

- Comparing behavior of real and simulated Kenaf

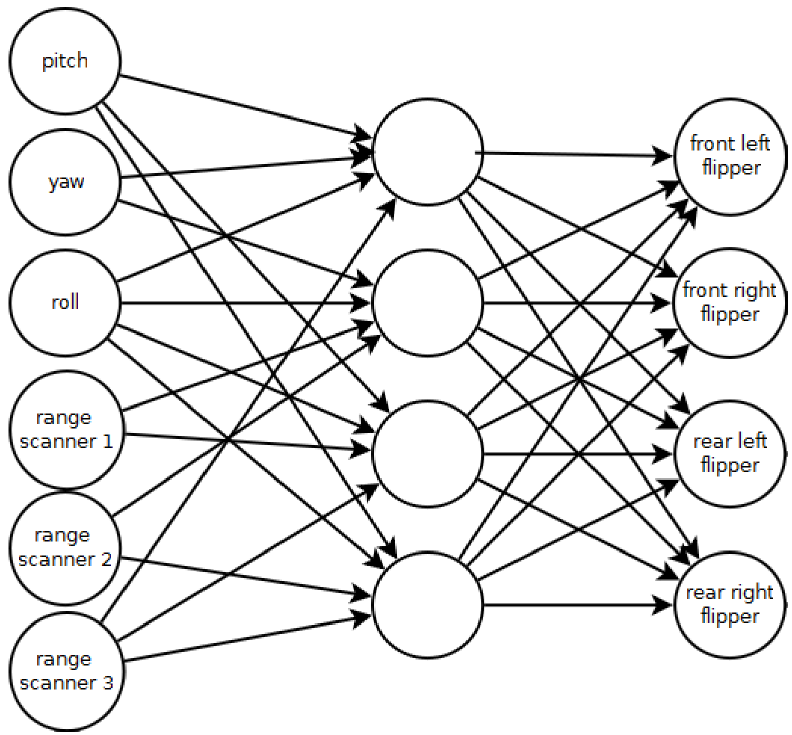
See Shogo Okamoto, Kensuke Kurose, Satoshi Saga, Kazunori Ohno and Satoshi Tadokoro "Validation of simulated robots with realistically modeled dimensions and mass in usarsim". In Proceedings of the 2008 IEEE International Workshop on Safety, Security and Rescue Robotics (SSRR'08).

Controlling a Kenaf



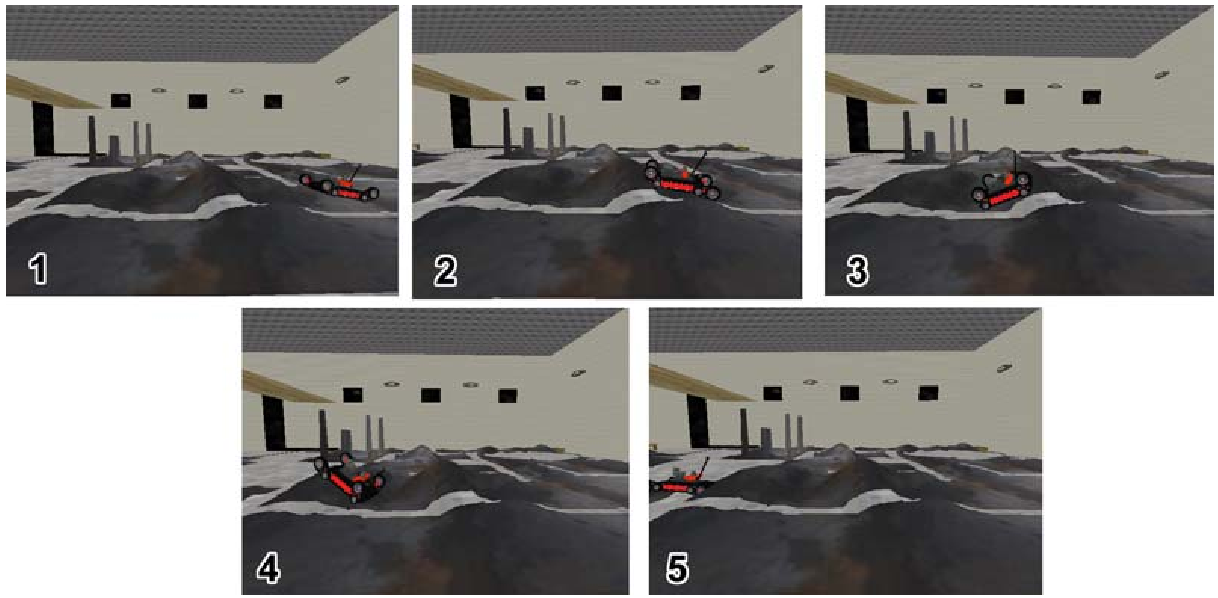
- 2 cameras, 2 range scanners → 2 tracks, 4 flippers

Machine Learning approach



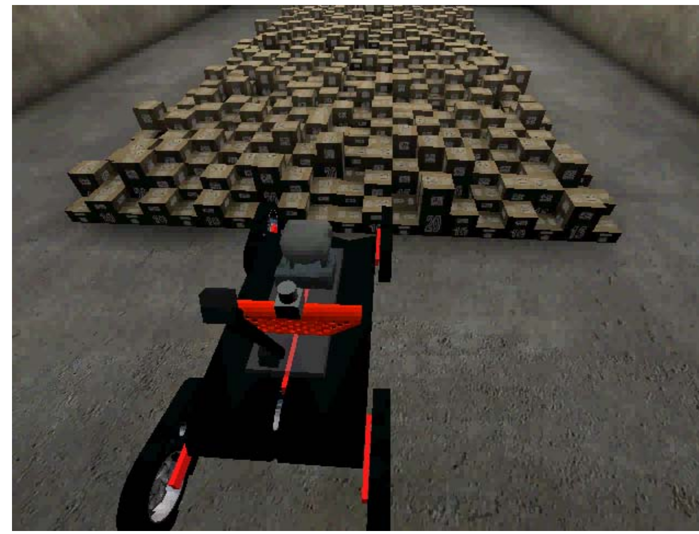
- Neural Network with one hidden layer

Training versus Testing



Completion time	Network controller	Human controller
Training course	41.2 s	46.5 s
Testing course	79.8 s	91.3 s

Validation



- Comparing flipper control for real and simulated Kenaf

Mobility challenge: Result

- Advanced Machine Learning techniques can be applied to robot control
- Training sessions can be used in several terrains
- Real and simulated results are compared

See Radoslaw Sobolewski, "Machine Learning for Automated Robot Navigation in Rough Terrain", MSc Thesis, Oxford University, September 2009.

Navigation Challenge:
A Color Based Rangefinder for an Omnidirectional Camera

Gideon Emile Maillette de Buy Wenniger,
Quang Nguyen, Tijn Schmits and Arnoud Visser

intelligent autonomous systems

Universiteit van Amsterdam
Informatica Instituut

Omnidirectional camera

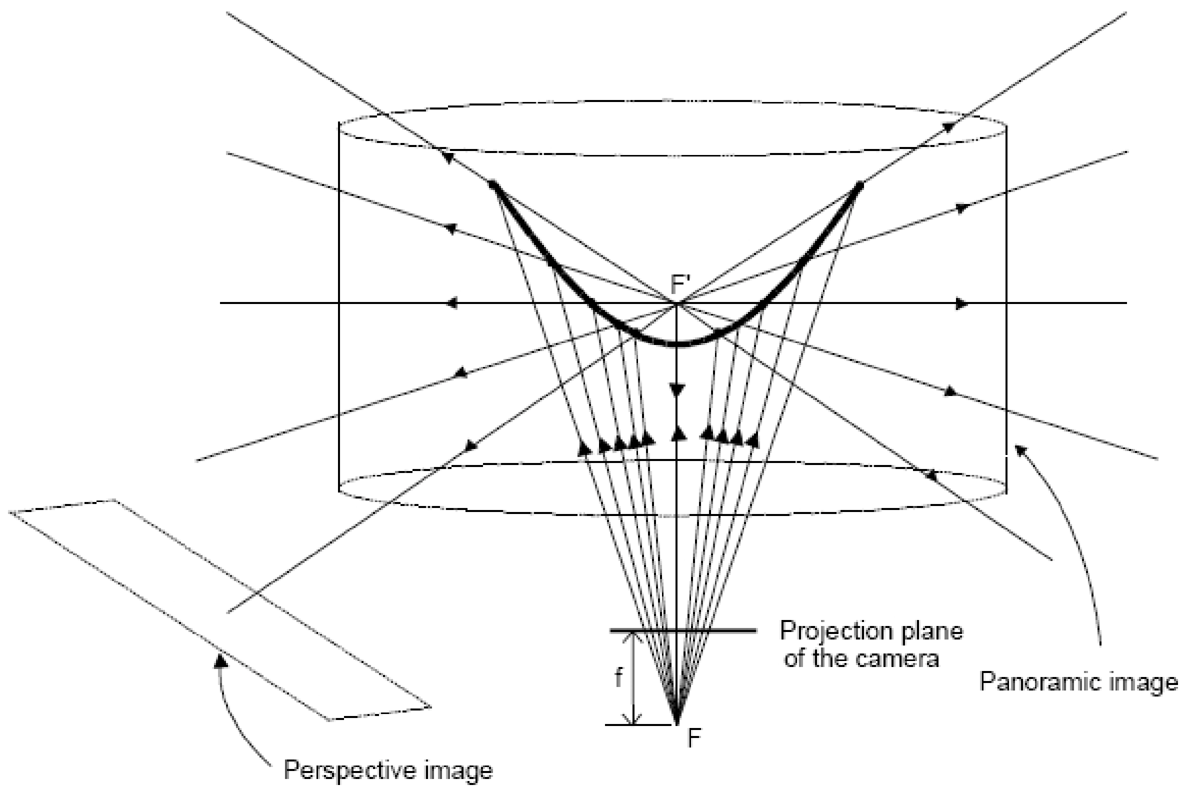
- Mirror based design (robust and cheap)
- Widely used in robotic research
- Available for validation at Amsterdam
  - DragonFly® camera
  - PanoramaEye® mirror
- Robotics:

  Navigation

  Self localisation

  VisualSLAM

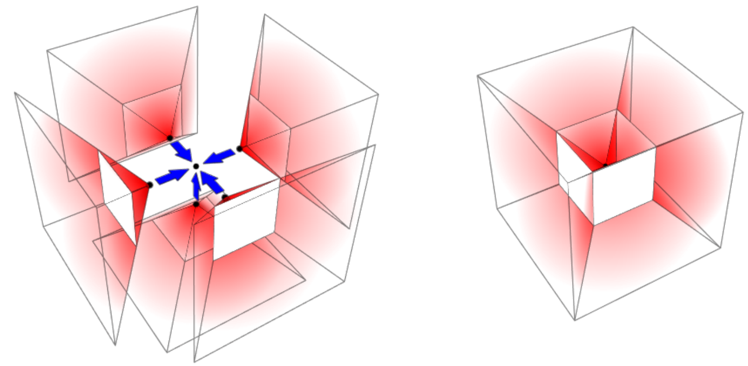
Single Viewpoint Constraint

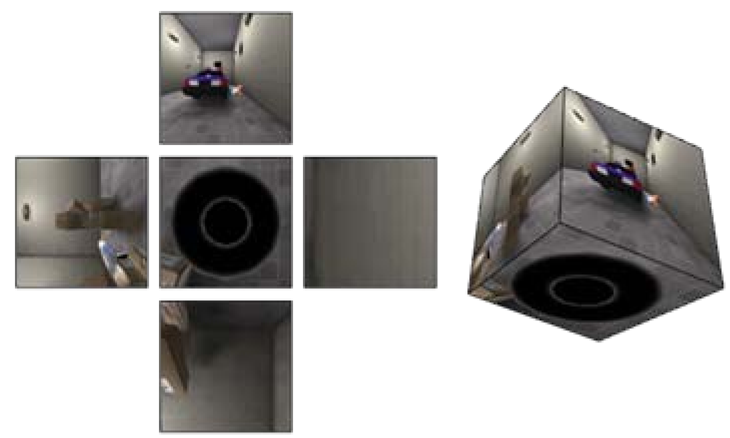


- Omnidirectional images can be translated into other perspectives

Simulation Model Development
- camera cube -

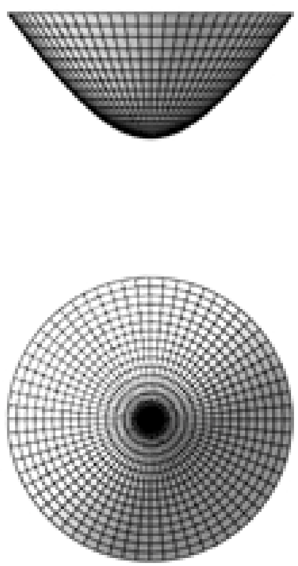
- Architecture:
  - 5 virtual cameras
  - 90 degree FOV
  - 90 degree angles
  - Cube mapping of the environment

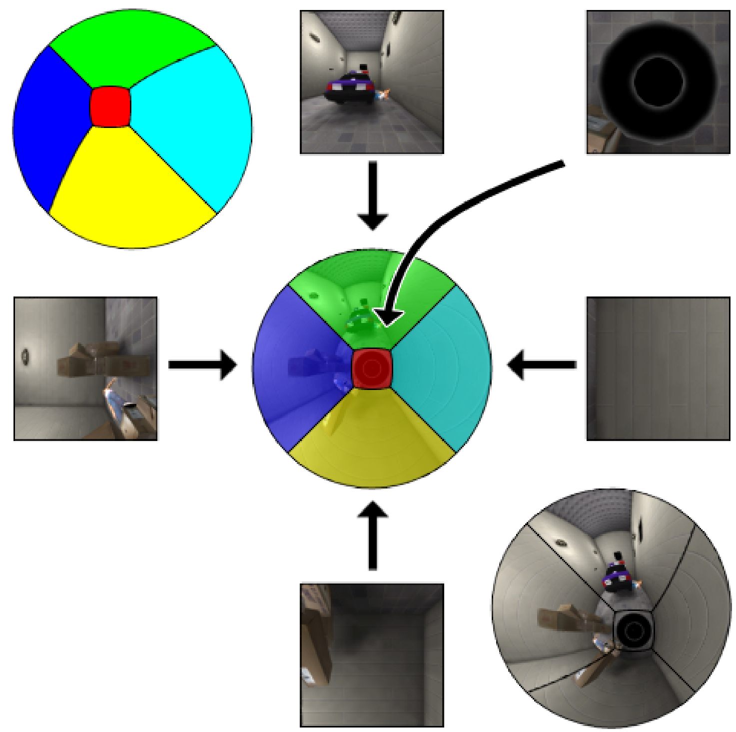




Simulation Model Development
- mirror surface -

- Architecture:
  - UV texture mapping



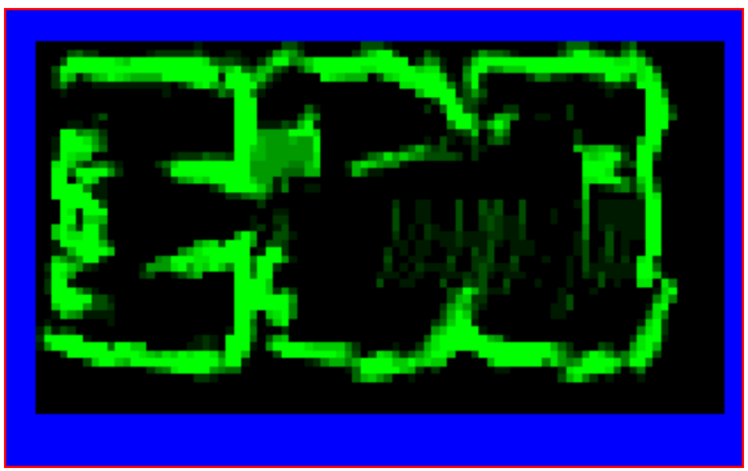


Simulation Model Development
- camera body -

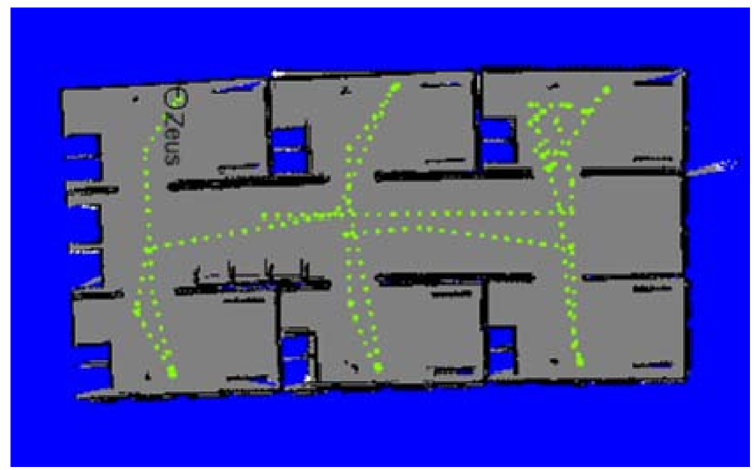
Tijn Schmits and Arnoud Visser, "An Omnidirectional Camera Simulation for the USARSim World", in RoboCup 2008: Robot Soccer World Cup XII", LNAI 5339, p. 296-307, Springer, June 2009.

Research Question

Can the omnidirectional camera be used effectively in navigation, equivalent to a rangescanner?



Sonar ring

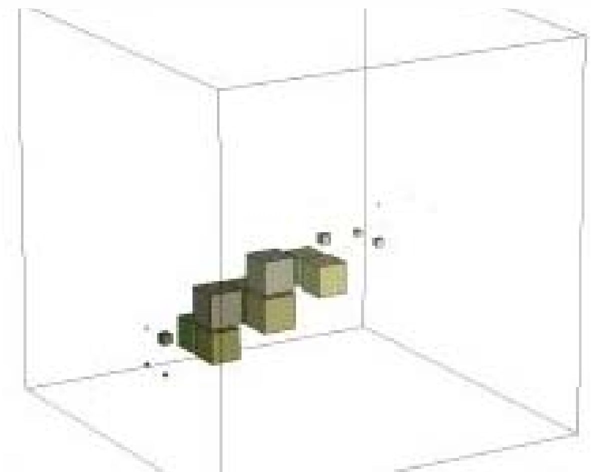


SICK laser scanner

Free space Pixel Classification

- Calculate probability of a color in the histogram

$$P_{HIST}(rgb) = \frac{c[rgb]}{T_c}$$



- Probability must be higher than a threshold to classify "free space"

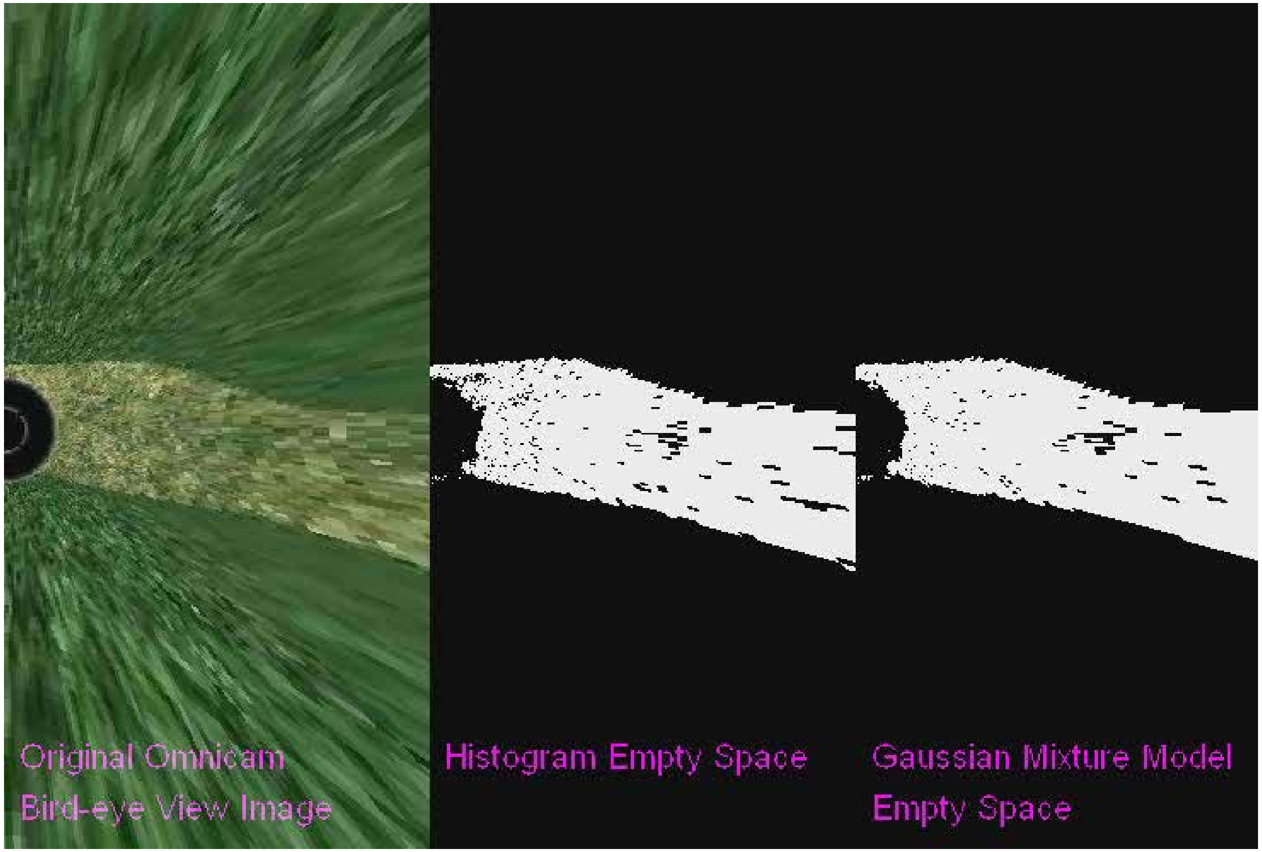
$$P_{HIST}(rgb) \geq \theta$$

- Classification can also be done with a Mixture of Gaussians

$$p_{GMM}(rgb) = \sum_{i=1}^{n} w_i N_i(rgb)$$

G.E Maillette de Buy Wenniger *et al*, "Identifying Free Space in a Robot Bird-Eye View", Proceedings of the 4th European Conference on Mobile Robots (ECMR 2009), p. 13-18, Croatia, September 2009

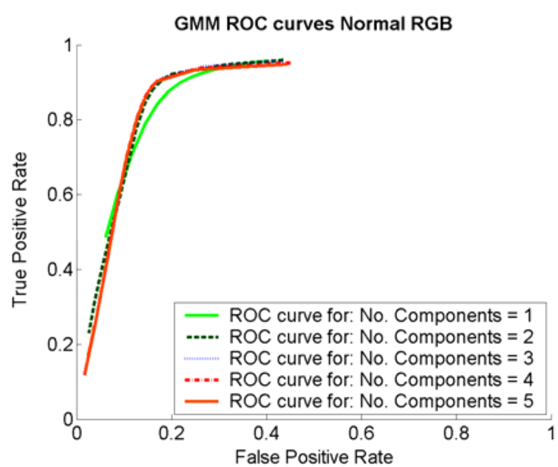
Free Space Detection Results

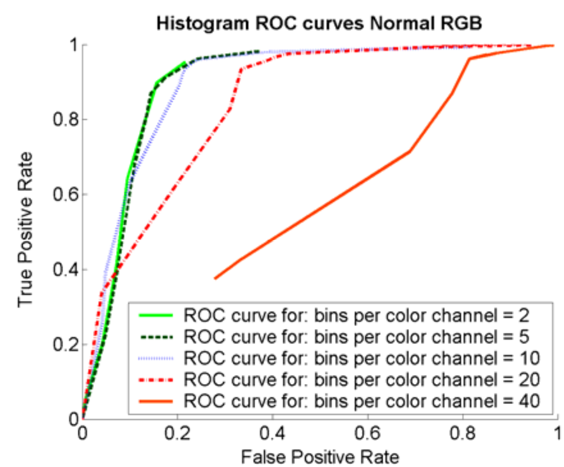


- Image processing can be used to verify the traversability of the surroundings.

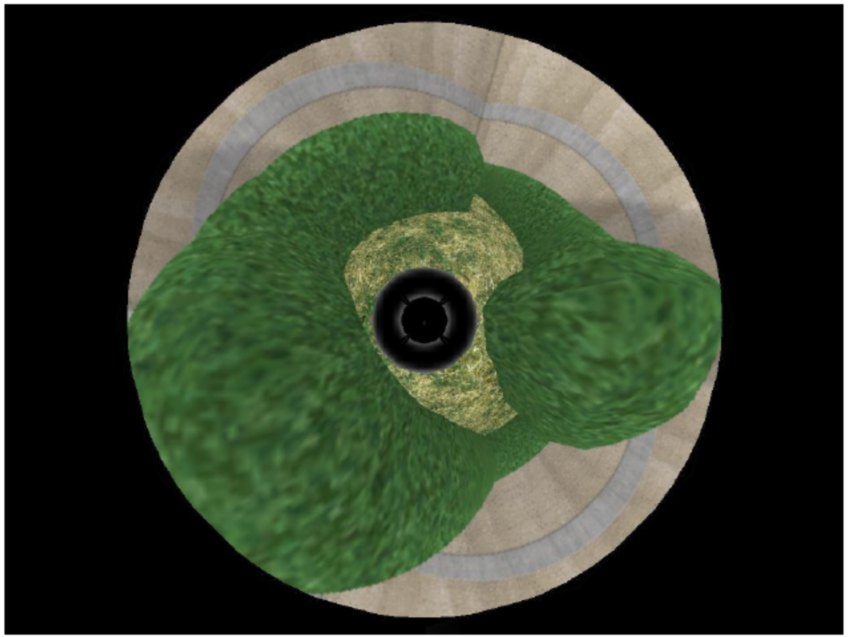
Reliability

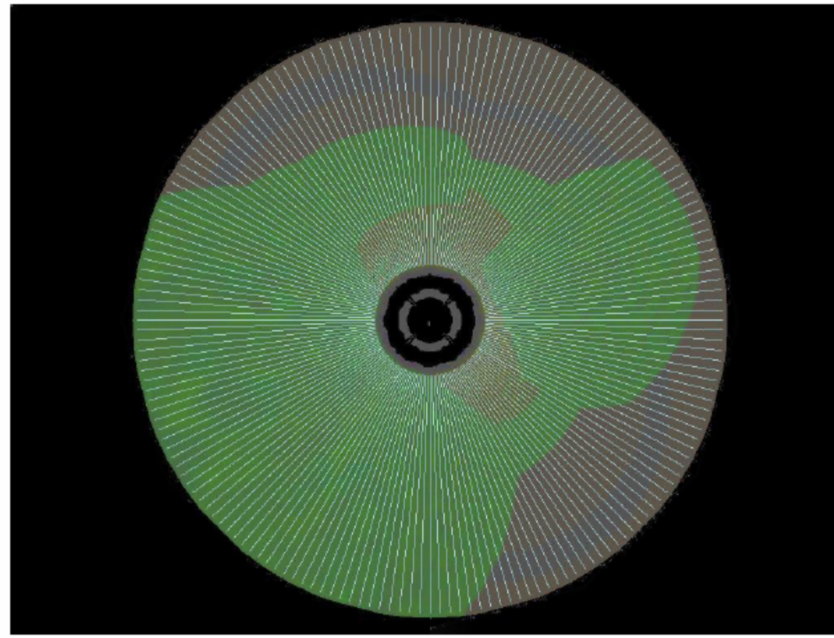
- In simulation a F-measure of 90% was reached.
- For real data a F-measure of 75% was reached.





Polar Scanning in omnidirectional image

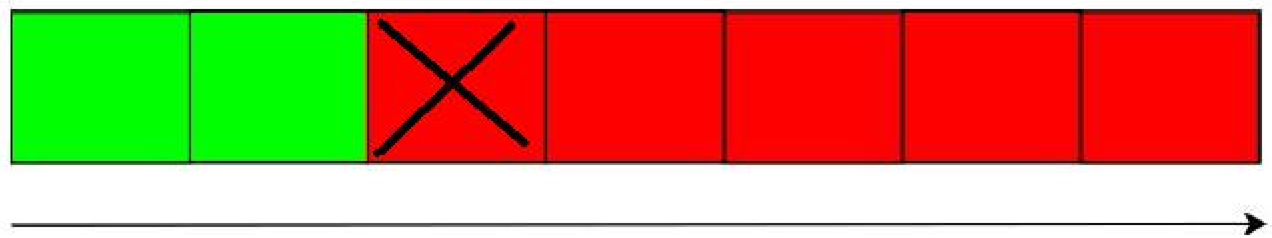




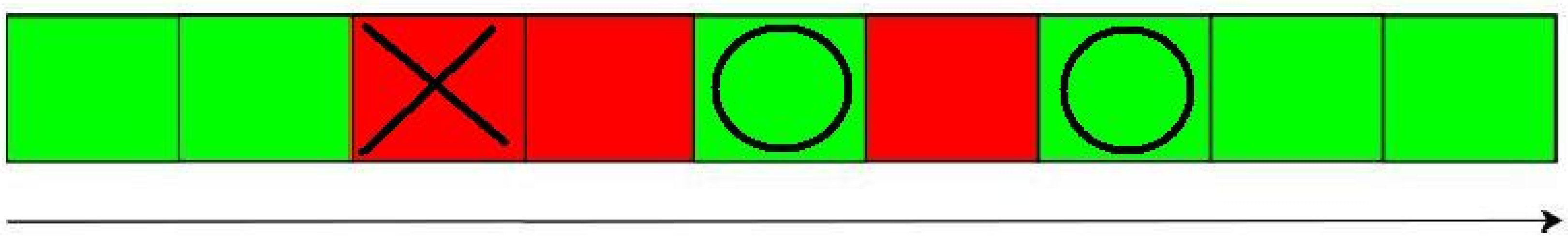
- 360 scan lines with 1^{o} angular resolution
- Minimum range 0.2m, maximum range 3.8m

Range estimate

Situation 1 False positive filter



Situation 2 False negative filter

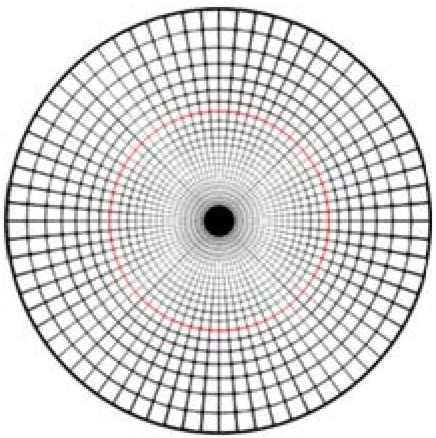


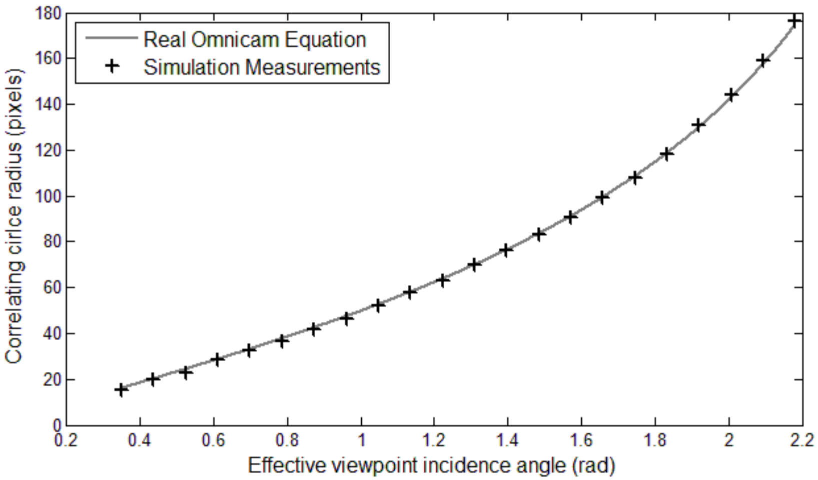
- At least *K* non-free pixels behind hitpoint **X** *K = 20*
- At most *N* free pixels inside sequence *K* *N = 2*

Mirror Equation

$$\left(z - \frac{c}{2}\right)^2 - r^2\left(\frac{k}{2} - 1\right) = \frac{c^2}{4}\left(\frac{k-2}{k}\right)$$

with *k=11.546* and *c = 2.321*





$$r = \sin(\theta)\frac{r_{horizon}}{(1+\cos(\vartheta))}$$

$$d = h\tan(\vartheta)$$

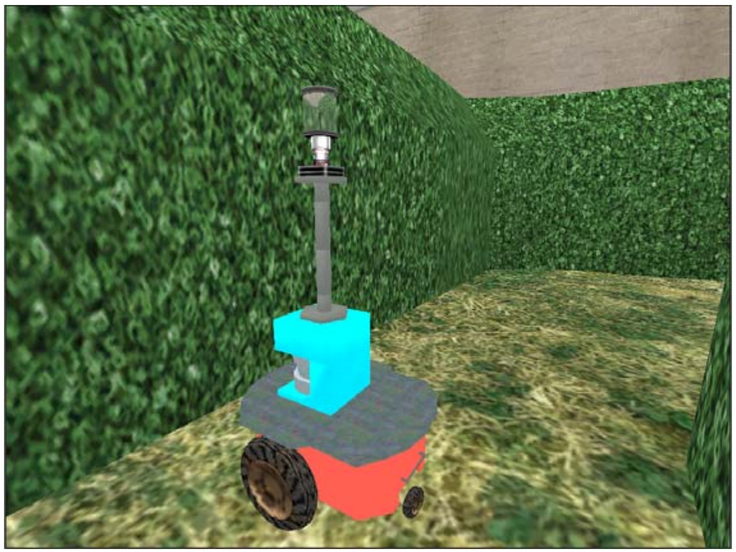
Experiments

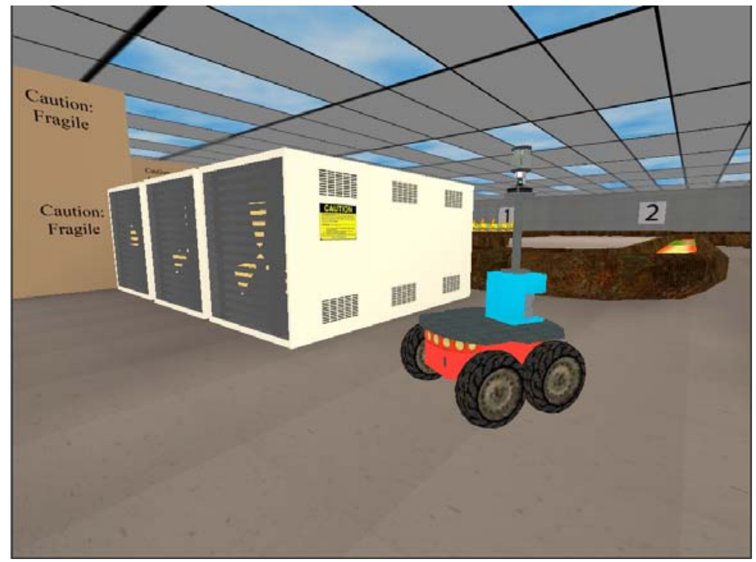
GrassMaze

Factory

Robot

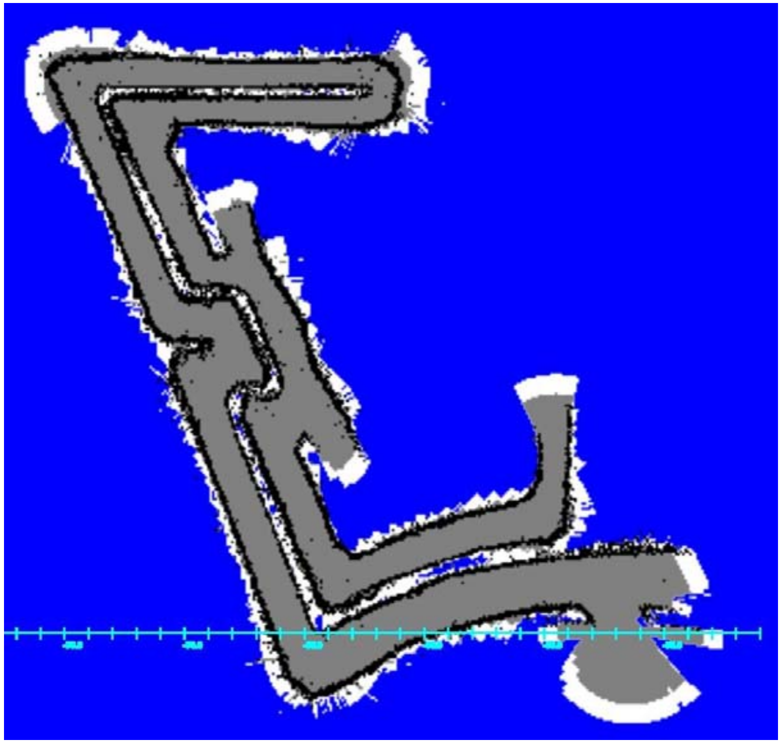
- OmniP2DX / OmniP2AT

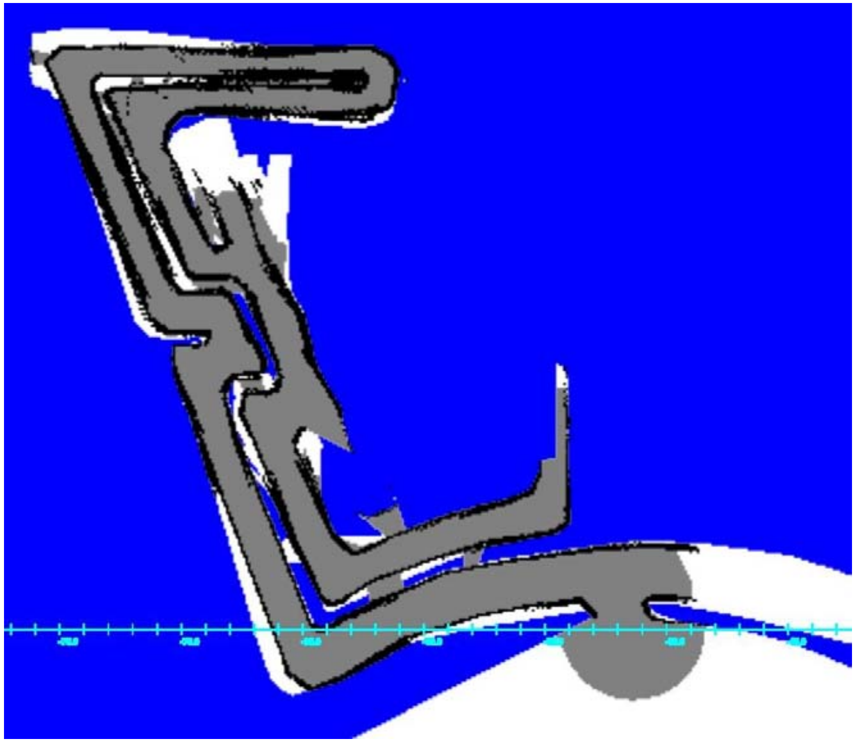




- Omnidirectional camera
- SICK 200 LMS

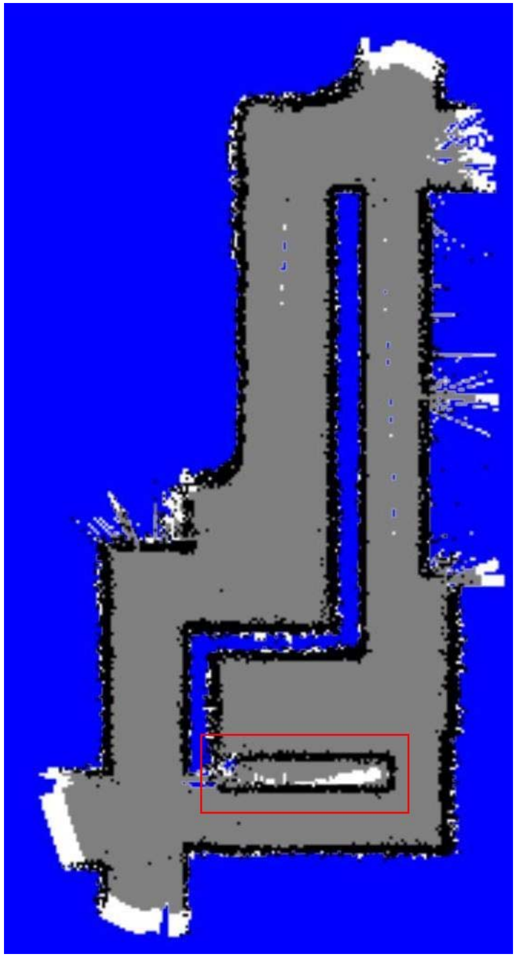
Grassmaze: Mapping

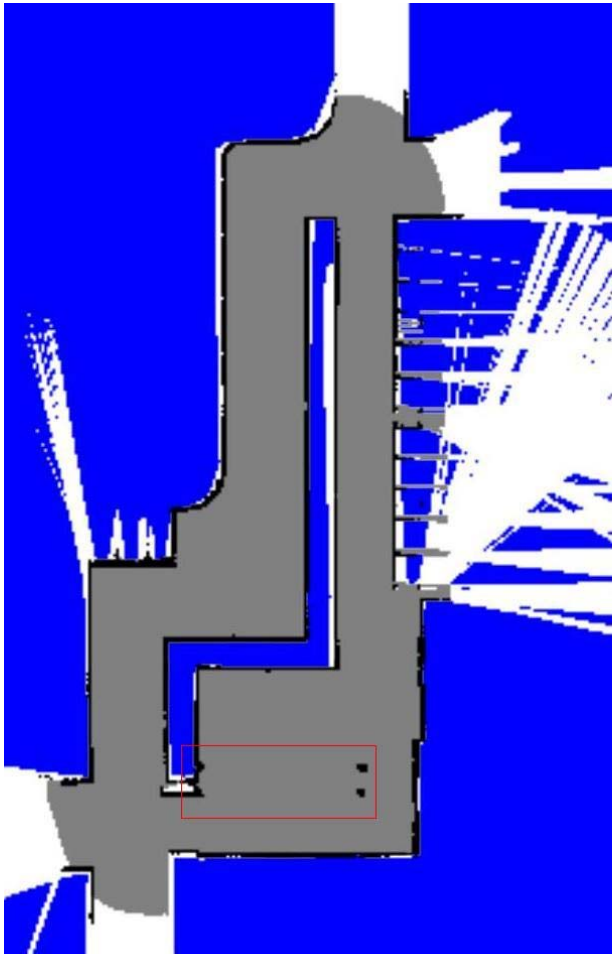




- Deadreckoning on ground-truth

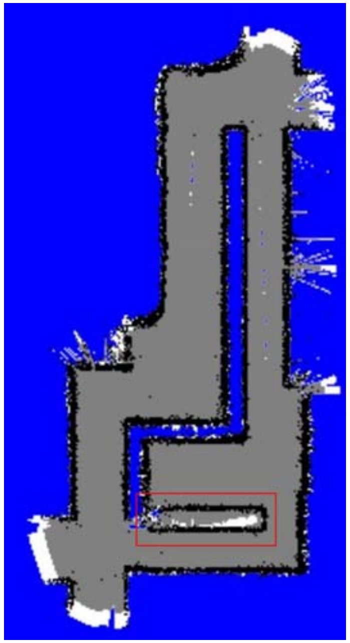
Factory: Mapping

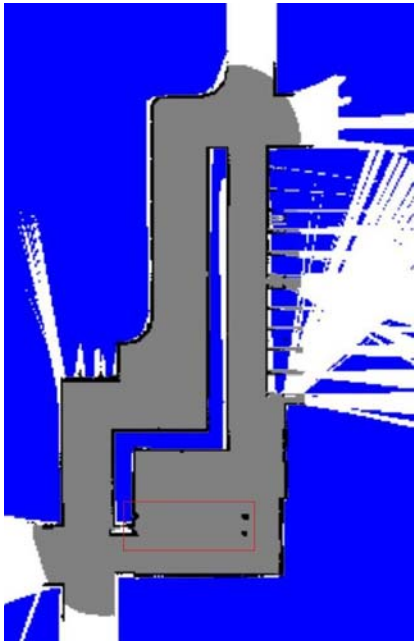




- Deadreckoning on ground-truth

Other means of detection





- Omnicam rangefinder found the cabinet

<u>Navigation Challenge:</u> Result

- An omnidirectional camera can be used effectively as a rangefinder
- Accuracy is less than a laser scanner, but better than sonar.
- The omnidirectional camera is an independent mean to detect obstacles.
- Results in simulation <u>can be exploited</u> in real applications

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

Virtual Robot Competition

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± Human, multi-robot interfaces

± 3D mapping and exploration by fusing information from multiple robots

✓ Development of novel mobility modes and sensor processing skills

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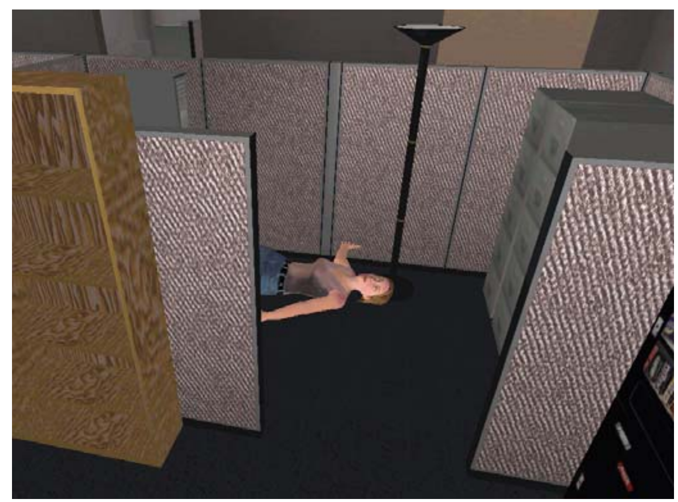
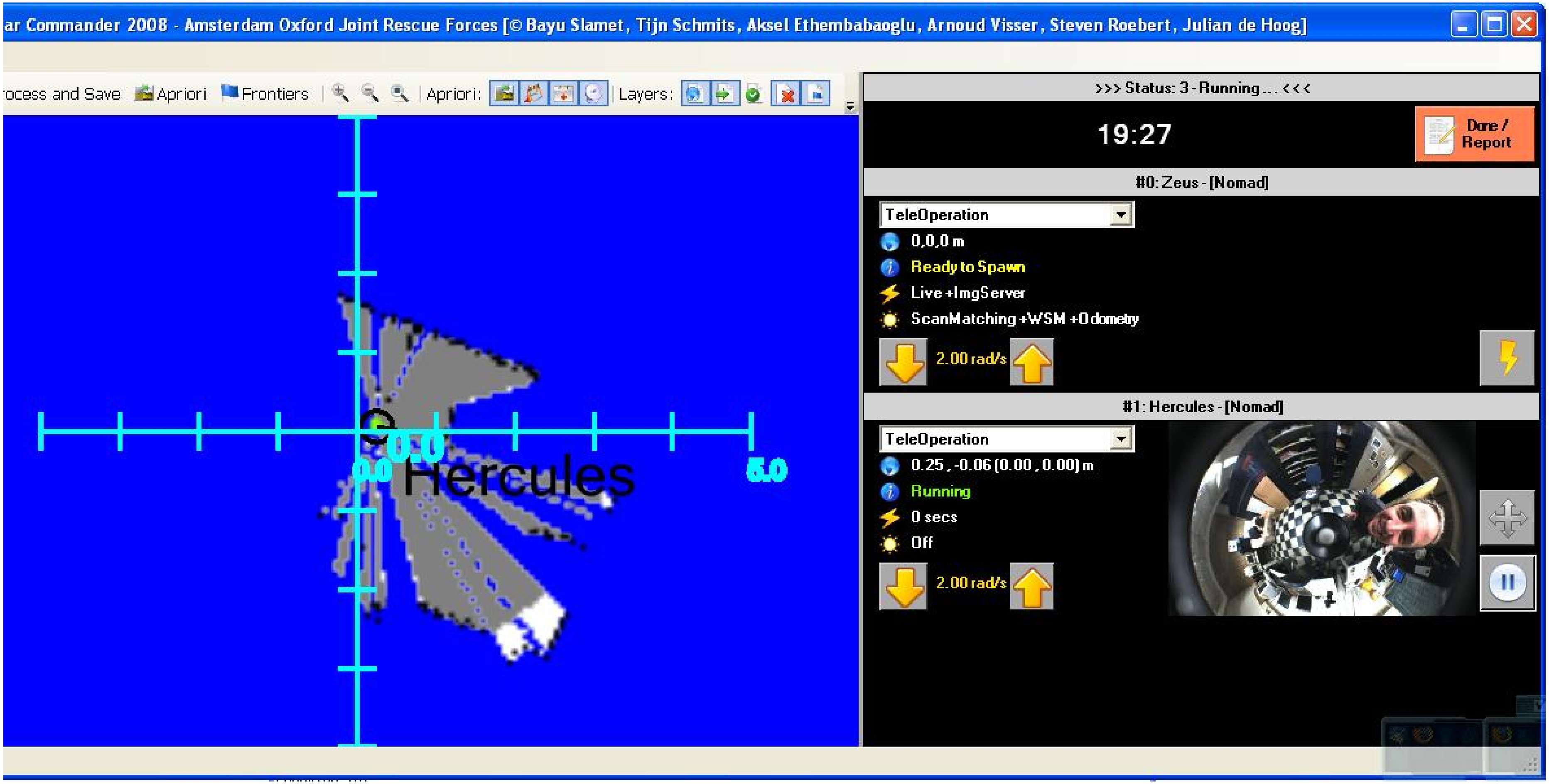


Multi-robot research is costly



Julian de Hoog, Stephen Cameron and Arnoud Visser, "Autonomous Multi-Robot Exploration in Communication-Limited Environments", Proceedings of the 11th Conference Towards Autonomous Robotic Systems (Taros 2010), Augustus/September 2010

Conclusion

The Virtual Robot competition allows:

- Researchers rapid prototyping tools.
- Extensive training possibilities for Machine Learning applications
- Students quick access to robotic testbeds

3rd place

4th place

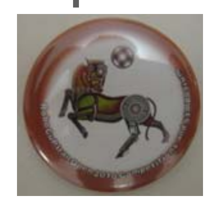
2nd place

BRAZIL OPEN

1st place

3rd place

Iran Open 2010



Development price

www.jointrescueforces.eu

Amsterdam Oxford Joint Rescue Forces
RoboCup Rescue Simulation - Virtual Robots Competition

Publications

Publications listed below are relevant to research conducted by UvARescue and Amsterdam Oxford Joint Rescue Forces in the USARSim simulator. For a more extensive list of publications related to this competition see the RoboCup Rescue wiki.

2010

- Julian de Hoog, Stephen Cameron and Arnoud Visser, "Autonomous Multi-Robot Exploration in Communication-Limited Environments", Proceedings of the 11th Conference Towards Autonomous Robotic Systems (Taros 2010), Augustus/September 2010 (PDF).
- Julian de Hoog, Stephen Cameron and Arnoud Visser, "Dynamic Team Hierarchies in Communication-Limited Multi-Robot Exploration", Proceedings of the IEEE International Workshop on Safety, Security & Rescue Robotics (SSRR 2010), July 2010 (PDF).
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