Realistic simulations of advanced robot control algorithms

Arnoud Visser

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

Multi-Robot 3D Interface

Autonomous exploration and navigation

3D point cloud segmentation
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
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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

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Virtual Rescue League

Simultaneously:
• Traverse Rough Terrain (Mobility)
• Where am I? (Localization)
• Where have I been? (Mapping)
• Find the victims (Exploration)
• Share this information and coordinate behaviors with others robots (Distributed Decision making)
Traversing 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

Controlling a Kenaf

- 2 cameras, 2 range scanners → 2 tracks, 4 flippers
Machine Learning approach

- Neural Network with one hidden layer
Training versus Testing

<table>
<thead>
<tr>
<th>Completion time</th>
<th>Network controller</th>
<th>Human controller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training course</td>
<td>41.2 s</td>
<td>46.5 s</td>
</tr>
<tr>
<td>Testing course</td>
<td>79.8 s</td>
<td>91.3 s</td>
</tr>
</tbody>
</table>
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

Navigation Challenge:
A Color Based Rangefinder for an Omnidirectional Camera

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

Research Question

Can the omnidirectional camera be used effectively in navigation, equivalent to a rangescanner?
Free space Pixel Classification

- Calculate probability of a color in the histogram

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

- Classification can also be done with a Mixture of Gaussians

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

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

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° 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 $\times$  \( K = 20 \)
- 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 \( c = 2.321 \)

\[ r = \sin(\theta) \frac{r_{\text{horizon}}}{(1 + \cos(\vartheta))} \quad d = h \tan(\vartheta) \]
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
Navigation Challenge: 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 can be exploited in real applications.
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Multi-robot research is costly

Conclusion

The Virtual Robot competition allows:

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


