H2020 RIA

Robust Mobility and Dexterous Manipulation in Disaster Response by Fullbody Telepresence in a Centaur-like Robot

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Motivation

• Capabilities of disaster-response robots insufficient for providing effective support to rescue workers
  – Mobility: difficulties with uneven terrain, stairs, and debris
  – Manipulation: only a single actuator with simple end-effectors
  – User interface: requires extensive training, not intuitive, situation awareness problematic

• Task complexity tasks and execution speed limited
Overall Objective

• Development of a Human-robot system where a human operator is telepresent with its whole body in a Centaur-like robot, which is capable of robust locomotion and dexterous manipulation in the rough terrain and austere conditions characteristic of disasters.
Centauro Robot

- Serial elastic actuators
- 42 main DoFs
- Schunk hand
- 3D laser
- RGB-D camera
- Color cameras
- Two GPU PCs

[Tsagarakis et al., IIT 2017]
Centauro Mobility

• Leg Features
  – 6DOF
    • Hip yaw/roll
    • Knee pitch
    • Ankle pitch
    • Ankle yaw & wheel
  – Mixed compliant/stiff Actuation
  – Wide joint range of motion
Centauro Mobility

Hybrid Legged-wheeled locomotion
Centauro Interaction Control

Whole body Impedance Controller
Main Operator Telepresence Interface

- Tendon-driven dual-arm exoskeleton
- Active wrist with differential tendon transmission
- Underactuated hand exoskeleton
- Head-mounted display
- Foot pedals

[Frisoli et al., SSSA 2017]
Main Operator Control

Manipulation Tasks
- Surface
- Valve (lever)
- Valve (gate)
- Snap hook
- Fire hose
- 230V connector
- Cutting tool
- Driller
- Screw driver
- Grasping

Used control interfaces
- Joystick
- Exus
- 6D
- Keyframes
- Stepping
- Autonomous
Turning a Valve
Connecting a Plug

Manipulation Tasks
- Surface
- Valve (lever)
- Valve (gate)
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- Fire hose
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- Cutting tool
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- Grasping

Used control interfaces
- Joystick
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- Autonomous
Cutting a Wire
Support Operator Interfaces

3D VEROSIM visualization
Robot state & Keyframe editor
Foot cameras
Panoramic view & RGB Kinect image
Task specific GUI
Pointcloud, ground contact & COM markers
Opening and Going Through a Door

Locomotion Tasks
- Ramp
- Small door
- Regular door
- Gap
- Step field
- Stairs

Used control interfaces
- Joystick
- Exus
- 6D
- Keyframes
- Stepping
- Autonomous

CENTAURO
Climbing over a Gap
3D Mapping and Localization
Walking over a Step Field
Terrain Classification

Color image → Augmented & fine-tuned CNN → Visual features

Registered point cloud → Feature extraction (Height, Slope, Roughness) → Geometric features

Random Forest → Traversability class
- safe (green)
- risky (yellow)
- obstacle (red)

[Schilling et al., IROS 2017]
## Hybrid Driving-Stepping Locomotion Planning

<table>
<thead>
<tr>
<th>Level</th>
<th>Map Resolution</th>
<th>Map Features</th>
<th>Robot Representation</th>
<th>Action Semantics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.5 cm, 64 orient.</td>
<td>Height</td>
<td><img src="image" alt="Robot Representation" /></td>
<td>Individual Foot Actions</td>
</tr>
<tr>
<td>2</td>
<td>5.0 cm, 32 orient.</td>
<td>Height, Height Difference</td>
<td><img src="image" alt="Robot Representation" /></td>
<td>Foot Pair Actions</td>
</tr>
<tr>
<td>3</td>
<td>10 cm, 16 orient.</td>
<td>Height, Height Difference, Terrain Class</td>
<td><img src="image" alt="Robot Representation" /></td>
<td>Whole Robot Actions</td>
</tr>
</tbody>
</table>

[Klamt and Behnke, IROS 2017, ICRA 2018]
Transfer of Manipulation Skills

Knowledge Transfer

[Rodriguez et al. ICRA 2018]
Object Perception

• Semantic segmentation

• Shape-aware non-rigid registration

[Rodriguez et al. ICRA 2018]
Grasping an Unknown Power Drill
Fastening a Screw
CENTAURO Team
Conclusions

• Centauro robot versatile and capable platform for mobile manipulation
• Full-body telepresence suite and autonomous assistance functions
• Demonstrated a large variety of manipulation and locomotion tasks
• Valuable insights for further development
• Plan to demonstrate integrated disaster-response missions
Thank you very much for your attention!