RESCUE AND SERVICE ROBOTICS

L. Zalud
Department of Control and Instrumentation
Brno University of Technology
Presentation Outline

1. Problem definition
2. Key issues
3. Robot examples
4. Reconnaissance robotics at BUT
Robots in General

MANIPULATORS
- cannot move their body
- industrial manipulators
- majority in robots used in industry

MOBILE ROBOTS
- contain a locomotion system
- in industry – only occasionally and in „simple applications”
Mobile Robots

**REMOTELY OPERATED**

Mostly robots without onboard intelligence and higher self-localisation and planning algorithms.

The robots are controlled in real time by human operator.

**AUTONOMOUS**

Autonomous robot is a machine that automatically performs a mission based on instructions.

It is supposed the robot uses so called artificial intelligence, i.e. is able to self-localise, avoid obstacles, should be able to react to environment changes, etc.
Where Rescue Robots May Operate?

- Space
- Terrestrial
- Subterranean
- Airborne
- Aquatic
Rescue Robot Division

OBSERVATION ONLY

ACTIVE ENVIRONMENT CHANGE
Possible Applications

- reconnaissance of dangerous and/or contaminated areas
- chemical/nuclear/biological analysis
- victim search and identification
- pyrotechnical robot
- robotic demining
Key Issues to be Solved

GENERAL
- mobility
- communication
- self-localisation and mapping
- perception
- power

SPECIAL
- contamination and decontamination resistance
- “STANAG grade” regulations – environmental, EMC, vibrations, low pressure, …
- resistance to fire, dust, water, …
Mobility

It has to be clearly defined:
• where the robot will operate – indoors, outdoors
• how fast it will move
• how often it will be used
• how long the missions will be

Dimensions are very important:
• will the robot carry any payload?
• will it move inside buildings? – less than 60cms wide
• teleoperated – camera has to be in the highest possible position

Lighter robot = more mechanically resistant! – falls, turnovers…
Communication

**TETHERED**
- reliable + stable data rate
- limits the mobility of robot
- safe and secure

**WIRELESS**
- in general lower reliability
- unpredictable in urban areas and uneven terrain
- limited EM frequency range
- mostly more energy-consuming
- may be distorted (jammed)
- someone else may listen
- may be hacked
Robot EXAMPLES
• quadruped robot
• gasoline engine that drives a hydraulic actuation
• weight 75kg
• size of a large dog or small mule (1m long)
Honda ASIMO

• development versions – E series
  • prototypes E0-E6
  • 1986-1993

• humanoid prototypes
  • P1-P3
  • 1993-1997

• ASIMO od 2000
  • new version 2004
Main parameters ASIMO 2004:
Walking speed: 3km/h
Mass: 54kg
Dimensions: 450x440x1300mm
DOFs: 34
Grasp force: 0.5kg

Supposed use:
• company presentations
• hotels, receptions
• elderly people help
• hospitals
• military applications
iRobot PACKBOT

- military, pyrotechnical, rescue robot
- several versions
- mechanical parts - plastics
- extreme mechanical resistivity

- lightweight
- fast - about 10km/h
- good in terrain/indoor
- easy control – console-like controller
Robocup Rescue

- from 2001
- worldwide
- regional opens (7 in 2008)
- strong community

- disaster simulation
- change of rules
- standardised approach to assess robots
- NIST, Intelligent Systems Division
Response Robot Exercises
Reconnaissance Robotics at BUT FEKT
Robotour

- DARPA Grand Challenge
- autonomous outdoor navigation – roads, sidewalks
- obstacle avoidance
- goods delivery

- Bc and MSc students
- inertial navigation + GPS
- ultrasound sensors and laser scanners
POSSIBLE ORPHEUS MISSIONS

- victim search
- pyrotechnical robot
- chemical/nuclear/biological contamination
- nuclear power plants
- research
User Interfaces
Operator should feel to be in the robot’s place

- increases concentration
- makes control easier and more intuitive
- better on direct sunshine
<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robot body</td>
<td>430x540x112mm</td>
</tr>
<tr>
<td>Dimensions</td>
<td>550x830x410mm</td>
</tr>
<tr>
<td>Wheels</td>
<td>ø410mm</td>
</tr>
<tr>
<td>Material</td>
<td>al alloy</td>
</tr>
<tr>
<td>Weight</td>
<td>35kg</td>
</tr>
</tbody>
</table>

Diagram showing COGGED BELTS with MOT1 and MOT2.
ORPHEUS-X1 - electronics scheme

- **Motor**
  - MAIN. PROC (AVR)
  - VIDEO SWITCH (AVR)
  - COMMUNIC. PROC (AVR)

- **Servo**
  - MAIN. PROC (AVR)

- **Wireless DATA**
  - MAIN PROC (AVR)

- **Wireless VIDEO**
  - COMMUNIC. PROC (AVR)

- **RS232 TTL**
  - MAIN F CAMERA
  - MAIN R CAMERA
  - FRONT CAMERA
  - REAR CAMERA

- **RS232**
  - MAIN F CAMERA
  - MAIN R CAMERA
  - FRONT CAMERA
  - REAR CAMERA

- **Analogue**
  - MAIN F CAMERA
  - MAIN R CAMERA
  - FRONT CAMERA
  - REAR CAMERA
ORPHEUS-EB

- embedded version for visual telepresence
- up to four cameras
- internal battery for 90 minutes
- wireless data transfer

- experiments with different robotic systems
- Talon – USA
- 9m helium airship
Visible spectrum and thermovision data fusion

CCD image (left), corresponding thermo-image placed over it (right)
Thermography & vision in fog or smoke
Visible spectrum and proximity 3D data fusion
Visible spectrum, thermovision and proximity 3D data fusion
ORPHEUS-AC

- military version of Orpheus-X2
- measurement in environments with radiation/chemical/biological contamination
- special sensors
- communication: wireless/by wire

- hard terrain
- extreme working conditions – temperature, EMC
- military-grade tests NATO – STANAG
- easy operation
Orpheus-AC

• is made do be both easy-to-construct and reliable
• electrical AC motors with integrated gearboxes
• main camera with two degrees-of-freedom
• sensor arm with one degree-of-freedom
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROBOT DIMENSIONS</td>
<td>881x590x426mm</td>
</tr>
<tr>
<td>WHEEL DIAMETER</td>
<td>426mm</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>42kg</td>
</tr>
<tr>
<td>BATTERY OPERATION</td>
<td>90 mins to 4 hours</td>
</tr>
<tr>
<td>OPERATING TEMPERATURES</td>
<td>-32°C to 85°C</td>
</tr>
<tr>
<td>CHARGING VOLTAGE</td>
<td>18-32V</td>
</tr>
<tr>
<td>MAX. CHARGING CURRENT</td>
<td>5A</td>
</tr>
<tr>
<td>MAX. SPEED</td>
<td>5km/h</td>
</tr>
<tr>
<td>MAX. OBSTACLE HEIGHT</td>
<td>20cm</td>
</tr>
<tr>
<td>CLIMB ABILITY</td>
<td>31°</td>
</tr>
<tr>
<td>MAX. REACH (CABLE)</td>
<td>100m</td>
</tr>
<tr>
<td>MAX. REACH (WIRELESS)</td>
<td>1km (line-of-sight)</td>
</tr>
<tr>
<td>Category</td>
<td>Specifications</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>ENVIRONMENTAL</td>
<td>STANAG 2895 – A2, A3, C1</td>
</tr>
<tr>
<td></td>
<td>COS 999905 – 302, 303, 304, 309, 310, 312, 313, 314</td>
</tr>
<tr>
<td>VIBRATIONS</td>
<td>STANAG 2914</td>
</tr>
<tr>
<td></td>
<td>COS 999902 – 401, 403</td>
</tr>
<tr>
<td>EMC RADIATION</td>
<td>COS 599902:2002 – RE102, RE103</td>
</tr>
<tr>
<td>EMC SUSCEPTIBILITY</td>
<td>COS 599902:2002 – CS114, CS115, CS116, RS103</td>
</tr>
<tr>
<td>SPECIAL TESTS</td>
<td></td>
</tr>
</tbody>
</table>
ORPHEUS-AC - electronics scheme

- AC MOTOR
- Electricity scheme
- AXIS LINUX GRABBER
- MAIN CAMERA
- REAR CAMERA
- LCD SENSOR
- BETA SENSOR
- GAMA SENSOR
- FREESCALE COLD FIRE
- RABBIT
- ETHERNET SWITCH
- WIRE-LESS
- 3DOF accelerometer
- Microphone

Connections:
- ETHERNET
- RS-485
- ANALOGUE
Operator’s Station – electronics scheme

- VIDEO
- CONTROL
- Nexcom EBC-300
- FREESCALE COLDFIRE
- ETHERNET SWITCH
- ETHERNET
- ANALOGUE
- LVDS
ORPHEUS-AC – op. station

- rugged operator’s station -
  to work in tactical conditions.
- battery-operated/continuous DC power operation
- easy and intuitive control
- robot body movements - joystick, other functions - series of buttons
- operation of the robot (and the whole robotic system) may be performed while wearing chemical gloves
ORPHEUS-AC – op. station

- own user interface program
- two processor solution
- Linux – based (own modified kernel)
- two videos
- transparent windows
Orpheus-AM

Medical version of Orpheus robot – UNDER DEVELOPMENT

The task is to find a victim and identify it’s status – alive, aware, etc.

• audio communication
• remote temperature measurement
• breathing identification based on CO2 emission
• pulse measurement
Heterogenous Rescue Robotic System

- multiple remotely operated/semiautonomous robots
- each robot is different i.e. has different “body” and features
- all of them controlled by one operator – sequential control
- unified user interface
### Orpheus-A

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (lxwxh)</td>
<td>950x590x415 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>48 kg</td>
</tr>
<tr>
<td>Operation time</td>
<td>60 mins</td>
</tr>
<tr>
<td>Drive type</td>
<td>differential</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>4 km/h</td>
</tr>
</tbody>
</table>
## Steropes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (lxwxh)</td>
<td>645x530x285 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>23 kg</td>
</tr>
<tr>
<td>Operation time</td>
<td>60 mins</td>
</tr>
<tr>
<td>Drive type</td>
<td>differential</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>3 km/h</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Dimensions (lxwxh)</td>
<td>500x350x250</td>
</tr>
<tr>
<td>Weight</td>
<td>6kg</td>
</tr>
<tr>
<td>Operation time</td>
<td>45 mins</td>
</tr>
<tr>
<td>Drive type</td>
<td>Ackermann</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>7 km/h</td>
</tr>
</tbody>
</table>
### Quadrocopter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (diameter x h)</td>
<td>620x230 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>1800 g</td>
</tr>
<tr>
<td>Operation time</td>
<td>20 mins</td>
</tr>
</tbody>
</table>
The whole system
Communication

- each robot works on separate frequency
  - much better performance
  - higher communication bandwidth needed
- even small robots can act as retranslation station
Head Movement Parameters
Kamera na tyči

- Kamera má dva stupně volnosti a regulovatelné přisvícení
- Variabilní použití – různá délka tyče (až 8 metrů), zavěšení na kabelu
- Zobrazení na operátorské stanici s možností nahrávání nebo na integrovaném displeji
Luděk Žalud, VUT Brno
Kolejní 4
zalud@feec.vutbr.cz