Mobile Robotics
Mobile robot classification

Lecturer
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Outline of today’s lecture

- What is a mobile robot?
- Mobile robot classification
  - Review of research achievements, challenging issues
- Mobile robot integration
  - Actuation; control system; sensor system; system hierarchy
- General research work on the mobile robot
  - Actuation and mechanical system; locomotion; kinematics; dynamics
  - GUI; interface; other issues
- Application

What is a mobile robot?

- Mobile robots have the capability to move around in their environment and are not fixed to one physical location. In contrast, industrial robots usually consist of a jointed arm (multi-linked manipulator) and gripper assembly (or end effectors) that is attached to a fixed surface.
- Mobile robots are the focus of a great deal of current research and almost every major university has one or more labs that focus on mobile robot research. Mobile robots are also found in industry, military and security environments. They also appear as consumer products, for entertainment or to perform certain tasks like vacuum cleaning or mowing.
Features of mobile robots

- Locomotion
- Navigation
- Autonomy
- Programmability
- ...

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Mobile robot classification

- According to the environment in which they travel:
  - Land or home robots; aerial robots and underwater robots
- Kinematics
  - Sliding frame robot; legged robot; wheeled and chain-tracked robot
- According to the autonomous levels:
  - Autonomous or semi-autonomous modes
- According to applications
  - Service robots; edutainment robots; pure research prototypes; space robots; and civil or military robots

According to their environment

Indoor
- Structured Environments
  - Transportation
  - Industry & service
  - Customer support
  - Museums, shops...

Outdoor
- Unstructured Environments
  - Cleaning
  - Lago, buildings
  - Research, entertainment, toy
  - Surveillance, buildings
  - Mining
  - Agriculture
  - Customers support
  - Air
  - Forest
  - Shotting
  - Construction
  - Underwater
  - Fire fighting
  - Military

Technical Aspects of Multimodal Systems

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According to their environment

- **Structured Environments**
  - Roads or highways with traffic rules and stay in their own lanes.
  - We call this kind of useful constrains as structure.
  - It is useful because it constrains the available actions of the vehicle and reduces the complexity of the navigation task.

- **Unstructured Environments**
  - In unstructured environments where there is no lane information to guide or constrain the actions of the vehicle.

Transportation and service

- Automated guided vehicles (AGVs)
  - Reduce costs of manufacturing and increase efficiency in a manufacturing system.
  - Tow objects in small trailers which can be used to move raw materials in line to get them ready for the production process.
  - Also store objects on a bed. The objects can be placed on a set of motorized treads and then pushed off by reversing them.
  - Some AGVs use fork lifts to lift objects for storage. Transporting materials such as medicine in a hospital situation is also done.

- Automated Guided Vehicles (AGV) are also known as **Laser Guided Vehicles** (LGV) or **Self Guided Vehicles** (SGV). In Germany the technology is also called **Fahrerlose Transportsysteme** (FTS).
Transportation and service (Cont’)

- Other prototypes of Automated Guided Vehicles (AGV)
  - Cycabs
  - VaMoRs/VaMP (UBM) *Highways, city streets*
  - Ranger (CMU) *Off-road*

Customer support and service in hospitals

- HelpMate robots, made by the San Diego-based Pyxis Corp., can cart around hospital items, such as food trays, pharmaceuticals, lab specimens, X-rays, bandages and blankets.

  - They have various on board sensors for autonomous navigation in the corridors. The main sensor for localization is a camera looking to the ceiling. It can detect the lamps on the ceiling as reference (landmark).
  - They save nurses trips to cafeterias, pharmacies and central supply areas, saving hospitals the costs of human couriers.

Customer support and service for shopping

- Robots can cart around shopping items, like food trays, clothes.

  - Sinas

  - Shopping cart robot

    - Running examination for "Indoor" controlled by operator (manual control)

    - Orients autonomously, without modifications to the environment;
    - Moves autonomously, with motions and behaviors tailored to your application.

Personal assistant

- Orients autonomously, without modifications to the environment;
- Moves autonomously, with motions and behaviors tailored to your application.
Personal assistant – Mats

- Mats
  - The MATS robot, developed in its entirety by the Robotics Lab of Universidad Carlos III de Madrid as part of the IST European Union project in 2004, aims to provide people independence in their own home. MATS is a service robot with high level of mobility.
  - The assistance of disabled, elderly and persons with special needs become one of the most important service applications of robotic systems in the near future.

Personal assistant – Humanoid Robots

Specifications:
- Weight: 7 kg
- Height: 58 cm
- Neck DOF: 4
- Body DOF: 2
- Arm DOF: 2 x 5
- Legs DOF: 2 x 6
- Five-finger Hands

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Cleaning and maintenance – BR 700

- BR 700
  - Cleaning robot based on a very sophisticated sonar system and a gyro.

Cleaning and maintenance – Scooba

- Scooba
  - Since 2003, 1.5 million robots sold in three years. The price is under 180$.
  - Active dirt response
  - Automatic docking and recharging
  - Increasing Intelligence in cleaning
  - Obstacle detecting and avoiding
  - Scooba can clean and dry floors now.

Research prototypes – Pioneers

- Pioneer robots
  - Pioneers are a family of mobile robots with two-wheel or four-wheel-drive. They are small, intelligent robots developed by Dr. Kurt Konolige of SRI International, Inc, and Stanford University.
  - Pioneer robots contain all of the basic components for sensing and navigation in a real-world environment.
  - They are all managed via an onboard microcontroller and server software.
Research prototypes – B21 Robot

- A sophisticated mobile robot with up to three Intel Pentium processors on board.
- It has different kinds of on-board sensors for high-performance navigation tasks.

Research prototypes – TASER

- Taser
  - Service-robot of the University of Hamburg
  - Mobile platform with differential drive
  - Two Mitsubishi PA10-6C manipulators
  - Two 3-finger robotic hands
  - Stereovision camera head
  - Omni-directional vision system
  - Two SICK laser range finders
  - Pentium 4 control PC
  - Wireless LAN communication

Research prototypes – Khepera

- Khepera robot
  - It measures only about 60 mm in diameter.
  - Additional modules with cameras, grippers and many other features are available.
  - More than 700 units have already been sold (by the end of 1998).

Education and entertainment robots
Edutainment robots – Aibo

- Sony Aibo
  - 25 cm long
  - Camera, microphone and other sensors
  - Communication interface

Edutainment robots – Lego mindstorms

- Lego mindstorms
  - Developed in cooperation with MIT Media Lab researchers in 1998.
  - RCX
    - 3 sensory inputs and 3 motor outputs.
    - Includes a display and buttons for selecting programs and viewing status of inputs/outputs
    - Includes an IR serial port, through which it is programmed
  - Robotics Invention System (RIS) and easy-to-use GUI

Edutainment robots – Fischertechnik

- Fischertechnik (Arthur Fischer in 1965)
  - Contains a great amount of educational aspects, both with respect to programming and especially with respect to the construction of the robots.
  - Contains a central processing unit, two motors, six switches, two light sensors and one light source.
  - The programming interface for the Fischertechnik robots is quite similar to that of LEGO Mindstorms
  - A bit expensive

Edutainment robots – Telebot

- Telebot (TAMS group based on cooperation with BUAA, 2006)
  - 9 channels for sensor inputs; 4 outputs for actuators
  - Communication interface
  - Java and C++ programming easy
  - More flexible and extended functions
Edutainment robots – Modular robot

- Main idea: Building robots composed of modules
- The design is focused on the module, not on a particular robot
- The different combinations of modules are called configurations

Some advantages:
- Versatility
- Fast prototyping
- Testing new ideas

Other example 1
Other example 2

Edutainment robots – Other toys

According to their environment
Space exploration robots

The NASA Space Telerobotics Program was shut down in 1997, and the research and technology development tasks supported by the program were transferred to other efforts.

http://telerobotics.oact.hq.nasa.gov/telerobotics_page/telerobotics.shtml
Space exploration robots – Sojourner

- Sojourner
  - The mobile robot was used during the pathfinder mission to explore the Mars surface in summer 1997. It was nearly fully teleoperated from earth. However, some on-board sensors allowed for obstacle detection.
Agricultural robots

- In 1998, an autonomous mobile robot for agricultural operations was developed by Halmstad University, which was able to successfully follow a row of plants at a speed of 0.2 m/s within 2 cm.
- In 1999 a color camera was mounted on the robot to provide the images for the plant recognition system.
- An accurate position estimation system was developed to allow the robot to exactly estimate the distance covered along a row.

Forest application

- The walking harvester was developed by Plustech Oy (Ltd), a Finnish R&D company specializing in forest machine technology applications.
- The walking machine adapts automatically to the forest floor. Moving on six articulated legs, the harvester advances forward and backward, sideways and diagonally.
- It can also turn in place and step over obstacles. Depending on the irregularity of the terrain, the operator can adjust both the ground clearance of the machine and the height of each step.
- In addition to the walking forest machine, Plustech has developed computer-based trainers for forest machine operators.
- Since January 1997, Plustech has been part of Timberjack's European R&D center focusing on advanced, long-term development. Some 37% of Plustech's shares are owned by Timberjack, which is the world's leading supplier of forest machines. Plustech personnel hold the remaining 63% of the shares.

Urban search and rescue & military

Forest application

- www.plustech.fi
- @John Deere company
Military robots – JL-I

- JL-I consists of three uniform modules.
- 35 centimetres long, 25 centimetres wide and 15 centimetres high.
- Two powered tracks, a serial mechanism, a parallel mechanism, and a docking mechanism.
- Changing its posture by pitching, yawing and rotating.

Urban search and rescue & military

Fire fighting robots – Anna Konda

- Anna Konda was developed in order to demonstrate the SnakeFighter concept. The robot is one of the biggest and strongest snake robot in the world and also the first water hydraulic snake robot ever constructed.
- Technical data
  - Length: 3 m
  - Weight: 75 kg
  - Number of DOFs: 20
  - Angular flexion in each joint: +/- 33 degrees
  - Actuators: Water hydraulic cylinders
  - Max system pressure: 100 bar (1450 PSI)
  - Max torque (at 100 bar): 300 Nm
Construction and building maintenance

Customized glass-roof cleaning robots

- The RobuGLASS™ robot, developed by ROBOSOFT, is a 4-track platform moving along the external glass surface of the Louvre’s Pyramid.
- Innovative technical solutions:
  - A suction system keeping the robot stuck to the surface while moving up and down, without any safety cable.
  - A remote control and autonomous navigation system, using sensors to track the windows frames.
  - A light chassis, made of carbon fiber.
  - A redundant control and vacuum system, for safety.

Inspection robots

- According to the environment in which they travel:
  - Open natural environment
  - Man-made environment

Inspection robots – MAKRO

- BMBF-funded project MAKRO at Fraunhofer
- To develop a prototype of a multi-segment robot platform to operate autonomously in sewer pipes of 300-600 mm diameter.
- Available for the video inspection of a real, roughly cleaned sewer in dry weather.
- Depending on the actually achievable quality of a radio link, a human operator can, but need not, interfere with the robot control.
Unmanned aerial vehicle – *Karma*

@zodiac.com

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Helium (160 cubic meters)</td>
</tr>
<tr>
<td>Weight</td>
<td>12 kg</td>
</tr>
<tr>
<td>Motors</td>
<td>2x2 motor, 3x3 motor, 5x5 motor</td>
</tr>
<tr>
<td>Processor</td>
<td>2.6GHz Intel Core i7-8700K</td>
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<tr>
<td>System</td>
<td>1/8th powered (15W)</td>
</tr>
<tr>
<td>Sensor</td>
<td>2x2x2 15x15x15 universal OCR</td>
</tr>
<tr>
<td></td>
<td>wind sensor, metal detector</td>
</tr>
<tr>
<td>Dimensions</td>
<td>87.5 x 76.5 x 75.5 cm</td>
</tr>
<tr>
<td>Weight</td>
<td>20 kg</td>
</tr>
</tbody>
</table>

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Mobile Robotics

Mobile robot classification continued

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Inspired Robotic Technology

http://sied.dis.uniroma1.it/ssrr07/
Thanks for your attention!

Any questions?