Robotics: Introduction

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Intelligent Robots

Sense/Think/Act

“AI” view
get the computer (robot) to do things that, for now, people are better at
Intelligent Robots

Sense/Think/Act

“AI” view
get the computer (robot) to do things that, for now, people are better at

“Reactive” view
“elephants don’t play chess”
Chess is easy - moving around is hard
What Can Robots Be Used For?

- Manufacturing
- 3 Ds: Dirty, Dull, Dangerous
- Space
  - Satellites, probes, planetary landers, rovers
- Military
- Agriculture
- Construction
- Entertainment
- Consumer?
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The three key questions in Mobile Robotics

- Where am I?
- Where am I going?
- How do I get there?

To answer these questions the robot has to:

- have a model of the environment (given or autonomously built)
- perceive and analyze the environment
- find its position/situation within the environment
- plan and execute the movement
Autonomous mobile robot | the see-think-act cycle

Knowledge, database

Localization Map Building

Environment model, local map

Information Extraction

Raw data

Sensing

Real World Environment

“Position” global map

Cognition Path Planning

Path

Path Execution

Actuator commands

Motion Control
Wheel types and its constraints
- Rolling constraint
- no-sliding constraint (lateral)
Autonomous mobile robot | the see-think-act cycle
Perception | sensing

Laser scanner
- time of flight

Cameras

- Lens
- Focal Plane
- Focal Point
- Focal Length: $f$

- GPS
- Omnidirectional camera
- IMU
- Laser scanners
- Standard camera
- Security switch
- Wheel encoders
Perception | information extraction

- **Keypoint Features**
  - features that are reasonably invariant to rotation, scaling, viewpoint, illumination
Perception | information extraction

- Filtering / Edge Detection

Image from [Rosten et al., PAMI 2010]
Autonomous mobile robot | the see-think-act cycle
Localization | where am I?

- **SEE**: The robot queries its sensors → finds itself next to a pillar
- **ACT**: Robot moves one meter forward
  - motion estimated by wheel encoders
  - accumulation of uncertainty
- **SEE**: The robot queries its sensors again → finds itself next to a pillar
- Belief update (information fusion)
Autonomous mobile robot | the see-think-act cycle
Cognition | Where am I going? How do I get there?
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- Global path planning
  - Graph search
Cognition | Where am I going? How do I get there?

- Local path planning
  - Local collision avoidance
Autonomous mobile robot | the see-think-act cycle
Autonomous Mobile Robots

Some recent examples
Rezero | Wheeled locomotion with single point contact

- Up to 17° tilt angle
- Up to 3.5 m/s

http://www.rezero.ethz.ch/
Wheeled locomotion in “3D”

- Paraswift - the vortex wall climbing robot
- Fast spinning impeller underneath the robot produces a strong vortex
- http://www.paraswift.ethz.ch
V-Charge | Autonomous driving using close-to-market sensors
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Flying Concepts

- **Helicopters:**
  - < 20 minutes
  - Highly dynamic and agility
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- **Fixed Wing Airplanes:**
  - > some hours; continuous flights possible
  - Non-holonomic constraints

- **Blimp:**
  - lighter-than-air
  - > some hours (dependent on wind conditions);
  - Sensitive to wind
  - Large size (dependent on payload)
  - Flapping wings
  - Non-holonomic constraints
  - Complex mechanics
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- **Flapping wings**
  - < 20 minutes; gliding mode possible
  - Non-holonomic constraints
  - Complex mechanics
Vision only UAV navigation

Swarm of small helicopters

- Vision only navigation (one camera, GPS denied)
- Fully autonomous with on-board computing
- Feature based visual SLAM

http://www.sfly.org/
Solar powered fixed wing airplanes: Long duration / continuous flights

- **sensSoar**
  - Wingspan: 3 m
  - Wing area: 0.725 m²
  - Peak Solar power: 140 W
  - Power Consumption: 50 W
  - Masses:
    - Overall: 3.72 kg
    - Batteries: 1.89 kg
  - Nominal Speed: 10 m/s
  - Sensors:
    - Air speed
    - IMU, GPS
  - Camera and **IR camera**

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Autonomous Mobile Robots
Varganta Chi, Paul Furgale, Marco Hutter, Martin Ruff, Davide Scaramuzza, Roland Siegwart

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Bell Island (CA) - Lisbon (P)
Google: Autonomous Driving in traffic

- Plan route like a GPS navigator but use extra data to decide on driving actions
- Boost safety and efficiency
- 700,000+ miles with minimal human intervention
- Autonomous cars are still years from mass production
Humanoid Robot: ASIMO

- Honda’s ASIMO - Advanced Step in Innovative MOBilly
- Designed to help people in their everyday lives
- One of the most advanced humanoid robots
- Compact, lightweight
- Sophisticated walk technology
- Human-friendly design
Beyond Mobility | PR2 robot from Willow Garage

Fold towels

Clean-up

Courtesy of Willow Garage
Lego EV3 Robots

- Lego EV3 robot contains a programmable EV3 controller (brick), user interface with an LCD screen, Lego building blocks, motors and various sensors such as light, ultrasonic, color, touch, gyro.
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- The brick contains 4 outputs (motors) 4 inputs (sensors), USB, Bluetooth, or Wi-Fi connection, LCD screen, 16 MB flash memory, 64 MB RAM, SD Card Port, EV3 Brick Button lights, sound.
LeJOS

LeJOS is a small Java Virtual Machine, which allows us to write Java programs for Lego robots

leJOS API documentation: http://www.lejos.org/ev3/docs/
DifferentialPilot: object for the movement of the robot
DifferentialPilot(double wheelDiameter, double trackWidth, RegulatedMotor leftMotor, RegulatedMotor rightMotor)
**DifferentialPilot**: object for the movement of the robot

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### Sensors: Example

1. `EV3UltrasonicSensor sonicSensor = new EV3UltrasonicSensor(SensorPort.S2);`
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4. `sonicSamplePr.fetchSample(sonicSample, 0);`
Setting up

- Connect your robot using a given USB cable to the computer and turn on your robot by pushing the middle square button on the robot.
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- WiFi (next week)
EV3 Gyroscopes

- Preserve their orientation in relation to a fixed reference frame
- They provide an absolute measure for the heading of a mobile system
- Measure rotational motion and changes in its orientation;
- +/- 3 degrees accuracy;
- Maximum output of 440 degrees/second;
- Sample rate of 1 kHz;
EV3 Ultra sonic Sensor

- An ultrasonic sensor works with waves and often it is used in applications for measure distance between a robot and surrounded objects.
- The sensor emits sound waves and receives their echoes to detect and measure the distance from one or more objects.
- Distance measure up to 250 cm (100-inch);
- +/- 1 cm (+/- 0.394-inch) accuracy;
- Recognize other ultrasonic sound
EV3 Touch Sensor

- Useful for detection with high accuracy.
- The EV3 Touch Sensor is an analog and simple tool with a button located in the front and a counter for press/release actions of the button.
- Usually used for start/stop control systems, games like maze-solving robots, and many other applications.
EV3 Color Sensor

- Detection for up to seven colors;
- Detect the absence of color;
- It works in ambient light;
- Sample rate of 1 kHz;
- Auto-ID is built into the EV3 Software;