W1. Objectives, Challenges, State of the Art, Technologies

- Socio-economic context
- Technological evolution of Robotics & State of the Art
- New challenges for Robotics in Human Environments
- Decisional & Control Architecture for Autonomous Mobile Robots & IV
- **Sensing technologies: Object Detection**
- Sensing technologies: Robot Control & HRI
- Basic technologies for Navigation in Dynamic Human Environments
- Intelligent Vehicles: Context & State of the Art
- Intelligent Vehicles: Technical Challenges & Driving Skills

Sensing Technologies

- **Sensing is one of the key functionalities of autonomous robots**

- Sensing is performed using various **Internal & External sensors**

Internal Sensors → *Odometry, Velocity, Acceleration, Inertial parameters (IMU) …*
(proprioception)

External Sensors → *Objects Detection, Localization, Control, HRI*
(exteroception)

Main Sensing Functionalities

- **Non contact sensors for *"Objects Detection & Localization"***
- **Touch sensors for *"Robot Control & HRI"***
  => next session
- **Combining sensor modalities for *"Robustness & Disambiguation"***
  => Week 4

Main Sensing Functionalities

- **Sensors for *“Objects Detection & Localization”***
  - **Proximeters** *(infrared, ultrasound, inductive)*
  - **Passive & Active Vision, Telemeters** *(laser, radar…)*

    ➔ *Improved hardware & Software technologies*

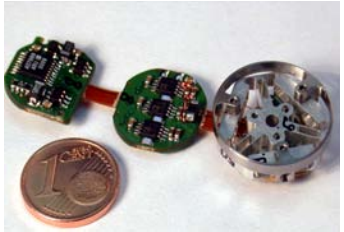
    ➔ *Specific sensors for automotive applications*

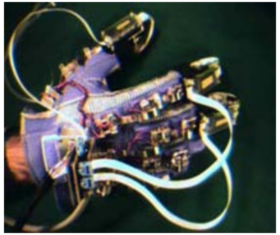
    ➔ *New Low Cost Sensors (Kinect)*

Main Sensing Functionalities

- **Touch sensors for *"Robot Control & HRI"*** *=> Next session*
  - **Force sensors** *(wrist, fingers, table, legs, wheels …)*
  - **Tactile sensors** *(fingers, endoscopes …)*

  ➔ *Miniaturized devices, Advanced integrated H/R interfaces (Haptic)*

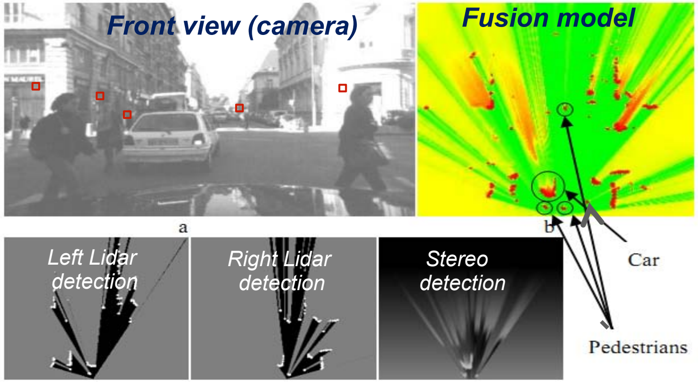




Main Sensing Functionalities

- **Combining sensor modalities for *“Robustness & Disambiguation”*** *=> Week 4*
  - *No sensor can give a sufficiently robust or complete information*
  - ***Sensor fusion*** *is necessary for* ***Robust Perception & Situation Awareness***

    ➔ Most of current Robotics applications



Sensors for Objects Detection & Localization

=> Widely used sensing modalities & Various sensors technologies

Ultra-sound & Infrared

RADAR

2D & 3D LIDARS

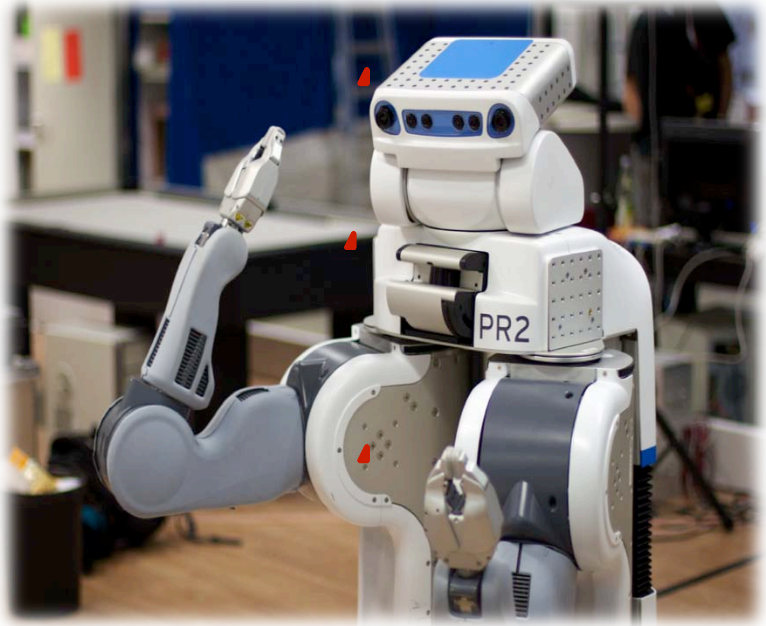
Vision

Stereo vision

Active camera
(e.g. Kinect)

Sensors for Objects Detection & Localization

=> Some examples of equipped commercial robots

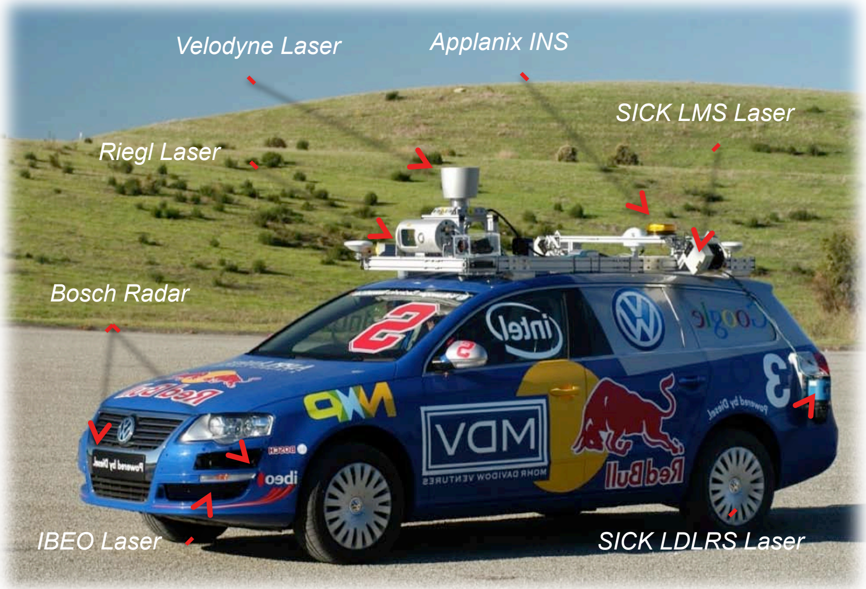


PR2 (Laser, Vision, Force …)

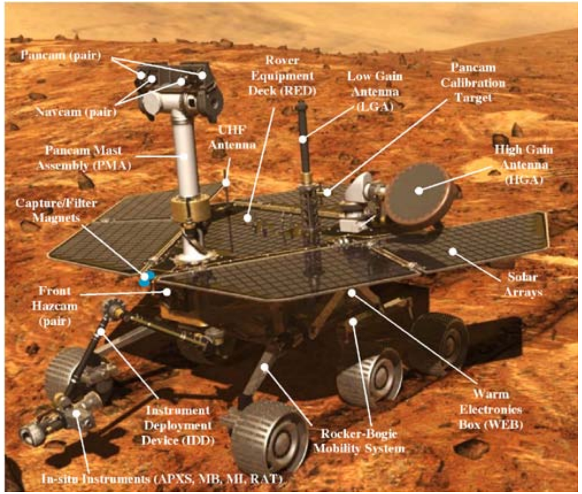
Roomba (contact, odometry …)

Sensors for Objects Detection & Localization

=> Some examples of experimental robots



Junior (Stanford University)



Mars Rover (Nasa / JPL-Caltech)

Ultra-sound sensors

- Measure the Time of Flight (ToF) after reflection of waves against an object/obstacle surface
- Use acoustic waves
- Example of applications:
  - ✓ *small indoor mobile robots*
  - ✓ *automobile (moving back obstacle detection)*

Ultra-sound sensors

Advantages	Drawbacks
• Detect any type of material	• Short range (0-2m)
• Low cost	• Sensitive to noise/wind
• Small	• Some configurations / shapes may be problematic *(e.g. thin rod, sharp edge …)*

RADAR: RAdio Detection And Ranging

- Use electromagnetic (radio) waves
- Distance measurement based on ToF
- Speed measurement based on Doppler effect (frequency change)
- Example of applications:
  - ✓ *Automatic cruise control (cars)*

RADAR: RAdio Detection And Ranging

Advantages	Drawbacks
• Long range (100m)	• Bad angular precision
• No moving part	• Bad reflection on certain surfaces
• Speed measurement	• Noisy data

LIDAR: LIght Detection and Ranging

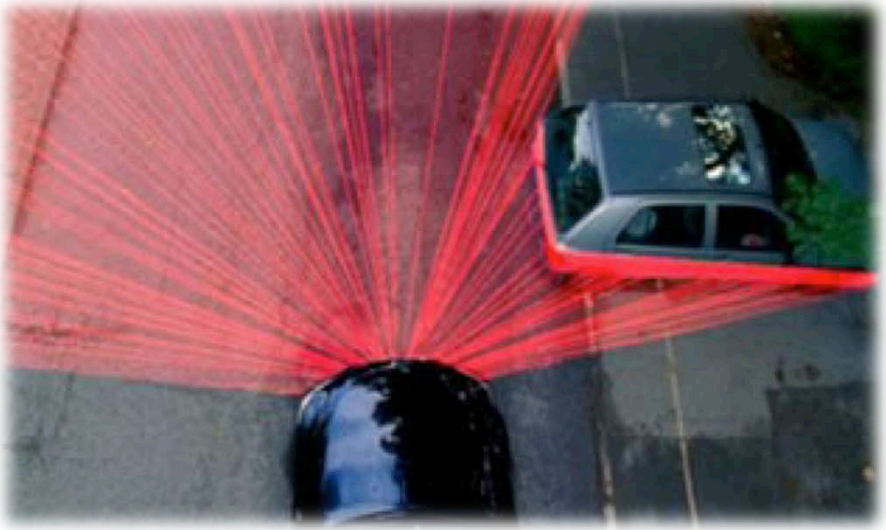
- Use light *(generally infra-red)*
- Distance measurement based on ToF
- Use a rotating mirror for scanning
- Exists in 1D, 2D, 3D scanners
- Example of applications:
  - ✓ *Any (expensive) mobile robot*
  - ✓ *Future autonomous cars ?*

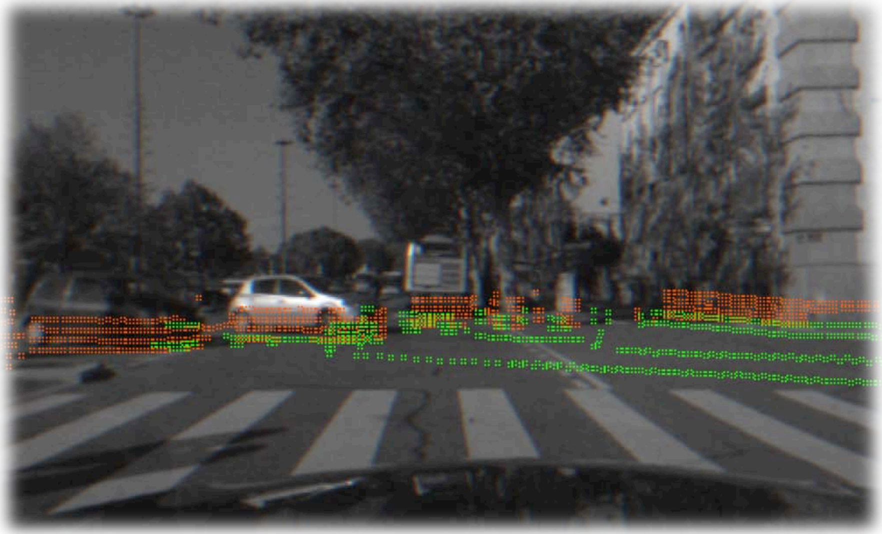
LIDAR: LIght Detection and Ranging

Advantages	Drawbacks
• Precise at every distance	• Some mobile parts
• Works in most situations	• Sensitive to rain/dust
• Easy to process	• Can be very expensive

Detection with 2D LIDAR

- 2D LIDAR data is a set of **impacts** in polar coordinates
- 2D LIDARS often use several scanning layers, *e.g. from 2 to 8 layers*





Detection with 3D LIDAR

- 3D LIDAR data is a set of impacts in polar coordinates
- Several scanning layers are used, *e.g. Velodyne: 64 layers, 32 layers or 16 layers*
- Sensor range, e.g. Velodyne HDL-64E: 64 layers, *360°horizontal, 27°vertical, 1.3 million points per s*

Computer vision

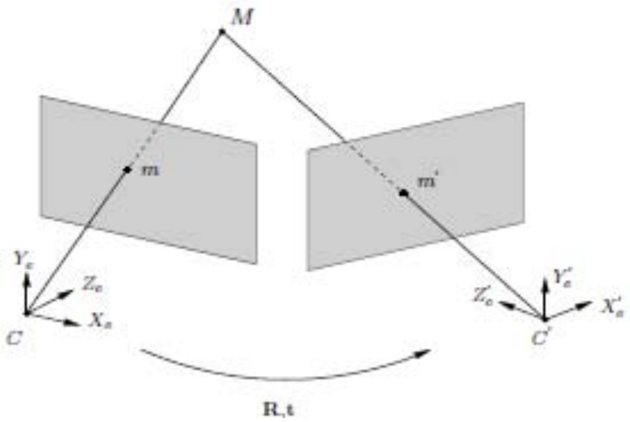
- Passive sensor, which acquires rays of light from the scene
  - ✓ Bearing information
  - ✓ Color / Intensity information
- No range information *=> Necessity of image processing*
- Projective sensor: *3D scene => 2D image (matrix of pixels)*

Computer vision

Advantages	Drawbacks
• Very rich information • Cheap sensor	• Noisy data • Necessity of processing image data *(large number of pixels, noise, interpretation …)*

Stereo-vision

- Vision system with multiple cameras
- Retrieves 3D data from triangulation
- Needs fine Calibration & Image processing



Stereo-vision

Advantages	Drawbacks
• Very rich information *(image + 3D)*	• Noisy data
• Rather cheap sensor	• Computationally costly
	• Needs fine calibration
	• Non constant uncertainty

Active vision sensors

- Active range cameras
  - ✓ *Kinect*
  - ✓ *Swiss ranger (TOF)*

Active vision sensors

Advantages	**Drawbacks**
• Very rich information *(image + 3D)*	• Short range
• Range data is directly accessible	• Not usable outdoor
• Kinect technology very cheap	

Pictures & Movies

- p. 4 & 7:
  - By Arduino Labs – flickr - CC BY 2.0
  - By Steve Jurvetson - CC-BY-2.0 via Wikimedia Commons
  - By Evan-Amos - Public domain, via Wikimedia Commons
  - © Point Grey Reasearch
- p. 8:
  - PR2 : By Jiuguang Wang – flickr - CC BY SA 2.0
  - Roomba : Amit Gupta CC BY-NC 2.0
- p. 9:
  - Junior: By kqedquest - flickr - CC BY NC 2.0
  - Mars Rover: Courtesy NASA/JPL-Caltech
- p. 10-11: By Arduino Labs – flickr - CC BY 2.0
- p. 12-13: Rights Reserved
- p. 14-15:
  - By S. Winkvist - Public domain, via Wikimedia Commons
  - By Steve Jurvetson - CC-BY-2.0, via Wikimedia Commons
- p. 16-19: Rights Reserved
- p. 20: © Point Grey Reasearch
- p. 22: Kinect: By Evan-Amos - Public domain, via Wikimedia Commons