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Systèmes robotisés intelligents
Smart Robotic Systems

Sensors and Variables Estimation

Gilles TAGNE

Sensors and variables estimation

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- ✓ Sensors for mobile robots
- ✓ Variables estimation
- ✓ Multi-sensor fusion

Sensors for mobile robots

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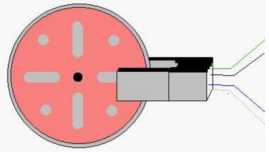
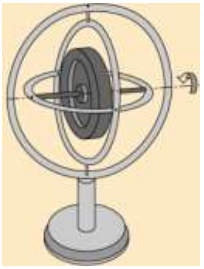
- **Proprioceptive sensors:** provide information on the internal state of the robot
- **Exteroceptive sensors:** provide information on the state of the environment





Sensors for mobile robots

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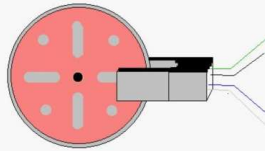
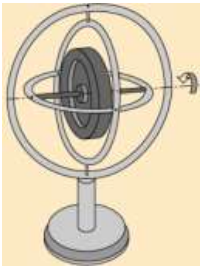
- **Passive sensors**
- **Active sensors**

- **Analog sensors**
- **Digital sensors**
- **Logic sensors**
- **Smart sensors**





Sensors for mobile robots
Classification example

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General Classification (typical use)	Sensor / Sensor System	PC: Proprioceptive EC: Exteroceptive	P: Passive A: Active
Wheel/motor sensors (wheel/motor speed and position)	Brush Encoders	PC	P
	Potentiometers	PC	P
	Synchros, Resolvers	PC	A
	Optical Encoders	PC	A
	Magnetic Encoders	PC	A
	Inductive Encoders	PC	A
	Capacitive Encoders	PC	A
Heading sensors (orientation of the robot in relation to a fixed reference frame)	***Compass***	EC	P
	Gyroscopes	PC	P
	Inclinometers	EC	P/A
Ground based beacons (localization in a fixed reference frame)	***GPS***	EC	A
	Active optical or RF beacons	EC	A
	Active ultrasonic beacons	EC	A
	Reflective beacons	EC	A
Active ranging (reflectivity, time-of-flight and geometric triangulation)	Reflectivity sensors	EC	A
	Ultrasonic sensor	EC	A
	Laser rangefinder	EC	A
	Optical triangulation (1D)	EC	A
	Structured light (2D)	EC	A
Motion/speed sensors (speed relative to fixed or moving objects)	***Doppler radar***	EC	A
	Doppler sound	EC	A
Vision-based sensors (visual ranging, whole-image analysis, segmentation, object recognition)	***CCD/CMOS camera(s)***	EC	P
	Visual ranging packages		
	Object tracking packages		

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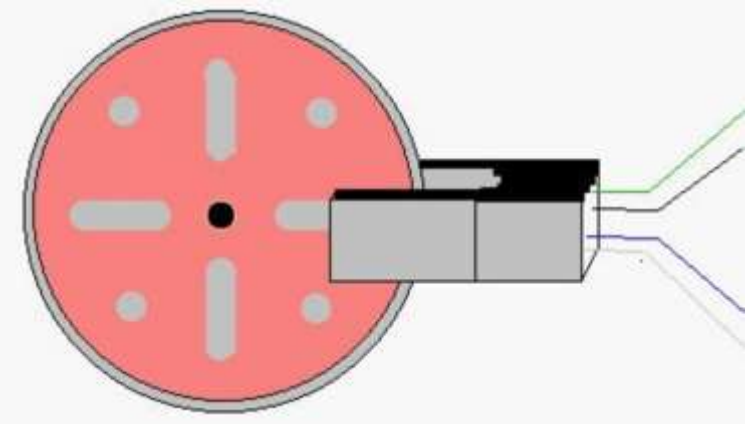
Odometry

Measurement of wheel speed rotation
Estimation of the robot's displacement
Distance traveled



Advantages: low cost, precision
Drawbacks: Sliding of the wheel, Drift over time

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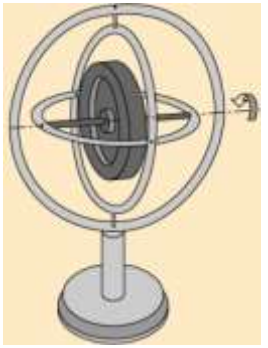
Inertial systems

Gyrometer: Measurement of orientation; angular velocity
Accelerometer: Measurement of accelerations
Magnetometer: Magnetic field measurement
Compass: Orientation to Magnetic North



Advantages: Good dynamics, precision
Drawbacks: Drift over time

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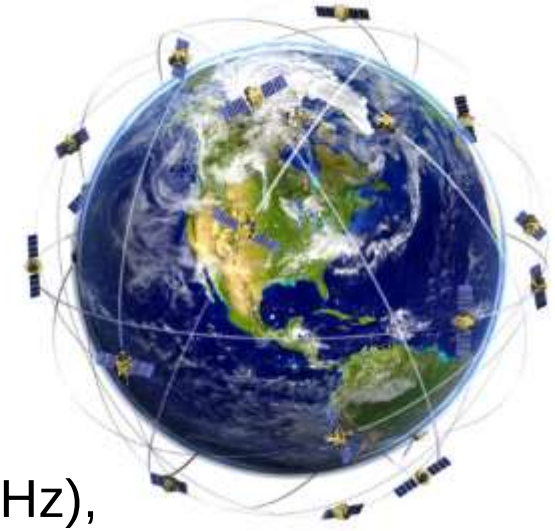
GNSS* sensors: GPS (Global Positioning System)

Measuring the absolute position of a point in a fixed landmark (the center of the earth)
3 Signals needed (4 more robust)
Outdoor Navigation
Useful for spot recalculations
DGPS: Precision centimeter



Advantages: No drift
Drawbacks: Low frequency <5Hz (typically 1Hz), unavailability of satellite signals

*Global Navigation Satellite System

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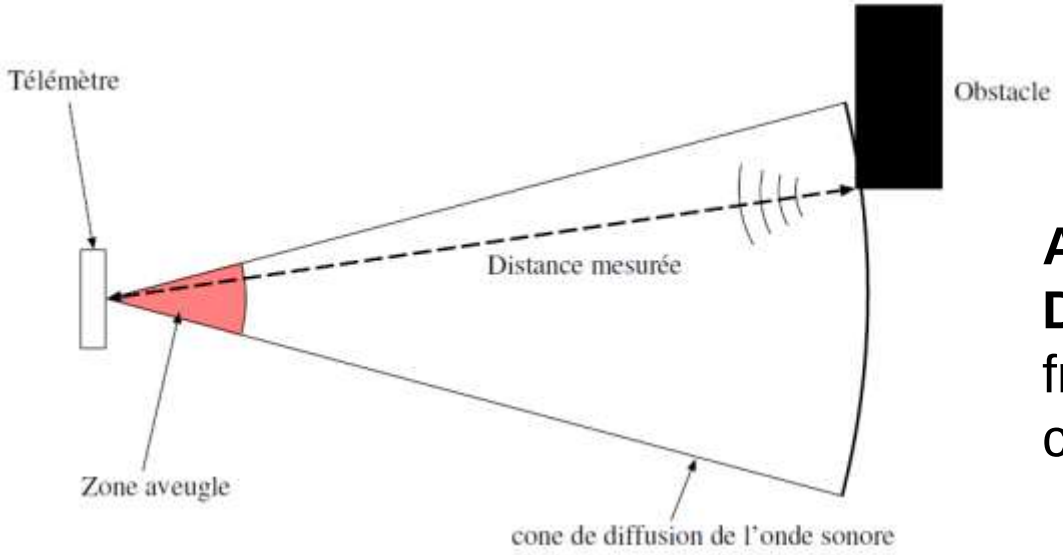
Ultrasonic telemeter

Proximity and distance measurement
Sound waves that reflect on the obstacles



Advantages: precision
Drawbacks: Maximum frequency of measurements, cone angle of opening

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Radar

Distance and Speed measurement

Advantages: Low cost, Highly industrialized
Drawbacks: Sound waves carried by air therefore unusable at high speed, Aerodynamic effects that destroy the ultrasonic signal, Absorption of sound waves by certain materials
applications: parking assistance

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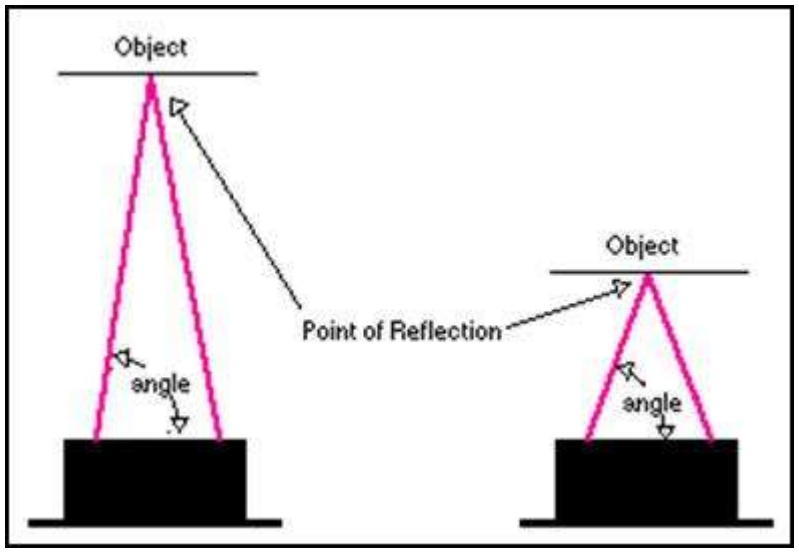
Infrared telemeter

Proximity and distance measurement



Advantages: Measurement frequency, precision
Drawbacks: Low distances <5m (Typically <2m)

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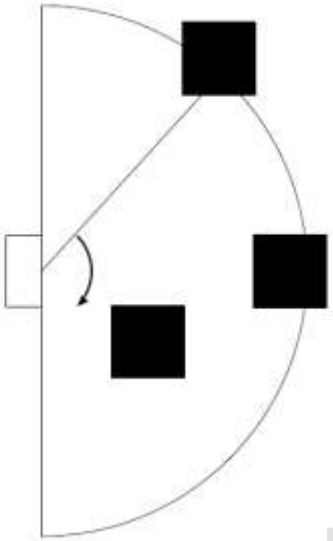
Laser telemeter (LIDAR)

Active Perception
Precise distance measurements
Cartography and localization



Example (characteristics):

Angle d'ouverture	$180°$
Résolution angulaire	$0,25 - 0,5 - 1°$
Temps de réponse (fonction de la résolution)	$13 - 26 - 52\ ms$
Résolution	$10\ mm$
Erreur systématique	$\pm 15\ mm$
Erreur statistique	$5\ mm$
Classe d'équipement laser	classe 1
Températures de fonctionnement	$0°\ C \cdots + 50°\ C$
Distance maximale de mesure	$80\ m$
Interface	RS-422 et RS-232
Taux de transmission	$9,6 - 19,2 - 38,4 - 500\ kBaud$
Consommation	$20\ W$
Poids	$4,5\ kg$
Dimensions $(L \times l \times h)$	$156 \times 155 \times 210\ mm$

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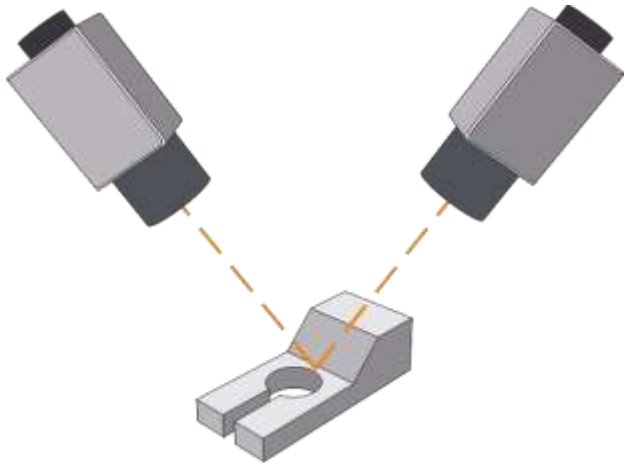
Cameras (Vision)

2D / 3D vision
Monovision color / grayscale
Omnidirectional vision
Stereovision: Gives a depth image (3D measurement)
Infrared vision: Pixels that react to heat sources or night vision



- “eye to hand” “Caméra deportée”
- “ eye in hand ” “ Caméra embarquée ”

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Cameras: Other vision systems

Kinect (structured light): pixel image and depth image.
TOF camera (Time Of Flight)

Cameras detecting color and depth
Microphone with voice recognition
Motorized sensor for tracking movements

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Cameras (Vision systems)

Advantages:

- Allows to recognize the type of obstacle
- Allows to track a specific target
- Gives a lot of information about the near environment of the robot

Drawbacks:

- Calculation time of the algorithms
- False detections

Sensors for mobile robots
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- **Analog sensors**
- **Digital sensors**
- **Logic sensors**

Exercise: Build an array sensors of the following robots :

- Pepper
- ISEN Mobile robot

Variables estimation

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Why ?

- Impossibility to measure
- Very expensive sensor
- Very noisy data

How to estimate ?

- By developing an oservator
- By filtering the data (Kalman filter)
- Combining or merging many information

Variables estimation

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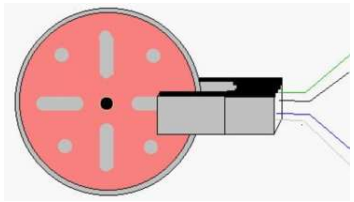
Before estimating a variable:

- Assumptions to verify
- The initial conditions
- The impact of the estimation on the behavior of the robot

Variable estimaion example :

Wheel speed by odometry



Multi-sensor fusion

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Purposes of data fusion :

- More robust estimate
- Get new information
- Analysis of the robot near environment
- Planning for future actions

Data fusion example :

- Odometry + GPS: Robust localization
- Camera + US + Lidar: Development of the robot dynamic local map

Multi-sensor fusion

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Data fusion Methods :

- Probability theory
- Theory of possibility
- Theory of fuzzy sets (fuzzy logic)
- Theory of belief functions
- Decision trees
- Rule bases
- Nearest neighbors
- Neural networks
- Bayesian networks
- Markov chains