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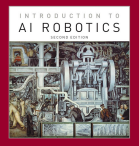
Sensing

How do you make a robot "see"?

What sensors are essential for a robot?

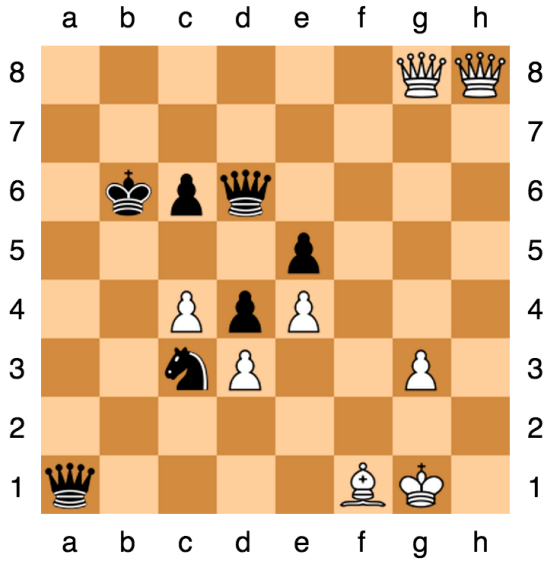
What's sensor fusion?

Doesn't the Microsoft Kinect solve everything?



Perception is hard!

- "In robotics, the easy problems are hard and the hard problems are easy"
  - S. Pinker. The Language Instinct. New York: Harper Perennial Modern Classics, 1994



beating the world's chess master: EASY

create a machine with some "common sense": very HARD

The Summer Vision Project

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1966

Abstract
The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. […] the construction of a system complex enough to be real landmark in the development of "pattern recognition".
[…]
The primary goal of the project is to construct a system of programs which will divide a vidisector picture into regions such as likely objects, likely background areas and chaos.
[…]
The final goal is OBJECT IDENTIFICATION which will actually name objects by matching them with a vocabulary of known objects.

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Sensors for Mobile Robots

- Why should a robotics engineer know about sensors?
  - Is the **key technology** for perceiving the environment
  - **Understanding the physical principle** enables appropriate use

- Understanding the physical principle behind sensors enables us:
  - To **properly select** the sensors for a given application
  - To **properly model** the sensor system, e.g. resolution, bandwidth, **uncertainties**
  - To **define the needs** in collaboration with sensor system suppliers

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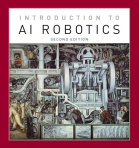
Objectives

- List at least one advantage and disadvantage of common robotic sensors: GPS, INS, ultrasonics, laser stripers, IR, IR rangers, laser rangers, computer vision
- If given a small interleaved RGB image and a range of color values for a region, be able to extract color affordances using 1) threshold on color and 2) a color histogram
- Be able to construct an occupancy grid and use polar plots for reactive navigation
- Define each of the following terms in one or two sentences: *proprioception, exteroception, exproprioception, proximity sensor, logical sensor, false positive, false negative, hue, saturation, image, pixel, image function, computer vision, GPS-denied area*
- Describe the three types of behavioral sensor fusion: *fission, fusion, fashion*



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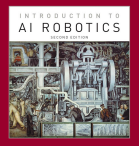
Return to Layers

- In *behavioral layer*, sensing…
  - Supports a behavior
  - Releases a behavior
- In *deliberative layer*, sensing…
  - Recognizes and aids with reasoning about objects
  - Builds world model
- In *distributed layer*, social sensing…
  - Is sensitive to proximity and targets affect

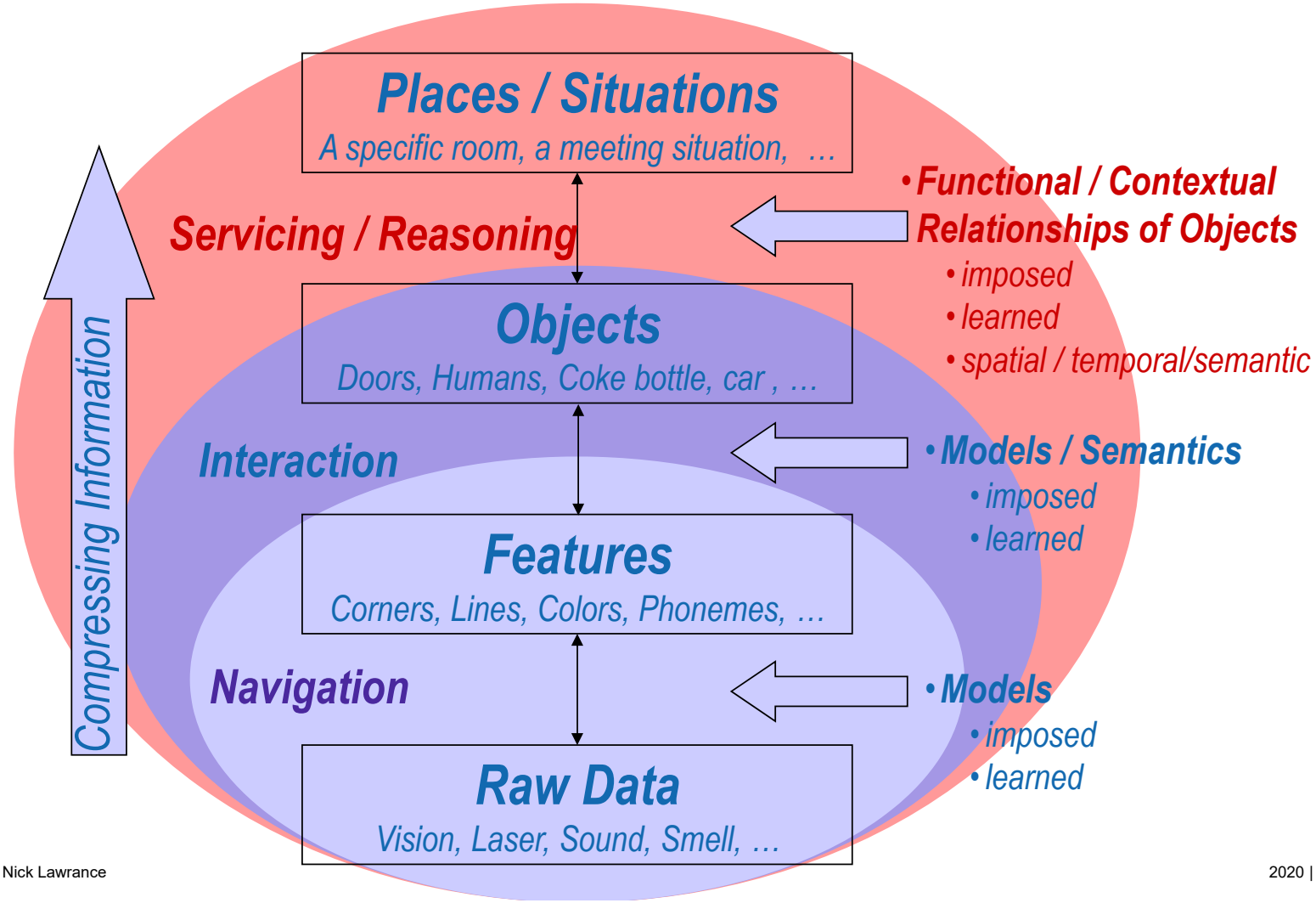


Robotics | challenges and drivers of technology

- The challenges
  - ***Seeing***, ***feeling*** and ***understanding*** the world
  - Dealing with ***uncertain*** and only ***partially available*** information
  - ***Act*** appropriately onto the environment

- Technology drivers
  | *technology evolutions enable robotics revolutions*
  - Laser time-of-flight sensors
  - Cameras and IMUs combined with required calculation power
  - Torque controlled motors, “soft” actuation
  - New materials

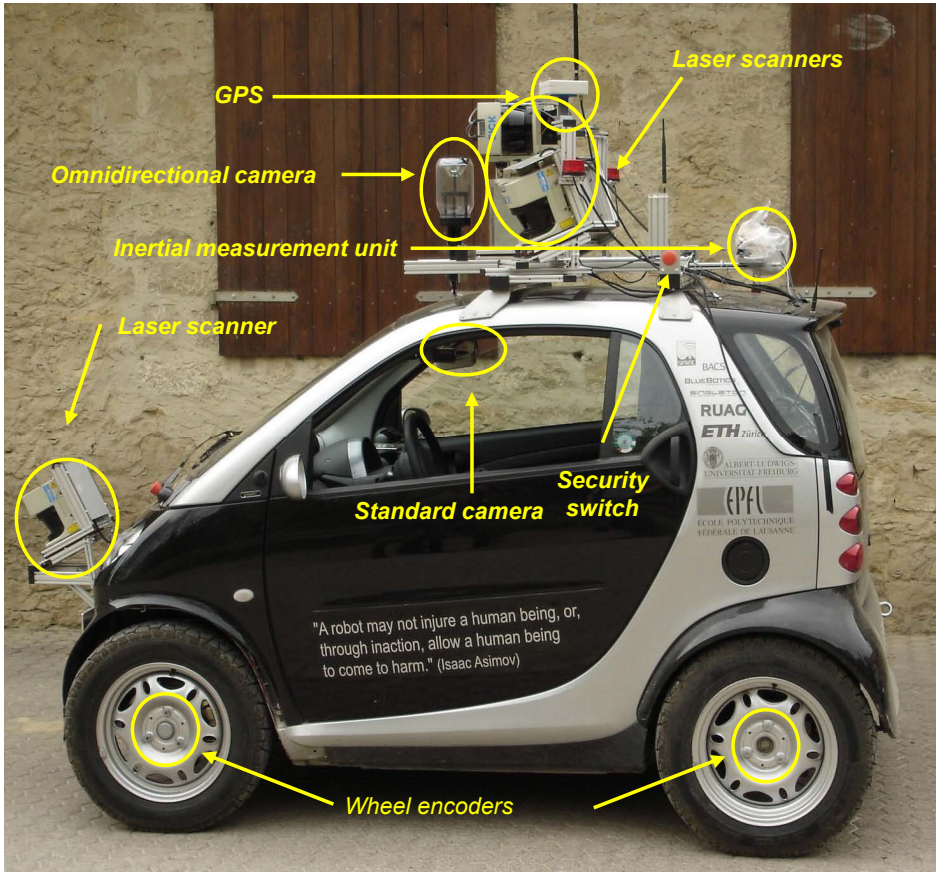
Perception | definition



- Sensors = sensors provide the raw data
- Sensing = sensing is the combination of the algorithm(s) and sensor(s) that produces a percept
- Sensor fusion = the sensing mechanism which allow multiple sensors to produce (higher level) percepts and world models

Sensors | common sensors and their use in mobile robotics

- Tactile sensors or bumpers
  - Detection of physical contact, security switches
- GPS
  - Global localization and navigation
- Inertial Measurement Unit (IMU)
  - Orientation and acceleration of the robot
- Wheel encoders
  - Local motion estimation (odometry)
- Laser scanners
  - Obstacle avoidance, motion estimation, scene interpretation (road detection, pedestrians)
- Cameras
  - Texture information, motion estimation, scene interpretation



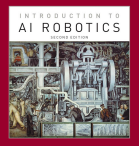
10 Ways of Organizing Sensors

- 3 Types of Perception
  - Proprioceptive =

    sensing
    stimuli that are produced and perceived within an organism especially those connected with the position and movement of the body.
  - Exteroceptive =

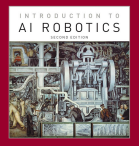
    sensing stimuli that are external to an organism
  - Exproprioceptive =

    The sense of
    the position of external objects relative to parts of the body



10 Ways of Organizing Sensors

- Input
  - Active vs. passive
    - § Passive sensors
      - energy coming for the environment
    - § Active sensors
      - emit their proper energy and measure the reaction
      - better performance, but some influence on environment
- Output
  - Image vs. non-image
  - Matrix vs. non-matrix



General Classification (1)

General classification (typical use)	Sensor Sensor System	PC or EC	A or P
Tactile sensors (detection of physical contact or closeness; security switches)	Contact switches, bumpers	EC	P
	Optical barriers	EC	A
	Noncontact proximity sensors	EC	A
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	A/P

A, active; P, passive; P/A, passive/active; PC, proprioceptive; EC, exteroceptive.

General Classification (2)

General classification (typical use)	Sensor Sensor System	PC or EC	A or P
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 geo-metric 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 analy-sis, segmentation, object recognition)	CCD/CMOS camera(s)	EC	P
	Visual ranging packages		
	Object tracking packages		