Università degli Studi di Padova

パドヴァ大学

Robots' Autonomy

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AUTONOMY vs AUTOMATION

- What is the difference between automation and autonomy?
- Why does it matter that there is a difference between automation and autonomy?
- What are the advantages of autonomy over automation? Can you tell me when to use one over the other? How much autonomy do I need?

Adapted from R.Murphy

AUTONOMY: DEFINITION(S)

Autonomy (Merriman-Webster):

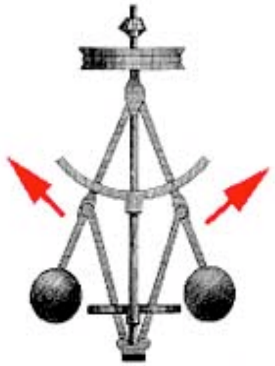
The quality or state of *being self-governing, self-directing freedom and especially moral independence.*

This definition causes the myth of evil robots

Adapted from R.Murphy

Autonomy Isn't All It's Cracked Up to Be

- Autonomy (Merriam-Webster) is the quality or state of *being self-governing, self-directing freedom and especially moral independence*
- But in robotics "self-governing" is from the mechanical tradition of self-governing
- And **bounded rationality** notes all cognitive agents have limits.



James Watt controlled his steam engine with a new self-governor

Adapted from R.Murphy

So What's the Difference?

- **Automation** is about physically-situated tools performing highly repetitive, pre-planned actions for well-modeled tasks under the closed world assumption.

- **Autonomy** is about physically-situated agents who not only perform actions but can also adapt to the open world where the environment and tasks are not known a priori by generating new plans, monitoring and changing plans, and learning within the constraints of their bounded rationality.

Adapted from R.Murphy

Practical Examples:

Automation

Autonomy

Adapted from R.Murphy

See a Difference?

- Closed world
- Delegating for a small set of repetitious tasks

Focus is on formal, stable control loops

Automation

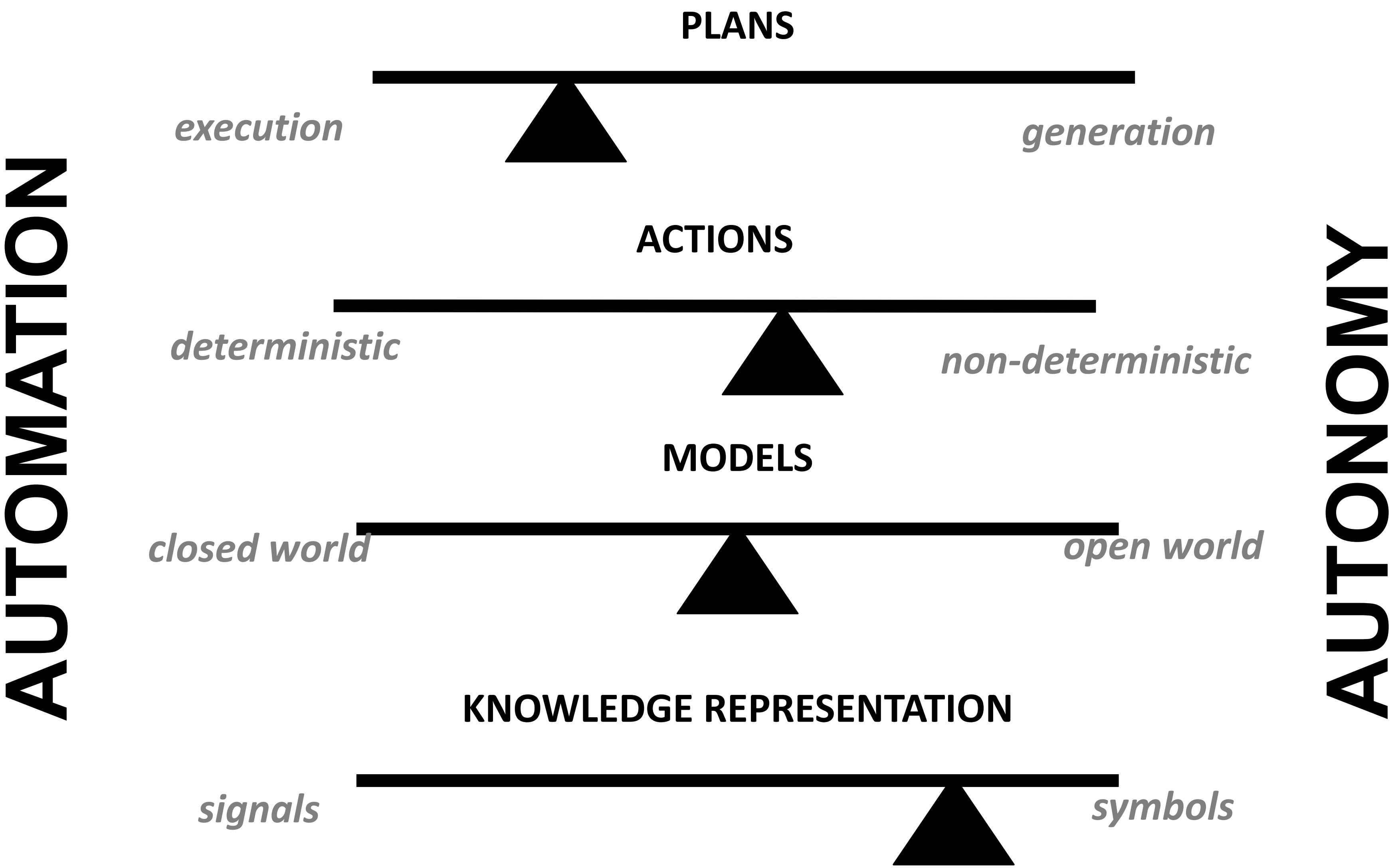
- Open world
- Delegating for a variety of tasks while operating in dynamic environments

Focus is on artificial intelligence

Autonomy

Adapted from R.Murphy

AUTOMATION vs AUTONOMY



Adapted from R.Murphy

AUTOMATION vs AUTONOMY

AUTOMATION

PLANS

execution — *generation*

ACTIONS

deterministic — *non-deterministic*

MODELS

closed world — *open world*

KNOWLEDGE REPRESENTATION

signals — *symbols*

AUTONOMY

Adapted from R.Murphy

AUTOMATION vs AUTONOMY

AUTOMATION

AUTONOMY

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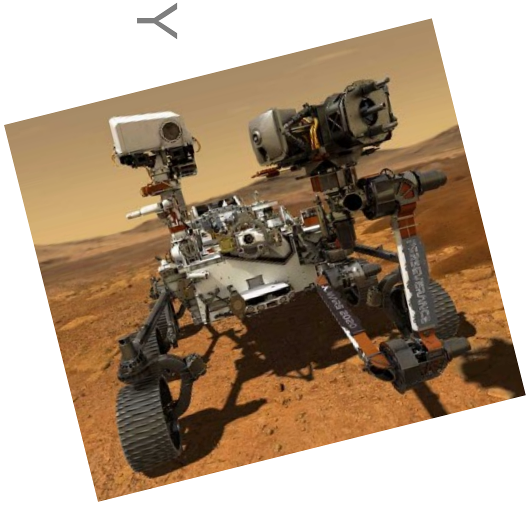
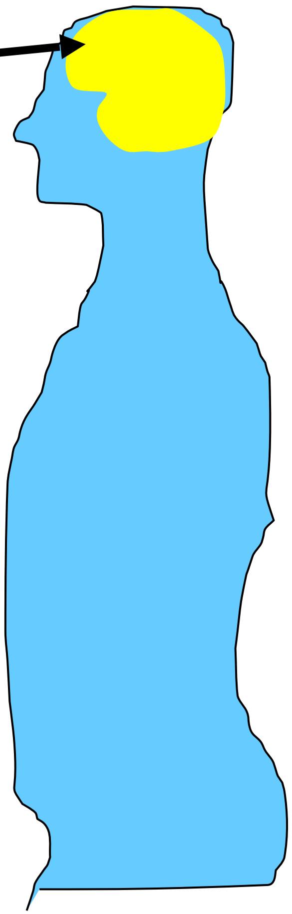


Adapted from R.Murphy

How to organize (artificial) intelligence?

Brain

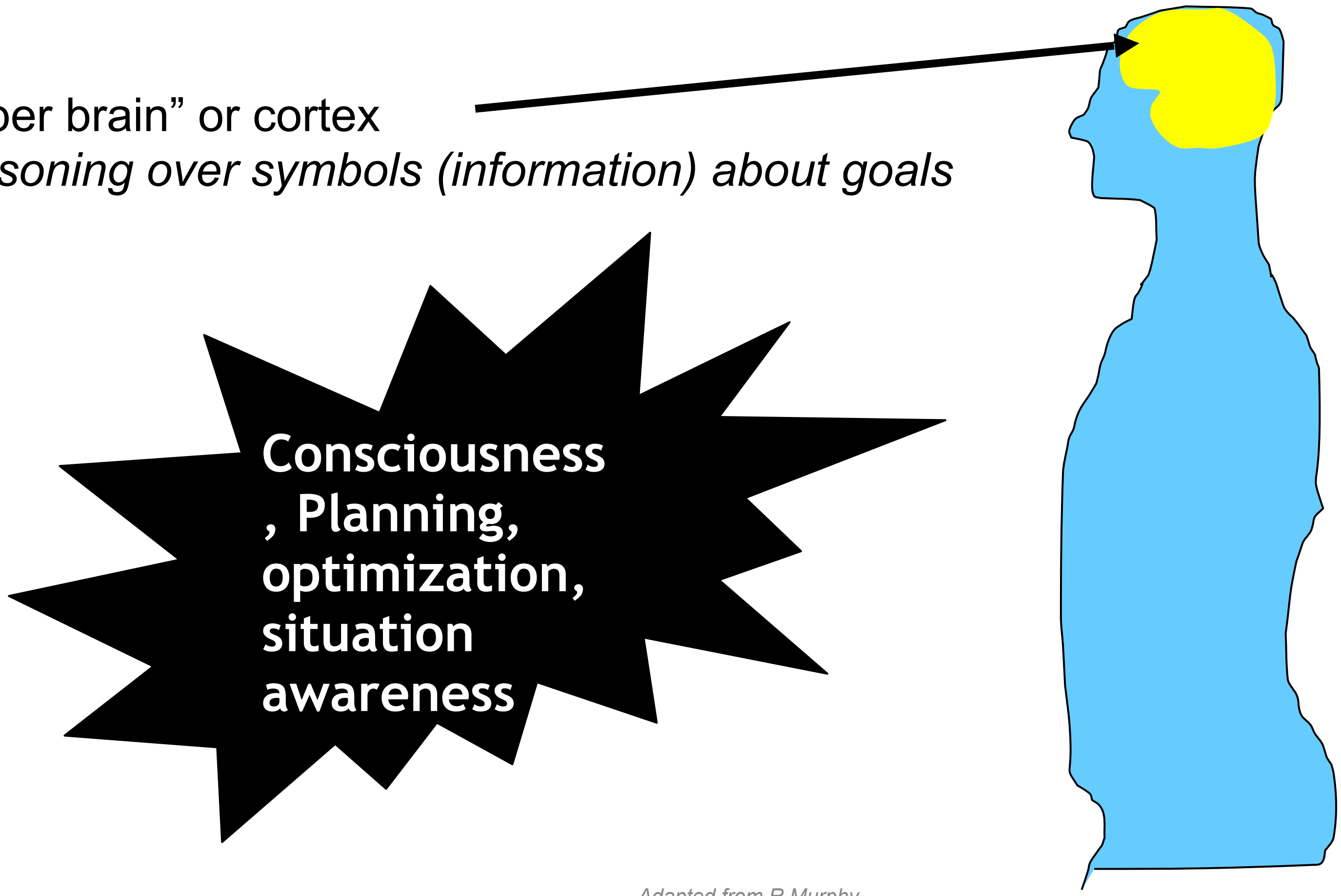
"Upper brain" or cortex
Reasoning over symbols (information) about goals



Adapted from R.Murphy

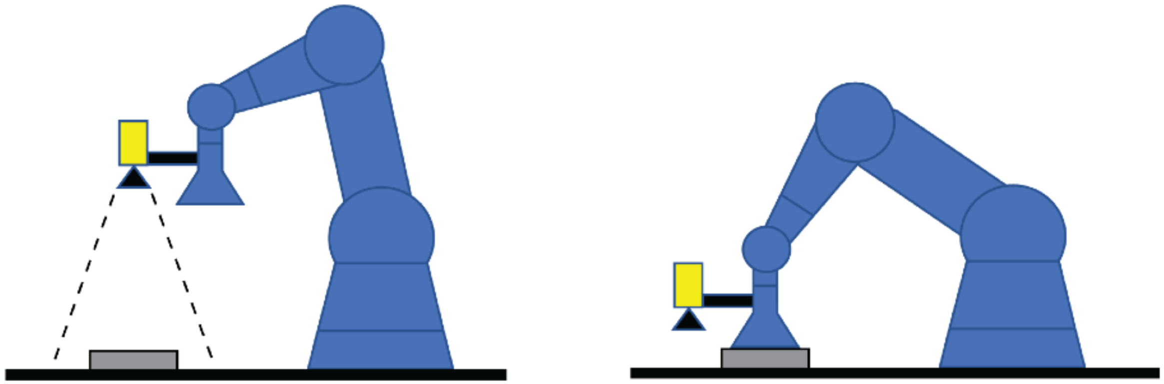
Loop 1: Deliberative, thoughtful, consciuos

“Upper brain” or cortex
Reasoning over symbols (information) about goals

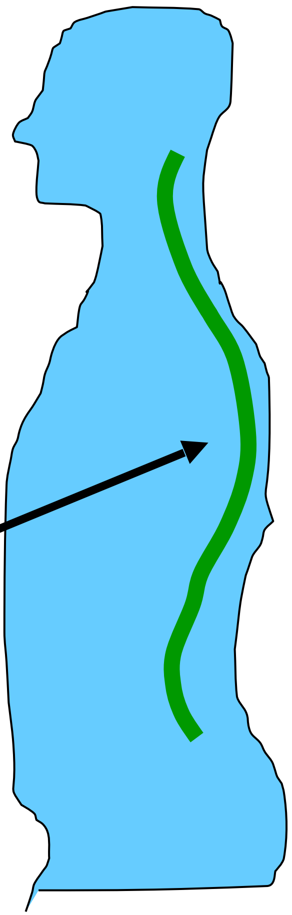


Adapted from R.Murphy

Guided Pick



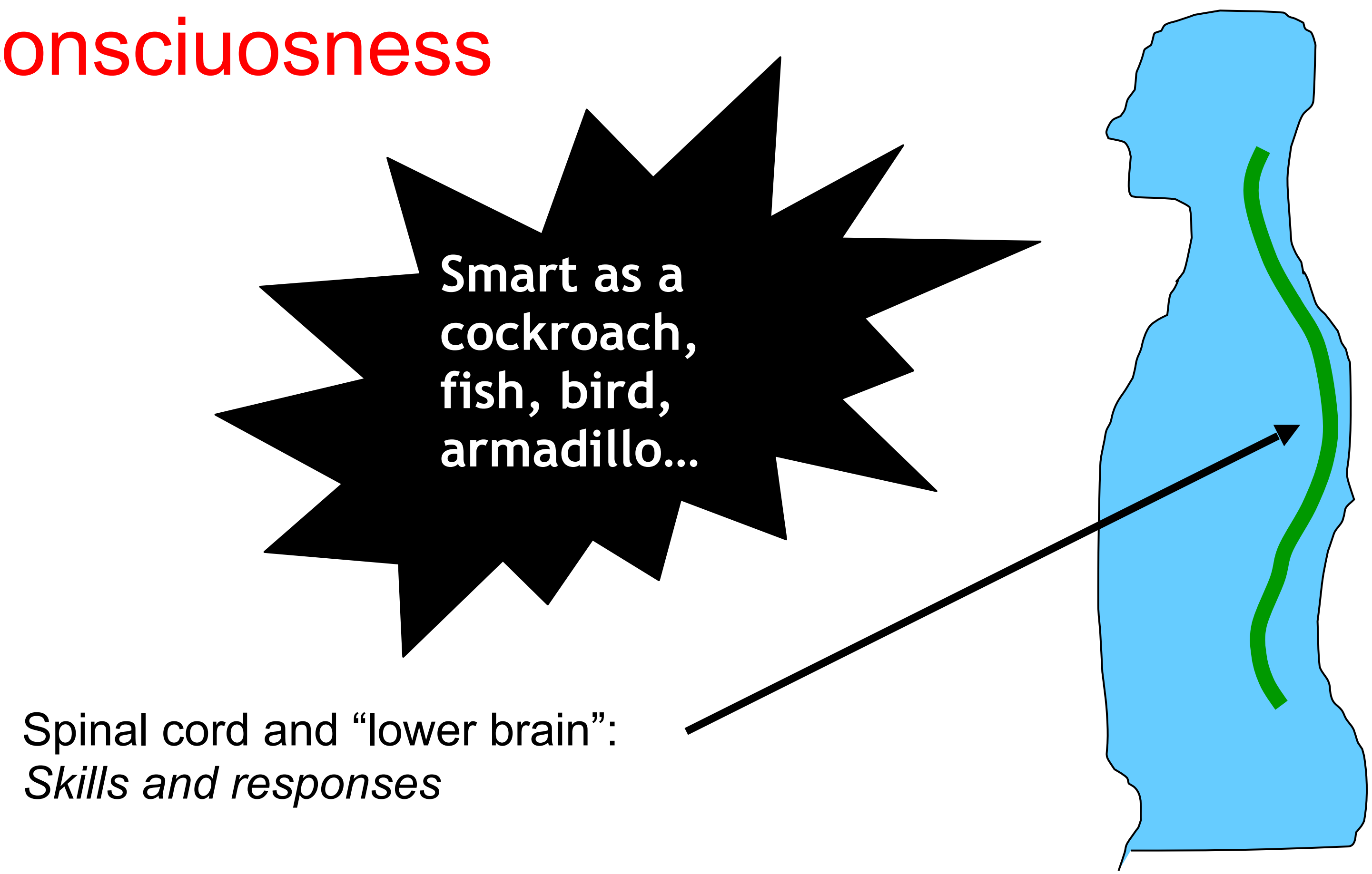
Lower Central Nervous System



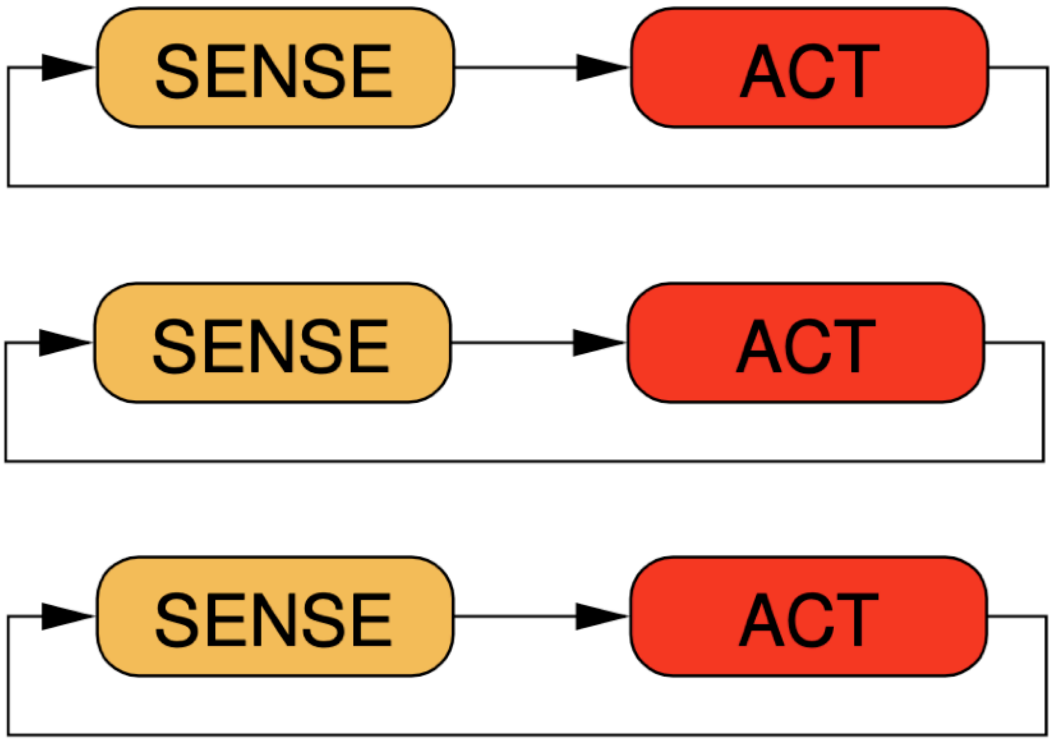
Spinal cord and “lower brain”:
Skills and responses

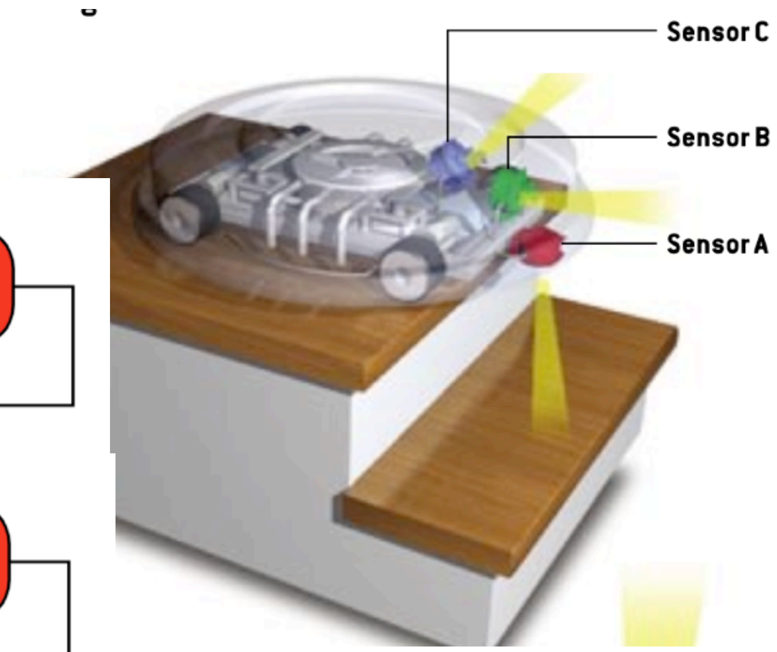
Adapted from R.Murphy

Loop 2: Reflexes, reactive, unconsciuosness



Reactive Architecture



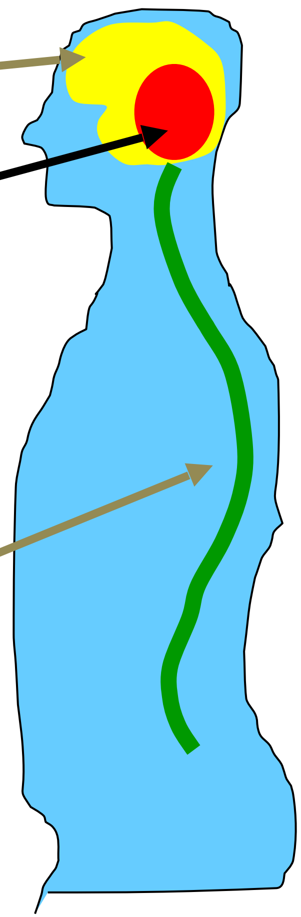


Direct Perception to Symbols

“Upper brain” or cortex
Reasoning over symbols (information) about goals

“Middle brain”
Converting sensor data into symbols (information)

Spinal cord and “lower brain”:
Skills and responses



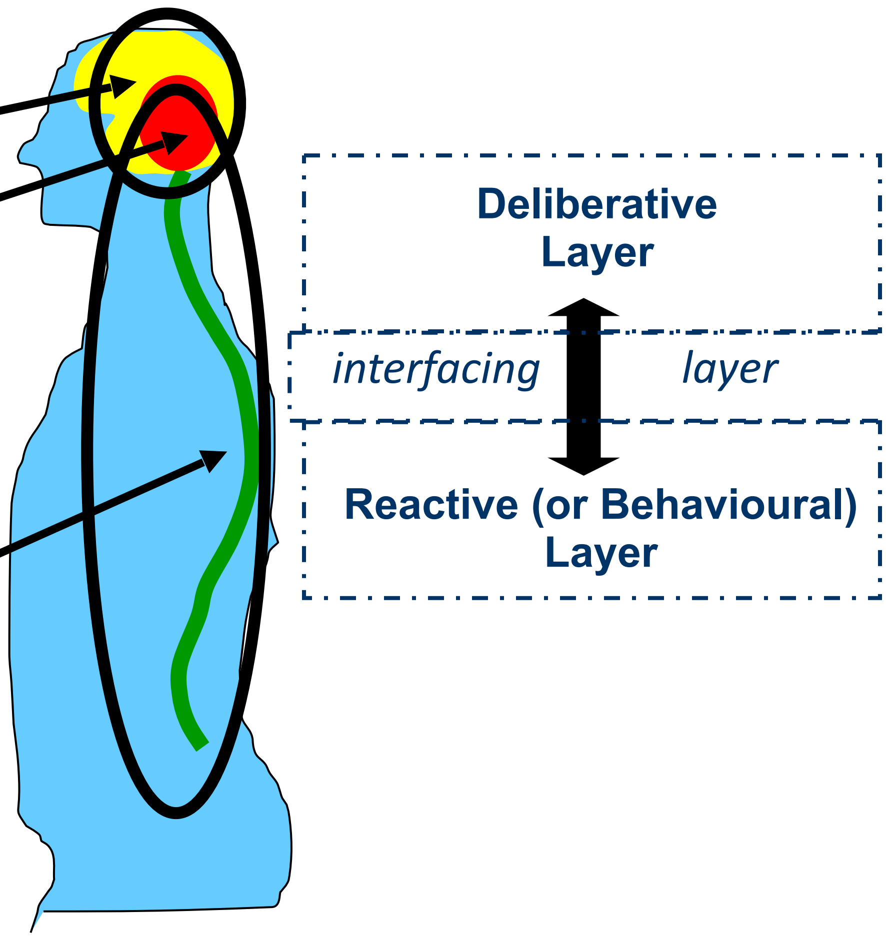
Adapted from R.Murphy

Two Layers in Architecture

“Upper brain” or cortex
Reasoning over symbols (information) about goals

“Middle brain”
Converting sensor data into symbols (information)

Spinal cord and “lower brain”:
Skills and responses



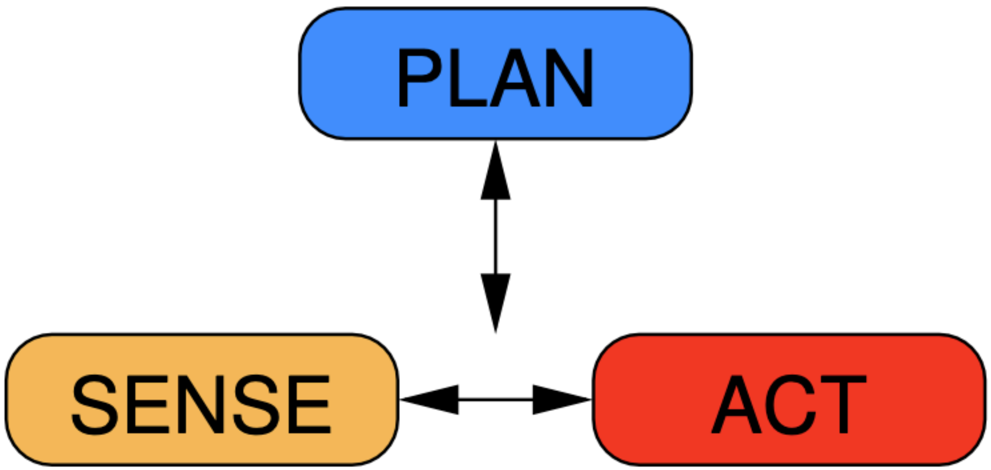
Adapted from R.Murphy

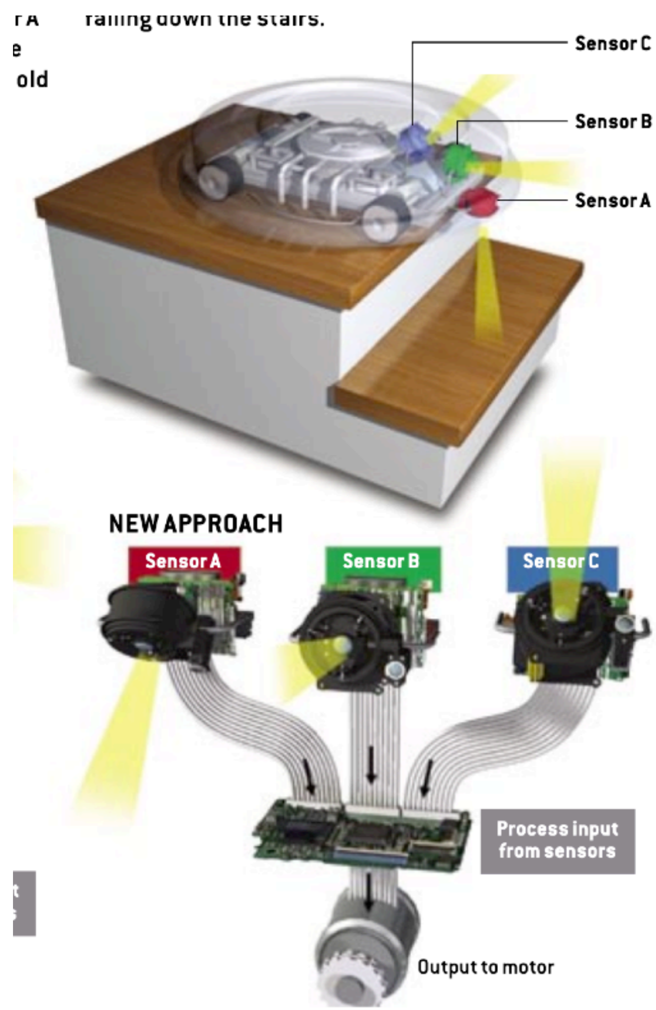
The Hard Part

- From Reactive to Deliberative
  - Two types of perception: DIRECT, **RECOGNITION (symbols)**
    - Impacts computer vision
  - Different time horizons
    - From Present to Present, Past, Future
    - Impacts sensing, storage, as well as algorithms reasoning, projecting
  - **Need a central structure (WORLD MODEL) to hold the symbols, history, knowledge but is tractable**

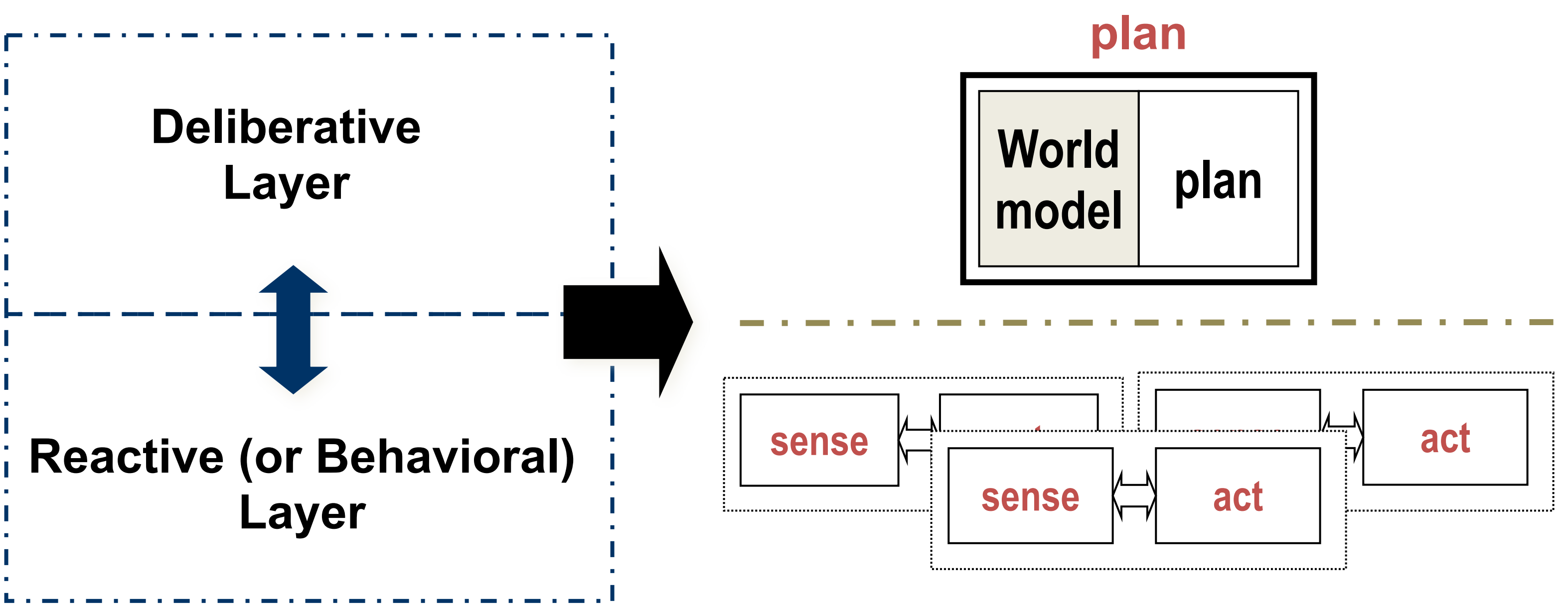
- From Reactive/Deliberative to Interaction
  - **Additional knowledge "theory of mind"– beliefs, desires, intentions (BDI) of the other agent, common ground**

Hybrid Architecture





"Hybrid Architecture"



- PLAN, then SENSE-ACT
- PLAN, then **instantiate appropriate** SENSE-ACT behaviors, **until next step** in plan, …
- PLAN requires a World Model (though it is bounded) plus the actual planning algorithms

How to perceive the World?

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

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The Summer Vision Project

Author(s)
Papert, Seymour A.
MIT - MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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.

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

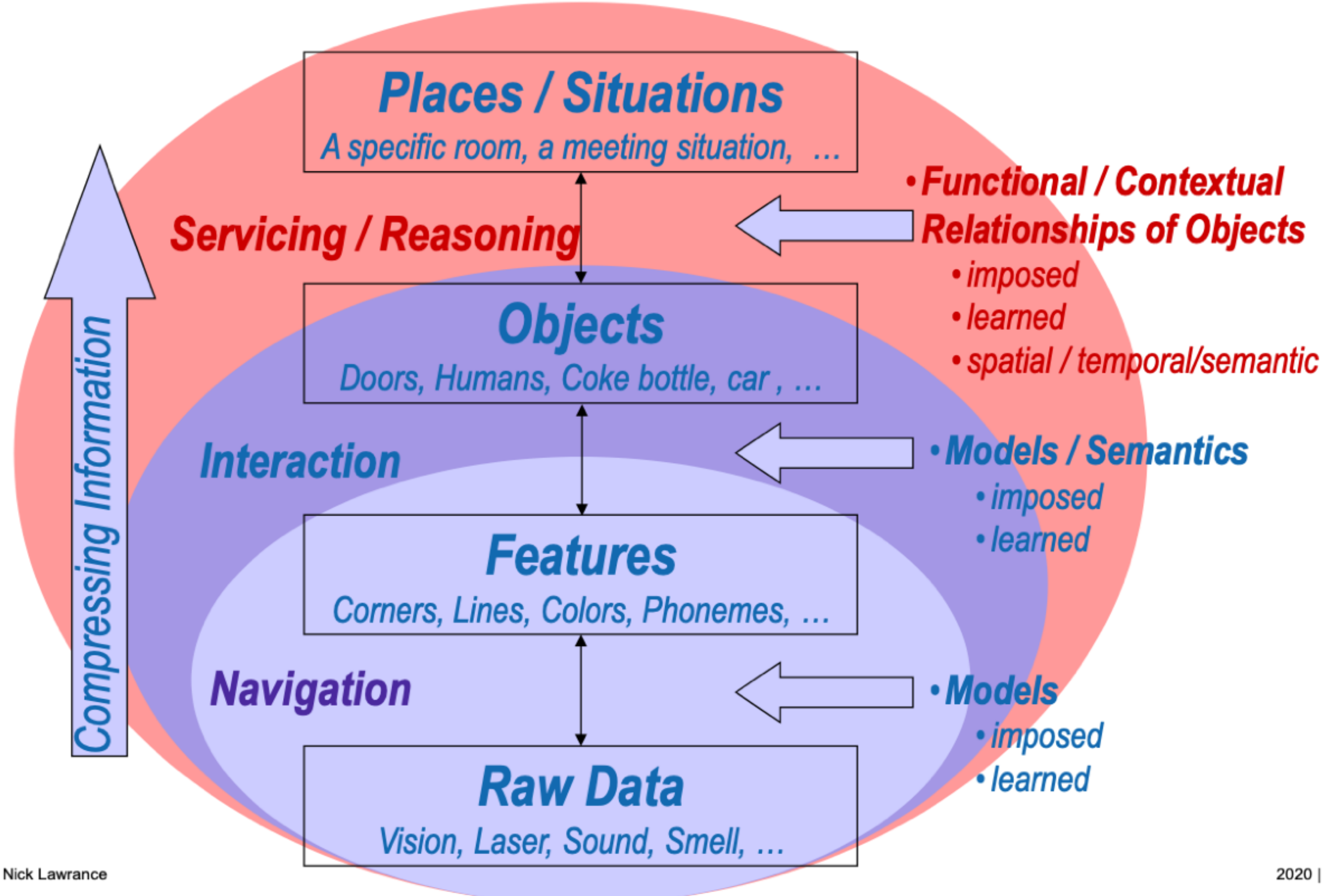
- Understanding the physical principle behind sensors enables us:
  - To **properly select** the sensors for a given application
  - To **properly model** the sensor system, e.g. resolution, bandwidth, **uncertainties**
  - To **define the needs** in collaboration with sensor system suppliers

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

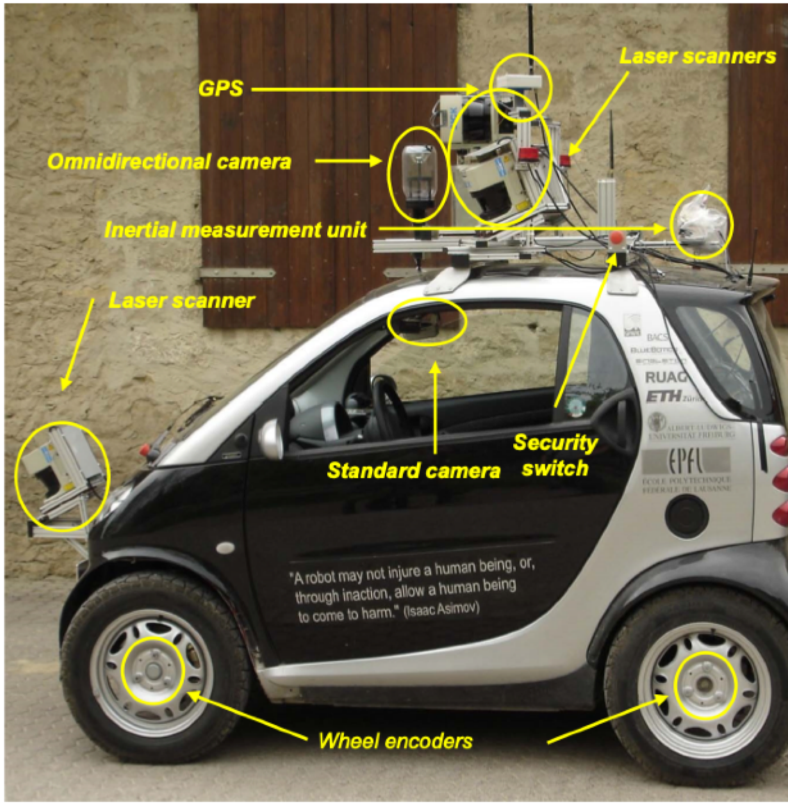


Sensor and Sensing

- 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



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 =

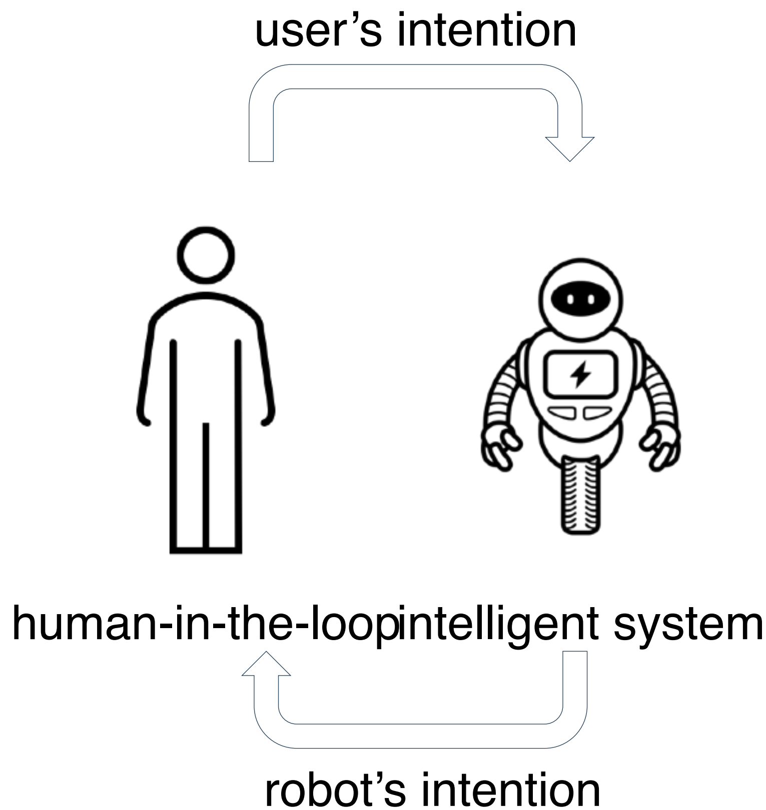
    sensing stimuli that are external to an organism
  - Exproprioceptive =

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

Human-Robot interaction

Human-robot interaction

Key concepts



Key concepts:

- sharing the intentions
- understanding the intentions
- producing joint action

joint action

Human-robot interaction

Classical taxonomy

Modes of cooperation between person and robot

physical	⇨	*person and robot in direct/indirect contact*
cognitiv e	⇨	*person and robot involved in joint work*
social	⇨	*robot designed to influence the person responds*

Human-robot interaction

Classical taxonomy

styles of cognitive engagement

taskable agent	remote presence	assistive agent
robot as independent agent with some degree of autonomy	*robot as a real-time extensions of a human*	*robot co-located with a human to support*

Human-robot interaction

Classical taxonomy

styles of cognitive engagement

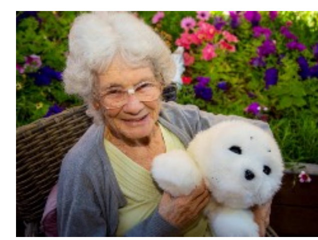
taskable agent | remote presence | assistive agent

modes of cooperation

physical

cognitive

social



Interfacing to the robot

Examples of human-robot interfaces

Summary:

- Definition of robot
- New applications for robots
- Industry 5.0
- Intelligence == Automation vs Autonomy
- Software to create autonomy
- Sensors to support Autonomy
- Once autonomous, interaction with the humans

To Conclude

- Intelligent robot is a physically situated *intelligent agent; it* is a system that perceives its environment and takes actions which maximize its chances of success.

- An intelligent robot is also called autonomous, where autonomous means autonomous capability, not political autonomy or that the robot can do the entire job.

- If you design a robot application, you will probably use a bit of ideas from automation and autonomy, but you will need to consider whether planning is involved, what kinds of actions, what type of model of the world, and knowledge representation.

Adapted from R.Murphy