Cognitive Systems : HRI

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Human–Robot Interaction (HRI) is a field of study dedicated to under- standing, designing, and evaluating robotic systems for use by or with humans. Interaction, by definition, requires communication between robots and humans. Communication between a human and a robot may take several forms, but these forms are largely influenced by whether the human and the robot are in close proximity to each other or not. Thus, communication and, therefore, interaction can be separated into two general categories:

- **Remote interaction:** The human and the robot are not co-located and are separated spatially or even temporally (for example, the Mars Rovers are separated from earth both in space and time).
- **Proximate interaction:** The humans and the robots are co- located (for example, service robots may be in the same room as humans).

- Search and Rescue
- Assistive and Educational Robotics
- Entertainment
- Military and Police
- Space Exploration
- UAV Reconnaissance and UUV Applications
- Education
- Field robotics
- Home and companion robotics
- Hospitality
- Rehabilitation and Elder Care
- Robot Assisted Therapy (RAT)

What is a Robot?

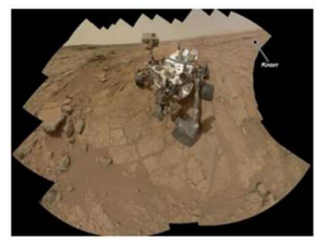
- "A robot is a reprogrammable, multifunctional manipulator designed to move … through variable programmed motions for the performance of a variety of tasks." (Robot Institute of America)
- "A robot is a one-armed, blind idiot with limited memory and which cannot speak, see, or hear."
- **In practice:** robotics intersects with any space in which computers move into the physical world.

Some Current Robots









What Are They Good At?

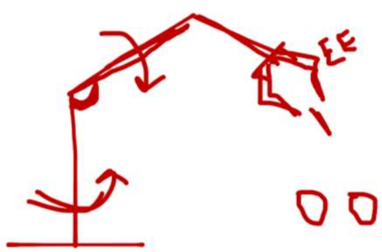
- What is hard for humans is easy for robots.
  - Repetitive tasks.
  - Continuous operation.
  - Complicated calculations.
  - Referring to huge databases/knowledge sources.
- What is easy for a human is (sometimes) hard for robots.
  - Reasoning.
  - Adapting to new situations.
  - Flexible to changing requirements.
  - Integrating multiple sensors.
  - Resolving conflicting data.
  - Synthesizing unrelated information.
  - Creativity.

Categories of Robot Systems

- Manipulators
  - Anchored somewhere
  - Factory assembly lines
  - International Space Station
  - Hospitals
  - Common industrial robots
- Mobile Robots
  - Move around environment
  - UGVs, UAVs, AUVs, UUVs
  - Mars rovers, delivery bots, ocean explorers
- Mobile Manipulators
  - Both move and manipulate
  - Packbot, humanoid robots

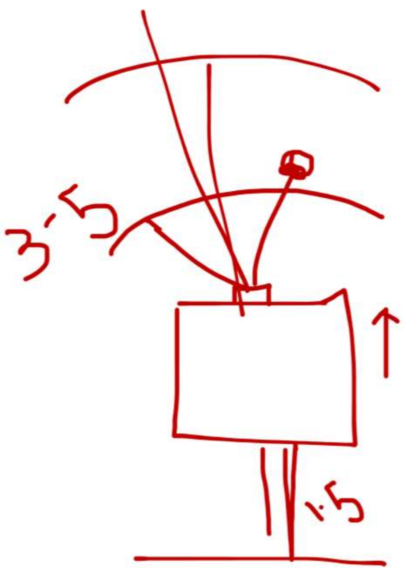
Subsystems

Robots have:



- Sensors
  - Some way of *detecting* the world
- Effectors
  - Some way of *affecting* things in the world
  - Manipulation
  - Mobility
- Control/Software

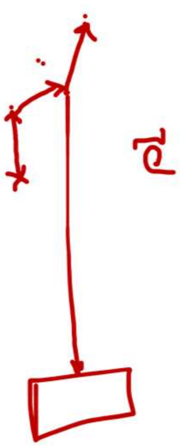
Sensors



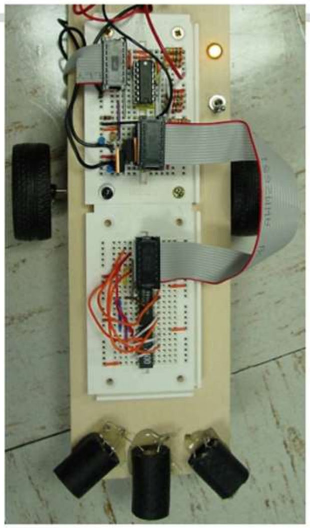
- Perceive the world
  - **Passive** sensors capture signals from environment. (cameras)
  - **Active** sensors probe the environment (sonar)
- What are they sensing?
  - The environment (range finders, obstacle detection)
  - The robot's location (gps, wireless stations)
  - Robot's own internals: *proprioceptive* sensors
    - Stop and think about that one for a moment. Close your eyes - where's your hand? Move it - where is it now?

A.I + C

What Are Sensors Used For?



- Feedback
  - Closed-loop robots use sensors in conjunction with actuators to gain higher accuracy – servo motors.
- Decision making
  - Mobile robotics
  - Telepresence
  - Search and rescue
  - Pick and place (with vision)
- Human interaction



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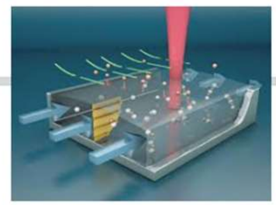
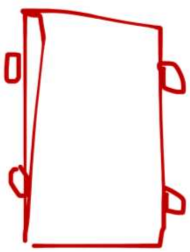
Some Sensors



- Optical
  - Laser / radar
  - 3D
  - Color spectrum
- Pressure
- Temperature
- Chemical
- Motion & Accelerometer
- Acoustic
  - Ultrasonic
- E-field Sensing

Actuators / Effectors

- Take some kind of action in the world
- Involve movement of robot or subcomponent of robot
- Robot actions include
  - Pick and place: Move items between points
  - Continuous path control: Move along a programmable path
  - Sensory: Employ sensors for feedback (e-field sensing)

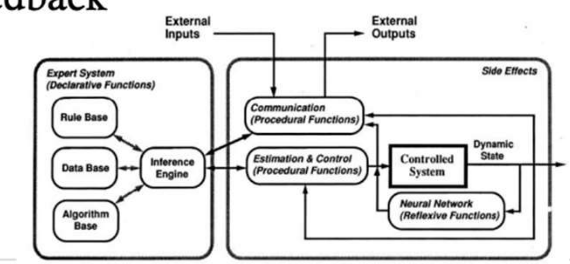


Mobility

- Legs
- Wheels
- Tracks
- Crawls
- Rolls

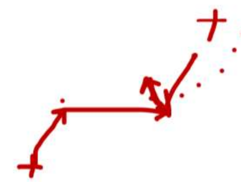
Control: The Brain

- Open loop, i.e., no feedback, deterministic
  - Instructions
  - Rules
- Closed loop, i.e., feedback
  - Learn
  - Adapt



RL + Cont

PID



Where Is AI Needed?

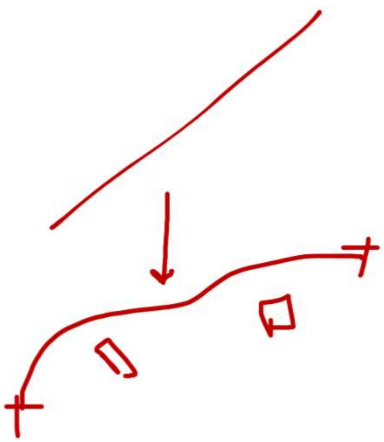
- Sensing:
  - Interpreting incoming information
    - Machine vision, signal processing
    - Language understanding
- Actuation:
  - What to do with manipulators and how
    - Motion planning and path planning
- Control:
  - Managing large search spaces and complexity
    - Accelerating masses produce vibration, elastic deformations in links.
    - Torques, stresses on end actuator
    - Feedback loops
- Firmware and software:
  - Especially with more intelligent approaches!

Robotic Perception

- Sensing isn't enough: need to *act* on data sensed
  - Data are noisy
  - Environment is dynamic and partially observable
- Must be mapped into an internal *representation*
- Good representations:
  - Contain enough information for good decisions
  - Are structured for efficient updating
  - Are a natural (usable) mapping between representation and real world

Some Perception Problems

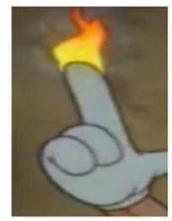
- Localization: where is the robot, where are other things in the environment
  - Landmarks
  - Range scans
- Mapping: no map given, robot must determine both environment and position.
  - SLAM: Simultaneous localization and mapping
- Probabilistic approaches typical
  - Especially machine learning!
- What about common sense? Learning?



Software Architectures

- Low-level, reactive control
  - Bottom-up
  - Sensor results directly trigger actions
- Model-based, deliberative planning
  - Top-down
  - Actions are triggered based on planning around a state model
- Which is an *intelligence* approach?
  - A? B? Neither? Both?

Hybrid



Low-Level, Reactive Control

- Augmented finite state machines
- Sensed inputs and a clock determine next state
- Build bottom up, from individual motions
- Subsumption architecture synchronizes AFSMs, combines values from separate AFSMs.
- Advantages: simple to develop, fast
- Disadvantages: Fragile for bad sensor data, don't support integration of complex data over time.
- Typically used for simple tasks, like following a wall or moving a leg.

Model-Based Deliberative Planning

- Belief State model
  - Current State, Goal State
  - Any of planning techniques
  - Typically use probabilistic methods
- Pros:
  - Can handle uncertain measurements and complex integrations
  - Can be responsive to change or problems.
- Cons:
  - Slow!
  - Developing models for, e.g., driving, is cumbersome.
- Typically used for high-level actions
  - Whether to move and in which direction.

Hybrid Architectures

- Usually, actually doing anything requires both reactive and deliberative processing.
- Typical architecture is three-layer:
  - Reactive Layer: low-level control, tight sensor-action loop, decision cycle of milliseconds
  - Deliberative layer: global solutions to complex tasks, model-based planning, decision cycle of minutes
  - Executive layer: glue. Accepts directions from deliberative layer, sequences actions for reactive layer, decision cycle of a second

Performance Metrics

- Speed and acceleration
- Resolution (in space)
- Working volume
- Accuracy
- Cost

- …plus all the evaluation functions for any AI system.

Human-Robot Interaction

- Social robots
  - In care contexts
  - In home contexts
  - In industrial contexts
- Comprehension
  - Natural language
  - Grounded knowledge acquisition
  - Roomba: “Uh-oh”
- Basic idea: Human-centric environments

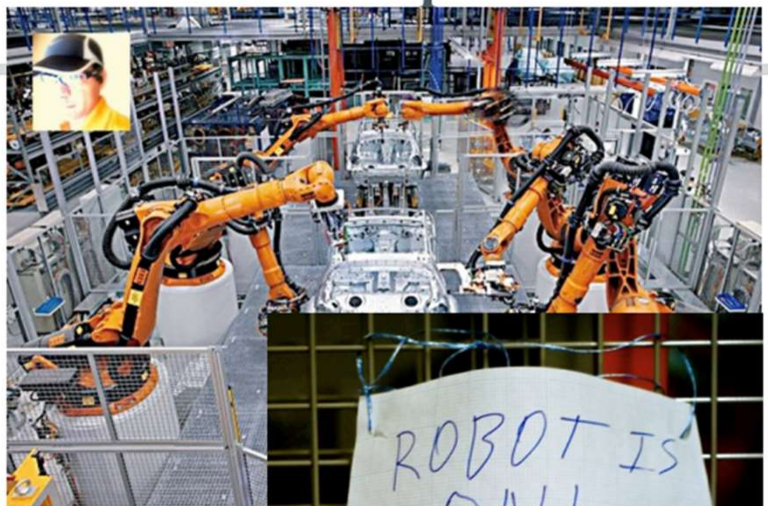
Why?

- Robots are getting smaller, cheaper, and more ubiquitous
- Humans need to interact with and instruct them, naturally
  - Language, gesture, demonstration, …
- Key requirements:
  - Language understanding learned from data
  - Follow instructions in a previously unseen world
  - Learn to parse natural language into robot-usable commands

NLP

Robots in Human Spaces

- Robots now:
  - Expensive
  - Complex
  - Special-purpose
- Environments
  - Dedicated
  - Constrained
- Use and Management
  - Controlled by trained experts
  - Slow and expensive to reconfigure/repurpose



Human-Robot Interaction

- How do *humans* handle human interaction?
  - Assumptions about retention and understanding
  - Anthropomorphization
- How do robots make it easier?
  - Apologize *vs.* back off
  - Convey intent
  - Cultural context (implicit vs. explicit communication)