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Intelligent robots

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ROBOT DESIGN: DAY ONE

Plan for this part:

- Agents, robots and other beasts
- Rationality
- Agent architectures
  - Sense-think-act
  - Subsumption
  - Layers

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An agent

[Wooldridge, Reasoning about Rational Agents, MIT Press, 2000]

- Agents are active, purposeful originators of action. These actions are performed in order to modify and shape the environment inhabited by the agent.
- Our focus: computer systems capable of *independent*, *autonomous action* in order to meet their design objectives or, in other words, capable of *deciding for themselves* what to do in any given situation.

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A rational agent

[Wooldridge, 2000]

An agent is said to be *rational* if it chooses to perform actions that are in its own best interests, given the beliefs it has about the world.

Properties of rational agents:

- Autonomy (they decide);
- Proactiveness (they try to achieve their goals);
- Reactivity (they react to changes in the environment);
- Social ability (they negotiate and cooperate with other agents).

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Agent (Ferber, 1/2)

An agent is a physical or virtual entity

- which is capable of acting in an environment,
- which can communicate directly with other agents,
- which is driven by a set of tendencies (in the form of individual objectives or of a satisfaction/survival function which it tries to optimise),
- which possesses resources of its own,
- which is capable of perceiving its environment (but to a limited extent),

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Agent (Ferber, 2/2)

An agent is a physical or virtual entity

- which has only a partial representation of its environment (and perhaps none at all),
- which possesses skills and can offer services,
- which may be able to reproduce itself,
- whose behaviour tends toward satisfying its objectives, taking into account of the resources and skills available to it and depending on its perception, its representations and the communication it receives.

ROBOT

An active, artificial agent whose environment is the physical world.

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Autonomous robots

Can make decisions on their own.
Why do they need to? Because of the following properties of real environments (cf. Russell and Norvig):

- the real world is inaccessible;
- the real world is nondeterministic;
- the real worl is nonepisodic;
- the real world is dynamic;
- the real world is continuous.

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Applications

Application areas for *autonomous* (possibly intelligent) robots:

- manufacturing;
- transportation;
- hasardous environments;
- telerobotics;
- entertainment;
- ...

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Physical symbol system, 1/2

A *physical symbol system* consists of a set of entities, called symbols, which are physical patterns that can occur as components of another type of entity called *an expression* (or symbol structure).
Thus, a symbol structure is composed of a number of instances (or tokens) of symbols related in some physical way (such as one token being next to another).
At any instant of time the system will contain a collection of these symbol structures.

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Physical symbol system, 2/2

Besides these structures, the system also contains a collection of processes that operate on expressions to produce other expressions: processes of creation, modification, reproduction and destruction.
A physical symbol system is a machine that produces through time an evolving collection of symbol structures.
Such a system exists in a world of objects wider than just these symbolic expressions themselves.

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The physical symbol system hypothesis

A physical symbol system has the necessary and sufficient means for general intelligent action.

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Requirements

- Multiple goals
  - conflicts
  - context-dependent interdependencies
- Multiple sensors
- Robustness
- Extensibility
- Purposefulness
- to cope appropriately and in timely fashion with changes in the dynamic environment

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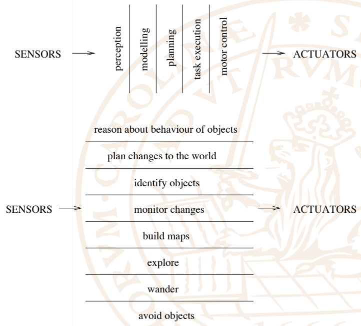
Rodney Brooks, 1985



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Agent architectures

- sense - think - act (serial decomposition, functional decomposition);
- parallel decomposition (e.g. subsumption, more general: behaviour-based control);
- hybrid, mixed, layered.

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Subsumption

- horizontal vs. vertical decomposition
- a system is more than a sum of its parts (emergent intelligence)
- each behaviour can sense the environment and generate a physical action

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Assumptions behind subsumption archite

- complex behavior needs not be a product of complex control system
- things should be simple
- map making is important
- map should be 3D
- map should be relational
- the world does not consist of polyhedra
- sonar data does not lead to rich descriptions of the world
- failure recovery should be quick
- robots should be self-sustaining

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Behavioural decomposition

- Avoid contact with objects
- Wander aimlessly around without hitting things
- “Explore” the world by seeing places in the distance that look reachable and heading for them
- Build a map of the environment and plan routes from one place to another
- Notice changes in the “static” environments
- Reason about the world in terms of identifiable objects and perform tasks related to certain objects
- Formulate and execute plans that involve changing the state of the world in some desirable way
- Reason about the behaviour of objects in the world and modify plans accordingly

Details of the subsumption architecture

Components: modules

Module: Augmented FSM

Communication:

- inhibition
- suppression

An example: ALLEN

The images from the lecture omitted here. They can be found in the original paper of Brooks.

They can also be found in the textbook (Murphy, Introduction to AI Robotics) in Chapter 4.3.

Important lessons

- Conclusion (1987):

  The world should be used as its own model.
- Hypothesis (1987):

  Representation is the wrong unit of abstraction in building the bulkiest part of intelligent systems.

An inventory

Constructed systems:

1. Allen (wanderer)
2. Tom and Jerry (toy cars)
3. Herbert (can picker)
4. Genghis (six legged)
5. Squirt (hiding bug)
6. Toto (map builder - rat)
7. Seymour (visually driven - steady gaze)

Symbol System Hypothesis

Main problems:

- interface between perception and symbols
- inadequacy of symbols
- symbol systems rely on emergent properties (search)

Physical Grounding Hypothesis

- situatedness

  "the world is its own best model"
- embodiment
- intelligence

  "intelligence is determined by the dynamics of interaction with the world"
- emergence

  "intelligence is in the eye of the observer"

Principles of computation

- an asynchronous network of active computational elements with a fixed topology network of unidirectional connections
- messages sent over connections have no implicit semantics
- sensors and actuators are connected to this network

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Consequences

- the system can have state
- no pointers or manipulable data structures
- search spaces must be bounded
- no separation of data and computation

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Observed principles

- no central locus of control
- no functional decomposition
- layering (= increase of competence achieved by adding new behaviors)
- no hierarchical arrangement (Not really! JM)
- behaviors run in parallel
- the world is a good communication medium

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Behavior-based systems

- can make predictions and have expectations
- can make plans
- can have goals
- have no central representation
- have no manipulable representation
- have no symbolic representation

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