CHAPTER 5: REACTIVE AND HYBRID ARCHITECTURES

An Introduction to Multiagent Systems

http://www.csc.liv.ac.uk/~mjw/pubs/imas/
Many problems with symbolic reasoning agents.

The development of reactive architectures has led some researchers to question the viability of the whole paradigm, and to seek alternative approaches.

Reactive Architectures

http://www.csc.liv.ac.uk/~mjw/pubsmomas/
Brooks put forward three theses:

1. Intelligent behaviour can be generated without explicit representations of the kind that symbolic AI proposes.

2. Intelligent behaviour can be generated without explicit abstract reasoning of the kind that symbolic AI proposes.

3. Intelligence is an emergent property of certain complex systems.
He identifies two key ideas that have informed his research:

1. Situatedness and embodiment: "Real" intelligence is situated in the world, not in disembodied systems. Systems such as theorem provers or expert systems are informed by the field of artificial intelligence, not in intelligence research.

2. Intelligence and emergence: "Intelligent" behaviour arises as a result of an agent's interaction with its environment. Also, intelligence is "in the eye of the beholder"; it is not an innate, isolated property.
To illustrate his ideas, Brooks built agents based on his subsumption architecture. A subsumption architecture is a hierarchy of task-accomplishing behaviours. Each behaviour is a simple, rule-like structure. Each behaviour competes with others to exercise control over the agent. Lower layers represent more primitive kinds of behaviour, such as avoiding obstacles, and have precedence over layers further up the hierarchy. An Introduction to Multiagent Systems
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Steels’ Mars explorer system, using the subsumption architecture, achieves near-optimal cooperative performance in simulated rock gathering on Mars. The objective is to explore a distant planet, and it is known that they tend to be clustered. The location of the samples is not known in advance, but it is known that they tend to be clustered. The objective is to collect samples of a precious rock.
• For individual (non-cooperative) agents, the lowest-level behavior, and hence the behavior with the highest "priority" is obstacle avoidance:

if detect an obstacle then change direction.

(1) If carrying samples and at the base then travel up gradient.

(2) If carrying samples and at the base then drop samples.

(3) If carrying samples and not at the base then travel up gradient.

mother-ship:
Agents carrying samples will return to the mother-ship.

Any samples carried by agents are dropped back at the mother-ship.

For individual (non-cooperative) agents, the lowest-level behavior, and hence the behavior with the highest "priority" is obstacle avoidance.
Agents will collect samples they find:

- If detect a sample then pick sample up.

- Agents will collect samples they find:

An agent with "nothing better to do" will explore randomly:

- If true then move randomly.
In the situated automata paradigm, an agent is specified in a rule-like (declarative) language, and this specification is then compiled down to a digital machine, which satisfies the declarative specification. This digital machine can operate in a provable time bound. Reasoning is done off line, at compile time, rather than online at runtime.
The theoretical limitations of the approach are not well understood.

• Compilation (with propositional specifications) is equivalent to an NP-complete problem.

• The more expressive the agent specification language, the harder it is to compile it.

• Compilation (with propositional specifications) is understood.

• The theoretical limitations of the approach are not well understood.
Many researchers have argued that neither a completely deliberative nor completely reactive approach is suitable for building agents. An obvious approach is to build an agent out of two or more subsystems:

- a deliberative one, containing a symbolic world model, which develops plans and makes decisions in the way proposed by symbolic AI; and
- a reactive one, which is capable of reacting to events without complex reasoning.

An obvious approach is to build an agent out of two (or more) subsystems.
Often, thereactive component is given some kind of precedence over the deliberative one.

This kind of structuring leads naturally to the idea of a layered architecture, of which TOURINGMACHINES and INTERRAR are examples.

In such an architecture, an agent’s control subsystems are arranged into a hierarchy, with higher layers dealing with information at increasing levels of abstraction.

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A key problem in such architectures is what kind of control framework to embed the agent’s subsystems. In effect, each layer itself acts like an agent, producing suggestions as to what action to perform. Horizontally, layers are each directly connected to the sensory input and action output. Vertically, sensory input and action output are each dealt with by at most one layer each.

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(a) Horizontal Layering

(b) Vertical Layering

(c) Vertical Layering

(d) One-pass control

(e) Two-pass control

Layer 1
Layer 2
...
Layer n

Layer 1
Layer 2
...
Layer n

Input
Perceptual
Action
Output

Input
Perceptual
Action
Output

Input
Perceptual
Action
Output

Input
Perceptual
Action
Output

Layer 1
Layer 2
...
Layer n

Input
Perceptual
Action
Output

Layer 1
Layer 2
...
Layer n

Input
Perceptual
Action
Output

Layer 1
Layer 2
...
Layer n

Input
Perceptual
Action
Output

Layer 1
Layer 2
...
Layer n

Input
Perceptual
Action
Output

http://www.csc.liv.ac.uk/~mjw/pubs/imas/13
The Touring Machines architecture consists of perception and action subsystems, which interface directly with the agent's environment, and three control layers, embedded in a control framework, which mediates between the layers.
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• The reactive layer is implemented as a set of situation-action rules, à la subsumption architecture.

Example:

rule-1: kerb-avoidance
if is-in-front(Kerb, Observer) and speed(Observer) > KerbThreshHold and separation(Kerb, Observer) > KerbThreshold and ɪs-ɪn-ɪ-front(ɪnfront, Observer) and
then change-orientation(KerbAvoidanceAngle)
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- The modeling layer contains symbolic representations of the 'cognitive state' of other entities in the agent's environment.

- The three layers communicate with each other and are embedded in a control framework, which use control rules. Example:

  ```
  censor-rule-1:
  if entity(obstacle-6) in perception-buffer
  then
    remove-sensory-record(layer-R, entity(obstacle-6))

  censor-rule-2:
  if entity(obstacle-6) in perception-buffer
  then
    remove-sensory-record(layer-R, entity(obstacle-6))
  ```

- The modeling layer contains symbolic representations of the 'cognitive state' of other entities in the agent's environment.

- The control rules are embedded in a control framework, which use control rules.