Reactive and Hybrid Agents

José M Vidal

Department of Computer Science and Engineering
University of South Carolina

September 2, 2005

Abstract

We summarize [Wooldridge, 2002, Chapter 5].
Deduction is slow.
Deduction is slow.
Deduction is complicated.
Deduction is slow.

Deduction is complicated.

Maybe, rationality requires an environment!
Deduction is slow.

Deduction is complicated.

Maybe, rationality requires an environment!

Maybe, intelligent behavior emerges from the interaction of simple behaviors [Minsky, 1988].
Deduction is slow.
Deduction is complicated.
Maybe, rationality requires an environment!
Maybe, intelligent behavior emerges from the interaction of simple behaviors [Minsky, 1988].
These trends gave rise to behavioral, situated, reactive agent architectures.
The Subsumption Architecture

- Proposed by Brooks in [Brooks, 1986]: for robots.
- Extended it into a new view of AI, [Brooks, 1991a, Brooks, 1991b]. Key ideas:
  - Intelligent behavior does not require explicit representations.
  - Intelligent behavior does not require abstract (symbolic) reasoning.
  - Intelligence is an emergent property of certain complex systems.

Rodney A. Brooks
Subsumption Basic Ideas

- **Situatedness and embodiment** - an agent sits in a world and has a body.

- **Emergent Intelligence** - an agent’s intelligence arises out of its interactions with the environment and is “in the eye of the beholder.”

- All these ideas are embodied in the **subsumption architecture**.
The agent has a set of behaviors which are purely reactive (action: $S \rightarrow A$).
Subsumption Implementation

- The agent has a set of **behaviors** which are purely reactive (action: \( S \rightarrow A \)).
- Many of them can fire at the same time.
Subsumption Implementation

- The agent has a set of behaviors which are purely reactive (action: $S \rightarrow A$).
- Many of them can fire at the same time.
- We choose an action using the subsumption hierarchy.
Subsumption Implementation

- The agent has a set of behaviors which are purely reactive (action: $S \rightarrow A$).
- Many of them can fire at the same time.
- We choose an action using the subsumption hierarchy.
- Behaviors are arranged into layers, so that lower layers inhibit higher one. The lower layers have the higher priority.
The agent has a set of behaviors which are purely reactive (action: \( S \rightarrow A \)).

Many of them can fire at the same time.

We choose an action using the subsumption hierarchy.

Behaviors are arranged into layers, so that lower layers inhibit higher one. The lower layers have the higher priority.

Formally,
Subsumption Implementation

- The agent has a set of behaviors which are purely reactive (action: $S \rightarrow A$).
- Many of them can fire at the same time.
- We choose an action using the subsumption hierarchy.
- Behaviors are arranged into layers, so that lower layers inhibit higher one. The lower layers have the higher priority.
- Formally,
  - a behavior $b$ is a pair $(c, a)$
The agent has a set of behaviors which are purely reactive (action: \( S \rightarrow A \)).

Many of them can fire at the same time.

We choose an action using the subsumption hierarchy.

Behaviors are arranged into layers, so that lower layers inhibit higher one. The lower layers have the higher priority.

Formally,

- a behavior \( b \) is a pair \((c, a)\)
- \( c \subseteq P \). \( P \) is the set of perceptions.
The agent has a set of behaviors which are purely reactive (action: \( S \rightarrow A \)).

Many of them can fire at the same time.

We choose an action using the subsumption hierarchy.

Behaviors are arranged into layers, so that lower layers inhibit higher one. The lower layers have the higher priority.

Formally,

- a behavior \( b \) is a pair \((c, a)\)
- \( c \subseteq P \). \( P \) is the set of perceptions.
- \( a \in A \). \( A \) is the set of actions.
The agent has a set of behaviors which are purely reactive (action: $S \rightarrow A$).

Many of them can fire at the same time.

We choose an action using the subsumption hierarchy.

Behaviors are arranged into layers, so that lower layers inhibit higher one. The lower layers have the higher priority.

Formally,

- a behavior $b$ is a pair $(c, a)$
- $c \subseteq P$. $P$ is the set of perceptions.
- $a \in A$. $A$ is the set of actions.

We call $c$ the condition and $a$ the action parts.
The agent has a set of behaviors which are purely reactive (action: \( S \to A \)).

Many of them can fire at the same time.

We choose an action using the subsumption hierarchy.

Behaviors are arranged into layers, so that lower layers inhibit higher one. The lower layers have the higher priority.

Formally,

- a behavior \( b \) is a pair \((c, a)\)
- \( c \subseteq P \). \( P \) is the set of perceptions.
- \( a \in A \). \( A \) is the set of actions.

We call \( c \) the condition and \( a \) the action parts.

We define the inhibition relation \( \prec \), and say \( b_1 \prec b_2 \) when we mean that \( b_1 \) inhibits \( b_2 \).
function action(p:P) : A
var fired
var selected
begin
    fired ← \{(c,a) | (c,a) \in R \land p \in c\}
    for each (c,a) \in fired do
        if \neg \exists (c',a') \in fired such that (c',a') \prec (c,a) then
            return a
        end-if
    end-for
    return null
end
Steels’ Mars Exploration Problem.

The objective is to explore a distant planet, and in particular, to collect sample of a precious rock. The location of the samples is not known in advance, but it is known that they tend to be clustered.

- There is a gradient field that emanates from the mother ship.
- Agents carry radioactive crumbs which they can drop or pick up.
- What are the rules?
Solution

1. If detect an obstacle then change direction.
2. If carrying samples and at the base then drop samples.
3. If carrying samples and not at the base then travel up gradient.
4. If detect a sample then pick sample up.
5. If true then move randomly.

1 ≺ 2 ≺ 3 ≺ 4 ≺ 5

OK, that works, but what if the samples are located in clusters?
Another Solution

1. If carrying samples and at the base then drop samples.
2. If carrying samples and not at the base then drop 2 crumbs and travel up gradient.
3. If sense crumbs then pick up 1 crumb and travel down gradient.

- $1 \prec 6 \prec 7 \prec 4 \prec 8 \prec 5$
- See the Ants models in netlogo.
Limitations

- Agents must have enough information in local environment to determine which action to take.
- How to take into account old or non-local information?
- How do reactive agents learn?
- Emergence (between agent and environment) is hard to engineer. We don’t have a methodology.
- It is very hard to build agents that have many behaviors.
Agents must have enough information in local environment to determine which action to take.

How to take into account old or non-local information?

How do reactive agents learn?

Emergence (between agent and environment) is hard to engineer. We don’t have a methodology.

It is very hard to build agents that have many behaviors.

On the plus side, it has been a very successful method for building robots, such as Roomba.
Hybrid Agents

- **In horizontal layering** all layers are connected to the inputs and output. At the end, a mediator is needed to determine which action to take.

- **In vertical layering one-pass** the input is connected to one layer, which is connected to the next, and so on until the last layer is connected to the output. Partial results are passed between them. Their functioning resembles that of a corporation.

- **In vertical layering two-pass** the message bounces off the last layer.
Touring Machines

Control subsystem

Perception subsystem

Modeling layer

Planning layer

Reactive layer

Control subsystem

Action subsystem
InterRRaP

- Cooperation Layer
- Plan Layer
- Behavior Layer
- World Interface
- Perceptual Input
- Social Knowledge
- Planning Knowledge
- Behavior Patterns
- World Model
- Action Input

- Employs bottom-up activation and top-down execution.

