# Reactive and Hybrid Agents

Based on “An Introduction to MultiAgent Systems” and slides by Michael Wooldridge

# The Subsumption (Reactive) Architecture

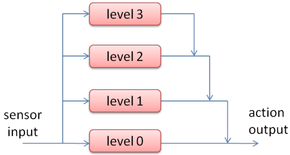
- Problems with symbolic/logical approaches (transduction, computational complexity) resulted in the reactive paradigm
- The best-known reactive agent architecture based on the following theses
  - Intelligent behavior can be generated without **explicit representations**
  - Intelligent behavior can be generated without **explicit abstract reasoning**
  - Intelligence is an **emergent property** of certain complex systems

# Characteristics of the Subsumption Architecture

1. An agent's decision making is realized through a set of *task-accomplishing* behaviors
   1. Each behavior can be seen as an individual selection function, which continually maps perceptual input to an action to perform
   2. Behaviors (behavior modules) are implemented as finite-state machines/rules and include no complex symbolic representation (situation $\rightarrow$ action rules)
2. Many behaviors can fire simultaneously
   1. Modules are arranged into a *subsumption hierarchy*, with the behaviors arranged into *layers*
   2. Lower layers in the hierarchy can *inhibit* higher layers (the lower a layer is, the higher is its priority)

# Action Selection in Layered Architectures

- Raw sensor input is not processed or transformed much
- Action selection is realized through a set of behaviors together with an inhibition relation
- We write $b_1 \prec b_2$, and read this as '$b_1$ inhibits $b_2$' – $b_1$ is lower in the hierarchy than $b_2$, and will hence get priority over $b_2$



# Mars Explorer

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. A number of autonomous vehicles are available that can drive around the planet collecting samples and later re-enter a mother ship spacecraft to go back to Earth. There is no detailed map of the planet, though it is known that the terrain is full of obstacles which prevent vehicles from exchanging any communication

# Mechanisms used in the Explorer

1. A gradient field
   - The mother ship generates a radio signal so that agents can know in which direction the mother ship lies
   - An agent needs to travel 'up the gradient' of signal strength
   - The signal need not carry any information

# Individual Behaviors

- $b_0$: **if** detect an obstacle **then** change direction
- $b_1$: **if** carrying a sample **and** at the base **then** drop sample
- $b_2$: **if** carrying a sample **and not** at the base **then** travel up gradient
- $b_3$: **if** detect a sample **and not** at the base **then** pick up sample
- $b_4$: **if** true **then** move randomly

The above behaviors are arranged into the hierarchy:
$b_0 \prec b_1 \prec b_2 \prec b_3 \prec b_4$

# Limitations of Reactive Agents

1. If agents do not employ models of their environment, then they must have sufficient information available in their *local* environment to determine an acceptable action
2. It is difficult to see how decision-making could take into account *non-local* information (a 'shot-term' view)
3. The relationship between individual behaviors, environment and overall behavior is not understandable. It is difficult to engineer agents for specific tasks and there is no methodology for building such agents
4. It is difficult to build agents that contain many layers ($> 10$) due to dynamics and complexity of interactions between the different behaviors

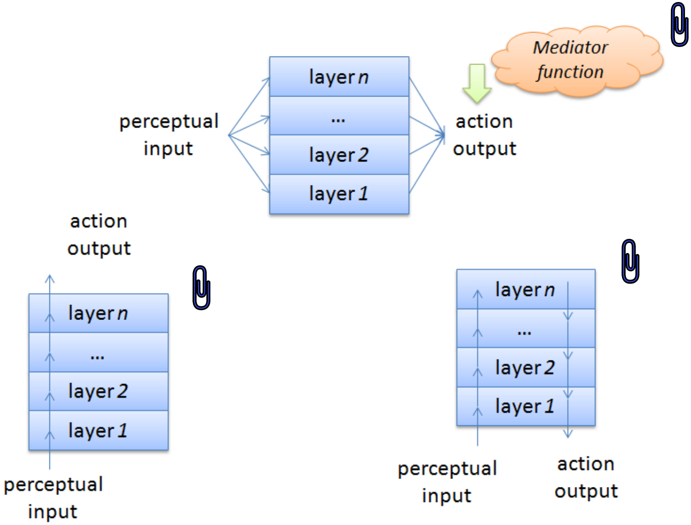
# Hybrid Agents

- It is claimed that neither a completely deliberative (pro-active) 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
  - a ***reactive*** one, which is capable of reacting to events without complex reasoning
- Subsystems are arranged into hierarchy of interacting *layers* ($\rightarrow$ layered architectures)

# Types of Layered Architectures

- Horizontal layering
  Layers are each directly connected to the sensory input and action output. In effect, each layer itself acts like an agent, producing suggestions as to what action to perform
- Vertical layering
  Sensory input and action output are each dealt with by at most one layer each

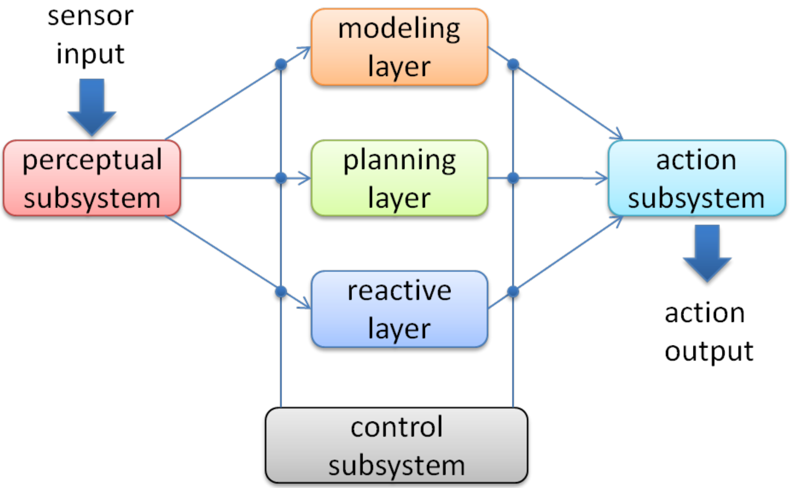
# Types of Layered Architectures



# TouringMachines

- TouringMachines consists of three horizontal activity-producing layers
- Each layer continually produces suggestions for what actions the agent should perform
- Demonstration scenario – autonomous vehicles driving between locations through streets populated by other similar agents

# Architecture of TouringMachines



# Layers in TouringMachines

- Reactive layer
  - provides immediate response to changes that occur in the environment
  - implemented as a set of situation-action rules, similarly to subsumption architecture

# Layers in TouringMachines

- Planning layer
  - achieves the agent's proactive behavior ('day-to-day' running of the agent)
  - constructs plans employing a library of 'skeletons' called *schemas* (hierarchically structured plans)
  - elaborates at run-time in order to decide which plan to follow
- Modeling layer
  - represents various entities in the world (including the agent itself)
  - predicts conflicts between agents and generates new goals to resolve these conflicts
  - these goals are posted down to the planning layer

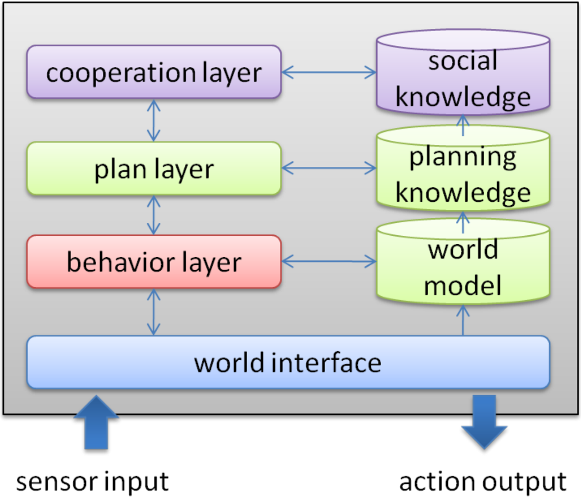
# Control Subsystem in TouringMachines

- It is effectively responsible for deciding which of the layers should take control over the agent
- It is implemented as a set of control rules
- Control rules can either suppress sensor information, or censor action outputs from the control layers

# InteRRaP

- InterRRaP uses a vertically layered two-pass architecture
- It contains three layers
  - *behavior-based* layer deals with reactive behavior
  - *local planning* layer deals with everyday planning to achieve the agent's goals
  - *cooperative planning* layer deals with social interactions
- Each layer has an associated *knowledge base* (i.e., representation of the world appropriate for this layer) – from 'raw' information to complex models

# InterRRaP Architecture



# Layer Interactions in InterRRaP

- Bottom-up activation
  a lower layer passes control to a higher layer because it is not competent to deal with the current situation
- Top-down execution
  a higher layer makes use of the facilities provided by a lower layer to achieve it goals
- The basic flow of control begins when perceptual input arrives at the lowest layer, and control may flow to higher layers, and then back again