AUTONOMUS AGENTS AND MULTI-AGENT SYSTEMS
AGENT ARCHITECTURES

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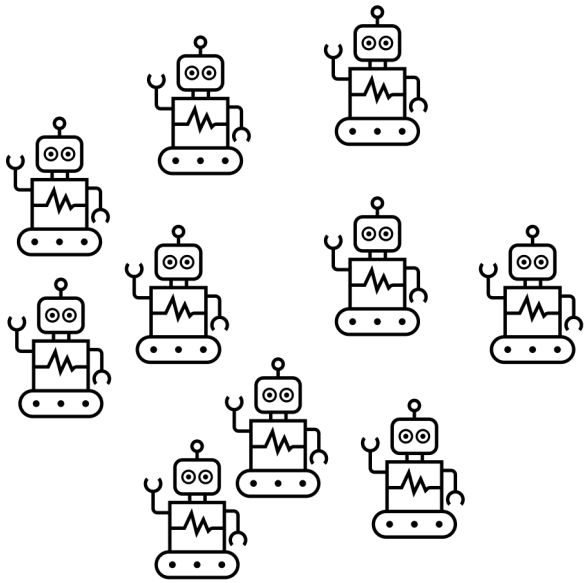
THE GOAL FOR TODAY



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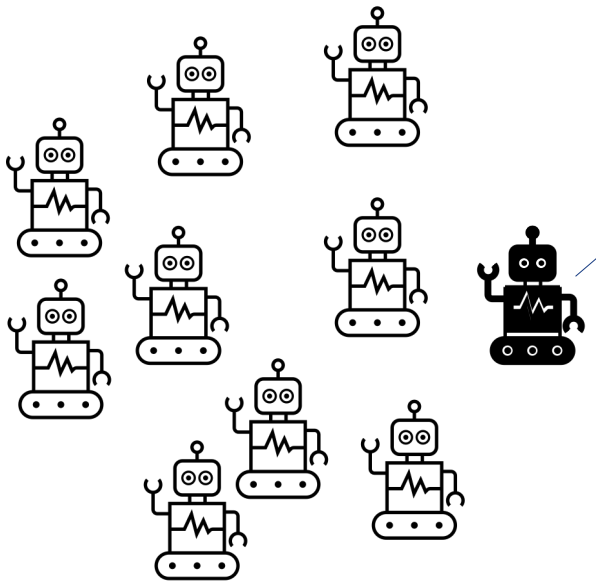

How do we build an agent?

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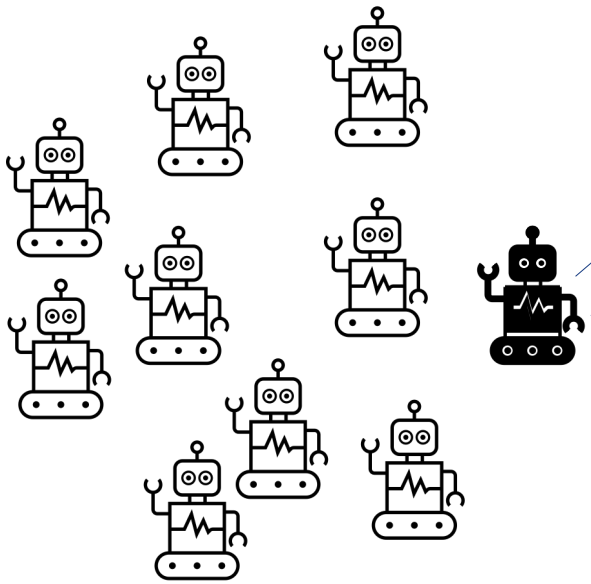

How do we build an agent?

How does an agent decide what to do?

AGENT ARCHITECTURES

> a particular methodology for building [agents]. It specifies how ... the agent can be decomposed into the construction of a set of component modules and how these modules should be made to interact. The total set of modules and their interactions has to provide an answer to the question of how the sensor data and the current internal state of the agent determine the actions ... and future internal state of the agent. An architecture encompasses techniques and algorithms that support this methodology.
>
> Maes, 1991

AGENT ARCHITECTURES

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> Maes, 1991

AUTONOMOUS AGENT

What can this be?
Not only physical environments!

"An *agent* is a computer system that is *situated* in some *environment*, and that is capable of *autonomous action* in this environment in order to meet its delegated objectives."

- Michael Wooldridge

What does this really mean?

AUTONOMOUS AGENT

Not necessarily a physical environment!

"An *agent* is a computer system that is *situated* in some *environment*, and that is capable of *autonomous action* in this environment in order to meet its ~~delegated~~ objectives."

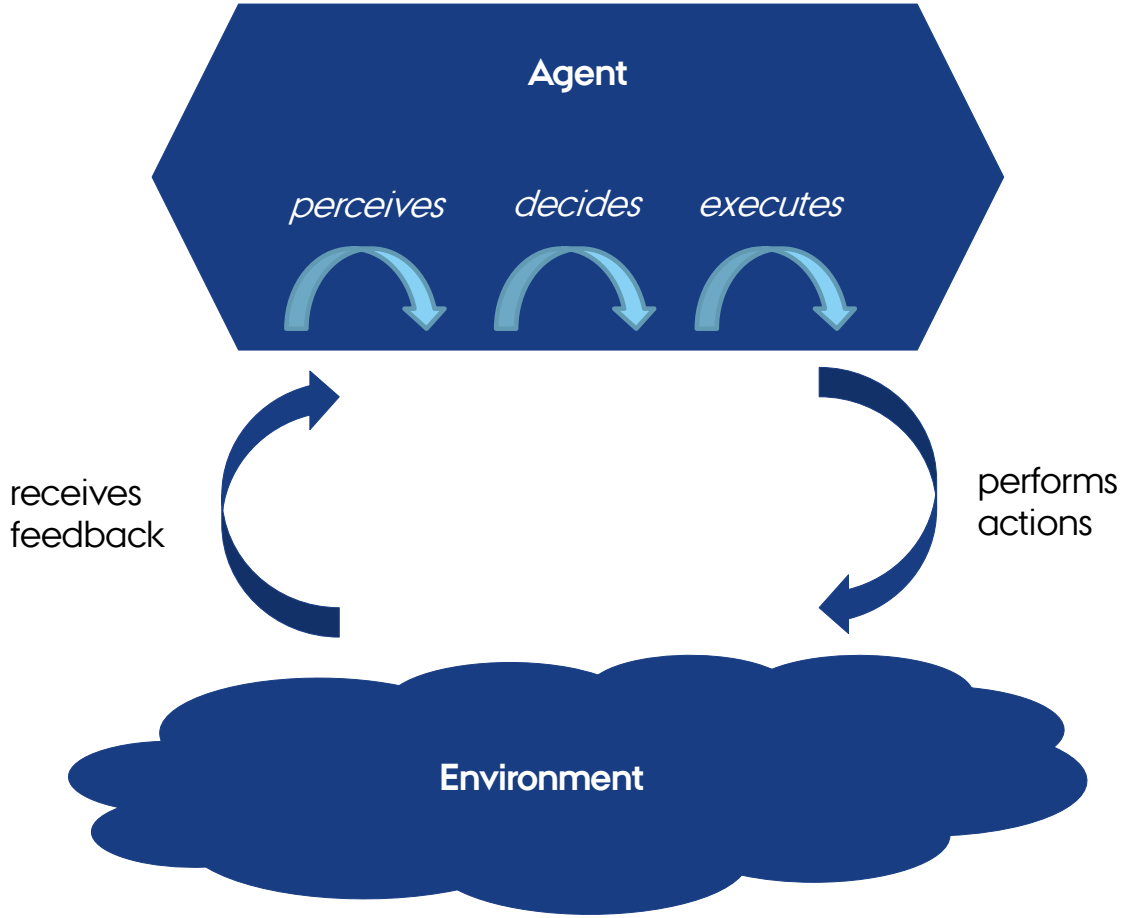
defined

- Michael Wooldridge

What does this really mean?
Where does *autonomy* start?

Externally defined?
By human operator?
Self-defined?

AUTONOMOUS AGENT



ENVIRONMENTAL PROPERTIES

- **Accessible vs inaccessible**

  Accessible → complete, accurate, up-to-date information about everything

- **Deterministic vs non-deterministic**

  Deterministic → each action has one guaranteed effect – no uncertainty

- **Static vs dynamic**

  Static → only the actions of the agent change the environment

- **Discrete vs continuous**

  Discrete → fixed, finite number of actions, and effects (percepts)

TYPES OF BEHAVIOR

- **Reactive behaviour**: Agents perceive and respond to their environment in timely fashion to satisfy their design objectives.
- **Proactive behaviour**: Agents operate towards their goal on their own initiative.
- **Social behaviour**: Agents can interact with other agents (including humans) to achieve their design objectives.

TYPES OF AGENTS

- Reactive Agents
- Practical Reasoning Agents
- Deductive Reasoning Agents

Simple implementation

Little to no knowledge

Complex implementation

Extensive knowledge

DEDUCTIVE REASONING AGENTS

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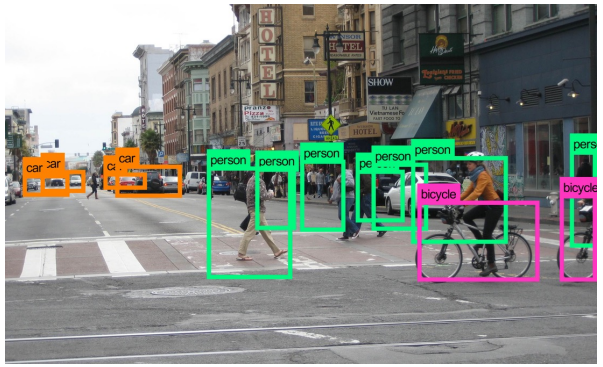
SYMBOLIC AI

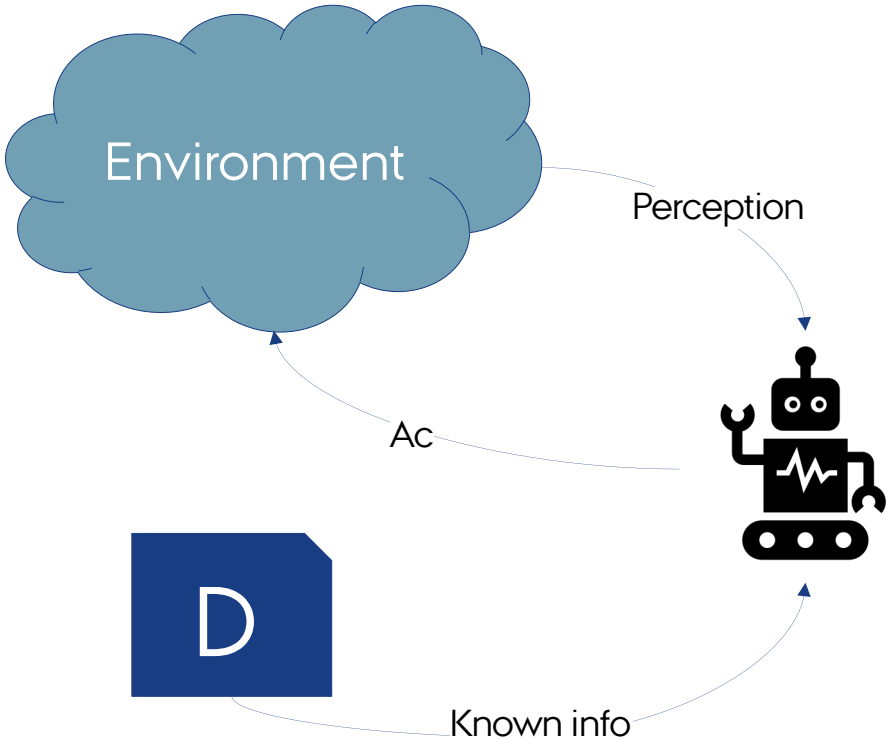
- 2 main problems
  - Transduction
  - Representation & Reasoning

SYMBOLIC AI



- 2 main problems
  - Transduction (**vision, learning, speech understanding**...)
  - Representation & Reasoning (**knowledge representation, automated reasoning and planning**)

SYMBOLIC AI – AGENTS AS THEOREM PROVERS



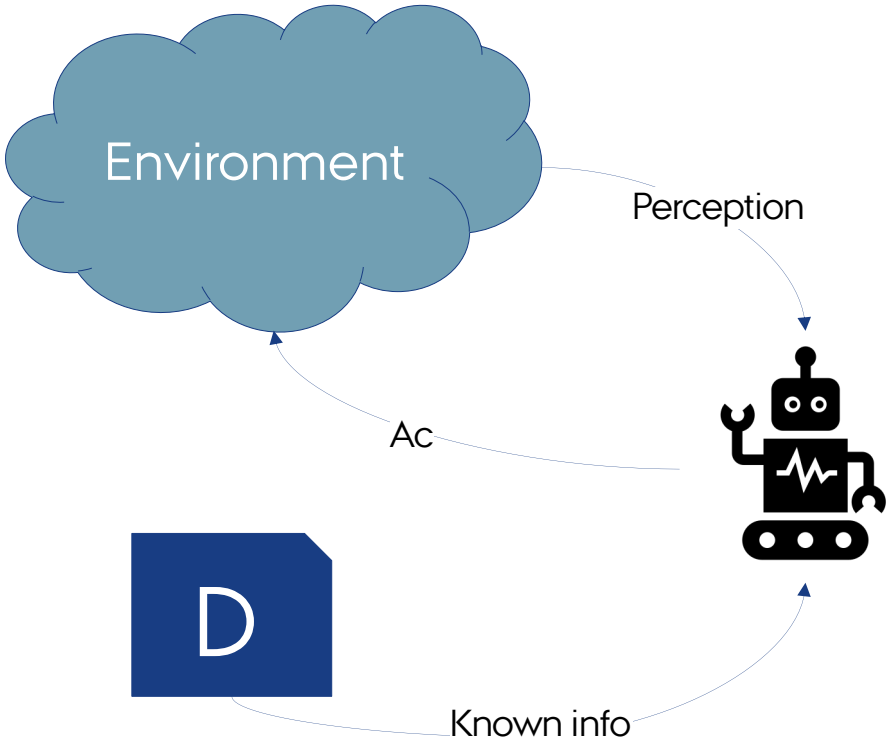
D - set of formulae

P - perception

Ac - action, where

action: D x P → Ac

SYMBOLIC AI – AGENTS AS THEOREM PROVERS



D - set of formulae

P - perception

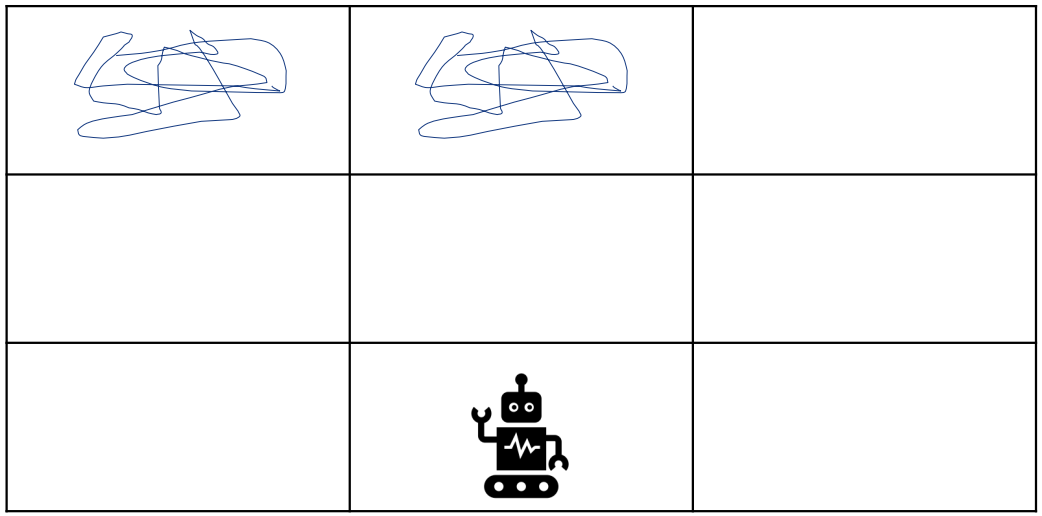
Ac - action, where

action: D x P → Ac

If Ac can be derived, it is executed by the agent.

EXAMPLES - I

THE VACUUM WORLD – CLEANING AGENT

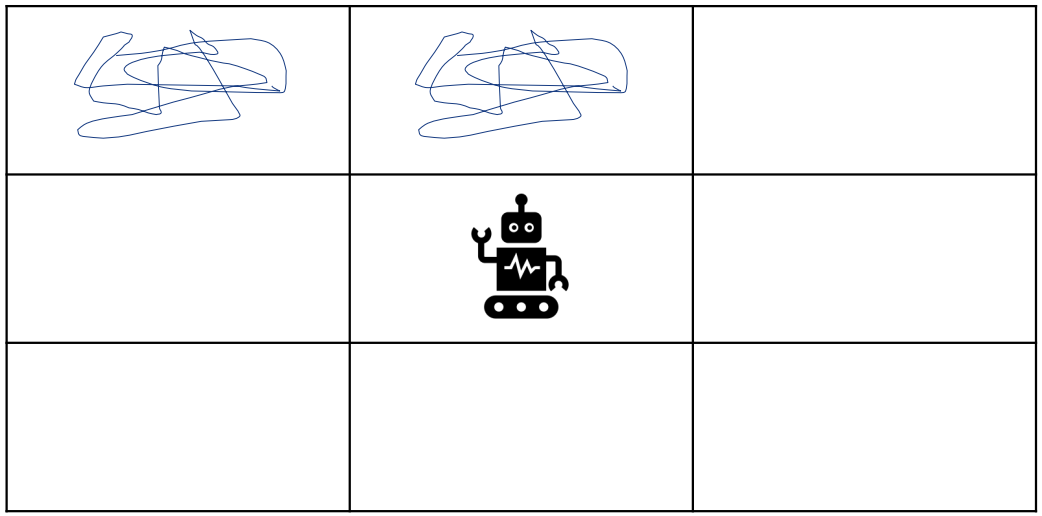


2 actions:

Clean

Explore

THE VACUUM WORLD – CLEANING AGENT



2 actions:

Clean

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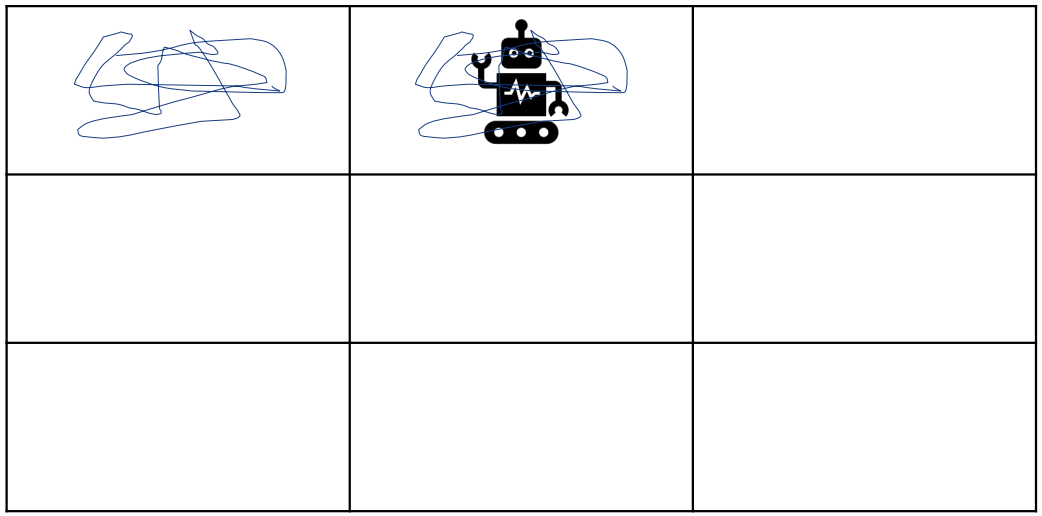
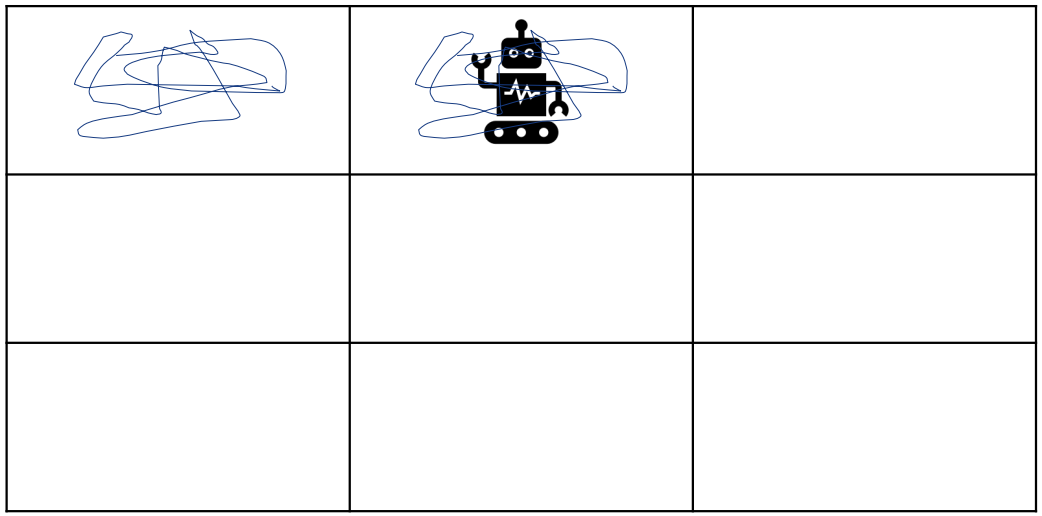


2 actions:

Clean

Explore

THE VACUUM WORLD – CLEANING AGENT



$In(x,y) \wedge Dirt(x,y) \rightarrow Do(clean)$

PRACTICAL REASONING AGENTS

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> Practical reasoning is a matter of weighing conflicting considerations for and against competing options, where the relevant considerations are provided by what the agent desires/values/cares about and what the agent believes.

PRACTICAL REASONING

- What to do: Deliberation

- How to do it: Means-ends reasoning/planning

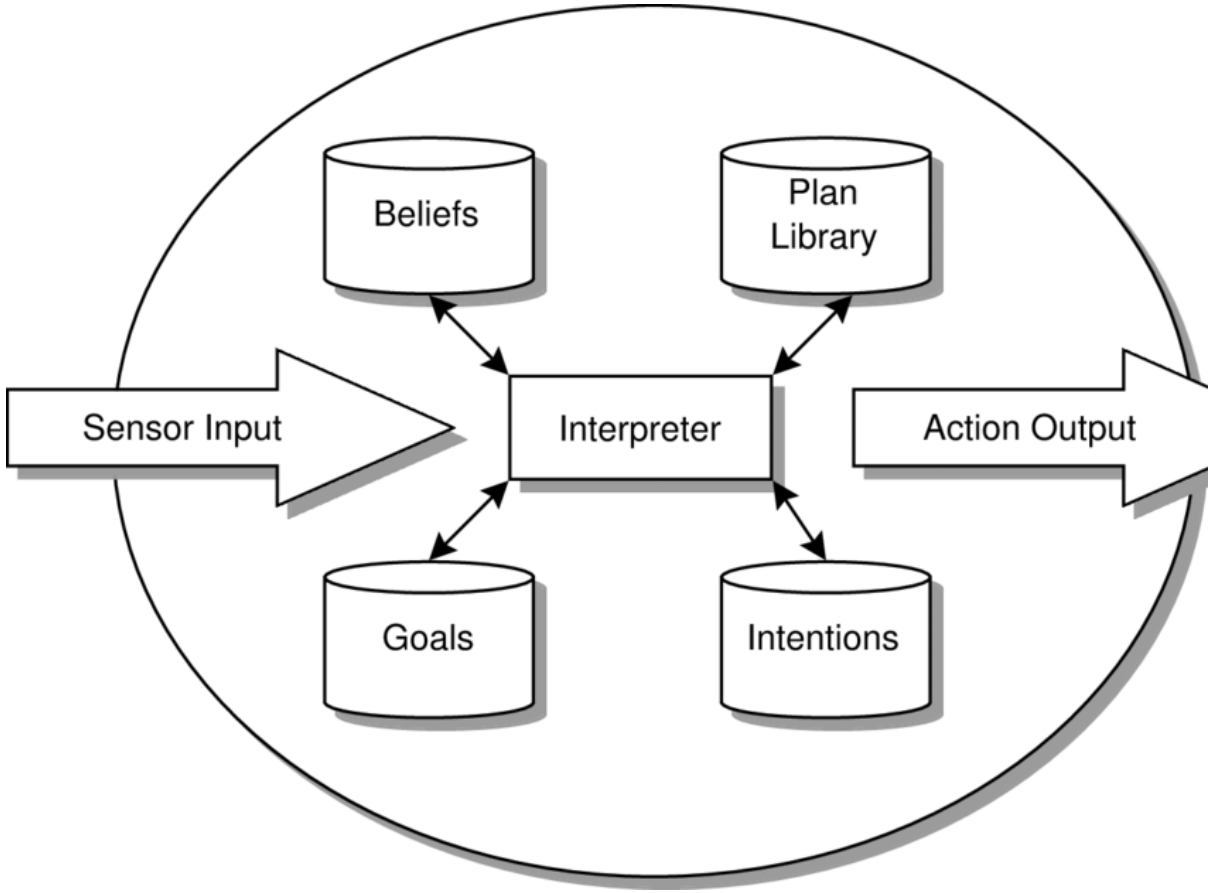
INTENTIONS

- Driver of practical reasoning
- Persistance
- Constrain future deliberation
- Influence beliefs

INTENTIONS CNTD.

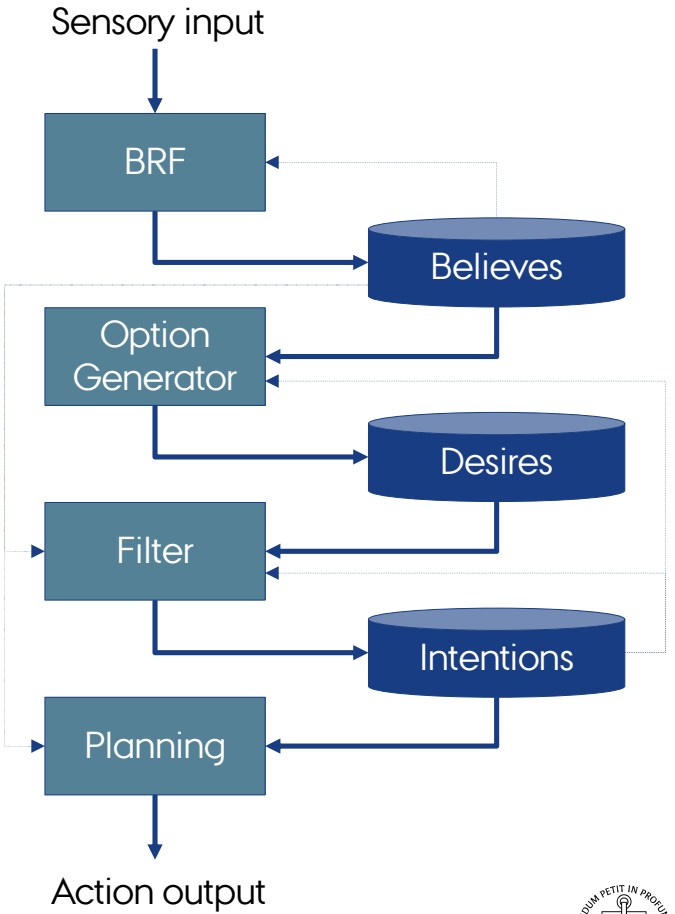
- Intentions vs beliefs
- Intentions vs desires
- Commitments to intentions

BELIEF DESIRE INTENTION: THE BDI ARCHITECTURE



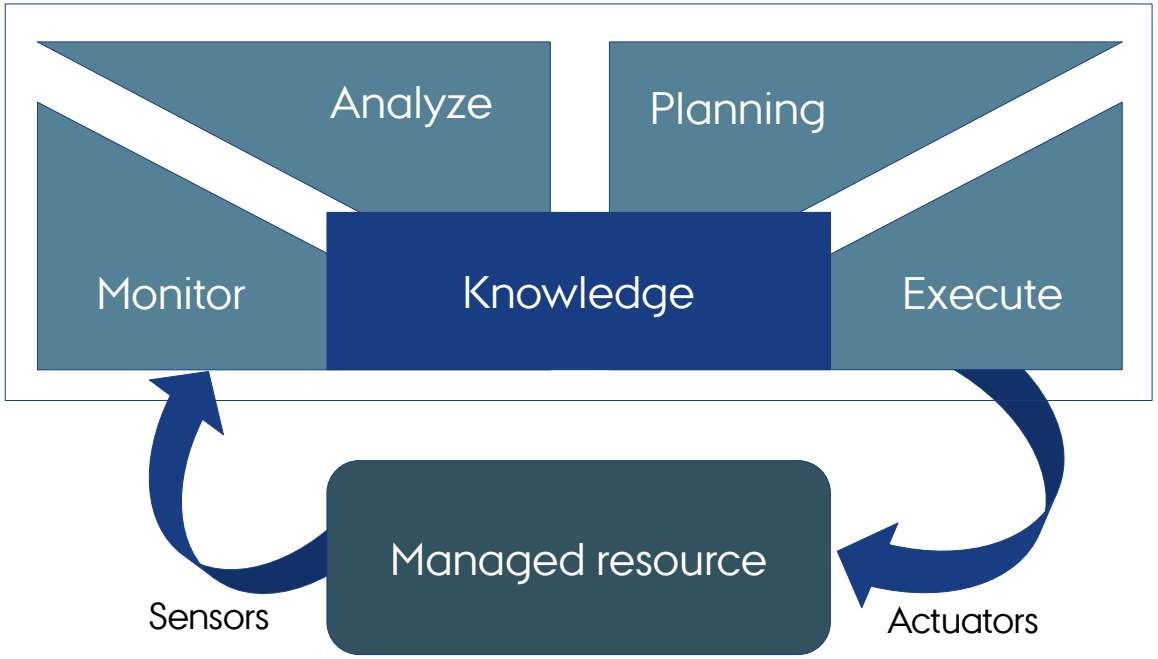
BELIEVES, DESIRES, INTENTIONS

- Belief revision function (BRF): Update beliefs with sensory input and previous belief
- Generate options: Use beliefs and existing intentions to generate a set of alternatives/options (= desires)
- Filtering function: Choose between competing alternatives and commit to their achievement – generate intentions
- Planning function: Given current belief and intentions generate a plan for action
- Action generation: iteratively execute actions in plan sequence



MAPE-K

- **Monitor**: keep record of sensed information
- **Analyze:** process current and previous information of managed resource and environment
- **Planning:** develop plan (set of steps) for next situations
- **Execute:** implement plan by performing actions on the managed resource



Kephart, Jeffrey O., and David M. Chess. "The vision of autonomic computing." *Computer* 36, no. 1 (2003): 41-50.

SELF-AWARE AGENTS - DEFINITION

"Self-aware computing systems are computing systems that:

1. *learn models* capturing *knowledge* about themselves and their environment (such as their structure, design, state, possible actions, and runtime behaviour) on an ongoing basis and
2. *Reason* using the models (e.g. predict, analyse, consider, and plan) enabling them to act based on their knowledge and reasoning (e.g., explore, explain, report, suggest, self-adapt, or impact their environment)

In accordance with *higher-level goals,* which may also be subject to change."

Kounev et al. *The notion of Self-aware Computing,* in Self-Aware Computing Systems, Springer, 2017

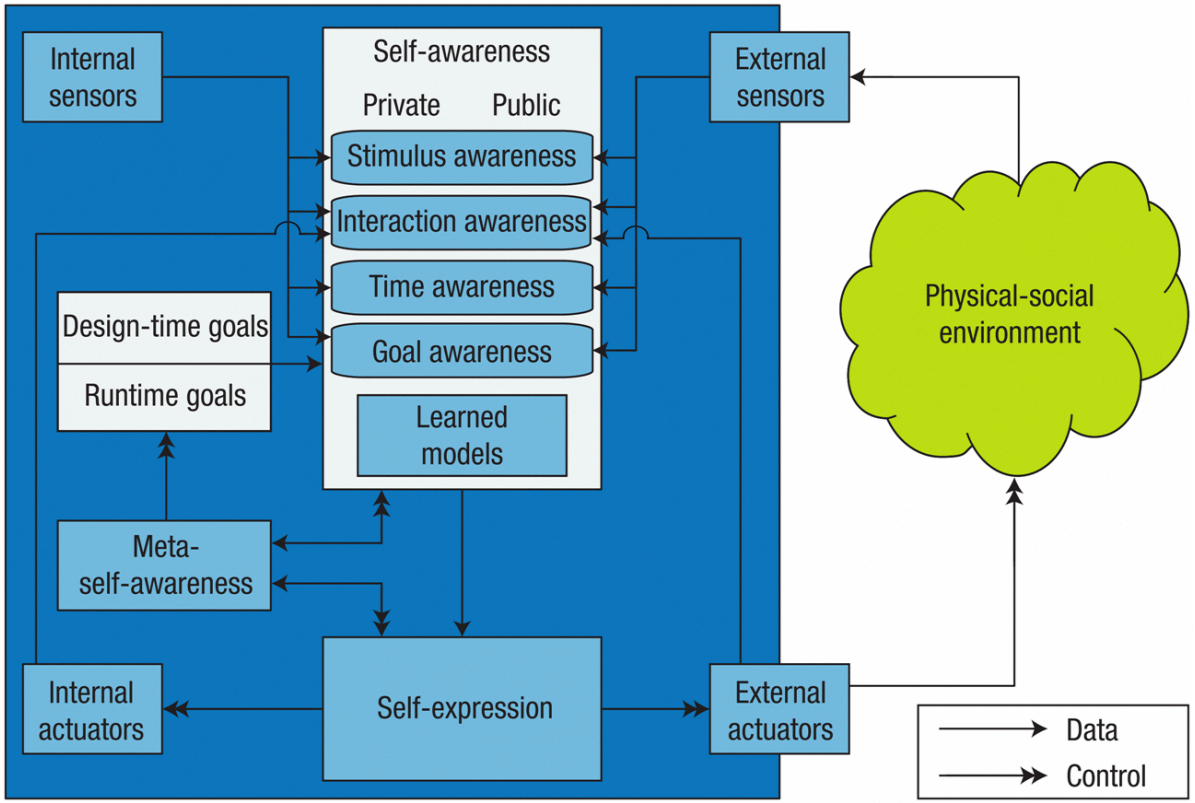
SELF-AWARE AGENTS

Levels of self-awareness

- **Stimulus awareness:** aware of stimuli and to differentiate between them
- **Interaction awareness:** awareness of the different interaction with others
- **Time awareness:** awareness of the passing of time, past and potentially future events
- **Goal awareness:** awareness of own goals and the ability to differentiate between them
- **Meta-self awareness:** awareness of the (other levels of) awareness

Similarity to *context awareness* as discussed for pervasive/ubiquitous systems

SELF-AWARE COMPUTING ARCHTICTURE



Lewis, Platzner, Rinner, Torresen, Yao (eds.) Self-aware Computing Systems: An Engineering Approach, Springer, 2016

EXAMPLES - II

REAL WORLD APPLICATIONS

- Air Traffic Management
- e-Health Applications
- Combat Air Mission Reasoning Control
- Automation of customer service application
- Cloud computing

https://www.ijert.org/research/bdi-applications-and-architectures-IJERTV2IS2173.pdf

REACTIVE AGENTS

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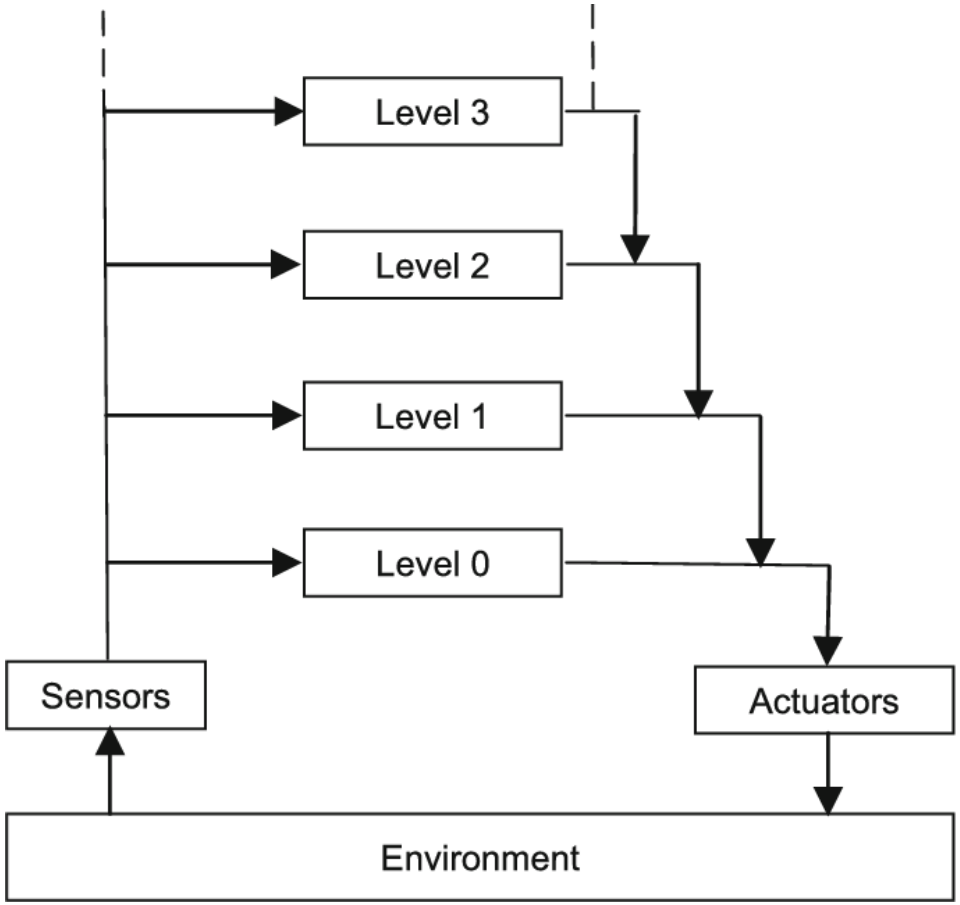
CRITICISM TO SYMBOLIC AI AGENTS

- Rejection of symbolic representation
- Intelligent behaviour is embodied
- Intelligent behaviour from the interaction of simpler behaviours

THE SUBSUMPTION ARCHITECTURE

- Set of task-accomplishing behaviours
- Behaviours can fire simultaneously
- Hierarchy, precedence to lower levels

THE SUBSUMPTION ARCHITECTURE CNTD.



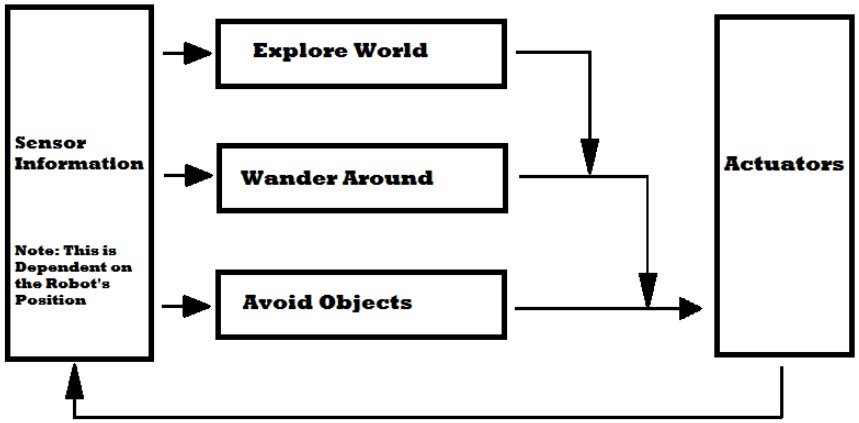
SUBSUMPTION ARCHITECTURE

Reactive agent operating on sensor information

Higher levels subsume lower levels

i.e. avoid objects when wandering around

Lower levels can be tested individually before testing higher levels

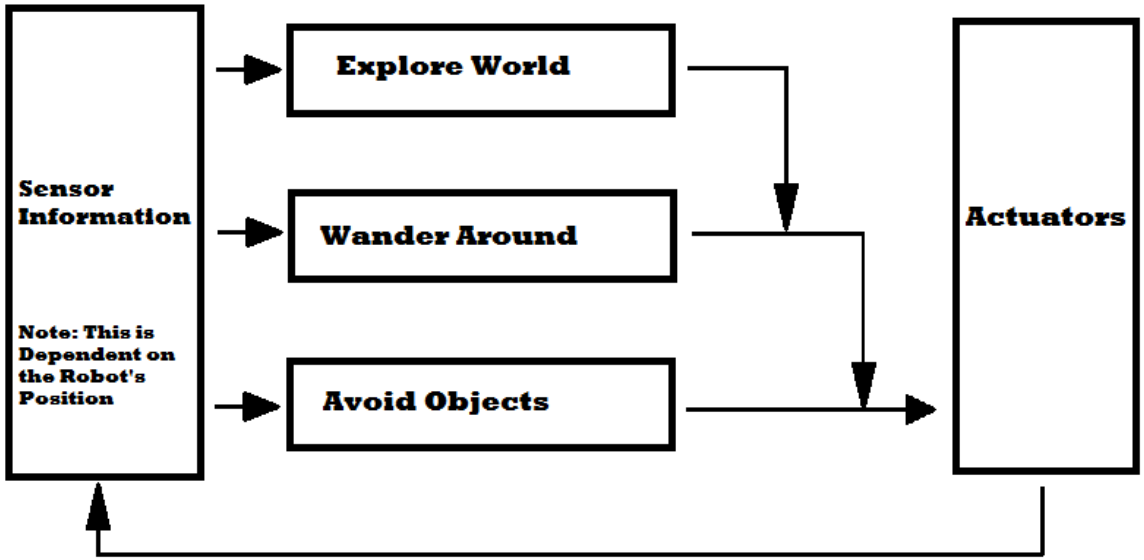


Rodney Brooks, Elephant's don't play chess. *Designing Autonomous Agents: Theory and Practice from Biology to Engineering and Back*. 1990.

Genghis: https://www.youtube.com/watch?v=K2xUHYFcYKI
Herbert: https://www.youtube.com/watch?v=YtNKuwiVYm0

EXAMPLES - III

THE SUBSUMPTION ARCHITECTURE CNTD.



https://www.youtube.com/watch?v=9u0ClQ8P_qk

Genghis: https://www.youtube.com/watch?v=K2xUHYFcYKI

Herbert: https://www.youtube.com/watch?v=YtNKuwiVYm0

LIMITATIONS

- Everything must be present locally
- Hard to understand emergent behaviours
- Complexity of many levels

HYBRID AGENTS

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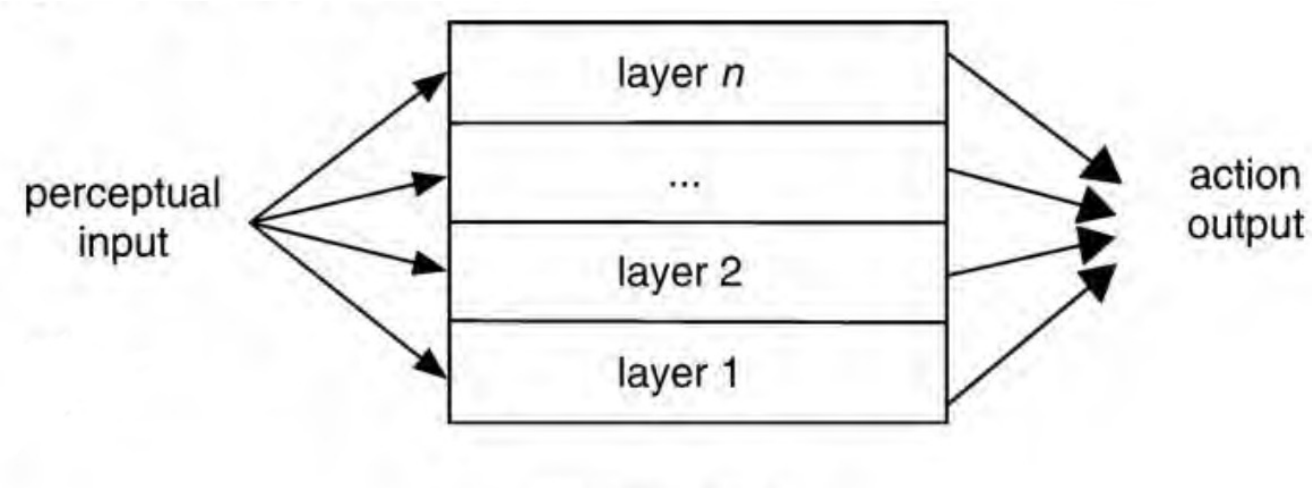
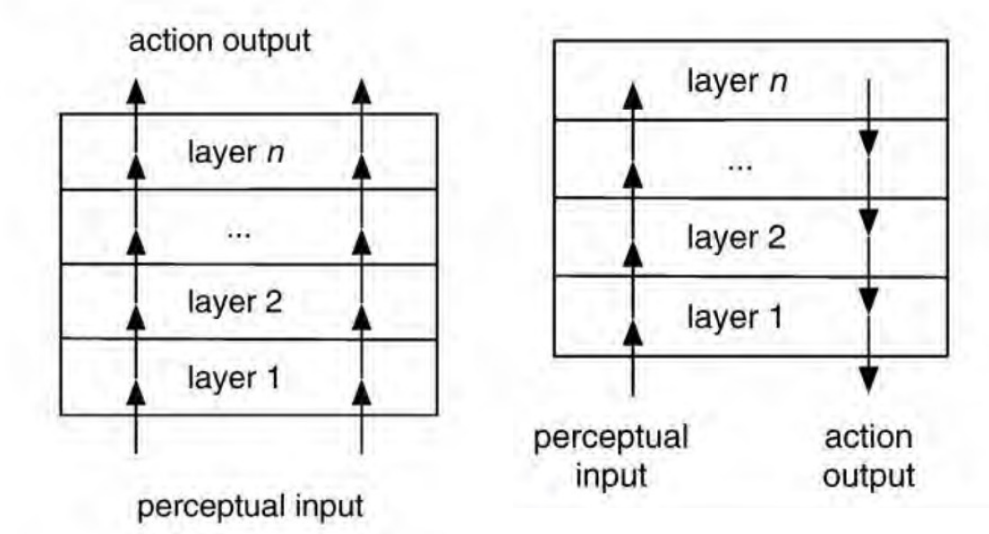
LAYERED ARCHITECTURES

- Horizontal
- Vertical



LAYERED ARCHITECTURES

- Horizontal
- Vertical



LAYERED ARCHITECTURES

- Horizontal
  - Touring agents
- Vertical
  - InterRap

QUESTIONS