Pervasive Computing

Ingegneria e Scienze Informatiche - UNIBO
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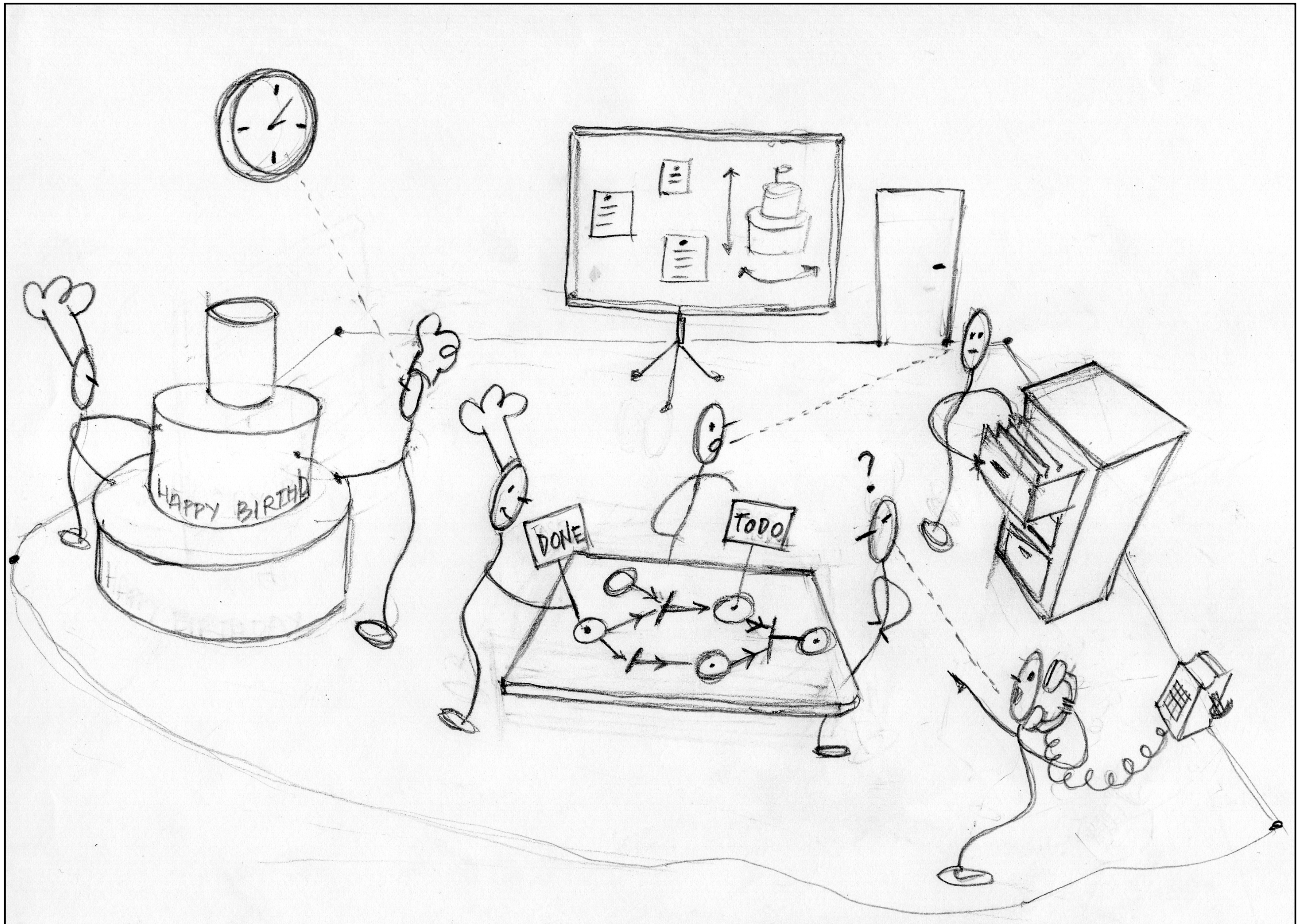
[PART THREE] THEME/ISSUE: AGENTS - BRIEF INTRO

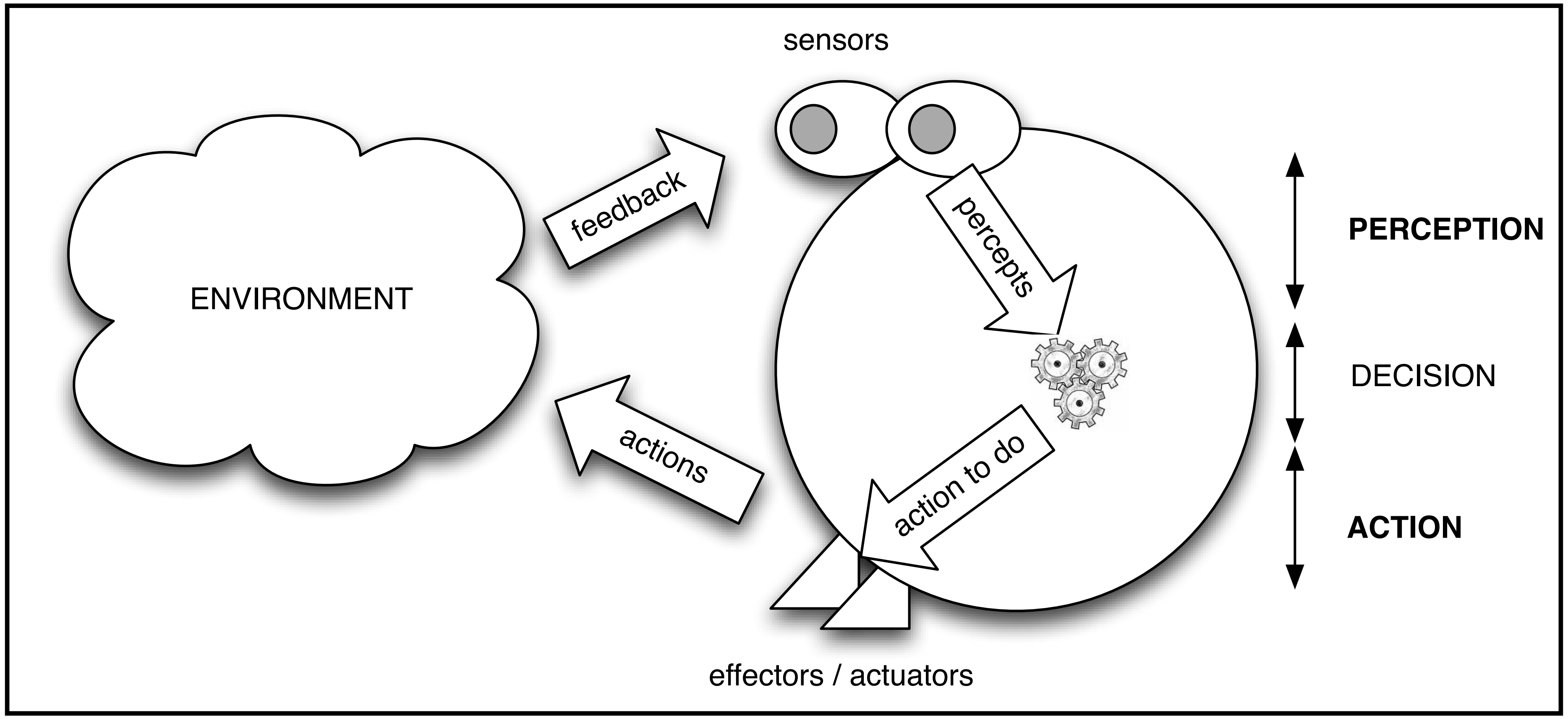
DESIGNING AGENTS' WORLD
- A HUMAN METAPHOR -



THE NOTION OF AGENT

- Agent definition
  - *“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 design objective”* [Wooldridge & Jennings, 1995]
  - *“An agent is anything that can be viewed as perceiving its environment through sensors and acting upon the environment through effectors." [Russell & Norvig, 1995]*
- Including both physical and software (“computational”, ”virtual”) environments

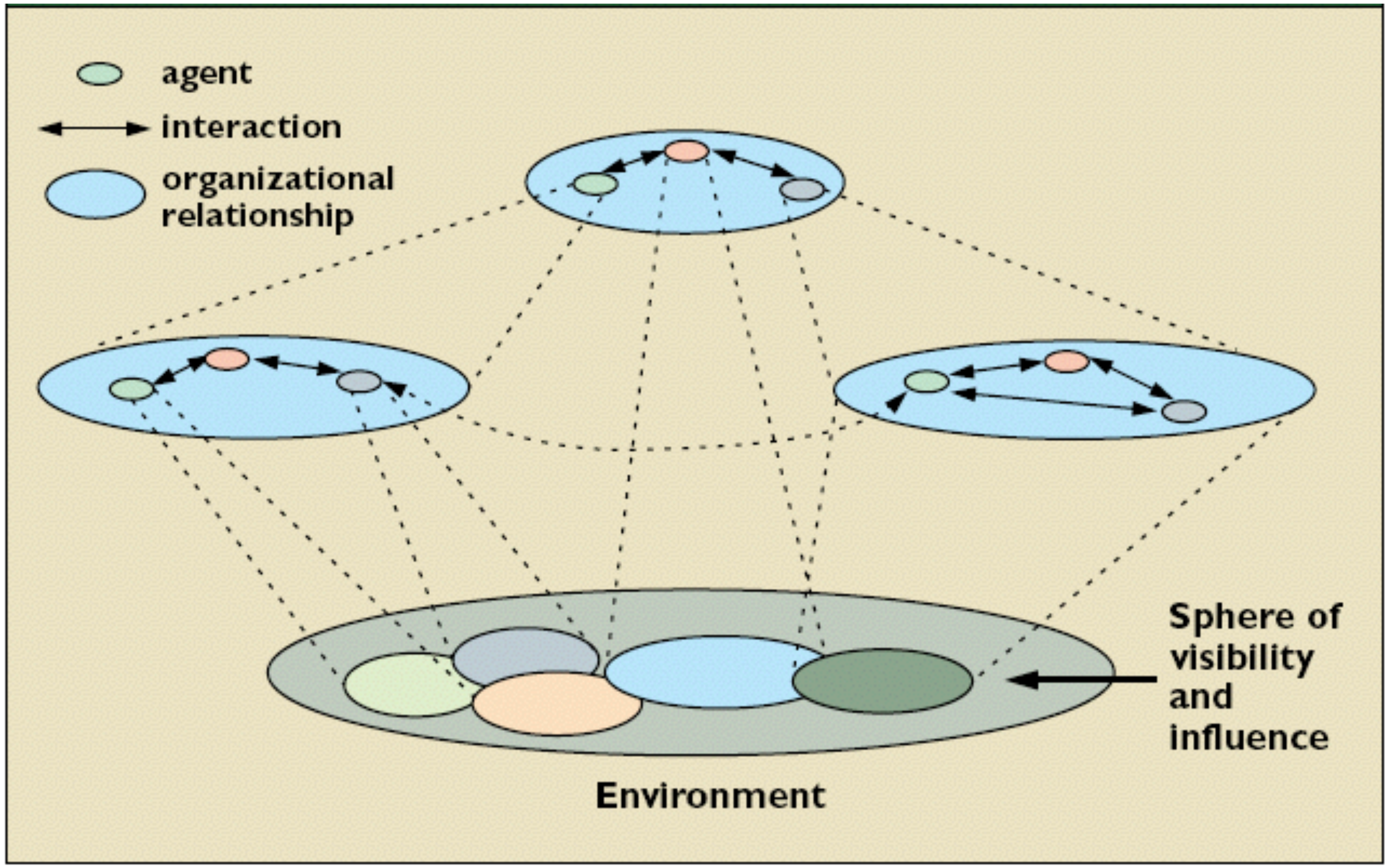
SINGLE-AGENT PERSPECTIVE



[Wooldridge, 2002]

- **Perception**
  - process inside agent inside of attaining awareness or understanding sensory information, creating **percepts**
    - perceived form of external stimuli or their absence
- **Actions**
  - the means to affect (change or inspect) the environment

MULTI-AGENT PERSPECTIVE



[Jennings, 2001]

- In evidence
  - spheres of visibility and influence
  - overlapping => interaction

ABSTRACT "ENVIRONMENT PROGRAM"

```
procedure RUN-ENVIRONMENT(state, UPDATE-FN, agents, termination)
   inputs: state, the initial state of the environment
           UPDATE-FN, function to modify the environment
           agents, a set of agents
           termination, a predicate to test when we are done

   repeat
      for each agent in agents do
         PERCEPT[agent] ← GET-PERCEPT(agent, state)
      end
      for each agent in agents do
         ACTION[agent] ← PROGRAM[agent](PERCEPT[agent])
      end
      state ← UPDATE-FN(actions, agents, state)
   until termination(state)
```

[Russell and Norvig,1993]

A BASIC CLASSIFICATION

- *Accessible* versus *inaccessible*
  - indicates whether the agents have access to the complete state of the environment or not
- *Deterministic* versus *nondeterministic*
  - indicates whether a state change of the environment is uniquely determined by its current state and the actions selected by the agents or not
- *Static* versus *dynamic*
  - indicates whether the environment can change while an agent deliberates or not
- *Discrete* versus *continuous*
  - indicates whether the number of percepts and actions are limited or not

FURTHER CLASSIFICATION

[Ferber, 1999]

- *Centralized* vs. *distributed*
  - **centralized** environment: a single monolithic system
    - all agents have access to the same structure
  - **distributed** environment: as a set of *cells* or *places* assembled in a network
    - the state of a place depends on the surrounding places
    - the perception of agents is related to one or multiple places
    - support for agent mobility, moving from place to place
- *Generalized* vs *specialized*
  - a generalized model is independent of the kind of actions that can be performed by agents
  - a specialized model is characterized by a well-defined set of actions

COMMUNICATIVE & SITUATED MAS

- Purely communicative MAS
  - agents can only communicate by message transfer
- Purely *situated* MAS
  - agents can only act in the environment
- Combination of communicating and situated MAS

AN ABSTRACT MODEL

- Classic model adopted in AI
  - modelling agents interacting with their environments as sequences of interleaved agent actions and environment states as responses
- System definition

$$\langle Ag, Env \rangle$$

  - pair containing an agent and an environment

AGENT DEFINITION

- Agent definition

$$Ag : \mathcal{R}^E \rightarrow Ac$$

  - function mapping runs ending with environment state to actions

- Agent runs $\mathcal{R}$

$$r : e_0 \xrightarrow{\alpha_0} e_1 \xrightarrow{\alpha_1} e_2 \xrightarrow{\alpha_2} e_3 \xrightarrow{\alpha_3} \cdots \xrightarrow{\alpha_{u-1}} e_u.$$

  - sequences of interleaved environment states and agent actions
    - $E = \{e, e', \ldots\}$ is the finite set of the environment states
    - $Act = \{\alpha, \alpha', \ldots\}$ is the finite set of agent actions

ENVIRONMENT DEFINITION

- Environment definition

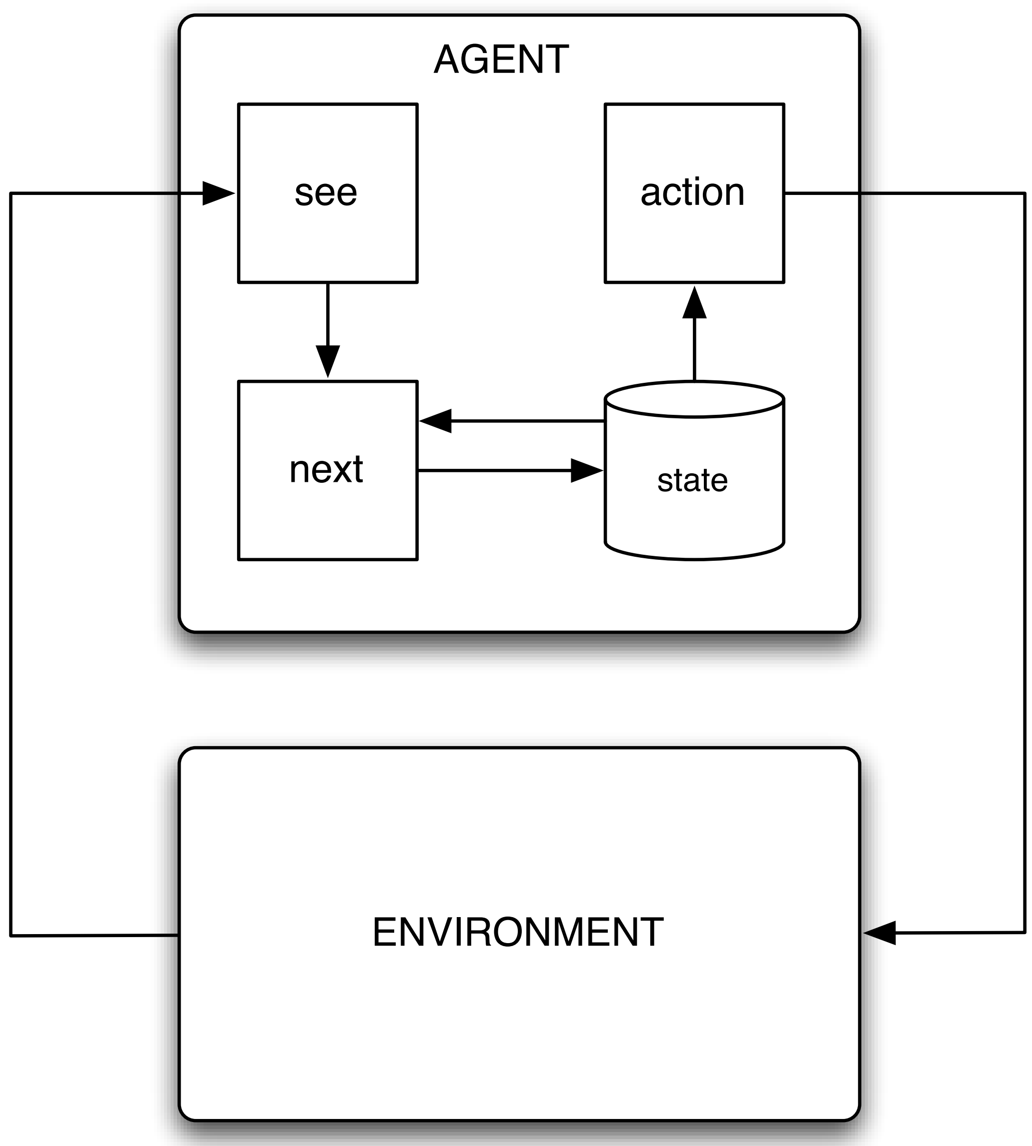
$$Env = \langle E, e_0, \tau \rangle$$

  - E is the set of environment state
  - $e_0 \in E$ is an initial state
  - τ is the state transformer function

$$\tau : \mathcal{R}^{Ac} \to 2^E$$

    - mapping a run to a set of possible environment states
      - those that could result in performing the action
    - modelling the effect of agent's actions on the environment

ACTION AND PERCEPTION IN AGENT ABSTRACT ARCHITECTURE



- Perception function ***see***
  - representing the ability to obtain information from its environment

    $$see : E \rightarrow Per$$

- Action-selection function ***action***
  - mapping from internal states to actions

    $$action : I \rightarrow Ac$$

- Update state ***next*** function
  - mapping an internal state and a percept to an internal state

    $$next : I \times Per \rightarrow I$$

REMARKS ON THE ACTION MODEL

- An action is defined as a transition of the environment state
  - as an operator whose execution produces a new state
  - from an observational point of view, the result of the behavior of an agent -its action- is directly modelled by modifying the environmental state variables
- Not fully adequate for modelling MAS in AOSE and MAS programming
  - *several agents* are acting *concurrently* on a shared environment
    - concurrent actions

RICHER ACTION MODELS

- *Influence & reactions* [Ferber and Müller, 1996]
  - distinguishing between influences and reactions to influences
    - influences come from inside the agents and are attempts to modify the course of events in the world
    - reactions, which result in state changes, are produced by the environment by combining influences of all agents, given the local state of the environment and the laws of the world
  - clear distinction between the products of the agents' behavior and the reaction of the environment
    - handling simultaneous activity in the MAS

ENVIRONMENT & REACTIVE AGENTS

- *Reactive* agents
  - no symbolic representations, no reasoning or symbolic manipulations in decision-making
- Strongly-based on the notion of environment
  - “reactive” ~ “***situated***”
    - reactive agents are typically situated in some environment rather being *disembodied*
  - agent “intelligent” behaviour is seen as innately linked to the environment agents occupy
  - the behaviour is a product of the ***interaction*** the agents maintain with their environment

ENVIRONMENT & INTELLIGENT AGENTS

- *Intelligent* agents [Wooldridge and Jennings, 1995]
  - reactivity
    - intelligent agents are able to ***perceive the environment*** and ***respond in a timely fashion*** to changes that occur in its order to satisfy their design objectives
  - pro-activeness
    - intelligent agents are able to exhibit *goal-directed behaviou*r by taking the initiative in order to satisfy their design objectives
    - goals are defined as ***state of affairs of the environment*** to bring about
  - social ability
    - intelligent agents are capable of interacting with other agents in order to satisfy their design objectives
    - role of ***mediated interaction***

TASK ENVIRONMENT

- The notion of *task environment* is used in literature to specify the property of the environment where the agent is situated and *the criteria by which an agent will be judged to have failed or succeeded in its task (goal)*

- Formally a task environment is defined by a pair $\langle Env, \Psi \rangle$ where:

  - Env is an environment
  - $\Psi : \mathcal{R} \rightarrow \{true, false\}$ is a *predicate* over runs

  Ψ specify the success/failure criteria.

- An agent Ag *succeeds* in task environment $\langle Env, \Psi \rangle$ if every run of Ag in Env satisfies Ψ, i.e. if $\Psi(r), \forall r \in \mathcal{R}(Ag, Env)$

ACHIEVEMENT TASKS IN THE ENVIRONMENT

- **Achievement** tasks
  - "*achieve state of affairs X*"
    - specified in terms of a number of *goal states,* which typically correspond to some *environment state*
    - the agent goal is to bring about one of these goal states

- $\langle Env, \Psi \rangle$ specifies an achievement task if and only if:

  $\exists \mathcal{G} \subseteq E$ such that $\forall r \in \mathcal{R}(Ag, Env) \rightarrow \Psi(r)$, and $\exists e \in \mathcal{G}$ such that $e \in r$

  - the $\mathcal{G}$ of an achievement task environment defines the *goal states* of the task
  - $\langle Env, \mathcal{G} \rangle$ denotes an *achievement task environment*, with goal states $\mathcal{G}$ and environment Env

MAINTENANCE TASKS IN THE ENVIRONMENT

- **Maintenance** tasks
  - "*maintain a state of affairs Y*"
    - specified in terms of environment states that the agent must *avoid*

- $\langle Env, \Psi \rangle$ specifies a maintenance task if and only if:

$$\exists \mathcal{B} \subseteq E \text{ such that } \Psi(r) \text{, and } \forall e \in \mathcal{B} \text{ we have } e \notin r, \forall r \in \mathcal{R}(Ag, Env)$$

  - the $\mathcal{B}$ of a maintenance task environment defines the *failure set* of the task
  - $\langle Env, \mathcal{B} \rangle$ denotes a *maintenance task environment*, with environment Env and failure set $\mathcal{B}$

GAME VIEW

- Achievement tasks *as the agent playing a game against the environment*
  - environment and agents begin in some state
  - the agent takes a turn by executing an action
  - the env. responds with some state, and so on
  - the agent wins if it can force the env. into one of the goal state
- Maintenance tasks as games in which the agents win if it manages to avoid all the states in the failure set
  - environment as the opponent trying to force the agent into failure set

REMARKS

- Traditional AI perspective: Environment is reduced to a discrete space to explore in problem solving
  - the “task environment” is a search space of choiches and outcomes (i.e., computer playing chess)
  - problem solving is an activity that take place wholly within an agent mind (problem solver)
- But the world involves complex interactions, between heterogenous entities
  - actions may have uncertain outcomes, uncertain knowledge

BOUNDED RATIONALITY

- Real, complex environments make the assumption of agents unbounded rationality *implausible*
  - Bounded Rationality vs. Rational Choice in economics
    - agents can plausibly exploit a subset of their resources to solve in a timely fashion a given problem [Simon, 1947]
    - computational resources needed to explore the search space are finite
  - Frame Problem [McCarthy & Hayes, 1969]
    - need to explicitly specify which conditions are not affected by any given action
  - Representational Content in Machines [Bickhard, 1993]
    - how translate raw percepts to formal, computable symbols
- BDI Agents and Practical Reasoning

ACTIONS AND PERCEPTIONS IN BDI AGENTS

- BDI agent model/architecture
  - agent programs specified in terms of mental attitudes (beliefs, desires, intentions)
  - based on *practical reasoning*
    - deliberation
      - deciding *what* states of affairs to achieve / maintain
    - means-ends reasoning
      - *how* to achieve / maintain the states of affairs
- Action and perception stage as part of the agent execution cycle

BDI AGENT EXECUTION CYCLE

```
B ← B0;          /* B0 are initial beliefs */
I ← I0;          /* I0 are initial intentions */
while true do
    get next percept ρ through see(...) function;
    B ← brf(B, ρ);
    D ← options(B, I);
    I ← filter(B, D, I);
    π ← plan(B, I, Ac);
    while not (empty(π) or succeeded(I, B) or impossible(I, B)) do
        α ← hd(π);
        execute(α);
        π ← tail(π);
        get next percept ρ through see(...) function;
        B ← brf(B, ρ);
        if reconsider(I, B) then
            D ← options(B, I);
            I ← filter(B, D, I);
        end-if
        if not sound(π, I, B) then
            π ← plan(B, I, Ac);
        end-if
    end-while
end-while
```