LEVELS OF ABSTRACTIONS IN DESIGNING & PROGRAMMING SYSTEMS OF COGNITIVE AGENTS

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OBJECTIVE

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- Some glances about Agent-Oriented Programming and Multi-Agent Oriented Programming
  - examples using JaCaMo framework/technology

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  - examples using JaCaMo framework/technology
- Main viewpoint
  - Level of abstraction, from design to runtime through programming
- Some points for the discussion
  - AOP and (M)AOP for the web/hypermedia?

AGENT-ORIENTED PROGRAMMING

- AI view
  - *modeling/designing/programming* **autonomous** *systems, referred as agents*
- SE view
  - *using agents as first-class modeling/designing/programming abstraction*

AGENT ABSTRACTION

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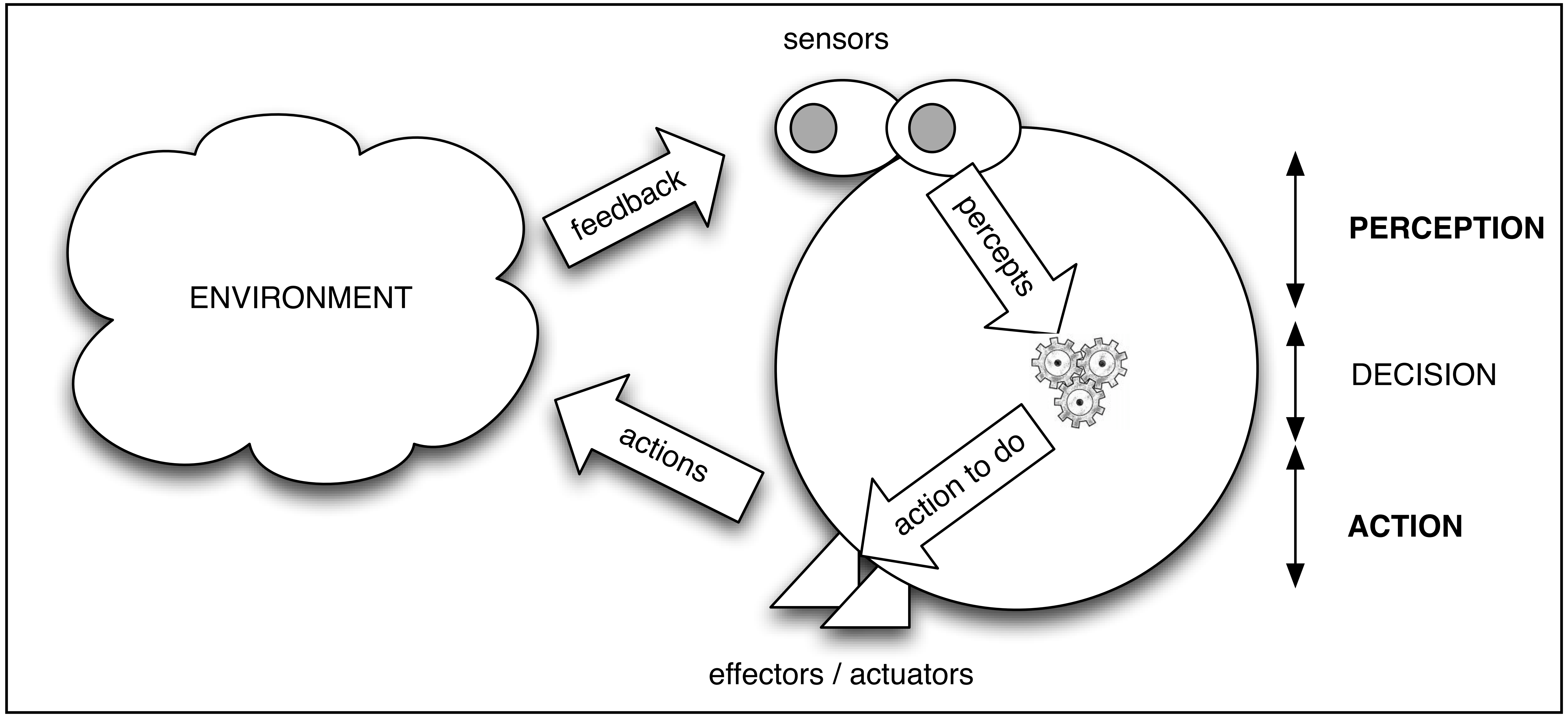

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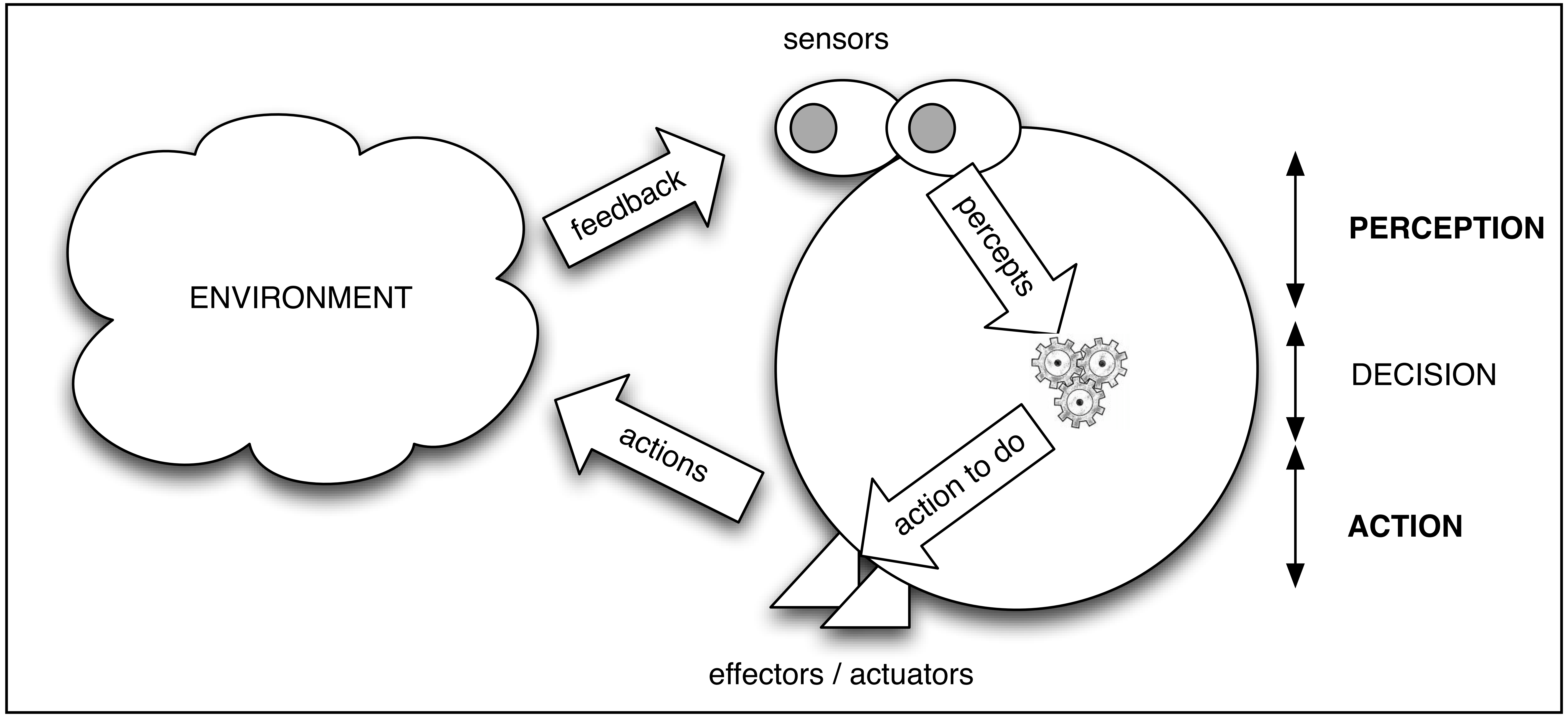

- task/goal-oriented
- pro-active + reactive
- decision making

PARADIGMS & METAPHORS

imperative =>	machines
functional =>	math
OOP =>	*world* of objects
agents =>	

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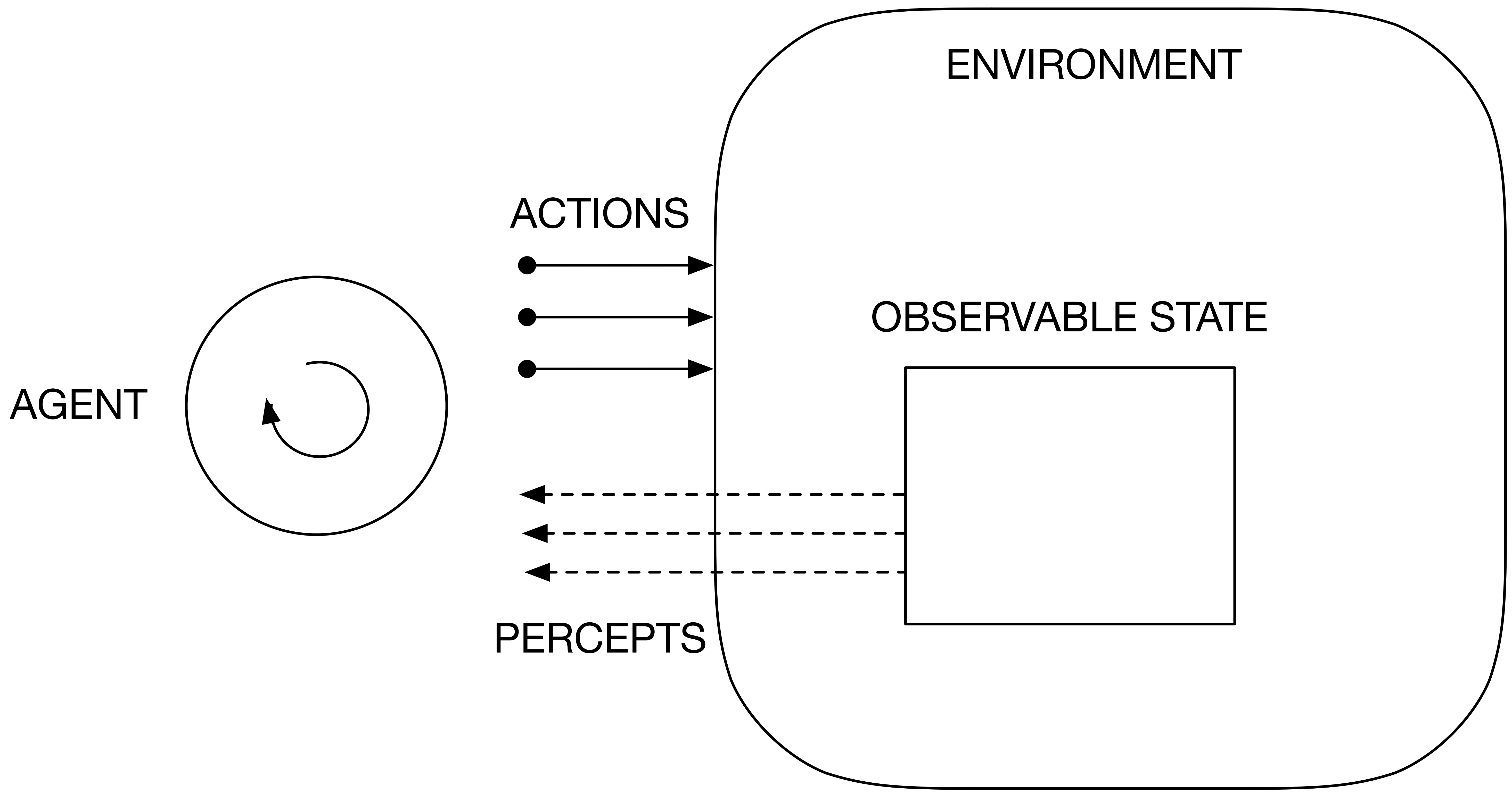
imperative =>	machines
functional =>	math
OOP =>	*world* of objects
agents =>	world of *humans*

ACTIONS & PERCEPTS



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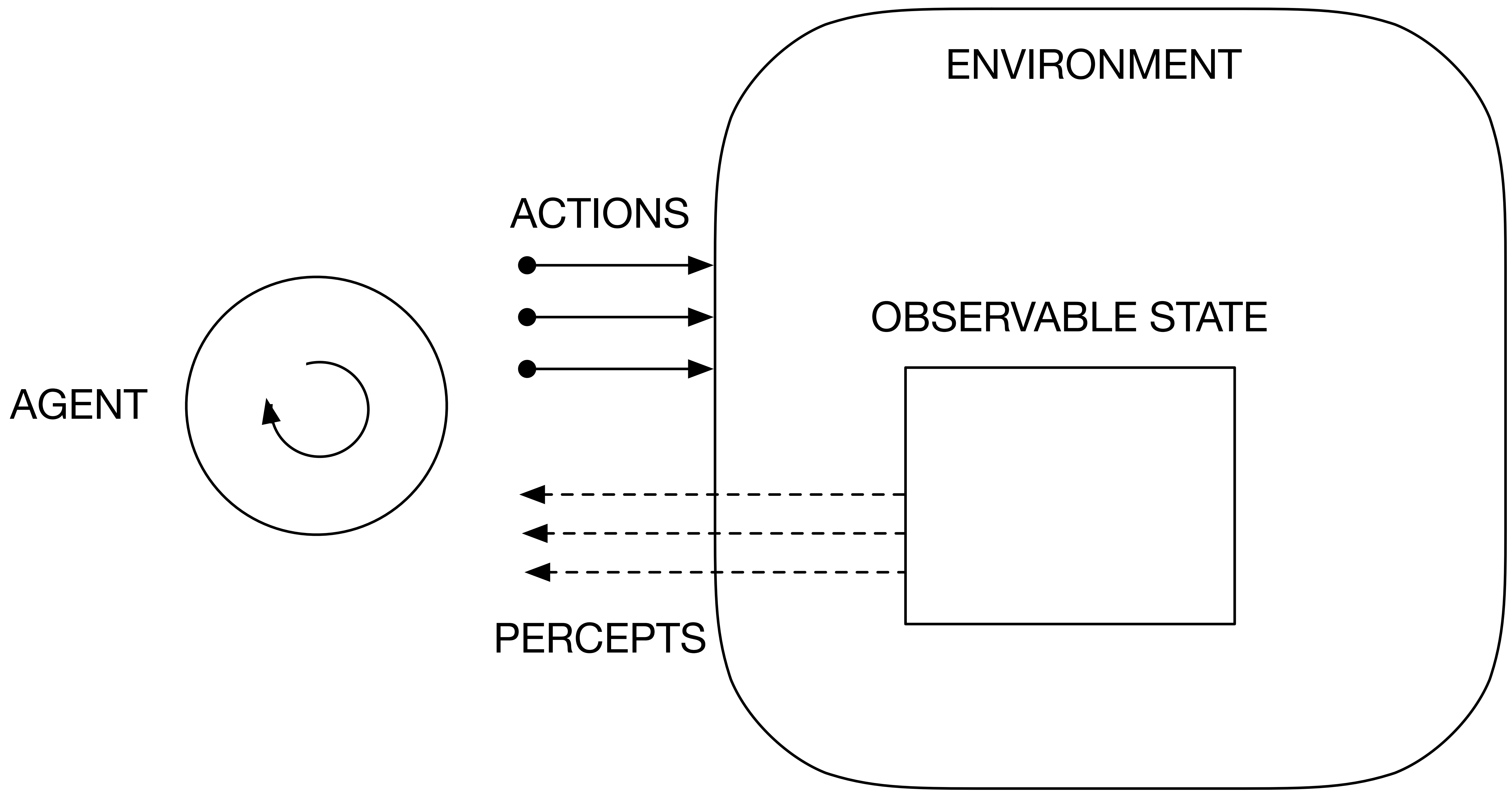

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  - action execution model is asynchronous
    - success/failure events
  - percepts as obs state events

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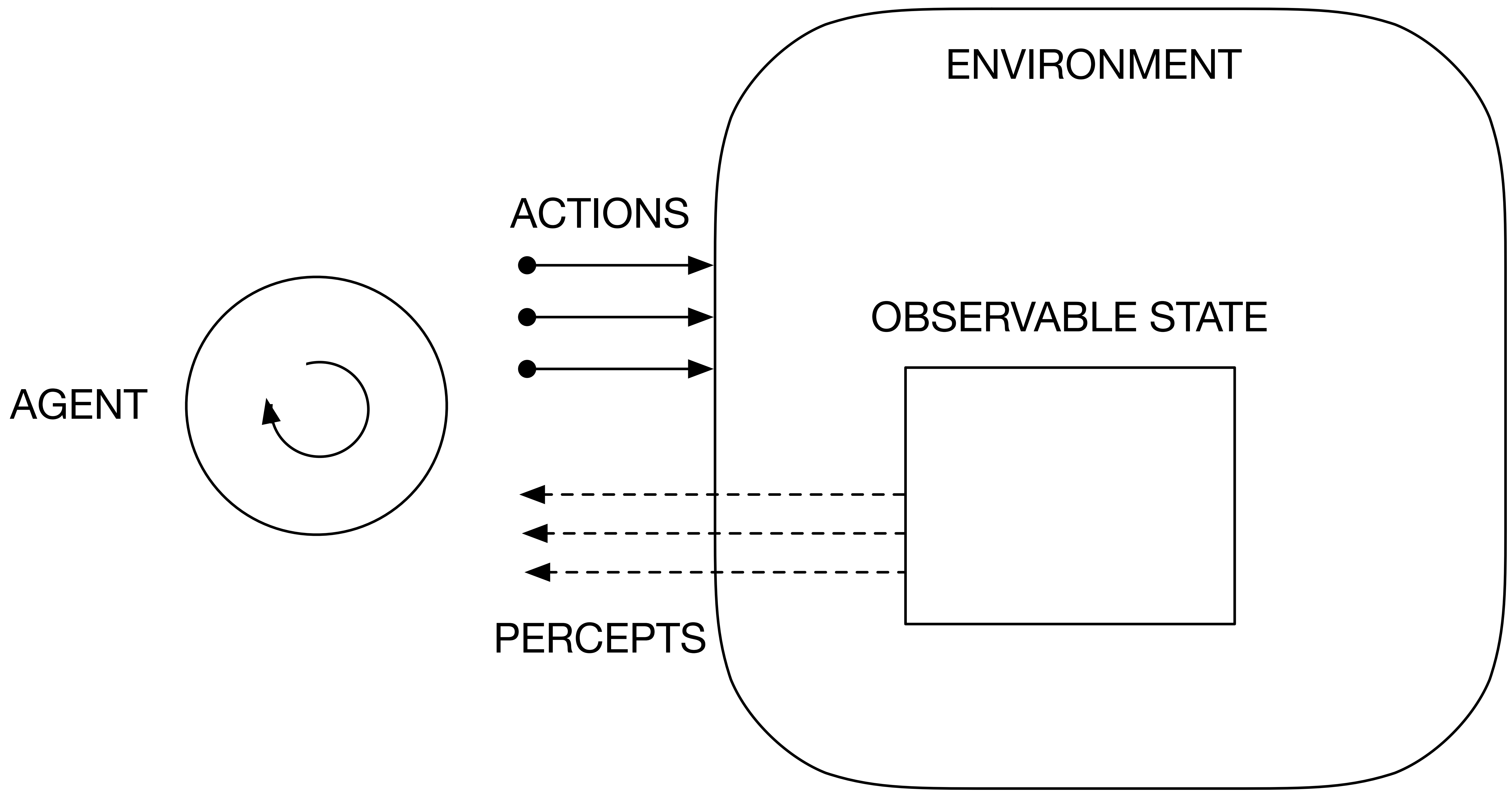
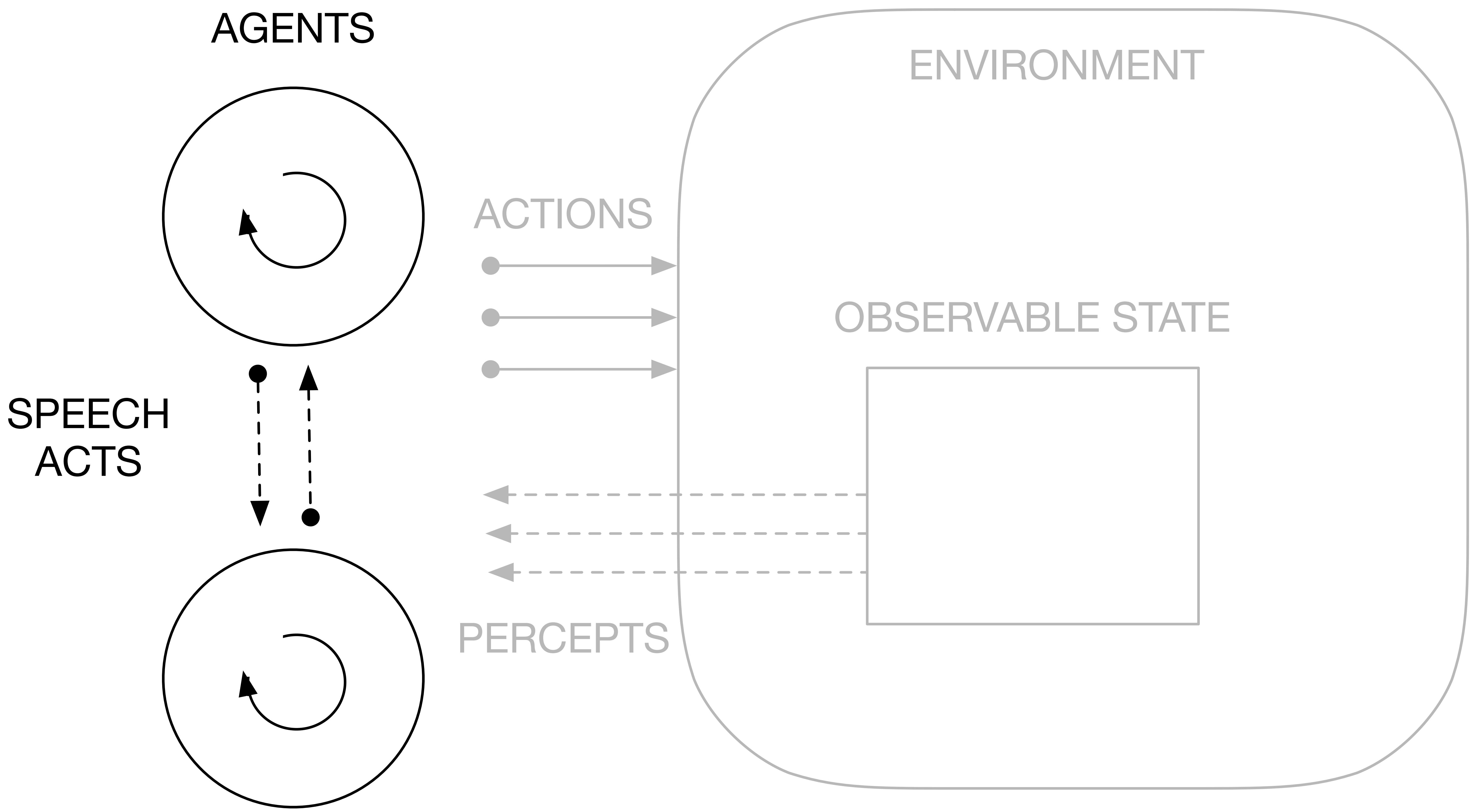
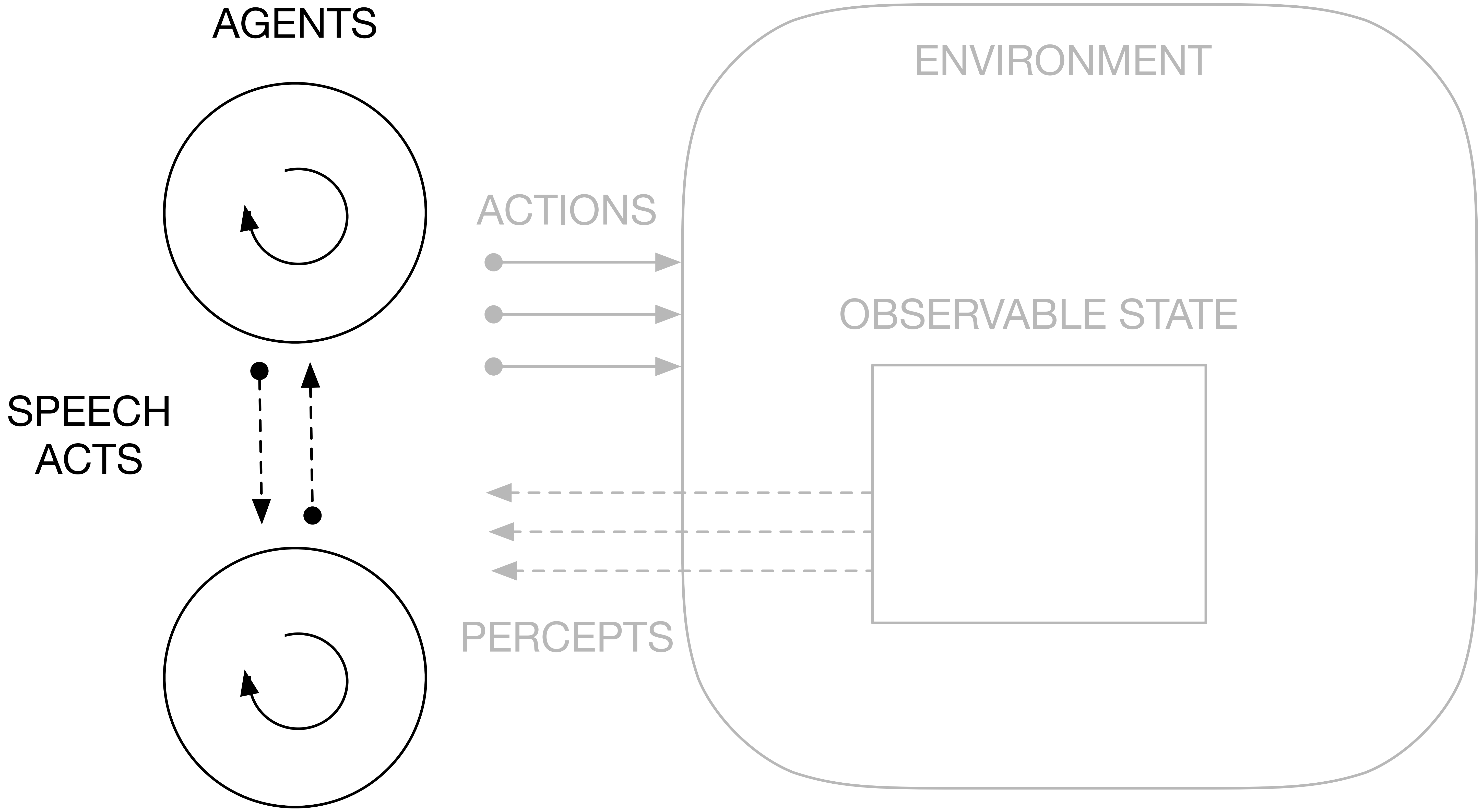


- control uncoupling
  - action execution model is asynchronous
    - success/failure events
  - percepts as obs state events
- vs. other models
  - vs. method/proc calls
  - vs. async msg (actor) passing

AGENT COMMUNICATION

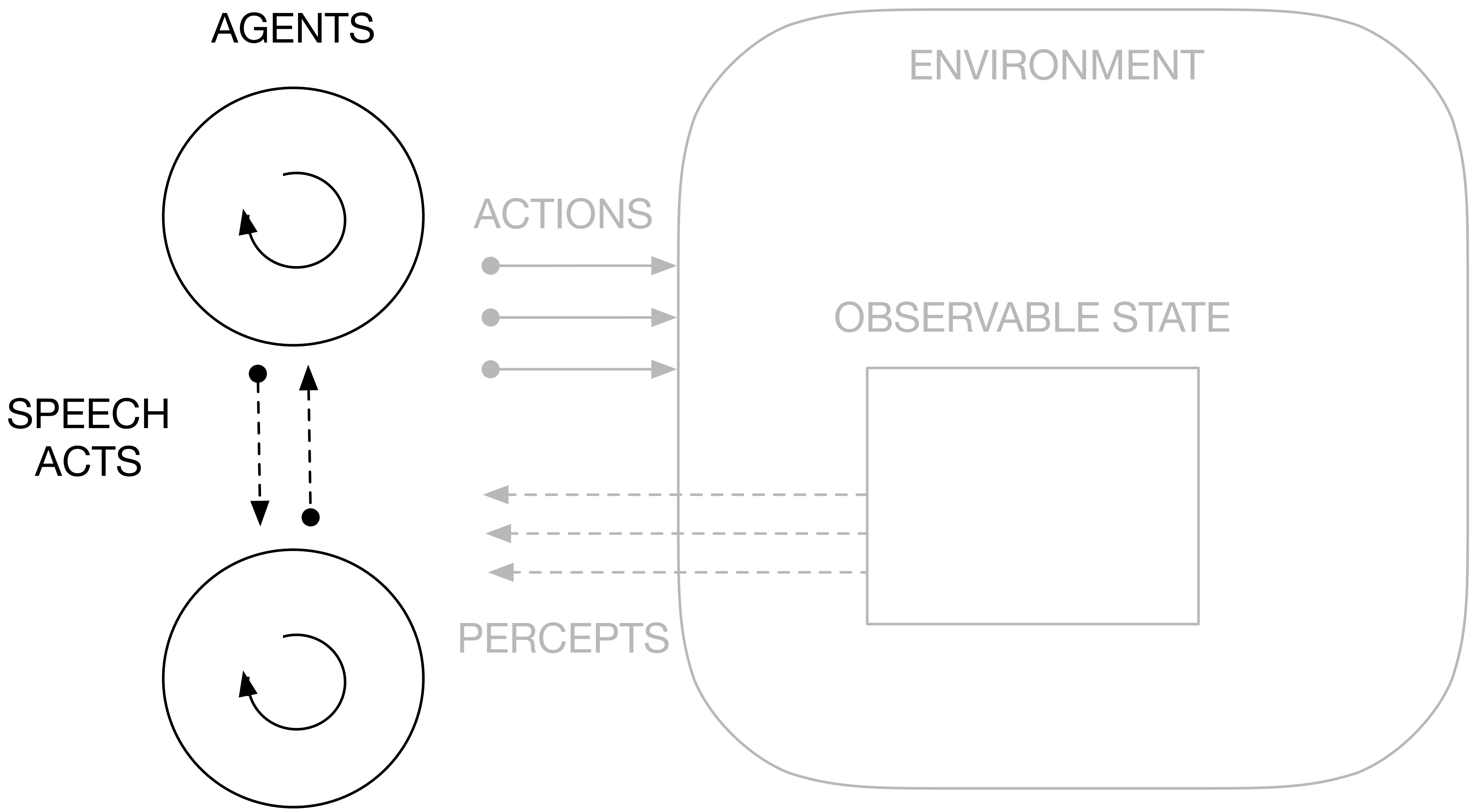


AGENT COMMUNICATION



- Agent Communication Languages
  - "speech acts"
  - ~asynchronous message passing + *action semantics*

AGENT COMMUNICATION



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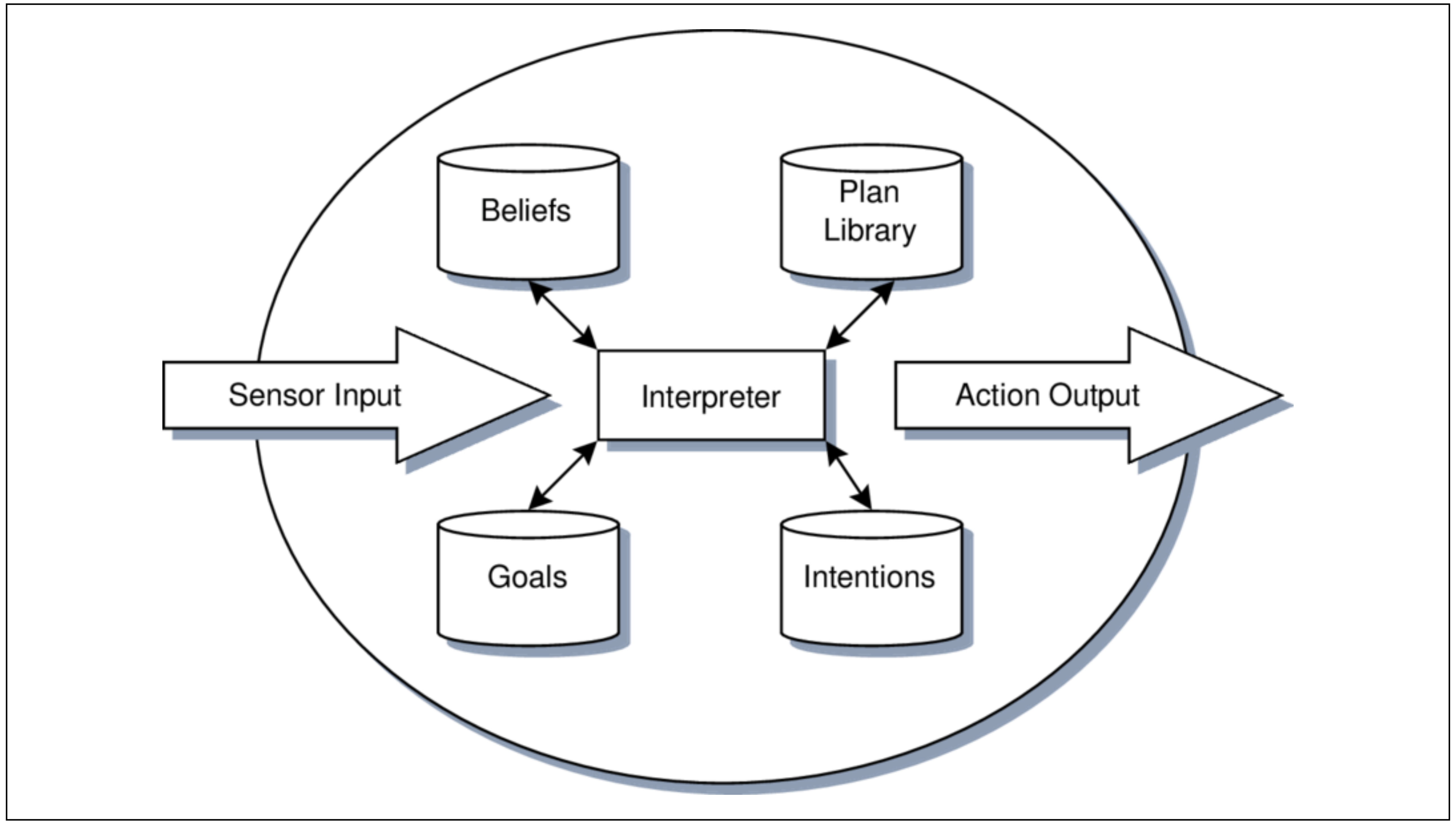
- AOP as a computing paradigm
  - ***mentalistic*** and ***societal*** view of computation [Soham, 1993]
  - level of abstraction to design and program

“COGNITIVE” MODEL

- AOP as a computing paradigm
  - ***mentalistic*** and ***societal*** view of computation [Soham, 1993]
  - level of abstraction to design and program
- **BDI** (Belief-Desire-Intention) model/architecture (80ies)
  - inspired by the theory of human practical reasoning [Bratman, 1987]
  - Procedural Reasoning System (PRS) [Georgeff et al, 1988]

"COGNITIVE" MODEL

- Beliefs
  - information state
- Goals
  - tasks to do
  - achieve | maintenance
- Plans
  - how to achieve the goals
  - modules of agent behaviour



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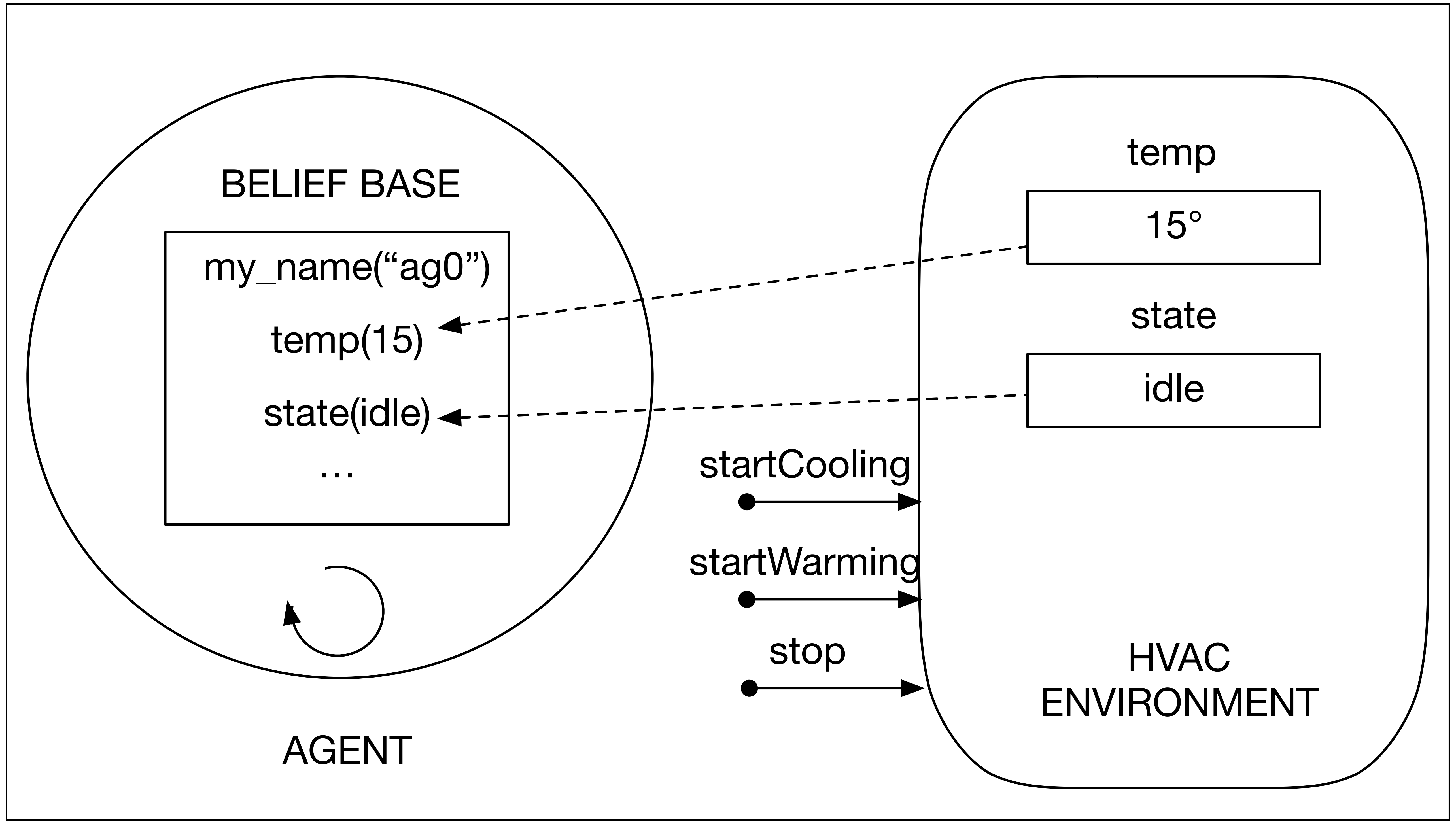


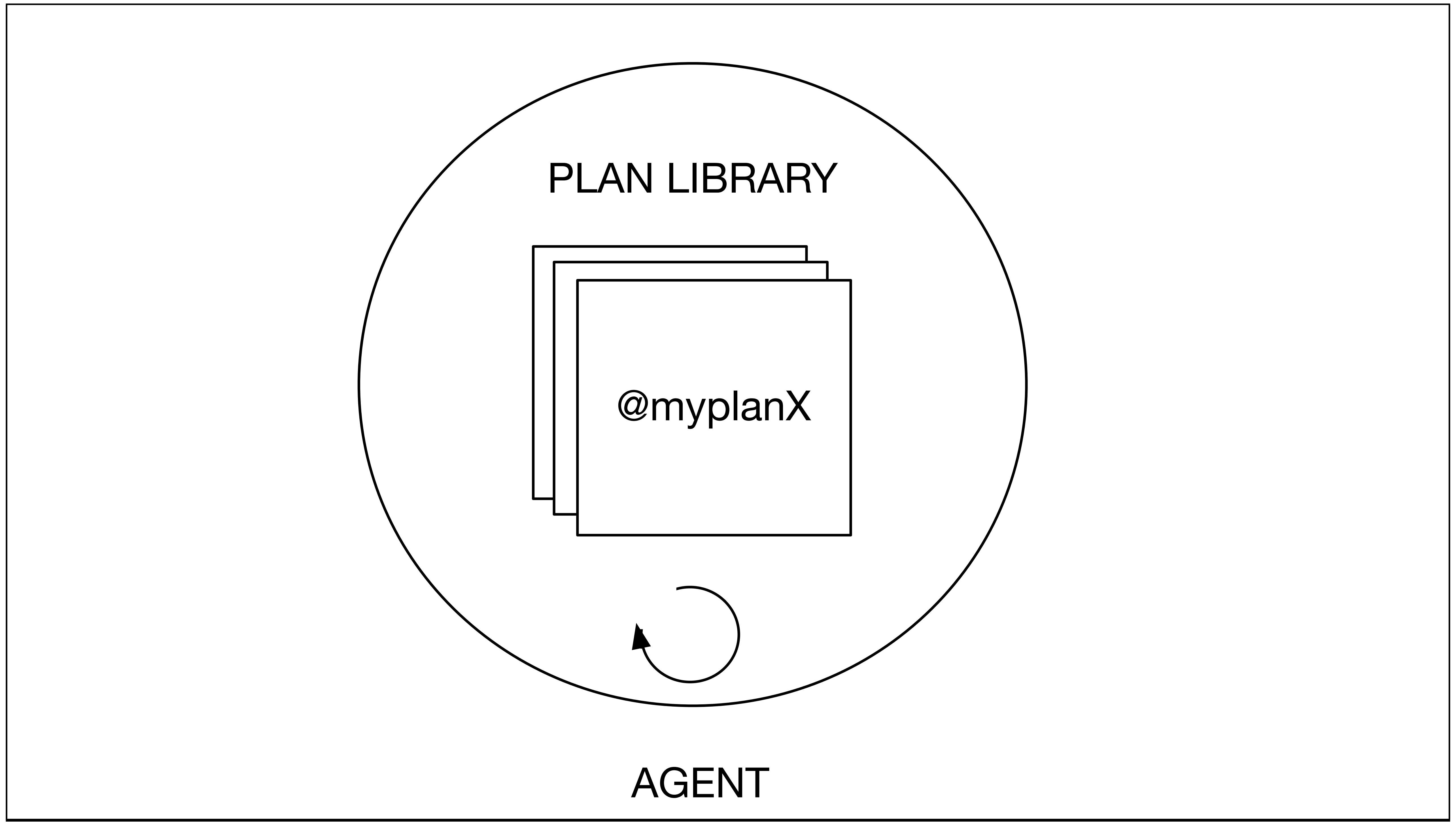
"COGNITIVE" MODEL

- Beliefs
  - information state
- **Goals**
  - tasks to do
  - achieve | maintenance
- Plans
  - how to achieve the goals
  - modules of agent behaviour

```
// examples in Jason

!achieve_temp(20).

/* more declarative style */
!temp(20).

/* long-term task */
!achieve_and_keep_temp(20).
```

“COGNITIVE” MODEL

- Beliefs
  - information state
- Goals
  - *what* tasks to do
  - achieve | maintenance
- **Plans**
  - *how* to achieve the goals
  - modules of agent behaviour



PLAN MODEL | JASON EXAMPLE

- **Plan model**
  - pro-active plans
  - reactive plans
- Hierarchical model
  - sub-goals

```
<event> : <context>
   <- <body>.
```

PLAN MODEL | JASON EXAMPLE

- Plan model
  - **pro-active plans**
  - reactive plans
- Hierarchical model
  - sub-goals

```
+!achieve_temp(Target) :
  temp(Current) & Target > Current
  <- startWarming;
     !warm_until(Target).

+!achieve_temp(Target) :
  temp(Current) & Target < Current
  <- startCooling;
     !cool_until(Target).

+!achieve_temp(Target) :
  temp(Current) & Target == Current
  <- stopHVAC.
```

PLAN MODEL | JASON EXAMPLE

- Plan model
  - pro-active plans
  - **reactive plans**
- Hierarchical model
  - sub-goals

```
// long-term / maintenance task
// target(T): belief used to track
// the target temperature

+temp(Current) :
  target(Target) & Target != Current
  <- !achieve_temp(Target).
```

PLAN MODEL | JASON EXAMPLE

- Plan model
  - pro-active plans
  - reactive plans
- **Hierarchical model**
  - sub-goals

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     !cool_until(Target).

+!achieve_temp(Target) :
  temp(Current) & Target == Current
  <- stopHVAC.
```

"COGNITIVE" MODEL

- **Intention**
  - a plan in execution
    - can fail => plan failure handling
    - can be inspected, suspended, resumed, aborted
  - multiple intentions can be in execution concurrently

```
+!achieve_temp(Target) :
  temp(Current) & Target < Current
  <- startWarming;
     !warm_until(Target).

-!achieve_temp(Target) :
  <- print("broken");
     send_email.

+!warm_until(Target) :
  temp(Current) & Current > Target
  <- .drop_intention(warm_until);
     !achieve_temp(Target).
```

"COGNITIVE" MODEL

- **Reflection/meta-level features**
  - adding/changing plans at runtime
  - inspecting/changing motivation state
  - …

```
// adding a plan action
+!g1 <-
  …
  .add_plan("+b : true <- .print(b).");
  …

// checking for an intention
+!g1 : .intend(g2)
  <- …
     .suspend_intention(g2);
     …
```

CONTROL LOOP | REASONING CYCLE

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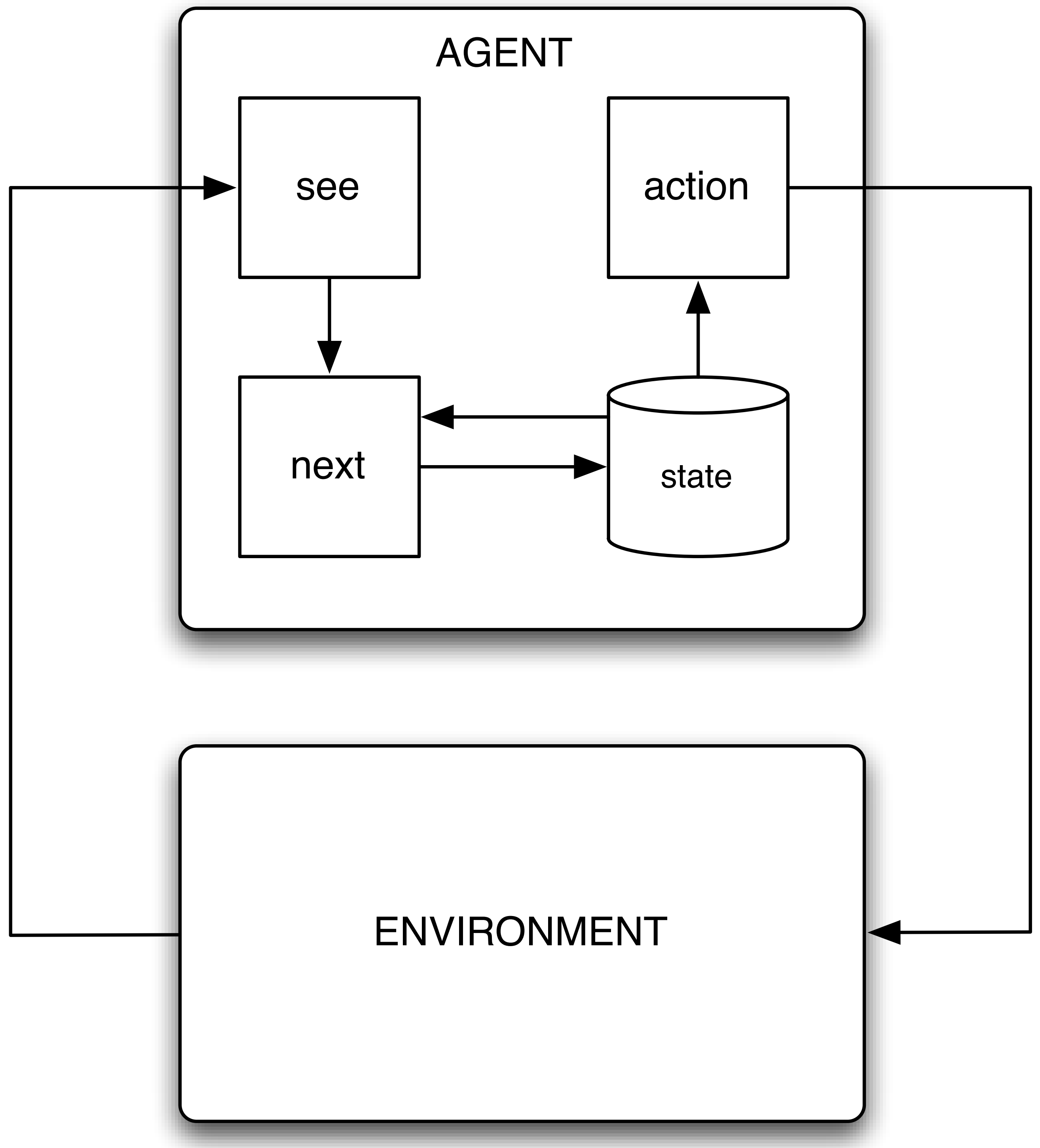
- Abstract/general



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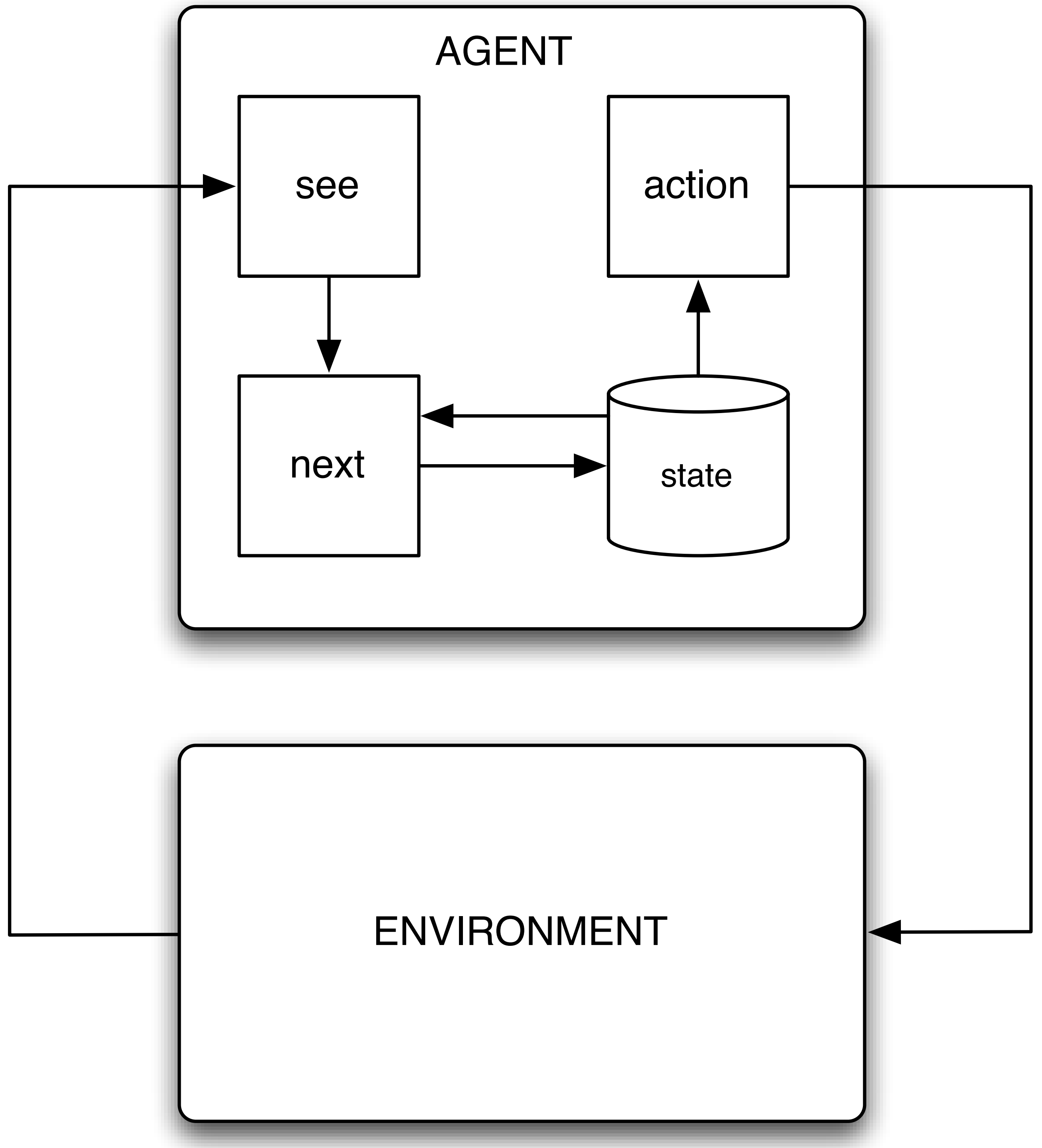
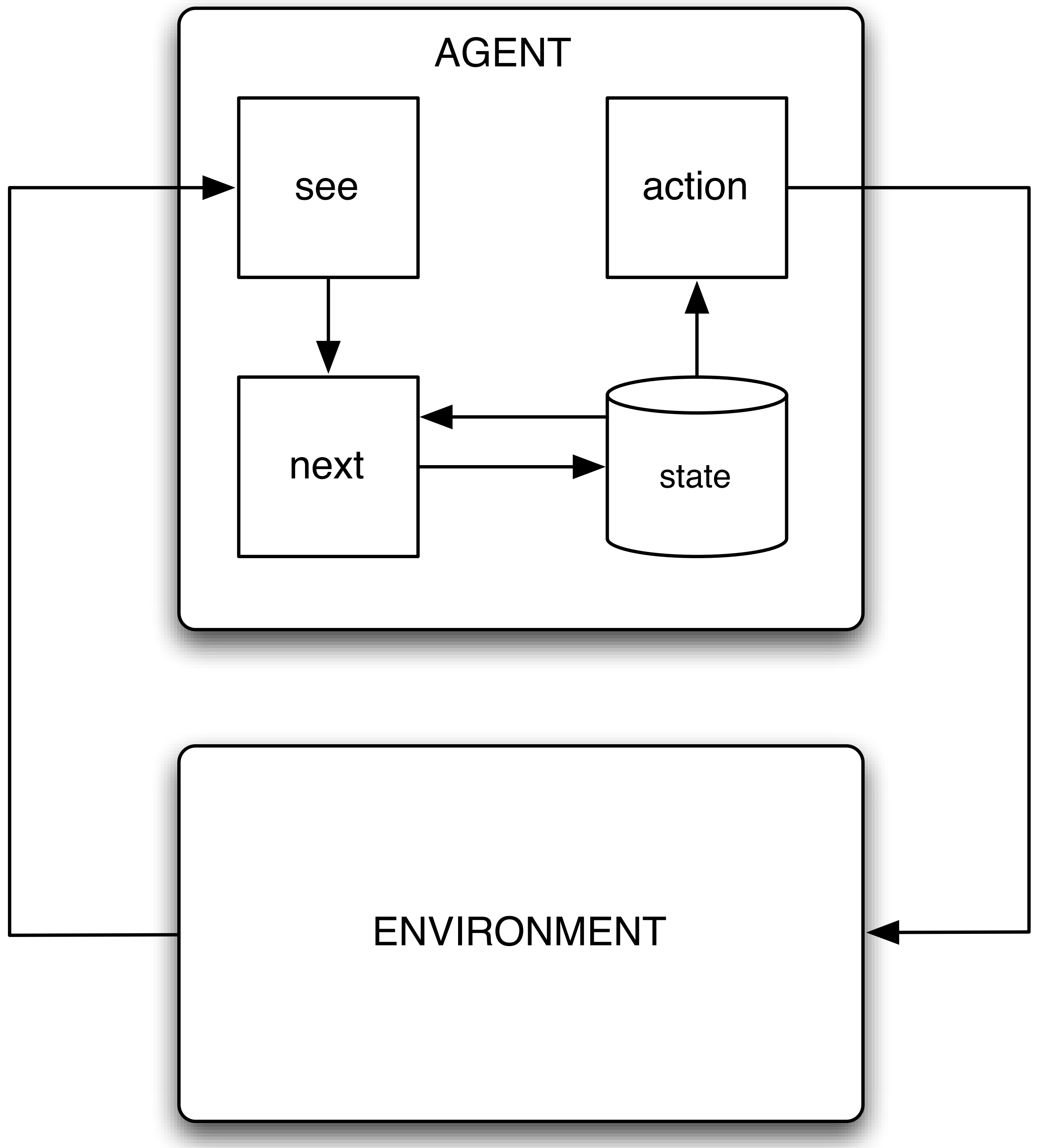


- (BDI) Reasoning cycle

```
begin
    while true do
        p ← perception()
        B ← brf(B, p) ;                 // belief revision
        D ← options(B, I) ;             // desire revision
        I ← filter(B, D, I) ;           // deliberation
        execute(I) ;                    // means-end
end
```

CONTROL LOOP | REASONING CYCLE

- Abstract/general



- (BDI) Reasoning cycle

```
while true do
    B ← brf(B, perception())
    D ← options(B, I)
    I ← filter(B, D, I)
    π ← plan(B, I, A)
    while π ≠ ∅ and ¬succeeded(I, B) and
        execute( head(π) )
        π ← tail(π)
        B ← brf(B, perception())
        if reconsider(I, B) then
            D ← options(B, I) ;
            I ← filter(B, D, I) ;
        if ¬sound(π, I, B) then
            π ← plan(B, I, A) ;
```

PLANS and **PLAN LIBRARY**
means-end in BDI =>
- get and exec a plan from a plan library

revise commitment to plan – re-planning for context adaptation

reconsider the intentions

AGENTS vs. OBJECTS/ACTORS

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- vs. objects in OOP
  - active vs. passive
  - stronger encapsulation
    - state + behaviour + *control* of the behaviour
    - “decision making”

AGENTS vs. OBJECTS/ACTORS

- vs. objects in OOP
  - active vs. passive
  - stronger encapsulation
    - state + behaviour + *control* of the behaviour
    - “decision making”
- vs. actors
  - not reactive but pro-activity
    - reasoning cycle vs. event-loop
    - task/goal-oriented vs. message-driven

FROM AOP TO MAOP
(“MULTI-AGENT ORIENTED PROGRAMMING”)

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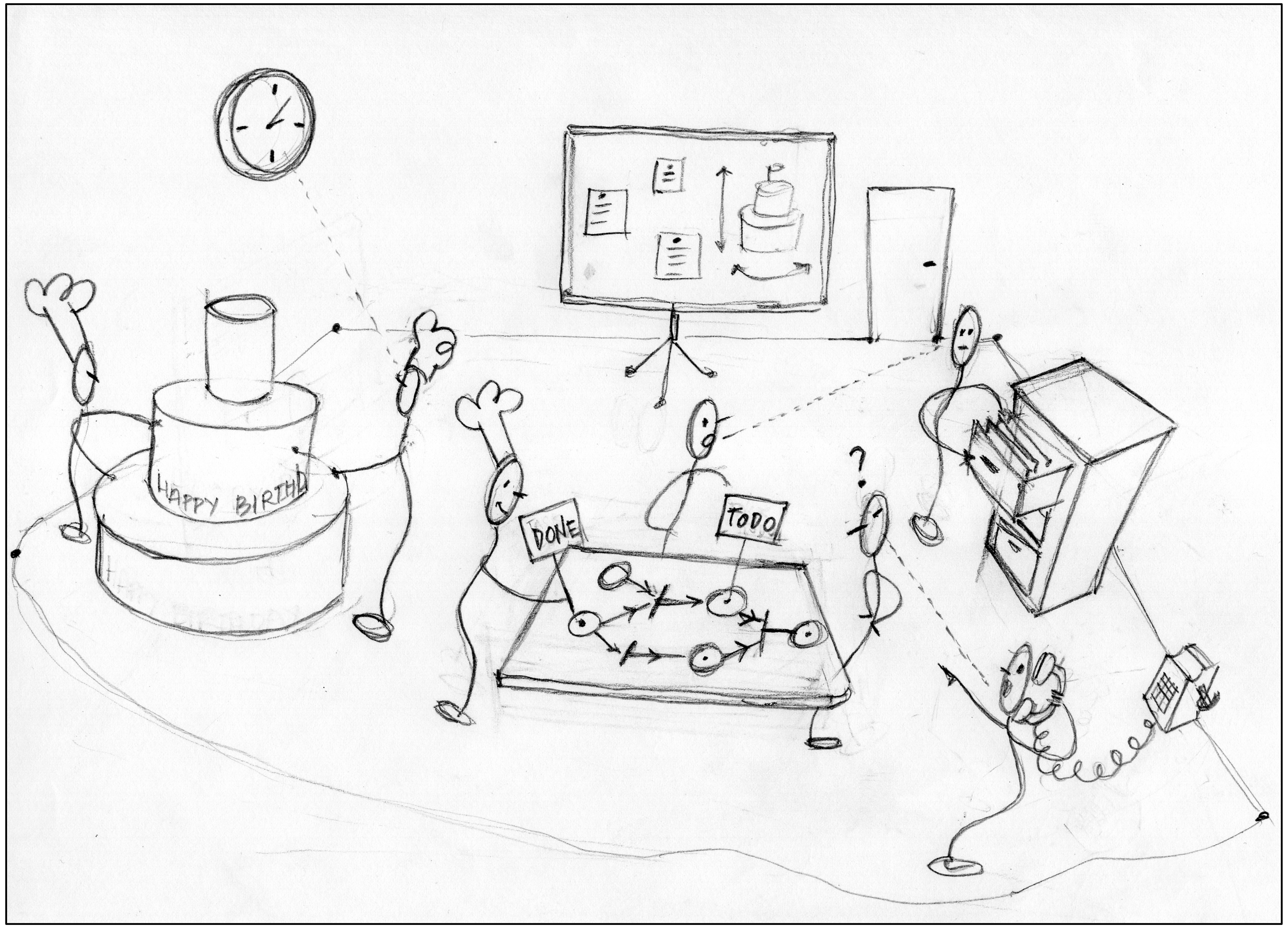
- Integrating further design & programming dimensions and abstractions aside to agent [Boissier et al, JaCaMo papers]
  - **environment** dimension
  - **organisation** dimension

FROM AOP TO MAOP ("MULTI-AGENT ORIENTED PROGRAMMING")

- Integrating further design & programming dimensions and abstractions aside to agent [Boissier et al, JaCaMo papers]
  - **environment** dimension
  - **organisation** dimension
- Key points
  - separation of concerns
  - again: level of the abstraction
    - i.e. away from the *everything-is-an-agent* perspective

ENVIRONMENT
AS FIRST-CLASS DIMENSION



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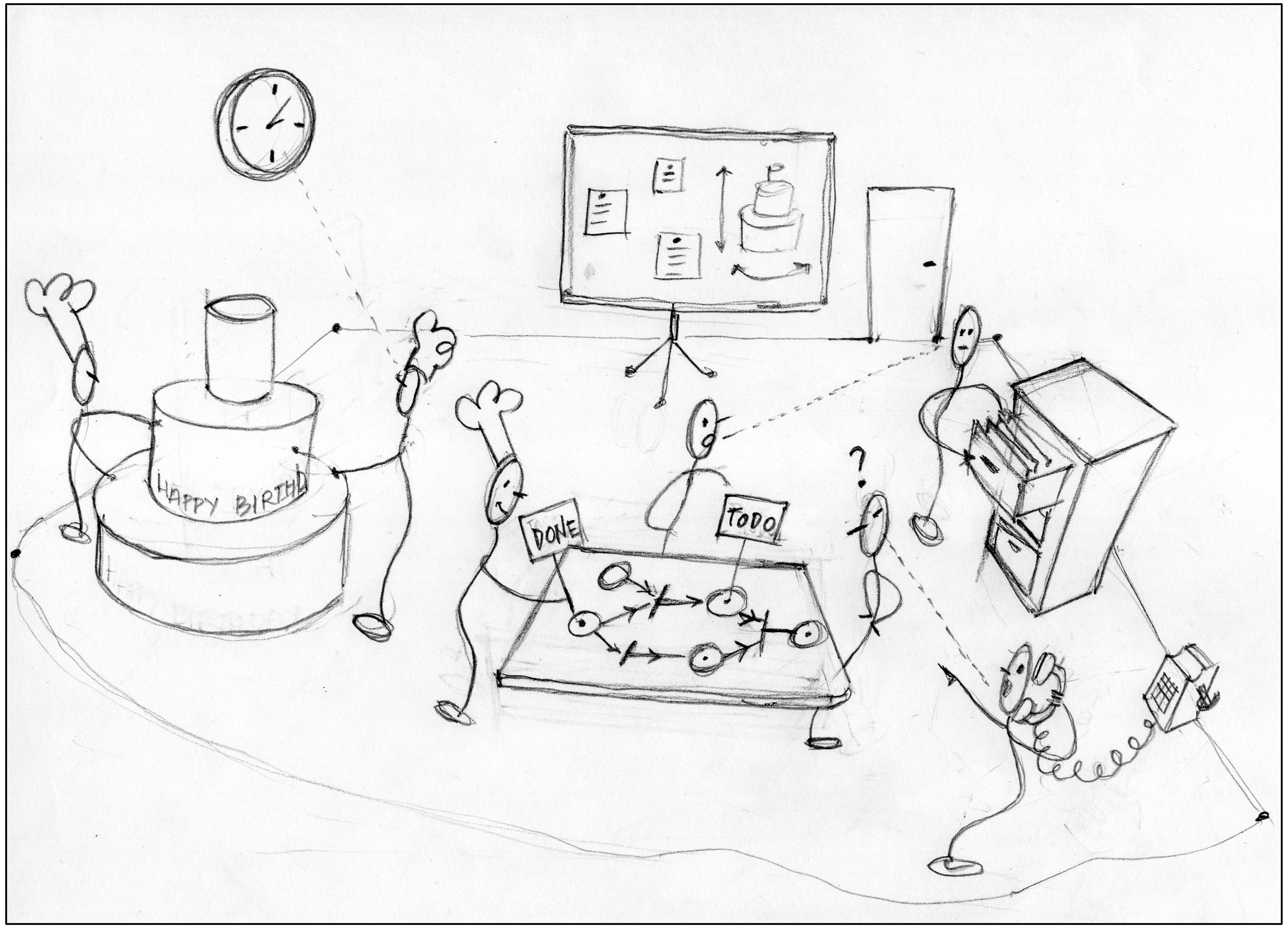

- Environment as first-class design/ programming abstraction
  - modularising functionalities and services available to agents

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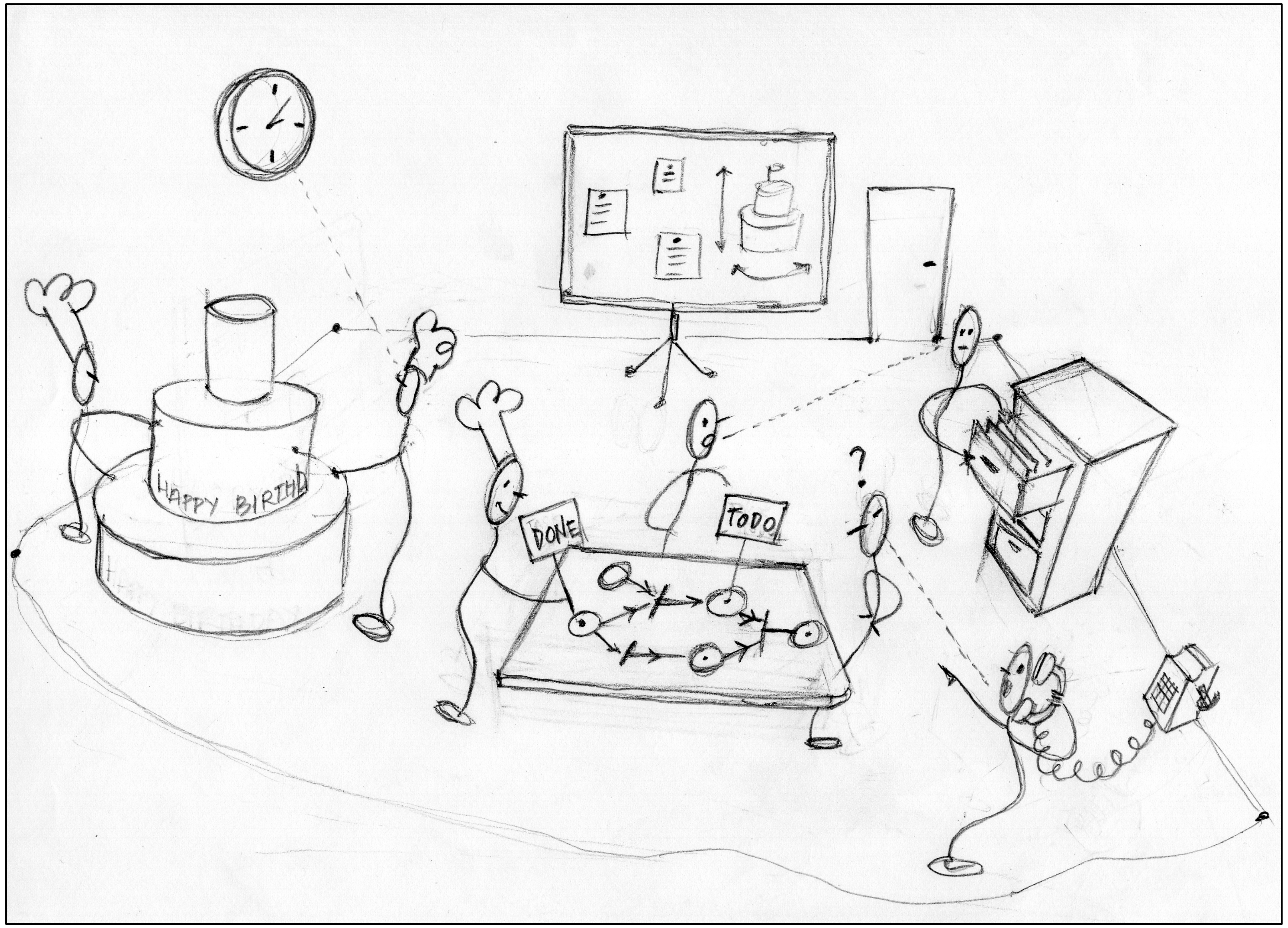
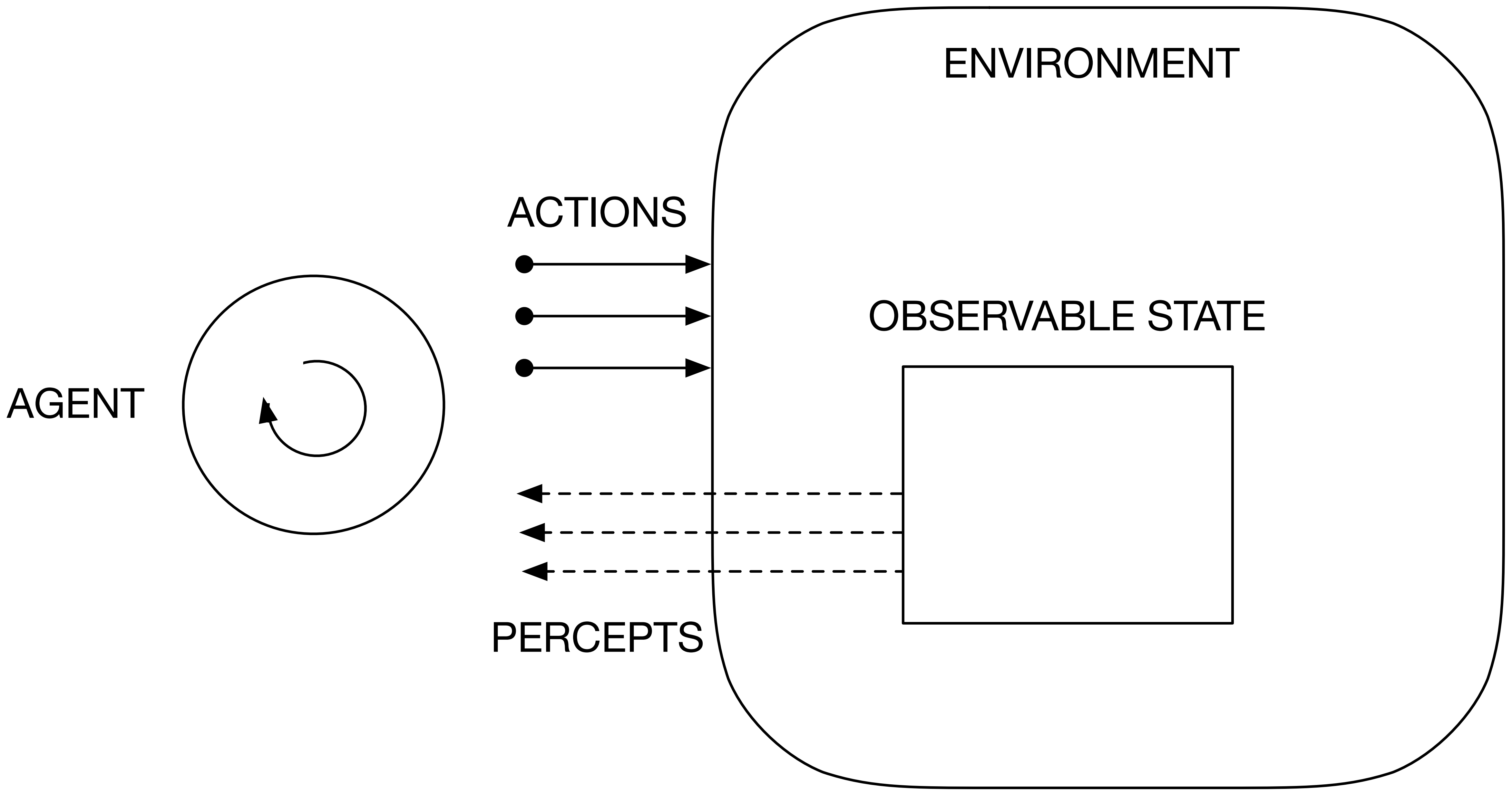


- Environment as first-class design/programming abstraction
  - modularising functionalities and services available to agents
- JaCaMo: A&A model (Agents & Artifacts)
  - inspired by Activity Theory & Distributed Cognition
  - environment as a dynamic set of ***artifacts***
    - created/used/shared by agents
    - *tools* mediating agent activities
    - ~objects at the agent LoA

ARTIFACT ABSTRACTION



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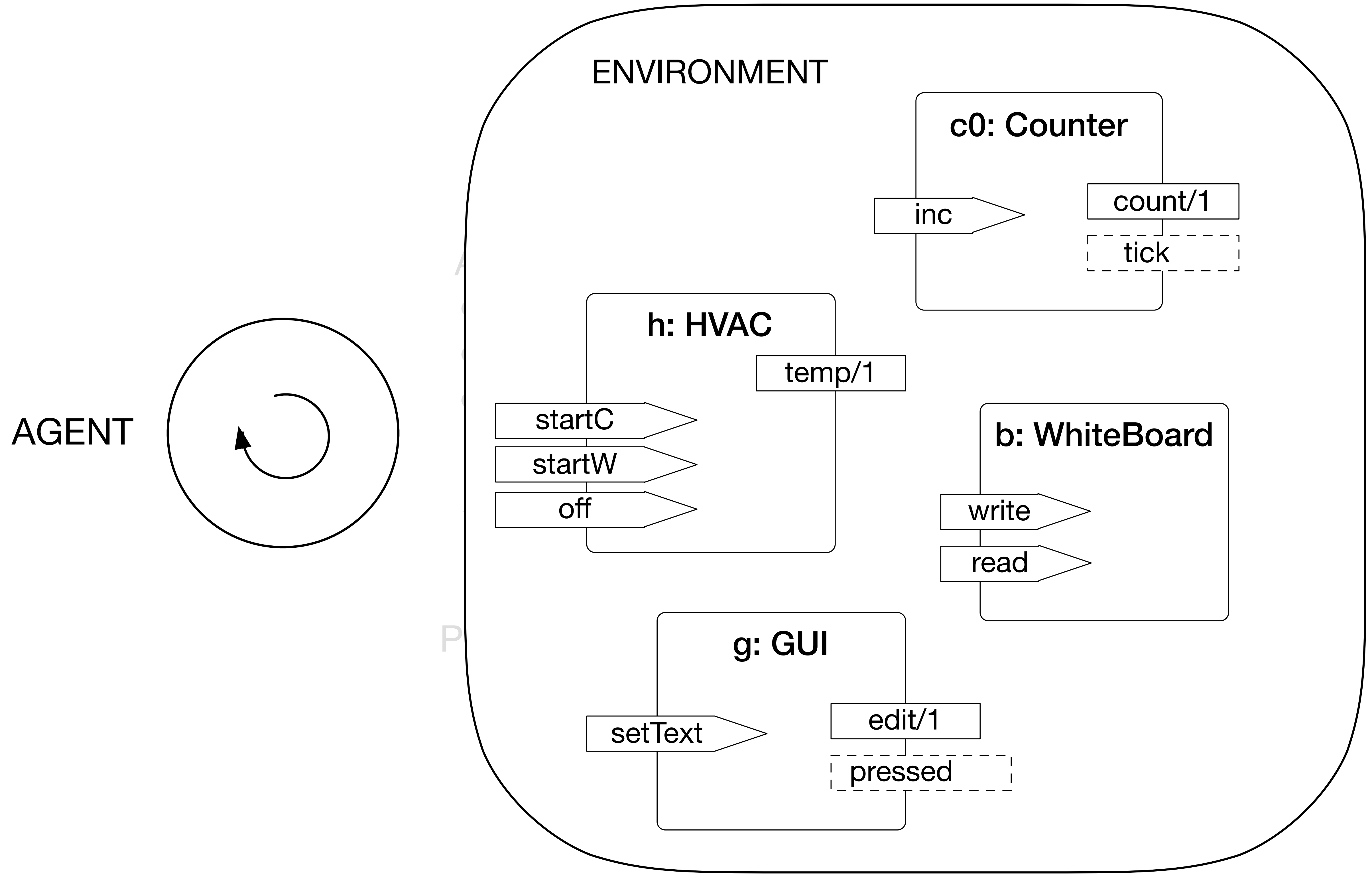
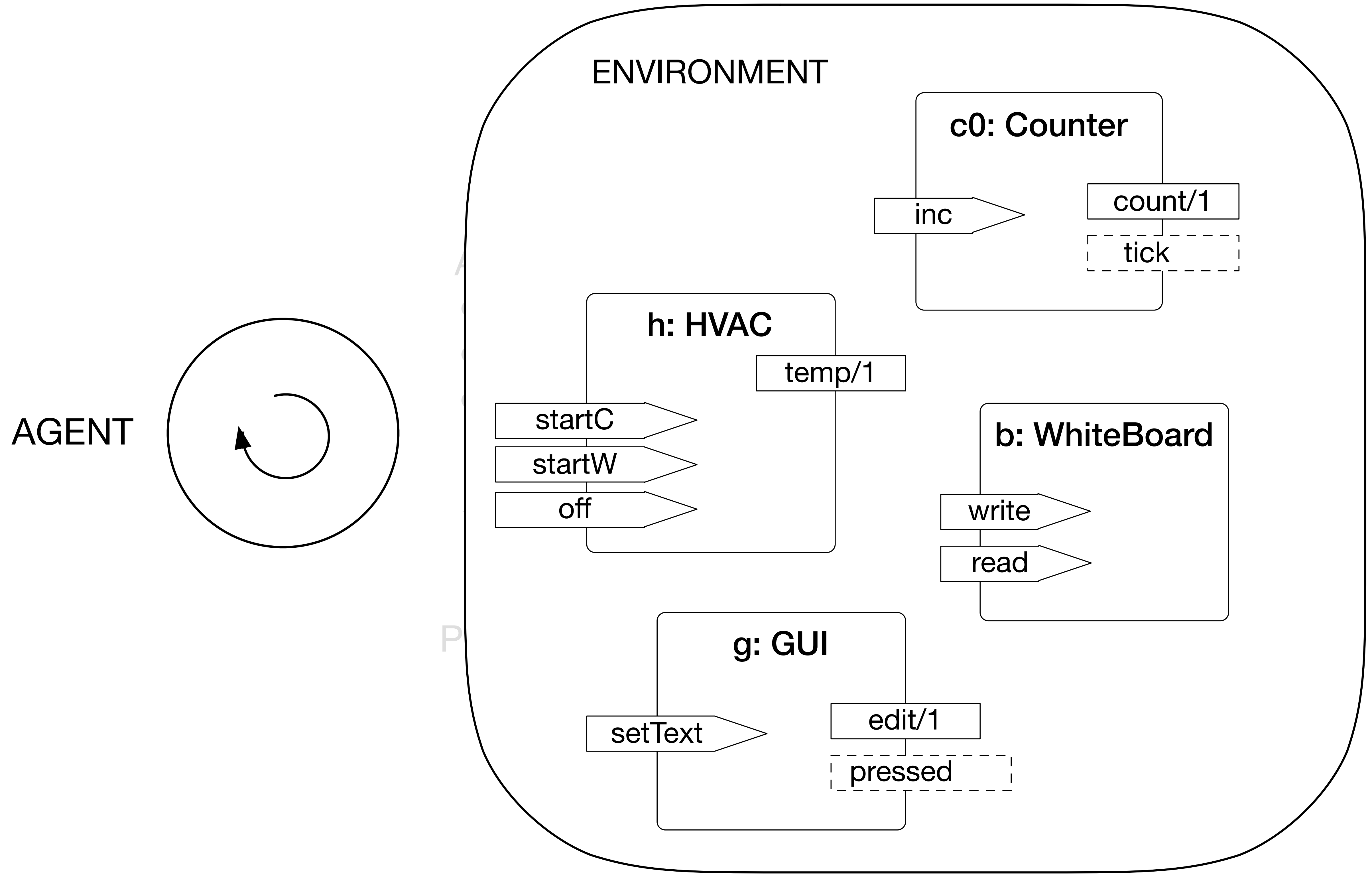


- Artifact first-class abstraction

ARTIFACT ABSTRACTION



- Artifact first-class abstraction
  - *usage interface*
    - **operations** (~actions)
    - **observable properties**

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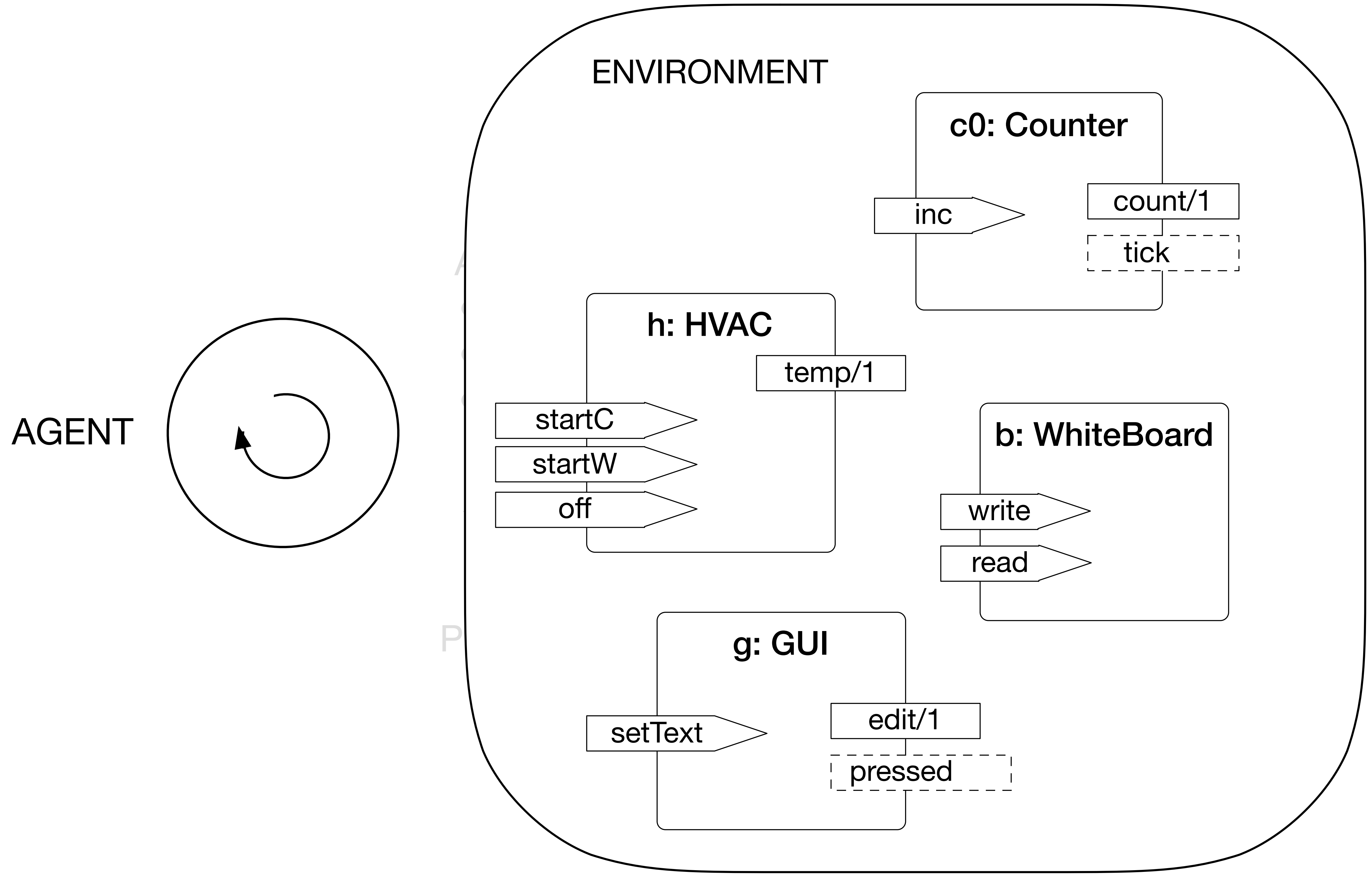

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  - *link interface*
    - to connect artifacts

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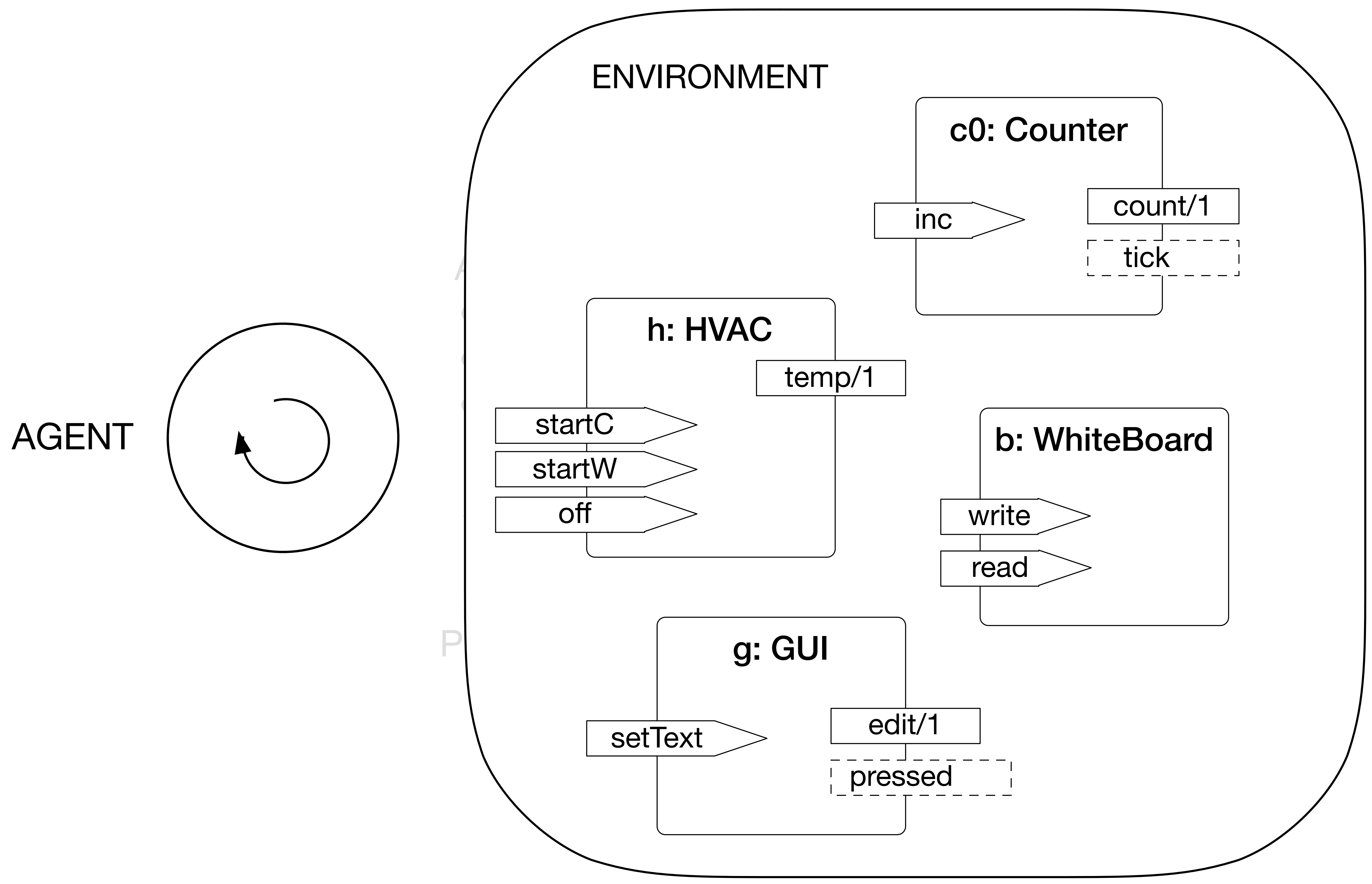
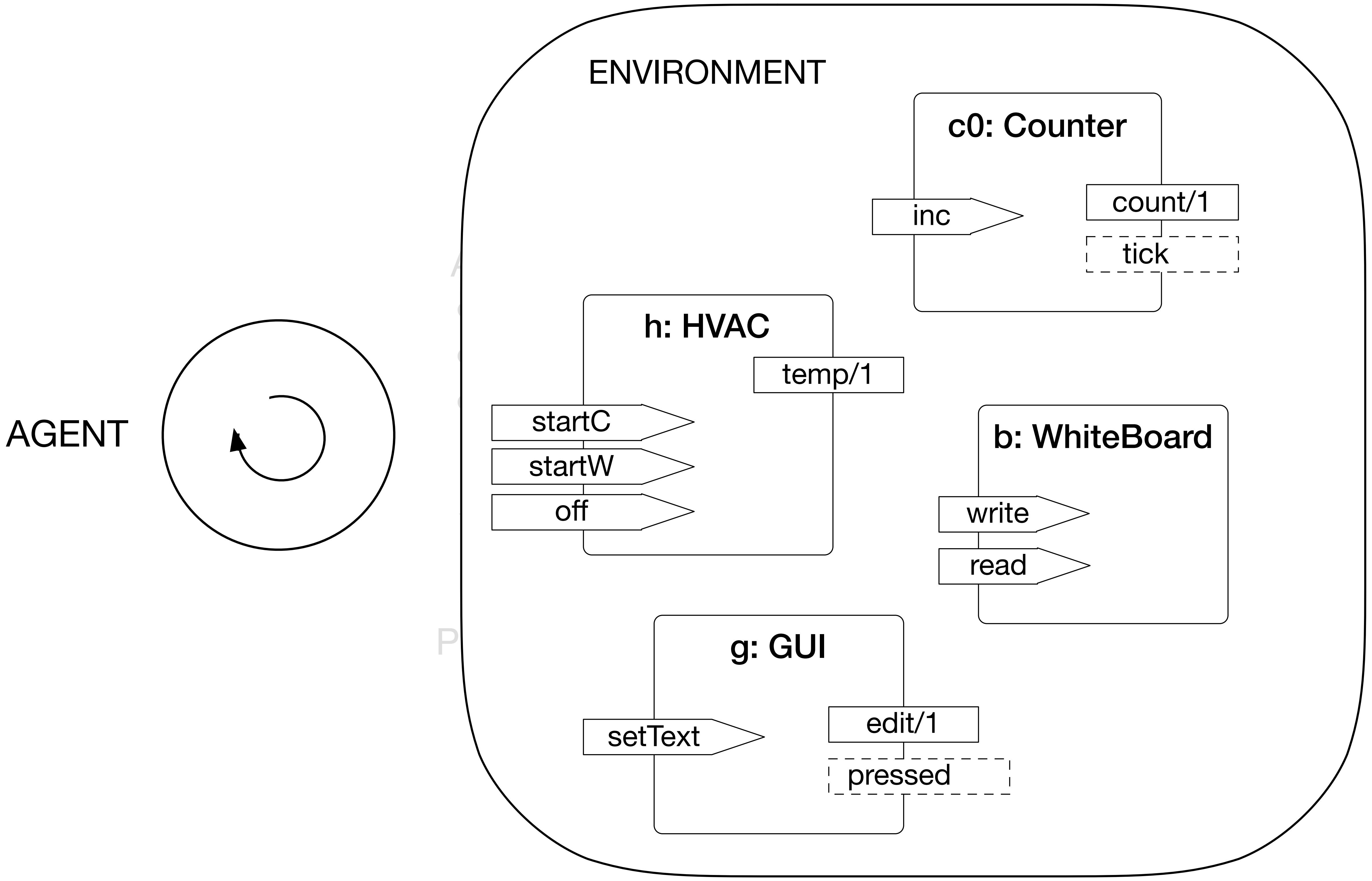


- Artifact first-class abstraction
  - *usage interface*
    - **operations** (~actions)
    - **observable properties**
  - *link interface*
    - to connect artifacts
  - *manual*
    - what functionalities & how to use
- JACaMo environment

ARTIFACT ABSTRACTION




```
public class Counter extends Artifact {

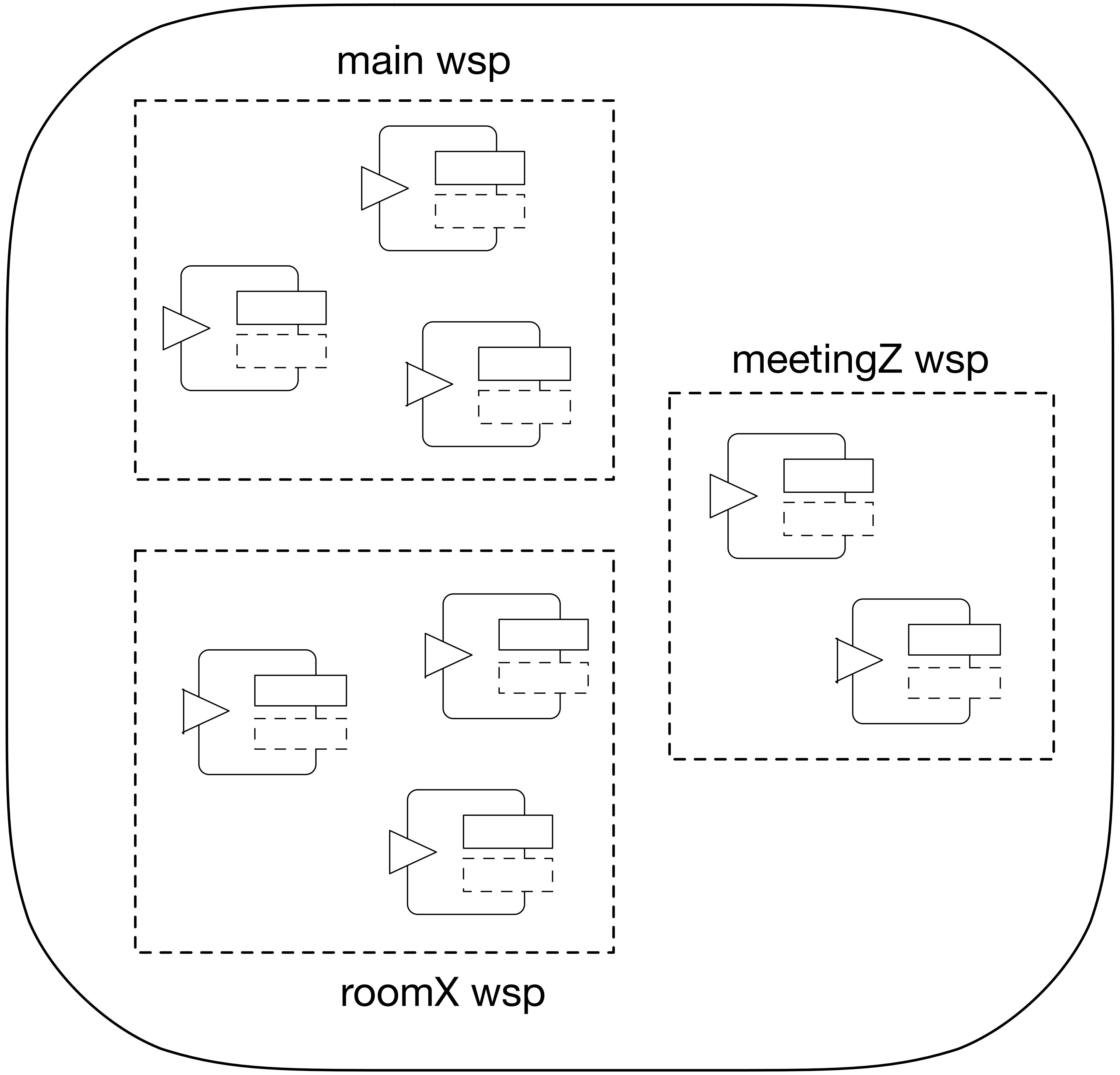
  private int nTicks;

  void init(){
    defineObsProperty("count",0);
    nTicks = 0;
  }

  @OPERATION void inc(){
    ObsProperty prop = getObsProperty("count");
   prop.updateValue(prop.intValue() + 1);
   nTicks++;
   signal("tick " + nTicks);
  }
}
```

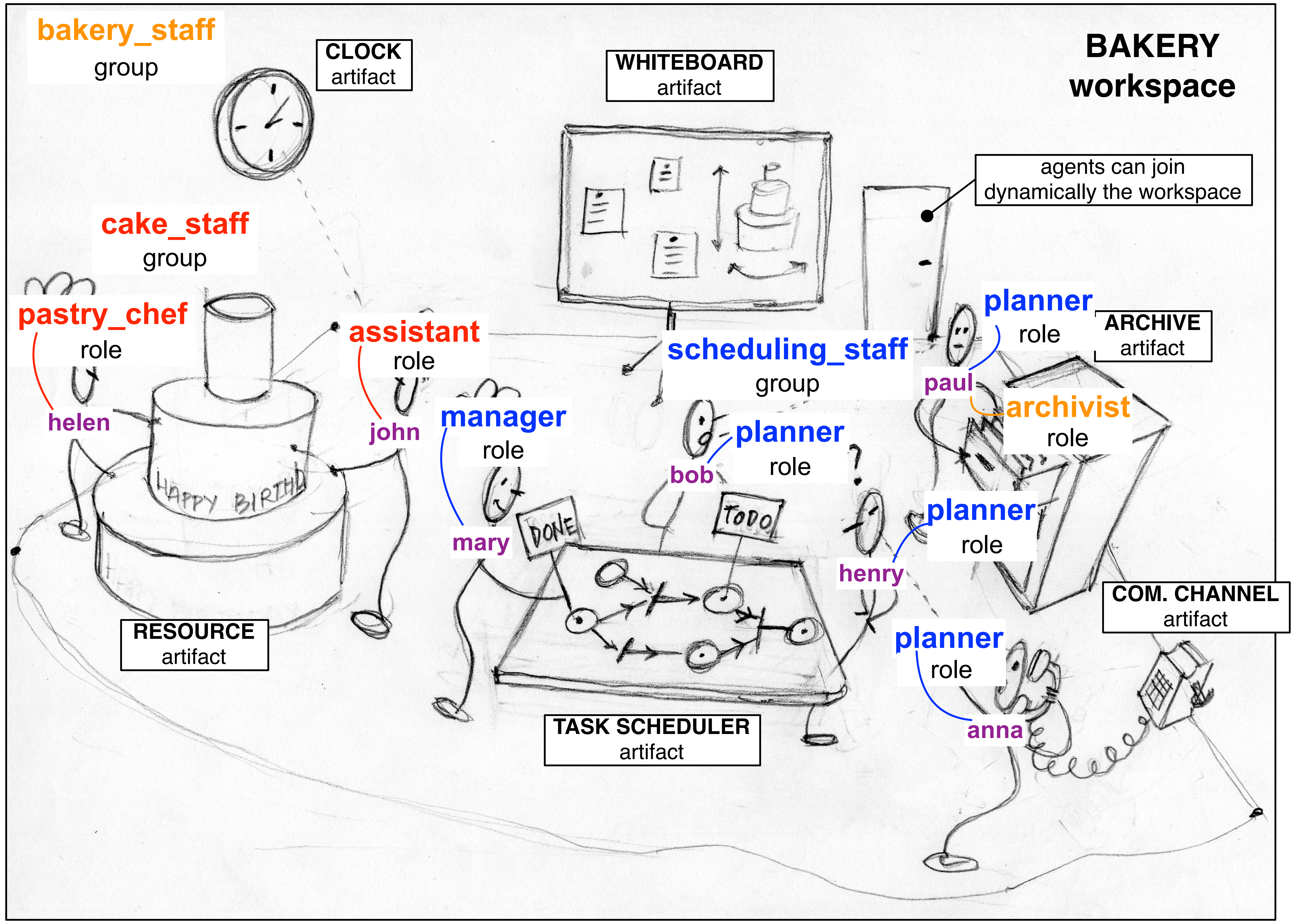
- JACaMo environment
  - Java-based API & runtime

WORKSPACES



- Structuring complex/distributed environments in *workspaces*
  - logical containers of artifacts
  - agents can dynamically join and work in multiple workspaces
  - workspaces can be distributed over the network

ORGANISATION AS FIRST-CLASS DIMENSION



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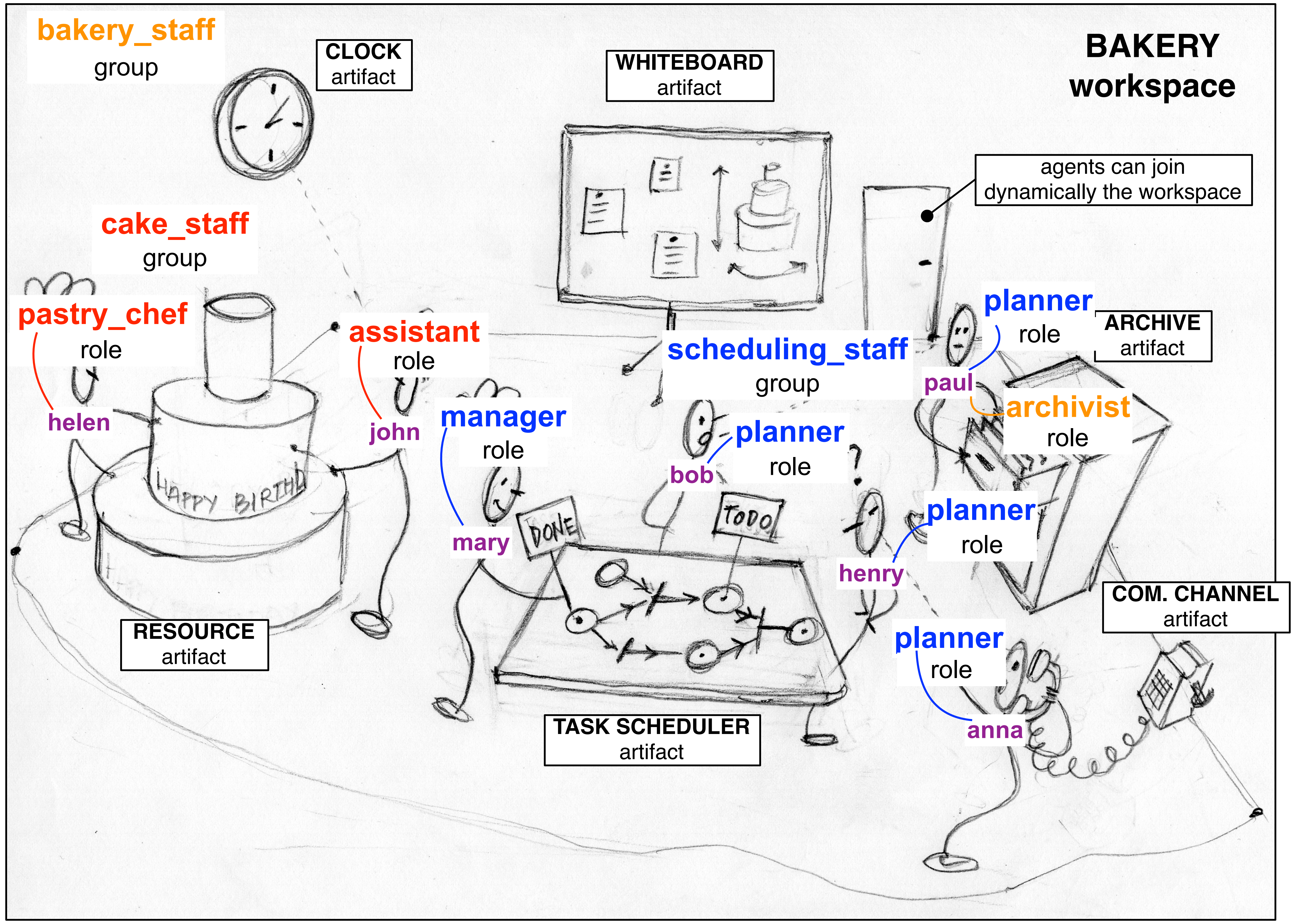

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  - specifying the structure and coordinated behaviour of a ***MAS as a whole***

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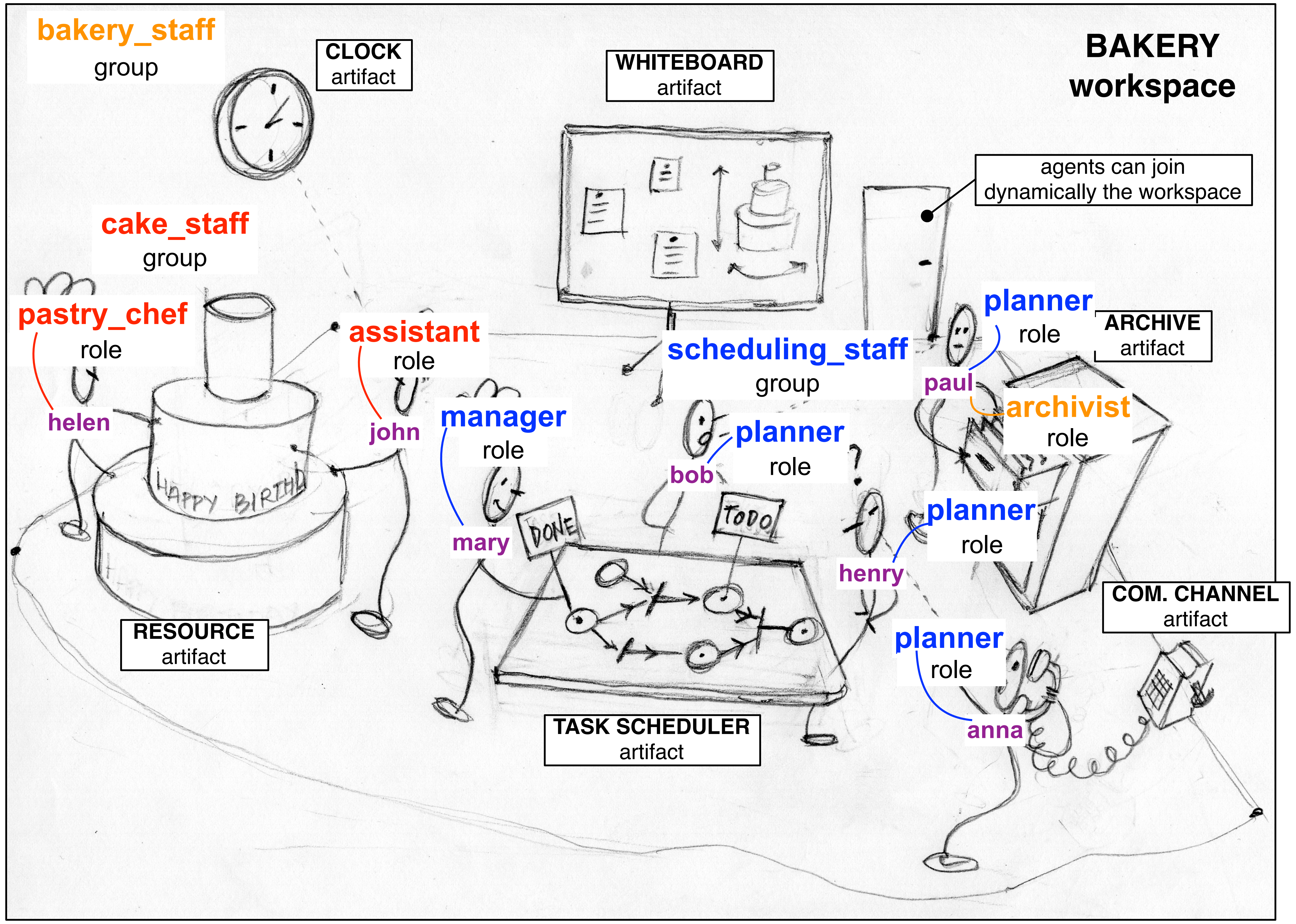

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- JaCaMo organisation
  - roles, links, groups
  - social goals, missions schemes
  - norms

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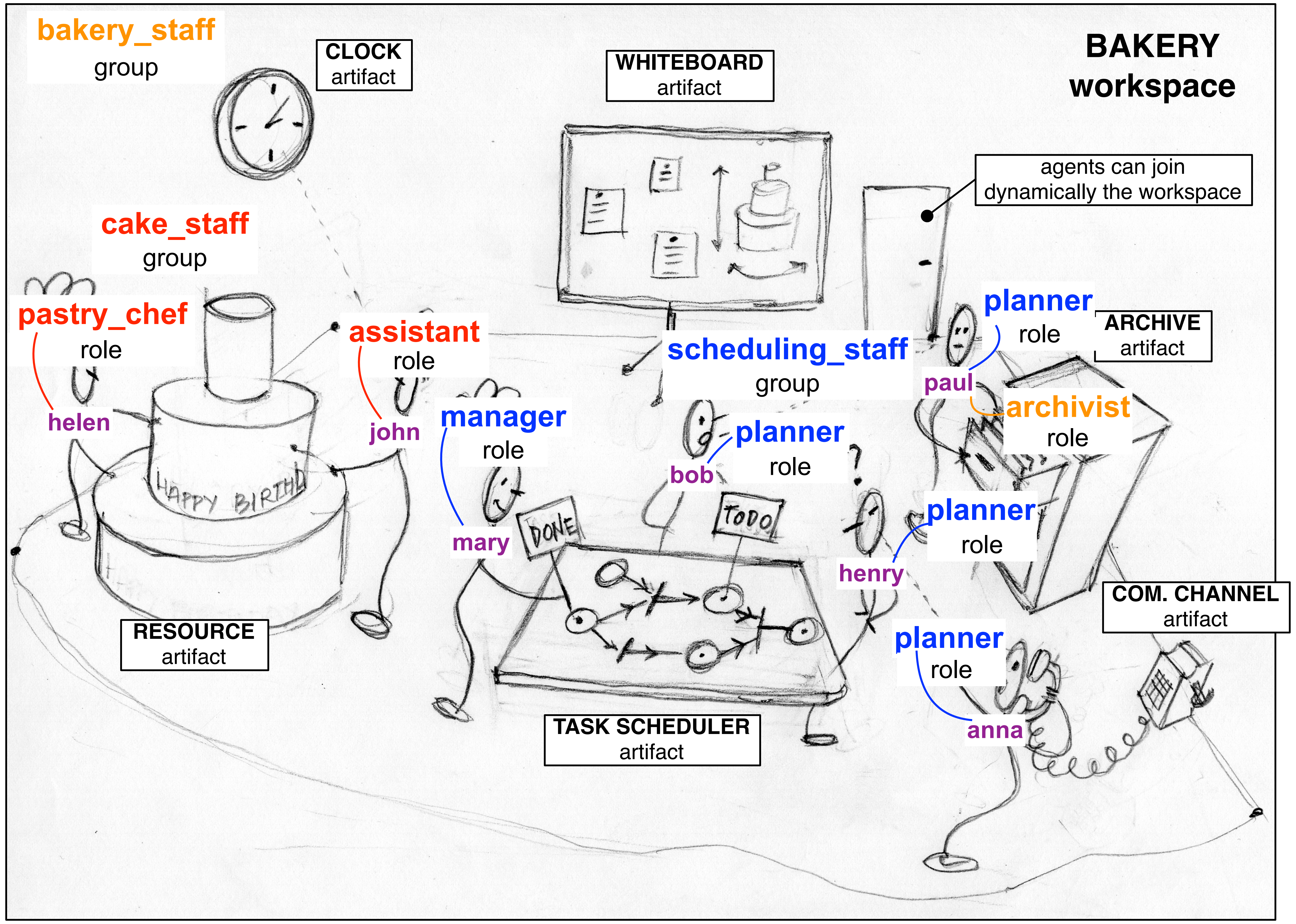
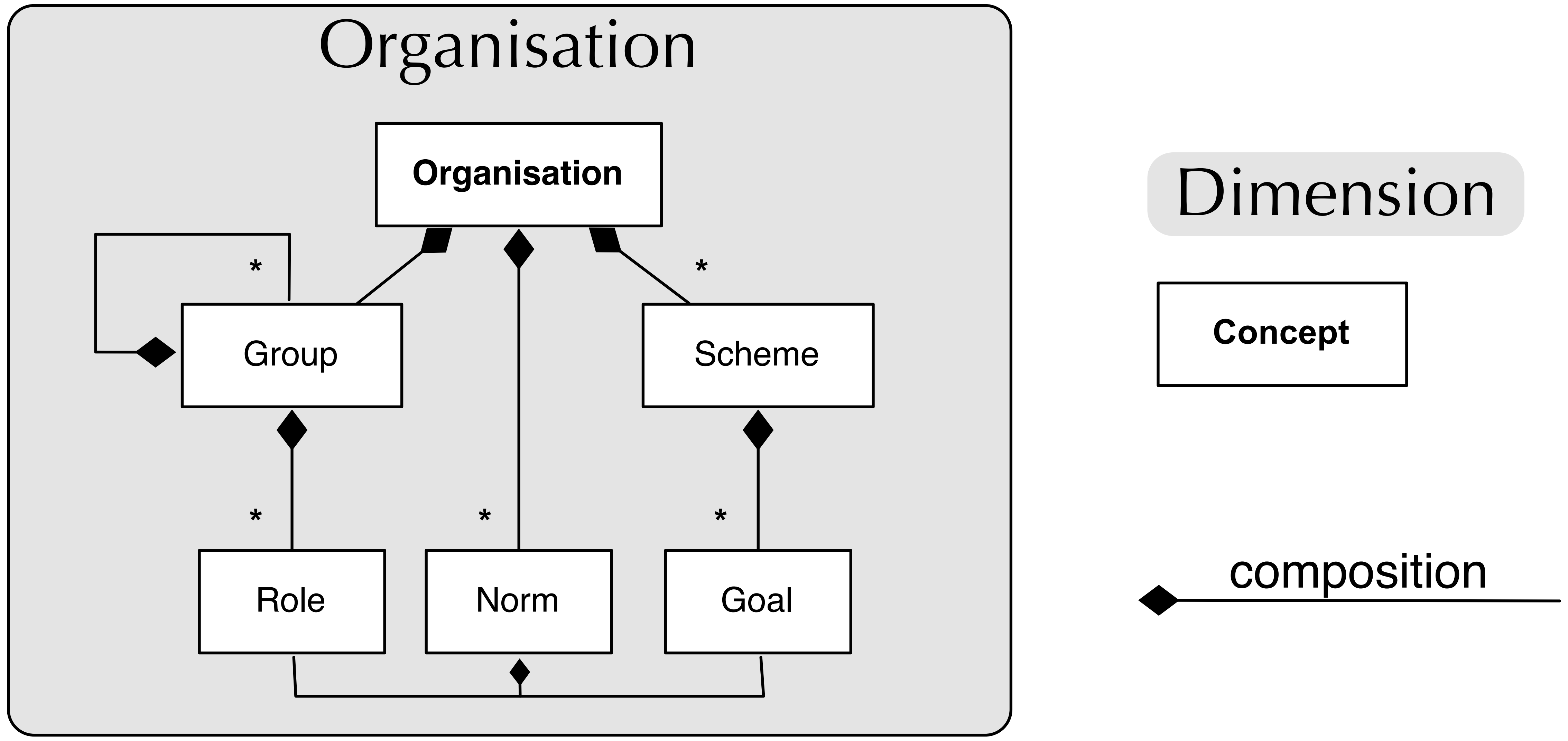


- Organisation as first-class design/ programming abstraction
  - specifying the structure and coordinated behaviour of a ***MAS as a whole***
- JaCaMo organisation
  - roles, links, groups
  - social goals, missions schemes
  - norms
- Tackling MAS-level complexity
  - coordination, openness, regulated autonomy



Simplified Conceptual View ($\mathcal{M}$OISE meta-model [Hübner et al., 2009])

Excerpts from organisation program:

```
<structural-specification>

<role-definitions>
 <role id="auctioneer" />
 <role id="participant" />
</role-definitions>

<group-specification id="auctionGroup">
 <roles>
  <role id="auctioneer"  min="1" max="1"/>
  <role id="participant" min="0" max="300"/>
 </roles>
</group-specification>
</structural-specification>
```

Structural spec.

```
<functional-specification>
 <scheme id="doAuction">
   <goal id="auction">
     <argument id="Id" />
     <argument id="Service" />
     <plan operator="sequence">
       <goal id="start" />
       <goal id="bid"    ttf="10 seconds" />
       <goal id="decide" ttf="1 hour" />
     </plan>
   </goal>
   <mission id="mAuctioneer" min="1" max="1">
     <goal id="start" />
     <goal id="decide" />
   </mission>
```

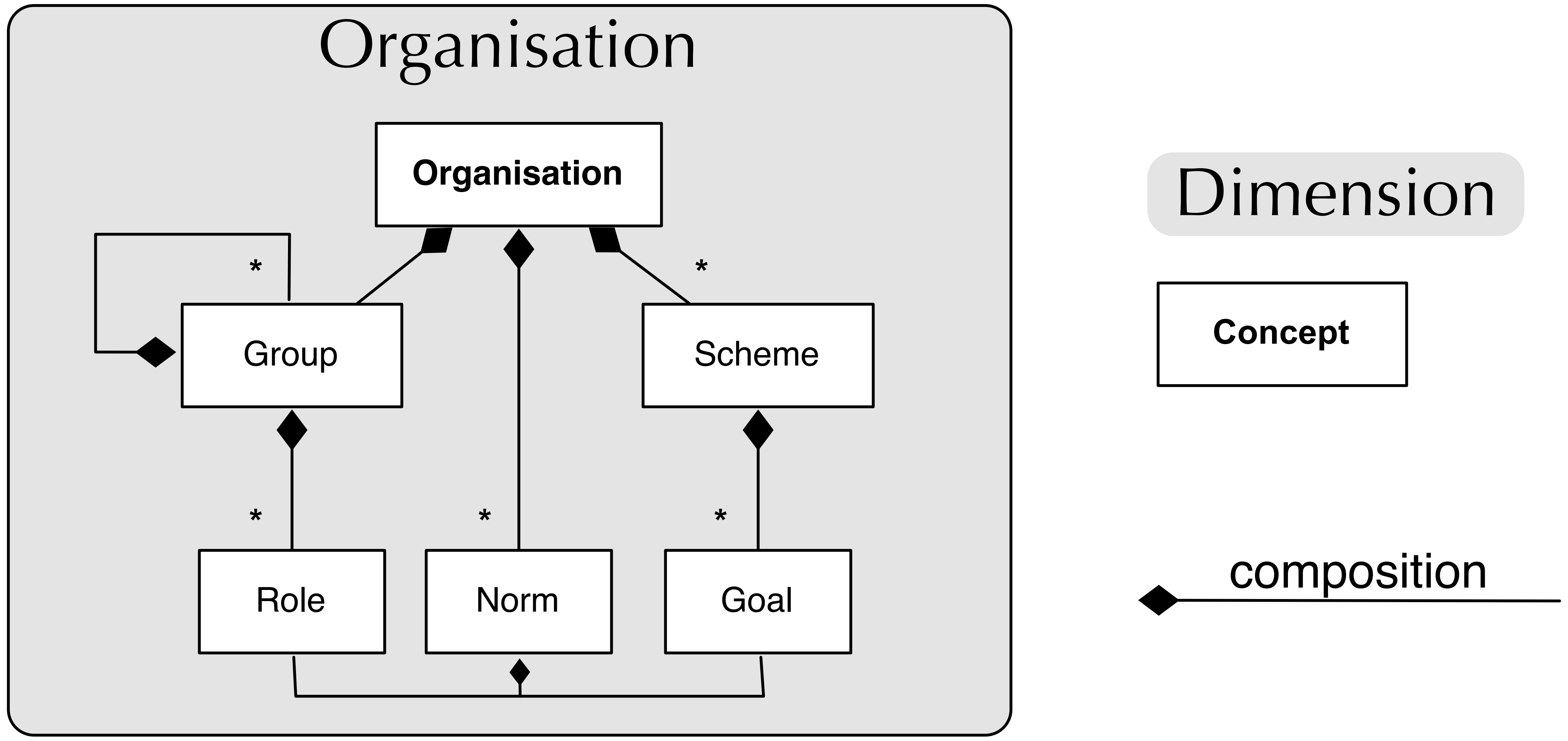
Functional spec.

```
<normative-specification>
  <norm id="n1"  type="permission"
        role="auctioneer"
        mission="mAuctioneer" />
  <norm id="n2"  type="obligation"
        role="participant"
        mission="mParticipant" />
</normative-specification>
```

Normative spec.

```
norm n1 : plays(A, auctionneer, G) ->
  forbidden(A,n1,plays(A,participant,G),
    'forever').
```

program in NPL



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```

Structural spec.

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...
</mission>
```

Functional spec.

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 <norm id="n1"  type="permission"
...
 'forever').
```
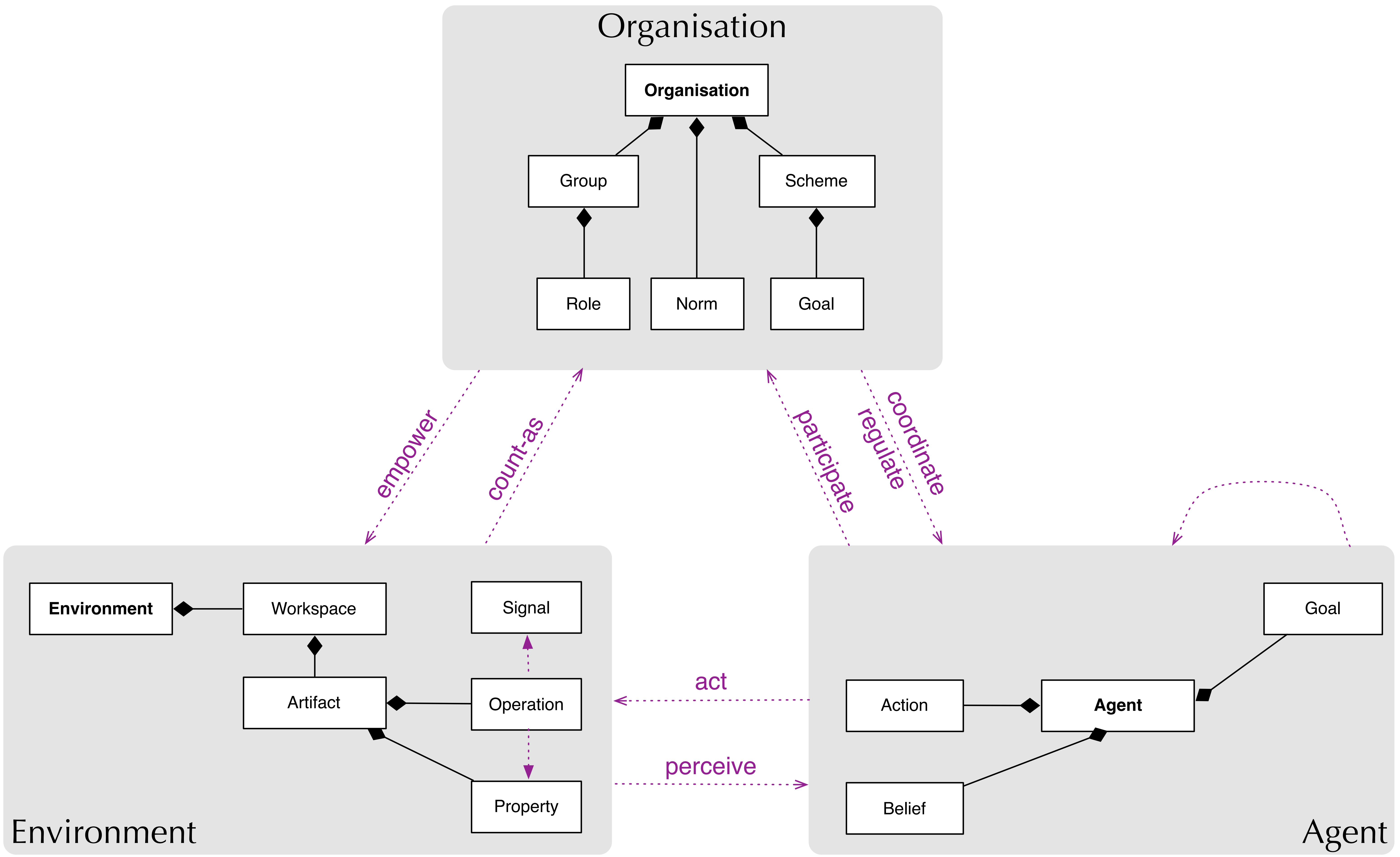

program in NPL

- Explicit representation of the org
  - that agents can inspect, reason about, and change
- Reified at runtime through artifacts
  - that agents can monitor, manage, adapt

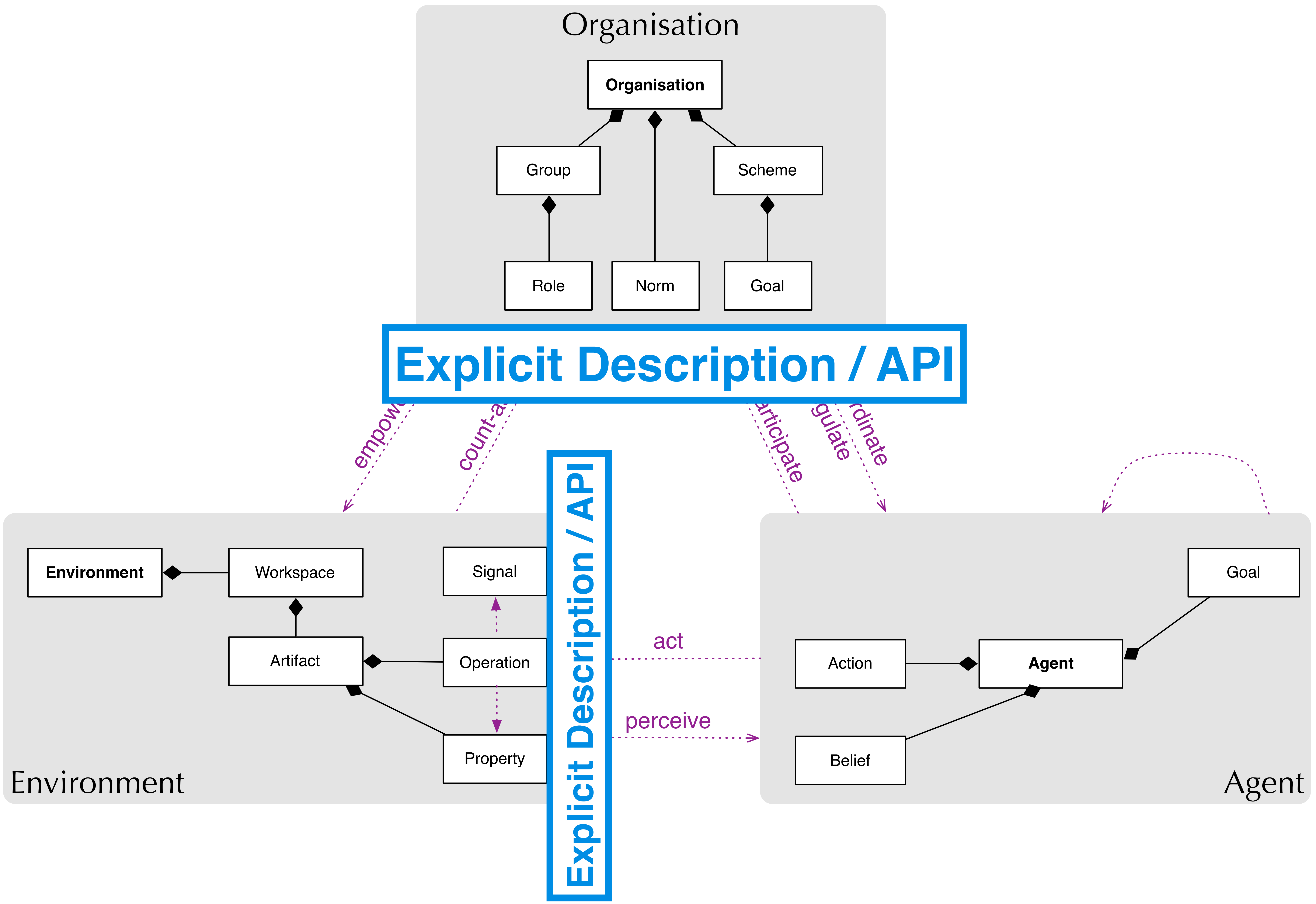
WRAP-UP

WRAP-UP



Organisation
Organisation
Group
Scheme
Role
Norm
Goal
empower
count-as
participate
regulate
coordinate
Environment
Workspace
Signal
Artifact
Operation
Property
Environment
act
perceive
Goal
Action
Agent
Belief
Agent

WRAP-UP


Organisation
Organisation
Group
Scheme
Role
Norm
Goal
Explicit Description / API
Explicit Description / API
Environment
Workspace
Signal
Artifact
Operation
Property
Environment
act
perceive
Goal
Action
Agent
Belief
Agent

POINTS FOR DISCUSSION

- AOP/MAOP for WoX/Hypermedia (?)
  - benefits
  - open issues
- Roadmap?
  - call for action?