Contextualize Agent Interactions by Combining Communication and Physical Dimensions in the Environment

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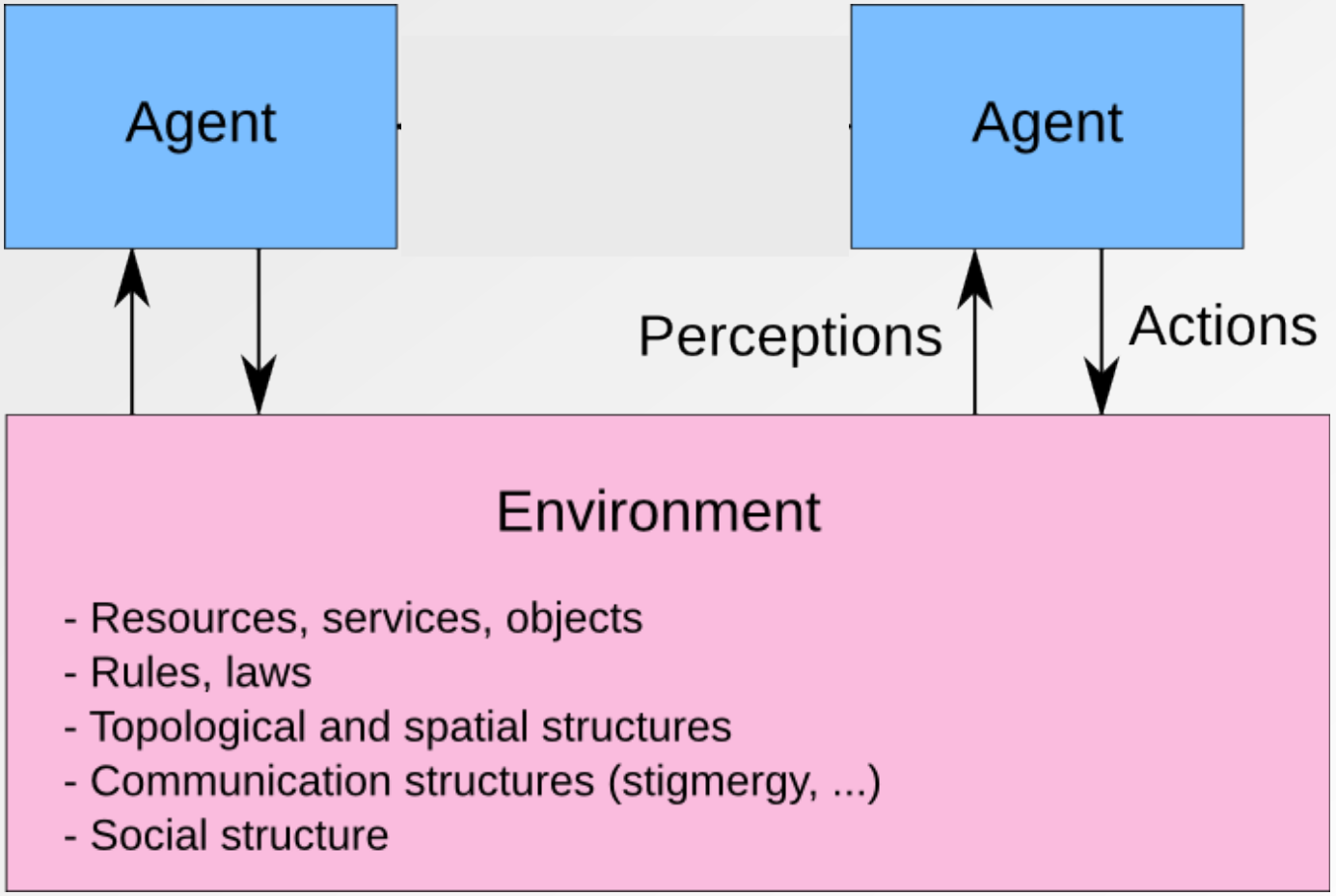
Context: Agents & Environment

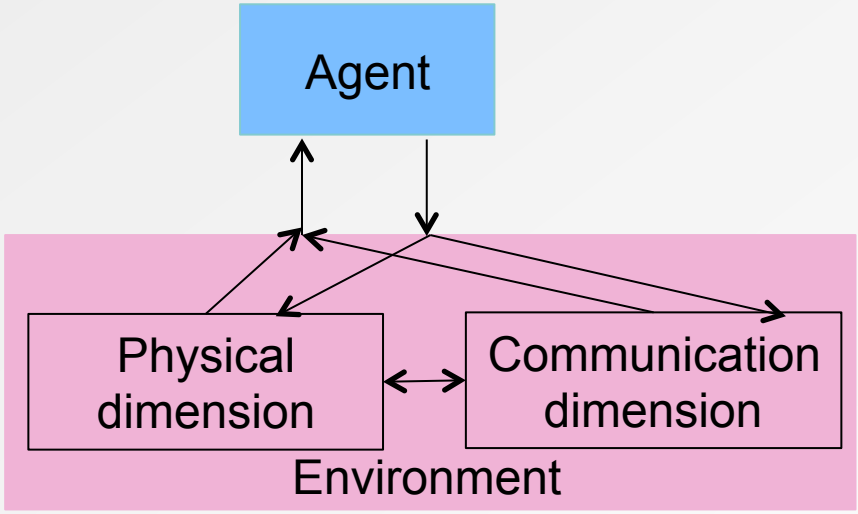


Environment has several dimensions [Odell, 2002]

- **Physical**
  - Principles and processes that govern and support a population of entities
  - Each agent has a body corresponding to its physical representation [Michel, 2004]
- **Communication**
  - Principles, processes and structures to transport information between agents
- **Social**
  - Principles, processes and structures to support coordinated interaction between agents in a communication environment

Problem

- **Hypothesis:** A change of state in a dimension can cause a change in another or several dimensions.
- **Solution 1:** agent as a propagation vector
- **Solution 2:** interactions between dimensions



How to model interactions between the dimensions?

Interactions among Dimensions outside of the agents

- **Multi-dimension diffusion / polymorphism**
  - An event/message can be simultaneously interpreted (differently) by several dimensions.

  e.g.: GPS Alert may change the social status and spatial indicator of dangerousness.
- **Propagation of interactions.**
  - An event/message in a given dimension generates another event/ message in the other dimension.

  e.g.: the detection of physical collision may trigger an emergency message in the communication dimension.
- **Constrained perception.**
  - A perception of an event/message in a dimension may be constrained by the properties associated with the other dimensions.

  e.g.: a traffic light (physical dimension) perceives only emergency vehicles (social status) that are close (physical dimension) to the light.

Approach

- **Modeling based on the SARL, general-purpose agent-oriented programming language.**

- **Major characteristics**
  - Agents are holonic (recursive agents)
  - Extendable interaction model (default is event-based)
  - Separation between the language and the running platform
  - Everything is performed in parallel without effort:
    - agent, behavior, etc.

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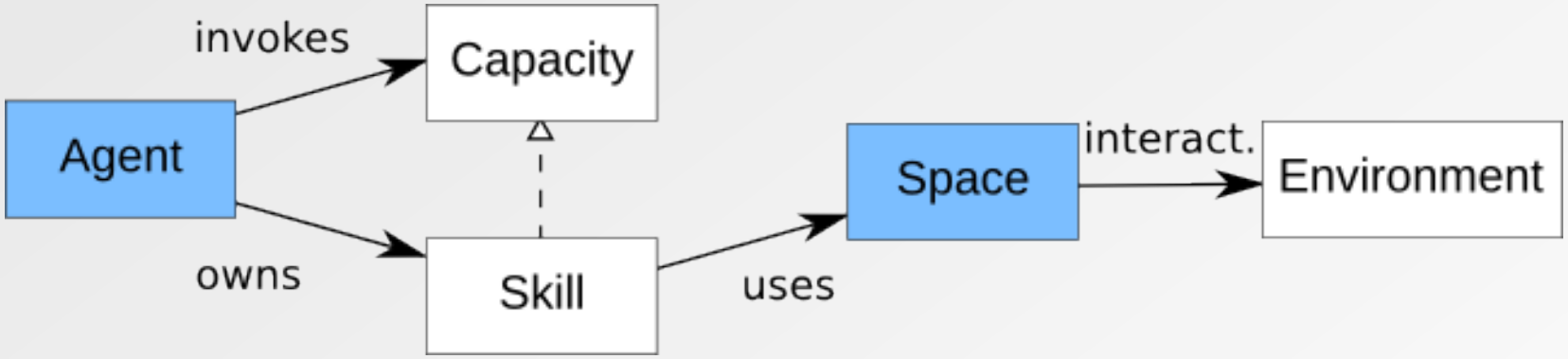
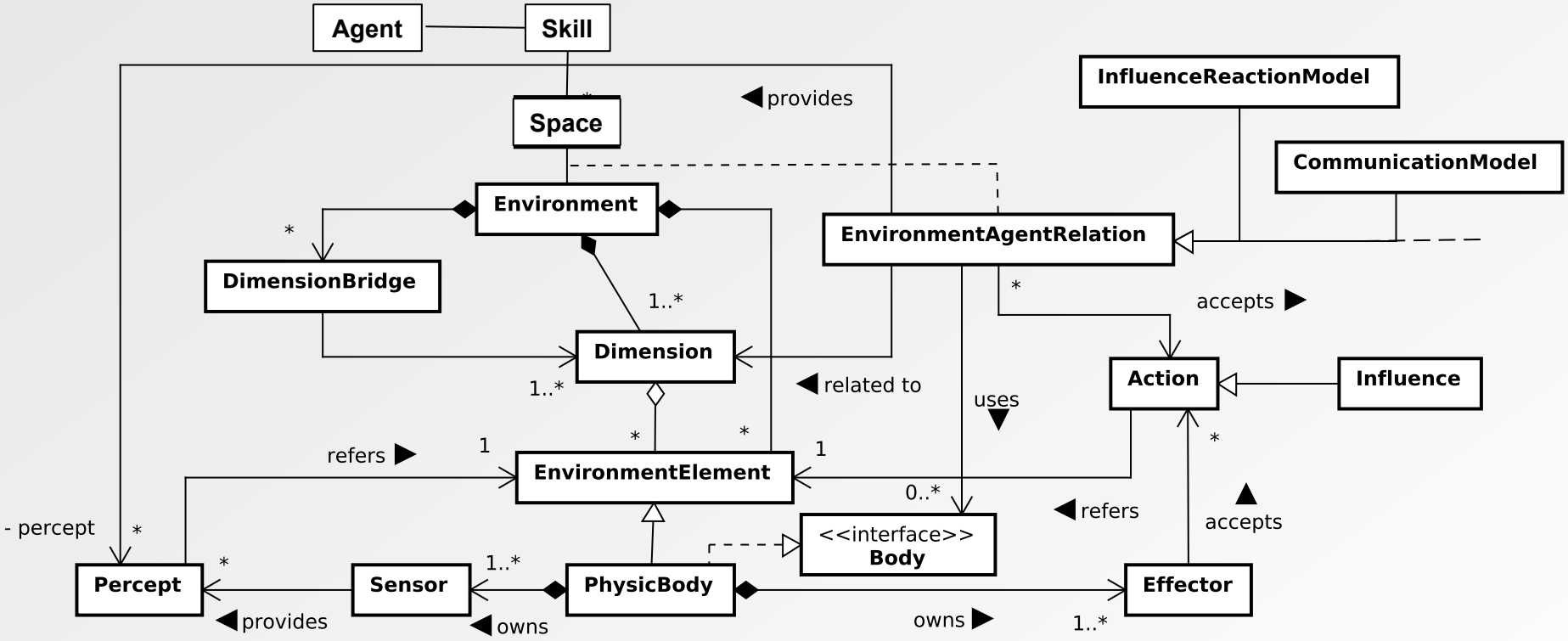
« SARL : a general-purpose agent-oriented programming language. »
Rodriguez S., Gaud N., Galland S. (2014). IEEE/WIC/ACM International Conference on Intelligent Agent Technology, IEEE Computer Society Press, Warsaw, Poland.

SARL Main Concepts



- **Space:** interaction place between *agents* or between agents and their *environment* (e.g. EventSpace EventSpaceImpl)
- **Agent:** autonomous entity with a set of *skills* to realize the *capacities* it exhibits
- **Capacity:** specification of a collection of *actions*
- **Skill:** possible implementation of a *capacity*
  - Skills realized by behaviors mapping a collection of perceptions represented by Events to a sequence of Actions. Event is the specification of some occurrence in a Space that may potentially trigger effects by a listener

Proposal: Environment Model



Environment: Physical Dimension

- Class of systems (real or simulated) in which the agents have an explicit position, and in which the actions and perceptions are also located (situated MAS)

- Properties
  - Contains physical objects
  - Manages the bodies of agents
  - Enforces the laws of the Universe (e.g. the Laws of Physics)
  - Agents interact via a dedicated capacity
  - Agent-environment relationship model: Influence-reaction [Michel,2006]

Environment: Physical Dimension

- "PhysicalSpace" supporting the interaction between agents and the physical dimension
  - Emit influences from a specific body
  - Destroy the body related to an agent

```
space PhysicalSpace {
  def getBodyFactory: PhysicBodyFactory
  def putEnvironment(body: AgentBody,
                     perceptionListener: Agent)
  def influence(body : AgentBody,
                influences : Influence*)
  def destroyBody(body : AgentBody)
}

class PhysicalSpaceImpl extends EventSpaceImpl
                        implements PhysicalSpace {
  var env : Environment
  def influence(body : AgentBody,
                influences : Influence*) {
    for (i : influences) emit(i, env.scope)
  }
  ...
}
```

```
skill RoadEnvironmentSkill
          implements RoadEnvironmentCapacity {
  var body : AgentBody
  def install {
    body = bodyFactory.newInstance
    getSpace(PhysicSpace)
        .putEnvironment(body, owner)
  }
  def influence(inf: influence) {
    getSpace(PhysicSpace).influence(body, inf)
  }
  def uninstall {
    getSpace(PhysicSpace).destroyBody(body)
  }
  ...
}
```

Environment: Communication Dimension

- Exchanges of messages on the Internet

```
space InternetSpace {
  def emit(e : Message, scope : Scope)
  def register(agent : Agent) : Address
  def unregister(agentAddress : Address)
}

class InternetSpaceImpl extends EventSpaceImpl
                        implements InternetSpace {
  val env : Environment
  def emit(e : Message, scope : Scope) {
    e.destination = scope
    super.emit(e, new Scope(env))
  }
}
```

```
event Message {
  var destination : Scope
}

capacity InternetCapacity {
  def emit(e : Message,
           scope : Scope = null)
}

skill InternetSkill
      implements InternetCapacity {
  def install {
    getSpace(InternetSpace)
        .register(owner)
  }
  def emit(e : Message, scope : Scope=null) {
    getSpace(InternetSpace).emit(e, scope)
  }
  def uninstall {
    getSpace(InternetSpace).unregister (owner)
  }
}
```

Combining Dimensions

- **Content**
  - One instance of the models for each environment dimension
  - Rules of interaction between the dimensions, defined with:
    - a predicate p: rule activation condition
    - a function f: actions to perform when the rule is activated

- **Missions**
  - To compute the environment reactions from the agent influences
  - To compute the perceptions for each agent in the physical dimension
  - To propagate messages within the communication dimension

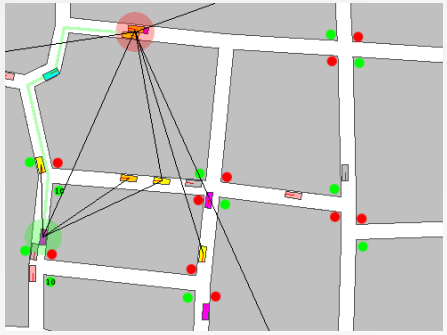
General Behavior of the Environment

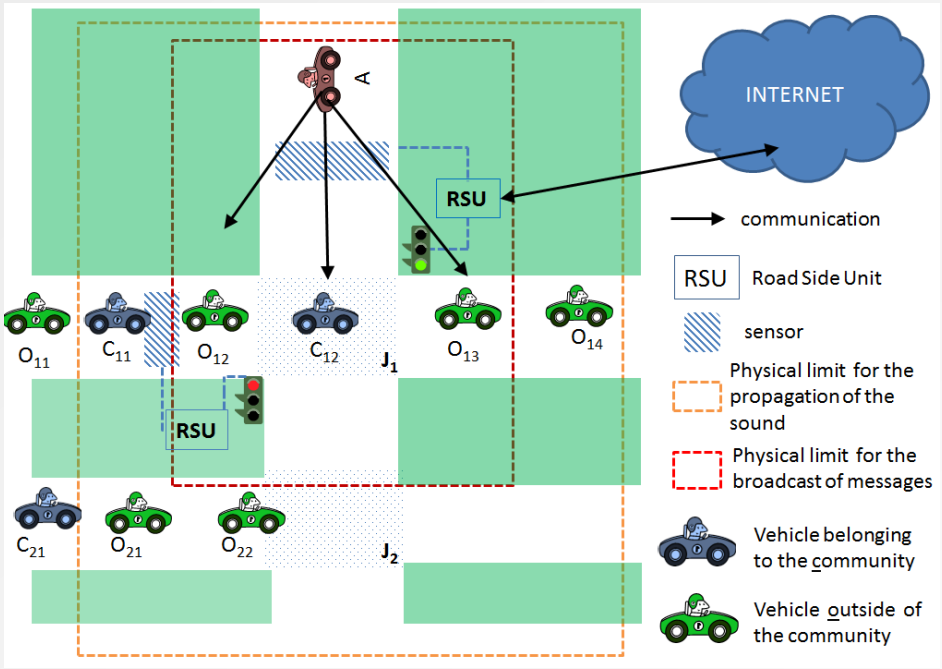
- When receiving an influence, the rules are applied, and the influence is preserved if no rule is deleting it
- When receiving a message, a similar algorithm is applied
- Influences and saved messages are stored for later use in the lifecycle

```
behavior Environment {
  var roads : RoadNetwork
  var physicSpace : space
  var communicationSpace: space
  ...
  on Influence {
    if (applyRules(occurrence, occurrence.object)) { saveInfluence(occurrence) }
  }
  on Message {
    for (participant : this.socialSpace.participants) {
      if (occurrence.scope.matches(participant) && applyRules(occurrence, participant))
      { saveMessage(occurrence) }
    }
  }
}
```

Proof of Concept: Traffic Simulation

- **Principles**
  - Simulation of traffic and car crashes
  - Simulation of the displacements of the emergency cars
  - "Green wave" for emergency cars
- **Dimensions of the environment**
  - Physical: Road network, traffic lights, road sensors
  - Communication: Wireless Network, RSU, Internet

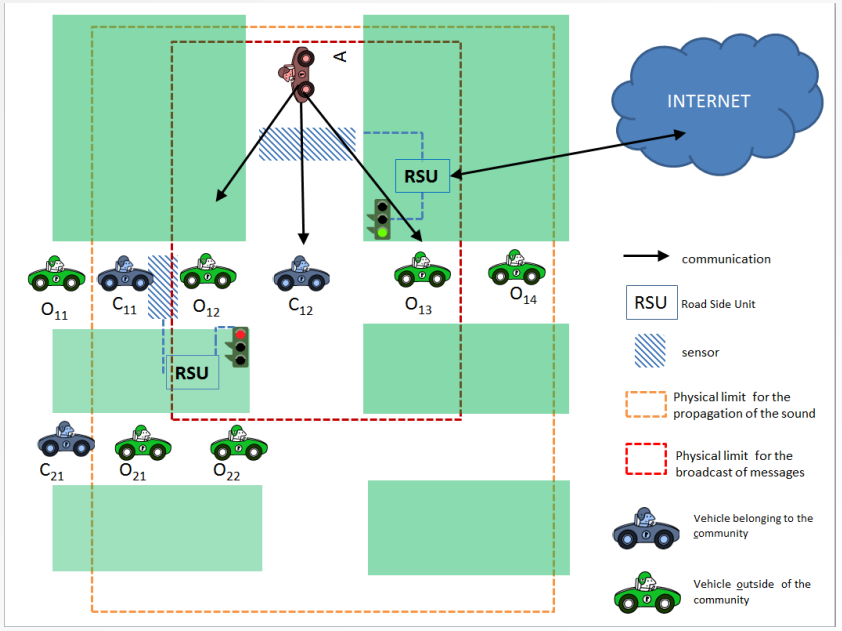




Rule examples (1/3): Interaction in one dimension constrained by the second

- **Agent A broadcasts a priority request within its community**
  - Priority request sent in the communication dimension, but the broadcast is limited according to the position of vehicles to the physical environment by the V2X propagation model

```
rules +=
    [ env, e, o |
      e instanceof PriorityRequestMessage ]
    =>
    [ env, e, o |
      e.scope =
        Scopes.addresses(
            env.roads.vehiclesAtDistance(
                  e.source, env.physicSpace.V2X_distance)
            )
    ]
```

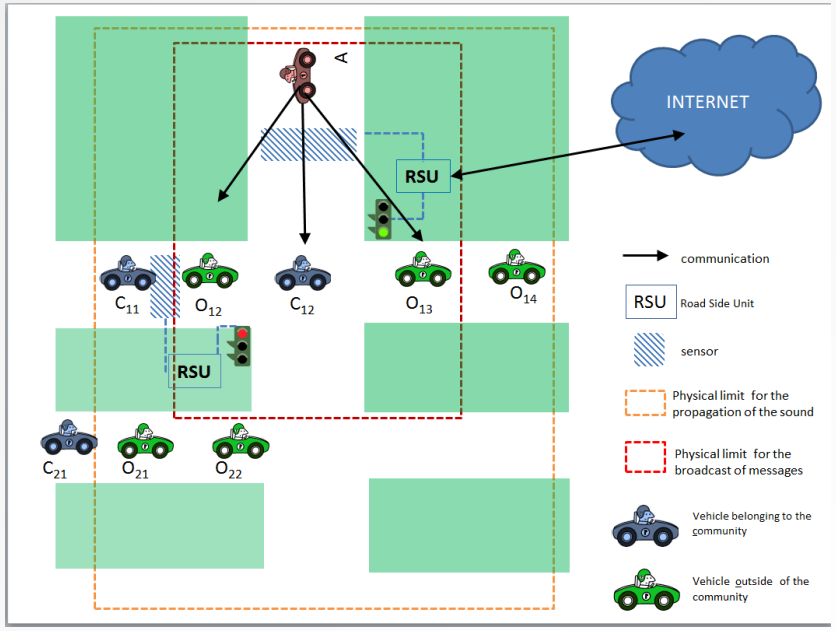


Rule examples (2/3): *same interaction taking different forms in the two dimensions*

- **Agent A sends a priority request (resp. Siren influence) that is transformed into Siren influence (resp. priority request)**

```
rules +=
    [ env, e, o |
       e instanceof Siren ]
    =>
    [ env, e, o |
       env.communicationSpace.emit(
           new PriorityRequestMessage(e.source)
       )
     ]

rules +=
      [ env, e, o |
         e instanceof PriorityRequestMessage ]
       =>
       [ env, e, o |
          env.physicSpace.influence(
             new Siren(e.source)
          )
        ]
```



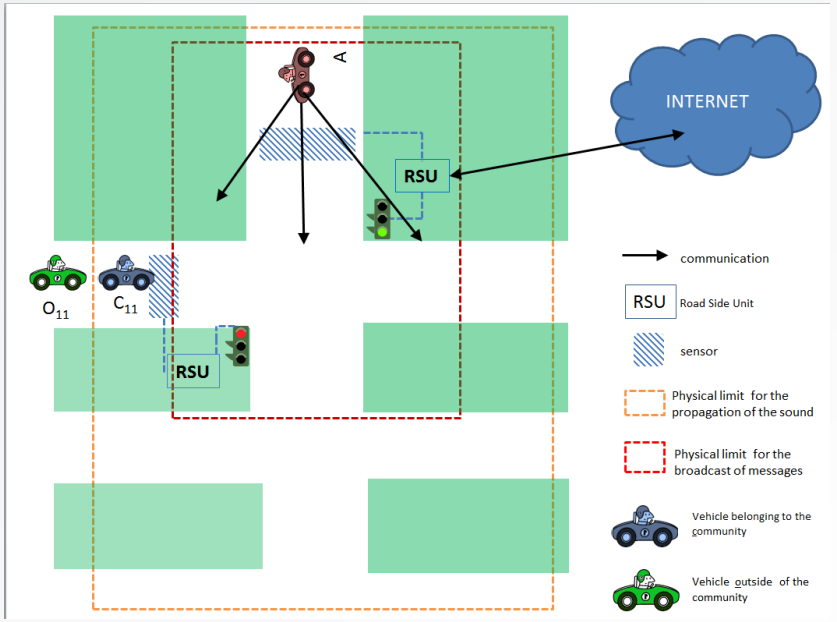
Rule examples (3/3): *interaction initiated in a dimension generates an interaction in the other dimension*

- **A physical collision involves sending an alert message in the communication dimension**

```
rules +=
     [ env, e, o |
          e instanceof PhysicalCollision ]

          =>

     [ env, e, o |
          env.emit( new Alert(e.position))
     ]
```



Conclusions and Perspectives

- **Conclusions**
  - Definition of models of the physical and communication dimensions of the environment
  - Definition of relationships between two dimensions of the environment
  - Environment model combining the two dimensions
  - SARL concepts are suitable for modeling and implementation

- **Perspectives**
  - Refinement of the definition of the interaction between dimensions
  - Compare this approach with a JaCaMo one with Artifacts, Workspaces
  - Possible connections with GAMA, OpenTraffic, MATSIM, etc

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- Rodriguez S., Gaud N., and Galland S. (2014). « SARL : a general-purpose agent-oriented programming language. » IAT 2014. Warsaw, Poland. IEEE Computer Society Press.

SARL: main Concepts (1/2)

- **Multiagent System in SARL**
  - A set of agents interacting together in a set of distributed and shared spaces
- **Main concepts**
  - Agent, Capacity, Skill, Space
- **Main perspectives**
  - **Individual**: Behaviors (Agent, Capacity, Skill)
  - **Collective**: Interactions (Space, Event, etc.)
  - **Holonic**: Holons (Context)

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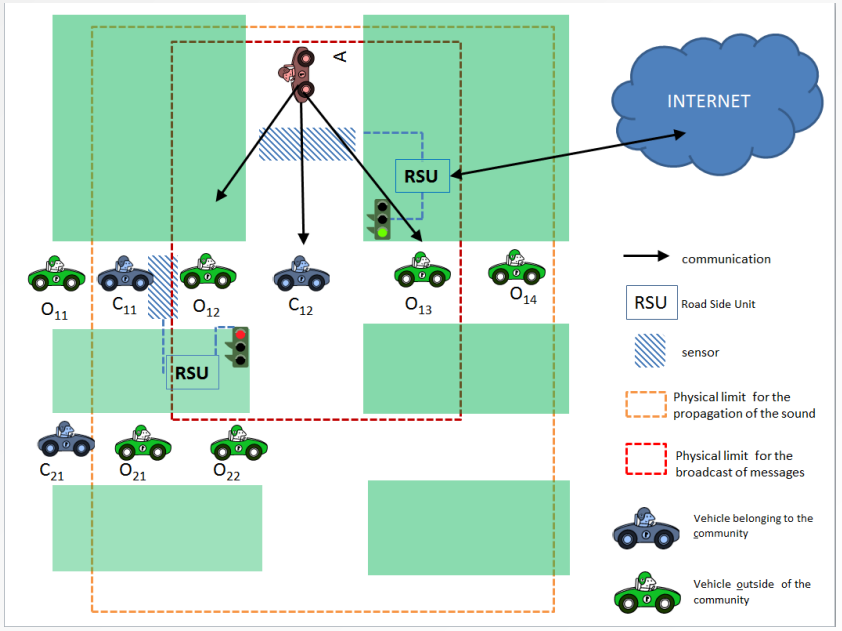
Examples of Rules (1/3)

- **Agent A priority request at traffic lights is accepted by the latter if the vehicle has priority status in the communication dimension**

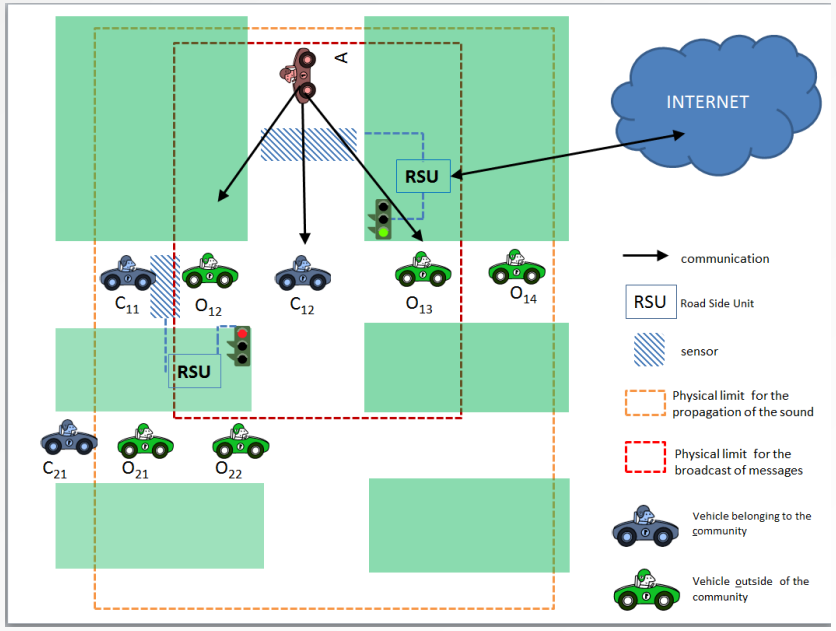
```
rules +=
        [ env, e, o |
          e instanceof PriorityRequest
          && o instanceof TraficLight ]

        ->

        [ env, e, o |
          env.communicationSpace
             .participant(e.source.ID).role
           instanceof PriorityVehicle ]
```



Examples of Rules (2/3)

- **A priority request to a traffic light increases the priorities of the road segments between the requester and the traffic light**

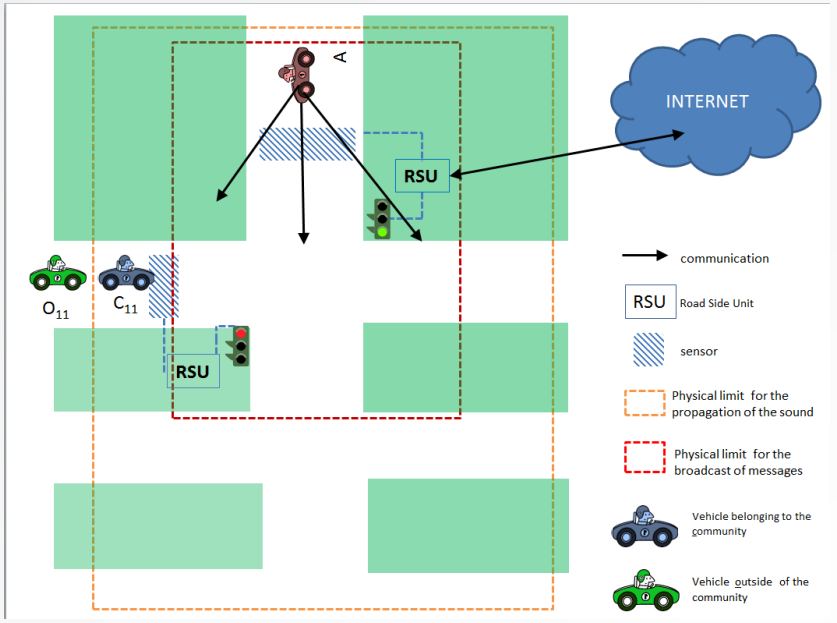
```
rules +=
        [ env, e, o |
          e instanceof PriorityRequest ]

        ->

        [ env, e, o |
          var sp = env.physicalSpace
          var p1 = sp.object(o.ID).position
          var p2 = sp.object(e.source.ID)
                     .position
          for (road : sp.roadsBetween(p1,p2)){
            road.priorityIndex += e.priority
          }
          return true ]
```



Examples of Rules (3/3)

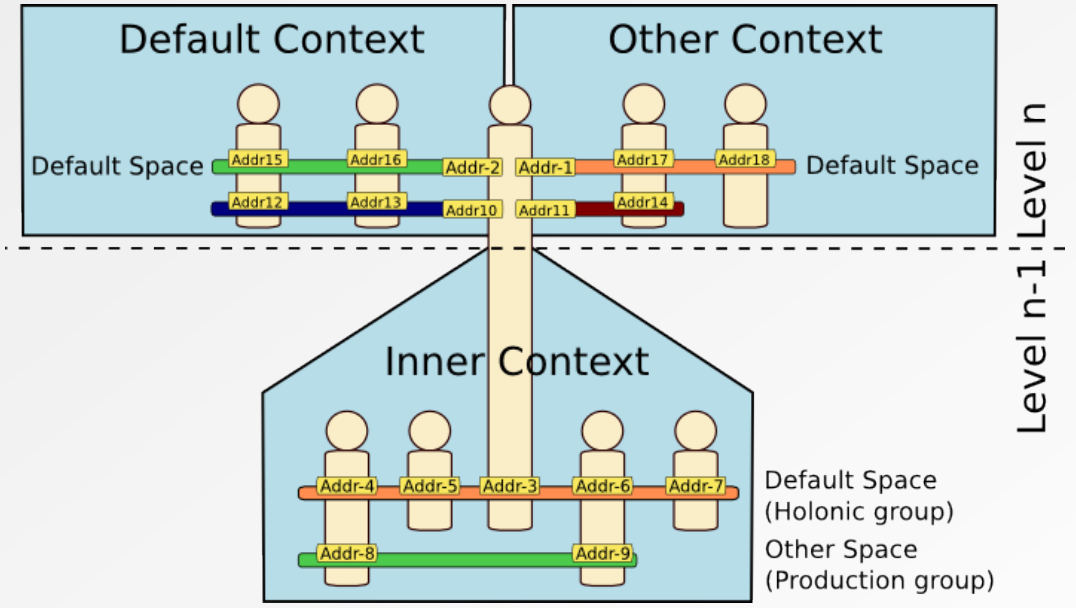
- **A physical collision involves sending an alert message in the communication dimension**

```
rules +=
          [ env, e, o |
            e instanceof PhysicalCollision ]

          ->

          [ env, e, o |
            env.emit( new Alert(e.position))
            return false ]
```



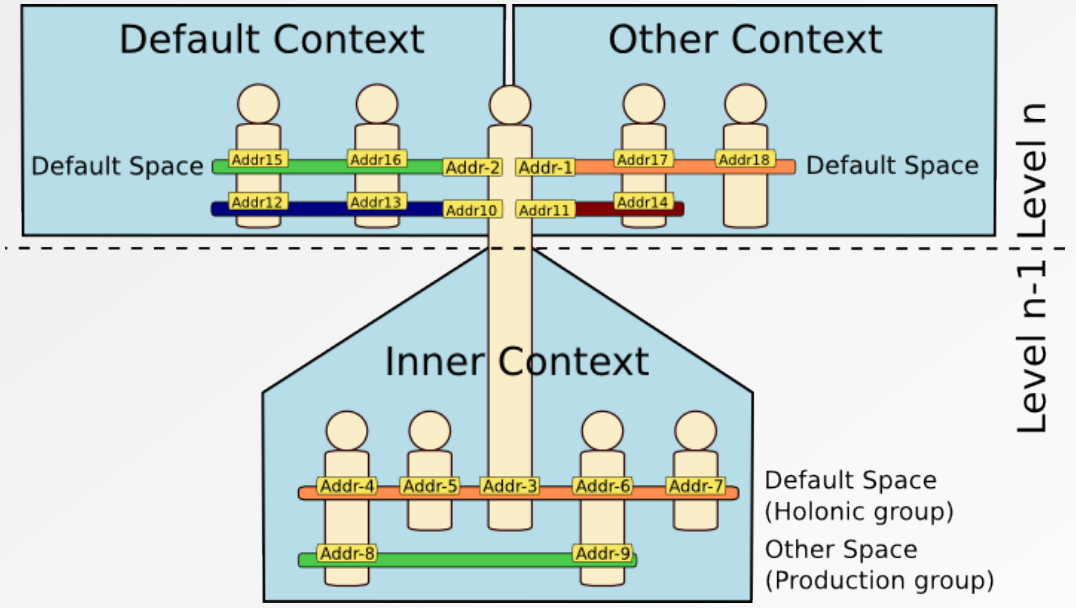
Collective Perspective on the Agent

- Member of its original/default context (where it has been spawn).
- Member of other contexts he joined.
- Interacts within the various spaces of its different contexts.



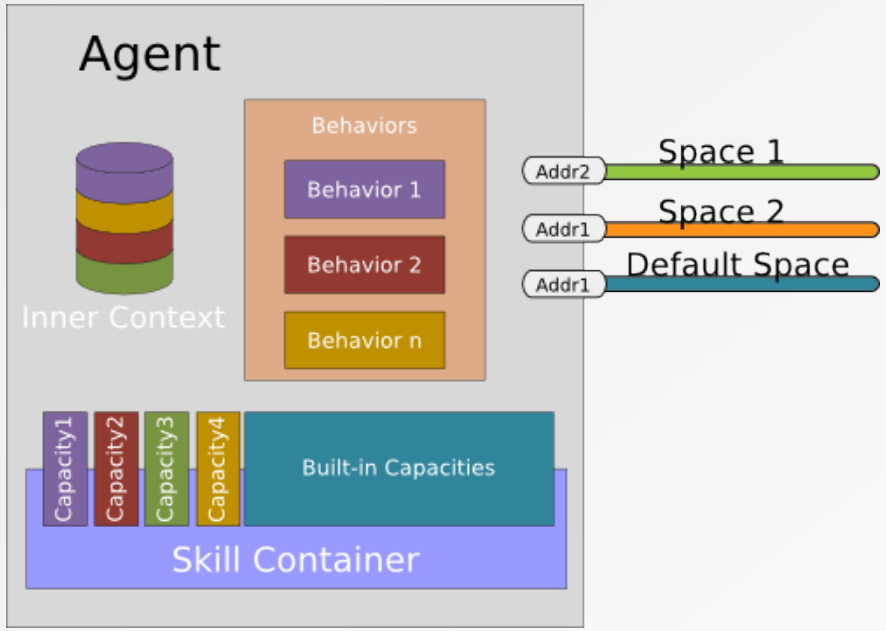
Holonic Perspective on the Agent

- Contains a context to which it belongs to:
  - the inner context
- Participates in the construction of hierarchies of agents.



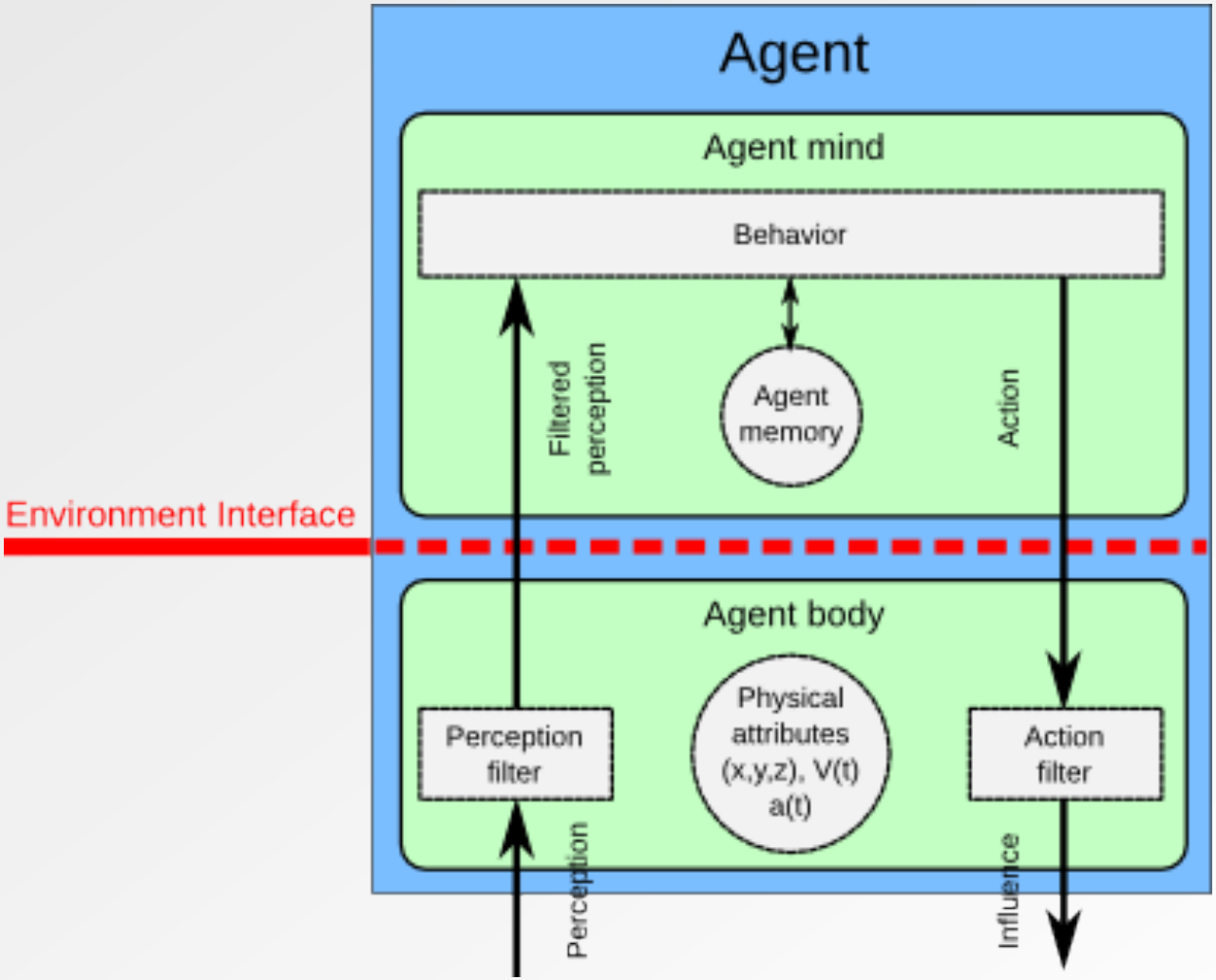
Agent and Capacity Concepts

- **Agent:**
  - An autonomous entity that has specific individual goals and the intrinsic ability to realize some capacities (thanks to its personal skills) [Cossentino, 2010].
  - Has intrinsic skills: communication, implementation of sub-behaviors, etc.
- **Capacity:**
  - Describes actions that could be performed by an agent.




```
agent HelloAgent {
  uses Lifecycle , Schedules
  on Initialize {
    println("Hello World")
    in (2000) [ killMe ]
  }
  on Destroy {
    println("Goodbye World !")
  }
}
```

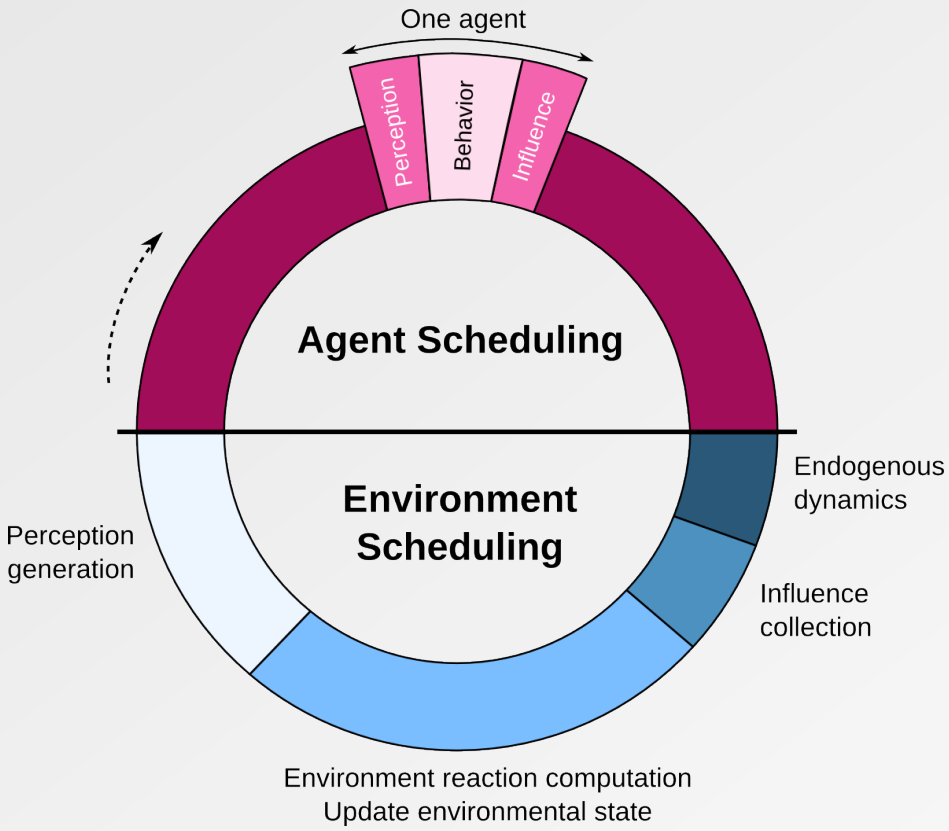
Body-Mind Separation [Béhé, 2014]



Communication Dimension of the Environment

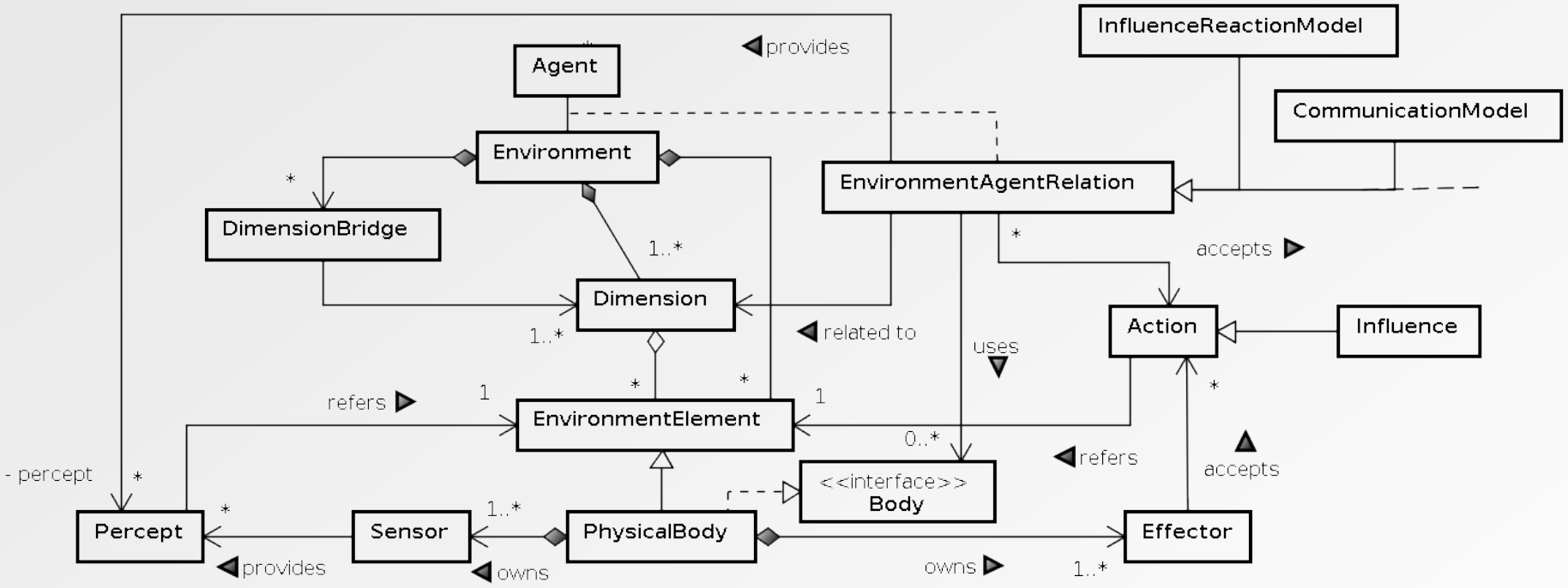
- Existing approaches:
  - Modeling for interaction: events, messages, etc.
  - Social relationships between agents: authoritative, auction, CNP, etc.
- Our approach:
  - Modeling based on the definition of a Space.
  - Use the SARL built-in default template : Event.
- Ability to set specific social environments:
  - FIPA
  - Organizational (MOISE, CRIO, AGR, etc.)

Simulation Lifecycle in the Environment Model: an example




```
behavior Environment {
  var time = 0

  on Initialize {

    every(500.milliseconds)

      (influences.size == participants.size
       || isTimeOut)

      => wake( new SimulationStep )

  }

  on SimulationStep {

    computeEndogenousInfluences
    computePhysicalReactionsFromInfluences

    time = time + 1

    computePhysicalPerceptions
    deliverPerceptions
    deliverMessages

  }
}
```

Model of the Environment



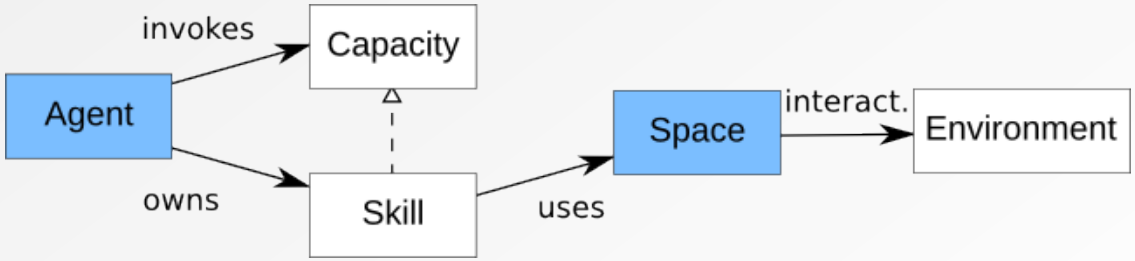
From Physical Environment to Agent: the Perception

- Perception of an agent: set of perceived objects
- Notification of perception changes with an event

```
event Perception {
  var objects : Percept[]
}
```

- Agent reacts to perception change:

```
agent A {
  on Perception {
    for (objectPerception : occurrence.objects) {
      /* Do something with the perceived object */
    }
  }
}
```



Capacities to Act in the Physical Dimension

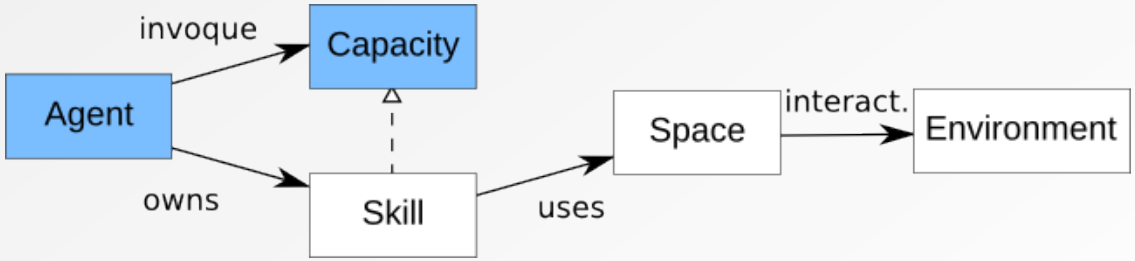
- Definition of the functions available to the agent:

```
capacity AbstractBodyCapacity {
  def getSpeed : double
  def killBody
}
capacity CarCapacity extends AbstractBodyCapacity {
  def getPosition : Pair<Segment, double>
  def getOrientation : Direction
  def accelerate(force : float)
  def turnLeft(angle : float)
  def turnRight(angle : float)
}
capacity PedestrianCapacity extends AbstractBodyCapacity {
  def getPosition : Point
  def getOrientation : Vector
  def move(force : Vector)
}
```

Abstract definition

For car driver

For pedestrian



Agent-Environment Relation : Influence-Reaction Model

- Agents do not directly change the state of the physical dimension.
- They emit influences of different types (motion, etc.) that are used for computing the dimension state's changes.

```
event Influence {
  var object : EObject
}

event Motion extends Influence {
  var linearSpline : double
  var linearShift : double
  var path : Segment[]
}
```

```
event Action extends Influence {
  var name : String
  var parameters : Object[]
}
```