Simulation

Outline

- Introduction
- Multiagent-based Simulation approach
- Multiagent simulation platform
- Turtlekit

Introduction

Simulation

- “*The process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behaviour of the system or of evaluating various strategies (within the limits imposed by a criterion or a set of criteria) for the operation of the system.*” (Shannon 1976)

- “*Simulation is the discipline of designing a model of an actual or theoretical physical system, executing the model on a digital computer, and analyzing the execution output*” (Fishwick 1994)

Model

- “To an observer B, an object A is a model of an object A to the extent that B can use A to answer questions that interest him about A. “ [Minsky, 1965]

R. E. Shannon. Simulation modeling and methodology. In Proc. of the 76 Bicentennial Conference on Winter Simulation, pages 9-15, 1976.

P. A. Fishwick. Computer simulation : Growth through extension. In Society for Computer Simulation, pages 3-20, 1994

M. L. Minsky. Matter, mind, and models. In Proc. of the Intern. Federation of Information Processing Congress, vol. 1, pages 45-49, 1965.

Simulation

Introduction

- **Simulation supports**
  - Understanding, Exploration, Clarification
    - to understand the behavior of the reference system thanks to a model that is considered as a miniature reproduction of the reference system.
  - *Validation, Assessment, Verification*
    - to test an hypothesis of the reference system, to validate or to certify the underlying theory.
  - Control, action, control
    - to support a decision process or a control that will influence the state of the real reference system.
  - Forecast, Prediction, Anticipation
    - to predict the possible evolutions of the reference system following evolutions or disturbances.
  - *Communication, Formation, Visualization*
    - to show and share the model of the dynamic of the reference system.

Multiagent-based Simulation approach

Fishwick

- The *model design* associates the real system with a representation of this system (*the model*).
  - This model is built from real observations (objective) or knowledge (subjective).
  - Data are usually formalized using formal semantics or mathematical logic to reduce ambiguities as much as possible.
  - It is then converted to algorithms,
- The *model execution* phase is the processing of the algorithm to produce numerical outputs.
- The *execution analysis phase*, deals with the analysis and confrontation of the results of the program with the behaviors observed in the model.

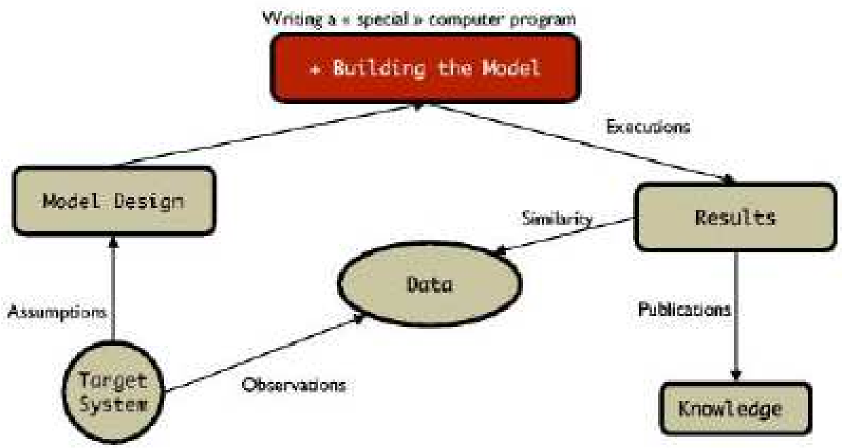
Fishwick, P.: Computer simulation: growth through extension. IEEE Potential February/ March (1996) 24 to 27

Drogoul, A., Vanbergue, D., & Meurisse, T. (2003). Multi-agent based simulation: Where are the agents?. In *Multi-agent-based simulation II* (pp. 1-15). Springer Berlin Heidelberg.

Simulation

Methodologies

- **Gilbert and Troitzsch**
  - Refine the Fishwick proposal with the addition of the model building phase
  - The initial model is written into a computer program: the operational model
    - Adaptation to the simulator
    - There are both operational models and Simulators.
    - The differences between models introduces bias.



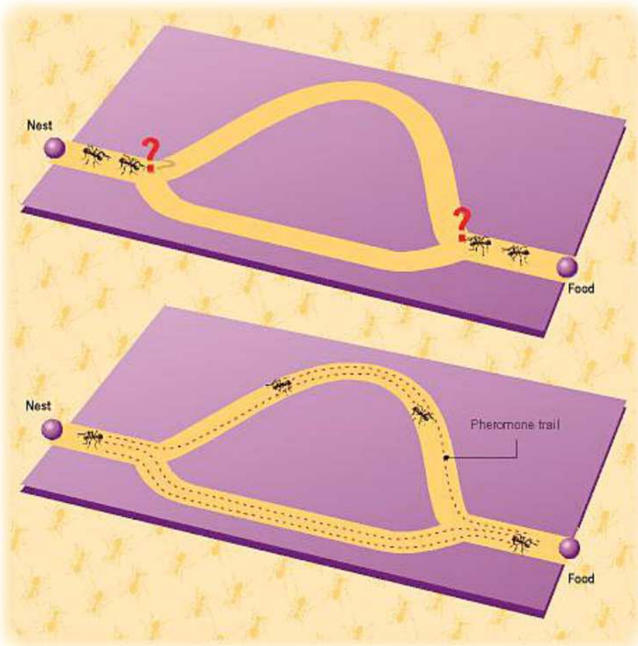
Drogoul, A., Vanbergue, D., & Meurisse, T. (2003). Multi-agent based simulation: Where are the agents?. In *Multi-agent-based simulation II* (pp. 1-15). Springer Berlin Heidelberg.

Gilbert, N., Troitzsch, K.G.: Simulation for the Social Scientist. Open University Press (1999)

Multiagent-based Simulation approach
bottom-up modeling approach

- **Microscopic level: simulation of the behavior of the components of the real system.**
  - The components: the agents
  - Their relation: interaction and organization at a micro level.
- **Macroscopic level: Observation, Analyze of properties of the multiagent system.**

- **Example: Ants**
  - Micro level: ants are agents which put pheromones in the environment
  - Macro level: the shortest path



Multiagent-based Simulation approach overview

- **A Multiagent-based Simulation (MABS) is a microscopic simulation model**
  - *A Multi-agent system*: the multiagent model of an actual or theoretical physical system
  - *Simulation*: controls of the evolution of the model in time.

- **Advantages**
  - MABS supports
    - Multi-level modeling:
      - Different models of “individuals”: from simple entities to more complex ones.
      - Different levels of representation: “individuals” and “groups” within an unified conceptual framework.
    - The simulation of complex systems:
      - Structure preserving modeling of the simulated reality,
      - simulation of proactive behaviors,
      - Parallel computations,
      - Dynamic simulation scenarios
- **Limits**
  - Computation costs

Multiagent-based Simulation approach
Contributors

- **The Thematician (expert of the domain)**
  - *Role*: Defines the intention of the simulation process.
  - *Result*: the *domain model* which describes the multiagent model of the reality. The agents are informally associated to the components of the system and their relations are identified (interaction, organization).

- **The modeler**
  - *Role*: He translates the knowledge of the thematician.
  - *Result*: the *design model* where the agents are a refinement of the agents in the *domain model*. Their properties are expressed using concepts taken from multiagent domain (behavioral model, communications, …)

- **The Computer Scientist**
  - Role: He designs the operational model and writes the computer program.
  - Result: the computational system where agents are computational agents.

Drogoul, A., Vanbergue, D., & Meurisse, T. (2003). Multi-agent based simulation: Where are the agents?. In *Multi-agent-based simulation II* (pp. 1-15). Springer Berlin Heidelberg.

Multiagent simulation platform

Multiagent, simulation platforms

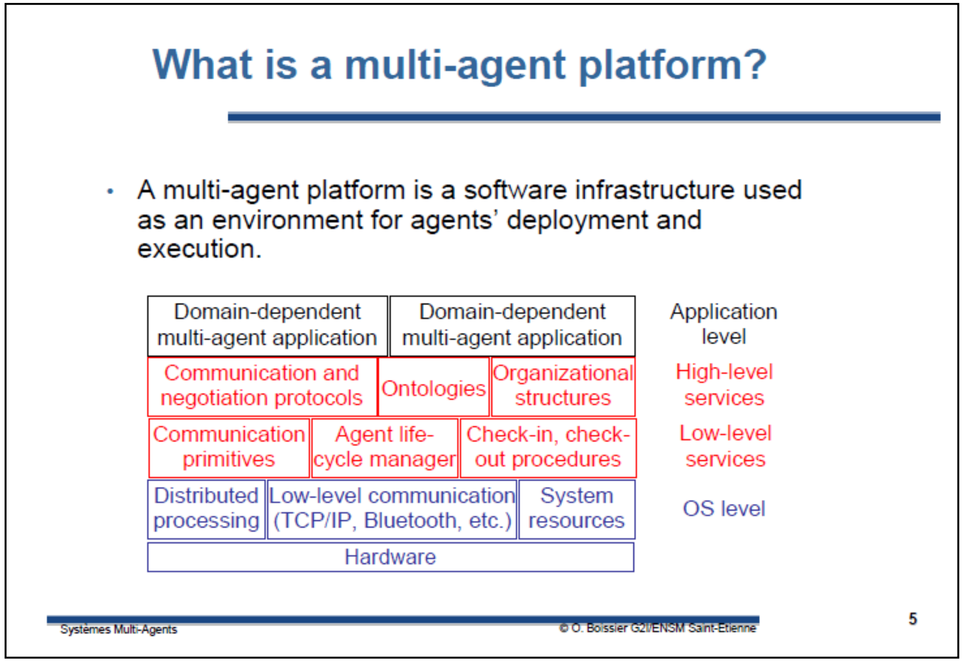
Typology

- **The operational, simulated model can be executed on a**
  - Generic multiagent platforms
    - *Advantage*: the computer scientist knows his environment, i.e. the platform and the related multiagent model.
    - *Limit*: The platform must be adapted (or not) to support the simulation,
    - *Example*: JASON, JADE (Tapas, PlaSMA), MASH, MADKIT (Turtlekit)
  - Generic simulation platforms
    - *Advantage*: the computer scientist can use the same environment for different design models.
    - *Limit*: a new operational model has to be built for each new simulations.
    - *Example*: MASON, SWARM, GAMA, CORMAS, TURTLEKIT, REPAST, NETLOGO, …
  - specialized simulation platforms
    - *Advantage*: some parts of the operational model can be already available.
    - *Limit*: adaptation to a new platform.
    - *Example* (traffic simulation platform): Archisim ,MATSim, MITSIMlab, …

Multiagent, simulation platforms

Components

- **Components of a multiagent platform**



- **A scheduler**
  - A temporal model: discrete, continuous, event
  - A scheduling policy
    - Synchronization of agent evolution
    - Simulation of the simultaneity

Temporal models

Discrete time model

- Time advances in discrete step, which are integer multiples of some basic period such as 1 second, 1 day or …
- If the state at time *t* is *q* and the input time *t* is x, then the state at time t+1 will be δ(q,x) and the output y at time t will be λ(q,x)
  - δ is called the state transition function
  - λ is called the output function

Discrete Time Simulation

$T_i = t_i$, $T_f = t_f$
$x(0) = v_0, \ldots, x(9) = v_9$
$q(0) = q_0$
$t=T_i$
while ($t <= T_f$) {
    $y(t) = \lambda(q(t),x(t))$
    $q(t+1) = \delta(q(t),x(t))$
    $t = t+1$
}

Zeigler, B. P., Praehofer, H., & Kim, T. G. (2000). *Theory of modeling and simulation: integrating discrete event and continuous complex dynamic systems*. Academic press.

Discrete event models

- appropriate for those systems for which changes in system state occur only at discrete points in time.
- A discrete points in time is called an event.

Discrete Event Simulation

1. Initialize the state variables
2. Initialize the ‘collection of pending events’
3. Initialize the simulation clock
4. while (there are pending events to be handled){

   Remove the pending event (E) with the smallest timestamp (t)

   Set simulation clock to that time t

   Execute the event handler for event E

   }

Scheduler

Multiagent scheduler

scheduling algorithm based on a continuous temporal model

```
T duration of the simulation
time = System.time();
T = time + T
Agents= {agents of the simulation};
For (a: agent)
      activate(a)
while (time < T)
   time = System.time();
```

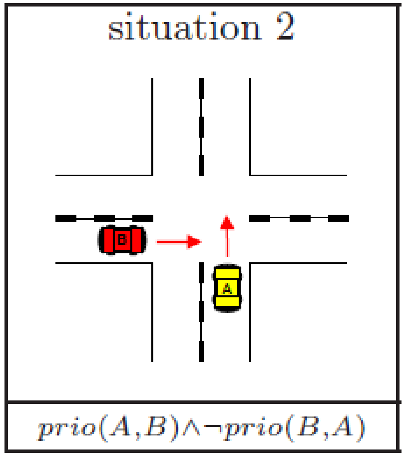
scheduling algorithm based on a discrete temporal model

```
T duration of the simulation
time = 0;
Agents= {agents of the simulation};
while (time < T){
    For (a: Agents){
      \\activate(a)
         a.ContextComputation()
         a.DecisionProcess()
        a.actionProcessing()
     }
    time++
}
```

Scheduler

Simultaneity problem

- **Discrete simulation**
  - Let *t* be the simulation time value and $a_i(t,q(t))$ the action of the i^{th} agent following the current state of the simulated system q(t)
  - How to ensure that q(t) will be the same for a_i and a_{i+1} since $a_i(t,q(t))$ modifies the current state



Dealing with Multi-Agent Coordination by Anticipation: Application to the Traffic Simulation at Junctions.
A Doniec, S Espié, R Mandiau, S Piechowiak - EUMAS, 2005

Simultaneity problem

Solution

- **No solution**
  - The most current solution,
  - The action of an agent should not change the world in an important way. The micro coordination problems resulting of the scheduling process are not taken into account.
  - The consequences of this choice have to be taken into account

- **The scheduling policy**
  - The activation order of the agents is randomized
  - If the number of agents and simulation steps are important then no agent should be advantaged.
  - If the simulation must be replayed, the random process has to be taken into account by the simulation model.

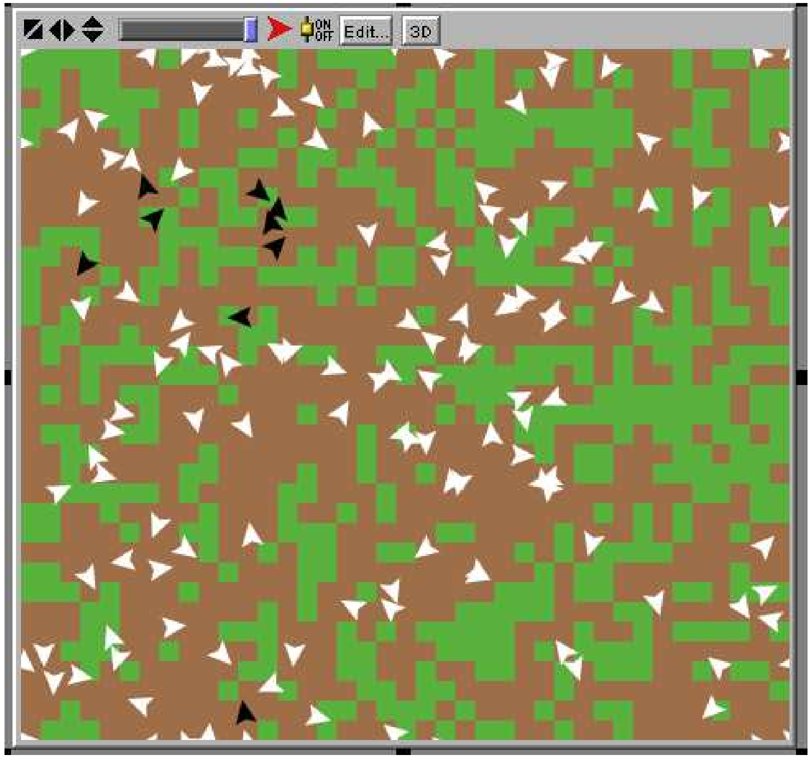
- **A dedicated mechanism**
  - The agents are activated in the same simulation state and the antagonism between their action is resolved by a decision process.
  - Influence / reaction model: The agents do not directly act in the simulation but emit influences that are validated by the decision process.

Ferber, J., & Müller, J. P. (1996, December). Influences and reaction: a model of situated multiagent systems. In *Proceedings of Second International Conference on Multi-Agent Systems (ICMAS-96)* (pp. 72-79).

Turtlekit

Illustrative Example

- **Prey and Predators**
  - A multiagent model
    - Environment: a grid
    - Prey: reactive agents who avoid the predators
    - Predator: communicative agents who coordinate to catch the preys
    - When three predators are around a prey, this last one die
  - Simulation
    - A scheduling process
      - Temporal model
      - Activation process

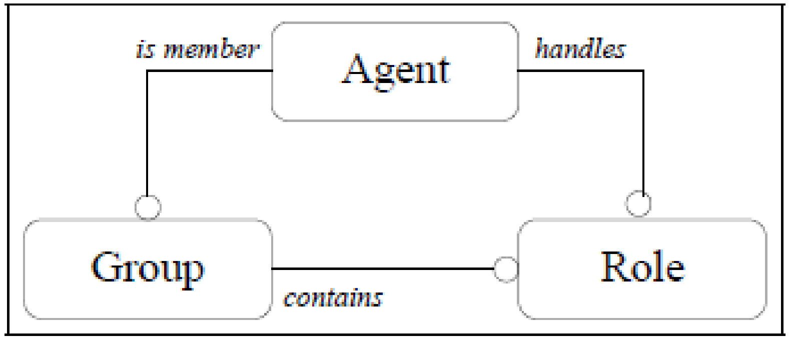


MINES Saint-Étienne

Turtlekit

overview

- **Plugin of the Madkit platform dedicated to the simulation**
  - Supports the Madkit organizational model: the AGR model



– Interaction are regulated by the organizational model
  - The communications are regulated following the organizational model
  - The perception can be implemented following the organizational model

MINES Saint-Étienne

Turtlekit

overview

- **Supports the simulation of heterogeneous multiagent model**
  - The superclass ***AbstractAgent*** contains the methods for the
    - Management of the life cycle:
      - activate(); end(); launchAgent(...) ;killAgent(...)
    - Communication management:
      - broadcastMessage(…); sendMessage(…) ; nextMessage(); isMessageBoxEmpty(); receiveMessage(Message m);
    - Organization management
      - createGroup(); leaveGroup(); requestRole() ; getRoles(); isGroup(…); getAgentsWithRole()
- **Example**

```
public void setup(){
    playRole("predator");
    ACLMessage m = new ACLMessage("INFORM",“I’m a new predator");
    broadcastMessage("Turtlekit","HUNT","predator",m);
}
```

Turtlekit

overview

- **Class Agent**
  - Inherits of the superclass AbstractAgent
  - Implements the Runnable Interface
    - Methods “to control” the its thread
      - exitImmediatlyOnKill() ; live() ; pause(int t) ; run().
    - Additional methods for communications
      - waitNextMessage() ; waitNextMessage(long timeout)

- **Example**

```
public void live()  {
        while (true)        {
          Message m = waitNextMessage();
          if (m instanceof ACLMessage)
                handleMessage((ACLMessage)m);
        } }
```

Turtlekit

overview

- **Class Turtle**
  - Inherits of the superclass AbstractAgent
  - Do not implements the Runnable interface
  - Additional methods
    - Related to the simulation process
      - setup, activate, end
    - A turtle is a situated agent, he has methods to
      - To be located in the environment
        - setX, xcor, dx, distance, towards, getHeading,
      - To move in the environment
        - moveto, fd, home, turnLeft, turnRight
      - To perceive the environment
        - countTurtlesAt, countTurtleHere, turtlesAt, turtlesHere
- **Example**

```
public void setup(){
        playRole("predator");
        randomHeading();
        setColor(Color.red);
        if (countTurtlesHere()>0)
                fd(1);
}
```

```
private boolean catched(){
int cpt=0;
for(int i=-1;i<=1;i++)
   for(int j=-1;j<=1;j++)
     if (! (i==0 && j==0) ){
        Turtle[] tur = turtlesAt(i,j);
         if (tur!= null && tur.length>0 &&
tur[0].isPlayingRole("predator"))
cpt++;
}
if (cpt>3) return true;
return false;
}
```

Simulation

Pseudo activation algorithm

time = 0; Turtle = {turtles of the simulation}; T duration of the simulation

While (time < T)

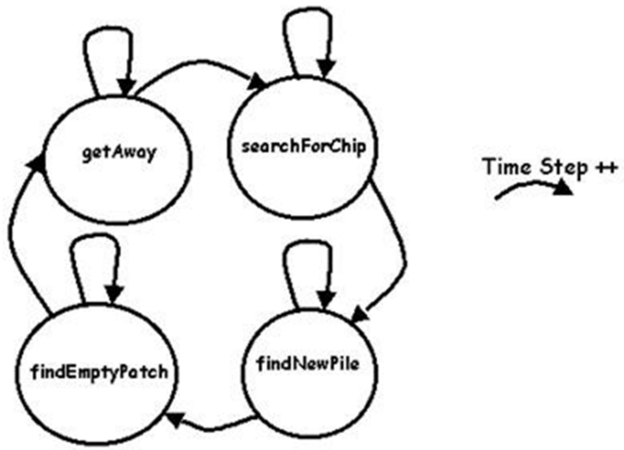
    For (t: Turtle)

        currentAction = scheduler.getCurrentActionTurtle(t)

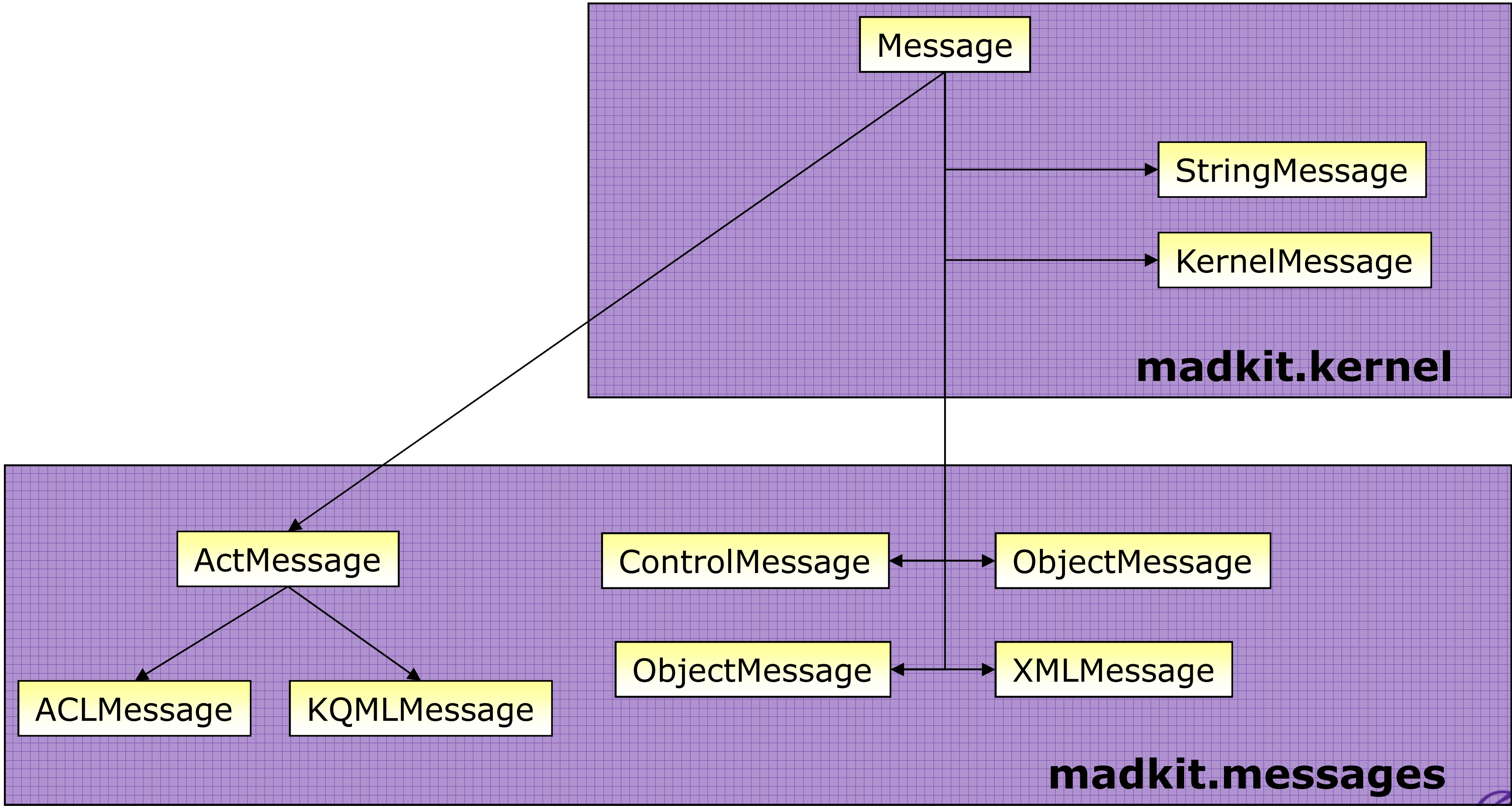
        nextAction = activate(t,currentAction)

        scheduler.setCurrentActionTurtle(t,nextAction)

time++



Message


Message
StringMessage
KernelMessage
madkit.kernel
ActMessage
ControlMessage
ObjectMessage
ACLMessage
KQMLMessage
ObjectMessage
XMLMessage
madkit.messages

Message

- **Message**
  - getCreationDate; getReceiver; getSender
- **ActMessage**
  - getAction; getContent; getFieldValue; getInReplyTo; getObject; setContent; setField; setInReplyTo; setObject
- **ACLMessage**
  - getAct, getPerformative; setPerformative; getReceivers;removeReceiver;clearAllReceiver.