Simulation

Outline

Introduction

Simulation

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.

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

Methodologies

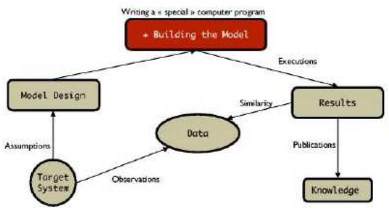
- **Fishwick**
  - The *model design* associates the real system with a representation of this system (*the model*).
    - This model is built from real observations (objective) or knowledge (subjective).
    - Data are usually formalized using formal semantics or mathematical logic to reduce ambiguities 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.

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.

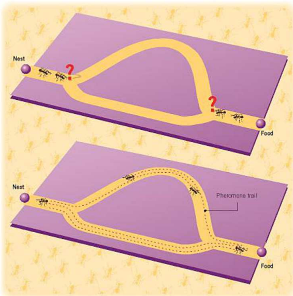


Drogoul, A., Vanbergue, D., & Meurisse, T. (2003). Multi-agent based simulation: Where are the agents?. In *Multi-agent-based simulation II* (pp. 1-15). Springer Berlin Heidelberg.

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.

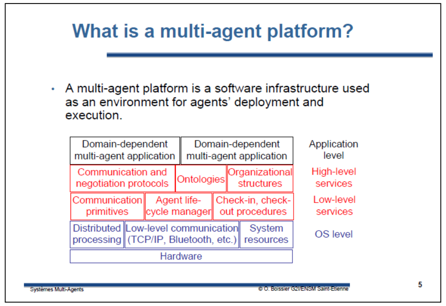
Multiagent simulation platform

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

Scheduler
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**

$T_i = t_i$, $T_f = t_f$
$x(0) = v_0$, …, $x(9) = v_9$
$q(0) = q_0$
$t=T_i$
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.

Scheduler
Temporal models

- **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();
```

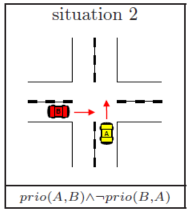
scheduling algorithm based on a discrete temporal model

```
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

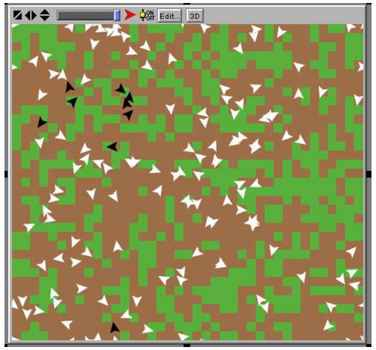
- **No solution**
  - The most current solution,
  - The action of an agent should not change the world in an important way. The micro coordination problems resulting of the scheduling process are not taken into account.
  - The consequences of this choice have to be taken into account
- **The scheduling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

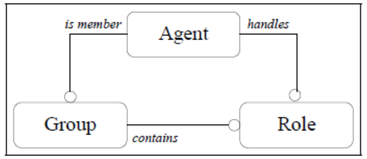
Illustrative Example

- **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



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

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);
}
```

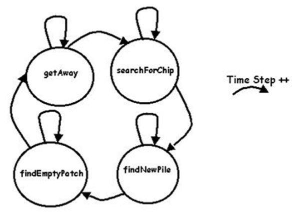
```
private boolean catched(){
int cpt=0;
for(int i=-1;i<=1;i++)
   for(int j=-1;j<=1;j++)
     if (! (i==0 && j==0) ){
        Turtle[] tur = turtlesAt(i,j);
         if (tur!= null && tur.length>0 &&
tur[0].isPlayingRole("predator"))
cpt++;
}
if (cpt>3) return true;
return false;
}
```


Turtlekit

Simulation

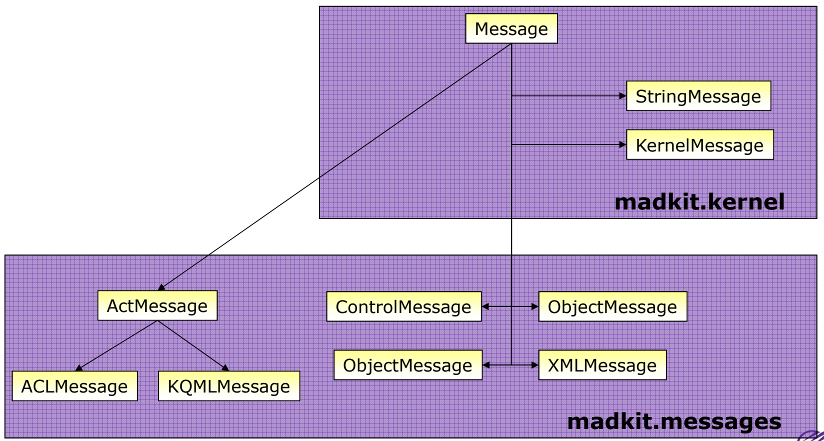
- **Pseudo activation algorithm**

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++



Madkit

Message



Madkit

Message

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