A Model and Language for Simulating Asynchronous Automata Networks

Stefania Bandini, Andrea Bonomi, Giuseppe Vizzari
Complex Systems and Artificial Intelligence research center
Università degli Studi di Milano–Bicocca
Viale Sarca 336/14, 20126 Milano, Italy
{bandini,bonomi,vizzari}@disco.unimib.it
Introduction

• Ambient Intelligence scenario: electronic environments that are sensitive and responsive to the presence of people
• Not only explicit service provisioning…
• … also relatively ‘simple’ forms of environment adaptation
• The last kind of application may benefit from the adoption of models supporting the definition of self-organizing systems
The passage through the building should be a **volume of color**, a solid of color. It’s a world of its own, a world in itself, separate from the streets outside at either end. Walking, cycling, through the building should be like walking through a solid, it should be like being fixed in color. The color **might change during the day**, according to the time of day: pink in the morning, for example, becomes purple at noon becomes blue, or blue-green, at night. This world-in-itself keeps its own time, shows its own time in its own way.

The thickness is pierced through with something, there’s **a sparkle**, it’s you that sparkles, walking or cycling though the passage, this tunnel of color. Well no, not really, it’s not you: but it’s you that sets off the sparkle – a sparkle here, sparkle there, then another sparkle in-between – one sparkle affects the other, pulls the other, like a magnet – a point of sparkle is stretched out into a line of sparkles is stretched out into a network of sparkles. These **sparkles are above you, below you, they spread out in front of you, they light your way through the tunnel**. The sparkles multiply: it’s you who sets them off, only you, but – when another person comes toward you in the opposite direction, when another person passes you, when a car passes by – some of these sparkles, some of these **fire-flies**, have found a new **attractor**, they go off in a different direction.
Scenario

• The desired adaptive environment comprises two main effects of illumination:
  – an overall effect of *uniformly coloring* the environment through a background, ambient light changing through time, but slowly with respect to the movements and immediate perceptions of people passing in the tunnel
  – a *local effect of illumination* immediately reacting to the presence of pedestrians, bicycles, cars and other physical entities
• The first effect can be achieved in a relatively simple and centralized way, requiring in fact a *uniform type* of illumination that has a *slow dynamic*
• The second requires a different view on the illumination facility:
  – it must *perceive* the presence of pedestrians, in other words it must be endowed with sensors
  – it must exhibit *local changes* as a reaction to the outputs of the aforementioned sensors, providing for a *non uniform* component to the overall illumination

Pictures appear courtesy of the Acconci Studio
(http://www.acconci.com)
The Adopted Approach

- We proposed the adoption of **distributed control system** composed of a set of controllers distributed throughout the system.
- Each controller has the responsibility of a part (**a portion of space**) of the whole system.
- The controllers must be able to interact, to influence one another to achieve more complex illumination effects than just providing a spotlight on the occupied positions.
- A **CA based** model was defined to manage the state of activation of the controller according to these two contributions.
• In theory, the CA based model can represent a suitable self-organization “engine”…
• … but does it really work?
• … and how do I select values for the significant parameters (not only for the CA model, but also for the illumination facility in general)?
• The model can be tested in silico, before actually implementing it, by feeding it with simulated data about the movement of pedestrians (and other vehicles) in the tunnel
The pedestrians (and vehicles) simulation model is based on MMASS
Previously adopted for various simulation scenarios, in particular for modeling crowds of pedestrians
Very simple scenario
- Two types of agents, respectively heading towards the two exits of the environment
- Obstacle avoidance through lane change in random side
- Collision avoidance (with other pedestrians) through presence fields, considered as repulsive
Discrete spatial structure of the environment derived directly from the 3D model realized by designers
The simulation environment is composed of two parts simulating:
- the network of controllers (with sensors and actuators)
- the actual environment in which the network is situated

The second one produces simulated inputs for the first one.

The simulation shows how controllers react when a simulated person (or vehicle) enters in the range of the sensors; the designer can thus effectively envision the interaction between the people and the adaptive environment.

The simulation environment allows the design configuring the network, defining the type, number, position of the sensors and actuators and specify a behavior for the controllers.
Multilayered Open Cellular Automata (MOCA)

- **Multilayered** - The cellular space is a hierarchical structure, deriving from Multilayered Automata Networks [Bandini and Mauri 1999]
- **Heterogeneity** - Cells are heterogeneous, in terms of space of the states and transition rule
- **Openness** - The dynamic behavior of the automata is influenced by the external environment and influences the external environment - Dissipative Cellular Automata [Zambonelli et al. 2002]
- **Asynchronicity** - The cells can be updated according to several update schemes, both synchronous and asynchronous
• MDCA cell are basic or composed. The basic cells are basic building block of the MDCA.
• Elaborate behaviors are defined composing cells
• Each basic cell is characterized by:
  – receptors
  – external states
  – transition rule

Example: XOR cell

receptor \( r_1, r_2 \) (boolean)
external state \( e_1 \) (boolean)
trans. rule: \( e_1^{(t+1)} = r_1^{(t)} \oplus r_2^{(t)} \)
Each composed cell is characterized by:
- receptors
- external states
- subcells
- wiring scheme
- update scheme
MOCA – Programming Language

- The MOCA Programming Language supports the definition of new cells and combining existing cells
- A MDCA programs consist in a set of cells descriptions
- A cell description determines the receptors, sub-cells, and external states composing the cell, their wiring and update schema

```java
cell rule6 {
    // Receptors and external state
    receptor boolean r1;
    receptor boolean r2;
    external boolean e1;

    // Cells
    cell not c1;
    cell inv c2;
    cell if c3;
    cell inv c4;
    cell xor c5;
    // Initial values
    c1.e1 = false;
    c2.e1 = false;
    c3.e1 = false;
    c4.e1 = false;
    c5.e1 = false;

    // Wiring
    c1.e1 -> c2.r1;
    c2.e1 -> c1.r1;
    c1.e1 -> c3.r1;
    r1 -> c3.r2;
    r2 -> c3.r3;
    c3.e1 -> c4.r1;
    c4.e1 -> c5.r1;
    c5.e1 -> c4.r2;
    c5.e1 -> e1;
}
```

```java
cell main {
    cell rule6 c1, c2, c3, c4, c5, c6;

    c1.e1 -> c2.r1;
    c2.e1 -> c3.r1; c2.e1 -> c1.r2;
    c3.e1 -> c4.r1; c3.e1 -> c2.r2;
    c4.e1 -> c5.r1; c4.e1 -> c3.r2;
    c5.e1 -> c6.r1; c5.e1 -> c4.r2;
    c6.e1 -> c5.r2;
}
```
MOCA – Compiler and Interpreter

• We developed a compiler able to translate MOCA source code into a neutral intermediate format (MOCA bytecode).
• A Virtual Machine able to interpret this format was developed as well into two platforms:
  – PC (for sake of simulation)
  – a specific embedded platform
• The purpose of the virtual machine is to provide an environment that abstracts away details of the underlying system.
• The virtual machine allows an automata to be executed in the analogously on any platform, from microcontrollers to PCs.

```plaintext
cell pow2 {
  receptor float r1;
  external float e1;
  cell mul cl;
  cl.e1 = 0;
  r1 -> cl.r1;
  r1 -> cl.r2;
  cl.e1 -> e1;
}
```
Future Developments

• Explored the possibility of realizing an ad hoc tool integrating traditional CAD systems for supporting designers in simulating and envisioning the dynamic behaviour of complex, self-organizing installations

• Used to understand the adequacy of the modeling approach in reproducing the desired self-organized adaptive behaviour of the environment to the presence of pedestrians

• Defined a model, language and tools for programming and deploying solutions based on this approach

• Investigating the possibility of “closing the loop”
  – use the adaptive environment to influence the behaviour of people
  – … might require an extension of the model or the integration of a ‘knowledge-level’ to process localized information
Thank you