MODELLING OF SOCIAL INFLUENCE WITH DEVS AND CELL-DEVS FORMALISM

Youssef Bouanan, Gregory Zacharewicz, Bruno Vallespir

University of Bordeaux, Lab. IMS, UMR 5218, 33405 Talence, France.

youssef.bouanan@ims-bordeaux.fr, gregory.zacharewicz@ims-bordeaux.fr, bruno.vallespir@ims-bordeaux.fr

ABSTRACT
The reactions of populations to the dissemination and propagation of information are, up to now, not modeled appropriately. There is however an interest in the ability to simulate and accurately measure the impact of information on population. The SICOMORES project objective is to provide solutions to artificially generate structured social networks of realistic population and simulate the effects of information on population, with a propagation algorithm of the effects across networks. The intention is to go further than current models which generally reduce the individuals of a population as simple obstacles or information transmitters without enough nuances in their behaviour and the influence they can have on a message. . In this article, we recall first the use of discrete modelling approaches in the social influence. Then we present models for human information treatment and propagation using DEVS and Cell-DEVS (Cellular DEVS). Finally, we present a simulation of the impact of information on individuals using CD++, a simulation tool for DEVS and Cell-DEVS.

Keywords: DEVS Formalism, Social Influence, Human Behaviour Modelling, Diffusion Models

1. INTRODUCTION

We observe that major works about modelling and simulation within social science, especially for social, organizational and cultural influences on opinion information spreading over a population, do not use specification languages to describe their models. These models are specified in the shape of math formulas and then directly coded using classical programming languages. The specification language can be a missing link. For instance, the DEVS formalism (Discrete EVent system Specifications) (Zeigler 1976), being general enough to represent dynamical systems, can provide an operational semantics applicable to this domain.

In 1970ôs, Professor Zeigler introduced this method that has proved successful. It represents: (1) a complex system from an interconnected collection with more simple subsystems; (2) a separation of the model from simulator, simulation algorithm are automatically generated according to defined models.so, the advantage is that it supports formalism interoperability. This formalism is open, flexible and offers a large extension capacity.

According to recent works (Garredu et al. 2011, Ameghino et al. 2001), it has been proved that DEVS formalism might be qualified as a multi-formalism thanks to its opening capacity, to its capacity to encapsulate others modeling formalisms. In one heterogeneous system, it is possible to use modeled subsystems from different formalisms, differentials equations, neuron networks, continuous systems. In PADS (parallel and distributed simulation) community, DEVS is widely spread as a modeling specification as it supports hierarchical, modular model representation. It also supports valid simplification, abstraction, and aggregation. Furthermore, extensions of the DEVS framework have been developed to handle variable structure, probabilistic, cellular, and logic-based representations (Sarjoughian et al. 2001).

This paper intends to present the premise of modelling and simulation of the impact of influence activities on individuals in social networks using Cell DEVS M&S formalism. The intention is to go further than current models which generally reduce the individuals of a population as simple obstacles or information transmitters without enough nuances in their behaviour and the influence they can have on a message. Cell-DEVS is a combination of CA (Cellular Automata) with the DEVS (Discrete EVent system Specifications) formalism that allows the definition of complex cell based systems. It appears especially suited to this study that takes into account several layers of social graph related with geographical networks. CD++ is a modelling and simulation tool that implements DEVS and Cell-DEVS. We use CD++ to build a model of influence of information on individuals in social networks.

In more detail, this paper will participate in the definition of a set of models that addresses the entities and the structure of a population. It will begin by representing the discrete modelling approaches including DEVS and CELL-DEVS Formalism. In addition, it will provide models of individuals with DEVS and groups of individuals characterized by a set of state variables (e.g. Using Maslow to construct the behaviour of an individual) and the mesh between the individuals within a social network. At last, the final part concerns the conclusion and a presentation of our future works.

2. BACKGROUND

2.1. DEVS Formalism

The DEVS formalism for modelling and simulation (Zeigler et al. 2000), is based on discrete events, and provides a framework with mathematical concepts based on the sets theory and systems theory concepts to describe the structure and the behaviour of a system. With DEVS, there is an explicit separation between a model and its simulator: once a model is defined, it is used to build a simulator (i.e. a device able to execute the modelôs instructions). DEVS knows two kinds of models: the atomic models, which describe behaviour, and the coupled models which describe a hierarchy. The tiniest element in DEVS formalism is the atomic model. It is specified as:

AM = < X, Y, S, ta, ŭint, ŭext, ə >

The semantics for this definition is given as follows. At any time, a DEVS atomic model is in a state $s \in S$. In the absence of external events, the model will stay in this state for the duration specified by ta(s). When the elapsed time e= ta (s), the state duration expires and the atomic model will sent the output ə(s) and performs an internal transition to a new state specified by ŭint (s). Transitions that occur due to the expiration of ta(s) are called internal transitions.

However, state transition can also happen due to arrival of an external event which will place the model into a new state specified by ŭext (s,e,x); where s is the current state, e is the elapsed time, and X is the input value. The time advance function ta(s) can take any real value from 0 to ∞. A state with ta(s) value of zero is called transient state, and on the other hand, if ta(s) is equal to ∞ the state is said to be passive, in which the system will remain in this state until receiving an external event.

Table 1 show the graphical notation to define the behaviour of atomic models.

Table 1: DEVS graphical notation

State	Internal Transition	External Transition
Name Ta	q0 Ta=e0 --- q0!20 ---> q1 Ta=∞	q0 Ta=∞ --- q0?10 ---> q1 Ta=e1

2.2. CELL-DEVS

Cell-DEVS (Wainer 2009), has extended the DEVS formalism, allowing the implementation of cellular models with timing delays. It improves execution performance of cellular models by using a discrete-event approach. It also enhances the cellôs timing definition by making it more expressive. Each cell is defined as an atomic model using timing delays, and it can be later integrated to a coupled model representing a cell space, as showed in Figure 1.

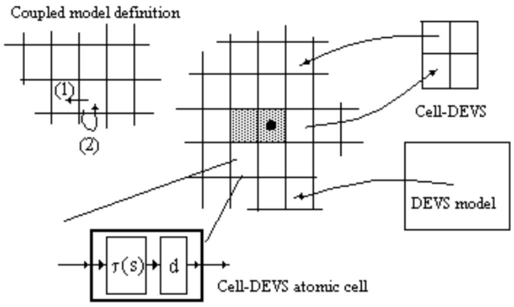

Figure 1: Informal Description of Cell-DEVS

Once the cell behaviour is defined, a coupled Cell-DEVS can be created by putting together a number of cells interconnected with their neighbors. A cellular model is a lattice of cells holding state variables and a computing apparatus, which is in charge of updating the cell state according to a local rule. This is done using the present cell state and those of a finite set of nearby cells (called its neighborhood).

Each cell uses N inputs to compute its next state. These inputs, which are received through the model's interface, activate a local computing function (t). A delay (d) can be associated with each cell. The state (s) changes can be transmitted to other models, but only after the consumption of this delay. Two kinds of delays can be defined: transport delays model a variable commuting time (every state change is transmitted), and inertial delays, which have preemptive semantics (scheduled events can be discarded).

2.3. CD++ Toolkit

CD++ (Wainer 2002), is a modelling and simulation toolkit that implements DEVS and Cell-DEVS theory. Atomic models can be defined using a state-based approach (coded in C++ or an interpreted graphical notation), while coupled and Cell-DEVS models are defined using a built-in specification language. We will show the basic features of the tool through an example of application. CD++ also includes an interpreter for Cell-DEVS models. The model specification includes the definition of the size and dimension of the cell space, the shape of the neighborhood and borders. The cellôs local computing function is defined using a set of rules with the form: {POSTCONDITION} {DELAY} {PRECONDITION}. These indicate that when the PRECONDITION is satisfied, the state of the cell will change to the designated POSTCONDITION, whose computed value will be transmitted to other components after consuming the DELAY.

3. HUMAN BEHAVIOUR MODELLING

3.1. General approach

Human behavior modelling as individuals, in groups, and in societies is the subject of several fields of researches; social science, economics, epidemiology and military service because it has such an important role in many aspects of daily life. Scientific literature abounds in heterogeneous and highly specialized, theoretically founded concepts of human cognition, emotion and other behaviour aspects. There are many lines of research on such models, which span several disciplines, have different goals, and often use different terminologies and various approaches. Human behaviour modelling or human behaviour representation (HBR) is an important field of study in military service research (Fei et al., 2007), robotics [(Kubota and Nichida, 2006)], brain-computer interface (BCI), human machine interface (HMI) and some specially oriented anthropology studies. Human behaviour models are often represented by finite state machines, rules, fuzzy rules (Dorsey and Coovert, 2003), artificial neural networks, multi-agent based modelling (Sun, 2007). The need for a variety of modelling paradigms stems from the fact that the different domains of knowledge needed to represent human behaviour cannot be done by only one paradigm.

3.2. Human Behaviour Modelling in military application

In military operations, the Human Behaviour Modelling or Human Behaviour Representation is an important field of study; the human has always been recognized as a key factor. Numerous examples illustrate how the actions of an individual or a group of individuals defeat into victory or how difficult it is to sustain operations in extreme climates. Current military missions need simulation models that can capture and foresee the behavior of humans acting in social units, ranging from small groups, cultural and ethnic groups, and entire societies. Models could be used to predict the effects of actions intended to disrupt terrorist networks, to predict the response of insurgents and the local population to the presence of friendly forces in a given area, or to predict the effects of alternative diplomatic, military, and economic courses of action on the attitudes and behaviors of the population in a region of interest (Zacharias et al. 2008).

There are numerous tools for human behaviour modelling that can be involved in the domain of military simulation of peace keeping or stabilization time. Most of them are tackling Political, Military, Economic, Social, Infrastructure, and Information (PEMSII) System by Diplomatic, by Intelligence, Military and Economic (DIME) actions on the region of interest System (Zacharias et al. 2008).

- Integrated Battle Command program (IBC); supports the commander's intuition, judgment, and creativity using flexible, intelligent decision aids in todayȏs complex operational environment. IBC proposes an interactive process that involves humans in the loop to guide the search for solutions.
- Pre-Conflict Anticipation and Shaping (PCAS); project examines the technical computer support for designing strategies for forming, or combining several different models representing relevant information and knowledge.
- CLARION (Connectionist Learning with Adoptive Rule Induction ONline); this tool is a cognitive architecture for connectionist/neural representation of implicit knowledge and semantic representation of explicit knowledge. It is provided for explicit representation of static knowledge as well as acquisition of sub symbolic knowledge through learning over time.

3.3. Using DEVS for Human Behaviour Modelling

Human behaviour can be difficult to understand and predict, thus it can be qualified as a complex system. DEVS is a well-defined formalism which has numerous ad-vantages over other formalisms in the modelling of complex dynamic systems. A few related works have provided DEVS models of human behaviour that we will use with slight modifications; (Seck 2004), present a DEVS based framework for the model-ling and simulation of human behaviour with the influence of stress and fatigue, (Faucher 2012), proposed a first approach using G-DEVS formalism for Civil-Military Cooperation actions (CIMIC) and Psychological actions (PSYOPS), which are actions of influence that take precedence over combat.

The purpose of this work is to go beyond previous works by providing a simple model but more performant and accurate which will allow us not only to model the behaviour of an individual, but also the simulation of the propagation of an information among a group of individuals and its influence on their behaviour.

This model (Figure 2) is describing the influence of message on the behaviour of an individual and potentially its dissemination. The first state consists in being in contact with another agent in its social network neighbourhood and calculating the strength of connexion between them. When the message is received, it creates an impact on the individual which change its behaviour eventually depending on the strength of the message (Faucher 2012). Then, if the message strength is still strong enough the receiver is preparing on its turn to transmit the message to its network neighbours considered as target info.

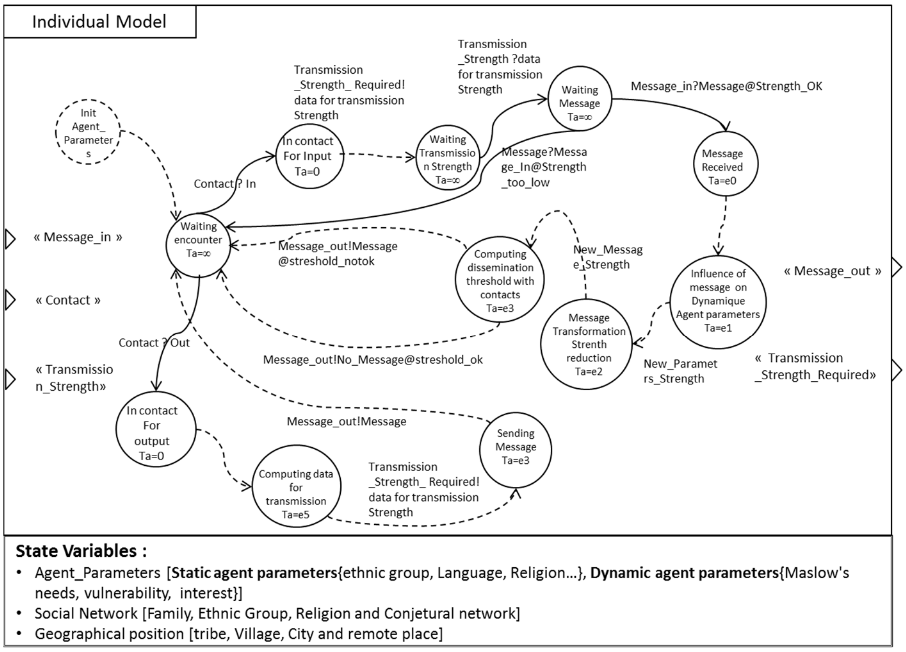

Figure 2: DEVS individual model

4. INFORMATION DIFFUSION MODELLING

4.1. Diffusion Models

4.1.1. General Approaches

The study of information spread and propagation of ideas, and influence in a social network has a long history in the social sciences (Rogers 1962, Coleman 2005), with the advent of computers with sufficient storage and computational power, this network diffusion process has become an emerging research area in computer science (Domingos 2005). Propagation models are designed to reproduce the phenomena that can be observed in social networks, in the viral marketing and the spread of disease. Communication between users of these actors in networks gives rise to a number of issues such as the discovery of the sphere of influence, the initial choice of diffusers for maximum dissemination or the identification of links to remove to limit the spread.

Most information diffusion models proposed recently are extensions of Independent Cascade model (IC) (Goldenberg et al. 2001), and Linear Threshold Model (LT) (Granovetter 1978). The two models characterize two different aspects of social interaction. The IC model focuses on individual (and independent) interaction and inþuence among friends in a social network. The LT model focuses on the threshold behavior in inþuence propagation; each individual has two mutually exclusive and exhaustive behavioral options available. For example, in Granovetterôs classic example, each individual chooses whether or not to join a riot. In addition, each individual is assumed to observe the behavior of all other individuals.

4.1.2. From Epidemics Spreading to Information Diffusion

In the past, the propagation was mainly studied in the epidemiological field to better understand the process of propagation of infection in certain conditions. Classical disease-propagation models in epidemiology are based upon the cycle of disease in a host: a person is first susceptible (S) to the disease. If then exposed to the disease by an infectious contact, the person becomes infected (I) (and infectious) with some probability. The disease then runs its course in that host, who is subsequently recovered (R) (or removed, depending on the virulence of the disease). A recovered individual is immune to the disease for some period of time, but the immunity may eventually wear off. Thus SIR models diseases in which recovered hosts are never again susceptible to the disease.

Sotoodeh et al. (2013), presented a general model of information diffusion, which is based on epidemic diseases. It is a result of developing SIRS deterministic model and including compartmental assumption.

Bouanan et al. (2014), presented an analogy between the dissemination of information among a group of individuals and the transmission of infectious disease between the individuals themselves. In addition the authors introduced the simulation of information diffusion using CELL-DEVS Formalism.

4.2. Modelling of Information Propagation in the context of PSYOPS actions using CELL-DEVS

In this section, we will introduce the PSYOPS Actions based on studies done by social scientists and we will simulate the spread of information through conversations between pairs of individuals within a small group in the context of PSYOPS operations with CELL-DEVS.

4.2.1. PSYOPS Actions

Psychological Operation (PSYOPS), planned activities using methods of communication and other means directed at approved audiences in order to influence perceptions, attitudes and behaviour, affecting the achievement of political and military objectives, (McLaurin 1982). It affects the behavior of a target by means of cognition or emotions.

Psychological operations aim at elaborating and spreading out a message that must be read, listened to and understood by the info-targets in order to get the desired effect, that is, influencing the info-targets to get from them the desired behavior by the modification of their attitudes, by acting on their perceptions, [N°069/DEF/CICDE 2008].

The info-targets are the people to whom psychological messages are intended. They are divided into intentional info-targets, that is the info-targets towards whom the messages are directed and non-intentional info-targets who will receive the message, but whom the analysts had not thought of, when designing the message. The intentional info-targets can be direct (they receive the message directly from the means of conveyance) or indirect (the message is propagated to them through social networks) (Faucher 2012). A message can generate in the info-targets, reasoned thoughts, spontaneous feelings and emotions and/or reflex behaviours, depending on the means used to spread the messages and the content of the message.

4.2.2. Proposed Model

4.2.2.1. CELL-DEVS Definition

The following is the formal definition for the CELL-DEVS model defined in Part 1.

CD = < X, Y, I, S, ɗ, N, d, ŭint, ŭext, Ǖ ɚ, D >

X = Y = Ø

S is the set of possible states for a given cell. Here a cell has a variable that contains four digits.

- First digit represents message transmission; 1, message received and 2, message not received.
- Second digit, is the mental factor, in this case we simulate the individual attitude.
- Third digit symbolizes the family network
- Fourth digit represents the religion network

N = {(-1, 0), (0, -1), (0, 1), (1, 0), (0, 0),}

d = 100 ms

Ǖ N→S is defined by the rules presented in table 2:

In this section, we present a simple model of the information impact using the formalism CELL-DEVS in order to show the feasibility to use DEVS and CELL-DEVS in social influence modelling. In more detail, we define the state of the individual as a value contains four digits; two digits represent static parameters (religion network, family network, languageé) and the others digits represent dynamic parameters (mental factors, Maslowȏs needsé). To develop a simulation model, we chose as static parameters religion and family network and individual attitude and state of message as dynamic parameters.

Table 2: Definition of rules

State Parameters value	Rules
1.1.Y.X	Two neighbors or more that have S=1.X.Y.X
1.0.Y.X	One neighbor that has S=1.X.Y.X
1.0.X.Y	Three neighbors or more that have S=1.X.Z.Y (Z!=X)
0.X.X.X	Other combinations

4.2.2.2. CD++ Implementation

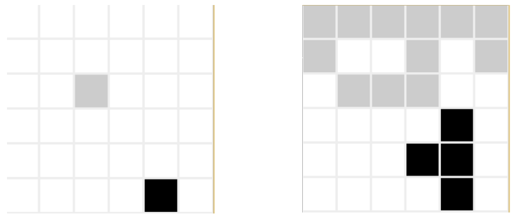

Figure 3: Execution result at time 00:00:000; 00:00:700

The model is intended to study the propagation of information and its impact within a group of individuals. Assume there is 6×6 mesh of cellular automata (CA). Each individual, residing in (i,j) node, is equipped with a number with four digits indicating different Parameters of the individual.

Each cell may represent one of two categories: one is person who did not receive the information represented by white color; the other is the person who received the message represented by black or gray color. Initially we have two sources of information which contain two kinds of messages. At the end of the simulation we can see that the message represented by gray color is received by a large number of individuals while the second message is received just by 3 individuals (figure 3). The individual can be opposed to the information and/or person that is transmitting the message and/or favourable to the emitter and message content. The simulation results show on the right picture of Figure 3 that depending on the opinion of individuals and the configuration of the social networks some individual can be reached by the information where some other not. This test is very simple; it is based on the abstract geographical situation of individuals and it takes into account only one dimension of a social network. We have not introduced yet the graph representation for defining the multilevel social network links between individuals or groups. Nevertheless the approach already shows how we can use DEVS and CELL-DEVS formalism to model a complexes phenomenon in particular social influence.

CONCLUSION

This paper introduced Formal Modelling and Simulation of the impact of Information on Individuals in a group. We have presented how DEVS and Cell-DEVS can be very useful techniques for modelling and simulating of Social influence. At the individual level, the DEVS model proposed is very simple keeping raw Maslow parameters as state variables and being simply influenced by arriving messages. In its turn the individual model can transmit the message after having potentially transformed its strength according to several criteria. The Cell DEVS structure then use these models of human extremely simplified and start building on top of its connected modules to form Cell-DEVS network. In addition, the separation between the model and simulator followed by DEVS and CD++, has enabled the modeller to concentrate on building the behavioural model on one side and preparing the spreading logic on the other side using the CD++ toolkit. The model shows a correct, even very simple, human behaviour impact regarding information perception and treatment.

PERSPECTIVES

The main perspective remains the definition of a multi-level social network. In detail the real social network is complex, it can refer for e.g. to the family environment, work, religion, geography to transport the information from one individual to another. The final result will be the combination of several networks graphs.

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