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DEVS-Based Framework for Message Diffusion in a Multidimensional Social Network

Youssef Bouanan, Judicael Ribault, Mathilde Forestier, Gregory Zacharewicz, Bruno Vallespir

Bordeaux University
IMS Laboratory, UMR 5218
351, Cours de la liberation
Talence, F-33400, France

ABSTRACT

Many research efforts focus on the definition of models and techniques to simulate and predict the reaction of individuals face to an information. In this context, great benefits could derive from the exploitation of individual personality/cultural values in the diffusion model process. In this paper we describe a new architecture for agent-based model using the DEVS (Discrete EVent System Specification) framework and show how this architecture is flexible and can serve in the dissemination process. In more detail, we define a set of models of individuals characterized by a set of state variables to construct the behavior of an individual and the mesh between the individuals within a multidimensional social network. Then, we introduce the platform architecture, sharing resources, specifically designed to simulate multidimensional social network. In the end, a military scenario of message diffusion during a stabilization phase is used to validate our models using the platform based on DEVS Specification.

1 INTRODUCTION

Nowadays, many researchers are interested in developing new and more efficient systems for social simulation. The issues explored include psychology, organizational behavior, sociology, political science, economics, anthropology, geography, engineering, archaeology and linguistics (Takahashi, Sallach, and Rouchier 2007, Bouanan, El Alaoui, Zacharewicz, and Vallespir 2014). In the field of military defense, modeling the human operators in a system is far more difficult. Military Simulation System has to support more detailed analysis of individual and organizational performance. The SICOMORES project aims to go further than current models. These models generally reduce the individuals of a population as simple obstacles or information transmitters: they lack to nuance people's behavior and their influence on a message.

Social networks play an important role in studying the propagation of information, innovation, ideas, and influence among its members. When an information appears - for example, the use of cell phones among students, the adoption of a new information system within the enterprise, or the rise of a political movement in an unstable society - it can either die out quickly or makes significant inroads into a population. Network diffusion process allows us to understand the dynamics and the propagation of information in social network. In a social network, people are linked by a relationship. In online medias we could find the friendship relationship, the coworker relationship, the follower relationship and so on. In real life, people are also connected by several relationships. Recent research gives us a framework to model multidimensional social networks (MSN) (Berlingerio, Coscia, Giannotti, Monreale, and Pedreschi 2013). So, based on this multidimensional network framework, we generate several links between people based on life relationships. People belong to families, have friends, neighbors and so on. We can generate as many dimensions as we want to build a population. This MSN allows us to define diffusion rules for each relation. Actually, people do not share the same information according to who they are talking to (friends, family, and so on).

Agent-based modeling approach is used to model complex systems composed of interacting and autonomous 'agents'. Agents have behaviors, often described by simple rules, and interactions with other agents, which in turn influence their behaviors. By modeling agents individually, the full effects of the diversity that exists among agents in their attributes and behaviors can be observed as it gives rise to the behavior of the system as a whole.

The purpose of this work is to provide a simple but efficient and accurate framework to model the behavior of an individual, but also to simulate the propagation of information among a group of individuals. So, we propose in this paper a simulation architecture which includes:

- a multidimensional social network allowing to model any relationship we want between people,
- an agent based simulation using the DEVS formalism,
- a framework allowing to define an accurate diffusion algorithm for each relationship in the MSN.

We validate our architecture with several simulations. These simulations shows that we can add or delete a network, easily simulate several scenarios and validate, verify and accredit our models.

This paper begins by representing the agent-based model approach, The DEVS formalism and the dissemination process in social networks. Then, it provides model of individuals with DEVS characterized by a set of attributes and it presents our architecture to simulate a multidimensional network using DEVS. At last, the final part concerns our experiments and the conclusion.

2 BACKGROUND

2.1 Agent-based social simulation

Agent-based social simulation (ABSS) consists of social simulations that are based on Agent-based modeling, and implemented using artificial agent technologies (Davidsson 2002). ABSS is scientific discipline concerned with simulation of social phenomenons, using computer-based multi-agent models. In these simulations, persons or group of persons are represented by agents.Three main fields in ABSS are agent based computing, social science, and computer simulation.

Different agent-based platforms have been used for implementing Agent-based social simulation (Tobias and Hofmann 2004). NetLogo is the highest-level platform, providing a simple yet powerful programming language, built-in graphical interfaces, and comprehensive documentation. MASON, Repast, and Swarm are "framework and library" platforms, providing a conceptual framework for organizing and designing ABMs and corresponding software libraries. Most of the simulation frameworks are oriented specifically towards applications in the field of artificial intelligence and are not sufficiently optimized for social scientific applications. they allow very abstract or other types of simulation, such as macro-simulation, evolutionary algorithms, cellular automata and so on. In our study we develop a new library based on DEVS formalism in witch agents can be modeled as 'free' and complex objects that represent real human beings, institutions, etc. as social scientific models do.

2.2 DEVS

The DEVS formalism for modeling and simulation (Zeigler, Praehofer, and Kim 2000) is based on discrete events modeling. It tends to represent more mathematical oriented notations consisting of sets and functions in algebraic representation. The sets in DEVS formalism specify the potential states, inputs, and outputs of the model; and the functions describe the transitions either from outside input or from the time expiration of the state. It provides a framework with mathematical concepts based on the sets theory and systems theory to describe the structure and the behavior 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 model's instructions). DEVS proposes two kinds of models: the atomic models, which describe behavior, and the coupled models which describe a hierarchy.

The DEVS formalism has numerous advantages. It allows the building of a very complex model by connecting different DEVS models, either atomic or coupled models, in a hierarchical manner. Besides, It can specify a specific state at any point of time as well as connect with other models with I/O events which are caused by state transitions. Furthermore, the DEVS formalism presents an explicit separation between model specification and its implementation (or simulation development). In other words, implementing DEVS models is easily achievable by using an implementation framework supporting the DEVS formalism. Finally, the formalism supports an open approach to formalism extension, allowing the researcher to explore new extended or specialized formalism (Zeigler and Vahie 1993). These extensions facilitate the development of models for various applications in many different domains such as biology, engineering, and sociology. For example, (Barros 1996) proposed the dynamic structure DEVS (DSDEVS) formalism which allows changes in model structure during execution. (Chow 1996) proposed the parallel DEVS (P-DEVS) for parallel execution benefits. (Hong, Song, Kim, and Park 1997) proposed the real time DEVS (RT-DEVS) for executing DEVS models within a real-world environment. From a network modelling perspective, (Uhrmacher, Ewald, John, Maus, Jeschke, and Biermann 2007) proposed Multi-Level-DEVS (ml-DEVS) which supports an explicit description of macro and micro level and (Wainer and Giambiasi 2002) proposed the cell-DEVS formalism which is a combination of cellular automata and DEVS that allows the implementation of cellular models with timing delays.

2.3 DEVS simulators

There is a large number of DEVS based simulators. It is difficult to compare the performance or the implementation of these tools. Once way is to implement a test model using the different tools. The DEVS group standardization lists on his web site the most used DEVS tools known by the DEVS community [1].

ADEVS was the first DEVS tool developed in C++ by the Arizona University. It consists in an ad-hoc simulator. DEVS abstract classes should be extended by users to define atomic and coupled models, and then the simulation can be launched. The drawback resides in the fact that users need programming skills to code the models.

DEVSJAVA is a Java framework in which the kernel simulator is ADEVS. It supports also modeling and simulation of DEVS with variable structures. However, at atomic level, the user should implement the corresponding DEVS behavior in Java (in our opinion the user has not enough skills to program his atomic models).

CD++ Builder is a DEVS modeling and simulation environment that integrates interesting features and facilities for the user. It allows modeling and simulation of other DEVS formalisms (cell-DEVS, Quantized-DEVS, etc). It provides a DEVS graphical editor to model coupled and atomic models, and to encapsulate them through components for further reuse.

VLE (Virtual Laboratory Environment) is an open source software and API under GPL which supports multi-modeling and simulation by implementing the DEVS abstract simulator (Quesnel, Duboz, Ramat, and Traoré 2007). It is able to integrate specific models developed in most popular programming languages into one single multi-model. VLE proposes several simulators for particular formalisms; for example, cellular automata, ordinary differential equations (ODE), difference equations, various finite state automata (Moore, Mealy, Petri-nets, etc.) and so on.

Some of these platforms are specialized by domain of modeling. Among them, the proposed DEVS models in this study will be implemented in the VLE because it supports multi-modeling simulation and analysis by using recent developments in the theory of modeling and simulation proposed by Zeigler. It is also possible to perform better statistical analysis of results thanks to a plug-in that allows communication between VLE and R.

[1] cell-devs.sce.carleton.ca/devsgroup/?q=node/8

2.4 Diffusion in Social Network

Social network consists of interconnected individuals linked by informal patterned flows of information and communication that are described as social ties (Tenkasi and Chesmore 2003). Some modern examples of social networks include online social networks, where vertices are user accounts and edges represent a relationship between accounts (e.g., friendship, coworkers), and communications networks, where vertices represent e-mail addresses or telephone numbers, and edges represent e-mails sent or telephone calls placed between vertices.

Social networks play an important role in studying the propagation of information, innovation, ideas, and influence among its members. An idea will appear - for example, the use of cell phones among students, the adoption of a new information system within the enterprise - and it can either die out quickly or make significant inroads into the population. The network diffusion processes have a long history in social sciences (Rogers 1962). With the advent of sufficient storage and computational power, this network diffusion process became an emerging research area in computer science (Domingos 2005). Propagation models are designed to reproduce the phenomena that can be observed in social networks with applications in viral marketing, spread of disease and diffusion of ideas and innovations. Most models proposed recently are extensions from the independent cascade (IC) (Goldenberg, Libai, and Muller 2001) and the linear threshold models (LT) (Granovetter 1978). The two models characterize two different aspects of social interaction. The IC model focuses on individual (and independent) interaction and influence among friends in a social network. The IC models can also be identified with the so-called susceptible/infective/recoverd (SIR) model for the spread of disease in a network (Bailey et al. 1975).The LT model focuses on the threshold behavior in influence propagation, which we can frequently relate to when enough of our friends bought a new phone, played a new computer game, or used a new online social networks, we may be converted to follow the same action. All the presented works consider only one relationship between people. It raises two assumptions: (1) authors only take into account one relationship and do not care about people related by an other relation, e.g., the message disseminates only within friends; (2) all people are related by one relation and the authors assume that a message disseminates in the same way on different relations, e.g., the message disseminates in the same way between two friends or two coworkers. Actually, the way how people communicate is highly dependent of the person who people are talking to. We base our work on the idea that the relationships that linked people together are really important in the diffusion process and have to be considered.

2.5 Human Behavior

Human behavior modeling 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 behavior aspects. A few related works have provided DEVS models of human behavior that we will use with slight modifications; (Seck, Frydman, Giambiasi, Ören, and Yilmaz 2005) present a DEVS based framework for the modeling and simulation of human behavior with the influence of stress and fatigue. (Faucher, Zacharewicz, Hamri, and Frydman 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.

3 CONTRIBUTIONS

In this section, we propose an agent-based model for the information diffusion in a social network.

3.1 Problem statement

The reactions of populations to the 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. In the context of the stabilization phase of conflicts, influence military actions have effects and impact on info-targets and aim at influencing their minds by generating feelings and behaviors. In the frame of SICOMORES project, we aim to provide solutions to artificially generate multidimensional social network of realistic population and simulate the effects of information on population, with a propagation algorithm of the effects across networks. The challenge is to improve the realism of socially intelligent agents and to take into account the impact of individual personality/cultural values in the diffusion model process. The SICOMORES system can be useful in the domain of military simulation for training and education.

3.2 DEVS-based Social Agent Model Framework

There are several methods to study the information propagation in social network, such as complex network analysis (Ma, Zeng, and Huff 2013), cellular automata (Goldenberg, Libai, and Muller 2001) and agent based modeling (Smith, Coyle, Lightfoot, and Scott 2007). Based on our needs, we use agent-based models ans simulations for this study. Computational models and simulations, especially agent based ones, have been widely used to study a variety of social, organizational and natural phenomenon. Agent-based models are capable of simulating macro-level structures resulting from micro-level interactions of heterogeneous agents within complex systems.

We do not find what we need in the actual frameworks that can be used directly. High level frameworks cannot be used to model precisely the characteristics of each individual. We decided to use a low-level framework (DEVS) to define an architecture and a methodology that promotes modularity and reusability, and thus the validation, verification and accreditation of models.

Indeed, we need modularity and reusability in the context of our study. We need to do a lot of simulation by varying the inputs but also the algorithms of agents. For example, messages transmitting algorithms and message acceptance algorithms may change depending on the targeted population, the type of message or network on which the message travels. In order not to have to fully develop the model for each combination of algorithm we want to put in the agent, we decided to opt for a modular approach. The modular approach allows, in addition to saving time, a simpler validation but need some methodology to be carrying through. Section 3.2.1 describes the proposed solution in terms of modular and reusable model design. Section 3.2.2 presents the architecture of simulation and methodology used.

3.2.1 DEVS model

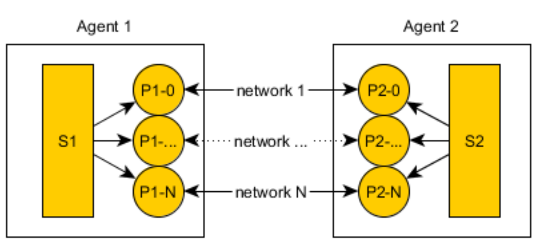


Figure 1: DEVS models representing the Server/Proxy modular design.

Figure 1 presents the solution we have developed to take advantage of a low-level framework allowing the development of algorithms that take into account the specificity of each individual. This solution also considers our needs for modularity and reusability.

Agent model Figure 1 presents the Server/Proxy architecture design between 2 agents connected through N networks. An agent (or individual) is the composition of one server (S1 for agent 1, S2 for agent 2) and several proxies depending on the number of networks to which the agent is linked to. In this way it is easy for an individual to have different behavior algorithms depending on the network on which it sends information, or on the network on which it receives the information.

Generator Each agent is created at run-time by a generator that has access to the experiment data. This generator initializes each individual, i.e., each server and proxy, and binds the server with all of its proxies. Then, each proxy is bounded to a 0-N proxy depending on the graph between individuals.

3.2.2 Architecture and methodology

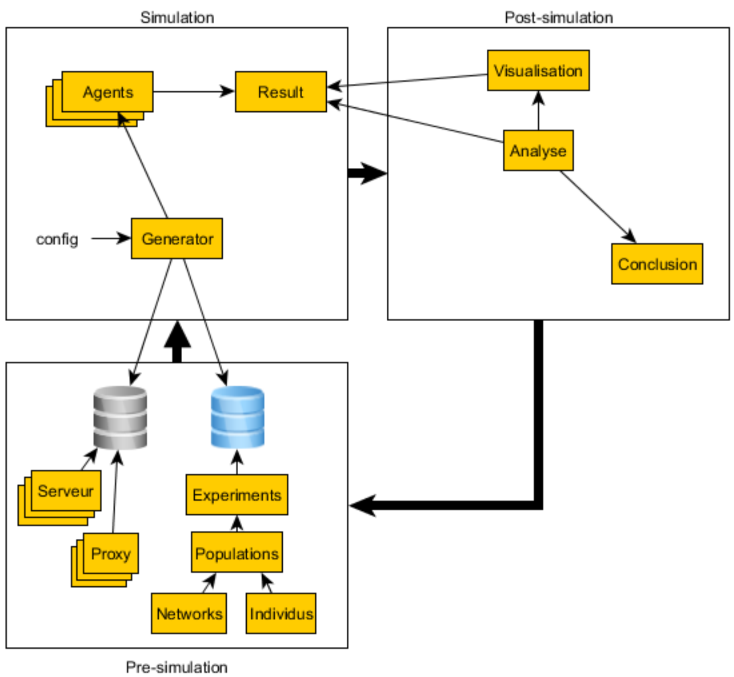


Figure 2: Agents simulation architecture and methodology.

Figure 2 presents our methodology and our simulation architecture.

pre-simulation Before making a simulation, we build a new experiment and develop the simulation models we need if they do not already exist in the repository. An experiment includes one or several populations. A population includes many individuals. A graph represents all relations between individuals. We opted for the storage of information in database so that each experiment is easily accessible and replayable. The repository contains all the models available to execute the simulations, i.e., all the servers and proxies that will be used by the generator to produce the simulation model.

simulation The simulation is started with a configuration file that contains the experiment to simulate, as well as servers and proxies to use. In this way, for the same experiment, we can test different behavior algorithms. The generator connects to the database to retrieve all the information from the experience to execute. The generator instantiates agents and related links. The DEVS simulation is executed and produces a result set in the form of a file.

post-simulation The result file is used in post-processing to visualize the course of the simulation and to develop an analysis and conclusion. The analysis can lead to a new simulation, i.e., makes a new pre-simulation, simulation and post-simulation.

3.3 Formalization of human behavior

In the agent-based model, individuals or group of individuals are represented as agents. Each agent is described by a set of attributes:

- Static attributes: gender, social status,religion and age class.
- Dynamic attributes (variables): opinion, interest, un/satisfied-needs.

Static attributes are intrinsic or unchanged parameters, i.e., time has no effect on them. Dynamic attributes evolve with time or events. For example, individuals can be reached or not by the information depending on its opinion and the social network configuration.

We use DEVS specification to describe the human behavior. As we presented in 2.2, DEVS is a well-defined formalism which has numerous advantages over other formalism in the modeling of complex dynamic system. The following notations describe the Controller model. We do not describe detailed operations of this model. We just explain the role and interface of the Controller model.

$$AM_{CM} = \langle X, Y, S, ta, \delta_{ext}, \delta_{con}, \delta_{int}, \gamma \rangle$$

$X = \{"In\_info"\}$
$Y = \{"Out\_info"\}$
$S = \{INIT, IDLE, STATE\_0, STATE\_1, STATE\_2\}$
$ta : INIT \to e$
$IDLE \to \infty$
$STATE\_0 \to e$
$STATE\_1 \to e$
$STATE\_2 \to e$
$\delta_{ext} : (IDLE, "In\_info") \to STATE\_0$
$\delta_{con} : \delta_{con}(S, \emptyset) = \delta_{int}(S)$
$\delta_{int} : INIT \to IDLE$
$STATE\_0 \to STATE\_1$
$STATE\_1 \to STATE\_2$
$STATE\_2 \to IDLE$
$\gamma : STATE\_2 \to "Out\_info"$

This model describes the message influence on the individual behavior and potentially its dissemination using the DEVS specifications. The first state is used to configure and initialize the agent's attributes. Then, when the agent is in the *"IDLE"* phase and if it receives a message from another agent on port *In_info*, it will enter in phase *"State_0"*. If the message strength is still strong enough the receiver enter in phase *"State_1"*. This message creates an impact on the individual, and eventually its behavior depending on the agents opinion and the relationship between him and the sender. After that two cases are possible; the receiver will transmit the message on its ego-network or it will ignore it according to the strength of the message and agent's attributes (the message was interesting to the receiver or not).

3.4 Dissemination process in multidimensional social network

The multidimensional social network is defined as a graph G=(V,E,L) where V is a set of nodes, L is a set of labels (also called dimensions), E is a sat of labeled edges, i.e., the set of triples (u,v,d) where $u, v \in V$ are nodes and $d \in L$ is a label. Each node represents an individual with characteristics who can share information on one of its networks L. Each individual who receives a message and does not have enough interest in it becomes "immune" and the message will no longer spread. In this regard, the nodes can belong to one of these three categories : (type A) dissemination node: A nodes receive the message and can spread it; (type B) uninfected node: B nodes do not receive the message, (type C) immune node: C nodes receive the message but do not spread it

Nodes who know the information and are type A will diffuse it to all their neighbors.[2]

If the neighbor node is type B, it rejects the information.

If the neighbor node is type A or C, it accepts the information.

Four conditions can cause the end of the dissemination process: (1) The individual who receives the information is a type C; (2) The strength of the message to be propagated falls bellow a given threshold; (3) All nodes are a type B; (4) It has been a long time (higher than a given threshold) since the scenario occurred.

4 CASE STUDY

We present in this section the case study and the experiments we made in order to validate our simulation architecture.

4.1 Overview

In the context of modern conflicts, the overall maneuver is an iterative process to achieve a desired effect on the environment. The actions to be deployed in this context are divided into influence and combat actions. Combat actions is rather limited in the context of a stabilization operation, priority is given to actions of influence. These actions of influence can be defined as all intentional activities to achieve an effect on perceptions in order to change attitudes and / or behaviors. Actions of influence aim at either an individual or a group of people: groups with common social or geographical characteristics where circulate ideas and opinions. In the context of stabilization phase of the conflict, the population is at stake and the major target of such actions. PSYOPS (psychological operations) use some media to share information customized to info-target's cultural and linguistic specific features. However, the whole population is not an homogeneous entity easy to convince. The population can be indifferent, opponent or ally. The aim of the SICOMORES project is to propose a realistic population allowing to describe and simulate the effects of the operations of influence within it.

4.2 Experiments

To validate our simulation architecture we generate a population of 100 individuals on three dimensions: family, friends and neighbors. These three dimensions represent the primary groups define by (Litwak and Szelenyi 1969). These dimensions are the basis of the social relationships and the information disseminates faster in these networks.

Each individual is defined by a sex, an age, an ethnicity, a religion, a language, a social level and an opinion. An individual can also have the role of head of family, political leader and religious leader.

We drive two experiments with the same population but with different algorithms of message propagation.

In the first experiment, we use probabilities to define if a message transmits to an other individual. Actually, a message has a context on which military wants to influence the population. We define for now two different contexts:security and health care

Figure 3 presents the initialization the simulation using the generator as explained in Figure 1 in Section 3.2.1. Each agent is represented by a node. Each node is colored according to its status: green for dissemination nodes, red for immune nodes and white for uninfected nodes. At t_0, all nodes are uninfected except for two: node V3 is immune and node V5 is a dissemination node. It means that node V5 is the info-source of the simulation. As we are working with an MSN, we have three kinds of link : family relationships (red links), friendship relationships (green links) and neighborhood relationships (yellow links).

[2] Note that we use here the term neighbors for people who are connected to a node whatever the dimension.

Table 1: Probability values for each proxy and each message context

DIMENSION	OUTPUT	EXTERNAL EVENT
Family	0.9 security O.9 health care	message strength -1
Friendship	O.4 security 0.6 health care	message strength -2
Neighbor	O.1 security 0.4 health care	message strength -3

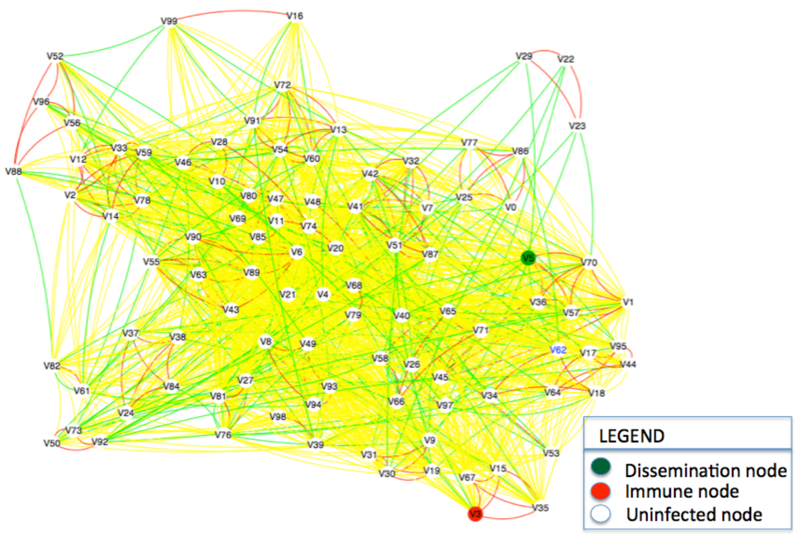
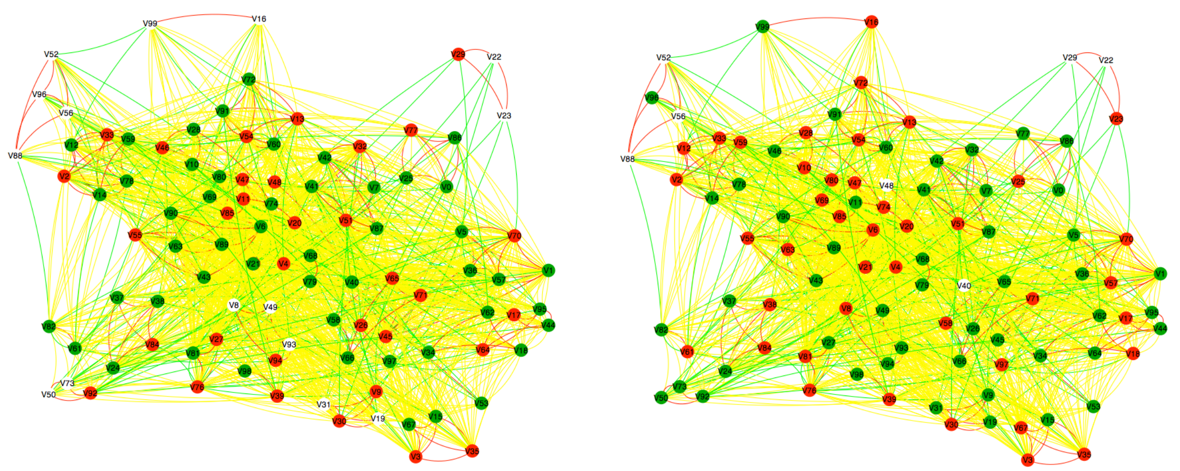


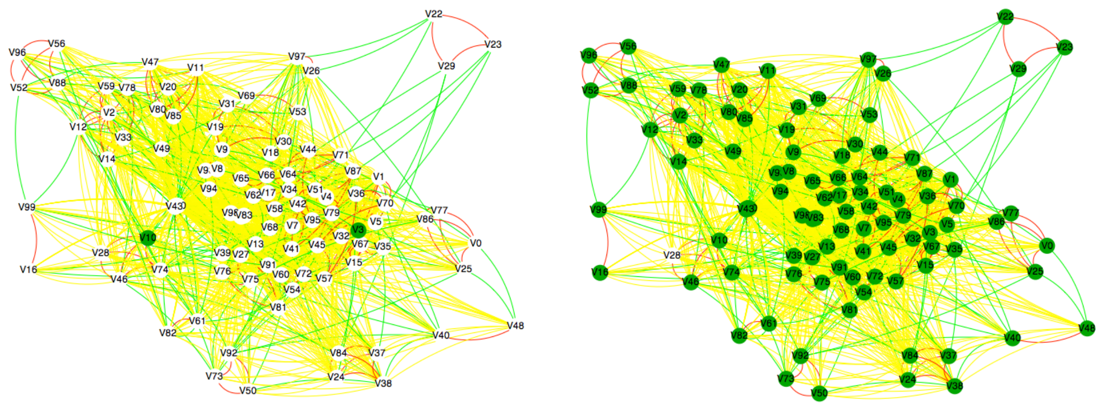
Figure 3: Initialization of the simulation



(a) Result of the simulation with a message of security (b) Result of the simulation with a message of health care

Figure 4: Results of simulation with several message contexts

Figure 4 shows the simulation set and the results of a message propagation in an MSN.At the end of the simulation, we can see that the information spread within the MSN depending on the type of the message and the configuration of the social networks. In the end of the simulations, we observe that the context of the message changes how it disseminates. The connection between two nodes is not the only condition for the diffusion process. On figure 4a, 15 nodes have not received the information (white nodes) while they are only 7 on figure 4b. Besides, the uninfected nodes are not the same in the two figures.



(a) Initialization of the simulation

(b) Result of the simulation

Figure 5: Results of simulation using one relationship

In the second experiment, we take into account only one dimension of the MSN (friendship). The diffusion process depends on the strength of the message. The simulation stops when the strength of the message falls bellow a given threshold.

Figure 5 presents the initialization and the result of the second experiment. We have two kinds of nodes: uninfected and dissemination nodes represented respectively by white and green colors. In the end of the simulation, all nodes have received the message except for one due to the configuration of our network: the node V28 has no friend.

4.3 Discussion

The DEVS-based framework presented in this paper is a computational models for representing, simulating and analyzing the military scenarios in a stabilization phase. The Server/proxy Architecture we develop allows the flexibility of our models. We can implement different algorithms of diffusion based on different parameters e.g., individual attributes, message context and relationship between people.

The two experiments show the flexibility of our Server/proxy architecture based on DEVS. We easily manage the diffusion process according to numerous parameters. We can add or delete a network, easily simulate several scenarios and validate, verify and accredit our models.

Finally, the algorithms we use are quite simple but will be improve using social sciences studies. Our architecture allows us to easily improve the rules of diffusion process as soon as our partner evolve in their studies of human's behavior.

5 CONCLUSION AND PERSPECTIVES

We present in this paper a new simulation framework based on the DEVS formalism, a low-level framework witch promotes modularity and reusability. This architecture is fully adaptable in order to simulate, as faithfully as possible, the propagation of information within a population. some mechanism are simple but they still configurable by experts. We based our work on the idea that relationships between people are to complex to be modeled by one link. Furthermore, information diffusion is dependent of the relationship between the two people who communicate. So, the DEVS-based agent framework with the Server/Proxy architecture is flexible and sensitive to the changing environment. In the last section, we managed two experiments showing (1) the importance of managing each relationship separately in the information diffusion process and (2) how it is easy to modify the diffusion rules for each relationship using our Sever/Proxy architecture.

The perspectives of our work are numerous. We will play with more variables than just the fact to be touched by the information or not. The inner idea is to simulate how information can make evolve people's behavior. We are also looking to adapt our model to other domains such as marketing, teaching and organization study.

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AUTHOR BIOGRAPHIES

YOUSSEF BOUANAN is a PhD Student in Electrical and Computer Engineering with the Department of Systems and Computer Engineering at University of Bordeaux. He received his Engineer degree from School of Engineering Science, Morocco and a M.Sc. in Enterprise System Engineering from University of Bordeaux, France. His email address is youssef.bouanan@ims-bordeaux.fr.

JUDICAEL RIBAULT is Postdoctoral fellow at the University of Bordeaux (IUT MP) Lab. IMS. He received his Ph.D. at INRIA Sophia Antipolis, France. He has published several papers in Conferences and is frequent Reviewer in Conferences (SpringSim, TMS/DEVS, etc.). He is involved in European projects. His email address is judicael.ribault@ims-bordeaux.fr.

MATHILDE FORESTIER is a is Postdoctoral fellow at the IMS laboratory, University of Bordeaux, France. She obtained her PhD "Enriched social network extraction for social roles analysis on online forum debates" in 2012 from the University of Lyon, France. Her email address is mathilde.forestier@ims-bordeaux.fr.

GREGORY ZACHAREWICZ is Associate Professor at University of Bordeaux (IUT MP) with both competences in enterprise engineering and computer sciences. He is recently focused on Enterprise Modelling and Semantic Interoperability. He has published more than 50 papers in international journals and conferences. His email address is gregory.zacharewicz@ims-bordeaux.fr.

BRUNO VALLESPIR is full professor at University of Bordeaux, IMS laboratory. He is member of several international working groups (IFIP, IFAC), he participated to 5 European projects, has directed more than 20 PhD students and written more than 120 papers in journals and conferences. His email address is bruno.vallespir@ims-bordeaux.fr