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Modeling and Simulation of Human Reaction in a Multidimensional Social Network

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Abstract: The impacts of information on individuals within a social network are, mostly, statically modeled and the dynamic is not frequently tackled. In addition, the works about modeling and simulation of the populations reactions to the information do not use explicit specification languages to describe their models. These models are specified in the shape of graph or math formulas and then directly implemented and coded using classical programming languages. We propose to model, in the frame of SICOMORES project studying stabilization phase of a conflict, the actions of influence in a multidimensional social networks (MSN). Each graph dimension corresponds to a predetermined social network (Family, religion, neighborhood). The purpose of this work is to provide a simple but efficient and accurate framework to model the behavior of an individual, but also the simulation of the propagation of information among a group of individuals and its influence on their behavior. In more details, we define a set of models of individuals characterized by a set of state variables (e.g. Using Maslow to construct the behavior of an individual) and the mesh between the individuals within a social network. Then, we introduce the platform architecture, sharing resources, specifically designed to simulate MSN. In the end, a scenario is used to validate our models using the platform based on DEVS formalism.

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Keywords: Human behavior; DEVS Formalism; Modeling and Simulation; Multidimensional social network

1. INTRODUCTION AND MOTIVATION

General definitions present human behavior as the collection of behaviors demonstrated by humans. Behaviors are influenced by numerous aspects (e.g. culture, attitudes, emotions, values, ethics, authority, rapport, persuasion, coercion, etc.). Also, human have many ways to communicate (e.g. word of mouth, phone, SMS, emails, and the mass diffusion as radio or TV). The communication takes place in the social networks where the individuals are involved. We propose a greatly simplified model of human behavior and the messages dissemination in the social networks using a defined media. Then these models are validated by simulation. The communication will be established thanks to the individual connection with other individuals within the different social networks. The results will consist in measuring the diffusion of the information and the capacity to reach targeted people.

The diffusion studies are numerous because diffusion phenomena are discussed in several disciplines: computer science (computer virus, information diffusion in a social network) [Girvan et al. (2002)], biology (epidemics) [Cauchemez et al. (2011)], physics, etc. In our case we diffuse a message represented by a packet. This packet contains several information which determine the reaction of the individual and time life of the packet.

In literature most multidimensional social networks (MSN) are flattened at the implementation of the solution. Today some approaches formalize MSN but they are little used in computer practice. No complete implementation is done that integrate the social networks and the dynamic message propagation. Most current MSN-based simulations flatten the several networks into one, which imply to manage all the network-specific rules into one place. This approach makes it hard to develop, validate and latter reuse the model. A shared component as proposed by Dalle et al. (2008), offers a good opportunity to have one human behavior model shared in several networks.

DEVS is a timed, highly modular, hierarchical formalism for the description of reactive systems. It can be appropriated to implement networks, propagation and human behavior. A few related works have provided DEVS models of human behavior that we will use with slight modifications; Seck et al. (2005)presented a DEVS based framework for the modelling and simulation of human behavior with the influence of stress and fatigue . Faucher et al. (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.

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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 MSN, The DEVS formalism and VLE toolkit. In addition, it will provide model of individual with DEVS characterized by a set of attributes and it will present our architecture to simulate a Multi-layer Graph using DEVS. At last, the final part concerns the case study and the conclusion.

2. BACKGROUND

2.1 Multidimensional Social Network

A social network is a modeling of a set of nodes (individuals, groups or organizations) and a set of relationships between them. It is structured as a graph G=(V,E) where V is a set of nodes and E a set of edges. Nowadays, research is directed towards multidimensional social networks [Berlingerio et al. (2013)]. This formalization also called multilayer networks [Kivelä et al. (2013)], can be seen as a 3D social networks where each dimension corresponds to a relationship.

Berlingerio et al. (2013) defined a structural framework for MSN: the graph is seen as an Edge-labeled undirected multi-graph G=(V,E,L) where V is the set of nodes; L is a set of labels; E is a set of labeled edges, i.e., a set of triples (u,v,d) where $u, v \in V$ are nodes $d \in L$. Note that we can also use the term dimension instead of label.

Although social networks have long existed, multidimensional formalization and modeling is fairly recent. We find a very few works about this subject as in [Pappalardo et al. (2012); Berlingerio et al. (2011); Forestier et al. (2011)]. In their paper, Pappalardo et al. propose a MSN where relations between people come from three websites of social networking: Foursquare, Twitter and Facebook. Then, they try to measure the strength of these links. As for Berlingerio et al., they analyze hubs in a multidimensional network. Actually, measures from social network analysis have to be adjusted to MSN. Finally, Forestier et al. propose a MSN from online discussions where relations are from discussion structure and text content. These relations help to find celebrities in the discussions.

2.2 The DEVS formalism

The DEVS formalism for modelling and simulation is based on discrete events, and provides a framework with mathematical concepts based on the set theory and the systems theoretical concepts to describe the structure and the behavior of a system [Zeigler et al. (2000)]. 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 instructions. DEVS is used to specify formally discrete events systems using a modular description. It knows two kinds of models: the atomic model, which describes behavior, and the coupled model, which describes a hierarchy. DEVS defines an atomic model as a set of input and output ports and a set of state transition functions. Every atomic model can be coupled with one or several other atomic model in order to build a coupled model. This operation can be repeated to form a hierarchy of coupled models.

Recently, several researchers propose extensions to the DEVS formalism. These extensions facilitate the development of models for different application in many different domains such as biology, engineering, and sociology. Multi-Level-DEVS (or ml-DEVS) supports an explicit description of macro and micro level [Uhrmacher et al. (2007)]. Information at macro level can be accessed from micro level and vice versa. Micro models can be synchronously activated by the macro model and also the micro models can trigger the dynamics at macro level. Wainer and Giambiasi (2002) presented an N-dimensional version of the Cell-DEVS Models.

2.3 VLE Toolkit

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 et al. (2009), Quesnel et al. (2007). This framework can be used to model, simulate, analyze and visualize dynamics of complex systems. 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.

3. CONTRIBUTIONS

In this section, we describe an agent based network modeling approach using DEVS formalism. We have defined basic DEVS model components, including nodes which communicate with its ego-network via links to exchange data. As part of this work, a network architecture is proposed to simulate the MSN under a software based on DEVS Formalism.

3.1 Micro level

Each node in the MSN represents an individual who is described by a set of attributes:

- Static attributes: gender, social status, religion, ethnicity, political opinion, media (through which they can be reached) and so on.
- Dynamic attributes: interest, satisfied-needs, unsatisfied-needs (according to Maslows classification of human needs [Maslow (1943)]).

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

The model presented by Figure 1 describes the message influence on the individual behavior and potentially its dissemination using the graphical representation of Sotoodeh et al. (2013). 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, 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 it and the

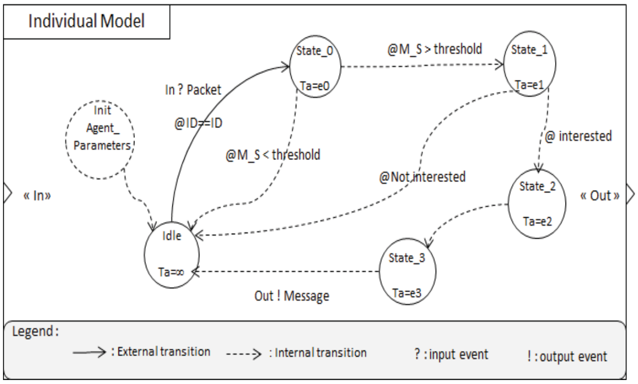

Fig. 1. Specification of node model

sender. After that two cases are possible; the receiver will transmit the message on its ego-network or it will ignore it according its attributes (the message was interesting to the receiver or not).

All data communicated among nodes are defined as DEVS messages. A packet type is defined to have the following fields: source name node, destination ID, Packet strength and data. Data can vary across the application. A packet can travel around the network for a long time depending on its strength. The strength varies from node to another and it will cause the end of the propagation if it falls below a given threshold.

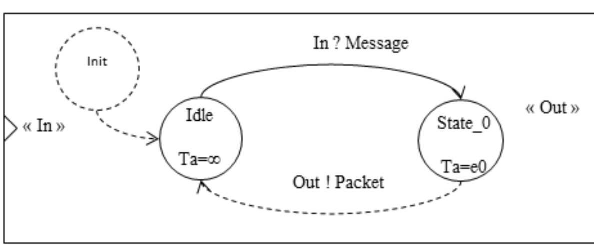

Fig. 2. Specification of data model

Figure 2 presents the specification o the data model. In this phase we prepare the packet which spread around the network.

3.2 Macro level

We use a multidimensional social network (MSN) as defined in Section 2.1 to generate a population. The MSN modeling allows a finer representation of reality by linking people with several relations: kin, friendship, religious, and so on. These relations are built according to rules and probabilities. These rules and probabilities can be changed in order to correspond at the population's culture: are large families ? Are people have a lot of neighbors ? And so on. The MSN is sequentially generated using node's attributes and previously generated links, e.g., we suppose that a family (household) shares a same religion, so people in families follow a same religious leader. At the time of writing, we generate four relationships.

First, we generate the number of nodes we want to create, i.e., the size of the population. All nodes have non-initialized attributes. We then generate the first dimension of our MSN: the family link. Note that in our model, a family is equivalent to an household. During this phase, we randomly define the size of families according to a general average and a deviation given by the user. Then we link the nodes in a clique (all members are linked to each others) and assign them attributes:

- a sex,
- a age group,
- a religion: all family members share a same religion
- an ethnicity
- a language
- a social status: we suppose that an household shares a same social status
- the role of head of family: a man with the oldest age group in the family

At this time our multidimensional social network looks like a set of cliques. We then generate the friendships links. Intuitively we follow the well known expression "birds of a feather flock together" to set probabilities of creating links between two randomly chosen nodes. We set decreasing probabilities according to the number of attributes in common they share. For example, two nodes sharing a same ethnicity, a same religion, a same sex, a same language, a same age group have a high probability to connect.

We now have two dimensions in our MSN. We then generate neighborhood links. This phase is simple: we randomly choose two nodes, if the do not already share a neighbors, we create a neighbor link. As we talk about household, we create links between all members of the two families.

Finally, we choose religious leaders to create the religious dimension. Religious leaders have to be men and not in the youngest age group. Once chosen, we create links from families to religious leader for families sharing the same religion.

So, a the end of these five steps, our MSN is generated with people (defined by attributes) and several relations. The inner idea of using a MSN is to develop message propagation rules for each dimension. The message propagation is not the same in a family than in a religious network, or with friends.

The study of information spread, propagation of ideas and influence in a social network has 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 [Goldenberg et al. (2001)] and linear threshold models [Granovetter (1978)]. In these models, the diffusion process is based on the interaction between network users (social pressure). The message contains the category of information and tracking data, for e.g. current emitter and final target.

There are clear relations between epidemic disease and the information diffusion through social networks [Bouanan et al. (2014)]. Epidemic models are used originally to study the spread of diseases among biological population. Various epidemic models have been proposed and studied over many years. Recently, researchers have also applied epidemic models to the diffusion of information and influence in social networks. Both diseases and information can spread from person to person, across similar kinds of networks that connect people, and in this respect, they exhibit very similar structural mechanisms. To drive the dissemination of information and test its impact on individuals within a social network, we developed some rules based on epidemiological models. We split the population into two compartments: info-targets and info-source(s). The first category contains individuals who do not have the information at time t=0; the other group represents people who have the information and who will diffuse it to their ego-network. Once the simulation started, the opportunities for information to spread are given by the MSN. Three conditions can stop of the propagation process:

- The individual who receives the message does not have enough interest to transmit it (the interest falls below a certain threshold).
- The strength of the message to be propagated falls below a given threshold.
- The time since the action occurred is higher than a threshold.

The different thresholds are to be defined during the experimentation.

4. GENERAL FRAMEWORK /ARCHITECTURE

The use of MSN in simulation is pretty new and raises architectural problems. Figure 3 represents a MSN composed by three networks (Network1, Network2, and Network3). Each network is independent from others and all networks contain the same nodes. Each layer shares the same nodes but has different connectivity properties. When nodes only exist on one layer of the network, they will be represented as isolated nodes on the other layer. We can see that f, f, and f are the same individual. In Network3, this individual is connected with b, and in Network1 it is connected with a and e.

The usual solution when we have to face the simulation of several graphs is to flat them into a single one (processes a Multidimensional system into a complex, single network) as represented by Figure 4. In this flatten network, individuals are connected to other individuals directly through weighted overlapping. Benefits are the simplicity of representation and the strict minimum number of components and bindings. In fact, we only have 6 nodes corresponding to the 6 individuals and 16 connections (5 for Network1, 6 for Network2, and 5 for Network3). Drawbacks are the non-separation of concerns. Each individual must contain concern (as an atomic or as a coupled model) about the network rules (to transmit or not the information on this specific network for example) as well as individual rules (affected or not by the message for example). This non-separation of concern prevents us to reuse the model with other networks or in other study. It restricts the possibility of using the different communication topology to drive the propagation of the message in a flatten network. It also

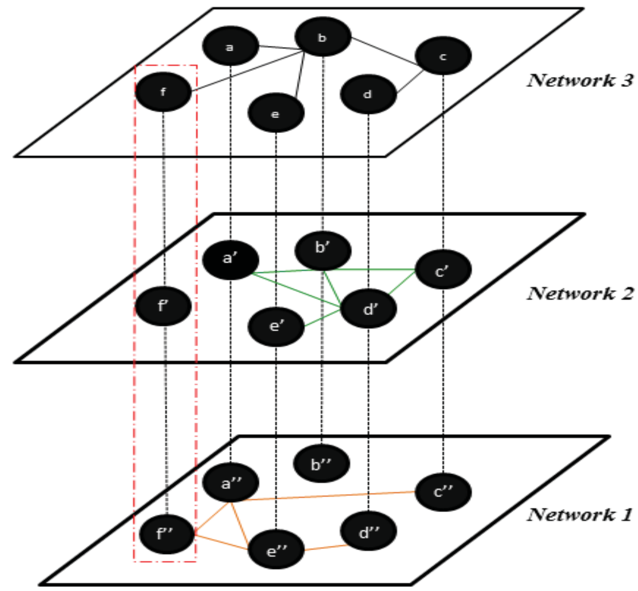

Fig. 3. Example of a Multidimensional Network

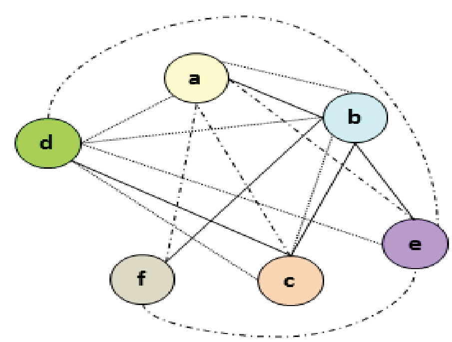

Fig. 4. Flattened Multidimensional Network

makes harder the validation, verification and accreditation process (VV&A).

Figure 5 represents the proposed architecture. We want to keep the separation of concerns at the network level, each network remains independant from the others. Node a, a, and a are called Proxy Node and contains the specific network rules for each individual. Each Proxy Node are connected to a Server Node representing the individual state and containing the individual rules. The sequence when an information arrive to a on Network1 is the following :

- Proxynode a sends an event to Servernode A
- Servernode A reads the event and depending on its state and rules, can propagate the information to its networks. Thus, an event is sent to Proxynode a, a, and a.
- Proxynode a, a, and a read the event and depending on their state and rules, can diffuse the information to their neighbors. In this case a already has the information and does nothing; a sends an event to b and d; a sends an event to b.
- Proxynode b, b and d send an event to respectively Proxynode B and D and so on.

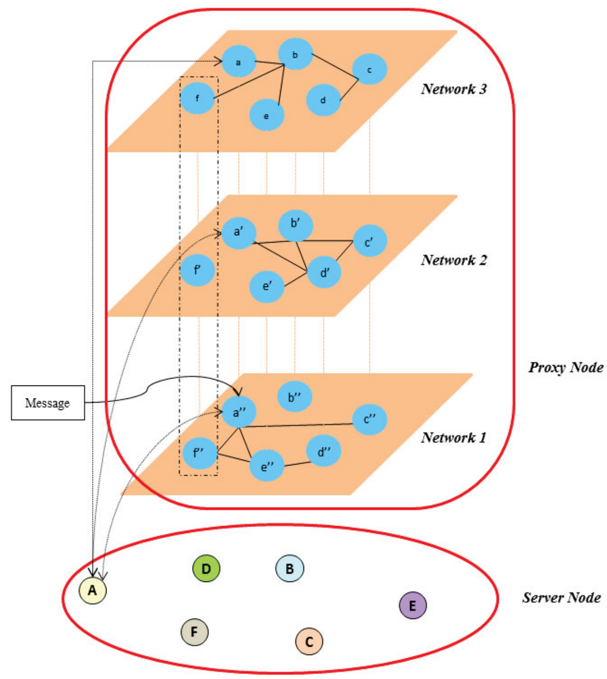

Fig. 5. Proposed MSN implementation architecture

This approach aims to enhance the reusability, the VV&A process, the model representation and thus eases the development. Its easy to add a new network: we just have to build the specific rules (if any) in a new Proxynode component. We can change individuals without changing the networks. Drawbacks are the increased number of nodes and bindings.

5. CASE STUDY

Our research is based on the project SICOMORES (Constructive sImulations and modeling the effects of influence operations in social networks). The project covers the operations of influence in a context of a conflict stabilization phase. During this phase, the Force has to convince hearts and minds to restore peace. So, SICOMORES project aims to simulate the operations of influence (modeled as a packet) in a realistic population (modeled by a MSN) according its socio-cultural parameters. For each action, there are info-targets that are reached through a mechanism of propagation.

We generate a MSN with four dimensions: family, friends, religious and neighbors. We create a city of 1000 individuals according to the characteristics given in the military exercise concerning the ethnicity, the size of families, the religion and the language. We also give to people some characteristics such as a sex and an age. Finally, some people have a particular role in the city as a religious or a political leader. Figure 6 represents the city of 1000 people. As we can see on this Figure we have women (pink nodes), men (blue nodes), heads of family (red nodes) and several relations: blue relations correspond to family, the red ones, the friendship relations, the yellow ones (respectively the green ones), the neighborhood relations (the religious relations).

VLE API is used to implement the DEVS propagation rules. One of the main problematic is the instantiation of a single node shared among several networks. Either we chose to flatten graphs into a single one. Either we chose to keep separate the different networks, which implies to implement the notion of a main agent (unique) and a proxy agent (one for each network). We chose the second solution for modularity concern. In fact, the addition of a graph becomes transparent from the main agent model. Moreover, each network can have their own acceptation/transmission rules set in the proxy agent. Then, the main agent decides to be affected or not by messages received from a proxy belonging to a trusted network or not.

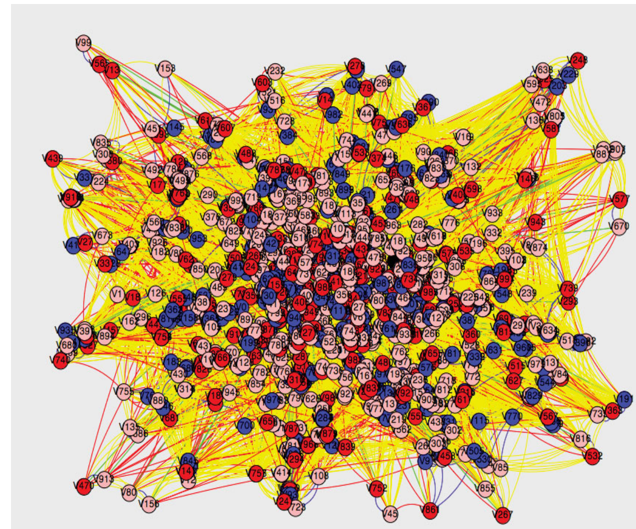

Fig. 6. Representation of a city of 1000 people

This study simulates the message propagation from info-sources to info-targets. The main goal is to test and verify the architecture proposed in this paper. This architecture allows the implementation of MSN in a software based on DEVS formalism.

The simulation takes in input 4 files representing the adjacency matrix (one file for each network) of the MSN. The simulation also takes in input an xml file containing all the attributes related to each individual. We use this file to initialize our model to resemble the population presented in a military exercise by assigning each agent the values of its attributes. At the time of writing, human behavior is simple but it will be extended with social sciences studies realized by our partners of the project.

The simulation generates data stored in a text file. This file contains the ID of the agents who received the message and at which time they received it, depending on their opinion, attributes and the network of the sender. These data allow us to analyze the relationship between two individuals who are not directly connected according to rules that drive the spread of the packet.

6. CONCLUSION AND PERSPECTIVE

In this paper, we model and simulate the human behavior and their reactions face an information. The idea is to describe the individuals with static and dynamic attributes. we also validate the use of the DEVS formalism to model MSN and the general architecture that implements the

MSN in a software based on DEVS (VLE). The scale test has been tested within SICOMORE project.

The next steps will consist in defining population with a higher number of individuals and proposing a more complex human behavior model based on social science studies realized by the social science specialist. In addition, our approach consisting on the simulation of information diffusion in a multidimensional social network using the DEVS formalism has been envisaged with other application domains including marketing, teaching and organization study.

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