Modeling and simulation of influence of informal communication in organizations

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Abstract: Social networks are the most salient concepts in social sciences. In industrial engineering, the informal communication between people in a social network has an important part in the change management. The choice to adopt a new technology, in particular Information System, in an organization or ecosystem is not always rational. The opinion of individuals is influenced by information gathered about the attributes of the technology from other members of their social network. Research in the domain gives significant results but the influence of information on individuals within a social network is, mostly, statically modeled where the dynamic aspect is not frequently tackled. In addition, the works about modeling and simulation of the population reaction to the information do not use explicit formal languages to describe their models. These models are classically specified in the shape of graph or math Expressions and then directly coded using classical programming languages. The DEVS formalism (Discrete EVent system Specifications) is being general enough to represent such dynamical systems. It provides an operational semantics applicable to this domain. These models are independent from implementation and so, easily reusable. The purpose of this work is to provide a simple but efficient and accurate framework to model and simulate the propagation of information and its influence on individual behavior. We present in this paper the results of three cases of simulation showing that our architecture is efficient and the numerous perspectives to this work.

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

1. INTRODUCTION AND MOTIVATION

The adoption process of new technologies in inter-organization has been largely studied. The choice to adopt a new technology in particular Information System in an organization or ecosystem is not always rational: the adoption of a new technology does not exclusively results from the analysis of its advantages and disadvantages. The opinion of individuals is influenced by information gathered about the attributes of the technology from other members of their social network.

General definitions present human behavior as the collection of behaviors demonstrated by humans. Behaviors are influenced by numerous aspects (e.g., age, role, position, values, ethics, authority, rapport, and so on). Humans have also many ways to communicate and share opinion and feelings: word of mouth, phone, SMS, emails, and so on. The communication takes place in the social networks where the individuals are involved. We propose a greatly simplified model of message dissemination and opinion change in a multidimensional social network (MSN). Then, these models are validated by simulation. The communication will be established thanks to the individual connection with other individuals within the different dimensions of the social network.

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 this paper, a message is represented as 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 integrates the MSN and the dynamic message propagation and opinion change. 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 belonging to several networks.

DEVS is a timed, highly modular, hierarchical formalism for the description of reactive systems. It can be appropri-

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ated 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 modeling 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.

In more detail, this paper participates in the definition of a set of models that addresses the entities and the structure of a population. It begins by presenting the MSN, The DEVS formalism and VLE toolkit. In addition, it provides model of individual with DEVS characterized by a set of attributes and it presents our architecture to simulate an MSN 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 [Berlingerio et al. (2011); Forestier et al. (2011); Pappalardo et al. (2012)]. 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 these discussions.

2.2 The DEVS formalism

The DEVS formalism for modeling 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. (2007), Quesnel et al. (2009)]. This framework can be used to model, simulate, analyze and visualize dynamics of complex systems. VLE proposes several simulators for particular formalisms; e.g., 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 defined basic DEVS model components, including nodes which communicate with their ego-network (all connecting people to a node whatever the dimension) and exchange opinion. As part of this work, a network architecture is proposed to simulate the MSN under a software based on DEVS Formalism.

3.1 Macro level

We use a multidimensional social network (MSN) as defined in Section 2.1 to generate a population of employees within a business ecosystem. The MSN modeling allows a finer representation of reality by linking people with several relations. Nodes are defined in Section 3.2. In this section, we define three relations linking people:

- people working in a same department: in a department all the individuals are linked together. We assume that everybody knows each other. Furthermore, according to the the adoption of the new information system, people should talk with closer colleagues;
- people working in a same company: in a company, relationships between people are not compartmentalized in the department. People can meet at lunch, at

coffee time, etc. All these socialization moments help in propagating the opinion about the new information system.
- people working in different companies within a same business ecosystem. People through companies are related: they can speak through mail and/or phone.

We can generate an MSN of N companies. Each company employs 30 to 50 people (the number of employees is randomly set). The generation of our MSN happens in four phases. The first one consists in creating nodes. The second generates cliques of people (corresponding to a department): a group of people are linked together. Then we generate the relationships of people inside a same company. As these relations are based on friendship, we intuitively we follow the well known expression "birds of a feather flock together" to set probabilities of creating links between two randomly chosen nodes inside a same company. We set decreasing probabilities according to the number of attributes in common they share. For example, two nodes of the same sex and age have a high probability to connect. Finally, the last relation is generated between people from different companies (with a higher probability when the two people are working in an equivalent department).

So, at the end of these four steps (nodes and links creation), 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, for example, not the same for people working in a same department than people seeing each other at lunch.

A network plays an essential role for social contagions to disseminate across multiple individuals. Social contagion refers to the diffusion of information, products, innovations, ideas, behaviors, and so on in the human society. 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)]. Most models proposed recently are extensions from the independent cascade models [Goldenberg et al. (2001)] or 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, 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 originally used to study the spread of diseases among biological population. Various epidemic models have been proposed and studied over many years. Examples include the susceptible-infected-recovred (SIR) model [Bailey et al. (1975)] and its variants. 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). Three conditions can stop the propagation process:

- Individuals who receive the message do 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.

3.2 Micro level

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

- Static attributes: gender and age.
- Dynamic attributes (variables): opinion, 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.

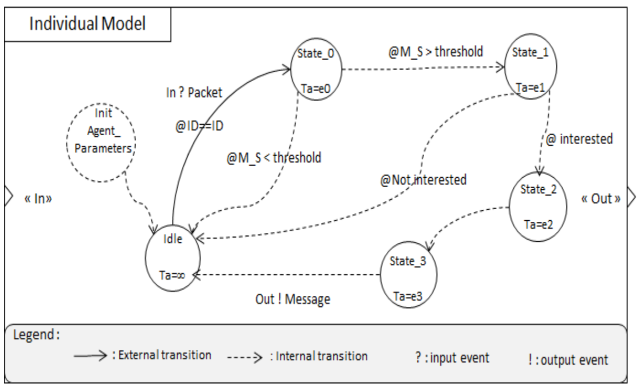

Fig. 1. Specification of node model

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 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).

All data communicated among nodes are defined as DEVS message. 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.

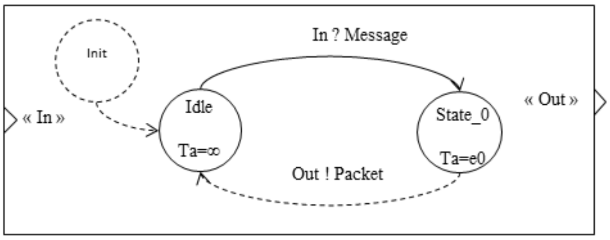

Fig. 2. Specification of data model

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

4. GENERAL FRAMEWORK /ARCHITECTURE

The use of an MSN in simulation is pretty new and raises architectural problems.

Figure 3 presents the proposed architecture. We want to keep the separation of concerns at the network level, each network remains independent from the others. Node a, a', and a" are called Proxynode 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.

This approach aims to enhance the reusability, the VV&A process, the model representation and thus eases the development. It is 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

In this research, we model and simulate the propagation of information and its impact on the opinion concerning the adoption of a new information system within a business ecosystem. We generate an MSN with three dimensions: (1) people working in a same department, (2) people working in a same company, (3) people working in different companies. This MSN represents three companies of four departments for a total of around 120 individuals. Each individual has an opinion (between 1 and 10) about the adoption of a new information system (e.g., enterprise resource planning). The protocol of opinion change is based on social influence and bounded confidence models. The message sender communicates a position about the new information system to the sender. As a result of this discussion, the receiver of the message may change its opinion positively or negatively according to the sender's opinion. This opinion is characterized by the opinion number, and the opinion confidence bounds. When the person receives an opinion, from another member within his social network, the receiver changes its opinion partially, in the direction of the sender's opinion. When the sender's opinion is outside the receivers confidence bounds, the receiver ignores the sender's opinion as shown in Figure 4. This model and the opinion scaling equations follow largely Friedkin and Johnsen (1999) and Hegselmann and Krause (2002).

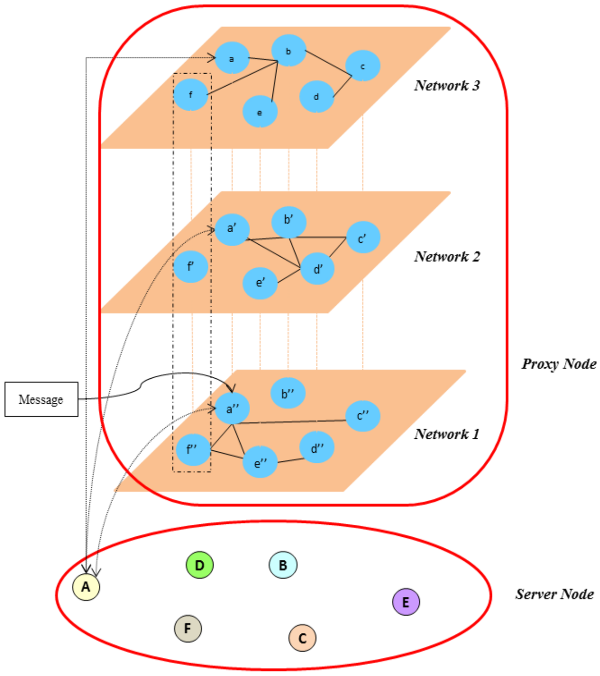

Fig. 3. Proposed MSN implementation architecture

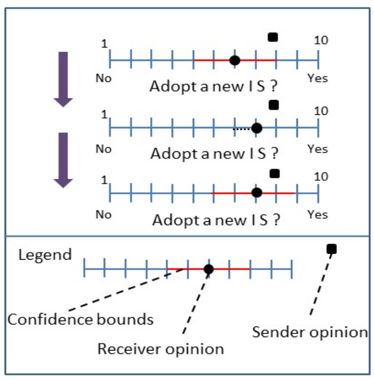

Fig. 4. The mechanism of opinion change

VLE 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.

The simulation takes in input the multidimensional social network containing the individuals, their attributes and their relationships. In this paper, We use the age attribute as a reason for resistance to change in organization [Bareil (2004)]. the human behavior is simple but it will be extended with social sciences studies realized by our partners of the project.

We define three different simulation games of around 120 people each. The first one defines a business ecosystem wherein members are mostly in the oldest age class; the second one, mostly in the youngest age class; and in the last one, we randomly define the member's age class. We also set the opinion according to Autissier and Moutot (2007): 10% proactive, 80% passive and 10% opponent.

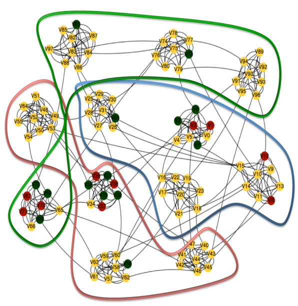

Fig. 5. An MSN of three firms

Figure 6 shows the simulation set and the results of a message propagation and the change in opinion. This model represents the opinion of enterprise members regarding the adoption of a new information system. The green nodes represent the proactive, yellow nodes represent the passive and the opponents are described by the red nodes. At the end of the simulation, we can see that the information spread within the MSN and the general opinion of individuals has changed. In the case 1 and at the end of the simulation people are mostly against the adoption of a new Information System partly due to the members age class. The situation is the inverse in the case 2 where people are young. Finally, in the case 3 the opinion is mixed.

This type of simulation provides an opportunity to predict the propagation and the influence of informal communication on the adoption of new technologies in an organization.

6. CONCLUSION AND PERSPECTIVE

In this paper, we model and simulate the human behavior and their reactions face change in a business ecosystem. The success of a project relies on the capacity of people in the organization to accept and get involve into it. So, we describe the individuals with static and dynamic attributes as the opinion on the project. 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). We lead an experimentation of information propagation and opinion change based on three cases. These three cases are based on the people age of the business ecosystem. The results show that our general framework (MSN, proxy/server communication) performs well and allow to obtain a tendency of change acceptation.

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 military study.

Finally, this application will help to determine the refractories, the important people to convince, the proactive, and so on, in order to facilitate the adoption of a new technology in organizations.

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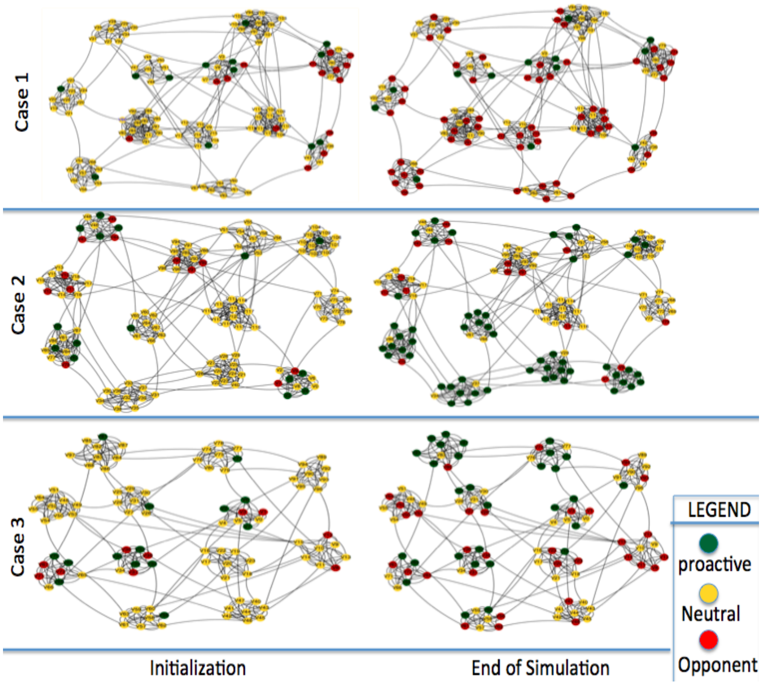

Fig. 6. Simulation results

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