Information Dissemination in Social Networks

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Abstract: Social networks are currently one of the most studied structures for information and knowledge exchange. These structures are very well described in terms of their static structure, this article attempts to propose the model of their dynamic behavior and the spread of information and knowledge in these networks. The heuristic event based model of the individual behavior in the network using the message passing will be presented. The main idea of the model is agent's need for information and knowledge in specific situations. On that is based multiagent model of the social network used for information exchange, which has been practically implemented and will be presented as well as some of its simulation outputs for tasks testing the dynamics of social networks.

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1 INTRODUCTION

Social networks are currently the most studied structures for information and knowledge exchange. These structures are very well described in terms of their static behavior; our contribution tries to describe the dynamics of information dissemination within them.

Social network can be thought of as a graphical structure whose nodes are objects or individuals (people) and edges represent some kind of connection between these objects. The nature of these connections may vary but they always express a certain link or communication between connected nodes. During the time the structure of the network varies; usually as a result of the communication between nodes (individuals).

This paper aims to show one possible way of modeling the dynamics of information dissemination in a social network. The first experimental results show some phenomena that were seen in the structural and information dynamics of modeled networks.

The rest of the article is structured as follows. In chapter 2 the actual state in simulation of social networks dynamics is presented. Chapter 3 is focused on principles and implementation of the proposed model. In chapter 4 are presented preliminary experimental results. Some conclusions and recommendations for future work are summarized at the end of the article.

2 STATE OF THE ART

For social networks modeling is very frequently used the agent based (AB) approach, which is preferred where local data about individual's behavior are available or where global probabilistic data allowing to set individual parameters can be inferred. The popularity of AB approach increases the quantity and quality of modeling tools, further information can be found in (Siebers at al., 2007). For single agent modeling we can use any technique which allows describing the agent behavior (e.g. system dynamics, event based modeling, state charts, flowcharts).

The social networking topics are discussed in a number of publications, an overview of social network analysis techniques can be found in (Wasserman et al., 1994). Several social metrics of the network useful for decision making including the FRINGE algorithm are also presented in (Palazuelos et al., 2012).

The rating of agents which influences the links in the network and its stability is described in (Wu et al., 2011). The idea of agent rating is also used in our approach.

Many papers are focused on analysis of the real data. Very interesting analysis of large real network dynamics can be found in (Zhao et al., 2012). The use of agent based approach in the analysis of social networks (e-mail based) is addressed in (Menges et al., 2008). Very actual is the field of social networks

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in Internet-based games. E.g. the analysis of the social network in bridge community is presented in (Balint et al., 2011).

The spread of ideas in online networks is also engaged in Ahmad's work (Ahmad et al., 2006), where authors use several measurements, such as acceptability, portability and accessibility. Our model was also affected with this approach. Visual analytics approach for analysis of network dynamics is described in (Federico et al., 2011). The work of Ma (Ma et al., 2013) is focused on detecting communities and their tracking in the dynamic network; new algorithm is proposed for this goal.

The idea of the event based social network model is presented in (Jelínek, 2011). The model is based on the agent's need for information to find the best possible reaction on randomly occurring events. The event is here a very general concept and we can imagine different thing under it, e.g. some situations in the environment, messages sent to agent, etc. Our model uses the same basic principle.

3 MODEL OF THE SOCIAL NETWORK

The model uses the multi agent approach based on the coexistence and interaction of elementary objects (agents). The state charts with event activated state transitions are used at the agent level to describe his behavior.

As the base of the model we assume the existence of the agents who are exposed to some "life" situations requiring their reaction (solution of the situation). Agents want to make the best solutions. They use their own information and skills but also try to find the solutions of the same situation created by the other agents in the network in the past. The model is based on the closed world assumption applied to the number of nodes in the network and the set of possible situations which is constant and unchanging over time. This assumption is an acceptable simplification of the reality. The dissemination of knowledge for solving new situations can be simulated with correct setting of the time when situations will arise. Our goal is to examine how agents improve their skills (the ability to use the best reaction on the situation).

The detailed modeling of the "life" situations is not a crucial issue; they are represented just like a message. The "solution" to every possible situation j from the total number of N is represented as a single number s_j from the interval <0, 1> which also describes the quality of reaction (1 = highest quality, that means the best solution). In the future versions of the model this number will be replaced by function describing more precisely the quality of reaction.

3.1 Detailed Description of the Model

The basic agent action in each simulation step is described on figure (1).

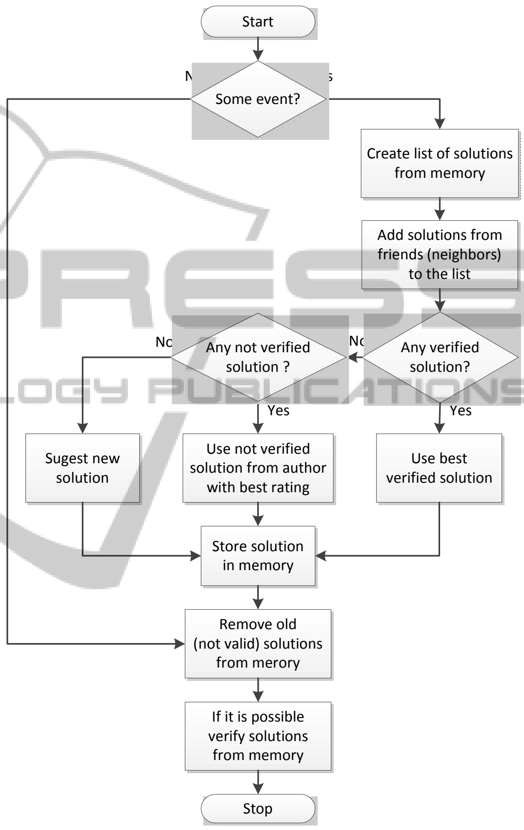

Figure 1: Diagram of agent actions at each simulation step. (Jelínek, 2011).

In each simulation step the environment sends messages according their activation rules (probability function or time based event) to (usually) randomly selected agents.

The agent can generate a new solution based on his education and knowledge level (simulated by the agent ability to generate a solution with the quality in the defined range). If the agent is part of a social network, he also tries to find a solution through asking his neighbors (connected agents - partners). The different willingness of every agent to communicate is respected so as the willingness to accept the question and answer to it. These parameters implement a simple model of agent's

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personality and emotional state.

In the process of finding the best solution to the given situation plays a crucial role the feedback, i.e. the evaluation (verification) of the solution's quality. Without it, the agent is not able to prefer better solutions. The model respects the fact that the solution may not be verifiable immediately after its adoption, but only after some period of time. The information about solution verification is represented by a special message sent to the agent.

The agent has its own memory for storing previous reactions on different situations. It forms the basis of a simple CBR (case based reasoning) system. Every newly created solution agent stores together with an identification of its author. The author needs not necessarily be the agent from whom the solution is obtained; it could be taken over from another individual in the network. In the memory is implemented the process of forgetting - old solutions are removed from memory a certain time after their inserting.

Information about the authors is used for rating agents in the network. Author of the solution is added to the list of partners and his rating is modified in the moment of verification of proposed solution. As we can see on figure (1), rating is used in situations where there is not verified solution in the agent's memory or obtained from the network. The rating is decreased when the partner does not want to communicate and answer agent's questions. The length of the partners list (number of links) can be limited and agents with lowest ratings are deleted. The described mechanism is one of the ways how to implement the principle of local trust describing the oriented link between two agents.

Our main goal is to explore the dynamics of the information dissemination in the network. To be able to characterize the amount of knowledge of each agent i, the quality q_i according to the formula (1) is calculated, where N is the total number of situations and s_{ij} the quality of the solution of situation j used (generated or obtained) by agent i. If a solution to the situation j is not available, the value s_{ij} is taken as zero. It's taken into account that agent may remember several solutions of specific situation.

$$q_i = \frac{1}{N}\sum_{j=1}^{N}\max(s_{ij}) \quad (1)$$

The overall quality Q of the network was also defined according to (2), where M is the total number of agents in the network.

$$Q = \frac{1}{M}\sum_{i=1}^{M} q_i \quad (2)$$

Also the "popularity" of the agent as normalized sum of agent's ratings from all agents in the network was defined according to (3), where p_i is a measure of agent's i popularity and r_{ji} is the agent's i rating on agent j (if agent i is not rated by agent j, the rating is set to zero - $r_{ji} = 0$).

$$p_i = \frac{1}{M}\sum_{j=1}^{M} r_{ji} \quad (3)$$

It is necessary to point out here that the rating is conducted also on agent itself (it defines the opinion of the agent about himself).

4 EXPERIMENTAL RESULTS

After the start of the simulation the network is set up so that agents have links only with closest neighbors (based on the distance between agents in 2D "world" space).

Several parameters were watched during the simulation experiments – especially the agent's quality q_i and the overall network quality Q. Also other data from the model can be monitored. Some examples from the experiments are shown in the following figures.

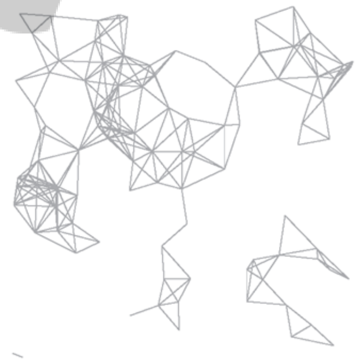

Figure 2: Network structure at the start of the simulation.

First experiments were performed on a network of 100 agents with the set of 10 situations. The maximum number of agent's links was 20. On figure (2) is the network topology on the beginning (the closest partners), on figure (3) the state after 500 simulation cycles. We can see the creation of "information centers", the agents with big popularity (represented with the big radius of the circle) based on their information competence and willingness to communicate with others. The colour of the node circle represents the quality of agent (darker circle = better quality).

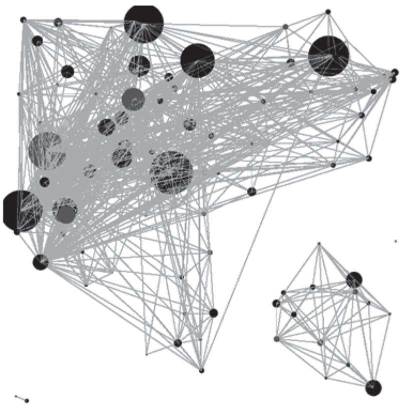

Figure 3: Network structure after 500 simulation steps.

We can see that modeled social network may be split into a number of non communicating agent groups. This is in compliance with reality - closed communities can get into the separation, which in turn affects the knowledge quality of their members because of limited access to information. To remove this phenomenon, agents can use some "initiative" in managing their lists of partners (e.g. using the model of search services for finding new partners).

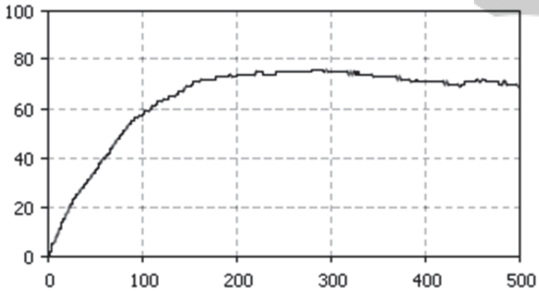

Figure 4: The overall network quality *Q* during the simulation (simulation steps on *x*-axis)

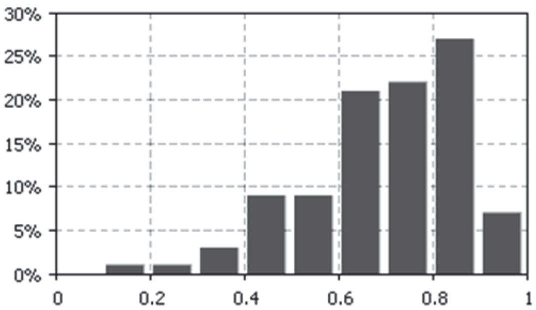

Figure 5: Histogram of individual agent's *q* after 500 simulation steps.

On figure (4) is presented the overall network quality based on equation (2), and its progress during the simulation. The *y*-axis shows percentage of overall quality Q (100 is the maximum value, every agent is able to use the best solutions for all situations). Here we can see the dynamics of information dissemination. On the beginning of the experiment, the maximum number of agent's connections was set to 20; agents created their personal networks (partner lists) and received the knowledge about solutions of all possible situations. In the step 300 of the simulation the maximum number of connections was reduced to 2. This reduction had minimal influence on the overall network quality because the substantial connections have already been created before.

We can also display the quality of individual agents after the simulation. The corresponded histogram is on figure (5).

We can compare the figures (4) and (5) with the situation where the agents had no possibility to communicate (number of links = 0 during the whole simulation). The results are on figures (6) and (7).

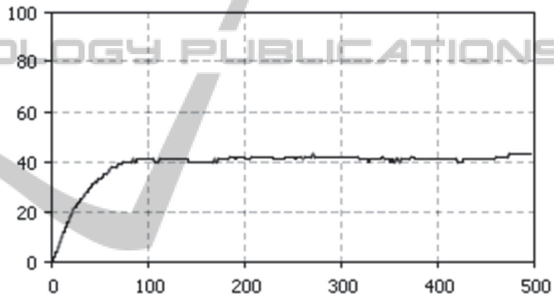

Figure 6: The overall quality *Q* of agents during the simulation (no network, simulation steps on *x*-axis)

From the results we can see the different behavior of the agents and the big influence of the social network on the quality of individual agents and the whole "network" and also on the dynamics of the information dissemination process.

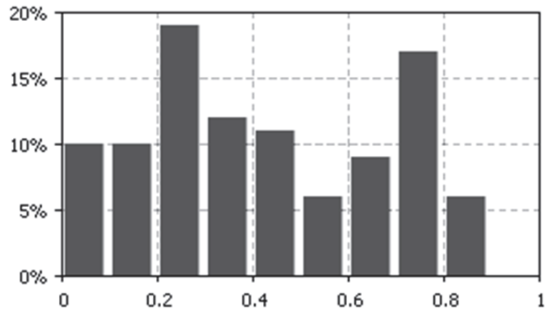

Figure 7: Histogram of individual agent's *q* after 500 simulation steps (no network).

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5 CONCLUSIONS

Proposed model extends and improves the model for simulating the dynamics of information dissemination within the social network presented in the earlier work of the author. The system of messages is now used, which is crucial for future work. The model can be used to study the dynamics in social networks of varying size and orientation created for the purpose of information exchange (such as corporate networks, on-line services, local structures aimed to solving everyday situations, etc.), not limited to on-line services and electronic transmission of information.

The presented results are only the beginning of the exploring and simulating of the social networks with this model, but experiments shown that model provides interesting outputs comparable with the behavior of individuals in the real world.

The model is continuously developing and modifying. We plan to do much more experiments to examine the influence of all parameters on the network dynamics. We are constantly searching for a suitable user interface, too. Stress will also be laid on model of the quality verification and setting model parameters using data from real social networks. The mid-term goal is also to implement in more detail the emotional states of agents.

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