Gossip and ostracism in modelling automorphosis of multi-agent systems

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Abstract

Automorphosis viewed in terms of IT systems requires that these systems have a range of features related to autonomy, dispersion of their components, and communication between their elements. Examples of IT systems in which the issue of automorphosis is an important modelling aspect include software agent societies where individual agent units create structures that specialise in performance of assigned tasks in a dynamic manner, depending on changing conditions. The use of automorphosis mechanisms in such groups of agents enables control of their behaviour and monitoring of their actions. The first chapter will address the issues of automorphosis of software agent societies. The second chapter will present an analysis of the theory of using gossip and ostracism in IT systems. The third chapter presents a proposal of the use of gossip and ostracism. It also includes results of an experiment. The aim of this paper is to analyse the possibilities of the concepts of gossip and ostracism as a control element of agent societies. To achieve that the extension of JADE (Java Agent DEvelopment Framework) was developed.
Keywords: trust, software agent society, simulation, gossip, ostracism

1. Introduction

The basic element of automorphosis is the organisation of a system. Organisation should be understood here as relation of a system's structure with its function [4]. The structure of a system defines the relationship of its elements as a whole in the manner determined by the system. This manner means that the elements enter into relations with each other, creating a specific sub-system operating as part of the main system. They are connected with each other and integrated. At the same time, the elements of a system are separated from each other as part of subsystems in order to prevent possible interferences. Such dependence of a system's elements is static in a specific point in time and changes with subsequent iterations. As a result, the relations that are created between a system's elements are changeable, and elements of a given sub-system may become elements of a different sub-system. However, this process cannot be random.

The element that impacts the change of the structure of sub-systems is a function. A function defines the objectives of a system and dynamically created sub-systems, impacting relations between its elements and defining them. A change of the objectives of the main system, and consequently its functions, leads to change of the relations between its elements, and as a result - change of the structure of sub-systems.

Thus, it can be indicated that automorphosis of a system results from accepted objectives of its operation, i.e. the functions it fulfils. These objectives can be defined through mechanisms of a system in which sub-systems are built or through the elements of the sub-systems themselves. It can be assumed here that all functions of a sub-system are regulated by the system in which such a sub-system is being build, whereas within sub-systems the relations result from the objectives of the units that compose them.

In the case of IT systems, the term automorphosis indicates systems' capability of independent creation of their internal structure, not in a random way, but a coordinated one and aimed at achievement of defined objectives. When creating IT systems, automorphosis of systems requires that they have a specific construction connected with the necessity to divide the system into coherent elements that have various functionality and are capable of cooperation through defined mechanisms of communication. Examples of such solutions include multi-agent systems, in particular software agent societies [13],[14],[15]. Software agent societies are treated as a sub-type of multi-agent systems whose fundamental characteristic is openness expressed in the capability of joining the structure of a society of new agents and dynamics connected with lack of clearly accepted relationships, e.g. hierarchical ones, between agents. Thus, a software agent society requires mechanisms that protect their operation and support coordination of the creation of groups of task agents designed to perform specific actions of an agent system.

Earlier research conducted by the author was focused on pointing out that a software agent society, in the context of modelling their structure, can be viewed as a metaphor of a social organisation in which an agent society can support an organisation's actions through delegation of its specific tasks of business process participants [18],[19]. The research was focused on defining possibilities of involving a process of modelling the operation of a social organisation in the process of modelling the architecture of software agent societies, which would contribute to better understanding of tasks of the agents in such a society. As an effect, a methodology was proposed [16] that combined a process approach and its modelling in BPMN with the possibility of connecting an organisation’s processes with the architecture of an agent society.

A certain limitation of the developed methodology for designing an agent society was the problem of defining the mechanisms of a society's automorphosis. While available methodologies for designing multi-agent systems enable presentation of their static structure and indication of possible states of a multi-agent system, in the case of the features of openness and dynamics that characterise societies, these methodologies do not enable illustration of control mechanisms that software agent societies have to possess [20]. For that reason, the author initiated research connected with the possibility of using trust mechanisms as an element supporting control of the operation of an agent society [17]. A complete list of papers on this subject can be found on the website www.projektncn.katowice.pl.
As will be pointed further in the paper, reputation and trust defined in an agent society can be extended to include the use of the concepts of gossip and ostracism.

2. Current state of research on the use of gossip and ostracism in IT systems

As for the development of software agent societies, their use may be connected with the mechanism of gossip [8] and ostracism [11]. These concepts, widely used in human societies, can be applied as an element that supports control of software agent societies. Research on human societies shows that a human being attaches greater importance to gossip than facts [10].

The first of the mechanisms refers to information propagation. The first application of the mechanism of gossip can be found in the work [2] where it was used to support the mechanism of preserving homogeneity of replicated data bases. The mechanism of gossip is an important element of the activity of a society, as it allows its members to express their opinions. When applying this mechanism in respect of IT solutions, it is necessary to specify a range of assumptions of its use. These are:

- Algorithm for gossip propagation in a system.
- Communication protocol of a system's entity.
- Style of the operation of a communication protocol.

The above-listed elements will be described in the context of their use as part of a software agent society.

Research on algorithms for gossip propagation in a system (without clear specification of its type) refers to its three main types [3]:

- **Information Spread:** this type of algorithms can be used in a situation when one element of a system possesses a specific piece of information and wants to propagate it among other elements of the system.
- **Computing Aggregates:** this type of algorithms can be used in the case of the necessity to propagate the information possessed by individual elements of a system in such a way that an assumed function of aggregation of this information is common to all its elements.
- **Overlay Management:** the last type of algorithms refers to a situation of incomplete knowledge of a system's elements about the existence of other elements in this system. Here, the problem is possibility of propagation of a given piece of information in an indirect way through successive elements of the system.

The research on algorithms indicated herein does not directly refer to the aspect of agent systems, but rather to efficiency and effectiveness of the operation of the process of propagating a given piece of information, and can be used in the process of controlling the flow of information in a multi-agent system. This results from the fact that these algorithms are oriented towards the aspect of time and possibility of propagating a given piece of information in all or at least a selected group of elements of a system, which may constitute a problem in the case of dynamic changes in the structure of a system. In particular, these algorithms refer to structures built as Peer to Peer solutions. As a result, they are largely oriented towards the aspect of a system's structure, rather than its function, which was indicated earlier as the fundamental element of automorphosis. The solution that will be presented further in the text uses the first type of algorithms, which is oriented towards propagation of gossip between those asking an agent and other agents and between a multi-agent platform and an agent.

From the perspective of gossip propagation in a system, it is also necessary to specify the protocol of information exchange between elements of a system. The model presented further in the text used a general protocol for handling gossip as proposed in the work [5]. The reason for using this protocol of information exchange was easiness of its adaptation to FIPA protocol used in the applied multi-agent platform.

The last element is style of the operation of a communication protocol. Literature [1] presents three styles of the operation of gossip defining protocols: dissemination (rumour-mongering) protocols, anti-entropy protocols for repairing replicated data, protocols that compute aggregates, or that accomplish some task as a side-effect of computing an aggregate. In the developed model, the application of the first type was adopted, in particular its sub-type: background data dissemination protocols. This results from the fact that in the case of a multi-agent platform that possesses information about entities of agents existing within it, it is not necessary to use more complex mechanisms. The mechanism is characterised by a periodical mechanism of propagating gossips in a system.

In agent societies, agents' new knowledge can be defined through their mechanism of artificial intelligence which generates a message or through information coming from the environment of a multi-agent platform. Such information, remembered by an agent unit, is treated as belief. This is due to continuous change in an agent's environment, as a result of which information possessed by an agent can be out of date at a given point in time. The second reason for such treatment of an agent's knowledge is possible lack of confirmation of the information it receives from its environment. When communicating with its environment, an agent is unable to verify all the information, which causes it to operate in the conditions of uncertainty, as it tries to perform its actions in a given society. As a result, the information it receives can be treated by it as gossip. It is necessary to distinguish here two types of information acquired by an agent. Information from the platform in which it resides and that from other agents. In the first case, the information acquired by an agent does not have to be confirmed by it, as it is formulated by the mechanism controlling the multi-agent platform

which by definition will strive for proper operation of the society. In the second case, information about other agents can be treated by a given unit as gossip defining information about other agents. In this case, an agent receiving a given piece of information has to rely on its trust in the agent that has formulated this piece of information and on trust in the agent to which the gossip refers.

The second mechanism that can be used in an agent society is the mechanism of ostracism. Literature distinguishes three types of ostracism [12]:

- **Punitive Ostracism** – in this approach, a group of units or a single unit stops cooperating with another unit or group as a result of actions taken by it/them.
- **Defensive Ostracism** – where a group or unit refuses cooperation because of fear.
- **Oblivious Ostracism** - where a unit or group is excluded without clearly specified intentions/reasons.

In the context of the earlier-addressed issues concerning automorphosis, structure and function of a system, the first of the presented approaches seems reasonable. The mechanism of ostracism in an agent society is connected with the necessity of supervision and control of agents' behaviour towards each other and in relation to the mechanisms controlling a multi-agent platform. In the case of communication in an agent society, there are two causes of ostracism. The first one concerns formulation of messages transmitted between agents. If a given agent unit detects that a message (which can be treated as gossip) is not true, it can decrease its trust in the agent propagating this piece of information. Decrease of an agent's trust in another unit may lead to the use of the mechanism of ostracism, where an agent ceases cooperating with a given unit due to low trust in it. The second reason for the use of ostracism is not so much propagation of untrue information as a given agent's lack of skills. In the proposed model [6] trust in agents is built through their proper performance of tasks assigned to them. If a given agent unit proposing to perform a specific task performs it incorrectly, the level of trust in it will decrease. As a result, this agent will no longer be taken into account during formation of a group of agents to perform a specific task. Decreased trust in a specific agent's skills can be propagated by agents through the mechanism of reputation [6] (propagated by a multi-agent platform) or, as was already indicated, through the mechanism of gossip (propagated by an agent).

As was pointed to, the mechanisms of gossip and ostracism support the process of controlling the activity of agent societies. One of the works where these mechanisms were addressed is [9]. In the proposed model, the authors made an attempt to define the parameters of an agent society, indicating the following parameters as reasonable [9] - c**ooperativeness value**: this attribute concerns how cooperative an agent is, **tolerance value**: which characterizes how much non-cooperation the agent can tolerate before it decides to leave the group, **rejection limit**: how many rejections the agent can face before it decides to leave for another group, **gossip blackboard length**: a gossip blackboard of certain length to store the gossip messages from other agents of its group, **life span**: determine how long the agents remain in the society and c**ost and benefit for sharing.** So defined parameters of agent behaviour control involve only the aspect of communication and do not address the problem of tasks performed by agents in a society. Thus, the approach proposed by the authors focuses on the aspect of cooperation in the context of information exchange without clear specification of the fundamental element of automorphosis, i.e. the already mentioned function of a system.

The solution, proposed later in the article, constitutes of developed research, carried out by the author, on building software agents societies [12 - 19] and is a proposal to extend the JADE platform functionality (which is one of the most functional multi-agent platforms [21]) with trust, reputation, gossip and ostracism elements. In the proposed approach the mechanism of agent's action is based on its reactive and proactive layer [22], which interaction allows to control the operation of a unit. As a result, a trust and reputation concept model was developed [17] and indicators, which can be used in the assessment of community agents [6], were pointed.

In the proposed article, this model has been implemented for the JADE platform and extended with additional elements. As a result, the following indicators governing agents' activities can be identified in the proposed trust and reputation model extended to include the mechanism of gossip and ostracism:

- **Level of an agent's cooperation** - defines the number of tasks that it was able to perform in a society relative to all the tasks that had to be performed.
- **Level of an agent's tolerance** - the number of tasks that an agent will propose to potentially perform and that can be rejected before an agent decides to leave the society.
- **Time of an agent's activity** - how long an agent waits for appearance of tasks that it can perform from the moment the last of such tasks appeared. After this time an agent leaves the society.
- **Agent's self-trust** - indicates level of trust that an agent has in its actions. An agent generates it based on its abilities connected with performance of actions and tasks as part of processes in a society. It is deterministic in character, as the model does not take into account a situation when an agent deceives itself.
- **Social trust in agent n** - defines the level of trust that an agent has in other agents. It is generated based on interaction with other agents connected with actions that they perform. Every agent stores a number of values of this parameter. The number depends on interactions with other agents.
- **Gossip social trust of agent n -** It is used when a new agent appears on platform and specific agent has to adopt gossip trust about other agent.
- **Reputation of agent n** - defines the level of agents' reputation on the platform. It is used when agent does not have social trust in a specific agent unit. It is used to eliminate the problem of "cold start" where an agent that does not have knowledge about other agents will not be able to make a decision about further actions.
- **Gossip reputation of agent n -** It is used when a new agent appears on platform and platform has to adopt gossip about agent reputation from another agent.

For illustration of the operation of the so defined parameters, the paper will present an example of the operation of a society developed based on the author's developed solution. This solution will present how a mechanism of gossip reputation can influence on a society.

3. Proposal to extend the model of trust and reputation

The model of trust and reputation presented in work [17], [6] can be extended to include the approach connected with gossip propagation and ostracism as indicated herein. In the presented model, a range of trust and reputation parameters were defined and divided into 3 separate groups. The first group of indicators refers to an agent's self-trust, the second group refers to an agent's social trust, whereas the third one - to an agent's reputation in an agent platform. Each of the indicators is examined in terms of four levels, defined as trust/reputation of an action, a task, a process and general one. As a result, indicated sets of agents form a two-dimensional matrix presented in table 1.

Table 1. Trust and reputation matrix developed in accordance with [6].

Level/Type	**Agent's self-trust**	**Social trust in agent n**	**Reputation of agent n**
action	0 to 1	0 to 1	0 to 1
task	0 to 1	0 to 1	0 to 1
process	0 to 1	0 to 1	0 to 1
general	0 to 1	0 to 1	0 to 1

Based on the model [6] which was extended to include the concepts of gossip and ostracism, it can be said that the proposed indicator of cooperation [9] should result from an agent's skills, i.e. an agent with knowledge in a given field or ability to perform a task should show a higher

indicator of cooperation. An agent's tolerance for non-cooperation is connected with the tasks that are propagated in the system. Temporal limit of participation in a society was also indicated in the project, i.e. time limit that an agent will spend in a society before it leaves it. It is counted from the moment of receiving information about a task that can be performed by a given agent.

For the implementation of the so defined model of a society, the JADE multi-agent platform was used as the basis for building software agents. The functionality of the platform was extended to include elements of the mechanism of trust and reputation control as well as the proposed indicators related to gossip generation and ostracism. The developed solution, in accordance with the adopted methodology of designing an agent society, involves the development of a process or a group of processes that should be supported by agents. In accordance with the trust and reputation model extended to include the elements of gossip and ostracism parameters, the following research methodology was adopted:

Parameters of the mechanism for controlling an agent society:

- Defining a set of business processes in which agents will participate.
- Defining a set of agents participating in a system.
- Defining initial indicators of agents' reputation in a system.
- Defining the limit indicator of ostracism of a system.

Parameters of agents that can become an element of a dynamic society:

- Defining skills/tasks of agents that they are able to perform.
- Defining the probability of an agent's performance of a task.
- Defining the level of an agent's ostracism.
- Defining the base self-trust of an agent.
- Defining the base level of social trust in agents.
- Defining the base level of an agent's reputation on the platform.

Parameters defined in this way were imported to a prepared simulator of a society behaviour, and a simulation of the operation of an agent society was carried out.

4. Observed mechanisms of the operation of a society

The developed simulator enables definition of a business process in which an agent society will participate. The defined processes are imported to the simulator of the operation of a society. Next, sets of agents are defined and assigned basic parameters, such as definitions of tasks that they can support and base values of indicators that are necessary to carry out the simulation. Results will be presented based on one of the prepared processes. The process is illustrated in figure 1.

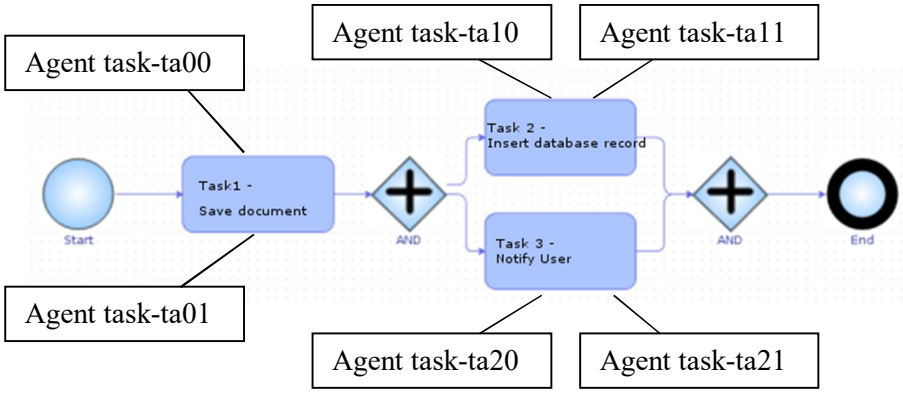

Fig. 1. Analysed business process

The process consists of three tasks. First the selected agent saves the document (task 1), then the information on saving the document is recorded in the database (task 2), and the user is

informed of this action (task 3). For each task two agent actions need to be done. Based on the prepared simulator, the tasks were assigned a set of three agents, each of which can perform a selected task. Prepared simulator was developed as the extension of JADE platform. In the simulation process, each agent behavior is monitored and its progress is recorded in the database. The simulator can operate in two modes. The first is the actual implementation of a business process, where the behavior of agents can be programmed, and the agent society oversees the process. The second one is a simulation mode, where the agents' behaviours are simulated. The probability of correct execution of the task results from the assumed probability level. Figure 2 presents the interface of a developed simulator.

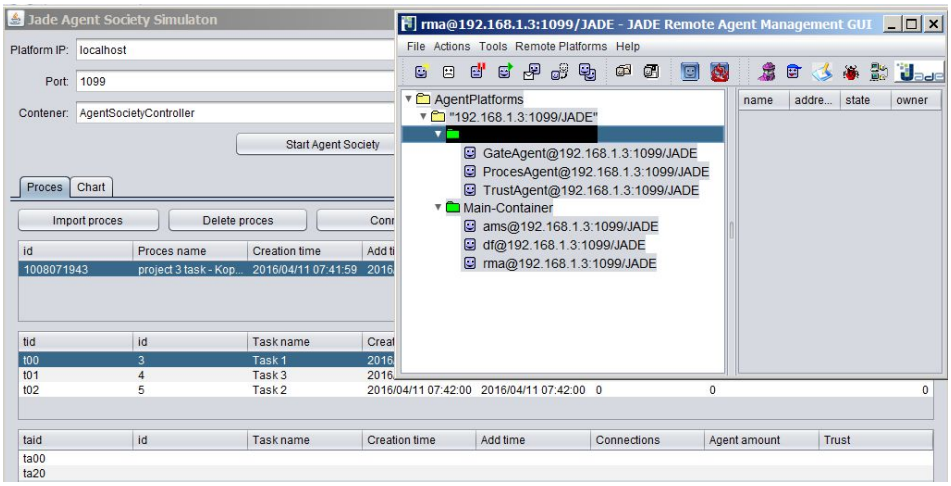

Fig. 2. Agent Society Simulator interface

Adopted initial assumptions are presented in table 2.

Table 2. Adopted initial assumptions

Level/Type	**Agent's self-trust (initial)**	**Social trust in agent n**	**Reputation of agent n (initial)**	**Possible agent**	**Success probability**
Action ta00	0	0	0	ServiceAgent01	0.7
Action ta01	0	0	0	ServiceAgent01	0.7
Action ta10	0	0	0	ServiceAgent02	0.7
Action ta11	0	0	0	ServiceAgent02	0.7
Action ta20	0	0	0	ServiceAgent03	0.7
Action ta21	0	0	0	ServiceAgent03	0.3

The table 2 shows a set of initial parameters for a single process, assuming a cold start. In this approach, only with the result of the activities of agents it is possible to indicate the value at a given point of time. The following figures will present the changes in the value of reputation for the individual agents and their actions.

For so prepared simulation, lack of the use of the mechanism of gossip and ostracism was first assumed. It was assumed that the simulation will cover 20 iterations of the performance of the indicated process.

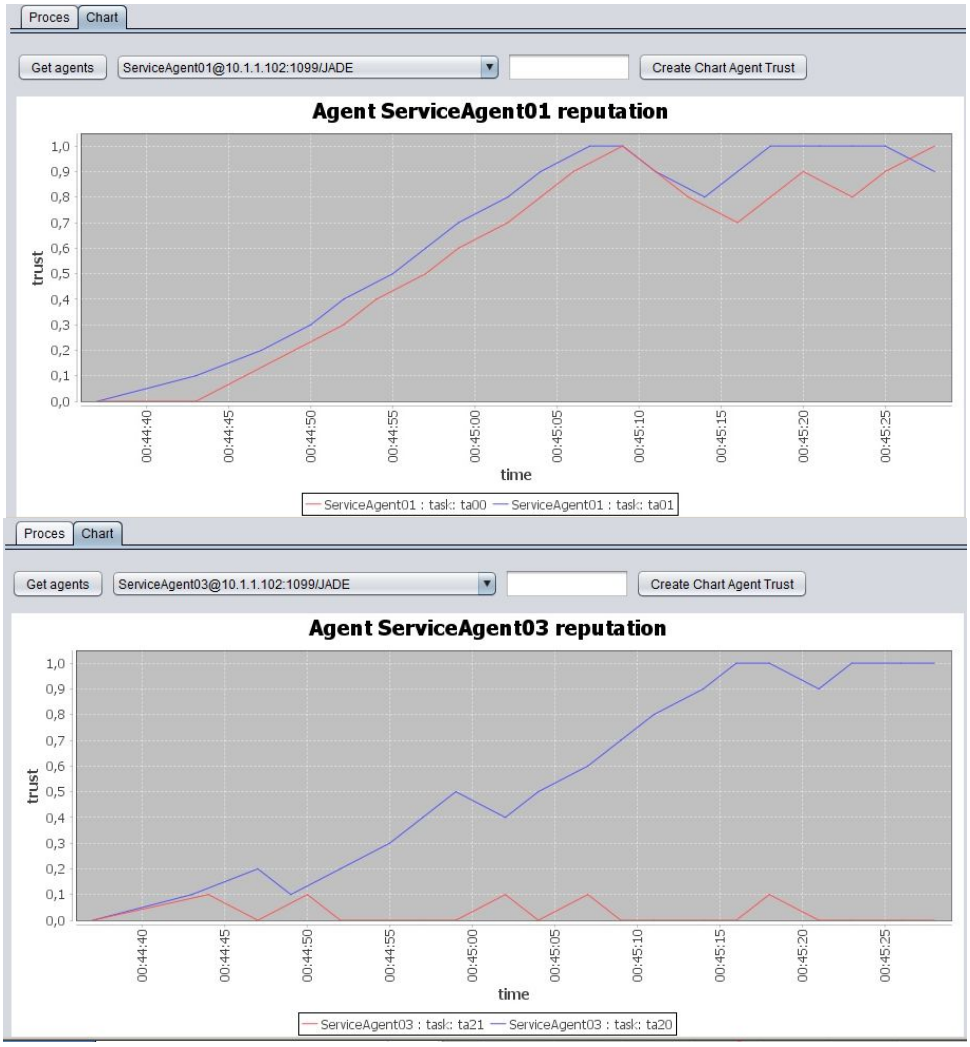

Fig. 3. An example of simulation without the use of the mechanism of gossip and ostracism.

As shown in Figure 3 reputation level of ServiceAgent03 for the action ta21 is very low. This is due to the low probability of the performance of the ta21 task. In the case of ServiceAgent01 the reputation is growing.

Originally used mechanism does not use the indicated mechanisms of gossip and ostracism. As a result, each new agent fed to the platform has a level of confidence at the same level (in the adopted simulation 0). This causes difficulty in the initial selection of agents for the process, because the introduction of a new agent to the process can only take place after the agent reaches a certain level of reputation. In the indicated example ServiceAgent01 has reached 0 reputation after 5 seconds of operating, what could result in its removal from the process. The low level of agent's tolerance could cause its escape from the society, despite its skills to complete the task. One certain solution here is to set the level of new agents' reputation level at 1. But then each new agent will be incorporated into the process without checking - that is why this approach has not been shown here.

As a result, changes in the reputation of the society for the implementation of this process are presented in Figure 4.

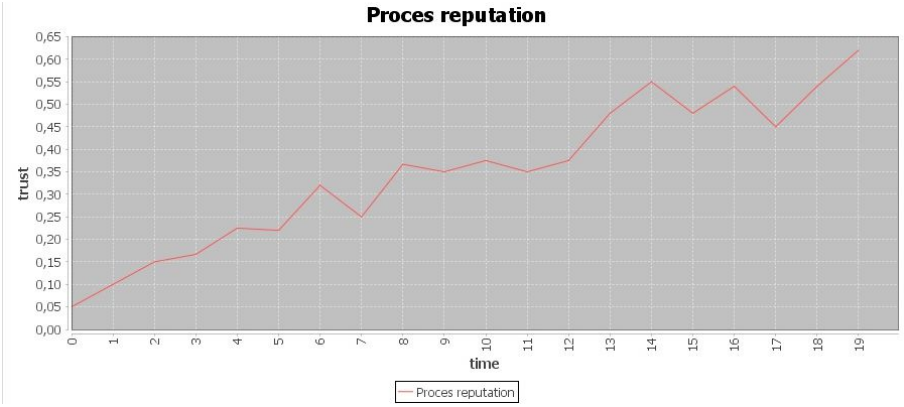

Fig.4. Example of process reputation

As shown, reputation does not exceed the level of 0.7 after 20 iterations, resulting in a poor reputation of ServiceAgent03, which alone has the ability to perform task ta20.
The solution to this problem of assigning a new agent to the process is the used mechanism of gossip and ostracism, allowing to determine the base level of agent's trust based on the knowledge of other units.

After 10th stage, a new agent capable of participating in the operation of the society will be introduced to the platform. The agent, due information about it, will join the society and replace an already operating agent unit. Its initial reputation level, determined on the basis of knowledge of one of the agents will be set at 0.5 for the ta21 task. Such a level should lead to its immediate inclusion in society operation and its assignment to the business process. The results of the research have been presented in figure 5.

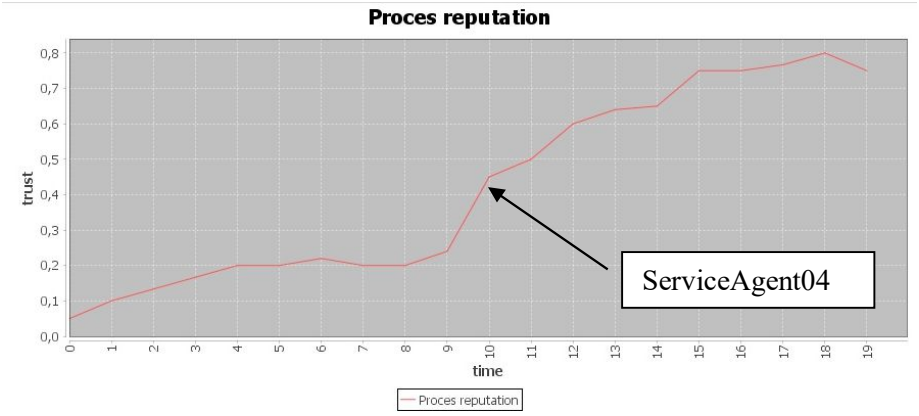

Fig. 5. An example of simulation with the use of the mechanism of gossip and ostracism.

The stage marked in the figure is the time when the agent appeared in the society. In the case when the agent performs its tasks well, the results of the society's operation are good, and the process is performed correctly. In the second case, the lack of the mechanism of ostracism causes the agent to affect the correctness of the society's operation and prevent its correct operation. The inclusion of a new agent to the society through the mechanism of rumors concerning the reputation of the agent shown in Figure 3 has caused a change of agent performing the ta21 task and the inclusion of a new ServiceAgent04 agent. As a result, the platform recorded an increase in the reputation of the society for the tested business process.

5. Conclusion

As was indicated in the paper, one of possible mechanisms contributing to definition of automorphism in multi-agent systems examined in terms of software agent societies is the

mechanism of trust and reputation extended to include elements of gossip and ostracism. To illustrate the possibilities of using those mechanisms, a simulator was prepared and a range of parameters were defined that can characterise a multi-agent platform, agent societies and single agent units.

As indicated earlier in the article, one of the solutions for the construction of multi-agent system is the JADE platform. This platform allows for constructing multi-agent systems, however, it does not have the mechanisms associated with behavioral simulation of agents' society, supported by mechanisms of trust, reputation, gossip and ostracism. In twenty performed iterations the multi-agent system has detected an agent unit which had a low probability of performing the task. As a result, a new agent was introduced to the agents' society, what raised the overall reputation of the process completion. The developed solution allowed to obtain positive results associated with the proper selection of purposeful tasks and enabled the improvement of indicators mentioned in this and previous articles of the author. On this basis, simulation of the operation of the society was carried out.

The result of the research is the use of model elements and proposed indicators (developed by Savarimuthu S. et all [9]) in a process-oriented society of agents using the mechanism of trust and reputation. In the article, these indicators were adopted to the developed model and used in a conducted simulation. As a result, developed model allows to improve business processes, in which the agents are engaged (Fig. 5).

The results, obtained on the basis of the experiment, confirm studies of other researchers. Ken Birman indicated in the conclusions of his research [1] "gossip is a tool, not an end in itself. It should be used selectively, in settings where gossip is the best choice". In the proposed solution the gossip and ostracism mechanisms complement with the model proposed in previous research. Olajide Olorunleke and Gordon McCalla [7] indicate in their experiments that gossip is useful, if it can be trusted. The proposed model, using the mechanism of trust and reputation, allows to specify these indicators for the agent, and thus the use of entities with high level of gosip or ostracism for units with low levels. Proposed by Savarimuthu S. et all [9] indicators, according to the authors, contribute to the efficient operation of multi-agent system, indicating eg. when the selected agent should leave the society. The results of this research have been confirmed in the experiment.

The use of gossip and ostracism mechanisms requires addressing a range of issues connected with defining the algorithm of gossip propagation in a system, communication protocol of system entity and style of operation of the communication protocol. In the case of a society of task-oriented agents that use proposed mechanisms of trust and reputation, the dedicated mechanism of ostracism is punitive ostracism connected with the function of the society's operation. In the case of normative multi-agent systems, a better solution would be defensive ostracism that would result from fear of punishment to an agent for violating norms defined in a society of agents.

The concept of using the mechanisms of gossip and ostracism in a society of agents employing trust and reputation as elements of control and monitoring of its activity, as proposed in the paper, has a range of advantages. They include:

- Possibility of using individual agents' knowledge about the operation of other units. Such knowledge may come from information possessed by an agent as a result of its presence in another society. In the adopted model, reputation has a local character, which refers to a specific multi-agent platform. In the case of agents moving between platforms, knowledge defined in the form of gossip can support the operation of a society.
- Shortening the time during which an agent will negatively affect a specific society and its operations.
- Speeding up the moment when an agent ceases being part of a given multi-agent platform. As a result, it releases its resources, contributing to a general improvement of the performance of the operation of the platform and agents.

- Exclusion of the agent from the performance of the task by the society using the mechanism of ostracism.
- Speeding up the moment of its exclusion through the defined mechanism of gossip that was propagated by an agent and that was subject to verification during the performance of the process.
- Elimination of the agent from the platform as a result of ostracism towards its actions. Implemented only if the agent does not take any action within a specified time.

The conducted experiments concerned the operation of agents as part of a single multi-agent platform. Further research in this area should concern propagation of knowledge possessed by agents and a multi-agent platform to other multi-agent platforms.

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