Modeling and Studying Cooperative Behavior between Intelligent Virtual Agents by Means of PRE-ThINK Architecture

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***Abstract*—This paper studies the behavior of cooperation between Intelligent Virtual Agents (IVA). The significant role of social emotions and empathy in realizing this complex type of social behavior has been proved. For the purposes of the experiment, a programming system with a scenario has been proposed, according to which intelligent virtual agents with PRE-ThINK architecture sort out the tasks at their workplace. When they mutually show consideration for the plans of the other agent, they manage to realize these plans. Their overall emotional state improves. They are friendly and perfect themselves. The dynamics of making decisions has also been shown: in problematic situations when mixed emotions occur; in justification the choices of tasks they make; in defining priorities and planning actions. Experiments with the agents have been discussed both for the case of collaborative behavior and for lack of communication, comments on the sequences from the chosen types of behavior have been given. The cooperative behavior is achieved by controlling the thoughts of the agents.**

Keywords-Intelligent Virtual Agents (IVA); architectures for IVA; social behavior; mixed emotions; cooperation.

I. INTRODUCTION

One of the biggest challenges in social and biological sciences is to understand the basic and the auxiliary mechanisms, facilitating and favoring the process of collaboration between people and groups of people [4][7]-[10][12][13][15][17]-[19][23][28].

The experiment conducted by Burton-Chellew et al. [23] by means of a public goods game proves that when people unite in groups in order to compete with other similar groups of people for a monetary award, they are more inclined to make greater investments within their own group than when they play individually. The members of the group see themselves as collaborators, not as competitors. The bigger their contribution to the purpose of cooperation, the stronger this image and vice versa. They proved that the strength of the emerging emotions of anger and guilt in an individual, who is a member of a group for cooperation, is a function of both his/her own contribution to the purpose of cooperation, and of the other members' contribution to the purpose of this cooperation.

Cooperation and competition between groups of people can be observed in academic research teams, in the army, in sports teams, etc. [28]. On the one hand, the competition between groups of people is the biggest form of competition, existing in the world. However, on the other hand, the establishment of competing groups favors the arousal of stable and strong cooperation between the group members [17]-[19][23]. This fact has not been studied yet to the depth at which other forms of achieving and maintaining cooperation have already been studied, e.g., by receiving penalties or rewards [6][11][16].

The present paper studies the behavior of cooperation between IVAs with PRE-ThINK architecture. A programming system and a scenario have been proposed, by means of which the complexity of cooperative behavior has been proved. This behavior is regarded here as a social type of behavior, requiring cooperation between the IVAs: sharing; empathy; expressing and understanding social emotions; knowledge of the circumstances, in which a conflict situation could begin; capabilities for recognition of the probable conflict situations; knowledge of the actions for solving or preventing conflict situations. This complex social behavior aims at finding the best solution for all members of a team in every situation. It can prevent from lots of conflict situations; can improve the fulfillment of the tasks; can improve the emotional state of the team members. Therefore, it is expected that the IVAs, which cooperate with the users, will easily gain their trust and will become irreplaceable friends and collaborators in any group united by common interests. For comparison, by means of a separate experiment it has been shown how the lack of cooperation (in particular – lack of communication and empathy) leads to: occurrence of conflict situations and problems; impossibility for the IVAs to achieve their goals and fulfill their plans: worsening the emotional state of the IVAs.

The rest of the paper is structured as it follows: in Section II, the modern tendencies in this field are considered, together with the motivation to model social behavior of collaboration. In Section III, the programming system and the scenario are presented. The concept and nature of the experiments with the system are explained in Section IV. The dynamics of the process of decision making by the IVAs both in case of lack of communication between them and in case of cooperation are considered in Section V. The experimental results are discussed in Section VI. In the Section VII, a number of conclusions are drawn and

 ISBN: 978-1-61208-390-2

directions for further development of the programming system are given.

II. BACKGROUND

Many researchers [3][25]-[27][29] model IVA's behavior in order to establish trust between the user and the IVA. For this purpose IVAs are modeled, having the capability to express so-called moral emotions (regret, joy, compassion, remorse) [5][25]. There has already been much work that promotes cooperation, through trust- and reputation-building models, in multi-agent systems [5].

A great amount of contemporary neurophysiologic research confirms the main role of emotions in rational behavior [1].

Ortony, Clore, and Collins (OCC) model defines a cognitive approach for looking at emotions [30]. This theory is extremely useful for the project of modelling agents which can experience emotions. The cornerstone of their analysis is that emotions are "valence reactions." The authors do not describe events in a way that will cause emotions, but rather, emotions can occur as a result of how people understand events.

The first modification to the OCC model is to allow the definition of different emotions with respect to others, which are known as social emotions. Social emotions can be defined as one's emotions projecting on or affected by others.

According to Lee et al. [24] mixed emotions, especially those in conflict, sway agent decisions and result in dramatic changes in social scenarios. However, the emotion models and architectures for virtual agents are not yet advanced enough to be imbued with coexisting emotions [24]. Modern cognitive architectures, which could be appropriate and would have good results in modeling complex social behaviour are ACT-R [31], Soar [32], CLARION [33], PRE-ThINK [21].

The PRE-ThINK architecture [20][21][22] allows for modelling an IVA, having capabilities to detect and analyze conflicts. Problem situations evoke conflicting thoughts, accompanied by mixed emotions and they are related to a number of different ways of action. The agent considers in advance (Pre-Think) in what way each possible action in a critical situation would reflect over all individuals concerned by it. The originated thoughts are assessed from emotional, rational and needs-related points of view in accordance with the knowledge, priorities and principles of the agent. Agent's behavior motivators are its needs according to Maslow's theory [2].

It is assumed that an IVA, capable of detecting a critical situation, of analyzing it and choosing the best possible option to take care of all individuals concerned, would easily gain trust. Such a behavioral model is presented in this paper with the help of the PRE-ThINK architecture.

III. DESCRIPTION OF THE PROPOSED PROGRAMMING SYSTEM AND SCENARIO

For the purpose of the experiment, a prototype of the programming system and IVAs with PRE-ThINK architecture were modeled. Their structural scheme is given in Fig. 1. The main modules of the programming system are: Module for simulating the passage of time; Module for initialization of the scenario; Module for realization of the scenario; Module for modeling IVA with PRE-ThINK architecture; Module for generation and choice of the thoughts, which will take part in considering the possible

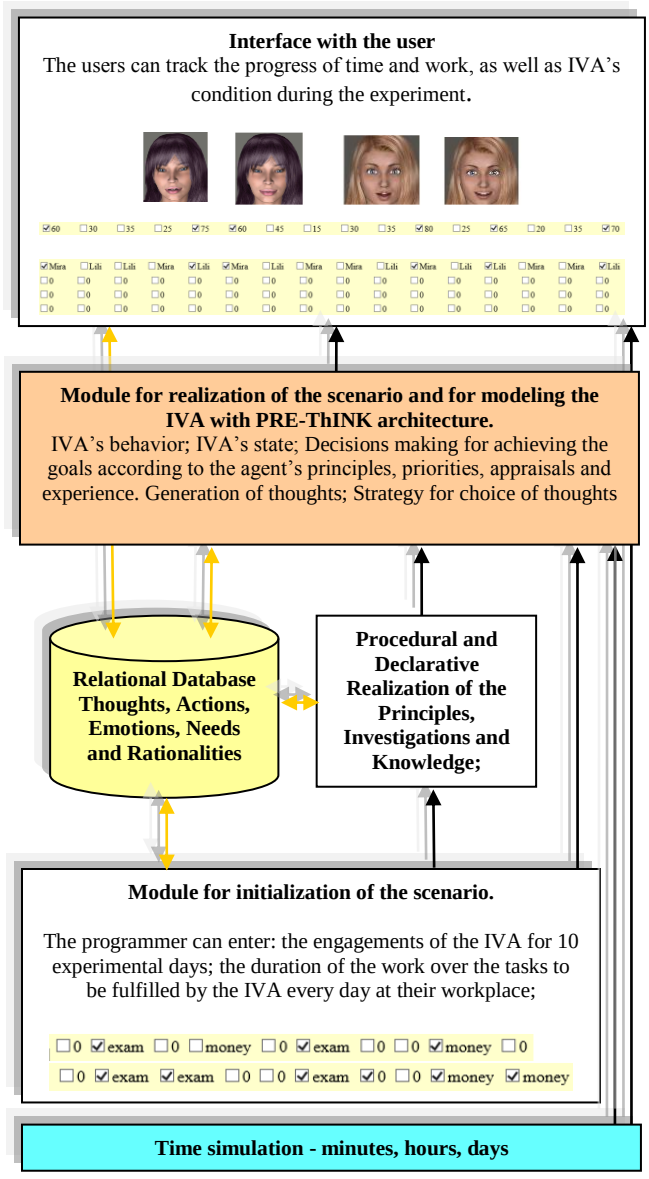

Figure 1. Structural scheme of the program system

actions for solving the conflict situation; Module for decision making; Interface with the user.

The system supports a Relational Database and a Knowledge Base. The components of the PRE-ThINK architecture - Principles, Investigations and Knowledge - are realized in a procedural and declarative way, while the components Thoughts, Actions, Emotions, Needs and Rationalities are presented in relational databases by means of tables and relationships among them. This way of

 ISBN: 978-1-61208-390-2

presenting allows for easy adding or deleting: actions for solving problem situations; thoughts to each possible action; arguments to each thought; emotional, needs-related and rational assessments of each thought-action.

The system allows for applying various strategies for choice of thoughts, which will take part in the process of decision making. For instance: it is possible that all thoughts are taken into consideration in making a decision; it is also possible to define randomly which and how many thoughts will be taken into account; another option is to choose the thoughts depending on the correspondence between their emotional assessment and the emotional state of the IVA or between their needs-related assessment and the needs of the agent at the moment, etc. There are thoughts, deserving attention; there are also thoughts to be suppressed and even overcome (misleading thoughts) in order to come to a good decision. In the experiment, presented here, the thoughts are randomly chosen.

The scenario, proposed and realized especially for the purposes of the present study, includes only participation of IVAs. It is intended that a further development of the programming system and the scenario will also include active participation in the experiment on the side of the users, who will interact with the IVAs and receive advice from them.

According to the proposed scenario for the first part of the study, two IVAs are students and at the same time work for a company. They go to work every day and have a set of tasks to fulfill for the day. The tasks are of various levels of complexity. Those of them, which require more than 45 minutes of work on them, are considered to be complex. Those, which can be fulfilled for 15 to 45 minutes are regarded as light.

It is considered that an IVA has fulfilled his/her daily obligations if he/she has managed to fulfill eight (8) tasks (regardless of their complexity).

An IVA gets a bonus if he/she manages to fulfill four (4) complex tasks within a day.

TABLE I. COMPLEXITY AND DURATION OF THE WORK OVER THE TASKS FOR A DAY AT WORK.

Complexity and Duration	C 60	L 30	L 35	L 25
	C 75	C 60	L 45	L 15
	L 30	L 35	C 80	L 25
	C 65	L 20	L 35	C 70

Every day the IVAs receive exactly sixteen (16) tasks with different time for fulfillment. The number of complex tasks is always six (6). So, the IVAs always have the necessary number of tasks needed for a successful day at work. However, they do not have a sufficient number of complex tasks to be able to get a bonus at the same time. On the other hand, the number of lighter tasks is insufficient for giving both of them the chance to fulfill their obligations by working on them only.

Table I presents an exemplary distribution of the tasks, got by the IVAs at their workplace within a workday. By the symbol C the complex tasks are marked, and the lighter ones are marked by L. The duration of the work over the tasks is measured in minutes.

TABLE II. A) PLANNED ENGAGEMENTS AND INTENTIONS OF THE IVA MIRA FOR THE NEXT 10 DAYS.

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
	Examination		Party	
Work	Work	Work	Work	Work

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Examination			Work for a bonus	Work for a bonus
Work	Work	Work	Work	Work

TABLE II. B) PLANNED ENGAGEMENTS AND INTENTIONS OF THE IVA LILLY FOR THE NEXT 10 DAYS.

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
	Examination		Work for a bonus	
Work	Work	Work	Work	Work

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Party			Work for a bonus	
Work	Work	Work	Work	Work

According to the scenario, the IVAs (Mira and Lilly) sometimes have examinations, sometimes they struggle for a bonus, and sometimes hurry for a party. When they have an exam or hurry for a party, they strive to take 8 light (minor tasks) and leave work as soon as possible. When the IVAs need more money or when they struggle to get a bonus, they strive to fulfill first the required four (4) complex tasks for the day and are ready to stay longer hours at their workplace.

When the IVAs do not have any other engagements for the day except for being at the workplace, and when they do not struggle for a bonus, they fulfill the tasks in their sequence and without any interest to the level of complexity.

TABLE III. PAYOFF MATRIX OF THE PROPOSED SCENARIO

		IVA Lilly	
		Lighter Tasks	*Complex Tasks*
IVA Mira	*Lighter Tasks*	Lack of enough lighter tasks	IVA Lilly - bonus IVA Mira - time
	Complex Tasks	IVA Lilly - time IVA Mira - bonus	Lack of enough complex tasks

For the IVAs, it is important to always fulfill the compulsory eight (8) tasks per day. Therefore, two conflict situations are possible (Table III) – when:

- There is an exam and a party for the IVAs on the same day – (lack of enough lighter tasks);
- Both IVAs have decided to work for a bonus on the same day – (lack of enough complex tasks).

These conflict situations can evoke mixed emotions in the virtual agents. The IVAs have to be able to recognize them and, after consideration, find the best possible solution.

 ISBN: 978-1-61208-390-2

Table II presents all planned engagements of each of the two IVAs (Mira and Lilly) for 10 days.

IV. CONCEPT AND NATURE OF THE EXPERIMENTS

Two experiments with the programming system have been conducted. Each of them tracks the behavior of the virtual agents within ten (10) experimental days.

The following aspects are tracked in each of the two experiments: how many tasks each of the IVAs has fulfilled on each of the considered workdays; what is the level of complexity of the fulfilled tasks; what is the emotional state of each of the virtual agents; what level of importance has been assigned to the different engagements of an agent per day. The aim is to show in which case best results are achieved in terms of work done at achieved personal aims by the IVAs, as well as to show the emotional state of the virtual agents.

In the first experiment, each virtual agent tries to realize his/her aims and engagements for each of the considered workdays not interested in the intentions and aims of the other agent. There is no communication between the two agents. There is no coordinated planning of aims and intentions, correspondingly.

In the second experiment, the virtual agents cooperate between each other. Each of them is interested not only in his/her own engagements and aspirations but also in the aims and intentions of the other agent. At the beginning of the week (on Monday) the agents share and coordinate their engagements for the week (from Tuesday to next Monday). If they think that there may arise a conflict situation on one of the next days, they have two options: 1. To shift the time of their commitments so that the conflict situation is avoided; 2. To choose a day to fulfill in advance some of the complex tasks, planned for days when they are engaged with urgent commitments outside the company.

V. DYNAMICS OF THE PROCESS OF DECISION MAKING

For the purposes of the experiment, IVAs with PRE-ThINK architecture are used [20][21]. The PRE-ThINK architecture consists of the following components: Principles, Rationalities, (+/-) Emotions, Thoughts, Investigations, Needs and Knowledge.

The IVA makes his/her decisions based on his/her principles. The following IVA principles have been modelled: “Choose the better possible action"; "Neglect the basic needs until reaching a definite threshold of dissatisfaction, giving priority to the highest-order needs”; “Evaluate the desires and commitments of the other IVAs as your own”; “Your personal commitments are as important as those, of the others”.

The agent has a set of thoughts related to the fulfillment of the tasks at the workplace and outside the company – thoughts, related to: self-observation; the other IVA’s state; the way in which the agent could help to solve the problematic situations.

Each thought is related both to an emotion, and to a need, and also has its rational component – importance – with a value from 1-3. Each thought is also related to an action.

As it concerns the emotional component of the thoughts – only the following emotions are taken into account: anxiety – a negative emotion with a value of (-1) and gladness – a positive emotion with a value of (+1).

The hierarchy of needs according to Maslow’s theory [2] is used – physiological (ph), safety (s), love and belonging (lb), esteem and self-assessment (es), self-actualization (sa), aesthetics (a). Weights of the needs are introduced – Wneed, corresponding to their priority: Wph,=10; Ws=20; Wlb=30; Wes=40; Wsa=50; Wa=60; When, because of the occurrence of an event, one or more needs prove to be unfulfilled, i.e., there is a crisis situation, then the needs rearrange so that the unfulfilled ones receive first priority. The unfulfilled needs are arranged in an order, opposite to the order of needs weights in a normal state of the agent.

Each action of the IVA is related to a need: the performance of the duties – to the need of safety; the meetings with friends – to the need of love and belonging; the struggling for a bonus – to the need of esteem and self-esteem; the examinations – to the need of self-actualization; the possession of more funds – to the aesthetics needs.

Let a thought addressed to the situation s be denoted by Th_s. If the importance of the thought Th_s is denoted by $I_{imp.Th\_s}$, the weight of the need, related to this thought is expressed by W_{needTh_s}, the emotion implied by this thought is marked by $E_{emot.Th\_s}$, then, following the formulae for calculating the assessment value of the thought A_{Th_s}, corresponding to the situation s, will be [21]:

$$A_{Th\_s} = E_{emot.Th\_s} * W_{needTh\_s} * I_{imp.Th\_s} \quad (1)$$

If a thought is partially related to more than one need, then the sum of the weight percentages of the needs to which it is related is taken into account in the formulae.

Each thought is related to an action. The assessment values of the thoughts related to one and the same action in one and the same situation are put on the one basin of the “thoughts balance”. The assessment values of the thoughts for the same situation, but related to another action, are put on another basin etc. Our “thoughts balance” will have as many basins as the alternative actions considered by the agent in the particular situation are. The module of the assessment values is summed and the action from the basin having the highest assessment value is undertaken [21].

A. The First Experiment

Here is an example of the thoughts, generated during the first experiment, when both IVAs only think about their own planned actions and are not interested in the plan of the other IVA. The second day of the experiment, when the IVAs Mira and Lilly have an examination is considered.

Mira’s first thought:

I have an examination today so I will fulfill 8 easy tasks in order to leave work at the earliest and go to the exam.

A thought, focused on the fulfillment of the tasks at the workplace and on the examination. Positive emotion – gladness $E_{emot.Th1\_1} = 1$, that she will manage both to pass the exam and to fulfill the tasks; rational component – importance with value $I_{imp.Th1\_1}=3$; motivator – the need of

self-actualization Wsa=50 and safety Ws=20, $W_{needTh1\_1}$=70, *action – going to the examination after fulfilling the compulsory 8 (easy) tasks for the day.*

$$A_{Th1\_1(work\_exam)} = 1*70*3 = 210 \quad (2)$$

Mira's second thought:

I have an examination today. However, I have to be at work and therefore I will not go to the exam.

A thought, focused on the fulfillment of the tasks at the workplace. Negative emotion – anxiety about the safety at the workplace $E_{emot.Th2\_1}$ *= -1; rational component* $I_{imp.Th2\_1}$ *= 1; motivator – the need of safety with weight Ws=20;* W_{needTh_s} *= 20; action – postpones the examination.*

$$A_{Th2\_1(work)} = -1*20*1 = -20 \quad (3)$$

Mira's third thought:

I have an examination today and therefore I will not go to work.

A thought, focused on the examination. Negative emotion – anxiety about the examination - $E_{emot.Th3\_1}$ *= -1; rational component –* $I_{imp.Th3\_1}$ *=1; motivator – the need of self-actualization Wsa=50;* $W_{needTh3\_1}$ = 50*; action – goes to the examination and does not go to work.*

$$A_{Th3\_1(exam)} = -1*50*1 = -50 \quad (4)$$

The thoughts about the two alternative actions are weighed as if on a balance and the IVA takes the decision for action.

Thoughts of going to the exam:

$A_{Th1\_1\ (work\ and\ exam)}$ = 210

$A_{Th3\_1\ (exam)}$ = -50

Thoughts of postponing the exam:

$A_{Th2\_1\ (exam)}$ = -20

It is obvious that here the thoughts of going to the exam outweigh. The most important thought which will be realized is the first thought. The IVA Mira will go to work in order to fulfill the norm of 8 (though easy) tasks and then will go to the exam in time.

B. The Second Experiment

In the second experiment, when the IVAs consider the first conflict situation, the following thoughts are generated:

Mira's first thought:

Lilly and I have an examination on the same day. i.e., we have the same commitment with the same priority. Consequently, it will not be fair if any of us gives up her commitment.

A thought, focused on the relationship between the agents; negative emotion – anxiety about the exam $E_{emot.Th1\_2}$ *=-1; rational component – importance with a value of* $I_{imp.Th1\_2}$ *=3; motivator – need of love and belonging Wlb=30;* $W_{needTh1\_2}$=30; *action – both of them go to the exam without postponing it.*

$$A_{Th1\_2(agent-exam)} = -1*30*3 = -90 \quad (5)$$

Mira's second thought:

Lilly and I have exams on the same day. We could postpone our exams in order to fulfill our task at the workplace by a schedule. There will be next dates for these exams.

A thought, focused on the relationships between the agents and the priorities at the workplace; negative emotion – anxiety about the exam $E_{emot.Th2\_2}$ *=-1; rational component – importance with value* I_{impTh2_2} *= 2; motivator – the need of safety at the workplace Ws=20;* $W_{needTh2\_2}$=20; *action – fulfilling the obligations at the workplace by a schedule and postponing the exams.*

$$A_{Th2\_2(agent-work)} = -1*20*2 = -40 \quad (6)$$

Mira's third thought:

If we go to our exams tomorrow, we could take and fulfill today two of the complex tasks, envisaged for tomorrow. Thus we will be able to follow the work schedule on the one hand, and go to the exam, on the other hand.

A thought, focused on the relationships between the agents at the workplace, on the work and on the exam; positive emotion – safety and gladness - $E_{emot.Th3\_2}$ *=1; rational component – importance with value* $I_{imp.Th3\_2}$ *= 3; motivators – the need of safety with weight Ws=20 and the need of self-actualization with weight Wsa=50;* $W_{needTh3\_2}$ = 70; *action – fulfilling the complex work tasks in advance (since there will not be any time to fulfill them on the day of the exam), going to the exam without postponing it.*

$$A_{Th3\_2(agent-exam-work)} = 1*70*3 = 210 \quad (7)$$

Thoughts in support of the idea of both IVAs going to the exams:

$A_{Th1\_2\ (agent\_exam)}$ = -90

$A_{Th3\_2\ (agent\_exam\_work)}$ = 210

Thoughts in support of the idea of both IVAs postponing their exams:

$A_{Th2\_2\ (agents\_work)}$ = - 40

The thoughts about the two alternative actions are weighed as if on a balance and the IVA takes the decision for action.

It is obvious that here overweigh the thoughts of Mira and Lilly of going to their exams after fulfilling in advance the complex tasks, for which there will be no time on the day of the exams.

One more example:

In the second experiment, when the IVA Lilly has planned a party and Mira has an examination, Lilly's thoughts are the following:

Thought 1:

I have planned a party for Monday, but Mira has an examination. She would probably also like to leave work earlier. The examination is more important than a party and I could help her by organizing the party on the next day. We will all be glad and have a good time together. We will also fulfill our tasks at the workplace.

A thought focused mainly on the relationship between the agents; positive emotion – gladness from the opportunity to

help in solving the complex situation $E_{emot.Th1\_3}$ *=1; rational component – importance with value* $I_{imp.Th1\_3}$ *= 3; motivator – the need of love and belonging with weigh Wlb=30;* W_{needTh_s} = 30; *action – having a party on the next day, which is free of commitments.*

$$A_{Th1\_3(agent-work)} = 1*30*3 = 90 \quad (8)$$

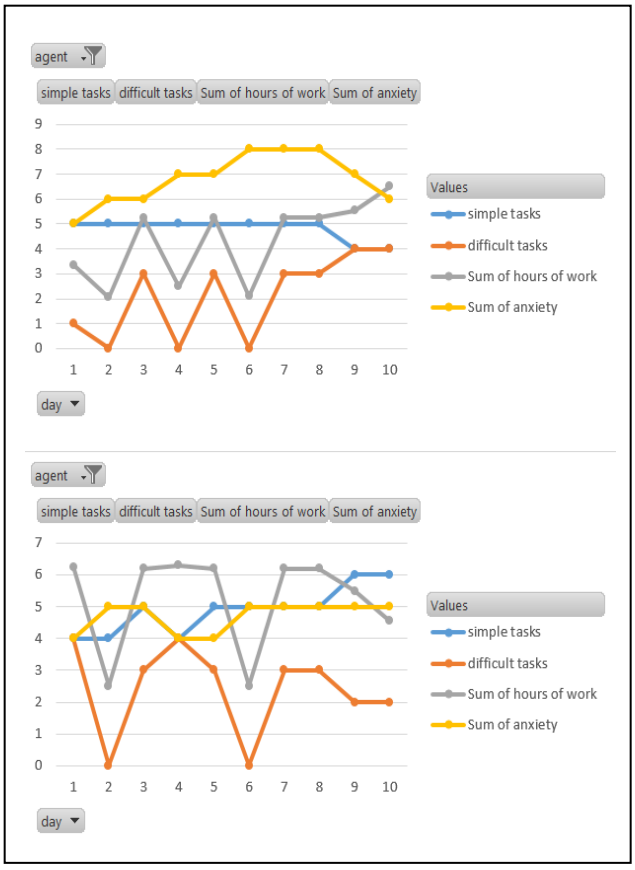

Figure 2a. Experimental results for the case of no cooperation between the IVAs (Mira and Lilly). It can be seen that there are no complex tasks fulfilled on the second and on the sixth day. On the nineth and tenth day only IVA Mira fulfills the needed 4 complex tasks in order to receive a bonus. Anxiety in the IVAs stays high.

Thought 2:

If I do not postpone the party and Mira does not postpone the exam, we will not be able to fulfill our tasks at the workplace. I could try to work overtime, but I will be very tired.

A thought, focused mainly on the fulfillment of the obligations at the workplace; negative emotion – regret $E_{emot.Th2\_3}$ *=-1; rational component – importance* $I_{imp.Th2\_3}$ *= 1; motivator – need of safety with weight Ws=20;* $W_{needTh2\_s3}$ =20; *action – work over the complex tasks in advance.*

$$A_{Th2\_3(work)} = -1*20*1 = -20 \quad (9)$$

The thought to postpone the party for the next free of commitments day outweighs here obviously and this is the action, which is taken up.

VI. Discussion of Experimental Results

The results from the described above experiments with the IVAs Lilly and Mira are given in Fig. 2a and Fig. 2b. For each of the ten (10) observed days the following data are shown: the number and the level of complexity of the fulfilled tasks; the duration of work of the agents, measured in hours; the summarized emotional state of the IVA depending on whether they have managed to realize all their stated commitments.

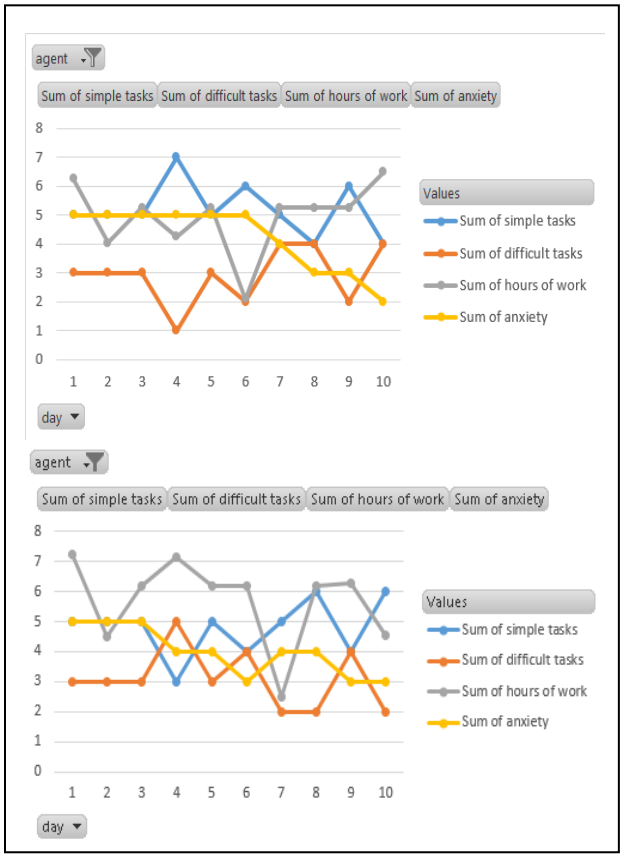

Figure 2b. Experimental results for the case when the IVAs distribute their commitments in advance. (Mira and Lilly). It can be seen that on the second and on the sixth day all complex tasks are fulfilled. Mira manages to fulfill the needed 4 complex tasks and receives a bonus on the nineth day of the expeiment, while Lilly receives her bonus on the tenth day. The tendency is that anxiety reduces with time due to averting the conflict situations.

From Fig. 2a, it can be seen that, in case of no communication, the IVAs often do not manage to fulfill their work obligations because they have other tasks with greater priority. For instance, during the first week on Tuesday and the second week on Monday, they leave work without fulfilling their norm because they have examinations and meetings with friends. On the other hand, on Thursday the second week they try to work more and earn a bonus but fail again. It turns out that because of the lack of communication and coordination between them, they compete for the complex tasks for the day.

Thus, day by day, their anxiety and dissatisfaction with respect to the workplace grow. If this tendency continues a

longer time the threshold of dissatisfaction for the need of safety will be overcome.

When this happens, the fulfillment of the obligations at the workplace will become first priority for the IVAs. All other commitments will have lower priorities. In further conflict situations they will have to miss examinations or meetings with friends. Their anxiety and dissatisfaction will grow further. Then, the IVAs may face extremely complex problematic situations and they will have to choose what to give up – work, university or friends. They may have to look for a new job or a new subject to study at the University. The occurrence of these extremely complex situations can be prevented by improving the communication and by cooperation between the agents.

From Fig. 2b it can be seen that the IVAs have managed to redistribute their plans and commitments in a way that has allowed them to prevent all conflict situations.

Firstly: Lilly has decided to meet her friends on Tuesday – the 7th day of the experiment – instead on Monday – the 6th day of the experiment. Thus on Monday Mira will be able to fulfill most of the easier tasks and go to her exam in time. Secondly: Mira has decided on Wednesday (the 8th day of the experiment) to work for a bonus, instead on Thursday (9th day of the experiment). Thus she gets a bonus, and Lilly gets her bonus on the next day (9th) of the experiment.

The most complex conflict occurs on the second day (Tuesday, first week) of the experiment, when both IVAs have examinations. This is because the assessment for importance of the commitment is one and the same. It is impossible to make a decision whose exam to be postponed. Therefore, they decide that each of them will fulfill two of the complex tasks on the day before the exams. It means that on the day of the exams they will have to fulfill five (5) easier tasks and one (1) complex task each. Thus only by coordinating their work, the IVAs manage to achieve all their goals and commitments and there is no stress at their workplace. On the contrary, they are glad because they get bonuses whenever they want, pass their exams and meet their friends with no problems.

Of course if the needs of money grow more or if the commitments outside the company grow more, this solution will not be good enough. But in the cases when the possibilities of coordination and cooperation between the IVAs are exhausted, the solution can be found:

1) By employing more IVAs (for the cases when Mira and Lilly will have to leave work earlier), and

2) By increasing the number of complex tasks, available for the two IVAs (for the cases when they more often want to work for bonuses).

VII. CONCLUSION

Cooperation is a complex social behavior, requiring empathy and preliminary consideration. It is related to planning and making decisions in complex situations, when mixed emotions arise. The realization of cooperation requires understanding of behavior, emotions, reasons and interests both of us and of the other participants in a considered scenario. This paper studies the cooperative behavior between IVAs. The significant role of social emotions and empathy in realizing this complex type of social behavior has been proved. For the purposes of the experiment, a programming system with a scenario have been proposed, according to which intelligent virtual agents with PRE-ThINK architecture distribute between the two of them the tasks at their workplace. When they mutually show consideration for the plans of the other agent, they manage to realize these plans. Their overall emotional state improves. They are friendly and self-actualize themselves. The dynamics of making decisions has also been shown as it follows: in problematic situations when mixed emotions occur; in justification the choice of tasks to fulfill; in defining priorities and planning actions. Experiments with the agents have been discussed both for the case of cooperative behavior and for lack of communication, comments on the sequences from the chosen types of behavior have been given.

Based on his/her own principles, knowledge and priorities in a critical situation, the agent evaluates the possibilities for action from emotional, rational and needs-related point of view and chooses the best possible action. The purpose of the software agent is to possibly take the best care of all his collaborators. It is assumed that such behavior would facilitate the establishment of trust between the IVAs and the users on the one hand; on the other hand, it could avert a great part of the conflict situations, which occur every day, including at the workplace (mainly due to the lack of cooperation and empathy).

It is envisaged to develop this prototype of a programming system by a learning module. It will allow the IVAs to learn by assessing not only their thoughts but also the thoughts of the other IVAs, with which they cooperate. When an IVA decides that another IVA's thought is a sufficiently strong argument in favor of a given action, then he/she will be able to save and use it in the future.

Thus, through communication, the IVAs will enrich with new and stronger arguments in support of a given action; they will gain more and more trust; they will be more and more useful for the users and will become irreplaceable, precious friends and members of every team in the world and in each sphere of life.

Experiments, in which the different IVAs will use different strategies for choosing the thoughts to take part in considering the possible actions for solving a given problematic situation, will be of interest.

The experiments will be extended with the aim to cover situations, in which rearrangement of the IVA's priorities will occur. An interesting question will arise in relation to the way in which the IVAs express empathy when their priorities are in a different order. The assessments of the desires and aims of the others will be different then. Certain arguments will look value for some IVAs, other arguments will be important to other IVAs. We believe that the results from such experiments will be of great interest to the scientific world.

It is intended that the programming system is extended by allowing the users to participate in the scenario, to communicate with the IVAs and receive advice from them.

 ISBN: 978-1-61208-390-2

The programming system can be useful as a Socially Assistive Application (SAA). In general, SAA are intended to motivate the users and make them change their social behavior. These applications are useful not only for people with social deficits, since all people sometimes need to share a problem or an experience and receive advice from a friend or a specialist. On the other hand, Cloud computing technologies give the chance to realize in the cloud data centers, knowledge base, task planners, deep learning, information processing. This will allow the users, IVAs and robots to share knowledge about and solutions for problematic situations and apply them when necessary.

And last but not least, modeling cognitive processes will help for their better understanding and management. This, in its turn, will lead to a better quality of life.

ACKNOWLEDGMENT

This research is supported by: the Technical University of Sofia and its Branch in Plovdiv; the Centre for education and innovation at TU-Sofia; and the Scientific and research sector at TU-Sofia.

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