Personality and Group Dynamics in Believable Multi-Agent Systems

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Abstract

Researchers identified personality as one of the most important requirements for believable and credible synthetic agents. By modeling a personality system in the agent's architecture we can bring the illusion of life to users, suspending their disbelief for more time, decreasing boredom and increasing usability of computer systems.

We extended an existing model for building believable synthetic agents (SGD Model) by improving its personality system. The objective is to provide a better experience and believability to users interacting with agents when they are grouped and engage in collaborative tasks.

One of the concluding remarks from previous experimental results of the original model states that very cohesive groups induce lower levels of user identification with the group. We made additional changes to solve this problem. A new motivation, action and reaction were added to the model to implement individualism. Our improved personality system dictates if an agent would rather choose to help the group or act for its own profit.

The model was tested in a computer game. Our evaluation shows that the extended version of the SGD Model and its implementation on Perfect Circle are working as intended. Agents' behaviors and reactions follow a well defined set of rules. Additional tests are needed to verify if the extended model offers to users a more credible and believable environment of cooperative synthetic agents, higher levels of identification with the group and users' satisfaction.

Keywords: personality, synthetic agent, believability, credibility, multi-agent system, teamwork, cooperation, individualism

Introduction

Studies from (Reeves and Nass, 1998) show that people interact with computers like they interact with other people by applying the same social rules. Synthetic agents bring a social dimension to user interfaces. In these kind of systems users interact with the computer like they do with other humans. To avoid boredom and provide the illusion of life, agents have to appear believable to users. Otherwise humans loose interest for synthetic agents.

Researchers like (Loyall, 1997) identified personality as one of the most important requirement for believability in synthetic agents. By embodying agents with personality we are providing them with the ability to bring the illusion of life (Thomas et al., 1981) to users and suspend their disbelief.

Our culture evolved over the last few decades and currently promotes cooperation and teamwork: “If you want to go fast, go alone. If you want to go far, go together” (an African proverb). It’s also true that “Individual glory is insignificant when compared to achieving victory as a team.” (Dot Richardson, M.D. U.S. Olympic Softball Team, two time Gold Medal Champions). Teachers, coaches, and drill instructors have long understood the value of teamwork. In virtual environments cooperation and teamwork is also important. Multi-agent and multi-user system are a reality today: almost every recent video games have a multiplayer mode with other human users and/or artificial intelligence controlled characters. Given the facts, there is clearly a need for research on teaming up humans and synthetic agents in coherent and believable environments.

Besides the ability to offer better human-computer interaction, this kind of research has also other amazing applications: interactive story telling (Cassel et al., 2000), entertainment and education (Rickel et al., 1998), learning (Mateas, 1997), social studies and recruitment process of business companies (Mount et al., 1998).

The SGD Model from (Prada, 2005) models synthetic group dynamics between users and agents. The problem is that its personality system is somehow very simplistic since it is composed of only two dimensions of the Five-Factor Model (McCrae and Costa, 1996) of personality: extraversion and agreeableness. Besides the limited number of personality dimensions, we noticed from (Mount, Barrick and Stewart, 1998) that two important factors were missing: conscientiousness and neuroticism - dimensions that most likely predict performance in jobs involving teamwork and interaction with others (Mount, Barrick and Stewart, 1998). So we came to a resolution that we could improve the original model to offer a more credible, more believable and better users’ experience. We settled to extend the SGD and model a complete personality system.

Furthermore, we noticed from experimental results (Prada, 2005), although inconclusive, that agents built according to the model show very high levels of cohesion, but this is not always desirable because it decreases the user’s identification with the group and the believability of the agents.

We changed the existing two personality traits and added the remaining three, giving the model a total of five: extraversion, agreeableness, conscientiousness, neuroticism and openness. Both the model and its implementation on a computer game named Perfect Circle suffered changes that are explained further in this document. Using a complete personality system we were able to introduce individualism to the model as a tendency to work alone rather than in group. This new concept pretends to solve the high cohesion - low identification problem. Agents choose between helping the group or acting for its own profit. Opting for the former or the latter option depends on the agent’s personality. We also developed some automated tools to help us evaluate the extended version of the model. They consist of log parsers capable of building CSV tables with important and required information for future statistical analysis. We had also made Perfect Circle to be able to run in batch simulation mode providing a simple text file with personality information of several groups.

Finally we made some experiments using our batch system to see if the results were coherent with our expectations and existing theories and models of personality in human psychology.

In this paper we first discuss some related work concerning personality of synthetic agents. Then we present the changes we made to the original SGD Model. Afterwards, we describe the implementation of the

model in the computer game Perfect Circle. Before the conclusions we show some tests regarding expected behaviors and reactions of agents according to their personality.

Related work

Believability is not the same as honesty and/or realism (Mateas, 1997) (Reilly, 1996). Believable agent is an agent that can suspend our disbelief and bring the illusion of life (Mateas, 1997)(Loyall, 1997). In (Loyall, 1997), A. Brian Loyall defines believable agents as personality-rich autonomous agents with powerful properties of characters from the arts.

There are a set of requirements for building believable synthetic agents (Loyall, 1997): (1) personality; (2) emotion; (3) social relationships; (4) change; (5) consistency of expression; (6) self motivation and goals; (7) reactive, responsive and parallel action; (8) broadly capable and well integrated but resource bounded.

Besides being one of the most important requirement for believable agents - and the main subject of this dissertation - (Loyall, 1997), (Castelfranchi et al. 1998) identified several independent reason for introducing personalities in agents: (1) social-cognitive modelling; (2) believability and interaction; (3) story and situation understanding; (4) agent modeling; (5) exploring and comparing strategies; (6) internal states and behavior.

An interesting study from (Goldberg, 1990) shows that we can achieve a scientific description of personality using a small number of dimensions. There are numerous theories on how to model personality in psychology. The Five Factor Model (FFM) was formulated by Robert McCrae and Peter Costa and is the most accepted model of personality traits (Mount et al., 1998). It uses five dimensions to define personality: extraversion, agreeableness, neuroticism, conscientiousness and openness. The following paragraph is from (John, 1990) and it describes each one of the five dimensions.

“Briefly, Extraversion implies an energetic approach toward the social and material world and includes traits such as sociability, activity, assertiveness, and positive emotionality. Agreeableness contrasts a prosocial and communal orientation towards others with antagonism and includes traits such as altruism, tender-mindedness, trust, and modesty. Conscientiousness describes socially prescribed impulse control that facilitates task- and goal-directed behavior, such as thinking before acting, delaying gratification, following norms and rules, and planning, organizing, and prioritizing tasks. Neuroticism contrasts emotional stability and even-temperedness with negative emotionality, such as feeling anxious, nervous, sad, and tense. Finally, Openness to Experience (vs. closed-mindedness) describes the breadth, depth, originality, and complexity of an individual’s mental and experiential life.”

Personality in synthetic agents is present in several research fields such as entertainment (Rousseau and Hayes-Roth, 1997) (Loyall, 1997), education and learning (Rickel , Johnson and Thiébaux, 2000) and multi-agent systems (Rizzo et al., 1997).

Rousseau and Hayes-Roth have successfully showed the importance of personality in synthetic agents in their work (Rousseau and Hayes-Roth, 1996) (Rousseau and Hayes-Roth, 1997). They created agents with different personalities in three dimensions (confidence, activity and friendliness) and asked users if they could easily identify them by observing the agents’ behaviors in a Cybercafé.

The Synthetic Characters Group at the MIT Media Lab created AlphaWolf (Tomlinson and Blumberg, 2002). It reproduces natural social behavior of a pack of gray wolves. The user interacts with the environment and other user-controlled or autonomous wolves by barking, whining, howling and growling into a microphone. The wolves are not completely controllable, but have strong personalities that affect the style of their behavior.

Extending the SGD Model

To better understand the following sections, we recommend reading (Prada, 2005) for detailed information about the original model and how it was implemented.

The main goal of the SGD Model is to support the creation of believable group dynamics on groups of humans and agents that engage and act in the resolution of cooperative tasks. This model is based on the principle that a character must be aware of the group and its members and should be able to build a proper social model of the group and reason with it (Prada, 2005). Agents built according to the SGD Model, gain knowledge about the group and its members during group interactions, and in turn, the occurrence of interactions (agents' behaviors) depend on this knowledge.

Agents maintain social relations of attraction and influence with other members of the group. Their social relations determine the agent's current group position in the group.

The whole group process in the SGD Model is characterized at four different levels representing the knowledge that agents should build in order to implement the SGD Model in their behavior:

1. **individual level:** knowledge about individual characteristics of each group member;
2. **group level:** knowledge about the group itself;
3. **interactions level:** knowledge about possible interactions and their dynamics;
4. **context level:** knowledge about the environment the agent lives in.

Furthermore, in addition to these 4 layers of knowledge, the agents' behavior relies on three processes (see figure 1):

1. **classification of the interactions:** detection and classification of interactions into categories of interaction with specific semantics;
2. **propagation of the interaction effects**: knowledge changes according to the interaction detected and classification made by the agent;
3. **influence of the agent's actions:** changes influence the agent's behavior.

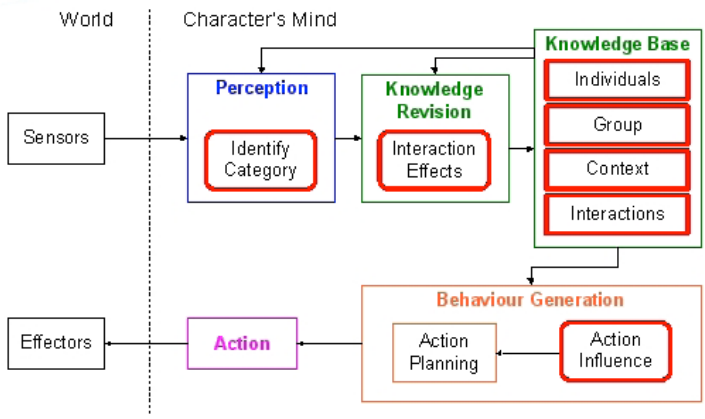

Figure 1 - The agent's mind's components and the SGD Model

By extending the original SGD Model we aimed at improving the credibility of synthetic agents and increasing the believability of their interactions when engaging in group for the resolution of cooperative tasks.

We made changes at the individual, group and interaction levels of the SGD Model. At the individual level we added a new ability, that allows agents to sell a gem, and modeled a complete personality system with five dimensions. Extraversion controls the agent frequency of interaction; Agreeableness its kindness to other agents; Conscientiousness determines an agent effort in group actions; Neuroticism how badly an agent reacts to negative emotional actions; and Openness the amount of individualism.

At the group level we changed the computation of members' group position to take into account the agent's personality. In the extended SGD Model group position is perceived differently by each member according to its personality. Group position is now a subject of individual perception and different agents may select different dominant agents inside the same group. Furthermore, we modeled a new motivation system for the group level. An agent built according to the extended SGD Model has now 4 types of motivation: (1) instrumental group motivation for instrumental interactions that pretend to help the group in reaching its goal; (2) instrumental individual motivation controls the agent's desire to act for its own good harming the group; (3) socio-emotional positive motivation and (4) socio-emotional negative motivation for positive (encourage, agree) and negative (discourage, disagree) socio-emotional interactions.

We also introduced the influence of personality at the interactions level. In the SGD Model an interaction is defined by a strength. Strength defines the importance that an interaction has in the group process. Instead of depending only on the group position of performers and supporters, the extended model also takes into account the agent's personality, so different agents may evaluate the same interaction with different importance values. Additionally to the reaction to interactions, personality also influences the frequency and type of interactions an agent is most interested in.

The statements below define the occurrence of interactions (type and frequency) in the extended version of the SGD Model.

- An extroverted agent with a high group position engages more often in interactions than an introverted agent with a low group position.

- Other variables come into play if we consider socio-emotional interactions, instrumental interactions and individual interactions separately. Low consciousness agents will engage in more socio-emotional interactions while high conscientiousness agents prefer instrumental interactions.
- High values of conscientiousness also means higher dedication and effort from the agent in successfully completing an instrumental group interaction that facilitates the group's problem. It high conscious agents are more successful than low conscious members.
- If we further divide the socio-emotional interactions into positive and negative, high values of extraversion and agreeableness means more positive interactions while high values of neuroticism and openness leads to more negative interactions.
- High agreeable agents would rather help the group choosing instrumental group interactions while high openness agents would rather interact for their own profit executing instrumental individual interactions.
- Finally, agents in a higher group position than the performer agent tend to be targets of positive socio-emotional interactions while agents in lower group positions tend to be targets of negative socio-emotional interactions.

Table 1 shows which variables (group position and personality) influence each type of interaction and illustrates the statements above.

	Group position	**Extraversion**	**Agreeableness**	**Conscientiousness**	**Neuroticism**	**Openness**
Encourage	x	x	x			
Discourage	x	x			x	x
Agree	x	x	x			
Disagree	x	x			x	x
Group instrumental	x	x	x	x		
Individual instrumental	x	x		x		x
Action execution effort	x	x		x		

Table 1 - Influence of variables (group position and personality) for each interaction

There are also rules that define how agents react to each type of interaction, considering social relations with the source agent, social relations with the target agent, the spectator agent's personality and group positions.

The statements below describe how agents react to each type of interaction:

- All interactions strength depend on the group position of the performer and on the observer's personality.
- Agents that are encouraged feel more motivated to perform group interactions and to engage in positive socio-emotional interactions and their attraction to the performer increases. The strength of the interaction depends on the extraversion and agreeableness.

- For an observer an encourage will increase or decrease its attraction for the source or target of the interaction. The rule follows Heider's Balance Theory (Heider, 1946). For example, if the encourage is targeted to an agent that it feels positively attracted to, then its attraction for the performer of the interaction increases.
- Agrees have the same kind of reaction of encourages, except that target agents won't increase their group motivation, only their attraction to the source. The strength of this type of interaction is less intense and observers don't react to agrees.
- Agents that are discouraged feel more motivated to engage in individual interactions and in negative socio-emotional interactions and their attraction to the performer decreases. The strength of the interaction depends on neuroticism and openness.
- For an observer a discourage will decrease or increase its attraction for the source or target of the interaction. The rule follows Heider's Balance Theory (Heider, 1946). For example, if the discourage is targeted to an agent that it feels negatively attracted to, then its attraction for the performer of the interaction increases.
- Disagrees have the same kind of reaction of discourages, except that target agents won't increase their instrumental individual motivation, only decrease their attraction to the source. The strength of this type of interaction is less intense and observers don't react to disagrees.
- An agent that succeeds in an instrumental group interaction facilitating the group's problem will increase its group motivation. Its social influence over all other members of the group also increases. The strength of the interaction depends on conscientiousness and agreeableness.
- An observer of a facilitate problem interaction will feel motivated to encourage the source of the interaction, but its social influence over the source decreases. The strength of the interaction depends on conscientiousness and agreeableness.
- An agent that fails an instrumental group interaction or does an individual action obstructing the group's problem will increase its individual motivation. Its social influence over all other members of the group decreases. The strength of the interaction depends on conscientiousness and openness.
- An observer of a obstruct problem interaction will feel motivated to discourage the source of the interaction. Its social influence over the source increases. The strength of the interaction depends on conscientiousness and openness.

Table 2 shows how agents react to each type of interaction and how variables influence agents' reactions and illustrates the statements above:

	G Mot	I Mot	SE+ Mot	SE- Mot	Att	Inf	GP	E	A	C	N	O
Encourage	↗		↗		↗		✓	✓	✓			
Discourage		↗		↗	↘		✓				✓	✓
Agree			↗		↗		✓	✓	✓			
Disagree				↗	↘		✓				✓	✓

	G Mot	I Mot	SE+ Mot	SE- Mot	Att	Inf	GP	E	A	C	N	O
Group instrumental success	↗		↗			↗	✓		✓	✓		
Group instrumental failure		↗		↗		↘	✓			✓		✓

Table 2 - Motivations and variables on agent's reactions to interactions

Legend:

G Mot - Group motivation

I Mot - Individual motivation

SE+ Mot - Socio-emotional positive motivation

SE- Mot - Socio-emotional negative motivation

Att - Social attraction

Inf - Social influence

GP - Group position

E- Extraversion

A- Agreeableness

C - Conscientiousness

N - Neuroticism

O - Openness

Implementation on Perfect Circle

In Perfect Circle the mind of the autonomous synthetic agents is composed of five main modules: (1) the knowledge base module where beliefs are stored; (2) the perception module where sensors translate events into meaningful perceptions; (3) the knowledge revision module for beliefs revision process; (4) the behavior module where deliberation takes place; and (5) the action module where action requests of the behavior module are translated into concrete actions. For more information of each module please refer to section 7 of (Prada, 2005).

We added the remaining three personality dimensions and the new action sell gem to the knowledge base module. In the perception module we introduced personality influence on the computation of an interaction strength. The knowledge revision module presents a major change regarding how new values for social relations are calculated. In the original model, the amount of change to apply is computed using a formula that simulates the tendency of the values to stay neutral. We don't agree with this tendency. For good and bad, first impressions have a great importance whenever people meet for the first time (Huston and Levinger, 1978) (Taylor, Peplau and Sears, 2000). Usually people make hasty judgements about other people as soon as they meet, based on social consensus stereotypes and previous experiences. So we defined a new formula to calculate the amount of absolute change to apply to new values (new value = old value + change) of social attraction and social influence (compare figures 2 and 3).

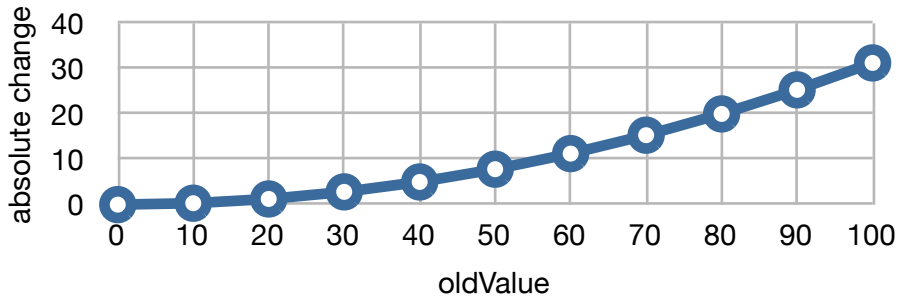

Figure 2 - Absolute change function of the SGD Model

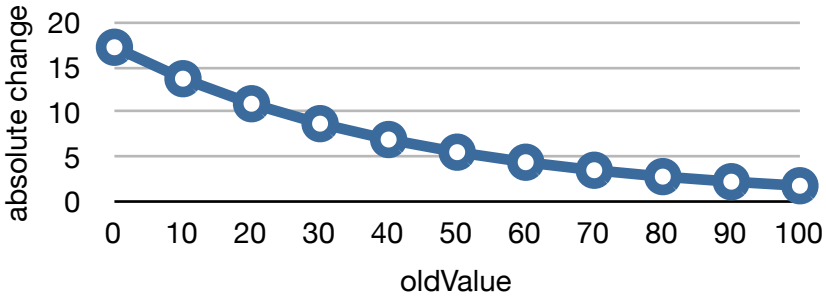

Figure 3 - Absolute change function of the extended SGD Model

Regarding the behavior module we implemented a complete new motivation system. Agents built according to the extended version of the SGD Model have the following types of motivation (the long description below is illustrated in table 3):

- **instrumental proactive group motivation:** increases at regular intervals of time; increases at different amounts depending on agent's personality and group position;
- **instrumental reactive group motivation:** increases as a result of encouragements and successful group interactions; the amount of decay over time depends on agent's personality; when the sum of the instrumental proactive and reactive group motivations fill one recipient, the agent is motivated in helping the group; both proactive and reactive motivations are emptied after that;
- **instrumental proactive individual motivation:** increases at regular intervals of time; increases at different amounts depending on agent's personality and group position;
- **instrumental reactive individual motivation:** increases as a result of discourages and failures; decays over time depending on agent's personality; when is filled the agent steals and sells a gem from the stack; is emptied after that;
- **socio-emotional positive proactive motivation** (for each agent in the group): increases to maximum value when detects an agent capable of doing something present in its plan;
- **socio-emotional positive reactive motivation** (for each agent in the group): increases when a specific agent helps the group and when the agent detects a socio-emotional interaction that is positive from its point of view according to Heider's Balance Theory; decays over time depending on agent's personality; when the sum of the proactive and reactive components fill one recipient, the agent is motivated to encourage a specific agent; both proactive and reactive motivations are emptied after that;
- **socio-emotional negative proactive motivation** (for each agent in the group): is always zero or does not exist;

- **socio-emotional negative reactive motivation** (for each agent in the group): increases when a specific agent obstructs the group and when the agent detects a socio-emotional interaction that is negative from its point of view according to Heider's Balance Theory; decays over time depending on agent's personality; when is filled the agent discourages a specific agent.

Notice that there is no socio-emotional negative proactive motivation. Perfect Circle is a team cooperative game where a group of agents have the same collaborative task. There is a reason for proactively encouraging an agent so it feels motivated to act. It may happen that only one agent is capable of executing a skill, so it's important to motivate it. On the other hand an agent has no interest in proactively discouraging other agents. We decided to leave the socio-emotional negative proactive motivation out of this implementation.

Experimental tests and results

In this section we describe some of the experimental tests we made to verify that agents in our implementation are behaving like we expected. Agents in Perfect Circle should follow the behavior and reaction rules and statements defined previously.

We did a personality dimensions test with a specific group composition (table 4). The game session had the following number of interactions (table 5):

	Extraversion	Agreeableeness	Conscientiousness	Neuroticism	Openness
Ana	1	1	1	1	100
Beatriz	1	100	1	1	1
Carlos	1	1	100	1	1
Duarte	1	1	1	100	1
Ema	100	1	1	1	1

Table 4 - Group composition of the personality dimensions test

	Encourage	Discourage	Agree	Join	Disagree	Instrumental Group Success	Instrumental Group Failure	Sell
Ana	0	0	10	1	1	7	0	5
Beatriz	1	0	4	5	0	11	0	1
Carlos	1	0	14	1	3	1	0	4
Duarte	1	0	15	0	3	0	0	4
Ema	19	0	15	0	0	3	0	1

Table 5 - Number of interactions during the game session

Everything worked as expected if we carefully analyze the information.

Ema is the extroverted agent. Although it was expected several instrumental interaction, it only has 3. Notice however the high amount of encouragements. Those are from several planning processes that found the best action and agent with the required ability. If we take into account this number of encourages, Ema is the most active agent as we expected.

Beatriz is the agreeable agent. Table 5 shows a high level of engagement in instrumental group interactions. Beatriz is also the agent with the most joined actions. Everything worked correctly according to our model.

Carlos is the most conscious. It's not very clear from table 5 to understand how conscientiousness influenced Carlos behavior. But we can make an interesting deduction. Carlos is one of the agents with the higher number of sold gems. Conscientiousness has a role regarding reaction to instrumental group interactions. The agent has one succeeded group action but saw other twenty one, so it feels with lower influence over all other members. Its group position got lower and its individual motivation increased.

Duarte is very neurotic. It has a weak opinion about itself and this reveals in having no kind of group participation from Duarte. Consequently, other members don't feel attracted to this agent and its influence over others is very low. This agent would rather sell gems from the stack than help the group in its quest.

Ana is very open. As expected is the agent that sold more gems.

Social relations and motivations also behaved accordingly. The two more relevant are Beatriz's and Duarte's social influences over other members. We expect the first one to rise and the second one to lower with time. Figures 4 and 5 shows that we are right and the implementation is working correctly.

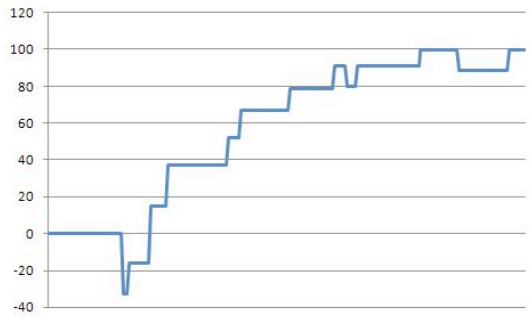

Figure 4 - Beatriz's influence over Ana from Ana's point of view

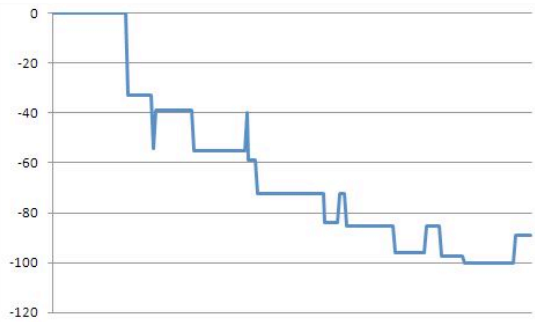

Figure 5 - Duarte's influence over Ana from Ana's point of view

According to the model, group instrumental motivation increase more drastically on extroverted agents than on open agents. Individual motivation works opposite. The following four figures shows what we had expected.

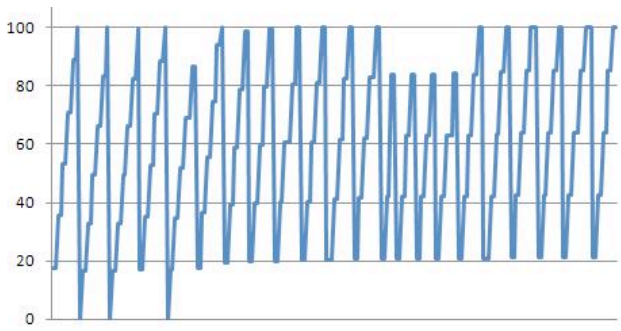

Figure 6 - Changes of Ema's group motivation

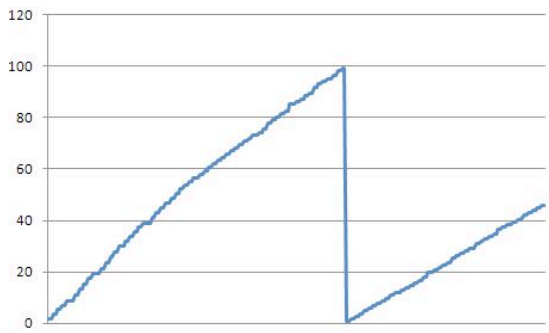

Figure 7 - Changes of Ema's individual motivations

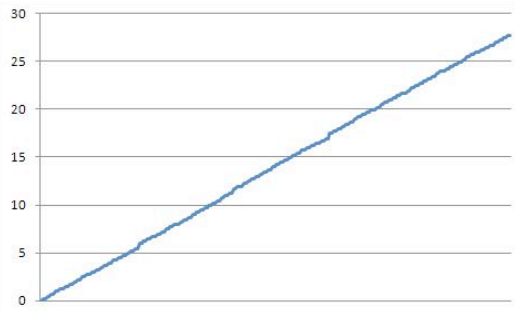

Figure 8 - Changes of Duarte's group motivation

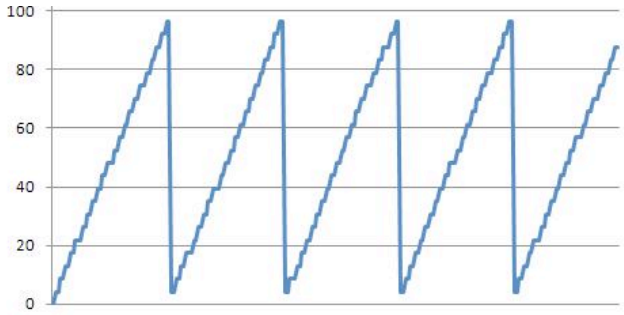

Figure 9 - Changes of Duarte's individual motivations

Agreeable agents like Beatriz also engage frequently in group interactions, but agreeableness is less relevance than extraversion when considering the frequency of interactions. Compare the following figure 10 with figure 6.

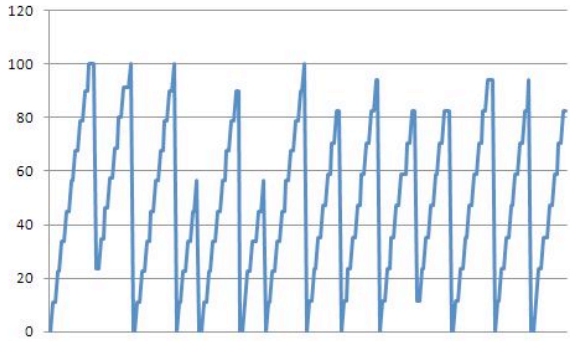

Figure 10 - Changes of Beatriz's group motivation

Conclusions

The SGD Model was built by Prada (Prada, 2005) to provide users a believable environment where synthetic agents engage in collaboration with human users. Despite the good experimental results that show high levels of believability the model presents a weak personality system composed of only two dimensions. Regarding this fact, we considered reasonable and possible that even higher levels of believability were possible if we improved the personality system.

Our work proposes an extension to the original SGD Model. We modeled a complete personality system based on the Five-Factor Model (McCrae et al., 1996). In addition to that, we also introduced a new feature to the model that solves the problem regarding very high levels of cohesion. It consists of a new type

of motivation that controls the agent's desire in engaging in individual selfish actions and a new action that fulfill this desire.

We implemented our version of the model on the computer game Perfect Circle to test if agents show the expected behaviors and reactions to socio-emotional and instrumental interactions.

Results from our experimental tests show that agents behave and react according to their personality. We consider that the system is ready to be tested with human users so we can evaluate and compare the original and extended versions of the SGD Model. The extended version should provide a better experience, better group identification and high levels of satisfaction and believability to users.

Even the extended version of the SGD Model uses a simplified view of reality and of the group process. There are many aspects of the group dynamics that could be further explored. It would be interesting to have dynamism on group compositions, where agents could join and leave a community of groups. Imagine also if agents could engage in communication interactions, for example to express emotions. It would be interesting to have a relation between planning and personality. Some agents could for example search deeply for solutions while others prefer simple things. The function that changes social relations can also be improved. It will be nice to have a function that changes depending on the time agents know each other. In the beginning of a relationship values would change more drastically, and with time this change would become calm almost neutral. It would be also interesting to see the individual motivation and personality influence the agent's decision in continuing an instrumental group action even if in the negotiation process its proposal is denied. At last but not least, the model and the implementation needs further evaluation with human users to test if the extended SGD Model provides a more believable and better experience to users.

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