Personality in Social Group Dynamics

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***Abstract*—The concept of personality has been used in multi-agent systems to create diversity in the behaviours of autonomous agents. This diversity is useful to explore different strategies in societies of agents, for example, to form coalitions, and is essential to model natural and "human-like" social agents. In the case of agents that interact with users, personality becomes a core issue and is one of the main drives to achieve the users' suspension of disbelief. This paper presents a computational model of personality based on the Five Factor Model (FFM) of personality that generates diversity in the behaviour of social agents that interact in teamwork scenarios.**

I. Introduction

Personality has been introduced into autonomous agents for the creation of social intelligence for several reasons [1]. One of the major objectives of AI as a science is modelling natural intelligence and in natural societies people show different personalities, thus, it is natural to include personality as a construct to generate intelligence [2]. This is particularly relevant in autonomous agents that interact with people, since people are very sensible to the "human-like" qualities of these agents. In fact, people seem to use similar social rules to interact with computers and other people, in particular, people perceive computers as having personalities [3]. For these reasons, personality (and emotions) have being seen as the driving force to generate believable characters [4][5][6] that are able to lead the users to the suspension of disbelief [7]. The goal is to archive the sense that each agent is unique and that its behaviour maintains some coherence over time.

In addition, personality has been used to explore and compare different strategies in multi-agent systems. It has been implicitly introduced in the different kinds of commitment defined by Cohen and Levesque [8] and it is often used to test different strategies for coalition formation [9].

Many definitions of personality in autonomous agents use traits to define individual characteristics of agents, however, the set of traits used is sometimes *ad hoc*, which can lead to combination of traits that produce personalities that are not coherent [1]. This may be a small issue when using personality as a exploratory tool in multi-agent systems, but may become a major problem if the goal is to create agents that show believable personalities. In turn, some systems create implicit cues of personality in the behaviour of agents, this are usually expressed in the animation of the agents in their virtual worlds, their voices and their gait. Other approaches define individuality in the set of actions available to the agents or the type of emotions they are prone to feel.

These more *ad hoc* approaches can be effective, however, they usually lead to more effort in the crafting of each individuality to avoid producing personalities that are not coherent.

Nevertheless, many systems use known and establish traits theories, such as, the Five Factor Model (FFM) of personality [10]. We defend that the use of these well establish theories provide a better tool to easily create coherent personalities.

In this paper, we propose a computational model of personality that explores several facets of the five traits defined in the FFM. This model is defined to create individuality in agents that interact in teams with the purpose of increasing their believability. The proposed model of personality was integrated into an existing model that supports the generation of group behaviour, which was adapted by integrating a motivational system just for this purpose.

The next section describes briefly some theories of personality with emphasis on the FFM. Then, the base model for the generation of group behaviour is described, followed by the description of the personality model. The paper is concluded with some discussion and notes for future work.

II. Theories of Personality

There are many different theories that try to model people's personality. Nevertheless, it is broadly accepted that personality is stable over time, even though it can change in result of significant events in people's life. Most of these theories try to categorize people in types or define certain dimensions to fit people's particular patterns of behaviour.

Some examples are: Eysenck's [11] two-dimension model that define personality in the dimensions of Extraversion and Stability; Cloninger's Temperament Theory [12] that delineate Self-directedness, Cooperativeness and Self-transcendence as character traits and Novelty seeking, Harm avoidance, Reward dependence and Persistence as temperament traits; Myer-Briggs [13] core types, which are based on Jungs' psychological types [14], and built on top of four dichotomies Extraversion/Introversion, Sensing/Intuition, Thinking/Feeling and Judging/Perceiving; or Catell [15] model that used 16 different trait descriptors to rate behavior of groups of people.

Among all these theories, the Five Factor Model of personality [10] is one of the most popular. It uses five dimensions to

define personality: Extraversion, Agreeableness, Neuroticism, Conscientiousness and Openness to Experience. They can be briefly described as [16]:

1) **Extraversion** implies an energetic approach toward the social and material world and includes traits such as sociability, activity, assertiveness, and positive emotionality.
2) **Agreeableness** contrasts a prosocial and communal orientation towards others with antagonism and includes traits such as altruism, tendermindedness, trust, and modesty.
3) **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.
4) **Neuroticism** contrasts emotional stability and even-temperedness with negative emotionality, such as feeling anxious, nervous, sad, and tense.
5) **Openness to Experience** describes the breadth, depth, originality, and complexity of an individual's mental and experiential life.

III. Base Model

The autonomous agents' base behaviour follows a model that is a generalization of the SGD Model [17][18]. The SGD Model was created to embed social intelligent in autonomous agents that interact in small teams. It implements behaviour patterns, inspired by results from social sciences, that allow agents to generate "human-like" group behaviours.

A. Motivational System

The base model presented here integrates the core ideas of the SGD Model with a motivational system.

One of the main claims of the SGD Model is that both social-emotional and task-related interactions are important to generate believable behaviour. For these reason, the agents' motivational system defines two different types of motivations, task related (instrumental) and socio-emotional. These can be summarized in different motivation categories as follows:

1) **Motivation to perform the group's task (instrumental) - IG:** represents the agent's motivation to perform actions that will facilitate the resolution of the task (e.g., execute on step of the solution plan).
2) **Motivation to perform an individual task (instrumental) - II:** represents the agent's motivation to perform actions that are not related to the group's task and that only bring benefit to the self (can eventually damage the resolution of the groups' task).
3) **Motivation to encourage one member of the group (socio-emotional) - SE:** represents the agent's motivation to perform actions with positive socio-emotional connotation towards another agent (e.g., support an agent when it fails to perform an important action).
4) **Motivation to discourage one member of the group (socio-emotional) - SD:** represents the agent's motivation to perform actions with negative socio-emotional connotation towards another agent (e.g., reprove an agent when it fails to perform an important action).

Different motivation variables can be created for each category. This occurs if distinctive entities of each category exist. For example, if the group has two very district tasks then the agent will have two motivational variables of type IG, one for each task. More commonly, agents interact in groups and, therefore, have individual motivational variables of types SE and SD for each member of the group (i.e., the intrinsic motivation to encourage one member of the group is independent of the motivation to encourage others).

Furthermore, all the motivation variables have two different components: a pro-active and a reactive. The pro-active component represents the inner motivation of the agent to perform in a particular way, while the reactive component represents the motivation from external stimulus that influence the agent. For example, an agent may have an internal "feeling" of hunger and, therefore, motivation to eat, but it can also see a very delicious meal and get a temporary reactive motivation to eat despite being hungry. The overall motivation is the sum of the two components.

B. Behaviour Generation

Agents' behaviour generation follows regular decision cycles. In each cycle the motivations are checked against a threshold to see if they are active (e.g., to check if the agent is motivate to act). If more than one motivation is active the more intense (with higher value) is used.

Motivations define intrinsic objectives that agents pursuit, but not specific actions. Therefore, if the agent is motivated to act it starts the appropriate action selection mechanism (e.g., planning, rule-base system). In this paper, we assume that agents have a planning mechanism to decide which action to take.

The motivations' value change overtime and with specific events. The reactive components of all motivation variables decay over time and the proactive components of the instrumental motivation variables increase over time. The proactive components of socio-emotional components do not change over time, because we are designing agents that are mainly driven to perform tasks. If the agents are built with stronger social goals, such as, being popular, for example, this should be reconsidered. The decay and increment rates may vary from agent to agent and, as we will describe later, are influenced by the personality of the agent.

As stated before, some events may change the value of the motivation variables. The occurrence of an event that fulfils the objectives behind the motivation with make its value to be reset to the neutral state. For example, if the agent has a motivation to encourage another agent, then, after doing it, it will no longer maintain the motivation to encourage the same agent. Note that the motivation may be increased by other factors (e.g., the agents finds different reasons to

perform the encouragement) and that it will only be reset if the encouragement is successful. The agent is persistent in its goals.

Other specific events may change the motivation values. These will be detailed in the next sections.

C. Group Model

Agents' group dynamics is modelled at 4 different levels:

1) **the individual level**: defines how individual characteristics of agents influence their behaviour in the group. Agents' skills and personality have an important role here.
2) **the group level**: defines how the group's structure influence agents' behaviour. The social relations play an important role at this level.
3) **the context level**: defines how social norms, culture and the nature of the task influence the agents' behaviour.
4) **the interactions level**: defines the type of interactions that occur in the group. This classification has a central role in the model, because the group dynamics is defined around the occurrence of interactions.

Agents maintain knowledge on all these four levels in their knowledge base. At the *individual level* they store knowledge about the abilities every member of the group has (including the self). These are the actions that are relevant to the resolution of the task and their proficiency level (e.g., success rate using the action). In addition, agents store knowledge regarding the members' personality, details on this are presented on the next section.

At the *context level* agents store knowledge about the task, which will help them plan their actions and knowledge about the social norms and culture of the group. This will be important to support the appraisal of events and the categorization of events into one of the categories defined at the interactions level. The knowledge in the *context level* is very dependent on the situation where the agents are applied, therefore, is kept open in the model.

At the *group level* agents store knowledge that defines the group. This includes the composition of the group, but, more importantly, it includes the structure of social relations established between all members of the group. Agents have a theory of mind of others that estimates the social relations each other agent maintains.

Social relations are defined in two different dimensions: (1) relations of *social attraction* that define the interpersonal attraction of the members in terms of like and dislike attitudes, and (2) *relations of social influence* that define relations of social power.

From the structure of social relations agents compute their relative position in the group. This position defines how important are their contributions and how well they are accepted by the group. For example, actions performed by members that have more social influence on the other members have stronger effects and are more likely to be accepted as good actions. The position of the group is computed by summing up (1) the overall social influence that the agent may exert on the others and (2) the social attraction that the others feel for the agent. The value is, then, normalized according to the number of elements of the group. An agent position in the group is computed using equations 1 and 2, where *Group(G, members)* denotes the definition of *G* as a group with its *members*, *SocialAttraction(A,B,S)* denotes the social attraction that *A* has for *B* in the situation *S* and *SocialInfluence(A,B,S)* denotes the social influence that *A* has on *B* in the situation *S*.

$$\forall G, A : Group(G, members) \wedge A \in members,$$
$$Position(A, G, S) = \sum_{m \in members}^{m} SocialAttraction(m, A, S) + \sum_{m \in members}^{m} SocialInfluence(A, m, S) \quad (1)$$

$$\forall G, A : Group(G, members) \wedge A \in members,$$
$$RelPosition(A, G, S) = \frac{Position(A, G, S)}{\sum_{m \in members}^{m} Position(m, G, S)} \quad (2)$$

At the *interactions level* agents store knowledge regarding the interactions that occur in the group. An interaction is defined as a set of events (or pattern of actions) that occur in a given situation. Interactions have a set of performers (agents that are responsible for the actions), a set of targets (agents that directly suffer/benefit from the effects of the interaction) and a set of supporters (agents that support the interaction, e.g., agree with it, but are not directly involved in the execution of the actions). Interactions have different strengths in the group according to the position in the group of it's performers and supporters. Similar to the concept of position in the group, the interaction's strength defines the relative importance of the interaction in the group.

Moreover, interactions are classified according to the knowledge the agent has of the situation, which can be different from agent to agent. Therefore, the same pattern of actions can be perceived as a positive interaction for the group by an agent but as a negative interaction by another. Interactions are divided into two main categories depending on if they are related to the task (instrumental) or related to socio-emotional issues [19]. Within this division interactions are categorized as positive or negative:

- Instrumental interactions
  - Positive
    - **Facilitate Problem:** This class of interactions represents the interactions of an agent that solves one of the group's problems or facilitates its resolution (e.g., execute part of the solution).
    - **Gain Competence:** These interactions make an agent more capable of solving a problem. This includes, for example, the learning of new capabilities or the acquisition of information and resources.

  - Negative
    - **Obstruct Problem:** This class of interactions represents the interactions of an agent that complicates one of the group's problems or makes its resolution more difficult or impossible.
    - **Lose Competence:** These interactions make an agent less capable of solving a problem, for example, by forgetting information or losing control of resources.
- Socio-emotional interactions
  - Positive
    - **Agree:** This class of interactions show the support and agreement of an agent towards one of the interactions of another agent, consequently raising the importance of that interaction in the group.
    - **Encourage:** These interactions represent an agent's efforts to encourage another agent.
  - Negative
    - **Disagree:** This class of interactions show the disagreement of an agent towards one of the interactions of another agent, consequently decreasing the importance of that interaction in the group.
    - **Discourage:** These interactions represent an agent's hostility towards another agent and its efforts to discourage it.

D. Group Dynamics

The interactions create the dynamics in the group. Such dynamics are supported by the classification presented in the previous section and are modelled by a set of rules that define, on one hand, how the model of the group influences the occurrence of each kind of interaction and, on the other hand, how the occurrence of each type of interaction influences the model.

First of all, the general frequency of interactions (of any kind) depends on the agents' relative position in the group. This is reflected on the regular increment rate of proactive components of the motivation variables and on the increment applied to the reactive components when events occur. The higher the position in the group the higher the increment of the motivation variables. Therefore, members with better position in the group will interact more often.

In addition, members with better position in the group are targeted more often with positive socio-emotional interactions (i.e. *Agree* and *Encourage*) while members with low position in the group are targeted more often with negative socio-emotional interactions (i.e. *Disagree* and *Discourage*). This is reflected in the value of the increment applied to the reactive component of the encourage and discourage motivation variables. In the case of the encourage motivation the increment is directly proportional to the position in the group of the performer and in the case of the discourage motivation the increment is inversely proportional. The reactive component of these variables is incremented in two different situations:

1) **in reaction to instrumental interactions.** When a *Facilitate Problem* interaction occurs the reactive component of the motivation to encourage its performers increases[1]. However, in the case of an *Obstruct Problem* interaction both the reactive component of the motivation to encourage and to discourage increase. Agents that fail actions related to the group's task will be more often encouraged if they have a high position in the group, but will be more often discouraged if they have a low position in the group.
2) **in reaction to socio-emotional interactions.** In this case a general rule of reciprocity is applied. Therefore, if an agent is target of an *Encourage* interaction the motivation to encourage back the performers increases but if it is target of a *Discourage* the motivation to discourage the performers increases. Moreover, agents react to socio-emotional interactions even if they are not directly targeted, this follows the ideas proposed in Heider's Balance Theory [20]. Agents check their relations of social attraction with the target of the interaction and react to the performers of the interaction accordingly. If the valence of the social relation and the interaction are similar (both positive or both negative) then the motivation to encourage the performers will increase, if valences are opposite (e.g., the agent likes the target and performers discourage it), then the motivation to discourage the performers will increase.

Furthermore, when computing the increment of *reactive-SE* and *reactive-SD* the social relations between the agent and each performer of the interaction are also taken into account. Agents encourage more often other agents that they are positively attracted to and/or agents that have high social influence over them. In turn, they discourage more often agents that they dislike and/or that do not have influence over them. This means that the increment is a function of (1) the position in the group of the performers, (2) the social attraction of the agent for performers, (3) the social influence the performers have over the agent and (4) the position in the group of the agent.

The occurrence of interactions will also change the knowledge agents build regarding the group model. Instrumental interactions are related to changes in the relations of social influence and the socio-emotional interactions induce changes in the relations of social attraction. Positive instrumental interactions increase their performers' social influence on the other members of the group, by means of expert and information power [21]. Any member that demonstrates expertise and solves one of the group's problems or obtains resources that are useful to its resolution, will gain influence over the others. In turn, members that obstruct the problem or lose competence will lose influence over the other members of the group.

Changes induced in the social relations by the occurrence

[1]Note, that we did not considered discouragements in reaction to *Facilitate Problem* interactions, because we considered that agents are built with the goal to solve tasks and do not have goals, such as, to be the one that contributes more to the task.

of socio-emotional interactions follow similar rules as used in the increments of the reactive components of the motivation variables (i.e. reciprocity and balance). This means that agents when targeted by positive socio-emotional interactions increase the social attraction for the performers, and decrease it if targeted by negative socio-emotional interactions. In addition, agents change their relations of attraction for agents involved in socio-emotional interactions, while not being directly involved. Agents check the absolute value of the intensity of their relation with the performer and the target of the interaction. They keep the relation with the highest absolute value and change the other relation according to the situation. If the valence of the relation kept and the interaction is the same (e.g., a *Discourage* interaction was performed and the agent dislikes the target/performer) then the attraction for the other increases, if valences are different then the attraction decreases (e.g., if an agent is encouraging one of my enemies I dislike him more).

The value of the change in the social relations depends on the strength of the interaction in the group. Changes are higher if the strength of the interaction is higher.

Furthermore, note that these changes are also computed in the perspective of other members in the group to keep the theory of mind updated.

Encourage interactions have the secondary effect to increase the target's reactive component of the motivation to perform the group's task. Conversely, *Discourage* interactions increase the target's reactive component of the motivation to perform individual tasks.

IV. Personality Model

The initial SGD Model defined personality as an important factor in group dynamics, but it used a simple version of the Five Factor Model of personality [10]. Only two dimensions of the FFM were used and they were not explored in their full extend.

In this section we present an extension to the initial personality model that includes all five factors of the Five Factor Model of personality.

Extraversion influences the general frequency of interactions in the group. More extroverted members interact more often. This affects the increment rates of the proactive components of the motivation variables and the decay rates of the reactive components of the motivation variables. The values of the proactive components increase more rapidly and the value of the reactive components decrease more slowly as the level of extraversion increases.

Furthermore, extraversion influences the interpretation of positive versus negative interactions. Extravert agents give more importance to positive events than negative ones. Therefore, the effects of *Encourage*, *Agree*, *Facilitate Problem* and *Gain Competence* interactions are increased as extraversion increases, while the effects of *Discourage*, *Disagree*, *Obstruct Problem* and *Lose Competence* are reduced. This means, for example, that an extrovert agent will increase its *reactive-SE* motivation to react to an *Encourage* interaction more than a non extrovert. At the same time, the social attraction for the performer of the *Encourage* interaction will increase more in the case of an extrovert agent.

Agreeableness influences the frequency of positive socio-emotional interactions. More agreeable agents agree more often with others and encourage others more often. Therefore, increments in *reactive-SE* motivation increase with the level of agreeableness of the agent. This is relevant, for example, in the case of the occurrence of negative instrumental interactions (*Obstruct Problem* and *Lose Competence*). In this case, agreeable agents will increase more the motivation to encourage (*reactive-SE*) than the motivation to discourage (*reactive-SD*).

In addition, agreeable agents perform more actions for the group than actions for themselves, this influences the increment rates of the proactive components of the instrumental motivations. Increments in the *proactive-IG* motivation increase as the level of agreeableness increases, while increments in the *proactive-II* motivation decrease in the same case.

Conscientiousness influences the interpretation of instrumental versus socio-emotional interactions. Agents with higher values of conscientiousness give more importance to instrumental interactions in detriment of socio-emotional interactions. For example, an agents that succeeds well in the performance of a group task (*Facilitate Problem*) will gain more influence over the agents that have higher values of conscientiousness.

In addition, agents with high conscientiousness will put more effort in the execution of task related actions. This is reflected in the agents in two different ways. First, the probability of success of the agent with such actions is increased. The result of an action depends on its proficiency level with a bonus from the level of effort put in its execution. Therefore, for agents with similar proficiency level in a given action the more conscientious will have an higher probability of success. Second, the level of conscientiousness affects the planning algorithm. High levels of conscientiousness imply more CPU time for planning (e.g., higher depth, higher node expansion limits).

Neuroticism, similarly to extraversion, influences the interpretation of positive versus negative interactions. Agents with high values of neuroticism give more importance to negative events than positive ones. This means, for example, that agents with high neuroticism increase more the *reactive-SD* motivation to discourage an agent that just discourage them than the *reactive-SE* motivation to encourage an agent that just encourage them. At the same time the social attraction for the performer will decrease more in the first case than increase in the second.

Openness to Experience, influences the frequency of instrumental interactions. Agents with high values of openness to experience conform less with the group and, therefore, give more importance to individual tasks. This is reflected in the increments of the proactive components of the instrumental motivations. The *proactive-II* motivation increases more in agents with higher levels of openness. In the same case the *proactive IG* motivation increases less.

In addition, since agents with high values of openness to experience care less for the success of the group, the effects of instrumental interactions are less intense. For example, the occurrence of positive instrumental interactions (*Facilitate Problem* and *Gain Competence*) will increase less the social influence of the performers over agents with high openness to experience and the increments of the reactive components of the motivation variables will increase less.

Moreover, openness to experience influences the planning algorithm. In cases of higher values of openness to experience, the agent uses heuristics that allow it to explore more unusual solutions.

Finally, note that, as part of their theory of mind on the others, agents know the personality of others[2] to try to access their reactions to the group interactions and, consequently, to estimate the social relations of all members of the group.

V. Discussion

Personality is important in the creation of autonomous agents systems. It can be used to create scenarios that explore and compare different strategies in societies of agents and it is crucial in the creation of interesting and coherent individualities that sustain the believability of agents that interact with users. For this later purpose, the use of trait theories, in detriment of *ad hoc* approaches, may simplify the process of the creation of coherent personalities. Following this idea we presented a model of personality, based on the Five Factor trait theory, that created individuality in believable team interactions.

The model is built on top of an already existent model for the generation of believable group interactions (SGD Model) that was adapted, by the introduction of a motivational system to support the group's dynamics.

The integrated model was used in the mind of agents that act as characters in an adapted version of the game "Perfect Circle: the Quest for the Rainbow Pearl" that was designed to evaluated the effects of the first version of the SGD Model [17][18].

This game places the user and four autonomous characters in a fantasy world where they work as a group. The difference from the first version is that now the characters have a secondary goal besides the common goal of the group. The secondary goal is to get some personal wealth while going on the group task. To achieve this, characters may sell some of the items that belong to the group.

We performed a preliminary study where all characters were played by autonomous agents and have extreme personalities (e.g. all traits very low except one that was very high). The results showed differences in the behaviour of characters. The influence of some personality traits was easily identified (in the case of extraverion, agreeableness and openness to experience), but the influence of others was not fully identified (the case of neuroticim). In the future we plan to perform more studies to better evaluate the influence of the personality model in the behaviour of the agents. We plan to perform similar tests to the one described, but with personalities from real people. The most interesting studies we envisioned are studies that compare the new and old version of the SGD Model and studies that involve the interaction with users.

[2]A more believable system would include an estimation of the personality of others, but, we decided to keep such complexity out of our model.

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