One for One and All for All
The Influence of Individual Goals in a Group of Agents with a Common Goal.

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Resumo

Vários sistemas lidam com agentes autónomos que trabalham como um grupo. Na maioria destes, contudo, os agents trabalham para um objectivo comum, não existindo objectivos individuais. Quando existem dois ou mais objectivos, muitos sistemas falham na credibilidade, pois a escolha de qual o objectivo a seguir é baseada sobretudo na utilidade. O nosso objectivo era criar um modelo que permitisse que agentes num grupo decidissem de uma forma credível sobre seguir o objectivo individual ou de grupo.

Estendendo o SGD Model, de Rui Prada, que implementava com sucesso agentes com personalidade baseada no Five Factor Model, criámos um modelo baseado em teorias de Psicologia e Sociologia que permitem aos nossos agentes decidir o que é mais importante, o grupo ou eles mesmos. Essa escolha é baseada no Egoísmo dos agentes, e na atracção e influência que sentem do grupo. Por sua vez, estes factores dependem doutros tão dispares como a personalidade, as relações inter-pessoais, estímulos do exterior, a auto-estima, ou o sucesso dos agentes ou do grupo.

Implementámos o nosso modelo em agentes que jogam um jogo semi-competitivo, o Power Pentagram. Neste jogo, os agentes são obrigados a cooperar para passar os vários níveis, ao mesmo tempo que devem competir se quiserem ter vantagem sobre os outros membros do grupo.

Os testes levados a cabo demonstram que o modelo implementado reflecte com sucesso comportamentos diferentes para grupos com diferentes constituições, com resultados que seriam esperados para grupos de humanos.

**Palavras-chave:** Agentes Autónomos, Objectivo Individual, Objectivo de Grupo, Credibilidade, Individualidade, Egoísmo
Abstract

There are several systems dealing with autonomous agents working as a group. In most of them, however, agents work for a common goal, not contemplating individual objectives. When two or more goals are available, many systems lack believability, for the choice is based mainly on utility. We aim at creating a system which allows agents in a group to decide in a believable manner whether to follow an individual or a group's goal.

Extending Rui Prada's SGD Model, which successfully implemented agents with personality based on the Five Factor Model, we created a model based on Psychology and Sociology theories, allowing agents to decide what is more important, the group or themselves. This choice is based on agents' Egoism and on the attraction and influence they feel from the group. In turn, these depend on other factors such as personality, social relationships, outer stimulus, self-esteem or group's and agents' success.

We implemented our model on agents playing a semi-competitive game, Power Pentagram. On this game, agents must cooperate to win the different levels, at the same time they should compete in order to be in advantage against other members in the group.

The tests on our model showed that it successfully reflects different behaviors for groups with different constitutions, with results that would be expected for human groups.

Keywords: Autonomous Agents, Egoism, Self-Esteem, Individual Goal, Group Goal, Believability, Individuality
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Chapter 1

Introduction

1.1 Motivations for Research

We are not alone! Humans belong to several groups: family, coworkers, club, and friends, among others. A social group [1] can be defined by two or more people who interact, and somehow identify with one another. As members of a group, and aware of it, we may see that we share experiences, loyalties, expectations, obligations, objectives or interests with other members. But not every set of individuals automatically forms a group: men, students, politicians, immigrants, though aware of others sharing the same status as themselves, have no relation whatsoever with them. Therefore, we may say that all of the above can be defined as categories [1]. In a group, individuals see themselves as members of a “We”, forming a special entity - the group - with special characteristics and several defining processes, differentiating it from other groups. But as members of groups, humans still keep their individuality, their personality, their own interests, their expectations and needs. We are not alone indeed. But “We” is also a set of “I”s.

Autonomous agents [2] are not alone anymore either! Social agents [3] interact with other entities, such as other agents or humans. Some agents even interact as members of a group in several applications, mostly in the entertainment area (the games and cinema industries), but also in learning and training. However, it is common for agents in a group to act in a non-believable manner, decreasing the quality of the user’s interaction with the system.

To increase believability [4] of such agents, much research has been made with the objective of modeling the group process in a satisfactory manner. However, what we can see is that when in a group, even if they have different personalities, agents tend to act in a very uniform way: they work towards the group’s objective, trying to increase the group’s welfare. In fact, even when there are two types of objectives, the group’s and the agents’, agents choose based mainly on their gain, doing the rational thing, but lacking the existence of other factors such as personality and social relations’ influence in that choice.

In order to model agents’ behavior in a group, when they have to choose in a believable way between two goals: the individual and group’s goal, we must therefore model the agents individually and the group’s structure and processes. Beginning with the “I”, our work intended to achieve a “We” where agents behave in a way that feels real, and not only rational. This is more important when a human user interacts as a member of a group of such agents. He must not think he is alone, as the only human among “stuff”, but as a member of a group of individuals with different personalities, goals, and behaviors.
1.2 Objective and Contribution of Research

The main objective of our work was to model the process of choice between an individual and a group goal for agents acting as members of a group. This decision brings a conflict to such agents, especially when they take into account factors as their interpersonal relationships with other members in the group, their personality and their position in the group.

The process of choice begins with the notion of egoism and altruism [5]. In our work we aimed at modeling agents which could act towards their own welfare (egoistic agents) and towards the group’s welfare (altruistic agents). We didn’t want, however, to base the agent’s choice strictly on egoism and altruism. We aimed at creating agents whose choice takes into consideration several factors, as the history of past interactions and personality, which together with egoism and altruism allowed us to model a well-structured, well-justified decision process.

By taking into account all these factors, based on sociology and psychology theories, we tried to develop believable agents. Achieving this believability was our secondary objective, for we wanted, as possible, to achieve the suspension of disbelief in anyone who interacts with the agents.

We developed a system extending Prada’s SGD model [6; 7]. In this system, agents already had an associated personality influencing their behavior. Besides this, SGD model already contemplated a way to represent group’s structure, based on social relations, as well as a well defined set of interactions.

Prada’s system, however, did not contemplate the conflict in the agents’ mind when they have one tough question to answer: “what matters the most to me, the group or myself?” Past versions of SGD successfully allowed agents to act in a believable way in a group, but did not care about how they should behave when more than one goal was taken into account. This means that our utilization of Prada’s SGD was not possible without extending it in order to allow the use of agent’s personality traits, the egoistic and altruistic levels and the interactions that occur within the group as factors for the agent’s choice. We also extended it in a way for it to have a representation of the individual and the group goals.

With the referred characteristics in mind, we aimed at creating agents differing from the field’s standard, which base their decision mostly in the notion of utility. We wanted that agents implementing our model, with their most believable behavior, would show useful in several areas, mainly in games development, where our system may have an important application.
1.3 Outline

This document is divided in six different chapters, as follows:

In chapter 2 (Related Work), we introduce a brief study on research projects somehow related with ours, separated by area of interest. We end this chapter by comparing them in terms of some of the characteristics of our system, and justifying our system’s relevance.

Chapter 3 (Psychological and Sociological Background) introduces the concepts and theories in the areas of Psychology and Sociology which were crucial in our model’s development.

Chapter 4 (SGD Model) describes the SGD Model, a model developed by Rui Prada and extended to include our work. The comprehension of this module is necessary to understand our own, and after its explanation, we explain how this works as a starting point for our own work.

In Chapter 5 (System’s Architecture), we give a conceptual description of our system’s architecture, explaining in detail its modules and introducing all the used concepts and relating them.

We begin Chapter 6 (Implementation) by introducing Power Pentagram, a game we developed exclusively for agents implementing our system to play. This chapter shows how the agents’ architecture (as defined in chapter 5) was implemented, using both Java and Jess. We explain how both these languages were used, why, and how they relate to implement our system.

Chapter 7 (Evaluation) defines the evaluation method used to test our works’ success in the objectives we aimed to achieve. It also presents the results used in the tests executed. The chapter ends with the conclusions taken from those results.

Finally, in Chapter 8 (Conclusion), we recapitulate the work from the initial problem to the proposed solution. After that, we reveal some work left undone, and some possible extensions to our work, which can make it more rich and complete.
Chapter 2

Related Work

In this chapter, we will present a brief state-of-the art, centered mainly on research concerning the modeling of behaviors usually associated with humans, specially the factors influencing the decision process, when applied to agents belonging to a group. We will also introduce research on game theory [8] and decision theory [9], emotional agents [10] and egoistic and altruistic behavior [11] in artificial agents. We tried to include some of the major names and works on the area, also giving importance to more recent works.

The following sections will explain the importance of such areas in our system, presenting related work on each of them and briefly introducing the conclusions of all the works presented, as well as some personal considerations on the strong and weak aspects of those works and an identification of similarities and differences regarding our system.

2.1 Game Theory and Decision Theory

2.1.1 Definitions and Importance for the Thesis

Both Game Theory and Decision Theory techniques have become important in implementing multi-agents’ systems [12].

Decision Theory [12] can be defined as a series of techniques that help to choose between a set of options where uncertainty about the result is present. Game Theory [13] is the area that studies the interactions between agents, defining strategies that can be used to improve the agents’ welfare.

These areas may show useful in our work for they present well defined techniques for agents to deal with multiple options regarding their behavior, with different levels of information. Game Theory and Decision Theory also introduce a formal way to define problems, which may be adapted in the definition of our system.

The decision in these areas, however, is based mainly in the notion of cost and benefit. The agent’s choice of actions is driven in order to minimize cost or increase benefit, not taking into account other factors. In our system we will also take into account the utility of actions, but not only. We will try to take our agents further, modelling other factors of influence, such as the individual personality or social relations.

In this section, we will present two works by Michael Wooldridge and associates, namely on Coalitional Resource Games and Cooperative Boolean Games, focusing on the most important aspects to our system.
2.1.2 Coalitional Resource Game

M. Wooldridge and P. Dunne defined Coalitional Resource Games (CRG) [14] as a type of games where a set of resources is given to participant agents. The agents need to consume such resources in order to achieve goals, with none of the goals being achievable with a zero expenditure of resources. In CRGs, none of the agents holds all the needed resources in the beginning of the game. This fact originates coalition formation, with every coalition having a set of common resources allowing its members to achieve their goals.

The authors stated that Coalitional Resources Games are not simply optimisation problems: agents don’t simply minimize resources, they engage into strategic considerations in order to achieve one of their goals. An agent has to decide which other agents to cooperate with, and in doing so, must consider those agents will also engage in reasoning of the same type.

2.1.3 Cooperative Boolean Games

Following the work on CRGs, Wooldridge et al, defined Cooperative Boolean Games (CBG) [15], a type of games played by agents whose primary goal is defined as a propositional logic formula over some set of Boolean variables. Agents try to achieve this goal manipulating variables under their control, incurring into a cost by doing so. This leads to agent’s secondary goal: minimizing that cost. To achieve this goal, agents form coalitions where the actions needed have a minimum cost, originating strategic behaviour.

The strong point of the project was the definition of a negotiation protocol for any number of agents, characterized by balancing the power given to the proposers and responders. This protocol may be used in applications where agents need to find a way to cooperate that is fair for all, and eventually be adapted to use other factors than only the cost of actions.

2.2 Emotional Agents

2.2.1 Definitions and Importance for the Thesis

As said before, we want agents to have a believable behaviour. They may not be flat, featureless characters. This believability becomes more important since the agents will interact with human users, who should be able to recognize human characteristics on them. One of the ways to aim for believability is to endow agents with emotions [43]: agents need ‘to act and react in a way that resonates in tune with our empathy and understanding of human behaviour’ [2]. Endowing agents with emotions will also make them present a less predictable behaviour, hence improving the experience of the users to whom they interact, especially in computer games.

We will next introduce three research projects where emotional agents are present. In such projects, the importance of emotions in achieving believability was stated [4], together with an example of how do emotions relate with the evolution of relationships between agents [16] and
how do different behaviours emerge from emotions [17]. All these aspects are important in agenis implementing our model, justifying the introduction of these related works.

2.2.2 The Role of Emotions in Believable Agents

Joseph Bates defined a “believable character” as one that provides the illusion of life, allowing the suspension of disbelief [4]. Following this idea, and the belief that the animation artists were who more effectively captured the essence of humanity, Bates et al, working on the Oz Project [44], tried to develop computational models to create believable interactive characters – believable agents.

The Oz project aimed at building a small simulated world containing several real-time, interactive, self-animating creatures, the “Woggles”. These creatures were based on the principles of traditional character animation, especially on those defined by Thomas and Johnston [18]. The Woggles architecture, based on the OCC model [19], uses a minimalist conception of goals to manipulate a dynamically changing set of behaviors, defining a clear emotional state in the creatures.

The work developed still remains up to date. Achieving believability in autonomous agents is very important, especially for agents which interact with users in virtual worlds, mostly in games. Bates’ idea that emotions are an important factor towards believable agents, together with the “inspiration” from character animation in representing such emotions on the agents developed by the Oz Project, make this work an important reference on the autonomous agent's area.

2.2.3 The Evolution of Emotions

On their work “Evolving Emotions with Animate Characters”, Prendiger and Ishizika addressed the problem of creating agents that change their attitudes as consequence of past interactions with other entities [16].

With an architecture based on the OCC model [19], the authors modeled agents whose emotional state varied from happiness over an interlocutor’s actions to a sense of resent, from sorry to gloat. The agent’s emotional state evolves through time, taking into account past interactions. The agent's were also built under the notion of social distance [20] an agent has toward an interlocutor, with the simplifying assumption that once two characters are socially close they cannot get unfamiliar.

Two types of agents were developed: a genie who works as an advisor for a human user in a black jack game, and an angel who interacts with the user, who tries to guess the agent’s wishes. Both agents have different behavior according to user’s actions, attitude and social distance between the agent and the human interlocutor.

As stated before, emotions are an important factor for agents presenting believable behavior. However, as it happens with humans, emotions are not constant: people tend to respond in different ways to the same stimulus, and one of the factors influencing that is the present
emotional state. Hence, in order to approach the agents’ behavior to that visible in humans, it becomes important to create agents whose emotions evolve through time. Prendiger and Ishizika succeeded in creating such agents. Although in two simple scenarios, the characters interacting with human users changed their emotional state and, as a result, their attitudes, becoming more believable to whom interacts with them.

### 2.2.4 Unpredictable Behaviors that Emerge from Emotion and Cognition.

The work of Henninger, Jones and Chow studied the implementation of a framework for modeling emotions in complex, decision-making agents [17]. The aim was to model military-type virtual agents in a battlefield simulation, who could act less predictably and more realistically, by incorporating emotional factors.

The agents were built with two separating components: the Cognitive-symbolic model and the Emotion-connectionist model. The Cognitive model includes the components responsible for the decision making and the emotional appraisal (based around goals, which influence emotions when become achieved, unachievable and likely or unlikely to be achieved). The Emotion-connectionist model works as an input for the Cognitive Model, giving it the agent’s levels of pleasure and pain, used to calculate the level of arousal (figure 2.1). When an agent gets highly aroused, it tends to act more instinctively.

When defining the personality-space, the authors modeled the introversion/extroversion dimension of personality by incorporating a susceptibility to arousal parameter. The neuroticism/stability was modeled using susceptibility to pain, and the explorer/preserver using susceptibility to confusion.

The developed agents were tested in a virtual military scenario, presenting a non-predictable behavior, similar to human behavior.

The work of Henninger, Jones and Chow used emotions to achieve unpredictable behavior. This may be an important aspect when modeling believable agents, for agents who always behave the same way are somehow more “machine-like”. Increasing the unpredictability of agents makes them more believable, hence more interesting to interact to, especially in scenarios like simulations or games.

![Figure 2.1 Block Diagram of Computational Arousal Mechanism](image)
2.3 Egoism/Altruism

2.3.1 Definitions and Importance for the Thesis

As we have seen before, agents often interact with other entities, whether human or synthetic. Under some scenarios, that interaction may be cooperative or competitive [45; 46], or even of both types, being usual for agents to have to decide on cooperating or not with others. One of the aspects influencing this decision is related with egoistic and altruistic levels of agents’ personality.

In a “free adaptation” of psychology’s definition of egoism and altruism, egoistic agents focus their behavior in achieving their own goals, aiming at their own well-being, even if it implies harming others. On the contrary, altruistic agents put the well-being of others (often a group) in front of their own.

We will next introduce three projects where egoistic and altruistic behaviors were modeled in different ways, influencing decisions on different situations. The following works also show the influence of those personality aspects on relations between two agents and in two societies with different complexities.

2.3.2 Altruism/Egoism in the Dictator Game

Alicia Ruvinsky and Michael N. Huns, developed agents who play a two-player game named Dictator [21]. In this game, an amount of resources is given to an agent, which decides the quantity it passes to another agent. After the Dictator game, agents play the Indirect Reciprocity Game, where they swap functions, and the agent who previously received the resources is informed about the percentage he received, and asked to reciprocate.

Both Dictator and Reciprocity games were played by seven types of players: four human, donating privately or publicly, and three autonomous agents, classified according to their behaviour: philanthropic (always donates 50% of its resource), selfish (accepts donations but never donates) and reciprocative (assesses its indebtedness to another agent on its consideration of how much to donate to that agent; periodically contributes to an agent to which it is not indebted).

The results of both games showed that humans tend to act the same way when playing against other humans as they do when playing against autonomous agents. This becomes important especially when we see that, giving the opportunity of reciprocate the opponents behaviour, players tend to benefit those who benefit them, and harm those who are armful. Players also tend to avoid egoistic behaviour, fearing the repercussions. This show useful when modelling the behaviour of agents interacting with egoistic and altruistic entities (whether human or autonomous): when aiming at emulating human behaviour, agent’s behaviour should not only be influenced by their level of egoism/altruism, but also on the perception of other’s behaviour. It should take into accounts both past and future interactions.
2.3.3 Altruism and Egoism Effect on a Society

On the work “The Roosting Effect: Insights from Simulated Vampire Bats” [22], M. Paolucci and R. Conte simulated the formation and maintenance of social structures (roosts) in the vampire bats specie as a way to preserve altruism from cheater’s exploitation. Vampire bats feed on herbivores, with the particularity of being able to regurgitate and share the ingested food with other bats on their roost which couldn’t find victims to parasitize. The decision to help others is based on the time the bats spent together in the past.

On the simulation developed by the authors, the time step represents 24 hours. Agents hunt during the night; with 93% succeeding and 7% beginning to starve (starving two days in a role originates death). During the day, agents do one of three actions: groom (agents are arranged in couples, reinforcing social ties), ask for help (trying to survive when starving, and dying if help is refused) and roost behavior (new roosts are created when reproduction in a roost leads to a threshold number of bats).

After several experiments on the model, the authors noticed that in long term, egoistic behavior doesn’t pay off, because by leading to the extinction of their roosts, egoists will die eventually. Therefore, altruism brings advantages to a society in long term, hence to individuals within that society. Bats don’t have conscience, but more complex individuals, in a more complex society, may have this “long-term factor” into account when choosing between egoistic and altruistic behavior.

2.3.4 Altruism and Egoism on the Vydia Game

On their work “Simulations of Egoistic and Altruistic Behaviors Using the Vydia Multi-agent System Platform” [23], M. Pita and F. Neto studied the impact of egoistic and altruistic behaviors in a virtual society built upon the Vydia game.

The Vydia game is a single (human) player strategy and God-like game. The Vydia’s world is inhabited by several types of virtual animals that compete for the available natural resources. There is, however, a special type of habitants: Jivas, intelligent agents designed to be autonomous, surviving in the environment and using evolutionary computation. The Jiva’s intelligence evolves over time, and they learn from their own experience, evaluating the correctness of their actions at a specific moment. Their main goal is to maximize a gain function: general vital condition, – GVC – their remaining life, energy and hydration.

The society within the Vydia game is structured in three levels: individuals, groups of individuals and the society itself. Individuals try to maximize their gain function, in an environment with limited assets. This originates competition, with two entities trying to get the same asset. One important way to face the competition is organizing into groups of individuals, maximizing the chance of gaining the needed assets. Opposing to competition is cooperation. In cooperation, two or more entities find a way to share the available resources, fitting the needs of all of those
who cooperate. Agents may cooperate within a group, as a strategy to improve their chance of beating competition (another group or individual agents).

The most important factor in the decision a Jiva has to do on whether to compete or cooperate is its level of egoism and altruism. Egoistic Jivas tend to try to maximize their gain function without worrying about others, even when in a group. Altruistic Jivas tend to cooperate with others within a group, aiming at a general well-being.

Egoism and altruism are also important in reputation formation. Jivas maintain a reputation on all other Jivas and groups of Jivas to whom they interact. This reputation may be positive or negative according to the benefits a Jiva obtains by that interaction. It is therefore logic that interacting with an altruistic entity brings more benefits than interacting with an egoistic one. Reputation is also related with clan creation (defining what Jivas to Invite to a clan, or what to answer to invites) and co-action (individual actions motivated by actions performed by agents with greater social prestige). Also, the clan’s leader is always the Jiva with bigger reputation.

Tests with the Vydia game showed that Jivas, with a personality based mainly on the notion of egoism and altruism have an interesting behavior. The formation of a mental model on social reputation allows the agents to aggregate on groups that form a not-so-simple society. Jivas with high reputation are also capable of influencing other Jivas’ behavior, with reputation and group formation being directly linked with egoism and altruism. The work showed the great influence those personality traits have in a society, especially in one where agents have to constantly decide on whether to cooperate or compete, having in mind an individual goal. This notions show useful in our system, for agents will also need to constantly decide on how to behave in a semi-competitive environment.

2.4 Agents as Members of a Group or Society

2.4.1 Definitions and Importance for the Thesis

Wooldridge [2] introduced a slogan in the multiagent systems’ community:

There’s no such thing as a single agent system.

In fact, when reading the research on autonomous agents, it is common to find systems where several agents interact – multiagent systems. It is also common to find agents acting within a group or a society [47], especially in agents designed to emulate the human behaviour. In our work, we model agents interacting with other entities, autonomous or controlled by humans, forming a group. It becomes important, therefore, to study how to model groups of agents, identifying the more important characteristics of such systems and agents.

In this section we will introduce a work by Castelfranchi defining the several elements of social action for autonomous agents [24]. We will also introduce the STEAM architecture [25], by
Tambe et al, implementing some of Castelfranchi’s ideas and designed to allow agent’s teamwork.

### 2.4.2 Social Action for AI Agents

Cristiano Castelfranchi’s “Modelling Social Action for AI Agents” [24] aimed at developing agents based on a synthetic paradigm in AI and Cognitive Science [26], reconciling situatedness (the idea that the development of individual intelligence requires a social and cultural embedding) and plans, reactivity and mental representations, cognition, emergence and self-organization.

In Castelfranchi’s conception, agents’ behaviour should aim at producing some result: a goal. A goal is defined (by Castelfranchi) as a mental representation of a world state or a process responsible for controlling and guiding action, determining the action search and selection and qualifying its success or failure.

Among other definitions, an important notion introduced by Castelfranchi was social goal adoption. In social goal adoption, an agent, named X, comes to have a new goal, or at least new reasons for an already existing goal. This new goal appears motivated by the fact that other agent, Y, wants to achieve this goal. Then, agent X knows this and decides to help/let agent Y achieve it. This way, in social goal adoption, an agent comes to have the same goal than other agent, because it knows the other agent’s goal. At this point matters to differentiate social goal adoption and imitation: in social goal adoption, X has the goal that P (wants P to be true) in order for Y to achieve it. This means X is adopting a goal of Y’s when X wants Y to obtain it as long as X believes that Y wants to achieve that goal. Social goals become of extreme importance in Castelfranchi’s work for he states that they are indispensable for joint actions, group activity, or collaboration, the basis of a society.

Castelfranchi’s work, much more complex than we presented, defined the main elements of a society, adopting them to social actions in agents. A central concept on this work was social goal adoption. In agents whose behaviour is goal-driven, social goal adoption becomes the basis in joint intentions, defining the cooperation and group activities of agents. Other important characteristic of social goal adoption is that with it, not all goals (and intentions) are originated from desires or wishes, but can be received from the outside. An autonomous agent must than decide whether or not to adopt the incoming goals, and that decision is what defines the agent’s behaviour in a group. Social goal adoption, together with some sociological or psychological characteristics, may be adapted to model the decision (or part of it) between two possible goals, in the agents.
2.4.3 The Steam Architecture

Tambe’s STEAM (a Shell for TEAMwork) is an agent’s architecture for teamwork [25]. STEAM was built on the joint intentions theory [27] together with concepts of team synchronization to establish joint intentions, constructs for monitoring and repairing team operators, and decision-theoretic communication selectivity (extending joint intentions’ theory).

On STEAM’s architecture, a team operator instantiates a team’s joint intentions and facilitates reasoning about teamwork. Individual operators express an agent’s own activities. After team synchronization, a team operator can only be terminated by updating team beliefs. If a member of the team has a belief that terminates the team operator, it communicates that belief to the other members.

Other characteristic of STEAM architecture is its ability for monitoring team performance by monitoring conditions to determine achievement, unachievability or irrelevancy of team operators. When an operator becomes unachievable, STEAM allows the repair of the operator, at the same time agents communicate this change between team members. Communication is used for team operator's synchronization and termination, but it is selectively used, since it represents significant overhead in the system, bringing risks to the agents when in hostile environments.

STEAM is one of the references in modeling groups of agents. The last work we presented, by Castelfranchi showed us how social goals originate joint intentions. STEAM, built on the Joint Intention Theory, although with a different theoretical background, implements a system sharing some ideas introduced by Castelfranchi. More than that, team synchronization, monitoring and communication selectivity are also important characteristics of STEAM. The good results in simulating military missions and the RoboCup showed the power of the framework, as well as the possibility using it under different scenarios.

2.5 Agents with Individuality Inside a Group

2.5.1 Definitions and Importance for the Thesis

As showed previously, agents may engage into social relations, often in a group. We presented some works modelling such behaviours. However, in the previous systems, agents follow the group’s objective, without the possibility to choose not to.

In this sub-chapter, we will present agents that, given the possibility to choose between cooperating and competing (regardless of being part of a group or individual members of a society), may decide on how to behave.

We will introduce several examples of systems where agents have decisions to make: compete or cooperate, agree or disagree, follow the leader’s orders or not following them, among others. Although different, what is common in the works we will present (and in some we presented in the previous sections) is the fact that agents actually decide what to do, with each agent having individual goals, and an individual “mind”.

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It is important to study this works because of their relation with ours: in our work, agents also have individual goals and choices to make, according to their personalities and social relations. We will identify what decisions agents make, and what motivates those decisions, trying to find relations among them, and how to relate them with the decisions the agents will have to do.

2.5.2 Collective Multi-Objective Planning

The “Collective Multi-Objective Planning” [28], by Abdel-Illah Mouaddib, addressed the problem of resolving conflicts between individual agent’s interests and the group interests using a Vector-Valued Decentralized Markov Decision Process (2V-DEV-MDP). The MDP uses a value function to return a vector, representing the individual and the group interests.

The system is composed by agents having a set of objectives to attain. Accomplishing them may influence the accomplishment of the objectives of other agents. An agent has a positive effect on the group when it improves the satisfaction of other agents and a negative effect otherwise. Representing this, an agent’s vectors have information on its positive and negative effect on the group, together with its individual satisfaction. Associated to an agent, also exists an operator to compare vectors, allowing it to choose between several decisions.

The authors modeled several types of personalities in agents. An agent is characterized by its level of egotivism, optimism and cooperation. These personality traits influence the way an agent chooses its actions. When the agent is able to balance them, becomes socially satisfied, allowing the agent to solve conflicts between individual and group interests.

The system was tested in a traffic simulation where 16 robots with different personalities in 4 teams need to move to a corner of a square world, starting in the opposing corner. This test showed that the best way to increase performance was to model the robots with a personality balancing all the factors of influence, without extreme values for any of them. The more important aspect of Mouaddib’s work, however, was the fact that it successfully found a way for agents to deal with individual and group goals, according to simple personality traits. Although tested in a simple environment with simple agents, it is possible to adapt to more complex behavior, where agents may choose goals in a way both believable and correct, according to their beliefs.

2.5.3 Trust/Honesty in Semi-Competitive Environments

Ka-man Lam and Ho-fung Leung developed an adaptive trust/honesty model for artificial agents’ interaction within a group [30]. In this system, agents must decide whether or not to trust in other agents in semi-competitive environments as well as on whether or not to lie to other agents. With this model, agents can learn from experience, adapting their behavior to the other players to whom they interact.

The model has three variable parameters: risk attitude (if an agent is more or less willing to take risks of believing in others), stubbornness (measuring the resistance of an agent to other who
tries to persuade it) and sincerity (the tendency for an agent to tell the truth to others). These are the basis of all the agents’ decisions.

In this system, agents trade messages announcing which action they intend to do next, with the option of telling the truth, or a lie. Receivers maintain an impression on each sender based on past history. Senders give a good impression when they tell the truth to receivers, bringing them some kind of benefit. The mean of these individual impressions defines the reputation of a sender, which combined with receiver’s attitude towards risk and its impression on the sender, defines sender’s trustworthiness. The persuasiveness of a message is calculated based on trustworthiness of the sender and the receiver’s risk attitude. A receiver believes a received message if persuasiveness of the message is greater than the receiver agent’s stubbornness. Senders also maintain an impression and reputation on each receiver about ease of being cheated and calculate deceivability of the receiver according to its own risk attitude. A sender lies if temptation of lying is greater than its sincerity, where temptation of lying is calculated from deceivability of the receiver, utility of lying, and sender’s own risk attitude.

In competitive environments, there’s no reason to have a trust-honesty model, since probably all the participating entities would lie. Similarly, in a full-cooperative environment, all entities would tell the truth. In a semi-competitive environment, however, it becomes important for agents to reason about whether or not to tell the truth and whether or not to believe in what others tell them. The work on Lam and Leung successfully defined a way for such reasoning, bringing an important new dimension to agents. We know that in real life, people don’t always tell the truth, and should not trust everybody. Adapting this fact to agent’s behavior, makes them more believable, and at the same time allows them to act less predictably. This may be important when applied to games or to human-life simulations, for example.

### 2.5.4 Competition/Cooperation with the Group’s Leader

Rhalibi, Baker and Merabti addressed the problem of creating realistic portrayals of leadership roles in computer game entertainment [32]. They developed a human-agent architecture based on psychology and using emotions and beliefs representation to drive action selection.

The agent’s mind was based on Maslow’s Hierarchy of Needs [33]. All five level’s of it are considered when selecting an action, starting from the bottom ones, and only climbing the hierarchy when a certain level doesn’t introduce any type of critical observations. The agent’s reasoning model is separated in default agent reasoning and team-based agent reasoning, with both supported by finite-state-machines, each of them responsible for a level of agent’s intelligence. The agent’s emotional state is constituted by four emotions: fear, love/belonging, pride/shame and happiness.

The authors modeled the agent’s interactions from the Iterated Prisoner’s Dilemma [34], adapted to express the individual cooperation/defection of the leader’s order. Generally, cooperation increases the “happiness” of the agent, whether it may decrease the “pride” if the agent is doing something against its own beliefs. Defecting may increase the pride, but
decrease the happiness. Agents apply norms in order to decide whether or not to cooperate, with the agents being punished by violating these norms. With this mechanism, it is possible to make agents that prevent future punishments if they break the norms. Norms provide the mechanism by which team cohesiveness can be improved by a leader and a team can grow into a more united, cooperative whole. Figure 2.2 illustrates the IPD-based team AI design.

Figure 2.2 Simplified Team AI Diagram.

The system proved useful for modeling a team-based agent reasoning and behavior, as tested in executing the game application. For our work’s sake, however, the important point is related with the decision process of agents. In this system, there is a leader who decides the actions for the group. Individual agents, however, only follow that action if it is consistent with their beliefs and emotional state. Even knowing that defecting will result in a punishment, an agent may choose not to "play along", following its own mind. These ideas may easily be adapted to agents having individual goals, having to decide on whether or not to follow a group’s goal, like we can find in our system.

2.6 Comparative Study and Concluding Remarks

When searching systems related to ours, we identified several characteristics which we believe may be important for agents to have. We will introduce such characteristics, explaining each of them individually. We will also introduce a table (table 2.1), comparing the systems we introduced as related work, by identifying which characteristics can be found on which system.

- **Semi-competitive scenarios [SCS]** – Identifies if whether or not the agents act on an environment where they have the option to compete or cooperate with others.
- **Multiple objectives [MO]** – Identifies if agents have more than one objective to consider when making a choice.
Utility influence [UI] – Identifies if agents consider the utility of their actions as a factor when deciding on how to behave.

Use of a personality model [PER] – Identifies if agents have some sort of personality directly influencing their behavior.

Egoism and altruism [EGO] – Identifies if the level of egoism and altruism define agent’s behavior.

Historical influence [HIS] – Identifies if agents consider the history of past interactions with others when deciding future actions. Past interactions may be used to define the agent’s reputation, creating some sort of hierarchy.

Individuality in the group [IND] – Identifies if agents, while in a group, have a “mind” of their own, deciding based on their beliefs, state, personality, etc.

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<thead>
<tr>
<th></th>
<th>SCS</th>
<th>MO</th>
<th>UI</th>
<th>PER</th>
<th>EGO</th>
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<tbody>
<tr>
<td>Coalitional Resource Games</td>
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<td>Cooperative Boolean Games</td>
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<tr>
<td>Emotions in Believable Agents</td>
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<td>Evolution of Emotions</td>
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<td>Unpredictable Emergent Behaviour</td>
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<td>Altruism/Egoism in Dictator Game</td>
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<td>Altruism/Egoism effect on a Society</td>
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<td>Altruism/Egoism on Vydia Game</td>
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<td>Social Action for AI Agents</td>
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<td>X</td>
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<td>STEAM</td>
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<tr>
<td>Collective Multi-Objective Planning</td>
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<td>X</td>
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<td>X</td>
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<tr>
<td>Trust/Honesty in Semi-Competition</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Competition/Cooperation with Leader</td>
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<td>X</td>
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</tbody>
</table>

Table 2.1 A comparison of the presented related work, concerning characteristics we consider to be important in our system.

Although finding several systems which somehow relate with ours, at least in some of their dimensions, we didn’t find any dealing with our problem in the way our work will deal (as may be seen in table 2.1). This justifies the existence of our work, for it would give an important contribution in defining a way for agents to choose whether to act according to what’s better for the group or for themselves.

The other thing we may easily observe is that systems concerned mainly about emotions and systems mainly concerned about social action or teamwork lack most of the identified characteristics. This shows us that we should consider emotions as an important factor to achieve believability, but not as an important factor in modelling the decision process. Similarly,
teamwork and social rules were important to “organize” our agents in the group, and potentiate the group process, but must be combined by a strong individual behaviour, for only agents with individuality will be capable of deciding which goal to pursue in the way we want them to. The works in this section were built under several approaches, which adapted to our system, may show important. More than that, they gave us an important overview of the state-of-the art in the autonomous agents’ research, centred on aspects common with those which will be studied in our work.

Searching works related to ours, encouraged the development of our system. We wanted our agent’s to choose between individual and group goals, taking into account multiple variables, and with a strong personality model attached. This would increase the believability of agents, and (as important) the pleasure users take for interacting with such agents. These objectives, if achieved, would represent an important leap in the area, with direct applications in several systems, mostly in entertainment, specially games and life simulation.
Chapter 3

Psychological and Sociological Background

This chapter introduces the theoretic basis for the agents’ psychological and sociological dimensions. Far from being an extended study, we will explain a personality model (the Five Factor Model [30]), the definition of Egoism [5] and its relation with the Five Factor Model, and the definition of Self-Esteem [36], and what are the factors influencing it. Regarding Sociology, we will define the notion of Social Group [1], and its process, structure, and interactions that occur in that group.

We will also explain what motivates Interpersonal Attraction [49] and Influence [51], and the Attraction [52] and Influence [53] somebody feels for the group it is inserted in.

3.1 The Individual

3.1.1 Five Factor Model

Trait personality is nowadays the dominant paradigm in personality psychology. The Five Factor Model of personality (FFM) is widely accepted as a taxonomy of personality traits. As the name indicates, the FFM represents personality using five traits: Neuroticism, Extraversion, Openness to Experience, Agreeableness and Conscientiousness, defined as follows:

- **Neuroticism**: Neuroticism can be defined as a tendency for psychological distress, unrealistic ideas, and the tendency to feel negative emotional states. Individuals with a high neuroticism tend to worry a lot, be temperamental, nervous, anxious, temperamental, hostile or depressive. Opposing to Neuroticism, we consider Emotional Stability.

- **Extraversion**: Opposing to Introversion, Extraversion is characterized by positive emotions, impulsivity, sociability and assertiveness. Extraverted individuals tend to be active, talkative, fun-loving, passionate, affectionate and joiners.

- **Openness to Experience**: A person scoring high on this trait tends to present intellectual curiosity, be very imaginative, enjoy new experiences, be creative, liberal and prefer variety. Low scores on this trait reflect in an uncreative behavior, preferring routine, being conventional and uncurious, as well as conservative.

- **Agreeableness**: Agreeableness is the tendency one has to be pleasant, trustful, compassionate and cooperative towards others in a social situation. Agreeable persons tend to be soffhearted, trusting, generous and good-natured.
- **Conscientiousness**: This personality trait is related with impulse control. Conscientious people tend to be hard workers, well-organized, punctual, ambitious and persevering. Low scorers on this trait tend to act negligently, to be lazy, disorganized, late, aimless and quitting.

### 3.1.2 Egoistic Behavior

The common-sense definition of egoists represents individuals who concern more about themselves than others, opposing to altruists, who sacrifice for the well being of others. This type of people is usually characterized as somebody who puts their own goods, interests or concerns above that of others. There are, however, several definitions for egoism, according to area of research. We will introduce three of such definitions.

**Psychological Egoism** [54] states that humans are always motivated by self-interest, not only when they worry about their own good (even if it means harming others) but also when they aim at benefiting others in ways costly to oneself. This means that, as an example, giving money to charity, is still motivated by self-benefits one may achieve by helping others.

**Ethical Egoism** [55] states that a person should do what is best for him/her. There are two definitions for ethical egoism: the strong definition states that it is always ethical (moral, praiseworthy, virtuous) to aim at own greatest good, and never right, etc. not to do so. The weak definition states that it is always ethical to aim at owns greatest good, but not necessarily never right not to do so.

Related to Ethical Egoism, **Rational Egoism** [56] states that it is always rational to follow own interest. Rational Egoism also comes in two versions: the strong definition of Rational Egoism states that it is never rational not to follow own interest, while the weak definition states that not doing it isn’t necessarily not rational. Rational Egoism is very plausible: when we do something against our interest, we must justify it to ourselves. When finding that justification, we show it is somehow of our interest after all.

D. Paulhus and O. John related egoistic and altruistic bias with the Five Factor Model of personality [35]. The authors used the notions of alpha and gamma personality constellations, with which it was possible to relate the existence of an egoistic bias with high levels of openness and extraversion on the Five Factor Model. Moralistic bias, opposite to egoistic bias (the same way as altruism is sometimes introduced as the contrary to egoism), is related with high levels of agreeableness and conscientiousness.
3.1.3 Self-Esteem

In psychology, Self-Esteem reflects the individual’s sense of his own worth, or how much a person likes himself. It may refer to how one thinks and feels about the way one looks, our abilities, our relationships with others and our hopes for the future. People scoring high in Self-Esteem will have confidence to make their own decisions, without needing the approval of others. This was showed, for instance, by M. Leary, G. MacDonald and J. Tangney [41], who stated that individuals with higher Self-Esteem tend to resist to factors of influence, feeling free to be themselves.

The work of Robin et al. studied the relation between the Five Factor theory and the Self-Esteem [34], showing that the Five Factor accounted for 34% of the variance in Self-Esteem. The authors proved the correlation between all five factors and Self-Esteem, especially in neuroticism, extraversion and consciousness.

But Self-Esteem is related to other factors. Rosenberg and Pearlin [57] related Self-Esteem with social class. Coopersmith related Self-Esteem in children with their parents’ acceptance and respect for actions [58]. Richman, Clark and Brown related gender, race and social class and Self-Esteem [59]. Gecas and Seff studied the relation with occupational prestige, education, income and Self-Esteem [60].

Resuming, we can state that Self-Esteem is influenced by both the people’s personality, and external factors. When studying external factors, one can conclude people tend to evaluate themselves by other people’s standards. Besides, Self-Esteem is related by the degree one is valued and accepted by other people. Self-Esteem is lowered by failure, criticism or rejection.

3.2 The Group

3.2.1 Definition

A social group [1] can be defined by two or more people who interact, and somehow identify with one another. As members of a group, and aware of it, individuals share experiences, loyalties, expectations, obligations, objectives or interests with other members. But not every set of individuals automatically forms a group: men, students, politicians, immigrants, though aware of others sharing the same status as themselves, have no relation whatsoever with them. Therefore, we may say that all of the above can be defined as categories [1].

We can define two types of groups depending on their members’ concern for others: primary and secondary. A primary group is usually smaller, with members who share long and personal relationships. Individuals within an individual group tend to have concerns for other members of the group, thinking about the group as an end in itself rather than a means to some goal. A secondary group, in contrast, is defined as a large and impersonal social group whose members pursue a specific goal or activity. When in such groups, individuals are weakly tied and have little knowledge of others. Such groups are usually short-term, but with time, may evolve into a primary group. Secondary groups have a goal orientation, and its members tend to
keep a score about what they have done for others, and what others have done for them. The following table summarizes the main characteristics of both group types.

<table>
<thead>
<tr>
<th>Primary Group</th>
<th>Secondary Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of relationships</td>
<td>Personal orientation</td>
</tr>
<tr>
<td>Duration of relationships</td>
<td>Usually long-term</td>
</tr>
<tr>
<td>Breadth of relationships</td>
<td>Broad; usually involving many activities</td>
</tr>
<tr>
<td>Perception of relationships</td>
<td>Ends in themselves</td>
</tr>
<tr>
<td>Examples</td>
<td>Families, circles of friends</td>
</tr>
<tr>
<td></td>
<td>Co-workers, political organizations</td>
</tr>
</tbody>
</table>

Table 3.1 A comparison between primary and secondary groups.

**Composition**

One important factor in group’s behavior is its composition. Group’s composition is defined by variables such as age, race, and number of elements, among others. We will explain different groups’ compositions according to different group sizes.

Size is an important factor when defining how group members interact. This is related with the number of relationships according to the number of members in the group. For instance, a group with two members (defined by Georg Simmel as a dyad) has only one relationship [61]. The relationship in a dyad is stronger than in larger groups, for none of its members shares the other’s attention with anyone else. However, with only two members, if the relationship ends the group collapses.

Simmel also studied the triad, a group with three elements and three relationships. This group is more stable than the dyad because a member can mediate a relation between the other two members. In a triad, however, two members can pair up to press their views on the third, or intensify their relation, leaving the other feeling left out.

As groups increase their dimension, become more stable and capable of withstanding the loss of members, but reduce the intensity of personal interactions. This is why larger groups are based less on personal attachment and more on formal rules and regulations.

**Structure**

Besides group’s composition, group’s structure also influences the way the group interacts. Jesuíno [39] defined group structure in terms of the following dimensions:

- **Structure of communication**: reflects the network of communication which the group uses to interact. It is somehow related with the size of the group, as previously explained.
- **Structure of social power**: reflects the relations of social influence that members exert on each other. We will explain social influence better in the next section.
- **Structure of social attraction**: reflects the relations of social attraction among members of the group. Again, this will be explained in more detail later.

Collin and Raven [62] characterized the group’s structure of social power and structure of social attraction in terms of individual relations of the group’s members. This way, in order to understand the group’s dynamics, it is important to understand the dynamics of interpersonal relations.

### 3.2.2 Influence and Attraction

As we said before, the relations of social attraction and social influence (social power) are very important in the definition of group dynamics. Group dynamics emerges from individual dynamics of its members, and social attraction and social influence among the group members define the structure of social power and social attraction within the group. However, an individual may be attracted not only by other individuals in the group, but by the group itself. In this section we will define in more detail the relations of influence and attraction.

#### 3.2.2.1 Interpersonal Influence

Raven and French [50] were the authors of one of the most important theories of Social Power. According to these authors, Social Power is the influence exerted by a social agent on a person. Furthermore, they stated that in order to fully understand Social Power, one must study both the person who is using the power and the person who is being influenced, defining the power a person A exerts on a person B as:

\[
\text{Power of A over B} = \text{Maximum force A can exert on B} - \text{Maximum resistance B can offer against A}
\]

Raven and French defined the power according to its source and the relationship between the person and the social agent, characterizing it in the following six categories:

- **Reward Power**: Occurs when a person is able to influence other by giving him positive outcome. An example of reward power occurs when a boss increases an employee’s salary.
- **Coercive Power**: Occurs when a person is able to punish other by giving him negative outcome. In the previous example, we may say the boss is exerting coercive power when he reduces an employee’s salary everytime the employee disagrees with him.
- **Legitimate Power**: This power is invested in a role, and is based on the perception someone has about the behaviors associated with that role, being sometimes
associated with organizational authority. Examples of legitimate power holders are policeman, kings, and managers.

- **Referent Power:** This type of power is associated with someone a person likes, or would like to resemble. An example of referent power is that held by big celebrities, or local social leaders. One can also exert social power on somebody to whom he is in a relationship.

- **Expert Power:** Power related with the knowledge and skill one possesses and other person needs. As an example, a web developer has expert power over a shop owner who wants a website for his shop.

- **Information Power:** The power a person has of influencing others by providing information and convincing them that their beliefs are accurate.

A person may exert more than one type of power at the same time. For example, a development team leader may exert expert power if he is recognized as the more experienced programmer, and at the same time exert coercive power if he is the one responsible for firing the less productive coworkers.

Power isn’t, as we stated before, dependent only on the person who exerts it. This way, the power someone exerts may be motivated by the one in which the power is being exerted. As an example, a younger programmer in the development team may agree with the team leader fearing to be fired, even if the team leader is the more sympathetic person in the world, and never fired anyone. This is a case of coercive power, nevertheless.

Studies relating social power and group’s dynamics showed that the behavior of a group’s member is influenced by his/hers social power. A group’s member with high social power is usually more appreciated by other members in the group, while a member with low social power tends to be underestimated by others.

### 3.2.2.2 Interpersonal Attraction

Social Attraction [49] defines the relation between two individuals in terms of likes and dislikes. This defines the affective ties between individuals, and can be either positive or negative. Interpersonal Attraction may be caused by several factors [63]. Next, we will introduce some of them:

- **Physical attractiveness:** The recognition of physical traits which are aesthetically pleasant in a person to whom somebody interacts. It is dependent on universal perceptions, on cultural and social perceptions, and on individual preferences.

- **Propinquity:** Another factor causing interpersonal attraction is propinquity. Propinquity is defined as psychological or physical proximity between two individuals.

- **Intimacy:** Intimacy is defined as the feeling of being in a close relationship, where the participants know or trust one another very well, or are confidants of one another.
- **Similarity**: Similarity between two individuals occurs when they tend to have the same mental representations, meaning they tend to resemble in the meaning of several concepts.

- **Complementarily**: Complementarily is somehow related with the popular notion that “opposites attract”. It can be defined by the fact that a person tends to be attracted by someone with different characteristics, complementing its own.

- **Reciprocal Liking**: Reciprocal liking happens when a person likes other by feeling other person likes him. Reciprocity isn’t always true, but it is often a reality.

- **Reinforcement**: The relation of reinforcement and attraction is linked with conditioning. A person tends to be attracted to other when interactions tend to result in some enjoyment or satisfaction.

Related with social attraction is Heider’s Balance Theory [64]. Balance Theory is a framework used to study the evolution on relations of attraction, until a balanced state is achieved. This is related with the fact that relations in a group tend to be balanced, for people need to have balanced cognitive configurations.

In balance theory, relations are categorized in two: positive or like, and negative or dislike. This theory is built on the concept of a POX triple, with P as a person, O another social actor, and X an object (such as another person, a physical object, an idea or an event). The triple represents a cognitive representation held by P, relating P’s attitude towards O and X, and P’s beliefs over O’s attitude towards X. The following figure shows a graphical representation of a POX triple configuration:

![Figure 3.1 A graphical representation of a POX triple configuration.](image)

According to relations of liking or disliking, a POX configuration can be either balanced or unbalanced. The balanced configurations are as follows:

- P “likes” O, P “likes” X, O “likes” X
- P “dislikes” O, P “dislikes” X, O “likes” X
- P “dislikes” O, P “likes” X, O “dislikes” X
- P “likes” O, P “dislikes” X, O “dislikes” X
- The unbalanced configurations are:
  - P “likes” O, P “dislikes” X, O “likes” X
  - P “likes” O, P “likes” X, O “dislikes” X
  - P “dislikes” O, P “likes” X, O “likes” X
  - P “dislikes” O, P “dislikes” X, O “dislikes” X
Or, as Heider resumed it:

\[
\begin{align*}
\text{my friend's friend is my friend} \\
\text{my friend's enemy is my enemy} \\
\text{my enemy's friend is my enemy} \\
\text{my enemy's enemy is my friend}
\end{align*}
\]

There could be the case that a stable configuration becomes unstable. As an example, we can consider the initial situation where P “likes” O and X, and believes O “likes” X. At a certain time, P comes to believe O “dislikes” X, in an unstable configuration, creating some tension in P, who will try to recover the balance. In order to do that, Heider’s model says that P may either develop a dislike for O, or a dislike for X, achieving a new balance. P may also influence O to change his/her attitude towards X, but this situation is more uncommon because it demands more of P’s efforts, and sometimes is impossible.

A usual relation in the area of Sociology is established between interpersonal attraction and friendship [65], mostly because some of the factors causing interpersonal attraction are also considered causers of friendship. Although being a somehow subjective concept, and by analyzing people’s answers, Michael Argyle [66] defined “friends” as individuals “who are liked, whose company is enjoyed, who share interests and activities, who are helpful and understanding, who can be trusted, with whom one feels comfortable, and who will be emotionally supportive”. This definition may vary according to gender, social class, among other variables, once its subjectivity.

### 3.2.2.3 Group Influence

Besides individual influence, a person, as a member of a group, may also be influenced by the group itself. Related with influence is conformity. Asch’s [40] showed how individuals tend to conform to the majority, when in a group. His experiments showed how a person, while in a group, is willing to compromise his/her own judgment to avoid the discomfort of being different, even from people they don’t know.

There are several factors influencing conformity [48]: a person with higher status is usually more willing to deviate from group norms. The number of individuals in the group also affects conformity: conformity increases with number of individuals, but levels off between 4 to 6 people. Having an ally in a group also influences conformity: without an ally in the group, a person tends to conform more. Another conformity influencer is related with the confidence one has in the group or the self: more self-confidence leads to less conformity, and more group confidence leads to more conformity. A more cohesive group tends to have individuals who conform more. If an individual is previously committed to a personal belief which differs from group belief, he/she conforms less. The conformity also increases with increasing task difficulty. Other factors, such as gender or culture, also influence conformity.
Milgram [67], a former student of Asch’s, showed that a person in a group tends to follow the lead of both authoritative figures and ordinary individuals, even if it means harming another person.

Janis [68] introduced the notion of groupthink, “the tendency of group members to conform, resulting in a narrow view of some issue”. Groupthinking manifests when members of a group try to minimize conflict and reach consensus without analyzing or evaluating ideas in detail. During groupthink, members of a group avoid promoting individual non-consensual viewpoints, increasing cohesiveness, but minimizing individual creativity, uniqueness and independent thinking.

### 3.2.2.4 Group Attraction

We can define group cohesiveness as the forces acting together to keep group members united, and engaged to the group. The term encompasses such ideas as “group pride”, “group solidarity”, “group loyalty”, “team spirit” and “teamwork”. Cartwright and Zander [69] defined group cohesiveness as “attraction to the group, including resistance to leaving it”; “morale, or the level of motivation of the members to attack their tasks with zeal” and “coordination of the efforts of members”. Looking at such definition, we can define group cohesiveness according to two dimensions: emotional (the connection that members feel to other members and to the group as a whole) and task-related (the sharing of goals by the members of the group, and the ability to work together to achieve such goals).

Festinger [70] stated that there are three factors defining group cohesiveness: the interpersonal attraction between the members of the group, liking (or committing) to the group’s task or goal, and the group’s prestige or pride. These represent attitudes towards group members and the group itself. Later, Hogg [71] noted that interpersonal attraction and depersonalized attraction exert unique effects in group cohesiveness: interpersonal attraction reflects attractions between individual group members that are based upon their respective, individualization characteristics. Depersonalized attraction occurs because they simply belong to or represent the group. Turner et al [72] related group membership’s rewards and cohesiveness. Their studies stated that cohesiveness increases to the extent that group membership is rewarding. Failure, defeat or other costs associated with group membership should decrease group cohesion. Turner et al, however, hypothesized that both success and failure can increase cohesion, for when individuals feel personally responsible for acting as group members, failure will produce more cohesiveness than success.

Cohesiveness increases motivation among group members, facilitating task persistence and task performance. It also decreases social loafing, which may be related with a cooperative interaction style. Johnson and Johnson [73] studied the influence of group cohesion among students, which motivates decreased absenteeism, lower dropout rates, increased commitment to educational goals and increased persistence toward educational goal achievement. Mullen and Copper reported that the commitment to task component of cohesiveness increases the quantity of group performance [74]. Spink and Carron, however, suggest that task oriented
cohesion increases performance under some conditions, whereas social cohesion increases performance under other conditions [75]. Nemeth and Staw [76] stated that a cohesive group is more likely to accept the group’s goal, while a cohesive group without good performance norms might be highly resistant to change.
Chapter 4

SGD Model

SGD Model, developed by Rui Prada et al, was built to model autonomous agents' behavior in a small group, where they may interact with a human user to accomplish some task. The model aimed at achieving believable behavior, creating characters whose actions are based on psychological and sociological factors, and acting together to achieve a common goal. SGD Model, therefore, merges tools to model teamwork with a way to allow social interactions and psychological elements in the definition of agents.

4.1 SGD’s System Overview

The SGD model [7] (figure 4.1) was built on the idea that an agent must be aware of other agents in the group and the group itself, at the same time that should be able to build an internal social model of the group. The model influences perception, knowledge, behavior and action of the agents, making them susceptible to being influenced by the group to which they belong. While interacting within the group, agents are also able to influence the group as an entity.

Figure 4.1 The SGD Model in the mind of each member of the group.

SGD Model defines the behavior of the agents, influencing their cognitive process. Figure 4.2 shows the agent’s behavioral cycle.

The knowledge the agent has, is maintained in the Knowledge Base, where the agents keep information about the individuals in the group, the relations between them, the group itself, the possible goals at a given moment, and about the interactions that may occur. This knowledge is used as an input for the agent’s motivational system, originating updates, or being read when motivational system updates automatically in its update cycle.
When an agent is motivated to act, the following module – behavior generation - decides how to do it: in a rational manner, usually associated with instrumental actions in an attempt to reach a goal, or in a reactive manner, usually engaging in some sort of socio-emotional interaction.

![Behavioral Cycle for Agents Using SGD Model](image)

Agents have the ability to “see” and classify the interactions occurring in the group. The identification of the interactions’ category is the first module allowing the agents to deal with information coming from their sensors. This module also takes into account the context to define how the actions of the group should be interpreted (for example, by means of social norms). After identifying the interactions, the effects are propagated in the knowledge base, updating the information it keeps. For example, the interaction may change the social relations established between the members that engage on it. The internal representation of social relations will be explained when we explain the knowledge base.

The model’s Knowledge base, as figure 4.2 shows, contains four different levels, explained next.

### 4.2.1 The Individual Level

The individual level holds information about the set of abilities all agents in the group have individually, as well as the definition of agents’ personality.

- **Agent's Abilities**: Define the agent's levels of expertise, which define what actions agents can execute in the environment. Agent’s level of expertise is used to define the agents' position in the group.
- **Agent's Personality**: Defines the internal representation of all five factors of personality for the five factor model. The agent's personality influences the agent’s behavior.
An agent is defined in a logical knowledge base as a predicate represented in expression 4.1. The agent’s personality factors are represented by predicates 4.2 through 4.6 and the agent’s abilities are represented by predicate 4.7.

\[
\begin{align*}
\text{Agent}&(\text{agentName}) & \text{(4.1)} \\
\text{Openness}&(\text{agentName}) & \text{(4.2)} \\
\text{Conscientiousness}&(\text{agentName}) & \text{(4.3)} \\
\text{Extraversion}&(\text{agentName}) & \text{(4.4)} \\
\text{Agreeableness}&(\text{agentName}) & \text{(4.5)} \\
\text{Neuroticism}&(\text{agentName}) & \text{(4.6)} \\
\text{Skill}&(\text{agentName}, \text{skillName}) & \text{(4.7)}
\end{align*}
\]

### 4.2.2 The Group Level

This level keeps the knowledge an agent builds regarding the group to which it belongs. The agent has information about the group’s identity, the group’s structure, and the agents’ attitudes towards that group.

- **Group’s Identity** – The group’s unique name, allowing the agent to identify it and refer to it.
- **Group’s Composition** – The set of agents that belong to the group.
- **Group’s Structure** - The information about the group’s structure of power, emerging from agents’ social influence, and structure of attraction, emerging from agents’ social attraction relations. The group’s structure of power and attraction are used to calculate the group’s hierarchy.

A group is represented by predicate 4.8 in the knowledge base. Identity defines the symbolic name for the group and agents define a set with the names of the agents that belong to the group.

\[
\text{Group}(\text{identity}, \text{members}) \quad \text{(4.8)}
\]

As stated before, the group’s structure emerges from social relations, namely relations of attraction and influence. We can define those relations as follows:

- **Social attraction**: The relations of interpersonal attraction represent the attraction agents feel for others, in terms of likes and dislikes. These relations are unidirectional.
- **Social influence**: These relations represent the influence one agent exerts over other, derived from the agents’ expertise level. These relations define the capacity of an agent
to influence others’ behavior. Influence is defined as the difference between the influencer’s social influence and the influenced agent’s ability to resist.

These relations are defined in the knowledge base by functions following definitions 4.9 and 4.10.

\[
\text{SocialInfluence}(\text{source}, \text{target}, S) \quad (4.9) \\
\text{SocialAttraction}(\text{source}, \text{target}, S) \quad (4.10)
\]

Social relations are defined relating one agent – source – to another – target, and are assessed by a value which can be positive, zero (neutral relation) or negative. The situation \( S \) determines the social relations at a given time, for they can change during the group’s process. Together with the agents’ levels of expertise, the agents’ social relations define the agents’ position in the group’s hierarchy. This position defines the importance of the agent’s contributions in the group, and how well they are accepted by other members. The agent’s position may be calculated using formula 4.11.

\[
\forall G, A(\text{Group}(G, \text{members}) \land \text{Agent}(A) \land A \in \text{members}) \rightarrow \\
\quad (\text{Position}(A,G,S) = \sum \text{SocialAttraction}(m,A,S) + \sum \text{SocialInfluence}(A,m,S))
\]

\[ (4.11) \]

### 4.2.3 The Interactions Level

In this level, the agent keeps information about the interactions that occur in the group, including their classification according to their class, and their dynamics. An interaction is an action or pattern of actions that can be classified and perceived by other agents in the group. Agents may support an interaction even if not directly involved in its execution. Also, an interaction has an associated strength, defining its importance in the group, and a target agent or agents, which are affected by it.

To summarize, we may define an interaction as follows:

- An action or pattern of actions, defining the type of interactions
- The performers, defining the agents that execute the interaction
- The supporters, defining the agents that support the interaction, without being directly involved
- The targets, defining the agents that are affected by the interaction
- The strength in the group, defining the importance of the interaction in the group

An interaction is represented by predicate 4.13 and functions 4.14, 4.15 and 4.16 represent the interaction’s performers, supporters and targets. An interaction’s strength is computed using the formula in 4.17, and is directly related with the performers and supporters’ group position.
To model group’s process’ dynamics, interactions fall into different categories. The agent acquires the knowledge to categorize interactions a priori, and this allows it to process the perception and identification of interactions when new interaction facts are asserted in the knowledge base.

It matters to state that classification of interactions, based on Bales IPA system [77], is more than just categorization, for it takes into account actions’ results, the context of the execution and the agents’ perception of the group. Interactions are classified as instrumental or socio-emotional and positive or negative (figure 4.3) as we will explain next.

$\forall G, A \ (\text{Group}(G, \text{members}) \land \text{Agent}(A) \land A \in \text{members}) \rightarrow$

$(\text{Strength}(I, G, S) = \sum_{p \in \text{Performers}(I)} \text{Position}(p, G, S) + \sum_{s \in \text{Supporters}(I)} \frac{\text{Position}(s, G, S)}{2})$

(4.17)

Positive socio-emotional interactions:

- **Agree**: These interactions occur when an agent supports or agrees with another agent’s interactions, raising the importance of that interaction in the group.
- **Encourage**: Represents agent’s efforts to encourage another agent.
Negative socio-emotional interactions:

- **Disagree:** When an agent disagrees with other, it is showing its disagreement towards other’s interaction, decreasing its importance in the group.
- **Discourage:** Discourage interactions represent an agent’s hostility towards another agent.

Positive instrumental interactions:

- **Facilitate Problem:** These types of interactions represent the actions of an agent trying to solve a group’s task or facilitate its resolution.
- **Gain Competence:** These interactions, occurring for example when an agent learns new capabilities or acquires information, make an agent more capable of solving a problem.

Negative instrumental interactions:

- **Obstruct Problem:** An interaction falling under this classification represents the attempt of an agent to complicate one of the group’s problems or make its resolution impossible.
- **Lose Competence:** These interactions represent a decrement in agent’s ability to solve a problem, for instance losing control of resources or forgetting information.

Predicates 4.18 to 4.21 represent the described interaction’s types as they appear in the knowledge base. This way, 4.18 represents an instrumental interaction while 4.19 represents a socio-emotional interaction. Predicates 4.20 and 4.21 represent a positive or negative interaction, respectively.

\[
\begin{align*}
    \text{Instrumental(I)} & \quad (4.18) \\
    \text{SocioEmotional(I)} & \quad (4.19) \\
    \text{Positive(I)} & \quad (4.20) \\
    \text{Negative(I)} & \quad (4.21)
\end{align*}
\]

In SGD Model, the dynamics created by interactions are supported by the classification presented in Section 4.5.1 and modeled by a set of rules consistent with French and Raven’s theory of social power [50] and Heider’s Balance theory [64]. In SGD model the agent’s and group’s state influence the interactions, and each type of interaction influence the agent’s and group’s state.

### 4.2.4 The Context Level

When defining the interactions that occur within a group, together with the individual and group characteristics, there are other variables which may influence those interactions. The context level is responsible for keeping information about such variables.
The context level includes factors associated with the nature of the task and the environment where it will be performed. It may also include information about inter-group relations, as well as cultural aspects and social norms, which may influence the agent’s behavior.

### 4.2 SGD’s Motivational System

SGD Model contains a motivational system, supporting agents’ decision making. We can define a motivation by a tuple (4.22) where $G$ represents the goal associated with the motivation; $Pv$ is the motivations’ component derived from internal stimulus (proactive component) and $Rv$ is the motivations’ component derived from external stimulus (reactive component), $Th$ is the threshold to activate the motivation and $Update()$ is a function to regulate the motivation’s value.

$$m = < G, Pv, Rv, Th, Update() > \quad (4.22)$$

As already stated, a motivation has two components: a proactive and a reactive one, related to the origin of such motivations. The proactive motivation comes from internal factors motivating the agent to act in a certain way. The reactive motivation is linked to external factors. The sum of both components represents the overall value for the motivation, which becomes active when it reaches the threshold $Th$. The motivation values ($Pv$ and $Rv$) vary from 0 to 100.

The $Update()$ function is called on regular intervals and updates the values for both motivational components. However, such values may also change by other events, like in response to some outer stimulus.

SGD Model was built on the idea that both socio-emotional and task-related interactions are important to generate believable behavior, having motivations for both of these interactions’ types.

Instrumental motivations can be related to the group’s goals or to individual goals an agent may have. 4.23 defines the individual task’s motivation, where $IG$ is one of the agent’s individual goals. 4.24 defines the group task’s motivation, with $TG$ representing one of the group’s goals.

$$m_{I\text{Task}} = < IG, Pv, Rv, Th, Update() > \quad (4.23)$$
$$m_{G\text{Task}} = < TG, Pv, Rv, Th, Update() > \quad (4.24)$$

Socio-emotional motivations (4.25 and 4.26) are related with the goals of encouraging or discouraging other agents in the team and lead to socio-emotional interactions. In 4.25, $Encourage(Ag)$ represents the agents’ goal to encourage another agent, $Ag$. Similarly, $Discourage(Ag)$ represents the agents’ goal to encourage another agent $Ag$.

$$m_{Enc} = < Encourage(Ag), Pv, Rv, Th, Update() > \quad (4.25)$$
$$m_{Disc} = < Discourage(Ag), Pv, Rv, Th, Update() > \quad (4.26)$$
The agent keeps different instrumental motivations for each goal (individual and team) and two socio-emotional motivations \((m_{Enc} \text{ and } m_{Disc})\) for each member of the team.

### 4.3 Behavior Generation

The `Update()` function controls changes in motivations’ values which occur over time and with specific events. Specifically, reactive components of motivations decay over time and proactive components increase.

In addition, motivations’ values may change as a response to the occurrence of certain events. For example, when a goal is achieved, the motivations to achieve that goal are reset to the neutral state \((Rv = 0 \text{ and } Pv = 0)\). Note that motivations may increase by different reasons and are only reset when the agent successfully reaches its goals. This means agents are persistent in their goals. Other factors related with motivation’s dynamics are explained in the following section.

As we said before, an agent is motivated to act when the sum of the reactive and pro-active components of its motivations reach the associated threshold. The following algorithm shows the process on which the agent compares its motivations to the corresponding threshold, and the actions taken when the threshold is reached.

```plaintext
While TRUE
  For all motivations
    If the sum of reactive and pro-active components of motivation is higher than the corresponding threshold
      Motivation’s goal is active
        Update Motivation
        Decides how to act to achieve the active goals
        Executes action
    If the objective was achieved, restarts the values for the motivation.
```

The algorithm shows how a goal becomes active, and that agents act to achieve active goals. Before really acting to a goal, the agents need to decide how to do it. An agent can act in a planned way or in a reactive way, depending on the type of goal. The sub-modules Planned Acting and Reactive Acting are responsible for the different types of actions.

Reactive Acting is responsible for controlling the agent’s actions related with socio-emotional interactions. When an agent is motivated to encourage or discourage other, it simply engages in the corresponding interaction, without any type of previous planning.

Planned Acting controls agents actions related with the individual or group goals. Before acting towards one of those goals, an agent makes a plan involving one or more actions which will allow it to reach its goal.
After choosing the needed actions to pursue a goal, the agent’s effectors are responsible for actually executing those actions. The action execution is dependent on the context, and is not part of SGD Model’s scope.

### 4.4 SGD’s Dynamics

In the SGD Model, the behavior of the agents is expressed in terms of the interactions they engage in the team. This reflects the dynamics of the motivational system. After the occurrence of an interaction, the social relations of the agents change, and so do the positions in the group. This way, to understand SGD Model’s dynamics one must understand the dynamics of the motivational system and the dynamics of the positions in the group.

#### 4.4.1 Motivation Dynamics

The frequency of an interaction is dependent on the agents’ positions in the group. Agents with better position interact more often, for their Update() function applies a higher increment to the proactive value ($Pv$) of the instrumental motivations and to the reactive value ($Rv$) of all motivations.

Agents with better positions in the group are also targeted more often with positive socio-emotional interactions and agents with lower positions in the group are targeted more often with negative socio-emotional interactions. This is explained by the way the reactive values ($Rv$) of the motivations $M_{Enc}$ and $M_{Disc}$ are incremented in response to certain events, as explained next:

- **Instrumental Interactions:** When a Facilitate Problem occurs, the $Rv$ of the $M_{Enc}$ increases. In the case of an Obstruct Problem the $Rv$ of both $M_{Enc}$ and $M_{Disc}$ increase. These increments are dependent on the difference between the positions in the group of the performer and the observer. For example, if observer has a better position in the group than the performer, the increment to the $M_{Disc}$ will be higher than the increment to the $M_{Enc}$.

- **Socio-emotional Interactions:** In this case, a general rule of reciprocity is applied. Therefore, if an agent is the target of an Encourage interaction the motivation to encourage back the performers increases (i.e. the $Rv$ of the $M_{Enc}$ increases) but if it is the target of a Discourage, the motivation to discourage the performers increases. In addition, agents react to socio-emotional interactions even if they are not directly targeted. This follows the ideas proposed in Heider’s Balance Theory. Agents check their relations of social attraction with the target of the interaction and react to the performer of the interaction accordingly. If the valence of the social relation and the interaction are similar (either positive or negative) than the motivation to encourage the performer will increase. If valences are opposite (the agent likes the target and the performer discourages it), the motivation to discourage the performer will increase.
The increments of $M_{Enc}$ and $M_{Disc}$ are also related with the social relations between the agent and the performer of the interaction. Agents encourage more often other agents they like 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. Finally, Encourage interactions have the secondary effect to increase the target’s $Rv$ for the $M_{GTask}$. Conversely, Discourage interactions increase the target’s $Rv$ for the $M_{ITask}$. The $Pv$ of $M_{Enc}$ may be increased if the agent’s planning process decides that a given member of the team needs an encouragement. This occurs if the agent reaches the conclusion that the best action for the team has to be performed by the other member.

4.4.2 Group Position’s Dynamics

When interactions occur, social relations in the group may change, and so do the agents’ positions. Instrumental interactions are related with relations of social influence. Positive instrumental interactions increase their performer’s social influence over the other members of the group, by means of expert and information power. Any member that demonstrates expertise to achieve one of the team’s goals or obtains resources that are useful to the team will gain influence over the others. In turn, negative instrumental interactions make the agents lose influence. Socio-emotional interactions are related with relations of social attraction, following similar rules as used in the increments of the reactive values of the motivations (reciprocity and balance). Reciprocity means that agents targeted by positive socio-emotional interactions increase the social attraction for the performers, and decrease it when targeted by negative socio-emotional interactions. Balance is taken into account for interactions where the agent doesn’t participate as target or performer. The basic rule for balance is that the agent checks the absolute values for the intensity of its relations with the performers and targets, keeping the relation with higher value and changing the relation with lower value. 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.

4.4.3 Agents’ Personality Model

As explained before, the individual level in SGD’s knowledge base keeps information about agents’ personality. We also said that personality influences motivations. Next, we will explain in more detail how the agents’ personality, based on Five Factor Model, influences the dynamics in the group.

- **Extraversion**: Is related with the frequency of interactions. Extraverted agents are more active. This is originated by higher increment rates for proactive values ($Pv$) and lower decrements for reactive values ($Rv$) in the $Update()$ function.
Besides, extraverted individuals give more importance to positive events than to negative ones. This means that the effects of Encourage, Agree, Facilitate Problem and Gain Competence increase while the effects of Discourage, Disagree, Obstruct Problem and Lose Competence are reduced.

- **Agreeableness** is related to pro-social and communal orientation towards others, influencing the frequency of positive socio-emotional interactions. More agreeable agents agree with others more often and encourage other more often.

  SGD model also relates agreeableness with altruism: agreeable agents perform more actions for the group than actions for themselves. This happens because the increment rates of the $Pv$ for $m_{GTask}$ are higher and increments in the $Pv$ for $m_{ITask}$ are lower.

- **Conscientiousness**: Higher levels of conscientiousness are shown in agents giving more importance to instrumental than socio-emotional interactions. This means that Facilitate Problem, Gain Competence, Obstruct Problem and Lose Competence have their effects increased, while Encourage, Discourage, Agree and Disagree interactions have their effects decreased.

  Agents with higher consciousness will also put more effort in execution of task related actions, increasing that actions’ probability of success, which is related with agent’s proficiency level but also with agent’s effort. Besides this, when planning on which action to execute, agents with higher level of consciousness take more time (higher depth, higher node expansion limits) than agents with lower level of consciousness.

- **Neuroticism**: Somehow oppositely to what happens to agents with higher levels of extraversion, neurotic agents give more importance to negative interactions than to positive ones. This means, for example, that an agent with high levels for neuroticism will increase more $Rv$ of $m_{Disc}$ when discouraged than $Rv$ of $m_{Enc}$ when encouraged. At the same time, 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 scores on this trait conform less to the group and give more importance to individual goals. The $Pv$ for $m_{ITask}$ increases more and the $Pv$ for $M_{GTask}$ increases less in case of an agent with high openness.

  Since agents with high values of openness to experience care less for the success of the team, the effects of positive instrumental interactions are less intense. Openness to experience is correlated with toleration for and exploration of the unfamiliar. Agents with high openness to experience use heuristics in their planning algorithm allowing it to explore more unusual solutions, and with potentially more risks for the group.

Table 4.1 summarizes the influence of the personality traits in the increment and decrement of the motivations.
<table>
<thead>
<tr>
<th>Personality Traits</th>
<th>Positive Influence</th>
<th>Negative Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extraversion</strong></td>
<td>$P_v$ increments</td>
<td>$R_v$ decrements</td>
</tr>
<tr>
<td></td>
<td><em>Encourage</em> effects</td>
<td><em>Discourage</em> effects</td>
</tr>
<tr>
<td></td>
<td><em>Agree</em> effects</td>
<td><em>Disagree</em> effects</td>
</tr>
<tr>
<td></td>
<td><em>Facilitate Problem</em> effects</td>
<td><em>Obstruct Problem</em> effects</td>
</tr>
<tr>
<td></td>
<td><em>Gain Competence</em> effects</td>
<td><em>Lose Competence</em> effects</td>
</tr>
<tr>
<td><strong>Agreeableness</strong></td>
<td>$R_v$ of $m_{Enc}$ increments</td>
<td>$P_v$ of $m_{GTask}$ decrements</td>
</tr>
<tr>
<td></td>
<td>$P_v$ of $m_{GTask}$ increments</td>
<td>$R_v$ of $m_{Disc}$ increments</td>
</tr>
<tr>
<td><strong>Conscientiousness</strong></td>
<td><em>Obstruct Problem</em> effects</td>
<td><em>Encourage</em> effects</td>
</tr>
<tr>
<td></td>
<td><em>Lose Competence</em> effects</td>
<td><em>Agree</em> effects</td>
</tr>
<tr>
<td></td>
<td><em>Facilitate Problem</em> effects</td>
<td><em>Discourage</em> effects</td>
</tr>
<tr>
<td></td>
<td><em>Gain Competence</em> effects</td>
<td><em>Disagree</em> effects</td>
</tr>
<tr>
<td></td>
<td>Increment of task-related motivations</td>
<td></td>
</tr>
<tr>
<td><strong>Neuroticism</strong></td>
<td>$R_v$ of $m_{Disc}$ increments</td>
<td>$R_v$ of $m_{Enc}$ increments</td>
</tr>
<tr>
<td></td>
<td><em>Decrease</em> in social attraction for agent who discourages</td>
<td><em>Increase</em> in social attraction for agent who encourages</td>
</tr>
<tr>
<td><strong>Openness to Experience</strong></td>
<td>$P_v$ of $m_{ITask}$ increment</td>
<td>$P_v$ of $m_{GTask}$</td>
</tr>
<tr>
<td></td>
<td>Instrumental interactions’ effects</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.1 Influence of personality in motivations

### 4.5 SGD as a Starting Point to Our Investigation

Our system will work as an extension to SGD Model to improve the process of choosing between individual and group’s goals. SGD Model already contemplates these two types of goals. However, the choice between one and the other only takes into account the agents’ personality.

We will use many of the functionalities already implemented in SGD, like the agents’ personality model, or the motivational system. Furthermore, we must expand the system in order to clearly emulate the sociological and psychological factors influencing the choice between an individual and group goal.

In the following chapter we will explain our model’s architecture, indicating which functionalities come from the original SGD and the differences between two systems.
Chapter 5

A Model for the Choice Between Individual and Group Goals

This chapter describes our extension to SGD Model. Our main objective was to create a believable way for agents in a group to decide whether to follow the group or individual objective, using Psychology and Sociology theories to support the agents’ decision making. We will focus on the modifications made to the original SGD, which was already explained in detail in the previous chapter. Therefore, we will not explain exhaustively the complete model, but simply indicate what characteristics were kept from the previous version, explaining in detail only the modifications we introduced.

5.1 Overview

Figure 4.2, in the previous chapter, already gave “an upper look” about SGD’s architecture and the agents’ behavioral cycle.

The main differences from the original SGD are more noticeable in the knowledge base and the agents’ motivational system. However, other changes were made in order to allow the agents to solve the type of problem that our system deals with.

We will explain the new model in more detail in the following sections.

5.2 Knowledge Base

As said previously, the agent keeps the knowledge it possesses in the knowledge base. Separated in four levels – Individual Level, Social Level, Interactions Level and Context Level - according to the type of knowledge they hold, the knowledge base is one of the main components of our model.

This component has some modifications relatively to the original SGD, which will be pointed as we explain the knowledge base in detail. The new knowledge base was designed to model the differences in the behavior for different agents with different individualistic levels, when choosing whether to pursue the group’s or the individual’s objective.
5.2.1 The Individual Level

The individual level, similarly to previous versions of SGD, keeps information about the agent’s individual characteristics.

In this level, the agent keeps information about its personality and abilities, as described in chapter 4. The major difference relatively to the original SGD is the introduction of the notion of Egoism.

Egoism is introduced for it is related with the importance an agent gives to the individual and common objectives, as explained in the Psychology and Sociology chapter. Directly related with personality, Egoism is a major factor when an agent needs to decide which its main concern is: itself or others.

We will consider the weak version of rational egoism for our agent’s behavior. This way, we consider it is always rational for an agent to follow its own interest, but it isn’t necessarily not rational not to do so [5]. This validates our option of making agent’s choices not based only on Egoism, as we will explain later. For now, all it matters to state is that although Egoism is important when deciding agents’ actions, an agent may decide to act altruistically without losing rationality.

When defining the factors influencing the agents’ egoistic level, we will follow D. Paulhus and O. John’s work relating Egoism and the Five Factor Model [35]. Based on their studies, we consider that Egoism increases when openness and extraversion increase, and decreases when agreeableness and consciousness increase. Formula 5.1 defines agent’s Egoism relatively to agent’s personality.

\[
(Egoism(A) = 50 + \frac{\text{Openness}(A) + \text{Extraversion}(A)}{4} - \frac{\text{Agreeableness}(A) + \text{Consciousness}(A)}{4})
\]

(5.1)

John and Paulhus’ work didn’t quantify exactly “how much” are egoism and altruism related with the Five Factor Model personality traits. For that reason we consider that the four factors of personality have the same influence. Egoism is defined as an integer between 0 and 100, with 50 working as a neutral level (an agent which is neither egoist nor altruist). These bounds for egoism are insured by formula 5.1, since all personality factors are also defined between 0 and 100. The value for egoism is constant, being independent of what the agent experiences.

5.2.2 The Social Level

This level keeps information about, or directly related with, social relations between the members in the group. The social level is separated in two sub-levels, related with knowledge regarding individuals’ relationships and relationships between the individuals and the group as an entity.
Regarding relations between agents, this level keeps information about social attraction and influence. Related with social relations, this level also keeps information about the agent's self-esteem.

Our model also keeps knowledge about the influence and attraction the group exerts on all of its members. This knowledge is also kept in the Social Level.

We will explain in detail the knowledge existing in Social Level’s sub-levels.

5.2.2.1 Social Level – Agents

This level keeps information about social relations between agents in the group, namely Social Attraction and Social Influence. The notions of Social Attraction and Social Influence were already introduced in the previous version of SGD Model, in the Group Level, and are kept immutable in our model.

This sub-level brings a new factor to the model: the agent’s Self-Esteem.

Following M. Leary, G. MacDonald and J. Tangney work [41], we consider that Self-Esteem can be related with the agent’s “courage” to follow its individual goal. Agents with higher Self-Esteem thrust more on their capabilities and resist more to influences than agents with lower Self-Esteem, more unable to deviate from the behavior of the majority.

In our model, we will use Self-Esteem as a way for the agents to resist to different factors of influence, either originated in the group or from other agents. This way an agent with higher Self-Esteem will resist to outer factors, and act according to its personality. Agents with lower Self-Esteem will tend to yield to outside pressure, having their behavior influenced by others.

Self-esteem is derived from personality, as Gecas and Seff studied, in conjunction with the Agent’s Success. In our model, agents have an individual objective, but are also members of a group with a common objective. This means that agents take into account their individual success, but also their success in the group to which they belong.

Considering the agent’s personality, agent’s individual success and success in the group, we define agent’s self-esteem by rule 5.2.

\[
\forall G, A \ ( \text{Group}(G, \text{members}) \land \text{Agent}(A) \land A \in \text{members}) \rightarrow \\
(\text{SelfEsteem}(A) = \text{Position}(A, G, S) + \text{Success}(A))
\] (5.2)

The agent's position, as defined in the original SGD Model, works is an indicator of the agent's success in the group, while agents' success (defined by rule 5.3) defines the agent's success in the past attempts to pursue its individual objective. In this formula, the predicate \( \text{Objective}(lo) \) represents an individual objective of a certain agent. \( \# \ \text{Possible}(lo) \) represents the number of possible objectives that the agent had in the game. To calculate agents’ success we need the ratio between successes/failures in the individual goal attempts. To calculate the agents’ success, represented by rule 5.4 (IndividualSuccess) or insuccess, represented by rule 5.5 (IndividualInsucess), at a given objective, we take into account the objective’s difficulty and the agent’s personality. In rule 5.3, \( \sum \text{IndividualSuccess}(A) \) and \( \sum \text{IndividualInsucess}(A) \)
represent the sum of the values of success and insuccess at past individual objectives of the agent. The predicate Difficulty(Io) represents the difficulty of an objective. As it was explained in the previous chapter, agents with higher levels of extraversion give more importance to positive events (in this case, succeeding at a given objective), while agents with higher levels of neuroticism give more importance to negative events. Also with a weight in the agent’s success’ calculation is consciousness. This is happens because agents with higher level of consciousness give more importance to task-related interactions. We consider the goal’s difficulty in the calculus of success so that agents give more importance to a success on a difficult goal than on an easy one. The same way, a failure in an easy goal will be “harder” to the agent than when it fails in a harder objective.

\[
\forall A, Io (Agent(A) \land Objective(Io, A)) \rightarrow \\
(Success(A) = \frac{\sum \text{IndividualSuccess}(A)}{\# \text{Possible}(Io)} - \frac{\sum \text{IndividualInsuccess}(A)}{\# \text{Possible}(Io)} \times \text{Conscientiousness}(A))
\]

(5.3)

\[
\forall A, Io (Agent(A) \land Objective(Io, A)) \rightarrow \\
(\text{IndividualSuccess}(A) = \text{Difficulty}(Io) \ast \text{Extraversion}(A))
\]

(5.4)

\[
\forall A, Io (Agent(A) \land Objective(Io, A)) \rightarrow \\
(\text{IndividualInsuccess}(A) = [\text{MAXIMUMDIFFICULTY} - \text{Difficulty}(Io)] \ast \text{Neuroticism}(A))
\]

(5.5)

By considering extraversion, neuroticism and consciousness in the calculus of success, we are making the agents’ personality influence the agents’ self-esteem, as Gecas and Seff explained [60], namely the three factors with higher influence according to their study.

5.2.2.2 Social Level – Group

This sub-level keeps the information related with, or derived from, social relations at the group’s level. Previously existent in the Group Level in old versions of SGD Model, the information about group’s position is now kept in this level, being calculated using formula 4.11, from the previous chapter. This level introduces the relations of influence and attraction between the agent and the group. Similar to interpersonal attraction and influence, but now modeling these relations between the agent and the group, and not between two agents, both concepts of Group’s Attraction and Group’s Influence were inexistent in the previous SGD. These two new concepts are important
in the type of choice between two objectives our agents need to do, for an agent more attracted
to or influenced by the group will act more on its behalf than a less attracted or influenced one.
Group’s Influence defines the conformity of the agent towards the group, representing how
difficult it is for an agent to deviate from the behavior of the group. In our system, this means
that agents with higher conformity have more probability to work to the group’s objective than to
their personal objective.

Rule 5.6 defines group’s influence in the knowledge base. Group’s influence takes into account
the agent’s Self-Esteem, decreasing when this factor increases. It also increases with the
increase of the cooperation level of other members in the group and with the group’s success.
An agent will act more on the behalf of the group if it feels all members in the group will also act
for the same objective.

5.6 introduces a new concept: Group Success. Group Success is the indicator of how well the
group is working towards its goals. Here, we introduce the predicate CurrentObjective(Go, G),
representing the group’s current objective. The group’s success is calculated similarly to
individual success (5.3, 5.4, 5.5), as defined by rules 5.7, 5.8 and 5.9.

The other new concept is Cooperation. This concept represents how committed an agent is to
the group, and is simply the ratio between the number of actions towards the group’s goal and
the number of actions towards its own goal by a given agent.

Besides these factors and according to what was explained in the Psychology and Sociology
chapter, the influence the group exerts on the agent is also dependant on the current goals’
difficulty (harder objectives lead to more conformity).

\[ \forall G, A, Go \ (Group(G, \text{members}) \land \text{CurrentObjective}(Go, G) \land A \in \text{members}) \rightarrow \]

\[ \text{(Influence}(G, A) = \sum_{p \in \text{members}}^{p} \text{Cooperation}(p, G) + \text{Success}(G) + \text{Difficulty}(Go) - \text{SelfEsteem}(A)) \]  \hspace{1cm} (5.6)

\[ \forall G, A, Go \ (Group(G, \text{members}) \land \text{CurrentObjective}(Go, G) \land A \in \text{members}) \rightarrow \]

\[ \text{(Success}(G) = \frac{\sum \text{GroupSuccess}(G)}{\# \text{Possible}(Go)} - \frac{\sum \text{GroupInsuccess}(G)}{\# \text{Possible}(Go)} \times \text{Conscientiousness}(A)) \]  \hspace{1cm} (5.7)

\[ \forall G, A \ (Group(G, \text{members}) \land \text{CurrentObjective}(Go, G) \land A \in \text{members}) \rightarrow \]

\[ \text{(GroupSuccess}(G) = \text{Difficulty}(Go) \times \text{Extraversion}(A)) \]  \hspace{1cm} (5.8)
The same way social attraction represents how attracted one agent is by other agent, our model also includes the notion of group attraction, representing the attraction an agent feels for the group. Cartwright and Zander defined Group Cohesiveness as the attraction an agent feels for the group [69]. Following this definition, together with the factors Festinger introduced as defining group cohesiveness [70], we represent Group’s Attraction in the knowledge base by rule 5.10. This way, Group’s Attraction is dependent on the attraction the agent feels for other members in the group and the group’s success.

\[ \forall G, A (\text{Group}(G, \text{members}) \land A \in \text{members}) \rightarrow \\
\text{GroupInsuccess}(G) = [\text{MAXIMUMDIFFICULTY} - \text{Difficulty}(\text{Objective}(G))] \times \\
\text{Neuroticism}(A) \]  

(5.9)

\[ \forall G, A (\text{Group}(G, \text{members}) \land A \in \text{members}) \rightarrow \\
\text{Attraction}(A, G) = \sum \text{SocialAttraction}(A, m, S) + \text{Success}(G) \]  

(5.10)

5.2.3 The Goal Level

The agents in our system have two types of objectives: the individual and group. When an agent acts towards an objective, its actions are perceived by others. This has an impact in the system, originating changes in the agents’ knowledge base. The ability to differentiate possible goals, together with the ability to identify other agents’ actions has, this way, a major importance in our system. The goal level defines the agent’s goals, as well as the associated gain for the agent and the group, and the associated time, as follows:

- **Goal Definition:** describes the representation of the goal, according to the context.
- **Group Gain:** describes the gain for the group when the goal is achieved
- **Individual Gain:** describes the gain for the agent when the goal is achieved.
- **Time:** represents the time associated with the goal. A goal is only valid within a given interval, and should be achieved before that time extinguishes to get the corresponding gain.

This way, a goal g is represented in the knowledge base by a tuple 5.11.

\[ g = \langle \text{Definition}, \text{IndividualGain}, \text{GroupGain}, \text{Time} \rangle \]  

(5.11)
According to the gains for the group and the individual, it is possible to differentiate the type of the goals. In our system, since we only want to model the choice between the individual and group goals, we decided to clearly distinguish these two types, with a goal being easily identifiable as “good for the group” or “good for an agent”.

The individual goal, this way, has maximum utility for the agent, and the group goal has maximum utility for the group. According to the type of the goal, the agent has different motivations, which are calculated in a distinguishing way.

The scheme in figure 5.1 shows a graphical representation of the existent information in the knowledge base. It shows the information regarding the agents, the group and the goal, together with information about the relationships established between agents, and agents and the group.

![Figure 5.1 The new model's knowledge base](image)

### 5.3 Motivational System (Goal Selection)

The agent’s motivational system defines the agent’s behavior. Like in the previous version of SGD, the agents’ motivations are related with a Goal, have a Proactive ($P_v$) and a Reactive ($R_v$) components, an Update function and a Threshold.

Agents have an Individual and Group goals, together with Encourage and Discourage goals, associated with socio-emotional interactions.

The agent acts towards a goal when the sum of proactive and reactive components reaches the associated threshold, resetting their motivations’ values to 0 afterwards. This way, the difference in the importance an agent gives to the individual or group’s goal is reflected in how fast it reaches the threshold associated with each of those goals. This is related with the update function for both goals.
The update function defines how different motivations decrease and increase, by returning a value to be added or subtracted to that motivation. The pro-active components of motivations increase with time, resetting when the agent reaches a given goal. The reactive components of motivations increase in response to interactions in the group which are percept by the agent. Table 5.1 shows which occurrences originate an increase in the reactive component for the motivation, related with the group’s goal and the individual’s goal.

<table>
<thead>
<tr>
<th>Individual $R_v$</th>
<th>Group $R_v$</th>
</tr>
</thead>
</table>
| - Detects an agent is acting to himself.  
- The agent is discouraged by other agent in the group | - Detects an agent is acting to others.  
- The agent is encouraged by other agent in the group |

Table 5.1 Factors influencing reactive component for goals motivation’s increase

As we already seen, the increases in the reactive components of motivations are triggered by interactions occurring in the group, while the increases in the pro-active components of motivations occur with time. It matters now to state which factors are taken into account by the update function when calculating new values for motivations.

Tables 5.2.1 and 5.2.2 show the factors contributing positively and negatively for the increment of the motivations related with the individual goal (5.2.1) and the group goal (5.2.2).

<table>
<thead>
<tr>
<th>Individual</th>
<th>Positive Influence</th>
<th>Negative Influence</th>
</tr>
</thead>
</table>
|            | Egoism             | Group’s Attraction  
            |                     | Group’s Influence   |

Table 5.2.1 Factors influencing individual goal’s motivation

<table>
<thead>
<tr>
<th>Group</th>
<th>Positive Influence</th>
<th>Negative Influence</th>
</tr>
</thead>
</table>
|       | Group’s Attraction  | Egoism             
|       | Group’s Influence   |                    |

Table 5.2.2 Factors influencing group goal’s motivation

Tables 5.2.1 and 5.2.2 show that the relations of attraction and influence are directly related with the increase of the motivation towards the group goal and inversely related with the increase of the motivation towards the individual goal. Egoism works as a factor influencing positively the increase of the motivation towards the individual goal while having a negative influence in the increase of the motivation towards the group goal. Synthesizing, we can state that agent’s egoistic level makes an agent care more about himself, while sociological factors (namely group’s attraction and influence) make an agent care more with the group.
Besides the factors in tables 5.2.1 and 5.2.2, interactions increasing the reactive component of motivations have different strengths according to the interaction’s performer’s position, as the next example illustrates:

When an agent X detects agent Y is acting for itself or the group, the reactive component for X’s individual goal or group goal increases, respectively. This increase is dependent on the agent Y’s position. The actions of agents with higher group positions have bigger influence on other agents than the actions of agents with lower group position. The group’s position has a similar influence on the increase of the motivations to perform a given task as a result of socio-emotional interactions ($Rv$ of $m_{ITask}$ and $RV$ of $m_{GTask}$).

Together with the motivations to act to the individual or the group goals, the agents also have motivations to engage into socio-emotional interactions (encourage or discourage), like in the previous version of SGD Model. In our system, we are modeling a way for the agents to choose between the individual and the group goals, hence those are the objectives whose motivations’ dynamics we must define. Motivations to encourage or discourage other agents, unrelated with the individual goal and the group goal are also present in our system, but are kept immutable from previous versions of SGD.

Figure 5.2 represents the factors influencing the motivations increase for the individual and the group goals, working as a synthesis of what was introduced in this section, and relating the knowledge in the knowledge base with the goal selection.

### 5.4 Concluding Remarks

Our main concern when defining the architecture of our system was to encompass factors which allow the agents to choose between an individual and a group goal in a believable way. This way, our architecture had to model psychological and sociological factors in order to allow agents’ behavior to emulate human behavior both as an individual and as a member of the group.

We developed our architecture adapting and expanding Prada’s SGD Model, which already implemented some factors taken into account when modeling a decision like the one our agents have to make. For that reason, we tried to keep our architecture an extension and not a modification to the original SGD as much as possible, having this way a stable system, successfully modeling the agents’ behavior in a group, as a starting point.

The main differences in our system are the inclusion of the notion of Egoism, Group’s Attraction and Influence and Self-Esteem. We also included a new level in the Knowledge Base – Goal Level – allowing the representation of different types of goals.

Egoism works as a “mask” for the agents’ personality, being directly related with four of the five factors in the Five Factor Model. Egoism represents the inner tendency for agents to give more or less importance to their well-being or the well-being of others in the group.

Group’s Attraction and Influence, similarly to what happens between individual agents, represent forces of attraction and influence between the agent and the group, in different
directions. Group’s Attraction represents how much the agent “likes” the group as a whole, while Group’s Influence represents the “power” of the group in the agent’s behavior. Self-Esteem represents the agent’s courage to resist to outer factors of influence. Self-esteem for itself doesn’t create an agent more or less willing to help the group, but makes an agent more or less capable of acting according to its personality and ignoring other factors defining its behavior.
Figure 5.2 Factors influencing motivation's increase
When updating the motivations towards the individual or group goals, the egoistic level makes an agent care more about himself, while the group’s attraction and influence make the agent care more about the group. This choice seems pretty simplistic. However, and when looking at schema 5.2, we can see that the agents’ behavior, namely when choosing which objective to pursue, is dependent on factors so distinguishable as the agent’s personality, the social relations between the agents and what happens in the group.

Older versions of SGD already had agents with individual and common goals. However, only with this extension can agents make a “justifiable” choice, based on factors that influence humans in the same position. We tried, as much as possible, to keep this decision simple, encompassing however the needed knowledge to allow this type of choice.
Chapter 6
Implementation

In the previous chapter we introduced the architecture for agents using our model, explaining the knowledge used to define their behavior, and how that knowledge relates with agents’ actions.

In this chapter we will detail our agent's implementation, describing the technology and including code segments, when justifiable. Furthermore, we will introduce Power Pentagram, a game played by agents implementing our model, whose results worked as a way to test the model’s success, as explained in chapter 7.

6.1 Case Study: Power Pentagram: A Semi-Competitive Game

Our model was implemented in agents who play a game named Power Pentagram. Power Pentagram was born as a modification to Perfect Circle [6]. Our main goal in this change was to transform Perfect Circle in a semi-competitive game, which we believe, successfully sets the environment for agents having to deal with the dilemma of collaborating or not with other members in the group.

6.1.1 What is a Semi-Competitive Game?

Power Pentagram is, as we said, a semi-competitive game. For this reason, it matters to explain what a semi-competitive game is before describing it.

A semi-competitive [29] game is a type of game where agents cooperate with others to increase their utility, at the same time that they must compete to win the game.

We decided to make Power Pentagram a semi-competitive game, for this possibility to cooperate/compete with others is a clear fit to test agents with different motivations for those two behaviors.

In order to assert about these different behaviors, we tried to find a way to force agents to cooperate in order to have success in different goals (more than a way to increase utility, cooperation appears this way as the ONLY way to get it). At the same time, to get advantages over other agents in the group, agents had to compete between them (as the only way to win the game).

Next section explains Power Pentagram in more detail.
6.1.2 Power Pentagram’s Definition

As we said, we implemented Power Pentagram as some sort of “expansion” to Perfect Circle. The changes, however, go far beyond a simple change in the game’s name.

6.1.2.1 The History

Junonia has always been a world of magic. Since the beginning of times, there were five magical schools, representing a different element. Ligni’s energy came from wood. Its school was situated in a great forest, filled with life, and dead for the bad intentioned. Ignis, situated in the biggest volcano, got its energy from fire. Aqua, the water school was built in a forgotten island. Humus, with Earth as its element was built in the Great Plains. In the dark mines lived the wizards of Metallum, getting their magical energy from metal.

Almost since their formation, the five schools engaged into a gigantic war, trying to dominate all the others, and with it, dominating the entire world. But the fierce battles never lead to nowhere, and every time a school got some advantage, the others formed an alliance, creating a new balance. Nevertheless, several wizards lost their lives for their school, creating wounds that not even eternity can heal.

The magic’s disappearing

One day, an outcast wizard, using evil magic, was able to open the Demon Gate, separating the world of the living from the Demon’s World. Hell broke loose that day, with demons hatching from the centre of the earth, killing thousands.

Joining forces, the five schools were able to use an ancient type of magic, spiritual magic, by combining all five types. Using this magic, it was possible to destroy the demonic threat. However, to do so, the five schools spent almost all the magical energy in the world.

Even after terminated, the demon’s invasion had a great impact in humanity. Instead of working together to rise from ashes, the world’s inhabitants, insane with the pain of relative’s deaths, became a raging species, without laws or rulers. The invasion showed one thing: the worse threat to mankind is mankind itself.

The present

The wiser wizards of all schools knew that the only way to stop the madness was to use magic, altering the mankind’s memory. Reading old writings they found one thing: magical energy can be created by combining long lost gems. But they found more: spiritual magic is nothing more than the combination of all five other magic, and may be used by every school. They also found an old manuscript with all the places in the world where the ancient gems could be found, which combinations could be done to get white magic and magic of each color, and which spells should be used to manipulate gems in different ways.

Each school chose a champion, teaming with the other four champions in a quest to restore magic in the world. To do that, they should find and manipulate stones, creating one of the
combinations described in the manuscripts. However, some of the combinations create spiritual magic, while others create only one color.
This tells the story of five men, united by need, separated by everything else, and their quest to save the world. Will they work together, or follow some hidden agenda allowing their school to gain more power than others? After all, when peace is restored there still exists a war which was over, but not forgotten.

6.1.2.2 The Game

Power Pentagram is a semi-competitive game, where five agents (all of them autonomous, or four autonomous and one human) travel a world of magic. Their mission is to find gems which, when combined, give them a predefined number of points. Gems can be found in different sizes, essences and purities.

In that search, agents have a different set of abilities which allow them to change the gems according to their needs. Agents' abilities are described as follows:

- **Harvest** – This ability allows agents to search their surroundings trying to harvest a gem. The harvested gem (if any) has any (random) size, essence and purity.
- **Merge** – The ability to merge two gems with the same characteristics in a bigger gem.
- **Split** - The ability to split one gem in two, where both gems have the same characteristics of the original gem.
- **Purify** – The ability to transform a gem in a gem with the same essence but higher purity. The resulting gem is smaller than the original.
- **Taint** - The ability to transform a gem in a gem with the same essence but lower purity. The resulting gem is bigger than the original.
- **Transmute** – The ability to change a gem's essence.
- **Use** – The ability to use the gem to achieve a level's goal.

Like in a RPG [78], agents' abilities are limited at first, but can be achieved or developed during the game, as the agent wins more experience. When an agent wants to use its abilities, acting in some way, he makes a proposal to the group. When an agent proposes some action, other members must vote on that proposal. After the voting, the proposing agent decides whether or not to continue with the action.

Besides the described abilities, every agent has the ability to use a gem of his own essence to himself. Contrary to other abilities, this one has a constant level during the whole game. When an agent decides to act for his own benefit, he does not make a proposal, simply acting.

Like in Perfect Circle, agents may also engage into socio-emotional interactions, encouraging and discouraging other members in the group.

A game has ten levels. Each level has an associated group goal, a combination of three gems of varying size and purity. Each group goal grants different points, divided by all members of the group. Besides the points associated with a group’s goal, there are individual goals, which when achieved, give the successful agent a given amount of points. To achieve an individual goal, an
agent must achieve a certain amount of points in a level. In the end of the game, the agent with higher score wins.

Each level has an associated time. To get the group objective points, agents must also achieve them in the corresponding level’s time. When the group fails to achieve the group goal, all its members’ individual points gathered in that level are also lost. This forces agents to cooperate with each other, no matter how egoistic they are. Connecting this to the game’s story, cooperation is the only way to get white magic, the only one which can save the world from its cruel faith.

Power Pentagram was designed to allow the testing of our model, including two types of goals (individual and group) with varying associated utilities, different types of interactions, and a success/failure level which allows all the psychological and sociological factors to change during the game. We will explain this in more detail in the following sections.

The main strength of Power Pentagram, as we already stated, is the inclusion of two “needs” forcing the agents to act: the need to win – making the agent follow its individual goal - and the need to help – making the agent follow the group goal. The fact that a simply-cooperative agent will certainly lose the game, and that an agent in a group with non-cooperating agents will achieve few points (loosing most of the levels by timeout, and correspondingly loosing that level’s group and individual points), gives “inner-motivations” for the agent to follow both goals, in a “semi-cooperative” dilemma. This dilemma suits perfectly the problem our work endorses, justifying the agent’s actions while playing the game, according to their personality and what happens while playing.

### 6.2 Implementation Details

In this section, we will give an overall description about how Power Pentagram was implemented, using Java and Jess. We don’t intent to explain exhaustively the implementation, but to give a few guidelines, eventually allowing future extensions in the future.

#### 6.2.1 Java

We used Java to implement the game’s logic and handle everything needed to allow agents to play it. Among other things, we used Java to implement the game’s loop and the classes responsible for having the two versions of the game (simulation and user game). There are Java classes representing the players, the group, the levels, the goals and the game itself. The player’s actions (corresponding to the agents’ effectors) and also implemented in Java, together with the connection to Jess or the user interface.

If for some reason we need to change our agent’s architecture, we can use Java as it is, for it works as a “lower” layer, allowing Jess to handle the agent’s mind, and only that. Next, we will
give a brief description of the most important Java packages, giving a high view of what they do (table 6.1).

<table>
<thead>
<tr>
<th>Package</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Responsible for reading the configuration files, loading the needed resources and launching the game.</td>
</tr>
<tr>
<td>Group</td>
<td>Holds the abstract class representing the group member, and the effectors responsible for adding and removing group members and setting the group's entities.</td>
</tr>
<tr>
<td>PerfectCircle</td>
<td>This package keeps the classes implementing all the game logic. It keeps the classes with information about the “Game”, the “Level”, the “Goal”, the “Character”, the “Gem” or the “Stash”.</td>
</tr>
<tr>
<td>perfectCircle.batch</td>
<td>This package holds all the needed classes implementing the Eval’s application.</td>
</tr>
<tr>
<td>perfectCircle.config</td>
<td>The classes in this package define the game’s configurations.</td>
</tr>
<tr>
<td>perfectCircle.gui</td>
<td>The classes implementing the panels in the game, the screens in the game and the animations. This package implements mostly what the user &quot;sees&quot; and interacts with while playing the game.</td>
</tr>
<tr>
<td>perfectCircle.skills</td>
<td>Implements the game skills of the agents. These classes are responsible for the agents’ actions in the game.</td>
</tr>
<tr>
<td>perfectCircle.world</td>
<td>Implements the Jess engine and an observer class, together with all the effectors responsible for agents’ actions. This package works as a connection between the agents’ mind (Jess) and the Java implementation of Power Pentagram.</td>
</tr>
</tbody>
</table>

Table 6.1 Power Pentagram’s Java Packages

At this point, it matters to state that the architecture we used was “inherited” from Perfect Circle, and we simply adapted the existing classes and added new classes to allow the implementation of Power Pentagram.

Power Pentagram is a game simply developed to allow demonstrating our system, and has no intent to be a commercial game. For that, we kept it as simple as possible, and didn’t give particular importance to its “look”, how “fun” it is to play or other game design factors of success.
Our system should work in any game (or other application) where agents have the same
decision to make. Hence, the real important time is the agent’s “mind”, and not the world where
their “body” exists. For this same reason, this section simply gives an overall vision of Power
Pentagram’s Java implementation, being out of our work’s specification a full description of the
game’s architecture.

6.2.2 Jess
Jess, a rule engine written in Java, was used to implement the agent's mind. If Java implements
and controls everything happening in the world, Jess gets inputs for the world, holds the agent’s
knowledge, and handles all the reasoning and outputs agents’ actions.
The agents’ mind is implemented in several Jess modules, the more important being the ones
we will explain next. For the corresponding modules, we will introduce the relevant functions
implementing the formulas in the Architecture section.

6.2.2.1 Group
The group Module keeps and updates the knowledge about the group, including its constitution,
hierarchy, success and failure. It also keeps the information about the group’s members,
namely their personality, Egoism, Self-Esteem, success or insuccess.
Broadly speaking, the group module implements the knowledge in our architecture's Individual
and Social Level.
We could implement this knowledge in two (or three) different Jess modules. However, since
most of the knowledge in those levels is directly related, we decided to use only one module,
facilitating the implementation.
We forced all the values to be between 0 and 100. That is noticeable in all formulas, with a
normalization used to grant this constraint.
The agent’s Egoism is represented by the following rule:

1  (defrule create-agent-egoism
2    (KNOWLEDGE::property (entity ?ent) (name "extraversion") (value
3     ?extraversion))
4    (KNOWLEDGE::property (entity ?ent) (name "agreeableness")
5    (value ?agreeableness))
6    (KNOWLEDGE::property (entity ?ent) (name "neuroticism") (value ?neuroticism))
7    (value ?conscientiousness))
8    (KNOWLEDGE::property (entity ?ent) (name "openness") (value ?openness))
9    (group-member (agent ?ent&(eq ?ent ?AGENT-ID*)) (group ?group))
10   =>
11   12   (assert (egoism (member ?ent)
13        (value (+ 50 (- (/ (+ ?openness ?extraversion) 4)
14           (/ (+ ?agreeableness ?conscientiousness) 4)))))))

Rule 6.1: Rule responsible for creating the agent’s egoism. Lines 2-9 get the agent’s
extraversion, agreeableness, neuroticism and openness. Lines 13-15 assert the egoism’s value,
using rule 5.1 from the previous chapter.
Egoism remains constant during the entire game.

To calculate the agent's success (5.3), we introduced the notions of agent’s success sum and agent’s insuccess sum (corresponding to formulas 5.4 and 5.5). These sums are initialized to 0, being updated every time an agent achieves/fails an attempt at an individual goal. The following rules are responsible for updating the sums and the group’s success.

```
(defrule update-individual-sum
  (declare (salience 100))
  (?f <- (increase-individual-success)
  (KNOWLEDGE::property (entity ?ent) (name "extraversion") (value ?extraversion))
  (?f1 <- (individual-success-sum (member ?ent) (value ?val))
  (group-member (agent ?ent:(eq ?ent ?AGENT-ID*)) (group ?group)))
  =>
  (bind ?newValue (+ ?val (/ (* (get-current-individual-goal-difficulty) ?extraversion) 100)))
  (retract ?f)
  (assert (modify-individual-success))
  (modify ?f1 (value ?newValue)))

(defrule update-individual-ins-sum
  (declare (salience 100))
  (?f <- (increase-individual-insuccess)
  (KNOWLEDGE::property (entity ?ent) (name "neuroticism") (value ?neuroticism))
  (?f1 <- (individual-insuccess-sum (member ?ent) (value ?val))
  (group-member (agent ?ent:(eq ?ent ?AGENT-ID*)) (group ?group)))
  =>
  (bind ?newValue (+ ?val (/ (* (- ?max-difficulty* (get-current-individual-goal-difficulty)) ?neuroticism) 100)))
  (retract ?f)
  (assert (modify-individual-success))
  (modify ?f1 (value ?newValue)))

(defrule update-individual-success
  (KNOWLEDGE::property (entity ?ent) (name "conscientiousness")
  (value ?conscientiousness))
  (?f <- (modify-individual-success)
  ?f1 <- (individual-success (member ?ent) (value ?val))
  ?f2 <- (individual-success-sum (member ?ent) (value ?is))
  ?f3 <- (individual-insuccess-sum (member ?ent) (value ?ii))
  (group-member (agent ?ent:(eq ?ent ?AGENT-ID*)) (group ?group)))
  =>
  (bind ?newValue (* (- (/ ?is (get-game-level)) (/ ?ii (get-game-level))) ?conscientiousness))
  (bind ?newValue (/ ?newValue 100))
  (if (eq ?newValue 0) then
    (bind ?newValue 50) else
    (if (eq ?newValue 0) then
      (bind ?newValue (+ 50 (/ ?newValue 2))) else
      (bind ?newValue (- 50 (/ (- 0 ?newValue) 2))))))
  (retract ?f)
  (assert (modify-self-esteem))
  (modify ?f1 (value ?newValue)))
```

Rule 6.2: Rule responsible for updating agent’s individual success (lines 33-56) and the auxiliary rules which update the agents’ success sum (lines 1-14) and agent’ insuccess sum (lines 17-30). Lines 10 and 11 define the increase in the agents’ individual success sum. Lines 26 and 27 define the increase in the agents’ individual insuccess sum. Line 36 guarantees that individual success is only updated when any of the associated sums change its values. Lines
44-46 implement rule 5.3, and lines 47-53 are responsible for normalizing the new value for individual success.

Group Success, as Rule 6.3 shows, is very similar to individual success, also with the concepts of group success sum and group insuccess sum.

```
(defrule update-group-sum
  (KNOWLEDGE::property (entity ?ent) (name "extraversion") (value ?extraversion))
  (?f <- (PERFECT-CIRCLE::group-achieved (difficulty ?diff)))
  (?f1 <- (group-success-sum (member ?ent) (value ?val))
  (group-member (agent ?ent & (eq ?ent #'AGENT-ID*)) (group ?group))
  =>
  (bind ?newValue (+ ?val (/ (* ?diff ?extraversion) 100)))
  (retract ?f)
  (assert (modify-group-success))
  (modify ?f1 (value ?newValue)))

(defrule update-group-ins-sum
  (KNOWLEDGE::property (entity ?ent) (name "neuroticism") (value ?neuroticism))
  (?f <- (PERFECT-CIRCLE::group-not-achieved (difficulty ?diff)))
  (?f1 <- (group-insuccess-sum (member ?ent) (value ?val))
  (group-member (agent ?ent & (eq ?ent #'AGENT-ID*)) (group ?group))
  =>
  (bind ?newValue (+ ?val (/ (* (- ?max-difficulty* ?diff) ?neuroticism) 100)))
  (retract ?f)
  (assert (modify-group-success))
  (modify ?f1 (value ?newValue)))

(defrule update-group-success
  (KNOWLEDGE::property (entity ?ent) (name "conscientiousness")
  (value ?conscientiousness))
  (?f1 <- (group-success (member ?ent) (value ?val))
  ?f2 <- (group-success-sum (member ?ent) (value ?gs))
  ?f3 <- (group-insuccess-sum (member ?ent) (value ?gi))
  (group-member (agent ?ent & (eq ?ent #'AGENT-ID*)) (group ?group))
  =>
  (bind ?newValue (/ ?newValue 100))
  (if (eq ?newValue 0) then
    (bind ?newValue 50)
    else
    (if (eq ?newValue 0) then
      (bind ?newValue (+ 50 (/ ?newValue 2)))
      else
      (bind ?newValue (- 50 (/ (- 0 ?newValue) 2))))
    )
  (retract ?f)
  (assert (modify-group-attraction))
  (assert (modify-group-influence))
  (modify ?f1 (value ?newValue)))
```

Rule 6.3: Rule responsible for updating agent’s group success (lines 28-51) and the auxiliary rules which update the group’s success sum (lines 1-11) and group’s insuccess sum (lines 14-25). These rules are quite similar to those implementing individual success. Lines 38-40 implement formula 5.6.
The following rule is used to calculate the agents’ Self-Esteem. Self-Esteem changes during the game in response to changes in agents’ group position and individual success.

```
(defrule update-self-esteem
  (KNOWLEDGE::property (entity ?ent) (name "conscientiousness"))
  (value ?conscientiousness))
  ?f <- (modify-self-esteem)
  ?f1 <- (self-esteem (member ?ent) (value ?val))
  ?f2 <- (individual-success (member ?ent) (value ?is))
  ?f3 <- (group-position (member ?ag) (group ?name) (value ?gp))
  (group-member (agent ?ent&:(eq ?ent *AGENT-ID*)) (group ?group))

  =>
  (bind ?newValue (/ (+ ?is ?gp) 2))
  (retract ?f)
  (modify ?f1 (value ?newValue)))
```

Rule 6.4: Rule responsible for updating agent’s Self-Esteem. Lines 2-8 get the agent’s conscientiousness, group-position and individual success. Lines 11-13 assert the egoism’s value, using rule 5.2 from the previous chapter.

Each agent in the group keeps information about the ratio between the times other agents acted for the group and the number of times agents acted for themselves. This knowledge is not extremely important per se, but it will be used in the calculus of group’s influence.

```
(defrule modify-cooperation
  (alter-cooperation (member ?aid))
  (cooperation (member ?aid) (value ?value))
  (self-actions (member ?aid) (value ?sa))
  (group-actions (member ?aid) (value ?ga))

  =>
  (bind ?val (* 100 (/ ?ga (+ ?ga ?sa))))
  (modify ?f2 (value ?val))
  (retract ?f)
  (assert (modify-group-influence)))
```

Rule 6.5: Rule responsible for keeping the cooperation levels for agents in the group.

The group’s influence is defined by the following rule. “How attracted” an agent is for the group, is dependent on the average of other agents’ cooperation, the current group goal’s difficulty (which varies in all levels) and group’s success.

Self-Esteem has a crucial role in group’s influence, working as a “filter” for the influence’s value. As rule 6.6 shows, after calculating the influence’s value, we measure the agent’s Self-Esteem. Self-esteem is then used to define the percentage of influence which actually affects the agent. The higher the self-esteem, the less influence from the group the agent will fell.
Rule 6.6: Rule responsible for updating the group’s influence. Lines 2-12 get the cooperation for all members in the group, the values for group success and agent’s self-esteem. Lines 15-18 calculate the new value for group success and lines 19-31 calculate group influence according to the agent’s self-esteem.

Group level also keeps and updates the agents’ group attraction. The agents’ group attraction is a reflection of the attraction agents feels for other agents individually, also taking into account the group success. Group attraction is defined by rule 6.7.

6.2.2.2 Actions

The Actions Module, as the name explains, is responsible for allowing the agents’ actions. Namely, the rules in this module interact with the Java’s application, inputting the agents’ actions in the world.

It has actions for all the agents’ skills, the socio-emotional interactions (encourage or discourage), proposals and voting, including the action which allows the agent to join other agents’ proposals, taking part in the proposed action if the proposing agent decides to execute it.
6.2.2.3 Power Pentagram

This module uses two other modules (Perceptions and Knowledge, responsible for getting the inputs from what happen in the world and transform them in information which can be interpreted in terms of the domain) and keeps information about what happens in Power Pentagram.

It keeps track about agent skills, goals, the group’s stash in the game, achievement and failure of goals (important for agents and group’s success and insuccess).

6.2.2.4 Behavior

Together with the Group’s module, the behavior’ module was the one which we had to alter the most to implement our model. These two modules altogether are the main responsible for the agents’ behavior, with the group module keeping all the sociological and psychological factors which define the agent and the behavior module handling the agents’ motivational system. The motivational system, as explained in the previous chapter, controls the frequency on which the agents act to a certain objective.

Every time a motivation changes, the agent checks to see if he is motivated to act, and if so, acts accordingly.

The increments in the reactive motivations to act for the group and individual goals are calculated in the same way, as the following rules show. These rules are triggered anytime the agent perceives other agent acting for the group or itself, and add to the previous value for these motivations, the value of that agent’s position multiplied by some constant, divided by

---

**Rule 6.7: Rule responsible for updating the group’s attraction.** Lines 2-10 get the attraction for all members in the group and the values for group success. Lines 13-21 calculate the new value for group attraction.

```lisp
(defrule update-group-attraction
  (bind ?att (/ (+ ?v1 ?v2 ?v3 ?v4) 4)))
  (printout t "att -> " ?att crlf)

(if (eq ?att 0) then
  (bind ?att 50)
else
  (if (> ?att 0) then
    (bind ?att (+ 50 (/ ?att 2)))
  else
    (bind ?att (- 50 (/ (- 0 ?att) 2))))

(bind ?newValue(/ (+ (* 2 ?gs) ?att) 3))
(retract ?f)
(modify ?f1 (value ?newValue)))
```
100. This constant is simply a reference value and can be changed if we want the agent to be more/less reactive.

Rule 6.8: Rules responsible for increasing the reactive components of individual and group motivations in response to an action some other agent (X) did for the group (line 3) or to himself (line 13). This increase is dependent on X’s group position.

To calculate the increment for pro-active motivation for the group’s objective, we used rule 6.9. Group’s attraction and group’s influence are directly related to this increment, while egoism limits it.

Although it can be defined differently, in the beginning of the game, group’s attraction and influence may be null for all agents. This way, the motivation to act to the group’s goal may increase very slowly until the factors influencing group attraction and influence increase (as shown in picture 5.2). This originates very few actions for the group, limiting the group’s success and cooperation. Low group’s success tends to reflect in low group’s attraction and group’s influence. It may become a cycle, without any agent in the group acting to it. To stop this from happening, we had to include a constant to be summed to attraction and influence dependant on the game’s level. This constant decreases as game level increases, eventually becoming 0. It simply works as a “trigger” for agents to start acting in the beginning of the games, when there are no motivations for it.

The motivation for the individual goal increases according to rule 6.10. In this rule, Egoism is directly responsible for the motivations’ increase and group’s attraction and influence reduce this increase, eventually nullifying it for agents with very low egoistic level, but very influenced and/or attracted by the group.
Rule 6.9: Rule responsible for increasing the pro-active component for group goal’s motivation. It is dependent on group attraction (line 7), group influence (line 8) and egoism (line 6). Lines 19-22 calculate the value for the motivation’s increase.

Rule 6.10: Rule responsible for increasing the pro-active component for individual goal’s motivation. It is dependent on egoism (line 4), group’s attraction (line 5) and group’s influence (line 6). Lines 20-24 calculate the value for the motivation’s increase.
Jess, being a rule based system, is very competent in executing all the calculus needed to maintain an updated knowledge base, and generating the agents’ behavior. Its easy integration with Java (since it was implemented in this language), allows keeping the game separated of the agents’ mind. Power Pentagram, implemented in java, is a simple game designed to allow testing our system, by making the agents constantly decide on which goal to pursue, for it obligates them to follow the group’s goal to get points, making them follow the individual goal to get more points that the other agents in the group, and hence win the game.
Chapter 7
Evaluation

If successfully implemented, agents using our system should behave differently when different psychological and sociological factors come into play. To evaluate these differences, we created different groups with different configurations (in terms of the agents' personalities). We kept track of agents' actions and the results of the groups' games. In this chapter we will introduce the methodology we used and the results obtained. After that we will point the concluding remarks about our system's success.

7.1 Methodology

We ran several games with different groups' constitutions, using agents with different personalities. Differences in the groups could be asserted in terms of agents' and groups' performance and behavior. Therefore, we needed to define both the groups' constitution and a methodology allowing comparing groups, taking into account the group as a whole, or the agents who are part of it.
We will begin by describing the different constitutions for the members of our test groups.

7.1.1 Group Constitution

Table 7.1 introduces the differences in the groups' constitutions. A group is defined by the letter G and a number representing the group's id. As an example, G1 represents group 1 and G2 represents group 2.

An agent in the group is represented by the name of the group to which it belongs and the letter A followed by the agent's id number. This way, G1A2 represents the agent 2 in the group 1.

Every agent in the group has an associated personality. In our table we represent the agents' personality as a tuple.

<Neuroticism, Extraversion, Openness to Experience, Agreeableness, Conscientiousness>.

Besides the described fields, there is also a column with a brief description about the group, for better understanding.
<table>
<thead>
<tr>
<th>Group</th>
<th>Agents</th>
<th>Personality</th>
<th>Group Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>G1A1</td>
<td>&lt;50, 50, 50, 50, 50&gt;</td>
<td>A group where all agents have a neutral personality in terms of all traits</td>
</tr>
<tr>
<td></td>
<td>G1A2</td>
<td>&lt;50, 50, 50, 50, 50&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G1A3</td>
<td>&lt;50, 50, 50, 50, 50&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G1A4</td>
<td>&lt;50, 50, 50, 50, 50&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G1A5</td>
<td>&lt;50, 50, 50, 50, 50&gt;</td>
<td></td>
</tr>
<tr>
<td>G2</td>
<td>G2A1</td>
<td>&lt;50, 100, 100, 0, 0&gt;</td>
<td>A group where all agents have maximum values for Openness to Experience and Extraversion and minimum values for Agreeableness and Conscientiousness, hence with maximum values for Egoism</td>
</tr>
<tr>
<td></td>
<td>G2A2</td>
<td>&lt;50, 100, 100, 0, 0&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G2A3</td>
<td>&lt;50, 100, 100, 0, 0&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G2A4</td>
<td>&lt;50, 100, 100, 0, 0&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G2A5</td>
<td>&lt;50, 100, 100, 0, 0&gt;</td>
<td></td>
</tr>
<tr>
<td>G3</td>
<td>G3A1</td>
<td>&lt;50, 0, 0, 100, 100&gt;</td>
<td>A group where all agents have maximum values for Agreeableness and Conscientiousness, and minimum values for Openness to Experience and Extraversion, hence with minimum values for Egoism (maximum altruism).</td>
</tr>
<tr>
<td></td>
<td>G3A2</td>
<td>&lt;50, 0, 0, 100, 100&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G3A3</td>
<td>&lt;50, 0, 0, 100, 100&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G3A4</td>
<td>&lt;50, 0, 0, 100, 100&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G3A5</td>
<td>&lt;50, 0, 0, 100, 100&gt;</td>
<td></td>
</tr>
<tr>
<td>G4</td>
<td>G4A1</td>
<td>&lt;50, 100, 100, 0, 0&gt;</td>
<td>A group where two agents have a maximum value for Egoism and two agents have a minimum value for Egoism. The remaining agent has a neutral personality in terms of all traits.</td>
</tr>
<tr>
<td></td>
<td>G4A2</td>
<td>&lt;50, 100, 100, 0, 0&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G4A3</td>
<td>&lt;50, 0, 0, 100, 100&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G4A4</td>
<td>&lt;50, 0, 0, 100, 100&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G4A5</td>
<td>&lt;50, 0, 0, 100, 100&gt;</td>
<td></td>
</tr>
<tr>
<td>G5</td>
<td>G5A1</td>
<td>&lt;50, 50, 50, 50, 50&gt;</td>
<td>A group with different levels of Egoism/Altruism for the agents. This group has a neutral agent, two altruistic agents and two egoistic agents. We can say that the egoists are “as egoistic” as the altruists are “altruistic”, creating a balanced group.</td>
</tr>
<tr>
<td></td>
<td>G5A2</td>
<td>&lt;50, 70, 70, 30, 30&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G5A3</td>
<td>&lt;50, 90, 90, 10, 10&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G5A4</td>
<td>&lt;50, 10, 10, 90, 90&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G5A5</td>
<td>&lt;50, 30, 30, 70, 70&gt;</td>
<td></td>
</tr>
<tr>
<td>G6</td>
<td>G6A1</td>
<td>&lt;50, 100, 100, 0, 0&gt;</td>
<td>A neutral group except for agent G6A1, who has a maximum value for Egoism.</td>
</tr>
<tr>
<td></td>
<td>G6A2</td>
<td>&lt;50, 50, 50, 50, 50&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G6A3</td>
<td>&lt;50, 50, 50, 50, 50&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G6A4</td>
<td>&lt;50, 50, 50, 50, 50&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G6A5</td>
<td>&lt;50, 50, 50, 50, 50&gt;</td>
<td></td>
</tr>
<tr>
<td>G7</td>
<td>G7A1</td>
<td>&lt;50, 100, 100, 0, 0&gt;</td>
<td>A group where agents have different altruistic levels, except for agent G7A1, who has maximum value for Egoism.</td>
</tr>
<tr>
<td></td>
<td>G7A2</td>
<td>&lt;50, 40, 40, 60, 60&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G7A3</td>
<td>&lt;50, 30, 30, 70, 70&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G7A4</td>
<td>&lt;50, 20, 20, 80, 80&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G7A5</td>
<td>&lt;50, 10, 10, 90, 90&gt;</td>
<td></td>
</tr>
<tr>
<td>G8</td>
<td>G8A1</td>
<td>&lt;50, 0, 0, 100, 100&gt;</td>
<td>A group where agents have different egoistic levels, except for agent G8A1, who has maximum value for Altruism.</td>
</tr>
<tr>
<td></td>
<td>G8A2</td>
<td>&lt;50, 60, 60, 40, 40&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G8A3</td>
<td>&lt;50, 70, 70, 30, 30&gt;</td>
<td></td>
</tr>
</tbody>
</table>
As the table shows, we only varied the agents’ personality in our test groups, which originates different egoistic levels. However, by controlling personality we may control other factors in the agents’ choice, and not only egoism. As figure 5.2 showed, variations in extraversion, conscientiousness and neuroticism are directly related with group success and individual success, which in turn are related with agents’ self-esteem, group attraction and group influence. The following table shows two groups were we control these traits for members’ personality, to assert their influence in our model. By comparing these two groups’ results, we wanted to test differences in the behavior for agents who give more importance to success/insuccess, hence have higher or lower increases in group influence and attraction, respectively.

<table>
<thead>
<tr>
<th>Group</th>
<th>Agents</th>
<th>Personality</th>
<th>Group Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G10</td>
<td>G10A1</td>
<td>&lt;0, 100, 50, 50, 100&gt;</td>
<td>A group where all agents’ personality has maximum values for Extraversion and Conscientiousness and minimum value for Neuroticism. All other traits have neutral values.</td>
</tr>
<tr>
<td></td>
<td>G10A2</td>
<td>&lt;0, 100, 50, 50, 100&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G10A3</td>
<td>&lt;0, 100, 50, 50, 100&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G10A4</td>
<td>&lt;0, 100, 50, 50, 100&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G10A5</td>
<td>&lt;0, 100, 50, 50, 100&gt;</td>
<td></td>
</tr>
<tr>
<td>G11</td>
<td>G11A1</td>
<td>&lt;100, 0, 50, 50, 0&gt;</td>
<td>A group where all agents’ personality has minimum values for Conscientiousness and Extraversion and maximum values for Neuroticism.</td>
</tr>
<tr>
<td></td>
<td>G11A2</td>
<td>&lt;100, 0, 50, 50, 0&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G11A3</td>
<td>&lt;100, 0, 50, 50, 0&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G11A4</td>
<td>&lt;100, 0, 50, 50, 0&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G11A5</td>
<td>&lt;100, 0, 50, 50, 0&gt;</td>
<td>All other traits have neutral values.</td>
</tr>
</tbody>
</table>

Table 7.1 Groups to test group and individual influence’s effects in our model

There is another factor worth controlling in the agents: social-attraction. In all other groups, social-influence is initialized as 0, changing during the game. Social-attraction is related with group influence. This way, we will have another group, G12, where all agents begin with maximum values for social-attraction regarding all other members in the group. In terms of personality, G12 is similar to G1.
We could also test groups with initial values for both the individual relationships for group’s attraction and influence. However, we want those values to emerge, not being handily defined. Although the decision process takes into account several factors, the most important ones in our system are agents’ egoism, group attraction and group influence, directly or indirectly related with agents’ personality and social relations. By controlling these factors, we hoped to achieve different (logical) results, showing our system’s success.

7.1.2 Eval
To test our system, we used Perfect Circle’s Eval [7], a Java application that analyzes the log files from Perfect Circle (or in our case, Power Pentagram) and creates CSV files with the data organized in tables for easier interpretation.

We wanted to test the differences in game’s results in an agent and group levels, as explained next:

7.1.2.1 Group
Using the results from groups G1, G2, G3, G4 and G5, we wanted to test the differences in the behavior for groups with different combinations of egoistic/altruistic/neutral personalities. In order to do that, we analyzed the groups’ performance in terms of final points, successful levels, number of individual and group movements and number of proposals.

We also wanted to test groups where the evolution for group’s attraction and group’s influence are enhanced or not by the agents’ personality. This way, we used the results from groups G1, G10, G11 and G12, also analyzing the group’s final points, successful levels, number of individual and group movements, number of proposals and the needed time to complete 10 levels.

7.1.2.2 Agents
Using the results from the groups G2, G3, G5, G6, G7, G8 and G9, and taking into account the results for agent 1 in all this five groups, we wanted to test the performance of altruistic/egoistic agents in different groups. To do this, we’ll analyze the agent’s individual final points, the agents’ final position in the group’s point ranking and the agent’s number of individual and group actions.

By testing groups G5 to G9, we also wanted to assess the group’s performance in terms of completed levels relatively to the test agent’s performance in terms of points. Whith this, we could conclude if agents are winning or losing in a strong or a weak group.

By using these groups, we expected to obtain different results which, if logical, would show that agents built under our version of SGD Model had different behaviors, also influencing the performance of the group to which they belong.

In the following section we will introduce the results obtained in our tests.
7.2 Results

The 12 games, as expected, originated different results. In this section we will introduce tables compiling the needed information to assert differences in groups and agent’s performance. We will introduce different information according to what we are testing: groups or agents. In section 7.3 we will introduce the concluding remarks from our tests. Table 7.3 introduces the results for groups G1 through G5, G10, G11 and G12. We will introduce the group’s results in terms of the number of proposals and actions, the number of individual actions and the number of succeeded levels.

<table>
<thead>
<tr>
<th>Group</th>
<th>Proposals</th>
<th>Actions</th>
<th>Individual Actions</th>
<th>Succeeded Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>548.0</td>
<td>119.0</td>
<td>31.0</td>
<td>4</td>
</tr>
<tr>
<td>G2</td>
<td>1159.0</td>
<td>69.0</td>
<td>21.0</td>
<td>0</td>
</tr>
<tr>
<td>G3</td>
<td>275.0</td>
<td>165.0</td>
<td>0.0</td>
<td>9</td>
</tr>
<tr>
<td>G4</td>
<td>917.0</td>
<td>205.0</td>
<td>60.0</td>
<td>5</td>
</tr>
<tr>
<td>G5</td>
<td>515.0</td>
<td>254.0</td>
<td>43.0</td>
<td>8</td>
</tr>
<tr>
<td>G10</td>
<td>392.0</td>
<td>208.0</td>
<td>26.0</td>
<td>9</td>
</tr>
<tr>
<td>G11</td>
<td>225.0</td>
<td>106.0</td>
<td>28.0</td>
<td>5</td>
</tr>
<tr>
<td>G12</td>
<td>466.0</td>
<td>198.0</td>
<td>38.0</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 7.3 Groups’ results

In table 7.4, we introduce the results for groups G2, G3, and G5 through G9. To assess the individual differences, we introduce the number of proposals and actions, the number of individual actions, the final points and final position in terms of points in the game, for all agents in the group.
<table>
<thead>
<tr>
<th>Group</th>
<th>Succeeded Levels</th>
<th>Agents</th>
<th>Proposals</th>
<th>Actions</th>
<th>Individual Actions</th>
<th>Points</th>
<th>Final Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>G2</td>
<td>0</td>
<td>G2A1</td>
<td>226</td>
<td>11</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G2A2</td>
<td>136</td>
<td>33</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G2A3</td>
<td>297</td>
<td>16</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G2A4</td>
<td>263</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G2A5</td>
<td>237</td>
<td>17</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>G3</td>
<td>9</td>
<td>G3A1</td>
<td>60</td>
<td>42</td>
<td>0</td>
<td>90</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G3A2</td>
<td>46</td>
<td>39</td>
<td>0</td>
<td>90</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G3A3</td>
<td>54</td>
<td>50</td>
<td>0</td>
<td>90</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G3A4</td>
<td>50</td>
<td>31</td>
<td>0</td>
<td>90</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G3A5</td>
<td>65</td>
<td>26</td>
<td>0</td>
<td>90</td>
<td>1</td>
</tr>
<tr>
<td>G5</td>
<td>8</td>
<td>G5A1</td>
<td>100</td>
<td>66</td>
<td>8</td>
<td>94</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G5A2</td>
<td>91</td>
<td>45</td>
<td>13</td>
<td>105</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G5A3</td>
<td>83</td>
<td>66</td>
<td>16</td>
<td>94</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G5A4</td>
<td>122</td>
<td>31</td>
<td>6</td>
<td>80</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G5A5</td>
<td>119</td>
<td>46</td>
<td>0</td>
<td>80</td>
<td>4</td>
</tr>
<tr>
<td>G6</td>
<td>5</td>
<td>G6A1</td>
<td>225</td>
<td>4</td>
<td>10</td>
<td>70</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G6A2</td>
<td>145</td>
<td>84</td>
<td>2</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G6A3</td>
<td>97</td>
<td>81</td>
<td>5</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G6A4</td>
<td>183</td>
<td>48</td>
<td>6</td>
<td>63</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G6A5</td>
<td>175</td>
<td>50</td>
<td>4</td>
<td>56</td>
<td>4</td>
</tr>
<tr>
<td>G7</td>
<td>9</td>
<td>G7A1</td>
<td>321</td>
<td>10</td>
<td>33</td>
<td>184</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G7A2</td>
<td>76</td>
<td>78</td>
<td>1</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G7A3</td>
<td>80</td>
<td>89</td>
<td>0</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G7A4</td>
<td>94</td>
<td>65</td>
<td>6</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G7A5</td>
<td>107</td>
<td>63</td>
<td>0</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td>G8</td>
<td>10</td>
<td>G8A1</td>
<td>52</td>
<td>49</td>
<td>0</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G8A2</td>
<td>60</td>
<td>55</td>
<td>15</td>
<td>133</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G8A3</td>
<td>55</td>
<td>52</td>
<td>8</td>
<td>116</td>
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</tr>
<tr>
<td></td>
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<td>92</td>
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<td>11</td>
<td>124</td>
<td>2</td>
</tr>
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<td>46</td>
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</tr>
<tr>
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<td>8</td>
<td>G9A1</td>
<td>73</td>
<td>48</td>
<td>0</td>
<td>80</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G9A2</td>
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<td>53</td>
<td>4</td>
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<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G9A3</td>
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<td>65</td>
<td>6</td>
<td>85</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G9A4</td>
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<td>53</td>
<td>9</td>
<td>94</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G9A5</td>
<td>118</td>
<td>21</td>
<td>12</td>
<td>109</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 7.4 Agents' results
7.3 Concluding Remarks

We will introduce the concluding remarks starting with the conclusions we took from comparisons in the group level. We will also introduce the conclusions from individual agents’ comparison.

7.3.1 Group

- By analyzing groups 1 through 5, it’s clear that different levels of egoism for the agents originate different results. This may be noticed simply by looking at the number of succeeded levels. In the extreme case of a comparison of a group with all its agents with maximum egoism (G2) with a group with all agents with minimum values for egoism (G3), we can easily see that an “all-egoists” group have worse results in our scenario.

G2 also has the worse ratio Proposals/Actions. This means that most of the proposed actions were voted “Disagree”. This is explained by the fact that with an all-egoistic group, agents will act less for the group. Other agents will perceive egoism and “dislike more”. Agents tend to disagree with agents they don’t like. At this point it matters to state that when an agent sees its proposed action being disagreed, usually drops the action. However, it will mostly propose it again, and keep proposing with small intervals (usually seconds) until its planning algorithm changes. This justifies the fact that G2 is the group with more proposals, even if theoretically it should be the group with fewer worries about the group’s success. This way, the number of proposals should only be analyzed together with the number of actions. Again, G2 is the group with the worse performance.

- When looking at the number of individual actions, we can see that contrarily to what one would expect, G2 is not the group where more individual actions occurred. For an individual action to happen, the needed gem must be present in the group’s stash. A group with more egoistic agents will spend many group gems with individual actions, emptying the stash, and not “filling” it so regularly (through “Harvest” actions) as other – less egoistic – groups. This way, the reason for agents in G2 not to act more for themselves doesn’t mean that they “don’t want to”, but simply that they “can’t do it”.

- By analyzing G1 through G5, we can see the influence of egoists and altruists in a group. An altruistic group (G3) has better performance than an egoistic one (G2), as we said. But this egoistic influence is also noticeable in more balanced groups: G4 and G5. In these groups, we can see that groups with “extreme egoists and altruists” (G4) tend to have worse performance than groups with more “moderate ones”. This means that it is better to have a group were everyone cooperates (even if just a little) than a group where some cooperate totally, while others care just about themselves. G5, for instance, has a performance which is not much worse than G3’s, only with a worse
Proposals/Actions ratio, showing that even in a group where agents act egoistically (60 individual actions against 0 for G3), it is possible to have success in the game. This group has more individual actions because all agents work for the group, keeping gems in the stash, allowing agents to use them for themselves when modified for it. A group with neutral agents in terms of egoism (G1) has an average performance, as expected.

- Comparing G10 and G11, we can assert differences in behavior for groups of agents which we modeled to potentiate more or less the increase of group’s attraction and influence. As we can see, G10 has less individual actions than G11 (even if with almost the double of actions), meaning that the motivation for individual actions grew slower for agents in G10, because of group’s attraction and group’s influence, which are stronger in this group. G10 also successfully completed 9 levels, against 5 of G11.

- Group’s attraction’s effect in a group’s performance is showed by the comparison between G1 and G12. These groups have the exact same constitution in terms of agents’ personality. However, the fact that G1’s initial values for social attraction are set to the minimum for all agents while in G12 they are set to the maximum, originate different results. G12’s ratio for Proposals/Actions is better than G1’s, also having the double of level’s successes. This shows that group’s attraction also has a real effect in the agent’s behavior.

7.3.2 Agents

- Groups G2, G3, G5, G6, G7, G8 and G9 were used to test agents’ individual performance in the group to which they belong. The “test” agent for all groups is always the agent with id 1.

- By looking at the final position for the agents’ we can see that agents with different egoistic levels, in different groups (also in terms of egoism) have different results. When there is a single egoist in the group (G6A1 and G7A1), that agent is in clear advantage, winning in both tests. Similarly, agents G8A1 and G9A1 show that a single altruistic agent tends to lose the game, worrying simply with the group and nothing about themselves.

- G5, a balanced group, has a good performance, as we already stated. By analyzing the agents’ final points, we can confirm that egoistic agents tend to win the game, for they gather more individual points. Agent G5A1, the only neutral agent, gathers more points than the altruistic agents (G5A4 and G5A5) and fewer points than egoistic agents (G5A2 and G5A3).

- The existence of a highly altruistically agent in a group contributes for the success of the group, even when all other members are egoists. This is proved by the comparison between the results of G2 and G8. On both these groups, all agents are egoists, except for agent G8A1 which is highly altruist. By looking at the number of successful levels in these groups we can see the effect of just one
egoistic agent. Agent G8A1 prejudices himself (ends in 5th place) but works as a dynamo for group’s success.

If we analyze G8, we can see that it succeeded in more levels than a fully altruistic group, like G3. The agents’ actions may end in success or insuccess, with the difference between these two outcomes being partially dependant on luck. Probably agents in G8 were more “lucky” than those in G3, and that may explain the difference in these groups’ results.

Analyzing G9 shows that the existence of an altruist has a positive influence in group’s performance not only when other members are egoists, but also in the case of neutral members (except for agent G9A1).

- The existence of an egoistic agent in a group of altruists doesn’t have a big effect on group’s performance, as proved by the results of G7 and G3. Both groups succeed in 9 levels, because except for agent G7A1, all members are altruists. However, by analyzing G7, we can see that one egoistic agent in a group of altruists clearly is in advantage, using other members’ work to increase his success. In fact, G7A1 is the agent which scores higher in all test groups. The most egoistic agent in a group is always in advantage. This shows by analyzing G6, where G6A1 takes advantage of other – neutral – members.

- Analyzing groups 5 through 9 shows that the differences in egoistic level are noticeable by the behavior and the results vary not only on group’s level, but also on agents’ level, proving that our model successfully implements the mechanisms allowing agents to choose between a group’s and an individual’s goal.

- The results of the test groups also proved the influence of a single agent in a group. The influence in group’s performance is more noticeable for a single altruist in a group of egoists. In this case, the altruist gets sacrificed for the group’s success. The existence of a single egoist in a group of altruists doesn’t have such a big influence in terms of group’s performance. However, when this sort of thing happens, the egoist is in clear advantage over the other agents, using their work for the increase of his own well-being.
Chapter 8
Conclusions

The work presented in this dissertation intended to create a model to allow agents that, while acting in a group, have the ability to decide whether to work for the group or themselves. This decision is present in all semi-competitive games, but is usually centered on utility. When searching systems related with ours, we found several which used complex planning algorithms, notions of teamwork, emotions and personality, but none of them combining more than one factor. We wanted our model to allow agents to base their choice not only on utility, but mostly on Psychology and Sociology. This way, we wanted to achieve believable behavior, with agents emulating human behavior when in these types of situations, and clearly distinguishing the actions of different agents.

One of the possible applications of our thesis is clearly in games. With the appearance of online gaming, the social dimension of games is now again present in some of the great industry successes. But we believe that a social dimension can be achieved not only with human players, but also with autonomous characters. We hoped that agents implementing our model could be a step forward in that objective. Besides games, our model could also have application in other areas, like live simulation or learning.

We started our work by a literature review, trying to find some documentation on research on a subject related with ours. The first difficulty was that we were unable to find any work which is exactly centered on our problem. Nevertheless, we found research on several areas which, although not using all the premises we established in terms of the decision process, worked as a good starting point, by successfully showing systems where agents’ decision process is centered in one (or more) of the factors we wanted our model to consider.

Our model was implemented extending and adapting Prada’s SGD Model, which already implemented a knowledge base including the agents’ personality, social relations and a motivational system allowing agents’ decision, among other characteristics explained in chapter 4. Our model’s expansions were mainly centered in the agents’ knowledge base and motivational module.

We introduced the goal level, clearly distinguishing between group and individual goals. We also introduced agent’s egoism, working as a factor motivating agents to work for themselves, and group’s attraction and influence, working as factors motivating agents to work to the group’s goal. Related with these factors, other levels of knowledge were introduced. The complete information added to the knowledge base of the original SGD can be seen on figure 5.1.

The information existent on the knowledge base, together with outer stimulus from the world, defines the variations in the motivations for agents to follow the group or individual goals. The motivations can be of the reactive or pro-active types. Reactive motivation to individual goal increases when an agent X detects other agent Y is acting for himself, or if X gets discouraged by other agent Z. Reactive motivations for group goal occur when agent X detects other agent Y
is acting for the group, or when is encouraged by Z. Agents’ Egoism is directly related with the increase in the pro-active individual motivation and indirectly related with increases in the pro-active motivation for group goal. The group’s influence and attraction are directly related with the increase in the motivations for group goals, and indirectly related with the motivation for the individual goals. An agent acts on a goal when the sum of the corresponding motivations reaches a given value.

After implementing our model, and to test its success, we created several groups with different characteristics playing Power Pentagram. It is a semi-competitive game, adapted from Perfect Circle, where agents have to cooperate to complete the levels, and compete with others to win the game. Our tests proved that for different agents we get different (logical) results, namely:

- A group where agents are mostly egoists (or totally) has worse results than a group where most of the agents are altruists.
- The existence of agents with higher levels of egoism in a group, even if the group is balanced, will jeopardize the group’s results.
- Groups where agents are more influenced and/or attracted by the group, cooperate more and have fewer individual actions.
- A single agent’s performance in the group is dependent on the group’s constitution and its characteristics. An egoistic agent in an altruistic group is in clear advantage. An altruistic agent in a group of egoists probably loses all games. A neutral agent in a group with two altruistic agents and two egoists will lose to the egoists and win to the altruists.
- The results also proved the influence of a single agent in a group. The influence in group’s performance is more noticeable for a single altruist in a group of egoists, with the altruist being sacrificed for the group’s success. The existence of a single egoist in a group of altruists showed that in this case the egoist is in clear advantage over the other agents, using their work for the increase of his own well-being.

The analysis of the tests’ results showed that the differences in egoistic level are noticeable by the behavior and the results not only on group level, but also on agent level, proving the efficiency of our model.

Our thesis successfully implemented a model for agents to deal with the choice between an individual and a group goal. The results of the executed tests showed that this choice can be based in psychological and sociological factors. Our test scenario, although simple, suggested that our model achieves logical results when we control the factors influencing the agents’ choice. We hoped that with this dissertation, we could establish some ground that motivates further research in this area, by expanding the model and applying it to more complex cases.
8.1 Future Work

There were some open issues in our dissertation which we believe may be relevant for further research. The following list introduces such issues:

- It would be interesting to test the model with human users. Different users could play the game and answer a questionnaire where they should answer about how believable the autonomous agents’ behavior is, and how interesting it was to use our model. These tests were planned in the beginning of the thesis, but weren’t executed by lack of time. It would also be interesting make a Turing Test, where users in different computers (and different physical space) would play in groups with other humans and autonomous agents. We could assert if the agents were able to “confuse” human users, or if they could easily understand which characters were autonomous and which were controlled by other humans.

- Power Pentagram is a simple, academic game. The system could be tested in a more commercial game. For instance, in a RPG where a guild was sent in quests where they have the need to defeat an enemy and catch individual items, for instance. It would be interesting to test the agents implementing our model in a more complex environment.

- The model could also be implemented in other applications, like a life simulation game, where once adapted to a society and not simply a group, we could access its results in longer terms.

- The system could be expanded with more psychological and sociological factors that also affect humans. This way, we could achieve a behavior even more believable.

- The agents implementing our system have a simple planning algorithm allowing them to decide which actions are appropriate to achieve a given goal. It would be interesting to implement other planning mechanism which would allow the agent to execute some strategic thinking on which objective to pursue at a given time. This algorithm would consider the agents’ points in the game, its adversaries’ points or the time until the end of the level, among other factors. According to this algorithm’s output, the agents’ motivations to the individual and group’s goals would increase more or less.

- In our system, when an agent is motivated to act, it uses a gem for his own well-being. When there is no such gem in the group’s stash, the agent does nothing. It would be interesting to have an individual action which is not dependant on the existence of gems for the agent to act individually. This action should clearly prejudice the group, benefiting the agent. This way, we could access if the agents’ individual actions harm the group without them being dependant on anything, and always being ready to trigger.

- In the case where the agent does nothing because of the lack of a gem in the group’s stash, it would be interesting to have a planning algorithm allowing the agent to make a plan to get the needed gem.
References


