Universidade do Minho
Escola de Engenharia

Gilberto Martins Felgueiras

Social Simulations of human behavior in virtual agents for sustainability management platforms

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Cesar Analide
Fábio Silva

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Resumo

O impacto negativo que o ser humano tem provocado no meio ambiente precisa de ser contrariado, assim, são necessárias soluções para atuar nesse sentido, soluções estas que precisam de assegurar a sustentabilidade entre questões ambientais, económicas, e sociais. Esta dissertação aborda este tópico no contexto de sistemas de informação, mais concretamente, na interacção social de uma pessoa com o meio em que está inserida. A ideia surgiu para colmatar uma lacuna existente nas soluções computacionais para gestão de sustentabilidade, pois estas centravam o problema nas questões externas ao utilizador, descartando o seu grau de conforto. Para isso, foi implementado um sistema de simulação de emoções humanas, baseado nas características psicológicas dos utilizadores, com o propósito de integrar este sistema numa plataforma informática de apoio à sustentabilidade. Esta simulação pediu emprestado os conceitos de Computação Afectiva, área da informática que tem ganho importância nos últimos anos, e é responsável por fundir os trabalhos em psicologia e computação. Assim, o trabalho presente nesta tese apresenta dados sobre a relação psicologia, sustentabilidade, computação afectiva e como estes campos se podem interligar. Foi desenvolvida uma plataforma utilizando tecnologia de agentes virtuais que recolhessem informações sobre o ambiente e procedessem ao cálculo de um estado emocional. Os resultados obtidos com o trabalho desenvolvido foram animadores, e revelam que este tipo de simulação poderá ser uma vantagem, para que um sistema de suporte à sustentabilidade, baseado em inteligência ambiente, possa tomar decisões e atuar sobre um meio, tendo informação prévia ou uma hipótese do estado emocional dos seus utilizadores.

Palavras chave - Computação Afetiva, Sustentabilidade, Inteligência Ambiente, Psicologia.

Abstract

The negative impact that humans have caused in the environment needs to be counteracted, thereby solutions are required to act. In this sense, these solutions need to ensure sustainability from environmental, economic, and social issues. This dissertation addresses this topic in the context of information systems, namely, social interaction of a person with the environment in which he operates. The idea came to fill a gap in computational solutions for sustainability management, as these focused the problem on the external issues to the user, discarding their degree of comfort. For this it was implemented a simulation system of human emotions based on psychological characteristics of users, in order to integrate this system into a computing platform to support sustainability. This simulation borrowed the concepts of Affective Computing, area of computing that has gained importance in recent years, and is responsible for merging the work in psychology and computing. Therefore, the present work in this thesis presents information on the relationship of psychology, sustainability, affective computing and how these fields can be interconnected. It was developed a platform using virtual agent technology to collect information about the environment and should proceed to the calculation of an emotional state. The results obtained from the work were encouraging, and show that this type of simulation can be an advantage for a system to support the sustainability based on ambient intelligence, It can make decisions and act upon an ambient, having prior information or hypothesis of the emotional state of its users.

Keywords - Affective Computing, Sustainability, Ambient Intelligence, Psychology.

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Glossary

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AC Affective Computing, p. 17.

ACL Agent Communication Language, p. 49.

AI Artificial Intelligence, p. 25.

AmE Emotional Aware Ambient Intelligence, p. xi.

AmI Ambient Intelligence, p. 25.

B

BDI Beliefs, Desires and Intentions, p. 23.

BFP Big Five Personality, p. 13.

F

FFM Five Factor Model, p. 13.

FIPA Foundation for Intelligent Physical Agents, p. 49.

G

GUI Graphical User Interface, p. 49.

H

HCI Human-Computer Interaction, p. 9.

HMM Hidden Markov Model, p. 19.

J

JADE Java Agent Development Framework, p. xii.

JUNG Java Universal Network/Graph Framework, p. 54.

M

MAS Multi-Agent System, p. 23.

MBTI Myers-Briggs Type Indicator, p. 15.

N

NES Newtonian Emotional System, p. 19.

NPA Newcastle Personalty Assessor, p. 60.

NUI Natural user Interface, p. 26.

O

OCC Orthony, Clore and Collins, p. 3.

OCEAN Openness, Conscientousness, Extraversion, Agreeableness, Neuroticism, p. 13.

P

PAD Pleasure Arousal Dominance, p. 20.

PHESS People Help Energy Savings and Sustainability, p. 34.

R

RRR Reactive, Routine, Reflective, p. 21.

T

TPB Theory of planned Behavior, p. 11.

X

XML Extensible Markup Language, p. 42.

Chapter 1

Introduction

Nowadays, the world is facing a serious environmental crisis. This is due to the increase of the world population (from three thousand million to seven thousand million people between 1960 and 2012) that makes domestic consumption such as the consumption of water, electricity, natural gas, petroleum and wood increase reflecting the social need of them [72]. To circumvent this problem, consumption should become lighter in the use of natural resources. In fact, in the past two decades, and despite the fact that household electronic appliances are more energy-efficient than in previous years, the number of appliances that every family has at home have soared making the power consumption also increases [35]. A small change in the domestic habits from individuals and families can save up 10% of household energy consumption [15]. The problem is that a change in personal habits can be a hard barrier to break.

To promote these changes, this work suggests a computational system to be aware of the behavior of people. This system has to take decisions by itself or it has to notify user to perform a task. To do so it must be aware of the context in which the user is inserted and realize how he reacts to certain events that are called into action i.e. it must perceive the users behavior.

The expression of feelings and emotions in all human interactions with nature plays a key role in the cognitive process, and also reflects his state of comfort before all activities that, directly or indirectly, are involved. In psychology, Pavlov's work on conditioned reflexes showed that reinforcement of a positive emotion is a mechanism for teaching [61]. In neuroscience, it is assumed that feelings and emotions are part of a complex neurobiological mechanism, but not abstract, that evolves continuously and is learned through interactions with the environment [21]. This emotional mechanism helps man give priority to certain events, to understand the environment in which he is inserted, and also helps him to communicate with others through body language. Therefore, in the computing sciences the interest in this human factor came naturally, thereby giving rise to a new field called affective computing, which aims to study and implement in software and robotics, simulation techniques and detection of emotions in order to help a system to be more reliable and to bring more comfort to the interaction between man and machine. The Affective Computing is directly related to Artificial Intelligence and Autonomous Systems, where the simulation of emotions in virtual agents has an essential role in making decisions made by them, thus it is possible to reduce the non-determinism of this process.

This document gives a description of the motivations and objectives that led to this project. Also, it presents a review of literature that addresses the relevant topics and concepts and it introduces some works that were made in this context. It presents the work done so far and the project in which it appears.

1.1 Motivation

This work addresses the need of the planet's inhabitants to reduce their impact on nature, promoting positive attitudes in their daily behaviors. It also discusses how the IT tools can play a major role in this topic. This leads to the motivation to use these tools to facilitate its users to become more aware in relation to expenditure of natural resources. In particular, it discusses ways to tailor a system to the emotional needs of users and make these users to become more friendlies about the system. Another motivation associated with this work is determined by "how human characteristics such as feelings and personality can be used in the implementation of computational agents?" and "how these agents will proceed?". When environments are related with virtual agents, what data will be significant; What data can be expected to receive from this three actors - Environment, People and Virtual Agents - in order to become sustainable. The idea behind these motivations is to counteract the lack of systems that aims to adapt the sustainability indicators, to adjust their social indicators

1.2 Objectives

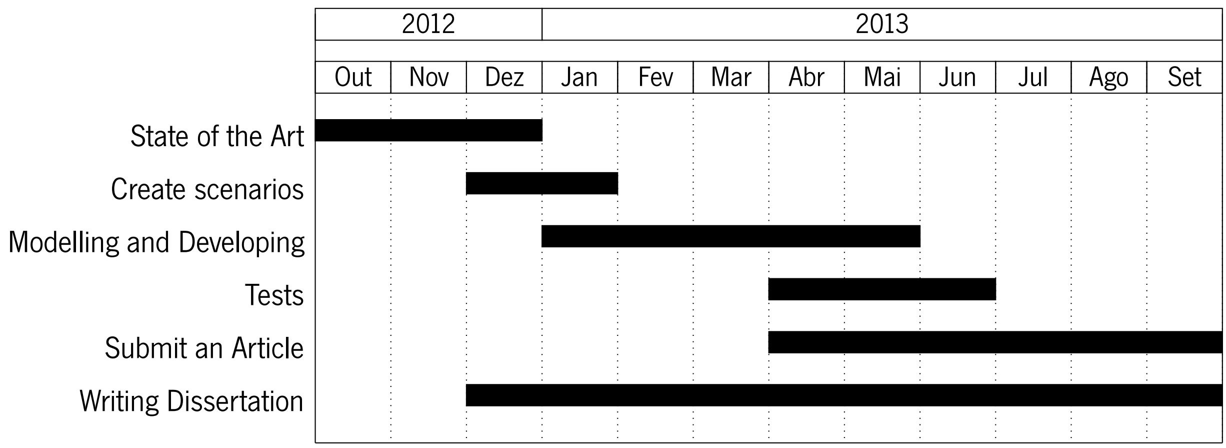
Under this project, it is necessary to understand how the environment experienced by the user and the decisions made or broadcast by the system can trigger feelings and emotions in user. This brings the main objective of this master's project: to build a social simulation system, allowing endow virtual agents with behaviors, reactions and emotions, realizing how they can influence a sustainable management platform. Thus arise other goals to achieve:

- Map the events and environment variables;
- Simulate emotions in virtual agents with personality induced;
- Bring the personality of the user to a computable set of parameters;
- Simulate emotions for a group of virtual agents (eg. Family).

The scope of this project will be map the events of the world, one has to take attention to variables that are significant to people's stimulus and how these can be related to promote a sustainable way to live, helping the creation of a social simulation environment based on human psychology upon a sustainable management platform.

1.3 Work Plan

The literature provides data showing that it is possible to create an emotional system based on human psychology to allow make decisions, a system oriented to the management of sustainability, more accurate and involving the user in the construction process of a greener mentality. The the conducted research demonstrates that many of simulation models based emotional activation in OCC model and to circumvent this information flow a complexity of the data, MAS appear as a reliable alternative. This complexity of data obtained through sensors provides tools for working on the reasoning of virtual agents and thus increase the degree of structured information on the environment so that you can act on it. Improve the world we live in, it may not be easy but with one person at a time to change his behaviors can bring global benefits. This literature review redefined the future work plan.



This work plan was made according with the duration of this Master's project, and with the considerations of what expect from each phase. The 'Modelling and Developing' stage had a duration of five month. The stage 'Submitting an Article' lasted most of the project because it was always a objective to achieve. The 'Writing Dissertation' was a duration of ten months so that the progresses were always recorded in a timely manner

State of the Art - as stated previously is the phase of the lifting of concepts and studies in the literature relevant to the project;

Create scenarios - relating the state of the art with scenarios, perceiving all the possibilities and how to approach the problem to reality;

Modelling and Developing - modelling the architecture, and its implementation in a real simulation system, according to the prospects achieved in earlier stages;

Tests - realization of test to validate the system implementation

Submit an Article - attempting to submit articles in the scientific community for the dissemination of this same project and/or projects where this one is involved;

Writing Dissertation - writing a report of all phases past, to stay on a register and help disseminate the results, methodologies and bibliography.

The initial declaration of these phases has the purpose of providing a way, that during work, there is no deviations which delay the process, maintaining a flow of task for check and proceed to next.

1.4 Research Methodology

To following a practical sequence in the research, it was used the Action Research Methodology. The idea is to collect information from literature, and then reflecting upon it and discuss it with supervisor and colleagues to form a plan to act. For validation of this step, it is made the plan implementation, once implemented the same steps are repeated, but this time the sequence of steps starts with observation of the implementation, it is made the reflection, constructed a new plan, and then it is implemented, for example adjusting some parameters on the previous development. Using this guideline promotes the observation of the chain act/reacts, and also it decreases the unusable work [44].

1.5 Structure of the Document

On the document structure it is included a introduction chapter that focus on a generic idea of the report's content, broach the Sustainability summoning Information Technology to its management. This section also makes reference to the motives attached to project and its objectives.

The state of the art chapter makes reference to several relevant concepts and to the technology available today to the continuity of this process, for example, there are explained topics like affective computing, ambient intelligence, psychology and sustainability, and also is presented a discussion to relate all of these topics.

In the chapter of relevant work are presented some applications based on the thematic of this report and it will be made a brief discussion of these past works about their limitations and breakthroughs and how these were addressed in this work. Also the PHESS section points to the main system that this project is inserted - an ambient intelligence based system for promoting sustainability by adjusting indicators of economic, social and environment. With this system it was possible to have a concrete platform that provides data if the environment.

Work developed chapter presents the actual work developed presenting the techniques that were used and the problems that were emerged in all processes, also it was made a brief discussion about all approaches.

The present report provides a chapter of the tests that shows the whole process it was necessary to validate the developed work well as the findings achieves from these tests.

For the last chapter was made the main considerations about all work, and its limitations and also it presents the future work to be done.

Chapter 2

State of the Art

To perceive the context of this work, this section introduces several concepts that are important to retain. The information contained was achieved with the use of some articles that explain: how the concept of Sustainability can be modelled; the problems of the psychology of sustainable behavior; models of human psychology and also which fields of computer science may be relevant to a modelling system based on a platform to support sustainable behavior.

2.1 Sustainability

This section presents the general concept of sustainability, and its psychological issues along with strategies to solve them provided by some authors that afford considerations about humans behavior that are relevant to this context.

2.1.1 Definition of Sustainability

The United Nations have defined Sustainability concept by "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Due to the importance of sustainability, different authors have defined measures to assess and characterize sustainability. Actually, Sustainable is based on three different indicators, used to measure the sustainability of a given environment [2, 73](Figure2.1). This approach is based on three different types of indicators - social, economic and environmental - with the specific restriction that until all those values are met, a system cannot be deemed sustainable. This is a theoretical diagram of the sustainable development.

Currently, government policies indicate that the economical concerns are larger than the social and environmental worries. Therefore to make the world a sustainable place there must be a delicate equilibrium between indicators, where actions to optimize one indicator might affect any of the other two. This work is

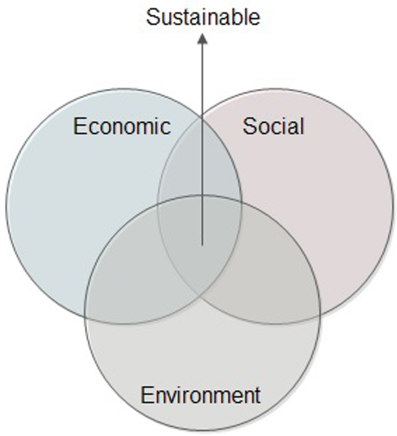


Figure 2.1: Three pillars of sustainable development.

addressed to domestic impact on sustainability issues.

To create a system based on human emotional architecture to induce changes on people habits we have to be aware of psychological barriers that prevent change.

2.1.2 Psychological Issues

A computational platform to support and promote a sustainable environment, in addition to touching in the energetic and economic problems, must take all the decisions as smoothly as possible so as not to cause discomfort to the user, reinforcing a positive attitude towards issues related to sustainability. For that, we need to analyse carefully cues in behavior and emotion in the users and answer to,

> "Why people engage in unsustainable behaviors despite their concern to change them? Why people go out of their way to behave sustainably?" (Manning [50])

This topic triggered several psychological researches [10, 57, 30, 74]; a common conclusion gathered in the articles indicates that humans are not always conscious about their behavior, i.e., human thinking is composed by two reasoning systems. One is a rule-based system that invokes rationality and this process takes a little time to conclude; the other is the associative system - it is spontaneous and unconscious and motivated by memories that link the event to past feelings about it, this memories are turned into habits [67]. Psychology of sustainable behavior area despite focus measurement and understanding the causes of unsustainable actions also tries to guide and supply clues to change them. In her work, Manning shows some aspects that are necessary to consider for promoting and instilling in people sustainable behaviors [50]:

- All behavior is situational, i.e., when the situation or event changes, the behavior changes too, even if exists intention to perform a certain action, circumstances can make it changes;

- There is no unique solution, people are all different because they have different personalities, they are inside in a specific culture, and they have distinct individual history;
- Fewer barriers lead to a great effect, when a person is facing social, physical and psychological obstacles his attitude tends to flinch, for example, the lack of knowledge about a procedure leads to a retreat;
- There is no unique form to act, to make an action for attempting a goal a sustainable one, there are many sustainable paths that a person can pass.

To overcome these barriers to sustainability, it is suggested to engage multiple users in a competitive environment of positive behaviors so that participants have the need to strengthen their knowledge of sustainable actions and also have the need to overcome social, psychological and physical barriers, involving them in a single culture with the aim of changing behavior in various situations and sharing their experiences. In this sense, the use of computer tools can help people overcome the barriers of unsustainable individual behavior. These systems must have the ability to suggest or convince the user, permanently, to improve the standards of behavior. The usage of such system does not pass immediately from a novelty to an abandonware, the interaction between the human and the computer (HCI) has to be smooth as possible not causing distress to the user; his relationship with computer must stay positive so it can be maintained. This objective can be achieved by making use of Affective Computing which is an area supported with certain concepts borrowed from Psychology.

2.1.3 Computational approach

T o make suggestion the user, a Sustainability management system has to perceive the environment around him and his standards of consumption and living. To have this capacity, a system has to collect external data and reasoning upon them, this goal can be achieve using Ambient Intelligence techniques (section 2.3.7), this area uses techniques and hardware from other areas, such case-based reasoning from Artificial Intelligence, or electric sensors to receive data from environment, even so from Autonomous System when actuators are used.

However, beyond that it is necessary to assess sustainability indicators so that they may be adjusted, for example there are studies that use Key Performances Indicators to evaluate a sustainable performance in Intelligent Buildings [6], also there are researches geared to creating indicators for the evaluation of energy systems [3].a system of sustainability management has to make decision upon the environment, therefore researchers have developed rules for making this decision, such as the support decision model developed by Doukas el al. that use a set of rules that relates all energy building's operation [22].

The present work is under an ambient intelligence based project called PHESS (section 4) that uses indicators to measure sustainability of domestic environment and attempts to make decisions upon it, for the measure of indicators it uses sensors that have the ability to get information about temperature, humidity, noise, illuminance and energy consumption. Gathered the data they are treated to have meaning.

2.1.4 Discussion

The previous section is related to Sustainability as a study case, specifically issues about the conduct of humans in their daily activities. The psychology of human beings appears, in this context, as barriers that difficult the process to achieve a balanced environment. Knowing these limitations when population tries to make unsustainable acts into sustainable ones helps to isolate the problem and also assists in the research of specific content that could explain, simulate or support this action. Due to the fact that "all behavior is situational", "all people are different" led to research in behavioral psychology such personality, habits, and emotions features of human mind and how can be related the various "sustainable paths of action" and the person to whom it is suggested i.e. if there are, like Manning says, various forms to be sustainable for the same action and all people are unique, then there should be some forms that are more indicated to certain people than others.

Also it is suggested a computational method that could help the resolution of some problems relating people and their surround, helping them to change their attitudes face to their own environmental impact. Knowing their sustainable indicators people could be more alert to their own impact. The indicators, beyond assess to building sustainable performance, could be used to measure specific action of users, or specific events in the world. This information of concrete actions or events in the terms of environment, social and economics impact could help alerting the user in a specific way.

The next two sections (2.2 and 2.3) will try to promote some concepts among Psychology and Computational Methods and in this last section it will be explained the concept of Affective Computing and it will be addressed the concepts of Ambient Intelligence.

2.2 Psychology

Sustainability is a multi-disciplinary area based in other fields such as economy, environment and sociology [10], these fields are interconnected but humans have different psychological approaches for them, so that is necessary to perceive the behaviors behind each. This will enable the creation of computational models for predicting behaviors and emotions more accurate. These models have to relate the mindset of human being and the various external stimuli.

2.2.1 Predict People's Behavior

To help people to act upon a sustainable form, a computational system it need to give them suggestions to improve their relation with the world's objects, resources and electrical devices. For this decision help, it is necessary to perceive the human behavior and analyse their past interactions in ambients that surround them, with the propose to find patterns and somehow predict their future interactions.

To predict actions, psychology field tries create methods to perceive the person's past actions and to get clues of what will be his future actions. In order to formulate methods to achieve this goal Ajzen presents a model called "Theory of planned behavior"(TPB) [4] (Figure 2.2).

This model considers that behavior is formulated by weighing three forms of individual beliefs such control beliefs, behavioral beliefs, and normative beliefs, that regulate the intention to perform a certain action, i.e., the final stage of the model is activated by how strong is the intention to perform it; this intention is calculated summing the weights of all beliefs and to understand the flow of information it is necessary to determine these three forms of beliefs processed by three initial states:

Perceived behavior control – this state determines if it is an unintentional behavior or not, if so, the person does not have time to formulate an intention, and the behavior is thrown; otherwise the intention is formed with the help of other states, i.e., this state treats the control beliefs;

Subjective norm – dataset of moral and immoral statements, normative beliefs , and cultural boundaries;

Attitude toward the behavior – perceived if the target behavior worths the effort, for example, a person believes that the behavior he will trigger will have a bad consequence for him, so he won't launch this behavior.

To undermine the weights of these beliefs, Ajzen proposes the usage of questionnaires to self report [5] and to obtain wanted data from questions is defined a set of parameters. First, it is necessary to define the action to predict, according to a structure defined in Ajzen's work - $behavior(target, action, context, time)$.

Then it is necessary to define a population group to study the formed action. Next, to acquire information about population's beliefs (behavioral, control and normative), questions are made using a semantic differential scale i.e. seven-point rate scale with bi-polar adjectives at begining and end, for example:

$$like\ 1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7\ dislike$$
$$pleasant\ 1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7\ unpleasant$$

To evalute the intention to perform the formed action, the answers are summed to measure the strength of beliefs. This theory presents a model for perceive if a person or a population set will repeat a behavior.

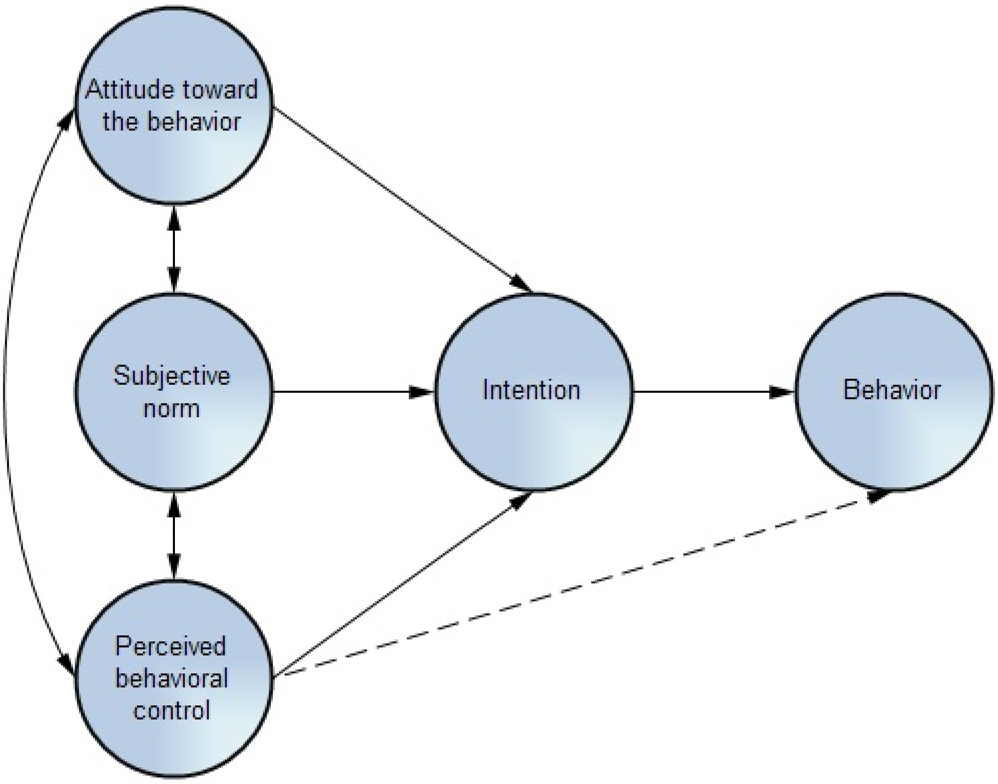


Figure 2.2: Theory of planned behavior by Ajzen [4].

This model is used in works that investigate and incite sustainable behaviors, for example, TPB was used to analyse laws imposed by Chinese government to reduce consumptions of water – reduce time of bath; reuse water for flushing toilets – these rules affect directly the people habits and behavior. So the goal of this work was to predict the intention of habitants to change their toilets into dual-flush toilets and, in conclusion the use of TPB by itself cannot predict a precise value of intention [45]. Another study which used this model to predict green behavior on recycling issues once again reported by Tonglet et al. the model by itself do not response precisely to determine the goal [74].

In both works, the TPB has been changed to meet the needs of the objectives, moreover provides a starting point to understand how behavior can be anticipated thereby helping governments, associations and groups to take policies that are appropriate to people's perspectives without having disruptive and attitudes that may gradually and almost naturally change their behavior.

Other propriety in the mind set related with memory are the habits, which are an implicit part of behavior prediction. It explains why it is difficult to people change their behavior because it has a pervasive effect on diary conduct, they are activated by indicators of the event such as hour of the day and local. In literature, the concept of habit is deduced in a spectrum from weak to strong, i.e., a certain habit is more probable to occur than other and this is achieved by the times that are repeated in life [54]. Other characteristic in the human nature is the existence of emotional system that can influence a person's behavior; it has the task to filter the information that comes from external outcomes producing a variable emotion which affects all inherent processes – decision making, cognitive [21, 65].

2.2.2 Relate Behavior with Ambient Conditions

The humans have the need to control their surroundings and to believe that they are auto-effective; the lack of these features can produce negative affect, reducing motivation, cognitive deficit [7]. However in a domestic environment exists stressors variables that its inhabitants can not control or predict such as noise [16], heat [28] even air pollution [23].

In a domestic environment, the perspectives of control situations are larger, the effect of these variables may be larger, and thus it creates emotions and states of mind more negative than in public spaces [71]. A Behavior like aggression may be provoked by extreme condition, for example a very noisy room. Also this stressors can affect the process of decision making [24].

Psychological and physiological adverse ambient conditions can produce significantly changes in a person. However, authors orient this topic to a set of variable. In noisy ambient people have different sensitivity to sound volume, for example sensible people to sound have more predisposition to be more anxious [40]. Others if provoked can be aggressive or hostile [17].In Hot places psychological states occur if temperature increase to high degree, such irritability, fatigue and discomfort. Very high degrees can provoke hostile or violent attitude [24].

When a system can access this type of information from the environment then it is also possible to realize the kind of emotional actions that may arise therefrom.

2.2.3 Personality Psychology

Other properties of the human mind, which are not addressed by the previous model and that are necessary to consider, are the personality and the habits of the individual. Personality – determines how a person reacts intrinsically to certain events - is like a long-term emotion, because it is formulated in the early years of life and remains almost unchanged during lifetime. The Big-Five Personality (BFP) theory – also called Five Factor Model (FFM)[20] – is a common definition of personality traits that indicates that is possible to separate it into five properties - OCEAN [48] .

Openness - it is the tendency for openness to new experiences, a characteristic of individuals with a great "opening for the new", being interested in art, creative, adventurous, and not sharing common ideas. A low degree of this essential makes an individual more traditional, with a preference for things less complex;

Conscientiousness - it is a feature of people wishing to do what is right, being therefore more organized and having their impulses under control. They are also more self-disciplined;

Extraversion - this type of property is often expressed by people who are extrovert, they have a positive emotional experience in various events and they are socially active. A low incidence of this feature is common in introverted people who like to be more isolated from society;

Agreeableness - this particular tendency contribute to a person with the ability to be compassionate and cooperative toward others, with an optimistic outlook of the society. On the other hand, people with a different predisposition are generally more skeptical, and tend to put their interest above any other;

Neuroticism - people with a high degree of this propriety have proneness, in general, to be more emotionally reactive and more vulnerable to stress, interpreting normal events as a threat. On the other hand, people with a different disposition are generally individuals with less stress, emotionally stable and more peaceful.

For mapping personality of an individual into FFM the authors use empirical methods such as surveys or questionnaires. There are various types of this kind of self-reports, below, are listed some of them.

NEO PI-R™ - The revised NEO (Neuroticism, Extraversion and Openness) Personality Inventory is a measure of 240 item to assess to the Big Five traits. This questionnaire has a duration of 30 minutes to 40 minutes plus 15 minutes to obtain a result [20].

NEO™-FFI-3 - NEO Five Factor Inventory is a short version of the self report above, that has 60 items, a duration about 10 to 15 minutes, and takes 5 minutes to have a score. [20]

IPIP NEO - International Personality Item Pool based on NEO PI-R™is a free questionnaire with 300 items, takes 30 to 40 minutes to conclude and because this is an online test the score is automatic. IPIP NEO also has a shorter version with 120 items and takes 10 to 20 minutes. [31]

NPA - Newcastle Personality Assessor based on all the above questionnaires, with 12 item [55]

Although, the number of questions in these self reports has an impact on the accuracy of big five values, the more questions to answer more accurate the results will be. The NEO PI-R™is the most precise, it was designed under a wide range of data collect from various types and group of persons, even the designer of the IPIP NEO admits that NEO PI-R™are unique and produce the most precious results [31]. However, this report is too long and when it is necessary quick information about the personality of a user it is suggested to use shorter versions like NEO™-FFI-3 or even NPA; to these shorter versions the questions from other extensive reports are mined and are only chosen the most relevant. For example NPA dimensions scores have high correlation with the dimensions scores of IPIP NEO [26].

The OCEAN model does not fully explain the personality but provides a good start and with time there will be new variables that will approach the values from FFM to reality [52].

This OCEAN model is one of the metrics used to construct personality traits and there are others, for example Myers-Briggs Type Indicator MBTI, also called the big four, this method evaluates personality under four dichotomies,

- Sensing - Intuitive;
- Extravert - Intravert;
- Thinking - Feeling;
- Judging - Perceiving.

In theory, these metrics suggest sixteen types of personality [14]. The MBTI is criticized by psychology researchers because, although it is possible to correlate it with FFM some traits such,

- Extraversion←(Extravert - Intervert);
- Conscientiousness←(Judging - Perceiving);
- Openness←(Sensing - Intuitive);
- Agreeableness←(Thinking - Feeling).

When trying to correlate FFM with MBTI the value of Neuroticism has no correspondence. This omission on MBTI of a "fundamental dimension of personality" such Neuroticism is one of the reasons why psychology researchers choose FFM instead of MBTI [27].

2.2.4 Discussion

This section introduces some concepts of human psychological, such behavior and how it can be perceive and predict, and personality and how it can be measure. To isolate this two properties, researchers use self-report questionnaires. To predict behavior, TPB, beyond this questions, it has a pre-process defining the population group and the specific behavior to analyse. To measure personality these surveys only have questions to choose. When concluded they have a post-process that is analyse the result.

By defining population sample as a family or a group of people that share the same house, TPB could be used to isolate the unsustainable action and predict the future repetition. A family or a group living under the same house is a small group to analyse with TPB because most of the work done with this theory is to predict action in a large group such consumers, students, population in general or a group of families, but it could be a starting to point to analyse all unsustainable actions in a building and evaluating the intention to repeat it for all group members, measuring what are the actions that have priority for intervention. This intervention could be done by using motivational content to nullify the intention to repeat an action. To assess the information given by TPB of a certain behavior, the system could questioning users over time, in other words, knowing that TPB is a well structure survey, the system could launch questions, included on this survey, to users at paced periods of time preventing annoying them. When the system has enough information to relate with specific action on the survey, it could take decisions to prevent non sustainable actions.

People are in fact unique, and this is a fence on sustainable development. Therefore, a system that needs to manage an intelligent building to promote the equilibrium between social, environmental and economics indicators also needs to access to these unique characteristics, an important one is Personality. Individuals can be characterized according to certain traits, in literature these traits can be divided into a set of five essential ones, called FFM. So the system has to be able to acquire these traits about all individuals that are living in the building. To get this information is suggested the usage of surveys too, and this could be done in a similar way that TPB, launching questions over time, or alternatively making a small survey in the first user interaction with the system. To choose a small survey it has to be noted that is necessary one that is not weary. Therefore, the literature points to the NPA, twelve small questions to answer, although the others that are known are more accurate. However, NPA provides adequate clues about personality [55].

Personality and Behavior are main topics in the psychology field but there are other concepts that are necessary to consider such Emotion and Mood, but for convenience they are introduced in the next section of Computational Methods.

2.3 Computational Methods

In order to improve the user's approach to sustainability management platform, it is necessary to reduce the "emotional distress" in the user, for that what is proposed is a simulation system based on emotional and behavioral responses of an human, i.e., providing the platform for an evaluation component that allows choosing decisions more acceptable to the user. To do so it is necessary to replicate the human behavior and emotions following psychological models.

2.3.1 Affective Computing

Affective Computing (AC) - the term was introduced by Picard [58] - is a computational area that tries to replicate the psychological mechanism of human behavior in order to include them in computer systems for interaction between these systems and man becomes closer i.e. knowing that, like the studies of psychology and neuroscience shows:

- A person reacts differently to certain emotions expressed by another person, when they come into contact;
- The emotional system affects the cognitive system;
- This emotional core is directly associated with the process of decision-making of the human nature.

Embedding this affective system in artificial system aims to increase the level of user interaction with increasing of its level of comfort and to reduce the non-determinism of decision making in a virtual agent, giving it another layer of intelligence. [59, 68]. In AC despite some critics who argue that certain emotions like anger or passion in a human-human relationship tend to be more harmful than beneficial and therefore not worth including these features in a logical system as computers, there is a rule underlying this field.

> "It has never been about making machines that would look more emotional; instead, it has been about making machines that would be more effective." (Picard [59])

Inside this category of systems there are some techniques for simulation emotions, personalities and behaviors - emotions models such as the OCC Model [69, 56] and the PAD space oriented to emotional mood [53, 29] are very common among computational researchers and they clarify the psychological process with a set of computable parameters.

2.3.2 Emotional Trigger

There are no consensual definition of the concept of Emotions, but in common sense they are seen as mental scenarios of humans triggered by certain events or situations in the real world, i.e., an emotional state of a person can be turned on by him, by others, by object aspects and by events consequences [76].

A computational approach for assigning emotional states for different events is achieved by the model created by Orthony, Clore and Collins in their work "The Cognitive Structure of Emotion". This model generally called the OCC Model is like a decision tree, the leaves are emotional states, they are activated depending on the event that is split on consequences, action/interaction of agents and aspect of objects and then it is determined the origin of it [56]; with this model it is possible to represent twenty two different emotions. In this report it will be given more emphasis to the model developed by Steunebrink et al. that it is a formalized and extended version of OCC and operates the same way as a decision tree since the original model suffers from logical ambiguities [69] (Figure 2.3).

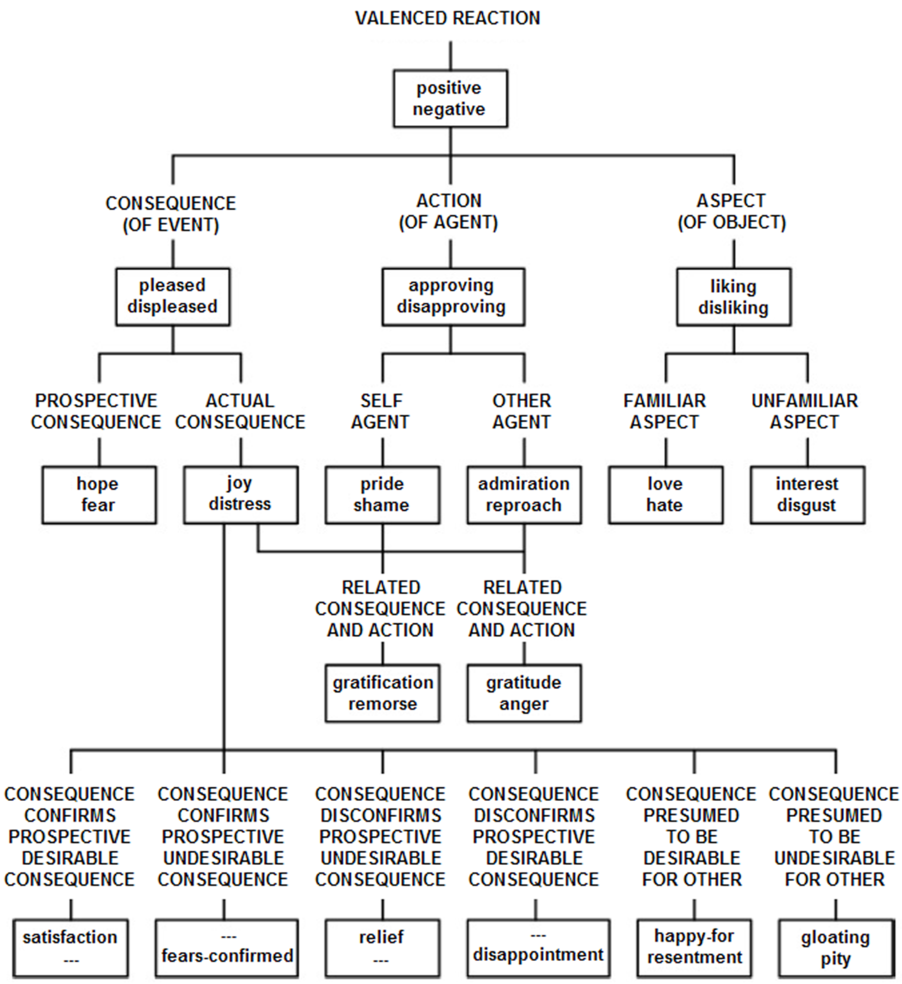


Figure 2.3: The OCC Model Revisited by Steunebrink et al. [69]

With this approach it is possible to represent thirty three different emotions, because certain variables used on original model became emotions in this extended one, for example positive or negative, which may be considered proto-emotions or primitive emotions.

2.3.3 Emotion Simulation

The OCC model helps to choose an emotion according to the nature of the external event, but emotions are seen as states, for example a sequence of events can cause an emotion transition to another state, therefore the need to control them.

A method to simulate emotional change and its update was presented by Guojiang et al.. This approach is based in the statistical model of Hidden Markov Model (HMM). In this work is assumed that emotional states are not isolated and that these states interfere with others and receive interference by others i.e. each state is part of a network and it is sensitive to an interaction between them.

This network makes appropriate use of the stochastic method of Markov model – for $S = \{s_i \mid i = 1, 2, ..., N\}$, N denotes the number of emotion states. Suppose p_i is the probability of $X = s_i$ then p_{ij} is the probability of transiting from i to j in a specific period of time, and p_{ii} is the probability for emotion to continue in the same state – so HMM has $\lambda = (N, M, \pi, \hat{A}, B)$ for signature, B is the observation matrix i.e. represents the external stimuli, M is the matrix for each emotion, π is the initial probability distribution, $\hat{A}$ is the emotion transition matrix that corresponds basically the personality i.e. same stimuli have different impact in different persons. This model has the capacity to model emotions and also to model personalities.The experiments in this work prove that this model can reflect the changes of emotion in human being and provide a different approach to existing models [33].

Newtonian Emotion System (NES) is other alternative in this field of simulation emotions based on psychological theories such Plutchik's wheel of emotions [60] and Appraisal theory from Lazarus' [47] work mixed with Newtonian physics. First it is defined the Newtonian Emotion Space – a set of concepts that enable emotional state to interact with other emotional with the world and itself influence.

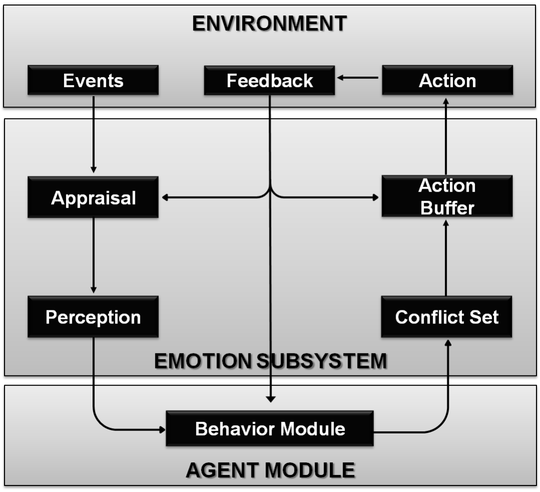


Figure 2.4: Newtonian Emotion System by Lungu [49]

This set of concepts is similar to Newtonian physics, such position (p) (of emotion) on Plutchick wheel; distance (d) – Euclidean distance – between emotion states; velocity ($\vec{v}$) that returns magnitude and direction of an emotional change per unit of time; acceleration ($\vec{a}$) that returns a magnitude and direction of emotional velocity change per unit of time; mass (m) represents the tendency to emotion's velocity to continue constant, a external stimuli can force this mass; force is the external stimuli influence. Emotion space has a center – neutral state of an agent – and emotional state have the tendency to gravitate around this center. All agents have different predisposition to a kind of emotive behavior – so different emotion space center. The gravitational force causes the emotional state decay to center after a certain period of time [49]. In fact the first two laws of Newtonian physics are defined in NES – Laws of Emotion Dynamic – in order to explain the relationship among external forces (external events) and to perceive the motion of emotion state in the space:

First Law – velocity ($\vec{v}$) of an emotional state is constant until an external force acts upon it;

Second Law - the acceleration of a body is parallel and directly proportional to the net force F acting on the body, is in the direction of the net force, and is inversely proportional to the mass m of it, i.e., $F = m\vec{a}$.

According to Appraisal theory, emotional system influences how we process and store information - the emotions that cause great excitement tend to be crowded and activated if there is at some point in the past a similar event has triggered a pleasant emotion, also this feeling in humans has the capacity to give priority on process scheduling. The NES architecture has a subsystem to analyse the input event because every action is saved in a buffer then an appraisal function is triggered (Figure 2.4).

The last two methods HMM and NES are similar. In fact they define a set of emotion and they move from state to state, and calculate the impact of external stimuli and decay of the intensity of the emotion per unit of time. To deduce what emotion they can pick through the external event OCC model can perform this choice. To perceive the environment event and evaluate it, it is required data form ambient. This process will be discussed in section Ambient Intelligence.

2.3.4 Mood Simulation

Mood or temperament is a medium term emotion i.e. its effect takes longer than emotions, it can last days or even weeks. The model was brought by Mehrabian the Pleasure Arousal Dominance Space (PAD) [53] and a computational approach was made in the framework ALMA by Gebhard [29].

The PAD-vector is a three dimensional vector, and defines the average number of emotional states related to real events, where each vector value is given in the form - (p, a, d) that takes values in the interval $[-1, 1]$. To initialize it is necessary take into account values from the personality - these values are taken from FFM. This equation calculates the values for the independent variables P,A, and D. One may have:

$$\begin{aligned} P &= 0.59a + 0.19n + 0,21e \\ A &= -0.59n + 0.30a + 0,15o \\ D &= 0.60e - 0.32a + 0.25o + 0.17c \end{aligned} \tag{2.1}$$

The variables (o, c, e, a, n) – FFM tendencies – take values from the interval $[-1, 1]$, and are evaluated according to a personality declaration. These equations return positive or negative values for each variable – P, A, D with that it is possible to define eight different moods [29] (see Table 2.1).

$+P, +A, +D$ - Exuberant	$-P, +A, +D$ - Hostile
$+P, +A, -D$ - Dependent	$-P, -A, +D$ - Disdainful
$+P, -A, +D$ - Relaxed	$-P, +A, -D$ - Anxious
$+P, -A, -D$ - Docile	$-P, -A, -D$ - Bored

Table 2.1: Mood in PAD Space

The mood can change or be intensified by emotional experiences. This creates two phases pull and push respectively. This model can infer emotion too, in fact every (p, a, d) value refer to different emotional state.

For example, if a person has personality with predisposition to pleasant emotions usually has a exuberant mood so his center are locate around – $(+P, +A, +D)$, will be easier to have emotions like joy–$(+0.4, +0.2, +0.1)$, and harder to have emotions like $distress$–$(-0.4, -0.2, -0.5)$; this last emotion is because it will change the mood state so the leap of emotion is greater (push phase). So a current emotion has a certain intensity and it will be returning to its center again in a certain period of time, because it does not last forever – short term emotion [29]. This can be done with decay functions, similarly to the HMM and NES models.

2.3.5 Information Process

Emotion and personality are intrinsic characteristics of the behavior control. This implies the use of several variables that lead to change, in human thought, different modules such as the cognitive component, motivation, perception, behavior and the control of future emotions.

The information of an external event needs to be processed, because this event may require user intervention. This process will trigger certain psychological mechanisms – personality, subjective norms, memories – all these mechanisms have impact on the behavior to be performed and self-effect. To control this information flow, Kazemifard et al. present a model that separates the information processing into three levels (RRR) and each invokes several internal mechanisms – behavior, motivation, affect, perception and cognition (Figure 2.5). It should be mentioned that this work is tested in a prey-predator environment, i.e., the function of perception was oriented to the proximity between these two actors[42].

Reactive Level - that receives external information and perception are calculated, then it is triggered a proto-emotion (only positive or negative), finds the motivation behind, if it is an habit defuses a behavior to outside, this level is like the associative component of thinking – in this reactive layer there is no cognition function;

Routine level – rule-based component which controls the other levels and also have access to emotion, cognitive functionalities, motivation and when it mediates a behavior between reflective and reactive level , defuses a behavior outside;

Reflective level – that receives an internal information from the perception acquired on routine level, activates an emotion – this emotion is more complex than the reactive or routine level – finds motivation behind, increments the cognitive system, defuses internal behavior – this level does not have perception function.

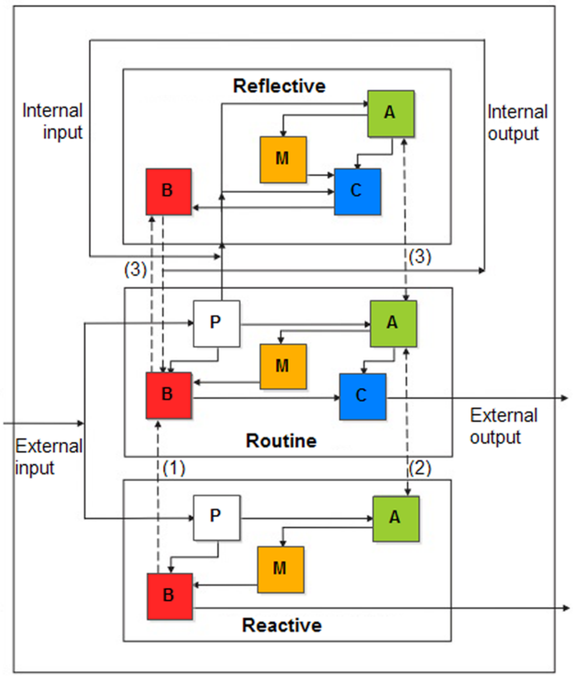


Figure 2.5: Information Processing by Kazemifard et al. [42]

This computationally model interprets the flow of information from external events to internal change of cognitive and emotional states which might open the possibility to correspond the changes of sustainability indicators to user behavior. This model uses the OCC Model to retrieve emotional state in affect functionality by external event.

2.3.6 Multi-Agent System

Most applications oriented to the simulation of emotions and behaviors use agent-based technologies because this simulation requires the use of some modules that process different operations (perceive the nature of event, change and update emotion state, attribute a personality, update cognitive status) that work distributively and they carry different tasks, for example the information processing of Kazemifrad et al. uses agent-based technology [42] to control the flow of information.

Currently a large part of the software systems have a need to solve complex problems, therefore, these systems must have the ability to be concurrent and distributive. In response to this need arises as a new paradigm - Multi-Agent System (MAS), a group of software agents able to perform task concurrently and distributively. These agents are autonomous and they do not need guidance to act and they have the ability to be flexible and dynamic in pursuit of its objectives set and they must complete them [78].

According to Wooldridge and Jennings beyond autonomy, agents to be considered as such, should have the ability to interact and communicate with other agents, should be reactive when they receive external signals and in addition they must also be proactive and act without being accurate outward signs him [77]. To be proactive, agents must have mechanisms that enable them to think about their acts or future acts. Such agents with this ability are called rational agents as Hoek and Wooldridge defined objectively that "a rational agent is an entity that is capable of acting on its environment, and which chooses to act in such a way as to further its own best interests." [36]

This definition promotes the use of the expression Intention in the formulation of the objectives pursued by agents. For that, agents must have certain primitives that may enable it to formulate the intention to act, such as beliefs, goal, fears, hope, desires and obligations. These primitives may be split into three fields, information attitudes such as beliefs, pro-attitudes, for example desires, and normative attitudes like obligations [36]. Rational agents allow the possibility for deployment of personalities and filtration of their reactions according to the expression of emotions.

There are various architectures for multi-agent systems, such as systems composed by reactive agents that respond to external stimuli, i.e, these agents have pre-defined behaviors that are activated when they receive an actions that needs reactions. Also there are systems composed by deliberative agents that choose the best behavior according to a path for fulfill a goal, and systems that conjugate the last two, and somewhat complementing the differences between the last two [62].

The BDI architecture fits in this last group. This is a cluster of agents with the ability to integrate the concepts of belief, desires and intentions (BDI). In theory this concept pretends to simulate the human decision-making and its pursuit to achieve goals. The figure 2.6 is a conceptual scheme of the BDI multi-agents implementation [12].

In Figure 2.6 is defined a pre compiled plan library that corresponds to the instructions from the programmer to the agent and consist in goals (a post-condition, what has to be done), context (pre-condition, what must be true in external event) and body (the procedures to verify the post-condition). The interpreter defines how all modules are combined together, this is a propriety form the framework that implements them, in this case, Bordini et al. use the Jason framework form AgentSpeak middleware.

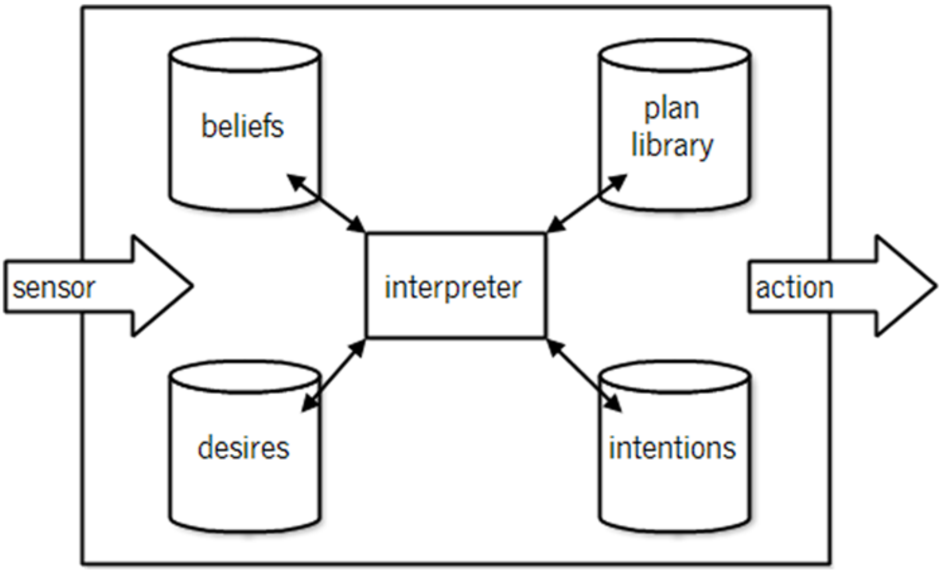


Figure 2.6: BDI architecture plan by Bordini et al. [12]

An reactive agent has to be able to continuously maintain environmental information and to respond promptly, for this and unlike BDI agents, this type of agent does not need a "mental" structure such as beliefs internally. It reacts upon external stimulus and provides a immediately solution or immediately takes an action to outside. In other words, like Brooks defends, an agent can perform an intelligent reaction to an event without the ability to reasoning upon it, as he stated "Intelligence is determined by the dynamics of the interaction with the world" [13].

This type of agent is behavior-based, i.e., it executes an action if receives data from environment without symbolic representation of the world. This characteristic requires less computational power because these agents require less complexity to execute an action[77].

Hybrid agents contain characteristics of deliberative agents and reactive agents, this propriety are implemented in different layers, for example, the TouringMachines developed by Ferguson, an hybrid agent architecture that use three layers inside a control framework that mediates the communication between these three components. These modules are a reactive layer that response to a external event(behavior-based) creating a pool of action, a planning layer that selects action and constructs plans to the agent achieves its goals (similar to BDI agents) and a modelling layer which has the simbolic representation of perception of the world and is responsible to identify and resolve conflicts in goals [25, 77].

2.3.7 Ambient Intelligence

Ambient Intelligence (AmI) is a technological field that provides methods to make smoothly decisions instead of a user i.e. "a digital environment that proactively, but sensibly, supports people in their daily lives"[8]. To do this decision making, the ambient must be surrounded by sensors to provide information from user and from ambient itself and it has to take intelligent choices supported by Artificial Intelligence (AI) algorithms. Ambient Intelligence systems implicate a complex cooperation between hardware, software and networks, and this has to be done efficiently and effectively to provide a proper result to users. [9].

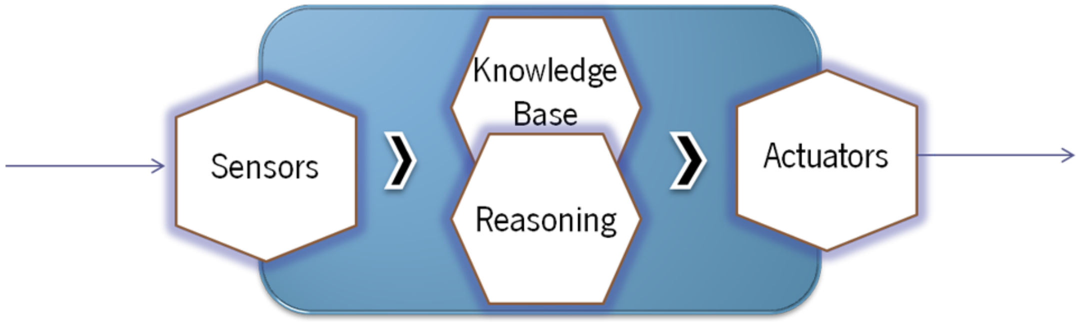


Figure 2.7: Simple information flow of an Ambient Intelligence System

In AmI, like Figure 2.7 represents, sensors have an important role because in order to perceive the environment it is necessary to request data from it; this is made by using sensors such as temperature, presence, humidity, temperature, stress and others. Actuators also have a role in this ecosystem and with that is possible to make autonomous changes on ambient like as controlling light and temperature, open windows, heating water. Therefore, mixing sensors, actuators, artificial intelligent techniques in order to give to ambient certain levels of intelligence without interfere in person's life must be the objective of a platform.

In fact, Ambient Intelligence is a multidisciplinary field as shown in Figure 2.8. Besides sensing and acting layers, a system of this type must have a reasoning component that makes decisions upon the entire system, to do that it must have a knowledge base about the environment, the data collected from sensors, and information about the users and their actions [19]. For example, to know user's actions and take decisions upon these actions, the system has to reasoning about spatial and temporal conditions of the events, this propriety gives clues about daily activities of users [32].

Another aspect of an AmI system is that it must be secure and ensure the privacy of users. A house equipped with pervasive devices which might change the ambient surrounding and realize what is being carried out, also has the potential to become a surveillance network used by external entities. To ensure the acceptance of users this capability (no privacy) must be counteracted and these systems must be reliable for consumers[11].

To ensure the acceptance of society, it is also necessary that AmI "should be made easy to live with"[19], to tackle this matter, this area has to be aware the concepts of Human-Computer Interaction (HCI). Sensors tend to have a pervasive effect or ubiquitous (almost invisible to naked eye and everywhere) and the raw data from sensors has to be taken to a context (Context Awareness) to introduce significant information from the action on environment and to act upon it [19]. The user's interaction with the system needs to be natural (Natural user Interface -NUI) without causing friction in users. This need is justified turning to the notion that human beings change dynamically through emotion and mood and they are unique, so, the platform needs to change and to take decision when users need and not when users are not capable to approve changes, in other words, the system has to be aware of users emotions and intention to perform certain behaviors (Emotion-Aware that is closely related to AC) [80, 51]. Sustainable behavior management

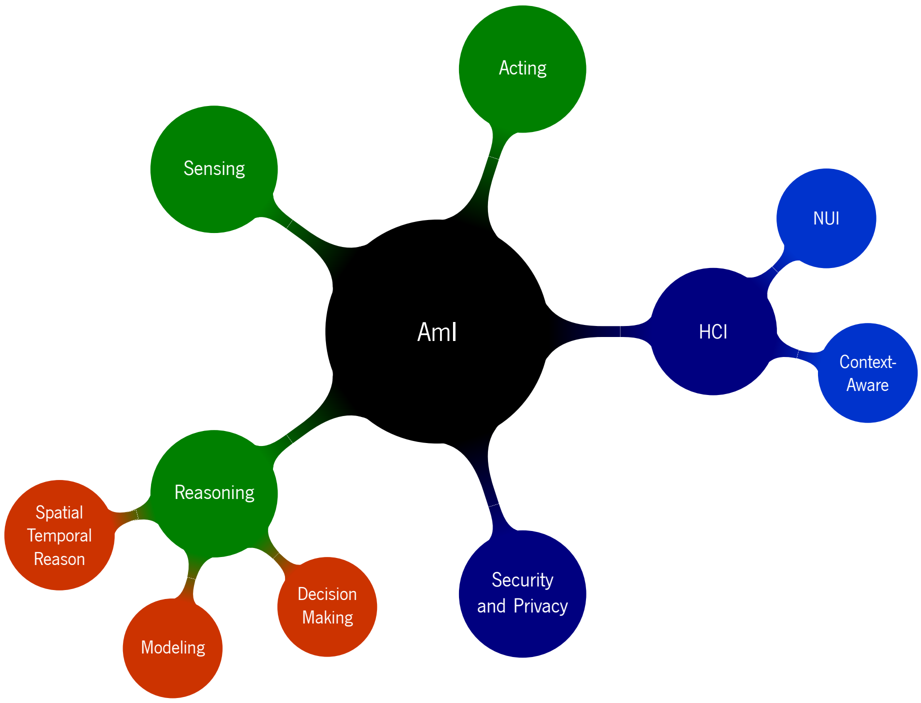


Figure 2.8: Ambient Intelligence as a multidisciplinary field by Cook et al [19].

must be quiet, unobtrusive but capable to change person's habits to be more efficient and to reduce the environmental impact of himit This is the step that approximates psychology and Ambient Intelligence and may result in a better understanding of how people can reduce their negative impact on the environment.

2.3.8 Discussion

This previous section of Computational methods represents the study about how it is possible to simulate the human nature requesting models from psychology and other social sciences and how the agents theory can help with the complexity of a person's mindset.

In fact Affective Computing has gained ground in scientific community in the past decade. Nowadays, emotion and mood simulation and representation techniques are accessible and with defined objectives such as increase interaction between humans and software or machines. In Related Work chapter it will be shown some AC applications with different goals and what are the techniques they use.

To simulate the emotional state models such as HMM and NES have different approaches to calculate the emotional process. The first uses stochastic methods and all emotions states are interconnected and the second uses the Newtonian laws of physics to produce movement of a particle around a world populated by emotions stated, this particle moves according to a gravitational field with a force produced by the event. The PAD space is possible to represent mood state of an individual and with this mood is possible to represent emotion too, and has the ability to relate the personality with mood. Comparison between PAD space and the other two is that one can access easily to mood type and all emotions that are associated to it, and the calculation of mood through personality are made by using big five factors. Besides that, literature suggests that PAD theory is the most used, although HMM and NES have appeared more recently.

To characterize emotions in respect to events that are happening in the world, the OCC model is widely used in the scientific community. It provides a structured plan for achieving what emotions will be triggered facing a specific event, for example the situation: "a very warm room when a person comes home", according to OCC and considering that "a very warm room" has a negative but familiar aspect, it is expected that the person hates this aspect of the world, or other situation like: "a teacher giving complements to a student" the OCC points that the student facing approbation from teacher who will be proud of his work.

This process of simulation behavior through event impact has an intrinsic complexity so it is necessary to control the information in different components of a simulated brain, the RRR is a structured architecture of multi-agent system to preform this change of information in all component. In fact MAS is a technology to promote this exchange distributively with a high level of abstraction.

Also, this section makes reference to Ambient Intelligence to support the idea of sustainability support systems as this is the field that brings together computational concepts with the environments used by humans to live. In chapter three, related work it will be shown some AmI applications.

Chapter 3

Related Work

Since this work is based on the attribution of emotional traits in virtual agents and their soaking on a sustainability management platform, the next section will be given relevance to this matter and how the existing systems and platform interconnect the previous concepts - Sustainability, Psychology and Computational tools.

3.1 Applications

The present section will focus on two types of applications that are directly linked with this work. Affective Computing systems, as already stated above (see 2.3.1), borrow to psychology various models to simulate humans behaviors, here the concept of sustainability has a context of applicability. In AmI systems, a sustainability might appear as a goal, as well as other goals might appear in these systems depending on defined objectives, for example, minimize costs while increasing the environmental impact, or else the opposite, decreasing environmental impact without taking into account the costs.

3.1.1 Affective Computing Systems

Over recent years the number of applications that use AC techniques has grown, due to the need that they have to make the user experience deeply [75].

In the gaming world the use of these techniques became a common practice, in order to reducing gamers' frustration and increasing their experience. Various games oriented to several objective like education, training, assessment, therapy, rehabilitation or entertainment are now tailored to user's emotional state [37].

Hudlicka's work resulted in a number of requirements should have the games' engine to get closer to the user's emotional state. This engine must have a knowledge-base about emotions, contain affective profiles from user and virtual characters, these components must be shared by the central modules – emotion recognition in player; emotion representation in virtual agent; representing dynamically the emotion state of player via affective modules; modelling the virtual agent to its current emotional state. The author states that to modelling computational emotion systems, process-models are needed which represents explicitly the affective mechanisms that allow greater degrees of generality and complexity for that appraisal models such as OCC provide this degrees of freedom. Facing the process of stimuli-behavior may require a structured representation of mind-set of virtual agents such as embedding them information about their beliefs, plans or norms [38].

Besides games, interactive computer-based environments that support group decision may require the simulation of affective structures, for example, in Ricardo Santos' et al. work is presented an agent-based system with embedded personalities and emotions for collaborative work in organizations. The group decision is presented in the Figure 3.1 [64].

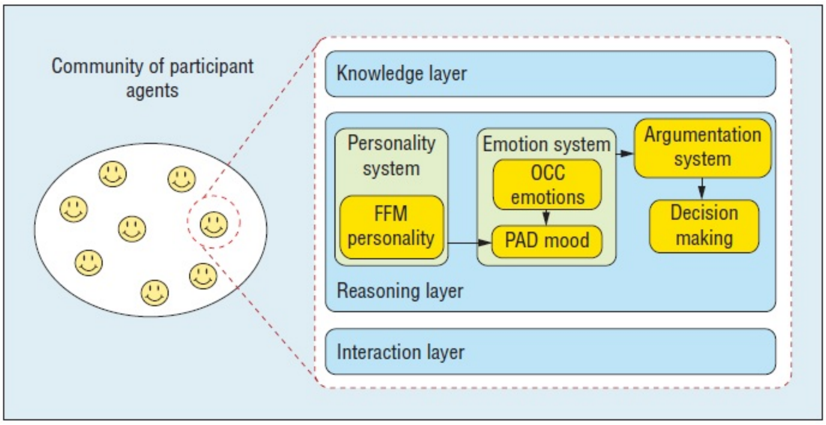


Figure 3.1: Group Decision model [64]

All participants of a community have a personality based on FFM, the emotions are acquire from OCC model and their mood and emotion are calculated from PAD space then the emotion pick the best argumentation to community. The initial mood are with PAD function with FFM parameters, and the calculus of emotion intensity is made by function $Intensity_{emotion}$.

$$Intensity_{emotion} = \frac{\sqrt{(P)^2 + (A)^2 + (D)^2}}{\sqrt{3}} \tag{3.1}$$

And its decay is made from the equation - $I_{emotion}(t) = Ie^{-t}n$ that is calculate per time unit.

The objective of this work is to mediate a decision in group, and their results show that personalities embedded in agents compromise of decision is more quickly.

Some AC systems are used to social support by helping people with some specific conditions, for example children with Autism Spectrum Disorder such as presented in Conn et al. work. In their work it is defined a framework to recognize, through wearable sensors, the emotional state of children with this disorder, and then the affect information obtained is adapted to the system, i.e, the system fits by children emotions and it becomes able to take decisions with this psychological notion. This module is supposed to be a part of an assistive intervention system such a robot or a software [18].

There are other AC based systems with similar goals, for example, works are being done with Conversational agents, that might be used to prevent the loneliness and isolation of older people. The Always-On project is designed to be a daily virtual companion for elders. In this project to assess the user's emotional state,the three-dimensional character simply asks to him "how are you today?" at the beginning of every conversations and then provides a empathetic feedback, for example a facial expression that tries to match appropriately the received response. The second objective of the virtual character is to engage the user in a small dialogue talking about social or cultural topics, for example local sports, this step has the propose to fortify the relationship creating a sense of companionship. To combat the isolation and loneliness consequences such as depression or stress, the virtual agent tries to provoke positive affect by telling a positive story like a joke or it tries motivational dialogue to promote physical or mental activity such as walking or reading a book. Like the results showed, the conversational agent helps to reduce significantly the sense of loneliness [63].

3.1.2 Ambient Intelligence Systems

Making an intelligent environment possible, aims to change people's lives and how they use what is accessible to them. A house can change dynamically according to the type of use that is given.

There are already various AmI based projects to include some level of intelligence in homes some of them are industrial and others academic, for example Philips HomeLab is a research laboratory to study the multi technologies related to Ambient Intelligent as shown in figure 2.8. By prototyping the complex networking system that links rooms and floors it is possible to perceive and solve issues that might appear in real context [1].

HomeLab possesses observation rooms that allows to researchers studies of social engagement of guested people. The observation enables the analysis of users interactions, thus contributing to the adjustment of parameters, helping the users to have a more natural experience.

Other project under this field is the Aware Home, a living laboratory to study the context-aware computing in daily activities i.e. this home has to be capable to understand the information about the activities of users and itself, performing changes on the ambient. Besides that, the Aware Home is oriented to study the human interaction with the home by learning about their habits and behaviors for delivery personalized information and where to place properly the sensors and the interaction screens. Another two properties in this house are the ability to find lost objects by using radio-frequency small devices attached in objects such as keys, remote controls and wallets, and the ability to track users positions and movements by using a Smart Floor which consists in a set of tiles sensitive to the force [43].

The PlaceLab, from the MIT House_n Consortium, and similar the previous one, it is an apartment designed to promote studies in AmIsuch as research about the daily activities about inhabitants. Besides that, it permits to monitoring biometric data about users with wearable devices to measure, for example, blood pressure or respiratory auscultation; this data is used to provide health information and to provide recommendations with the objective to motivate people change their behavior [46, 39].

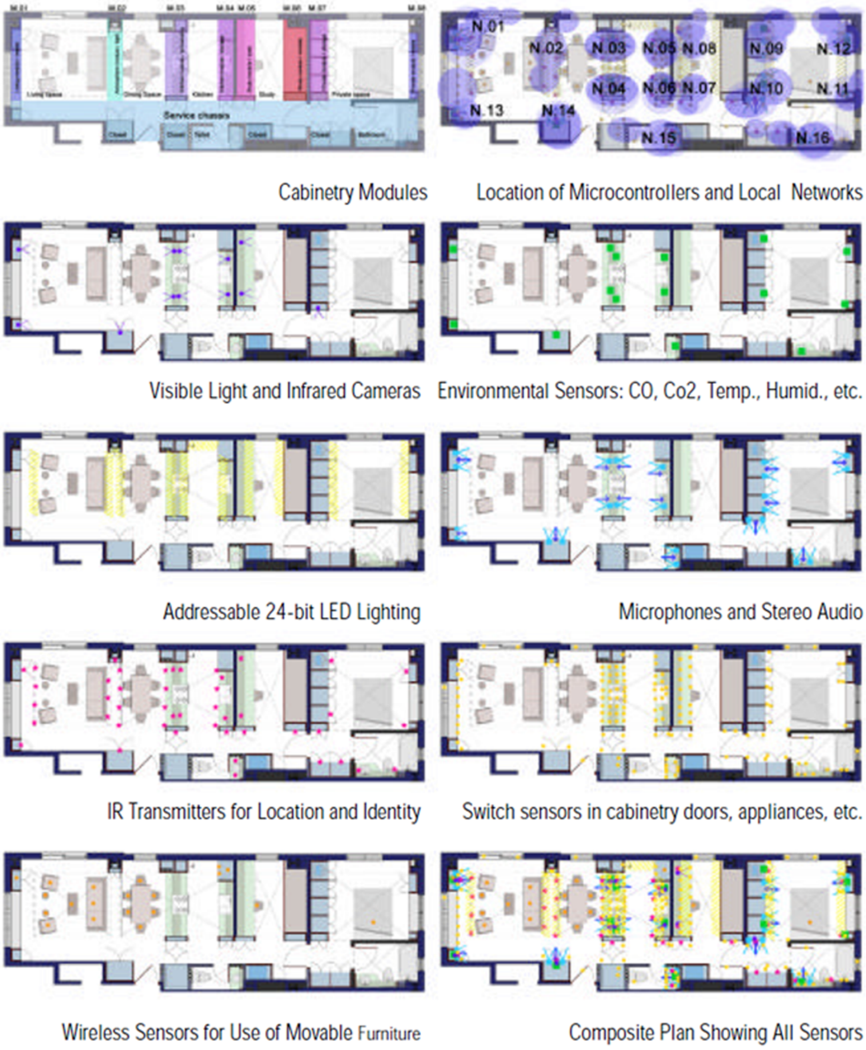


Figure 3.2: PlaceLab Sensors [46]

The figure 3.2 represents all the features that are available to researchers inside the apartment, such as normal or infra-red cameras, microphones, environmental sensors, infra-red transmitters and wireless sensors on objects that can be moved. Some of this components can be attached to the cabinetry interior for turning some devices invisible to human eye, keeping the ubiquity of all system and reducing the discomfort of the user [46].

AmI systems also can be oriented to industry, for example the AmI-MoSES platform is an European research project to optimize the energy consumption on the manufacturing process on small and medium enterprises. The objective is to support decisions by understanding and monitoring the energy usage and to be aware of its context to acquire consumption patterns. The results show that platform can reduce the Green House Gas effect and also can inform constantly users of energy indicators which permits balancing them [34].

In AmI-MoSES the ambient intelligence appears to support the flow of information between operators and ambient collecting data through sensor and then acquires information about the energy usage context. Knowing about interaction operators and manufacturing equipment or ambience could bring the optimization of operators' processes and support recommendations for elevate their production without increase the effort [70].

Among academic and business projects for housing or industry, understanding or modelling person's emotional response to the whole environment or in a specific event is a requisite. For example in PlaceLab [39] by accessing biometric data an emotional context can be derived or similar to the Aware Home [43]: to study human interaction with this intelligent house it is necessary to perceive his behaviors and it is known that some behaviors are triggered by emotional response. For this topic Zhou et al. developed a framework for emotional awareness in Ambient Intelligence AmE [80].

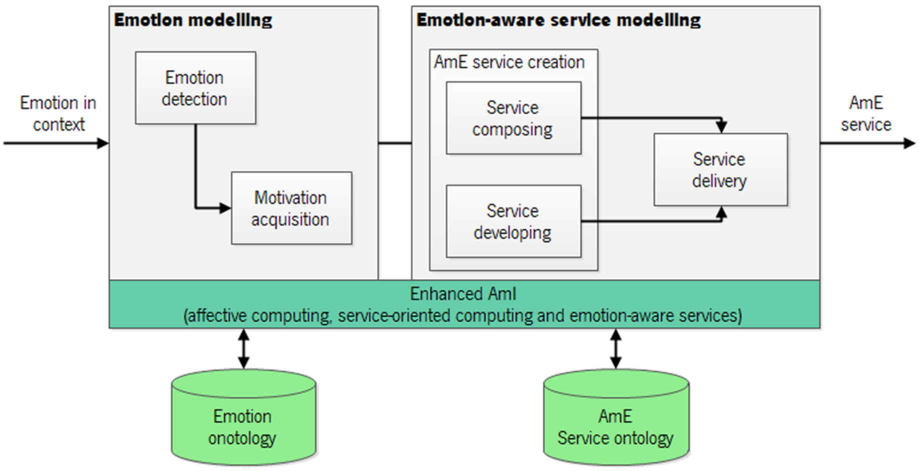


Figure 3.3: AmE framework [80]

AmE is an AmI environment that tries to ensure the emotional comfort of the inhabitants of this same environment by providing Emotion Services on time and adequately. Emotion Services are informative responses to generate emotion. For example a person being praised by some work done, the praise action can generate positive emotion like joy or happiness in a person, this is a service to provoke emotional response [79].

The AmE framework is presented in figure 3.3, the general idea is to include in a AmI system a service of emotional response to the user and to do so it is necessary to have a knowledge base about the emotion type, emotion action, emotion response, when it is applied and it is also necessary to know the relation about all these knowledge - in this case this data is presented through ontologies.When information about emotional event related to a specific context is acquired, the first step is to model this emotion and perceive what is the motivation behind, then the emotion service is created trying to be the best fit possible to the event received.

3.2 PHESS

The project PHESS - People Help Energy Savings and Sustainability, in development at the Laboratory of Intelligent Systems at the University of Minho, has the scope to create a platform, supported by artificial intelligence techniques, which aims to combat the unnecessary waste of resources, promoting an economically sustainable environment supporting everyday tasks to one or more persons [66]. The present thesis is an attempt to create a simulation system of the human behavior and emotional response to support decision under this platform. This will allow the possibility to use this emotional information and relate it with the information obtained from PHESS system to address specific decisions to users, helping them to be more affective with the platform having a lasting experience, guaranteeing platform's life.

3.2.1 Specifications

In project PHESS, to calculate the sustainable index, there are considered indicators that are within the domain $[-1, 1]$. To perform this calculus, the economic index is the division of Budget by Cost; environment index is the division of the Emission emitted by the Emission launched, the social index is the division of the Time inside a room by Time outside. These calculations allow us to determine the index of the global sustainability (S_{index}) by:

$$\begin{gathered} S_{index} = \alpha I_{economic} + \beta I_{environment} + \gamma I_{social} \\ \alpha + \beta + \gamma = 1 \wedge 0 < \alpha < 1 \wedge 0 < \beta < 1 \wedge 0 < \gamma < 1 \end{gathered} \tag{3.2}$$

For each indicator is associated a weight that determines its importance in equation i.e. policies oriented for economic issues tend to give more weight to economic indicator. Despite that, the pursuit of sustainable place such as a home or even the world, need to adjust these indicators in order to balance them.

3.2.2 Architecture

The use of agents to make decisions is needed to be able to help and guide the user to take more effective measures. Thus, the use of virtual agents that simulate or perceive the environment and react emotionally can contribute to the system by increase the number of positive emotions in the user, thereby improving his experience and keeping it affect to the system. This project is centred in the term of AmI which means it is a digital platform to support a user in his daily life, capable to understand user's needs and to make sensible decisions to improve his life quality. In this way the PHESS project can be characterize as an ambient intelligence system.

Its architecture is somewhat similar to the generic one presented in section 2.3.7. It has three layers - data gathering, reasoning and actuating, the first component is made by using sensors, the second one is a layer to reasoning about the gathered data, the last one is made by actuators that perform changes in environment, as presented in figure 3.4. This is built on a multi-agent system [66].

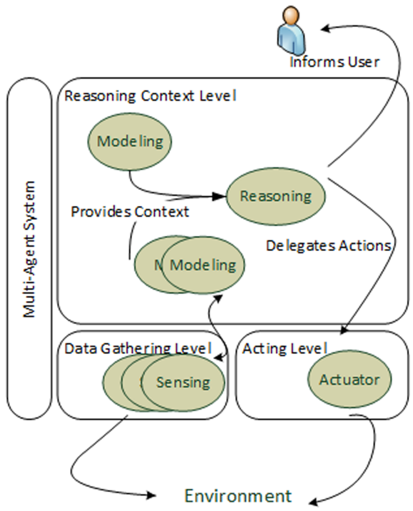


Figure 3.4: Architecture from PHESS system

The sensor layer has the ability to get information about environment conditions such as presence, humidity, temperature, noise, illuminance and energy consumption. This information is important to characterize an event in the world, so to perform simulation of a possible behavior from user, is important to retain this data. A internal layer is in reasoning context level and it is responsible to calculate a possible decision in ambient with models of past situations and relating with new models of new information, this means that it is made a Case-based reasoning. Then the user is informed, or it is committed an order for the actuators level, this last one has the ability to change the environment, for example to reduce the amount of light in an house.

The project presented in this thesis addresses the inclusion of a simulation system of the emotional response under the PHESS project, which it is responsible for feeding the simulation system with environment information. The data used are provided temperature and luminosity sensors, and a microphone as a noise sensor. These hardware are linked to agents of PHESS.

3.3 Discussion

The present chapter is a presentation of various works under distinct topics such affective computing and ambient intelligence but they are linked by the fact that the first one complements the other one.

In the first section application, in AC, all of the works have different purposes: one tries to use emotional system to create a game engine more believable to human players; other work presents an application to support a argumentation system inserted in a community of virtual agents; and the last two are oriented for helping people with certain conditions.

A critic goes to the game engine which proposes that it should recognize user preferences and relate them in the virtual agent, why not to create the agent's personality progressively among the game, learning about player's choice. In the beginning, virtual agent could be a little different from real player but in some point in the middle of the game, the agent personality becomes more similar to user emerging him in the game's world.

In the decision making platform by Ricardo Santos et al. and because it is not an AmI platform, there is no representation of the state of the variables of the world. That could provoke different emotions in participants if they are included in hostile ambient, for example a very hot place. Also there is no reference to personality traits acquisition time that could be a factor for the engagement of participants in the interaction.

The other two projects have the propose to assist people. The first one has the propose to recognize the emotional state of children with Autism Spectrum Disorder and this is done by using wearable devices, because it has a therapeutic purpose but the fact is that wearing none invisible sensors to application for daily purpose can promote distrusting of users. The second platform to help the elders combating loneliness and isolation uses conversational agents for dialogue with users; in this work there is no reference to relate agent personality with user's personality, if the conversational agent relate is own personality with users personality it can increase comfort in the interaction.

The AmI applications section presents enterprise research such as the Philips HomeLab and academic research such as Aware Home and PlaceLab for habitational purpose and the AmI-MoSES for industrial purpose. The habitational AmI projects are designed buildings for conducting these researches but with different fields of study. The HomeLab is to study the people engagement on an intelligent house and to replicate the complex network that links every room of the house. The Aware Home is a building to study the humans daily activities and perceive their context; in other hand, PlaceLab has the purpose to construct a technology apartment with all the necessary ingredients to promote system ubiquity in an invisible way to collect data house environment. All of these systems have large costs because they require a place and sets of material, although their promotion and continuity could help to reduce the costs of a intelligent house in a near future.

The AmI-MoSES is an industrial system that tries to help a small or a medium enterprise reducing costs of energy optimizing its usage. This could be done by understanding the consumption patterns of energy inside the enterprise and to analyse the relation between operators and all energy appliances. In this work there is no reference about personality of operators that could be an interesting factor to analyse operators' behaviors and relating with their personalities. Also the system could integrate a system to analysing beliefs and desires of operators and perceive if they have motivation to help enterprise to reduce waste of energy; this could be done, for example, by integrating a framework system based on TPB and acquiring information about operators' intentions to change or to perform certain positive or negative behaviors and act upon this knowledge to motivate them for maintaining or changing.

AmI applications section presents a framework to include emotion services in ambient intelligent systems, the AmE framework presented is a prototype. Here, personality is apparently discarded, the emotion is acquired by recognition of facial expressions, hand gestures or speech, and to do that is necessary to have cameras and microphones, this could be led to users' distrust in whole system. Personality could be a starting point to suppose an emotional state without directly extract from users' actions.

In the present work, the usage of personality as a calculated structure differs from other works of affective computing that by used methods of direct analysis for emotion recognition such as facial expressions, gestures or voice through cameras or microphones, instead, here it is attempt to reproduce emotional response by calculate it by using models and the personality structure including them on virtual agents and relating these agent to real people.

The system presented in this work it will integrate the PHESS platform that is a system, based on Ambient Intelligence techniques and it has the purpose to manage the sustainable index of a place. The main idea it is that this system will be a component of PHESS, that receives information from it and retrieves information to it.

Chapter 4

Work Developed

This project is being done within the project PHESS. Under this project some considerations were made on the system architecture, and how can events that occur in the environment be modelled, so that they can introduce stimuli to activate behaviors on agents. The present chapter will introduce a draft of architecture made according to literature review i.e. relating the concepts of state of the art and related applications (chapters 2 and 3)and it also will show the implementation done with all concepts used and what technologies were employed under this project, besides that it will show as well decisions that were made during the whole development process including decisions from the first thoughts to final implementation.

4.1 Sketch of Architecture

In a preliminary stage, inspired by the concepts and applications of the previous two chapters, a prototype was made (Figure 4.1) of a multi-agent system to perform the emotional simulation. The main agent ($\mathbb{M}$) will it responsible to control the appraisal function and this may work upon RRR levels (section 2.3.5). The main agent will communicate with psychological layer and physical layer determining what are the conditions to provoke an emotion change, for example calculating if a physic condition such as temperature of the ambient is appropriated to a certain context.

Psychological Layer – is module composed with four independent pieces, the beliefs, desires and norms, responsible to choose their knowledge about economic, environment and social, and the knowledge about the limitation of Agent. This layer will communicate with emotional control component, being responsible to attribute an emotional state and to update the agent.

Physical Layer – a module responsible to control agent's physic limitation. It will communicate with psychological layer that will perceive if the physical limitations cause discomfort or a enjoyable state.

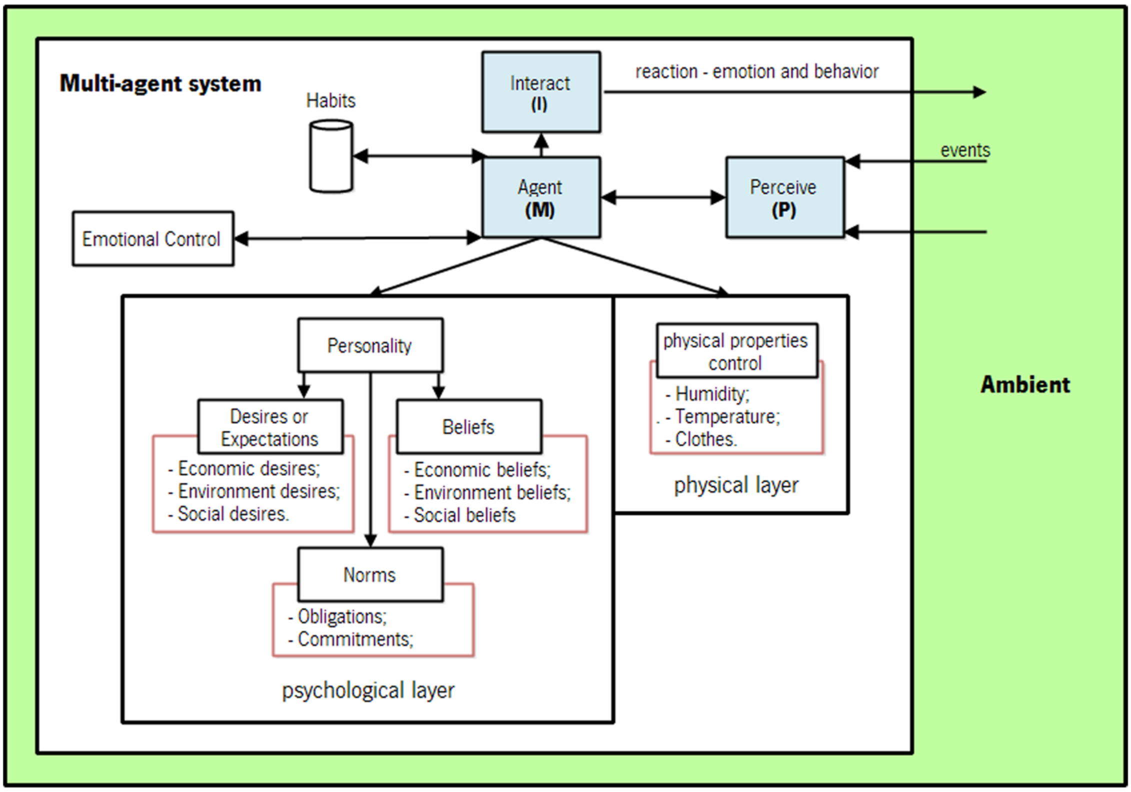


Figure 4.1: Sketch of a multi-agent system to reproduce emotional response

In this figure the psychological component presents a module that is responsible to maintain belief and desires about social, environmental and economics topics; this is suggested to maintain a relation between the events in the world and what are the sustainable indicators about the user action. For example, this idea is that a person with a little concern about his economics and low expectation to saving money could understand that if one of his actions have a negative impact on social or environmental indicators and a positive or null impact in his economics indicators, he could change this action to another that could reduce the negative impact on environment or social indicators but could affect his economics without put at risk his own financial beliefs or desires.

To do this differentiation of scenarios would require the classification of events and actions in world based on social, economic and environmental indicators. The perceive agent (PA) should have capacity to distinguish "how external events are made?" assuming that events in world have various and infinite aspects. These first thoughts propose that all event have economic (Ec), environment(En) and social(So) aspects, and they could be mapped into levels, on a set of symbols $\{++,+,0,-,--\}$ that represent: very positive, positive, neutral, negative and very negative aspect, respectively. For example, $World_{Event}(++Ec,++En,0So)$ configures an event like turn off a TV in standby - the user saves money, has a good behavior to environment, but this act has not significant impact on social field. Or for example using air conditioning to make the proper temperature will have the configuration $World_{Event}(-Ec, --En, ++So)$, this creates, for each event, a structure that is able to correlate itself with human mindset about these three aspects.

The physical limitation of the user must have the definition to the user's barriers that could have an impact on his mood, for example the building's comfort indexes that agent (PA) should have the ability to obtain values such humidity, temperature, noise, luminosity and should have the ability to provide them to the agent (M). This feature is needed because humans are naturally more adapted to certain levels of temperature, noise, luminosity and humidity and changes in these levels may cause changes in mood and emotions. The emotional impact with this characteristics could have increased by other limitation, for example, the amount of clothes that user has is related with temperature, the eyes diseases relating with illuminance.

In this draft, it was thought to include a habit dataset with information about user's action that could operate in a similar way to "action buffer" from NES (section 2.3.3) i.e. saving information about past emotions, associated events, times, local and other specific context. This implies to get information using TPB (see section 2.2.1) and to put habits as an attribute like $habit(behavior(t, a, c, time), s)$.

A habit is a repetitive behaviour so, when $behavior$ occurred with the target (t), the action (a) and context (c) with $time$, this behavior has a value s associated that is the value for strength, representing the factor of habits repetition. It would be incremented or decremented depending if it occurs when it supposed to occur or not. The strength of the habit determines the probability of a behavior to be repeated and this result may be calculated relating the intention to perform a certain $behavior$ using the TPB with s.

The information flow could be similar to RRR (figure 2.5); for example a habit with high probability to occur could activate a reactive response which produces a simple emotion only positive or negative. The routine layer could be activated by daily activities not exactly in the form of habits or habits with low probability to occur. This could activate emotional responses that most commonly occur, as in level two and three of OCC model (figure 2.3).

4.2 Implementation

The implementation step brought some decisions with regard to the draft of a possible architecture made in previous section.

It was developed a MAS to create the simulation system, as well as the structures necessary to include in each agent. Also, it was developed a graphical interface to display information from the simulation.

The next subsection will present the steps of implementation taken to date as well as the technologies used.

4.2.1 Personality

The personality in this work has been defined like OCEAN structure similar to ALMA framework (see 2.3.4) [29] and to the system to support group decision (see 3.1.1) [64] i.e. the personality is defined like:

$$personality(o, c, e, a, n); \quad \text{let } o, c, e, a, n \in [-1, 1] \tag{4.1}$$

These o, c, e, a, n variables represent five personality traits and mean Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism, respectively. It was created a simple class in JAVA called $\mathrm{Personality}$ that produces an object $personality$.

This structure is saved in a XML file to be accessible externally through the platform, and easy to access specific information. To create and manage personalities a class in JAVA has been implemented that load the XML and get the OCEAN values or creates a new personality file. With this class is possible to update all values. Here is an example of a personality XML based:

```xml
<persona>
  <ocean>
    <openness value="0.25"/>
    <conscientiousness value="0.75"/>
    <extraversion value="-0.50"/>
    <agreeableness value="-0.56"/>
    <neuroticism value="0.75"/>
  </ocean>
</persona>
```

The node persona is the main node, the idea is that in a near future the XML file will hold information about other characteristics such as economic, environmental and social beliefs, information about desires, monthly budget, eyes diseases, and all information that could be relevant to mood and emotional simulation. In this work the personality influences on the mood has more relevance. Therefore the personality attribution on agents has a key role over other human individual features. Personality is acquired form real people through their responses to questionnaires.

4.2.2 Mood

The mood as already mentioned earlier is a temporal state of the human mind, it can last for minutes, hours or even days, and can be seen as medium-term emotion. This step was based on the PAD space computationally designed by Gehbard in his work ALMA [29], as seen in the section 2.3.4. To implement the mood structure a class in JAVA was created, called Mood, with a set of instance variables to support the dynamics that one can produce along the time. An object sourced by this class in this report is called $mood$ to facilitate understanding.

First, the three variables that define PAD space, P, A and D for actual pleasure, arousal and dominance respectively, must be in the domain $[-1, 1]$ to create the representation of the eight moods that are possible (see table 2.1).

Other variable includes on Mood is the $emotionalWeight$, which represents the weight of the emotions related with $personality$. All the people are different and like the literature suggests, persons with high trend of neuroticism (n) have more probability to be negative emotionally i.e. they have predisposition to feel emotions like hate, anger or distress more often than people with low score of this trend. In other hand, extraversion (e) awakens in people, more often, feelings more positives like joy, love, gratitude.

Therefore, the weight calculation is made by knowing the signal of emotion, if it is positive than $emotionalWeight = (e + 1.0) * const$ else $emotionalWeight = (n + 1.0) * const$. This variable is in the set $[0, 2]$ turning $emotionalWeight$ positive to facilitate future calculus. The constant ($const$) is used to reduce or increase the velocity when $mood$ is crossing from state to state, in the whole project the value used was 0.1 which helped to ensure a reasonable speed. The emotion signal is obtained recurring to other class that defines specific emotion, it is presented in next subsection 4.2.3.

One of Mood's parameterized constructor receives as parameters $personality$'s values o, c, e, a, n. To initiate $mood$ in relation to personality like the equation 2.1 described in 2.3.4:

$$\begin{aligned} P &= 0.59a + 0.19n + 0,21e; \\ A &= -0.59n + 0.30a + 0,15o; \qquad \text{let } o, c, e, a, n \in [-1, 1] \\ D &= 0.60e - 0.32a + 0.25o + 0.17c; \end{aligned} \tag{4.2}$$

This creates an initial state different from agent to agent, giving them a $mood$'s foundation that allows agents deal with different emotion type during life time.

As PAD space intends to keep the $mood$ within a three-dimensional space so that it circulates from type to type, the variables P_final, A_final andD_final, were also defined. These final variables are the final state of mood relating with an emotion triggered by an event.

Let the variables P, A, D form a point M_{actual} in the space, the variables $P\_final, A\_final, D\_final$ form another M_{final}, so it is possible to calculate a vector from on point to another using the expression:

$$\begin{aligned} \overrightarrow{M_{actual}M_{final}} &= M_{final} - M_{actual} \\ \overrightarrow{M_{actual}M_{final}} &= (P\_vec, A\_vec, D\_vec) \end{aligned} \tag{4.3}$$

The P_vec, A_vec, D_vec variables represent the resultant values of each parameter from vector.

To calculate the displacement vector for each portion of time it is used an expression that makes the update of the current value with the displacement times the weight of emotion like:

$$M_{actual} = M_{actual} + \overrightarrow{M_{actual}M_{final}} * emotionalWeight \tag{4.4}$$

The multiplication operation is done to divide the $\overrightarrow{M_{actual}M_{final}}$ in small pieces that are relative to $emotionalWeight$ and this causes mood state moves more or less slowly, depending on the person, over the time, thus preventing the instant passage from one state to another which does not happen in real life.

4.2.3 Emotion definition

The emotions are defined using an enum class in JAVA called EmotionOCCtoPAD based on Kasap et al. work [41] which are mapped in PAD space the emotions represented in OCC model.

```
public enum EmotionOCCtoPAD {
    //emotion(p, a, d, weight)
    JOY(0.40, 0.20, 0.10, "POS"),
    PLEASED(0.20, 0.10, 0.10, "POS");
    HOPE(0.20, 0.20, -0.10, "POS"),
    RELIEF (0.20, -0.30, 0.40, "POS"),
    PRIDE (0.40, 0.30, 0.30, "POS"),
    GRATITUDE (0.40, 0.20, -0.30, "POS"),
    LOVE (0.30, 0.10, 0.20, "POS"),
    DISTRESS (-0.40, -0.20, -0.50, "NEG"),
    DISPLEASED(-0.20, -0.10, -0.25, "NEG");
    FEAR (-0.64, 0.60, -0.43, "NEG"),
    DISAPPOINTMENT (-0.30, 0.10, -0.40, "NEG"),
    REMORSE (-0.30, 0.10, 0.60, "NEG"),
    ANGER (-0.51, 0.59, 0.25, "NEG"),
    HATE (-0.60, 0.60, 0.30, "NEG");

    /*omission of variables,
     getters and constructors*/
}
```

The EmotionOCCtoPAD class creates objects with a defined emotion. An event in the world creates a corresponding emotion, so the objects of this class may indicate the point at which mood state must walk until the final values are achieved.

The class also defines if it is a negative or a positive emotion and this is helpful to calculate $emotionWeight$ on the $mood$.

4.2.4 Modelling external events for emotions

The PHESS platform provides a set of data obtained through the use of sensors attached in the ambient. The sensors such temperature, luminosity and a microphone to capture the noise, provide information in real time of these same conditions. So these data will be used as events that change the behavior and emotions because as stated, in the 2.2.2 section, the ambient conditions have impact on the human actions.

In this sense, it is necessary to assign an emotional state as defined in the previous subsection to each received values. These values are real numbers in $\mathbb{R}$ so there are infinite possibilities to agent trigger different types of emotions. As an example, the temperature values vary from negative values such $-20.4°$ and positive values such $45.2°$; the noise values can vary between $0.0dB$ to $55.5dB$ or the illuminance can vary from $0.0lux$ to $995.8lux$, therefore, the values have to be treated. This project suggests to discretize these values, i.e., grouping the values in sets of values. To do this step, were used reference values according to two websites that are specialized in green engineering for temperature comfort[1] and ergonomics for illuminance values[2] and for noise[3].

Two tables (4.1 and 4.2) show the temperature values according to the reference in the European Climate. They present two types of configuration, $ConfT_A$ which is grouped into five discrete values such Very Hot, Hot, Acceptable, Cold and Very Cold, and the configuration $ConfT_B$ which is an extended set of values such Very Hot, Hot, Slightly Hot, Acceptable, Slightly Cold, Cold and Very Cold.

Temperature	**in celsius degrees ($°C$)**	**Emotion**
Very Cold	< 8	Anger
Cold	≥ 8 and < 16	Distress
Acceptable	≥ 16 and< 20	Joy
Hot	≥ 20 and < 24	Anger
Very Hot	≥ 24	Hate

Table 4.1: Configuration $ConfT_A$ temperature values

The first table 4.1 shows emotion relation with the temperature values, with only five values the emotions are more extreme. There is no middle ground hence the emergence of a second table (4.2) with finest values.

[1] http://www.greenstructureplanning.eu/COSTC11/comfort.htm
[2] http://www.engineeringtoolbox.com/light-level-rooms-d_708.html
[3] http://www.engineeringtoolbox.com/decibel-dba-levels-d_728.html

Temperature	**in celsius degrees ($°C$)**	**Emotion**
Very Cold	< 4	Anger
Cold	≥ 4 and < 8	Distress
Slightly Cold	≥ 8 and < 16	Pleased
Acceptable	≥ 16 and < 24	Joy
Slightly Hot	≥ 24 and < 27	Pleased
Hot	≥ 27 and < 32	Anger
Very Hot	≥ 32	Hate

Table 4.2: Configuration $ConfT_B$ temperature values

The tables were constructed under the consideration of the section 2.2.2. High temperatures cause hostile emotion like Anger and Hate, and low temperatures cause less hostile but still negative emotions, like Distress and also Anger. In $ConfT_B$ the middle between Acceptable value and Hot or Cold, the values Slightly Hot or Slightly Cold respectively cause a Pleased emotion. The idea is that it is still positive with respect to Joy of Acceptable value, but causes a lower impact.

The table 4.3 is the reference values for comfort for a given noise of an ambient. These values were discretized yielding three types of noise levels like Acceptable for silent place, Noise for place somewhat noisy and Very Noise for very noisy places.

Noise	**in decibel (dB)**	**Emotion**
Acceptable	< 40	Joy
Noise	≥ 40 and < 54	Distress
Very Noise	≥ 54	Anger

Table 4.3: Configuration $ConfN$ - noise values

After analyse the information obtained in the section 2.2.2 about the effect of the sound on human emotional response and the OCC model, it was decided that emotion like Hate was a bit extreme to very noisy places, so an emotion like Anger satisfied this condition which has lower negative impact than Hate.

In table 4.4 it is shown the treatment that was given for illuminance values and how they could be put on clusters. The reference values point to three groups, Dark for dark places, Acceptable for places where lighting is adequate and Light for places where excessive lighting cause discomfort.

Illuminance	**in lux (lx)**	**Emotion**
Dark	< 400	Fear
Acceptable	≥ 400 and < 1000	Joy
Light	≥ 1000	Hate

Table 4.4: Configuration $ConfI$ - illuminance values

The same considerations made in $ConfN$ were taken in $ConfI$ when analysed information section 2.2.2 with OCC model. In this case Dark could trigger Fear and Light could trigger Hate emotion - this is because the excessive light or no light at all, it has an extreme impact on human being in an ambient as the place where this work was developed that has characteristics of a workplace.

4.2.5 Effects on emotions through past events

In the Mood class, it was also added a variable text $lastFeeling$ that provides information about emotion related to previous event. Having information about what happened before, and knowing that the transition of emotions is not instantaneous as explained by OCC, intermediate emotions were created according to information provided by the variable $lastFeeling$.

For example, the figure 4.2 shows what occur when the actual state is Hot and how $lastFeeling$ about past feeling can make impact on the current $mood$.

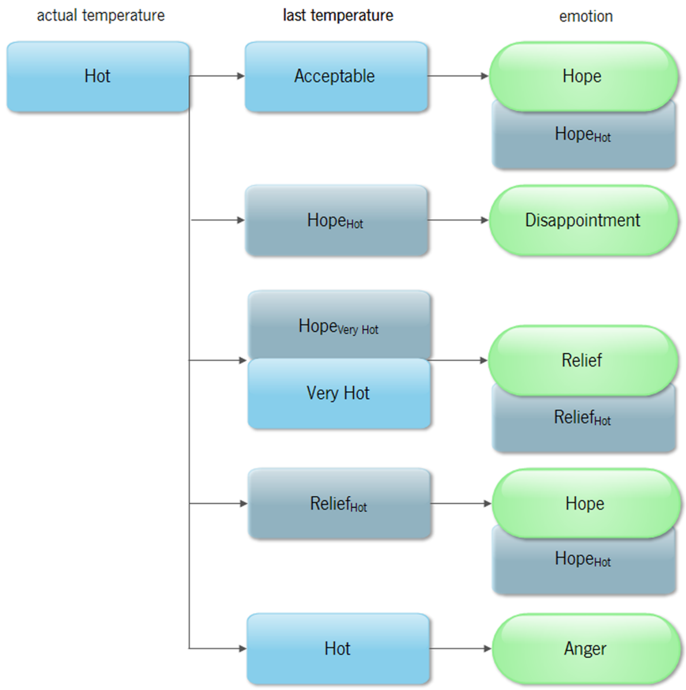


Figure 4.2: Emotions triggered by relating Hot as actual temperature with last temperature felt.

In the figure 4.2, and relating with configuration for temperature $ConfT_A$, when an actual event is Hot if the $lastFeeling$ is Acceptable, the agent triggers the emotion Hope. The new value of $lastFeeling$ will not be Hot, instead that it will be Hope$_{Hot}$ that means that user hopes that the actual Hot can be temporary and come back to what was previously. If in the next period of time the temperature is still Hot, the user triggers Disappointment because hope was not fulfilled and put $lastFeeling$ equal to Hot. Other case if a higher value of temperature occurs like Very Hot the user triggers Relief, that means that user feels that the worst is over and puts the $lastFeeling$ information like Relief$_{Hot}$. If Hot is still the actual temperature when the $lastFeeling$ is Relief$_{Hot}$ then the user triggers Hope once again, which means that he believes that is possible temperature will reduce to a lower value like Acceptable.

In the other hand, if an actual temperature is Hot and the previous temperature was also Hot, the emotion associated is Anger, as referenced in the table 4.1.

Other example is the flow of emotions and events through time for Very Hot as actual temperature, as presented in figure 4.3.

In this case the amount of process is smaller, because this is an extreme value and it is assumed that there are no very large variations in temperature, for instance, if the temperature rapidly changes from cold to very hot, this case is not treated.

The last temperatures are analysed and then it is attributed an emotion. If the actual temperature is equal to the last one the agent trigger Hate, else intermediate emotions are released.

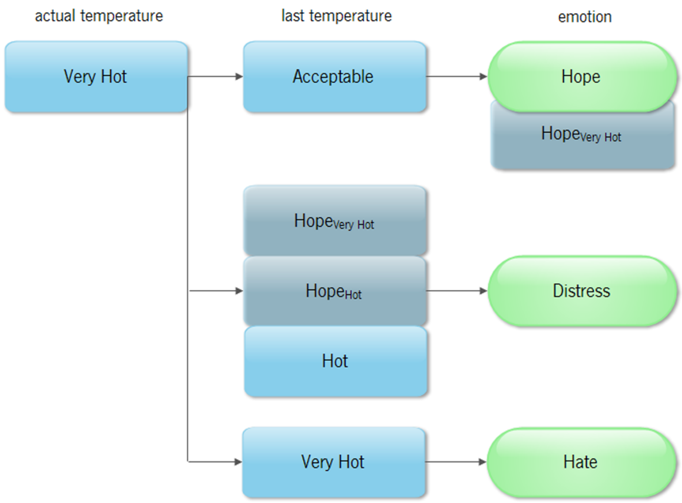


Figure 4.3: Emotions triggered by relating Very Hot as actual temperature with last temperature felt.

The fact is that the process is similar for $ConfT_B$ and $ConfN$; in the other hand, $ConfI$ has no intermediate emotions because it is assumed that values for temperature and noise will slowly taking effect, but in relation to lighting, though with less emotional weight than the other two, have immediate effect. To $ConfT_B$ process is the same with $ConfT_A$, only more conditions of rating are added that force the release of two new types of emotions such Displeased and Pleased. In $ConfN$ the middle emotions are Hope and Disappointment - the Hope emotion also creates intermediate events as last temperature for Hope$_{Noise}$ or Hope$_{VeryNoise}$.

$$\begin{aligned} &\text{pressStressForTempA}(actualTemperature, lastFeeling) && \text{for temperature } ConfT_A; \\ &\text{pressStressForTempB}(actualTemperature, lastFeeling) && \text{for temperature } ConfT_B; \\ &\text{pressStressForNoise}(actualNoise, lastFeeling) && \text{for noise } ConfN; \\ &\text{pressStressForIllu}(actualIllu, lastFeeling) && \text{for illuminance } ConfI; \end{aligned} \quad (4.5)$$

The function presents previous (function 4.5) is included on Mood class and defines the update of the final $mood$ for a given condition and its configuration (tables in 4.2.4), relating the actual feeling with the the last feeling felt about this same condition, for example like the figures 4.2 and 4.3 show. All of these methods change the final state for PAD space, updating the final PAD point and use the function 4.3 to get the vector from the actual to final $mood$.

4.2.6 Agents

To support the dynamism of a simulation of this type, two Agents were created, one that includes these structures and methods spoken earlier in this Implementation section and the other requests information in the environment through other platform like PHESS or an simulated environment.

The Agents are defined according to a Java Agent Development Framework with acronym JADE. This is an open-source framework and totally developed in JAVA, that allows the communication between agents via asynchronous message passing either on the same or different platform. All agents have a mailbox that saves the messages from other agents, these messages are in ACL (Agent Communication Language) format specified by FIPA (Foundation for Intelligent Physical Agents)[4].

An agent in JADE has its own thread that determines its life cycle giving it autonomy to perform its action. It is possible to define behaviors and their schedule. Once it is activated, it runs up to the end or, if scheduled to be cyclic, forever.

In fact, this framework provides an abstraction called $\mathrm{Behavior}$ to define the tasks of an agent. The programmer can define what a $\mathrm{Behavior}$ does or what the type of it it wants. For example, there is various types of this concept such $\mathrm{SimpleBehaviour}$ to do a simple task, and cannot be interrupted; $\mathrm{OneShotBehaviour}$ to do a task only one time; $\mathrm{CyclicBehaviour}$ to create behaviors that keep executing continuously; $\mathrm{TickerBehaviour}$ to execute action periodically and $\mathrm{SequentialBehaviours}$ that execute task by task with a specific order.

It is possible that an agent defines the kind of service that makes and then puts this information in a yellow pages service so that other agents can search this service and request the agent to perform it.

JADE provides methods to an agent interacts with a GUI (Graphical User Interface) and vice-versa, for example, if a GUI implements an $\mathrm{ActionListener}$ it is possible to send to agents what happens in the GUI (eg. if a button if pressed), extend the agent as a $\mathrm{GuiAgent}$, this agent can manipulate what happens in the GUI.

The next paragraphs will present the agents that have been developed under a JADE environment, the Main Agent and the Perceive Agent.

[4] http://www.fipa.org/

Main Agent (M)

The Main Agent (M) was based on the preliminary draft, in which it was decided that it would have the task of controlling the flow of information, receive information about the agent responsible for acquiring information from the environment, control information about their physical condition and information about their psychology.

The process of implementation was included in M structures previously spoken. In M, the relevant structures are $personality$ and four $moods$ called $mood$, $moodTemperature$, $moodNoise$ $moodIlluminance$. The definition of three different moods is due to the control of emotional response from every sensor. Since, these ambient conditions provoke different emotions (see tables 4.1, 4.2, 4.3 and 4.4). Therefore, a method for fusion all moods into the $mood$ was develop like figure 4.4 shows. For each $mood*$ is attributed a weight that relates the importance of a condition of the environment in the emotional state, in this case 50% for temperature, 30% for noise and 20% for illuminance. This method allows the calculation of a final emotional state in the PAD space and then gets a balanced mood type related with ambient.

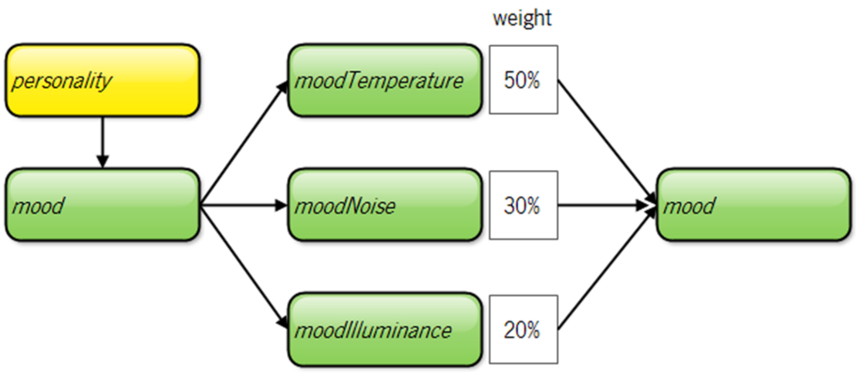


Figure 4.4: Method to fusion all related emotion to an ambient condition into a $mood$, and generic for all user.

M is a $\mathrm{GuiAgent}$, so the graphical interface can be present changes of emotional state when it is updated, these changes will be spoken more ahead.

In the beginning of execution, the agent M launches a form to the user, so that he fills his name and last name. With this information, the agent get access to his personality XML file, then the agent creates an object $personality$ with the OCEAN values.

Next, with this structure it initiates a $mood$ structure to attribute a initial emotional state to agent reflecting a possible approximation of user's mood. This is done by using the equation of mood's initialization in section 4.2.2.

Then $mood$ is replicated in three structures, such $mood$, $moodTemperature$, $moodNoise$ and $moodIlluminance$ as stated before (figure 4.4). These first steps are a initialization of M.

Next, the agent M will try to discover agents that provide a service called $\mathrm{world-service}$ that gives to M information about the world in its surrounding. This step is done by a $\mathrm{TickerBehaviour}$ that awakes every $15000ms$.

Then M starts a $\mathrm{SequentialBehaviour}$, first the agents that provide $\mathrm{world-service}$ are discovered, it launches a message for request world's information, if an agent replies with sensor values the emotional state is calculated and updated. The values in this work are saved into a $\mathrm{HashMap}$ called $\mathrm{PhysicsMap}$ for easy access through ambient condition.

Key	**Value**
Temperature	$double$
Noise	$double$
Illuminance	$double$

Table 4.5: $\mathrm{PhysicsMap}$

The table 4.5 represents the structure of the $\mathrm{PhysicsMap}$ and each variable is a primitive of the type double, for a certain environmental conditions. In the next turn, the values on the environment are updated for a given key, so $\mathrm{PhysicsMap}$ will always have a size of three entries and simplified access.

When the agent is served with information, or in this case, is served with $\mathrm{PhysicsMap}$, it has to deal with the values of this structure. This treatment involves discretization of these values according to the tables 4.1, 4.2, 4.3 and 4.4. For that, the platform is supplied with methods available by a class called $\mathrm{DiscretizeClass}$, the methods are:

$$\begin{aligned} &\mathrm{tempA\_Discretize}(value) && \text{for temperature } ConfT_A; \\ &\mathrm{tempB\_Discretize}(value) && \text{for temperature } ConfT_B; \\ &\mathrm{noise\_Discretize}(value) && \text{for noise } ConfN; \\ &\mathrm{illu\_Discretize}(value) && \text{for illuminance } ConfI; \end{aligned} \tag{4.6}$$

Then the $moodTemperature$, $moodNoise$ and $moodIlluminance$ are updated with these values using the functions included in Mood (function 4.5)like:

$$\begin{aligned} &moodTemperature.\mathrm{pressStressForTempA}(actualTemperature, lastFeeling); \\ &moodTemperature.\mathrm{pressStressForTempB}(actualTemperature, lastFeeling); \\ &moodNoise.\mathrm{pressStressForNoise}(actualNoise, lastFeeling); \\ &moodIlluminance.\mathrm{pressStressForIllu}(actualIllu, lastFeeling); \end{aligned}$$

In the methods above, in particular $moodTemperature.\mathrm{pressStressForTempA}(...)$ the temperature uses the method to change its internal state, more specifically the final state of this $mood$. This step is done for all ambient condition, then as figure 4.4 shows, all $moods$ are merged into a single one, and by using the function 4.4 the actual merged $mood$ is updated. Therefore, the actual values of $mood$ are getting closer to the final state previously inferred.

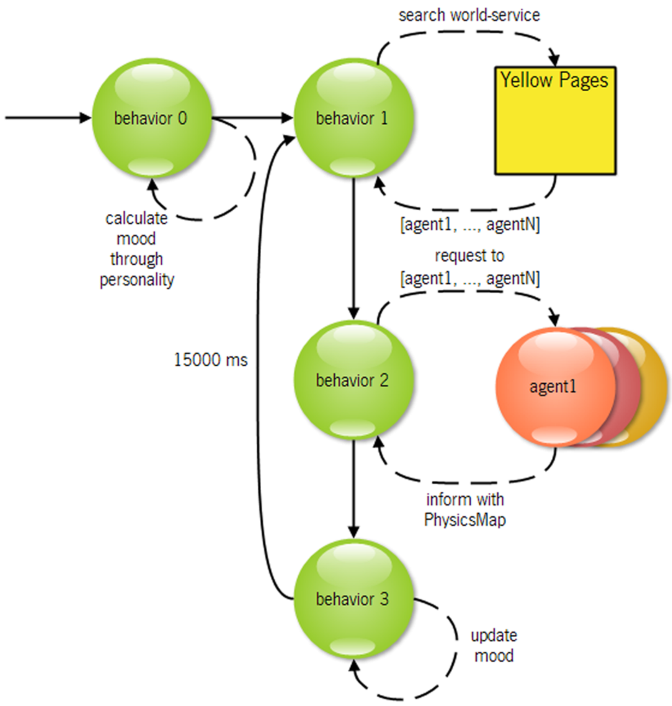


Figure 4.5: Behaviors of Agent M.

In the next turn (in this work approximately $15000ms$ after) this agent performs the same steps again, like figure 4.5 shows. The figure 4.5 shows the steps done by M. The first behavior (behavior 0) is the initialization of the emotional structures $personality$, and $mood$ through $personality$ values. Then, in the behavior 1, the agent tries to discover, in the JADE's yellow pages, services that could inform it with ambient conditions. Next, the agent launches a request to the discovered agents. When one of these agents replies to it with the information that is required, M starts to update it own mood. The same process is repeated later.

Perceive Agent (PA)

The platform has an implementation of an agent that provides $\mathrm{world-service}$ that can be used to provide information to agent M. This agent is called Perceive Agent (PA)

To obtain values of the world, in this case (PA) requests information from PHESS platform that, via sensors, gets information about certain features of ambient and then informs PA with values. Currently the agent can obtain Information about temperature, noise and illuminance of a confined space. The PHESS system has agents such as PhessPhidget and PhessSound that belong to the sensor layer, the first receives entries from a sensor defined to get outside temperature, and other to get outside luminosity, the second one receives entries from a microphone that get the outside sound.

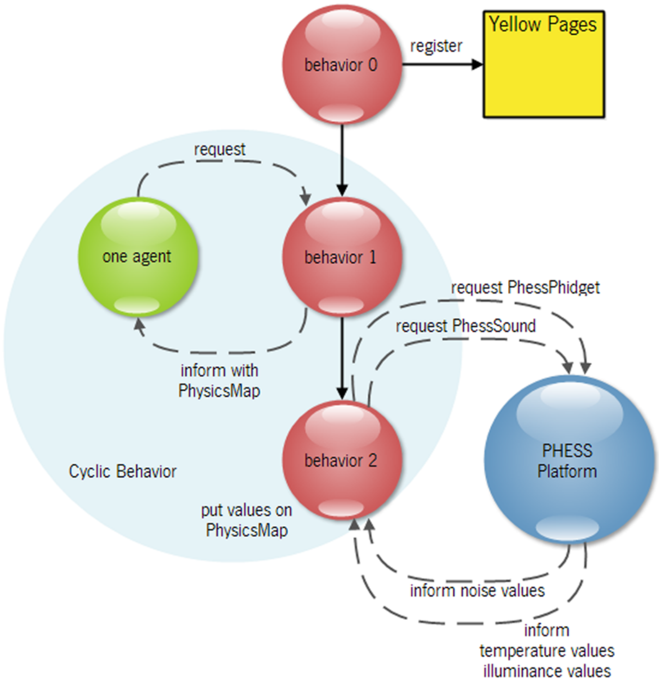


Figure 4.6: Behaviors of Agent PA.

The figure 4.6 shows the flow of steps from agent PA. In the first step (behavior 0) the agent registers its service in the yellow pages content with the name $\mathrm{world-service}$, then launches a cyclic behavior with two steps that are repeated through time. In the behavior 1, PA waits for a service request from an agent, when it receives one, inform the other agent with the values in $\mathrm{PhysicsMap}$. The behavior 2 is to acquire these values: PA makes two requests to PHESS, one for access values from PhessPhidget and other to PhessSound, then waits to a reply, when it comes agent PA updates the hash $\mathrm{PhysicsMap}$, if the PHESS does not reply, the entries in the hash are maintained equal.

4.2.7 Graphic Interface

To understand better the emotional dynamics of what is happening internally in the M, a graphic interface was developed. For its creation, it was used the Swing library that is totally implemented with JAVA. Previously it was told that the JADE has classes and methods for an agent to communicate with a GUI and vice versa.

In fact, when considering M as a $\mathrm{GuiAgent}$ it becomes accessible methods such $\mathrm{onGuiEvent}$ or $\mathrm{postGuiEvent}$ that are responsible to allow interaction with agent and the GUI, the first process is done in the agent and the second method posts on interface.

Thus it is possible to create a control of what is happening in the GUI such as pressing a button or tab or scroll. Besides that, JADE allows passaging objects via parameters. Therefore, it is possible to collect values and data from interface.

The window designed to display content has four tabs, as the captured images from GUI show (figures 4.7, 4.8, 4.9 and 4.10)

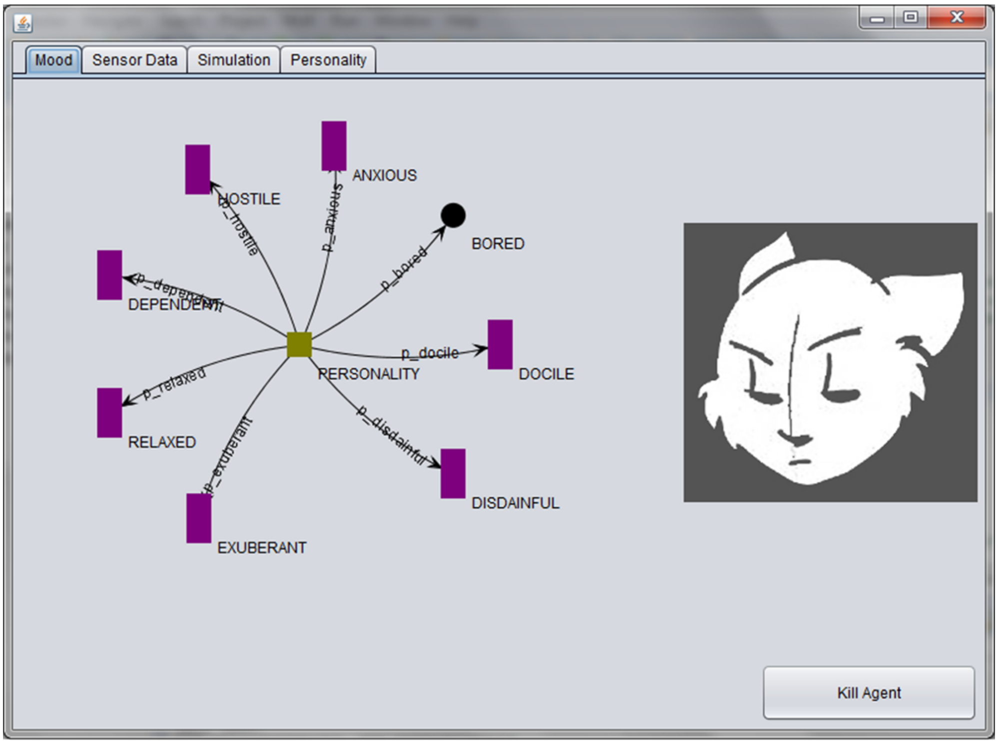


Figure 4.7: Screenshot of Mood tab from GUI.

The figures 4.7 and 4.8 show the Mood tab. The difference between them is the mood state that they present, in the first (figure 4.7) the mood is Bored, in the second is Anxious. There are two types of presentation, one uses a graph that have nine vertices (all mood types from PAD space and personality), and the edges connect personality to the remaining vertices. This graph is done using the JUNG (Java Universal Network/Graph Framework)[5] library that is oriented to data visualization and includes implementations algorithms of graph theory, random graph generation and other entities. The second type of mood presentation is a showcase of images that gives some expression to the related mood.

To visualize data from sensors on real time, like in figure 4.9, it is used a library called JFreeChart[6] that provides free set of charts inclusive dial plots which display information about temperature, sound and luminosity. Also, the discretize value of each sensor is included, like in tables 4.1, 4.2, 4.3 and 4.4.

[5] http://jung.sourceforge.net/
[6] http://www.jfree.org/jfreechart/

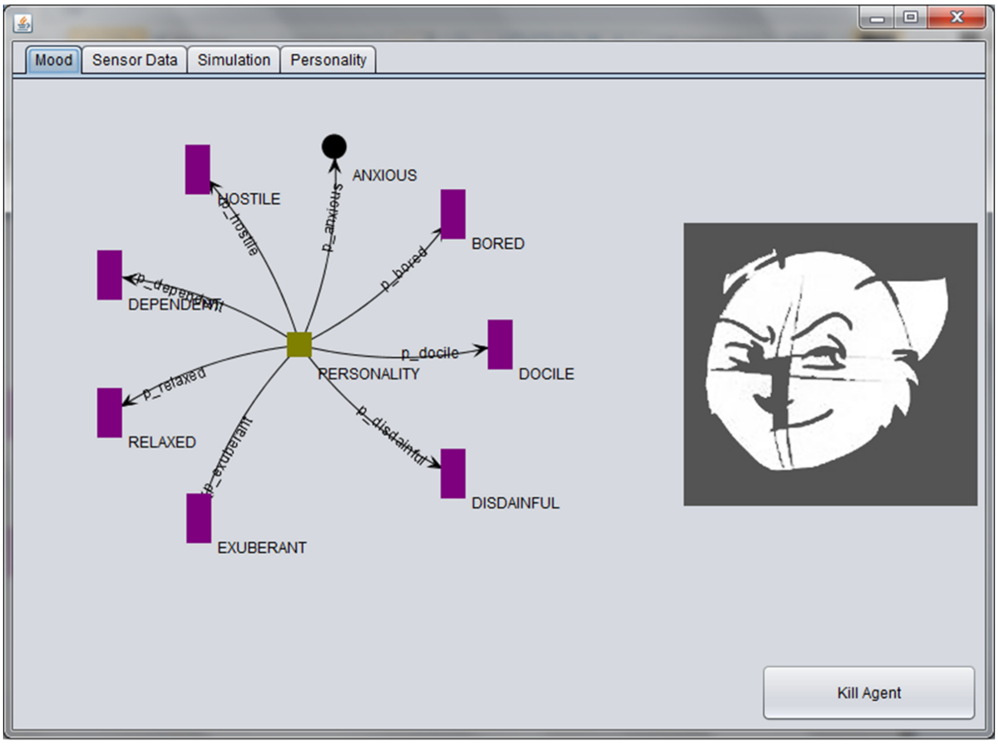


Figure 4.8: Screenshot of Mood tab from GUI with different mood presented.

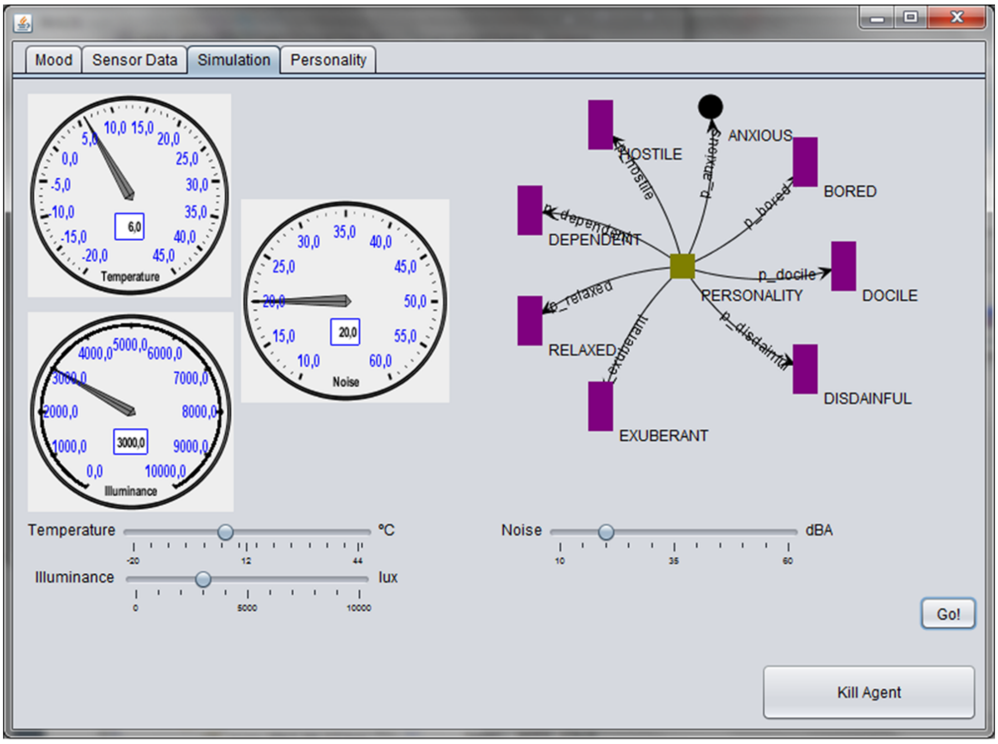


Figure 4.10: Simulation tab from GUI.

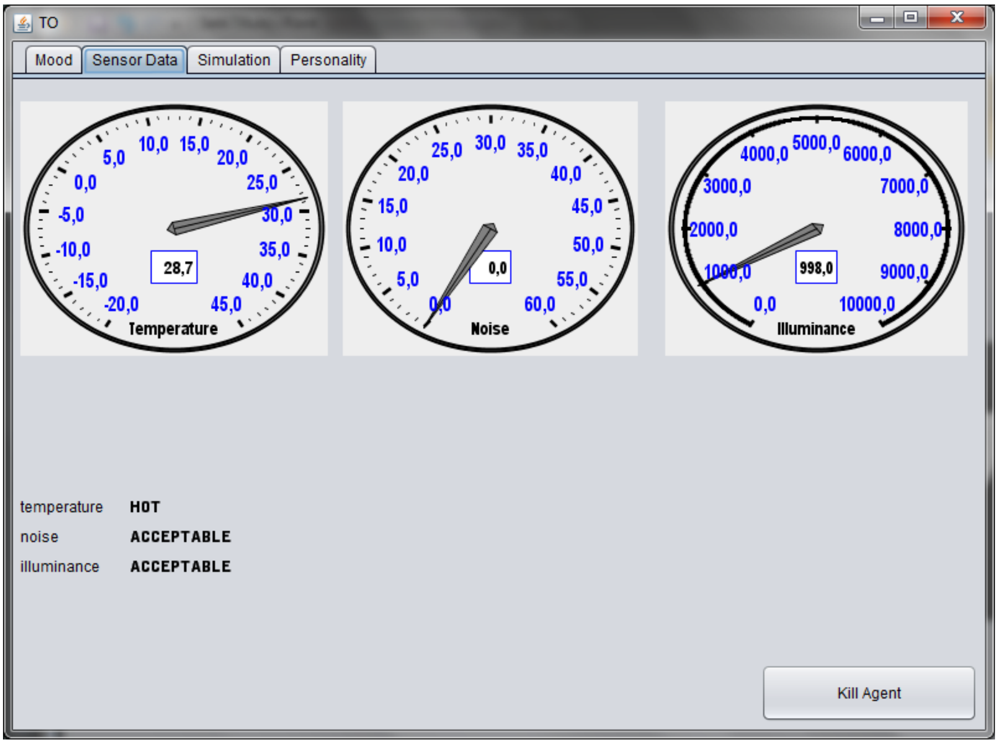


Figure 4.9: Screenshot of SensorData tab from GUI.

The Simulation screen that appears on figure 4.10 is an interactive panel that allows enter in a simulated environment to test individual mood state with sensor values chosen by the user by moving the slide bars and the Go button. So the new final state, where the mood must travel, is calculated. The update step is done by using as a host agent M, i.e., in this simulated environment, that are done in real time, the agent M continues to calculate the mood with actual and real data through agent PA, so with that cyclic process an auxiliary mood is calculated and updated, thereby avoiding stopping the platform.

Also, in Simulation tab appears dial plots similar to SensorData tab but in these contents it shows the data defined by the user. The actual mood state is displayed in the graph like in Mood tab.

4.3 Discussion

The present chapter explains the work that was done. In a brief introduction a sketch of a possible architecture library, translating graphically the reflection made through the research carried out in chapters of the State of the art and Related work (see chapters 2 and 3) and what would be possible to develop about the themes and perspectives presented there. This reflection helped to develop what would be the foundations of the implemented work.

With this step, it was possible to realize that it would be necessary to develop at least two agents: one that should control the emotional state and who possessed the human simulated characteristics and another that communicates with the outside world or sustainability management platforms. Thus it arouse the first signs of what would be the agents M and PA and what would be their missions.

The idea to include a dataset about the habits of people and what structures related to the human emotional system could provide an emotional system application, focused on the exposure of certain conditions in the environment, also appeared with the architecture.

This section it was suggested to use questionnaires to model the personality and perceive the intentions of a person to perform a certain action again. The use of frameworks that are used by psychologists too, could be done over time and sparsely for discourage users to abandon the use of the platform, effecting them.

The Implementation section describes the steps that were made to materialize the set of ideas previously described. However, due to the finite period of time and lack of data, some ideas have gained the highest priority, subjecting others to future implementation.

Inclusion of personalities and characterization of mood was a natural step. For personality the usage of XML file, to save values according to big five theory, is due to the easy access to the contents of the file. The FFM for personality appears on large amount of work related to affective computing, compared to other models.

Then a class in JAVA was developed to materialize the concept of mood based on the mind structure used in ALMA work. By Working with mood it was possible to create an emotional state of medium term, instead of using short term emotions, such as NES and HMM, since the physical conditions of environment, such temperature, light and sound, has an pervasive effect with slow variations. Thus the use of quick emotions in this work only helps to achieve a certain final state which is inserted in a certain mood like the PAD space admits.

Knowing that platform PHESS provides information through sensors about temperature, sound and light, and knowing that this information comes at intervals of real values, the section of Modelling external events presents a way to treat values that are received, and thus characterizes a certain value according to the established ergonomic values.

Despite the short emotions only help you find the ultimate mood, they can help to walk slowly to the final state, because they will send emotions also in accordance with old data such last emotions related to an ambient condition. Therefore the section 4.2.5 shows the flow of emotions that occur with changes on environment.

Using the PAD space, and the OCEAN structure as methods of affective computing, it was possible to materialize the emotional response and show the result through a visual panel, and with that demonstrate the actual mood of an agent.

By using JAVA as main implementation language, was possible to work with several libraries like Swing, JUNG and JFreeCharts, and also work with JADE that is framework, for developing agents, totally implemented in JAVA.

In the Agents section is presented routines and the decision of the two agents implemented (M and PA), and they are graphically represented by 4.5 and 4.6 figures. Like that agents are JAVA classes it is possible to reproduce them multiple times, thereby creating a platform for multiple users. The agent also has a graphical interface to make the information, of its internal state, visible.

As mentioned, JADE admits that an agent possesses the interface and communicate with it. So another task of the developed work was to create an GUI to better understand the evolution of mood through time and through ambient condition.

The next chapter refers to the tests that were done to evaluate the work. Therefore, it is presented the methodology from behind each test and its analysis, also the findings achieved are presents.

Chapter 5

Results

To validate the previous chapter a series of steps were made with the intention to provide data and set the used techniques so that they can be adjusted to maximize the accuracy of subsequent results. This chapter introduces the methodology of the tests and the conditions available to perform them. Also it presents in detail the results, the steps to obtain them and analysis of them.

5.1 Methodology and Conditions

To test the simulation of emotional response based on human behavior through virtual agents and its associated GUI, some tests were made. The objectives were to perceive how a defined $personality$ could interact with an emotional structure like $mood$ and also to understand the evolution of this structure through time and how it was affected through ambient properties such temperature, noise, and luminosity. The testing procedure followed a determined set of steps, as presented below:

1. To collect information about the personality of real people through a survey;
2. To test personalities in a real environment;
3. To test personalities in a simulated environment;
4. To analyse of results;
5. Discussion.

To collect information about these steps, it was necessary to store the information in the CSV (Comma Separated Values) file with information about the state of actual and last temperature, noise and illuminance and also the mood and related values PAD.

The next sections explain, with more detail, what was done in each step and why it was done. Besides that, the next section make reference to the tools used for analysis.

5.2 Personalities through questionnaires

To isolate the values of OCEAN traits, a test seen on section 2.2.3 was used. In this sense, a quicker test with a high degree of accuracy was chosen. As seen in the literature, the NPA questionnaire could be the most suitable for this purpose, since only has twelve questions and the answers are calculated quickly [26], compared to the other listed tests.

In this summarized version of NPA (in Appendix), questions were suppressed but it only retains how they are evaluated. The common way is to attribute a value from 1 to 5, to Very unlikely until Very likely, respectively. In some questions the values are inverted, which means that they are attributed from Very likely to Very unlikely. To evaluate the score, the values of related like in the Nettle's NPA [55] are summed:

$$\begin{aligned} O &= q(3) + q(8) + q(11) \\ C &= q(4) + q(9) \\ E &= q(1) + q(6) \qquad \text{let } q(x) \in \{1,2,3,4,5\} \\ A &= q(2) + q(7) + q(12) \\ N &= q(5) + q(10) \end{aligned} \tag{5.1}$$

To interpret the traits of each personality dimensions it is necessary to follow guidelines that evaluate the calculus form 5.1 and give levels of each trait in a person, like presented below.

- If C, E and N equal to:
  - 2, 3 and 4, low score of this trait;
  - 5 and 6 low-medium;
  - 7 and 8 medium-high;
  - 9 and 10 high;
- If A equals to:
  - 3 until 9 if men, 3 until 11 if women, low score of this trait;
  - 10 and 11 if men, 12 and 13 if women, low-medium;
  - 12 and 13 if men, 14 if women, medium-high;
  - 14 and 15 if men, 15 if women, high;

- If O if equals to:
  - 3 until 8, low score of this trait;
  - 9 and 10 low-medium;
  - 11 and 12 medium-high;
  - 13, 14 and 15 high;

The problem is that the final outcome of each variable is not in accordance with the calculations performed to calculate the initial mood, as in the equation 4.2 of the previous chapter, so it is necessary to map these values to match with domain of $[-1, 1]$.

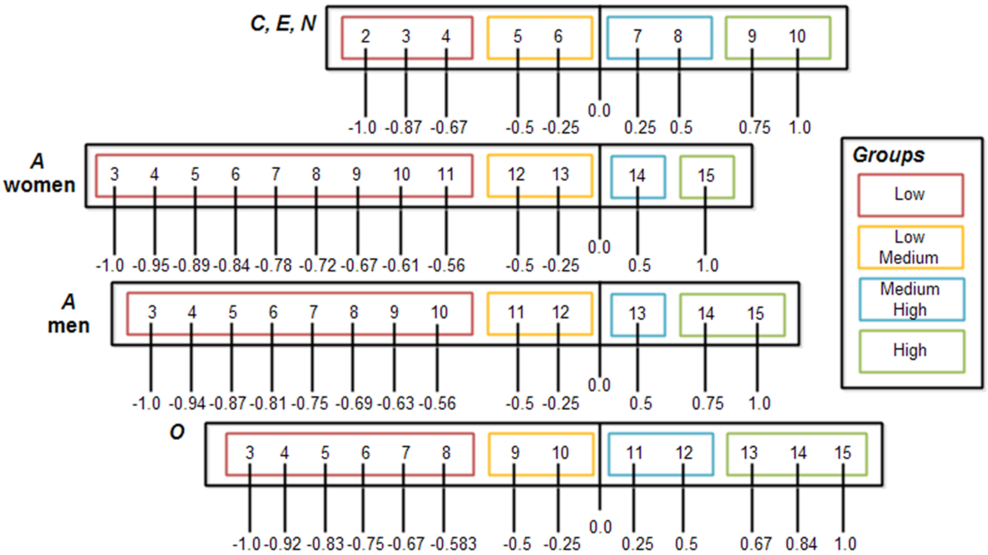


Figure 5.1: Map NPA scale into $[-1, 1]$ domain.

This method was done for each group by solving the division between a group length with the group cardinality ($\#group$) then from the group beginning to it border and the result are summed. In all the cases, all groups have the length equal to (0.5), the $0.5/\#group$ is summed with the last value, for example the low medium and the medium high start from zero and go until -0.5 and 0.5 respectively, the low and high groups go from -0.5 and 0.5 to -1.0 and 1.0 respectively.

For the tests, five volunteers filled out the NPA questionnaire. They took about two minutes to respond and about a minute to review the results. With this step, it was possible to isolate personalities variable an include them on main agents the table 5.1 shows the results of each volunteers.

According to these results, it was noticed that all the personalities to include on the agents would be different, some had the values of neuroticism higher than others, in the other hand some had higher values of extraversion, which would allow different emotional weight.

	MP	FB	GO	TO	JR
O	0.25	-0.67	-0.25	0.25	-0.583
C	0.75	0.5	-0.67	1.0	0.5
E	-0.5	-0.25	-0.5	-0.87	0.25
A	-0.56	-0.5	0.5	-0.5	0.5
N	0.75	-0.25	-0.67	0.75	-0.67

Table 5.1: Five volunteers with OCEAN variables

5.3 Live tests

To obtain results with platform activated in integration with PHESS system in the ISLab at University of Minho as the real environment for request data, tests were carried out with various agents according to personalities recreated above. These agents have been put into action simultaneously, so that the ambient conditions reached with information from the PHESS were equal for all.

First test was with configurations stated in the previous chapter 4 section 4.2.4, $ConfT_A$, $ConfN$ and $ConfI$ (see tables 4.1, 4.3 and 4.4), with three agents M defined with personalities MP, FB and GO. The time per turn of agent M was $15000ms$ that are the equivalent to fifteen seconds.

In this first test the three-dimensional graphics 5.9, 5.10 and 5.8 are the result of first sixteen minutes, although the measures were made until thirty four minutes.But because, most of the time, the ambient conditions were still the same, temperature: ACCEPTABLE, illuminance: ACCEPTABLE, only the noise varied. Thus, this variation is presented in figure 5.2. The analysis of the results of this test is presented below, in the section 5.5.1.

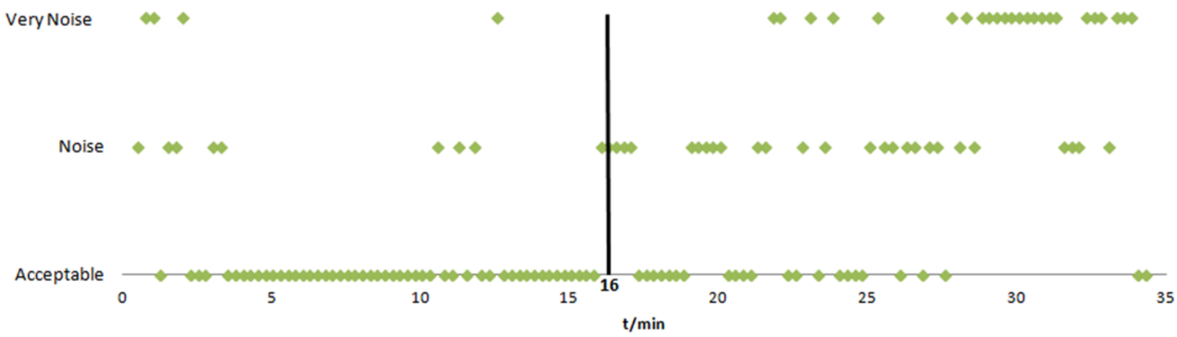


Figure 5.2: Variation of noise per minute. The minute 16 mark where the three-dimensional graphics were designed

In the analysis of this test (test A), it was perceived that the temperature values were in a range too short, preventing the trigger of various emotions, and since the temperature had a stronger weight in the fusion value, it controlled the final mood. Thus it arose the creation of a new configuration $ConfT_B$ (see table 4.2), in order to adjust the temperature values with the aim of creating a more varied emotional state.

The second test (test B) was done with the intention to perceive the functioning of the system over a long period of time. Therefore the system ran since 11AM until 4PM. In this test, instead of the agent M having $15000ms$ per round, it had $300000ms$ per turn. Besides that, it used the $ConfT_B$ for temperature, and maintained the other configurations.

The analysis of the results of this test is presented below, in the section 5.5.2. It should be noted that in the interval of hours that the test occurred, the ambient conditions did not vary. The temperature, noise and illuminance, were still Hot, Acceptable and Acceptable respectively. Other important factor, was the remotion of the control of the final mood at the temperature because its excessive weight on the calculus; all weights of mood (see figure 4.4) were balanced: 40% for temperature, 35% for noise, e 25% for illuminance.

Besides the test, it was taken a screen shot of the communication environment promoted by JADE to perceive agents set of behaviors.

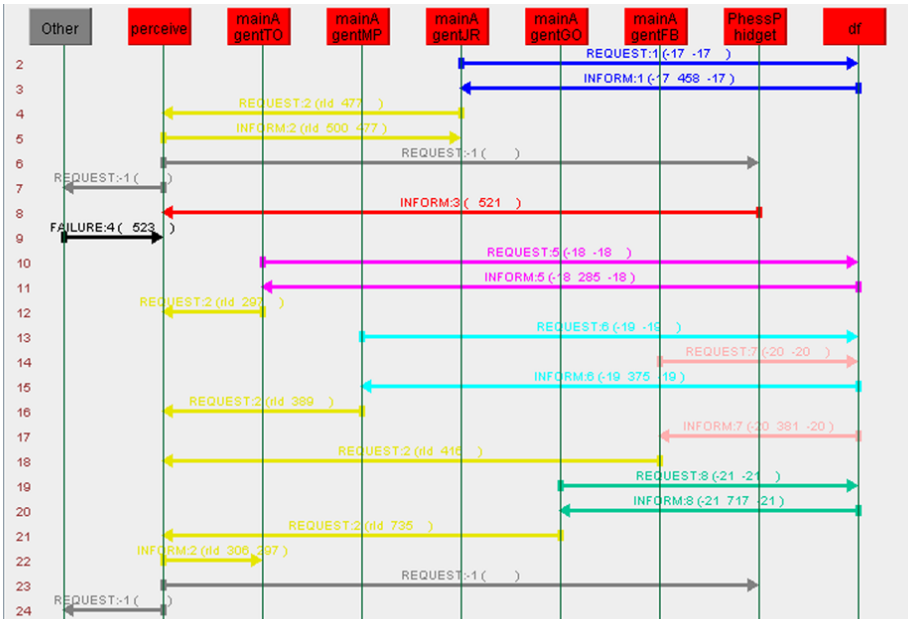


Figure 5.3: The agents sniffer of JADE

Figure 5.3 shows the asynchronous communication between all agents and it also presents the request information of the agent perceive PA to PHESS that includes the agents PhessPhidget and PhessSound; this last one in this test was deactivated and therefore it throws a failure. It also presents the service discovery from all main agents of $\mathrm{world-service}$.

Because the lack of variation of ambient conditions, the analysis of the test B is near to the previous analyse for test A. So for the deficiency of this change it was necessary to simulate the data and hence the idea of developing an interface to agents arose for induce them a forced change in the variables of the world.

5.4 Simulator test

Like shown in the section 4.2.7, it was developed a graphical interface and this interface includes a simulation tab, this tab allows users to provoke virtual values for the environment, in this case, only the conditions such temperature, illuminance, and sound are available. Like the image 4.10 shows, slide bars to all conditions are available, and also a button called Go for inducing these values.

In this step, it was tested an agent with the MP personality; the objective behind was to introduce variety on the ambient conditions, for example to increase and decrease temperature in a short period of time. This variation is present in the next charts (figure 5.4, 5.5 and 5.6).

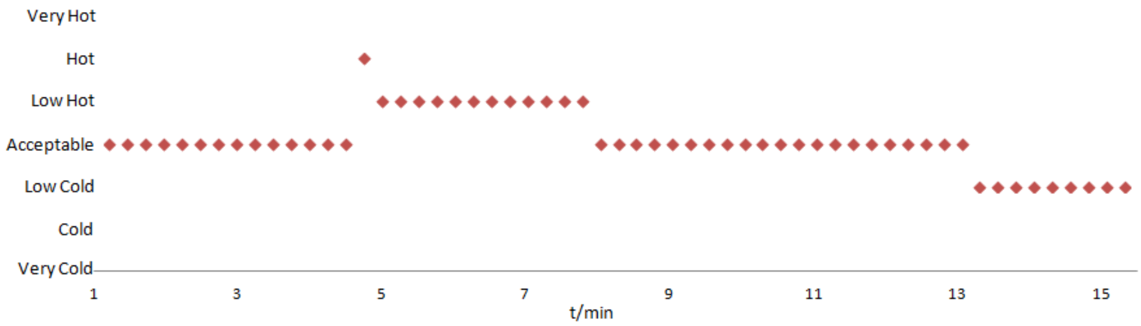


Figure 5.4: Variation of temperature per minute in the simulation.

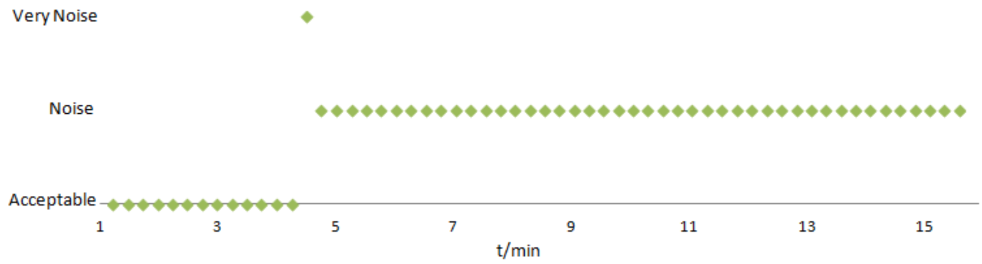


Figure 5.5: Variation of noise per minute in the simulation.

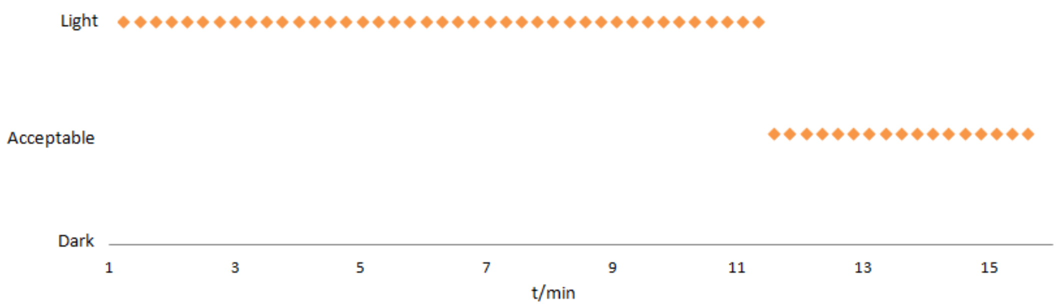
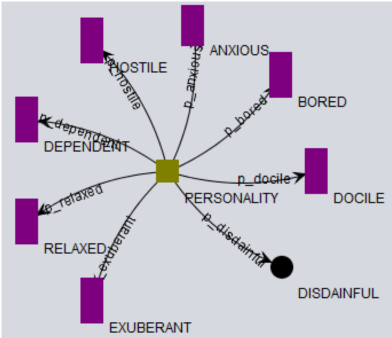
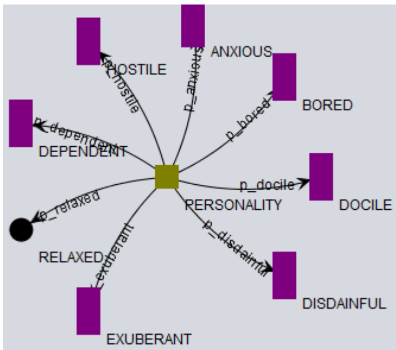


Figure 5.6: Variation of illuminance per minute in the simulation.

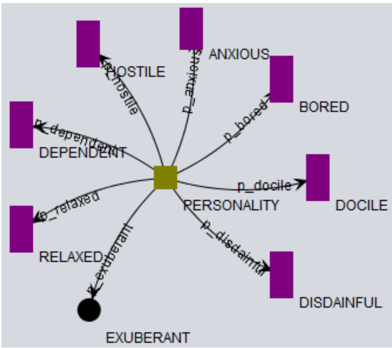
The purpose of this simulation of environment conditions is to induce emotions that are related with these variations. The agent subject to these emotions will hit several mood states. The next image displays these same changes in the graph drawn on the graphical interface.



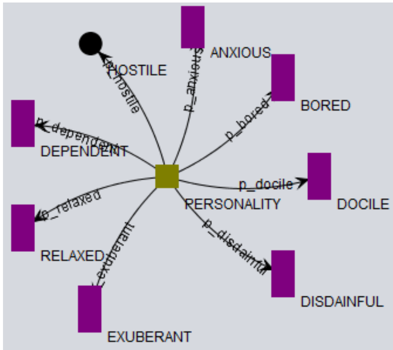
temperature: 19; noise: 24, illuminance: 1000



t: 19; n: 24, i: 1000



t: 19; n: 24, i: 1000



t: 25; n: 48, i: 1000

Figure 5.7: The mood change on the Graph in the developed GUI

As it is possible to see the graph that represents the mood is being updated per turn until it achieves the field mood of emotions. If in the course of this path, the agent is subjected to other conditions the path will change for other state, it may even be in the same mood but with different depth. This concept of depth represents the hardness of this change.

5.5 Analysis

To analyse the data, three-dimensional graphics with data collected in tests were generated. For this task the tool used was the Wolfram Mathematica version 7.0 which has a function to draw three-dimensional content and it allows interaction that enables the observation of multiple views $Graphics3D[...]$. Besides that this function permits the addition of various shapes, so to perceive the different states of mood it was designed translucent squares centred on the zero (0.0) value of all axis (P, A, D). This tool also allows saving the graphics in various formats which helped to expedite the process of choosing the sights that help to better perceive the scenario.

5.5.1 Analysis Live test A

As stated before, the first test occurred in the conditions of the AI lab where were tested three different characters - MP, FB and GO.

The following graphics show different mood through time under three different personalities and they also show the speed and direction at which the final state is achieved by environmental conditions. In this case, by fusion mood with temperature, mood with noise and mood with illuminance, the final mood is EXUBERANT.

MP

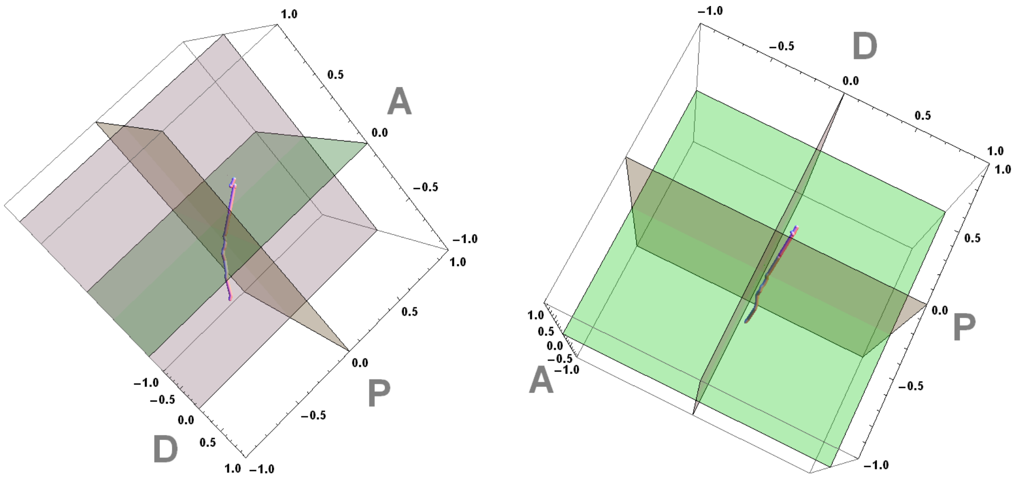


Figure 5.8: Two views of the plot of agent MP in real test A.

Plot	Figure 5.8
Description	Results of MP, 64 iterations in test A
Initial Mood	Disdainful
Final Mood	Exuberant
All mood transitions	Disdainful $\xrightarrow{11}$ Relaxed $\xrightarrow{11}$ Exuberant $\xrightarrow{41}$ Exuberant

Table 5.2: Details of agent MP in test A.

In sixteen minutes (or sixty four turns of $15000ms$), the agent with personality MP reached two mood states until it achieved the final state, and lasted about twenty two turns (approximately five minutes) to become Exuberant. The calculus of initial mood points to a Disdainful mood. It is possible to see in the three-dimensional graph that Dominance value (D) is always positive, and other two factors Arousal (A) are still negative until Exuberant mood is achieved, and Pleasure factor becomes positive when Relaxed mood is achieved and keeps up to final state.

FB

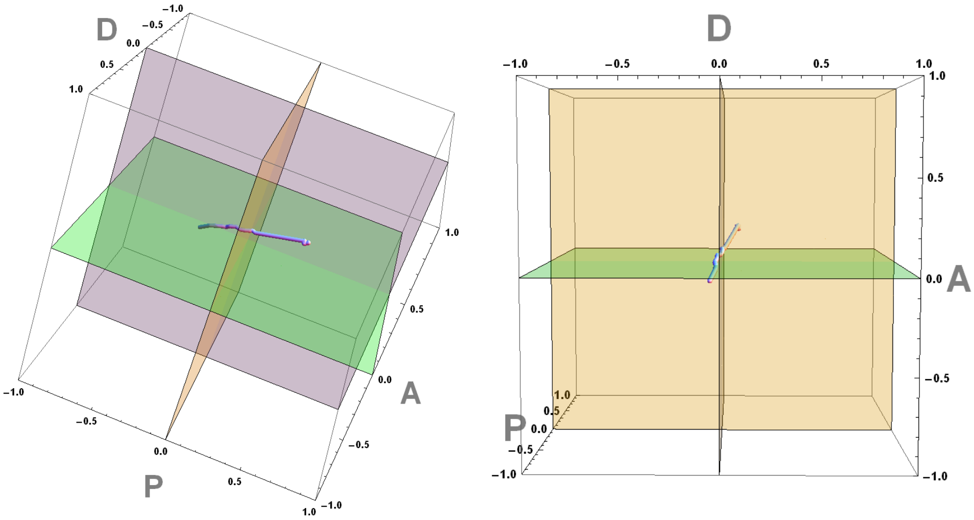


Figure 5.9: Two views of the plot of agent FB in real test A.

Plot	Figure 5.9
Description	Results of FB, 64 iterations in test A
Initial Mood	Bored
Final Mood	Exuberant
All mood transitions	Bored $\xrightarrow{4}$ Anxious $\xrightarrow{6}$ Hostile $\xrightarrow{1}$ Dependent $\xrightarrow{1}$ Exuberant $\xrightarrow{51}$ Exuberant

Table 5.3: Details of agent FB in test A.

This agent FB starts with Bored mood, passes for Anxious, Hostile, and Dependent before achieve the Exuberant mood, these steps lasted less two minutes than the MP agent. In figure 5.9 FB starts with all PAD factors negative, and signals are changing as the mood moves to the final state, first the A factor becomes positive and holds it to the end, then D factor changes to positive but only a turn, becoming negative again, then the pleasure P gets positive and keeps thus until the end and, the last step, the D turns once again positive.

GO

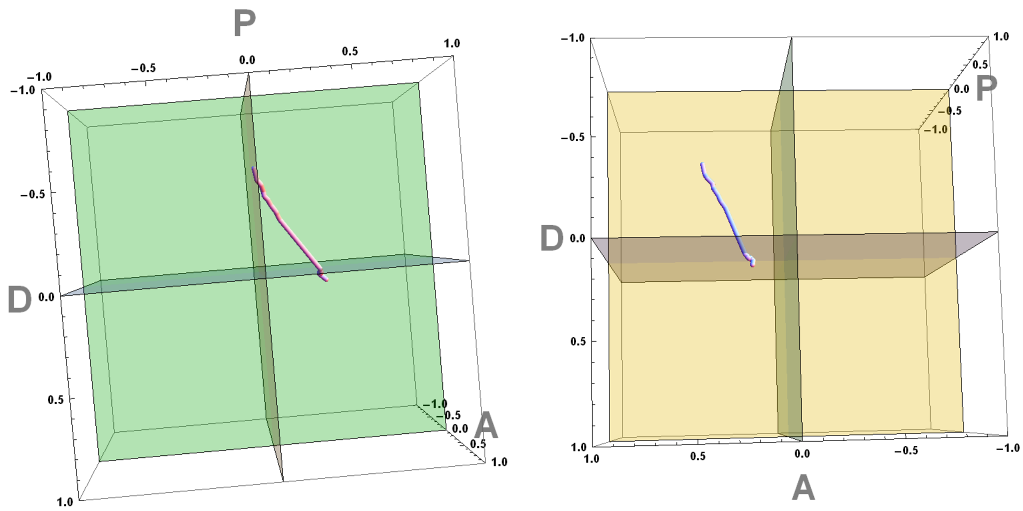


Figure 5.10: Two views of the plot of agent GO in real test A

Plot	Figure 5.10
Description	Results of GO, 64 iterations in test A
Initial Mood	Dependent
Final Mood	Exuberant
All mood transitions	Dependent $\xrightarrow{39}$ Exuberant $\xrightarrow{24}$ Exuberant

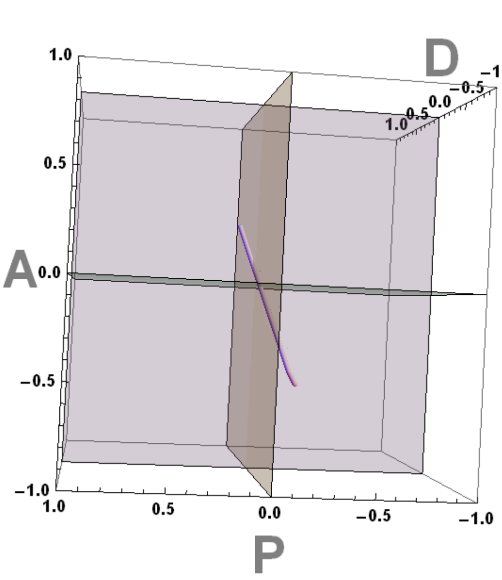
Table 5.4: Details of agent GO in test A.

The agent GO starts with Dependent state which lasted most of the time (about ten minutes). In graphic 5.10 only the signal of D varies, the other two factors maintain positive. To explain all of the results of MP, FB and GO, One has to look at the personality of each one, as the initial mood that they are associated. Particularly, one has to look to neuroticism (n) and extraversion (e) values, both are responsible to calculate the emotional weight of each event, as explained in section 4.2.2. As the event has a positive character, because final state is Exuberant despite noise varies to negative events.

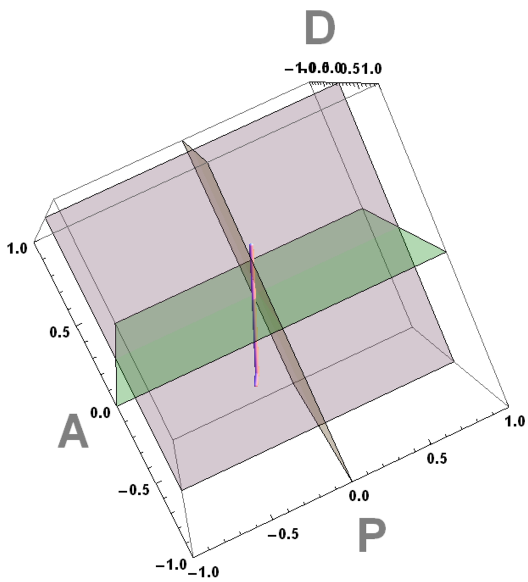
The mood fusion also has the ability to calculate a balanced $emotionalWeight$, in this case, temperature has force to control the mood ending and also its weight. Observing the table 5.1, it is noted that FB has a higher e than other two agents, this explains the ability to accelerate the positive feelings. The difference between MP and GO is that, despite e has a higher impact in positive feelings, the value of n cannot be omitted because some negative events happened and the MP agents have a higher n than GO. Therefore it is faster to achieve the final state.

5.5.2 Analysis Live test B

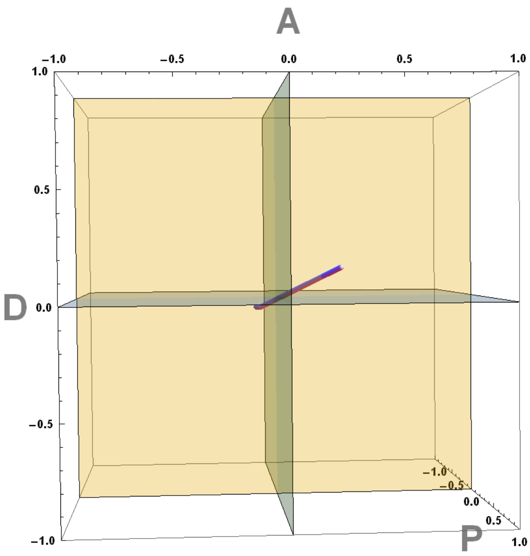
As stated in section 5.1, the second test occurred in the conditions of the AI lab where five different characters were tested - MP, FB, GO, JR and TO. The following graphics show different moods through time under five different personalities and also show the direction at which the final state is achieved by environmental conditions. In this case, fusion mood with temperature, mood with noise and mood with illuminance, the final mood is Exuberant ($+P, +A, +D$). Here are presented two different visual perspectives for each agents.



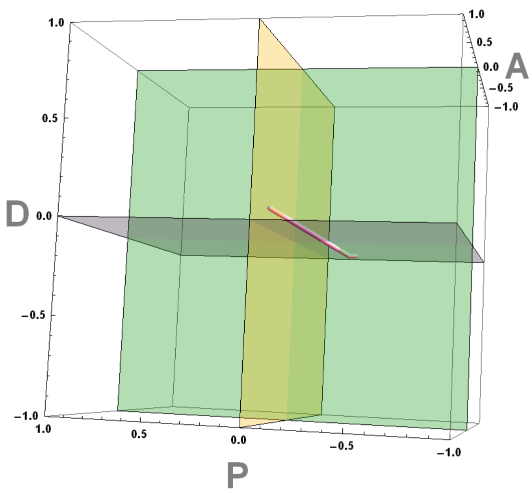
MP view 1



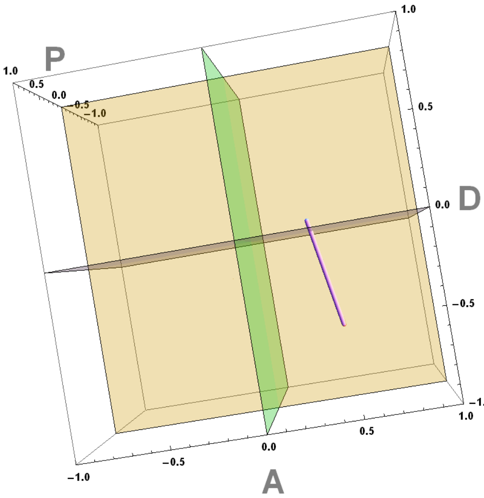
MP view 2



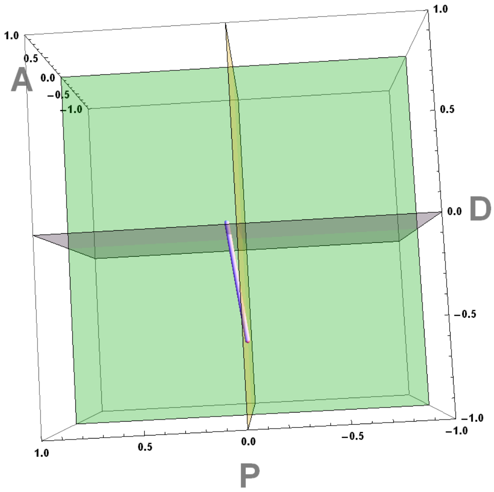
FB view 1



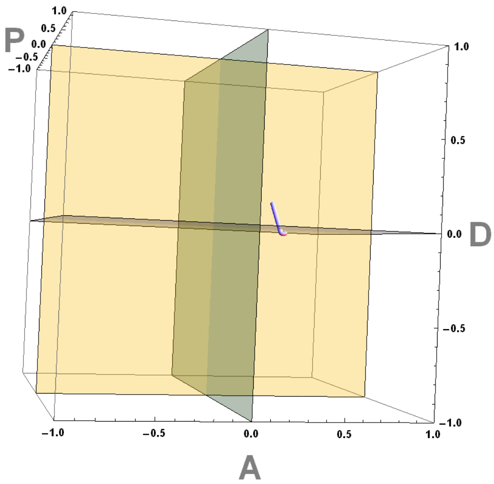
FB view 2



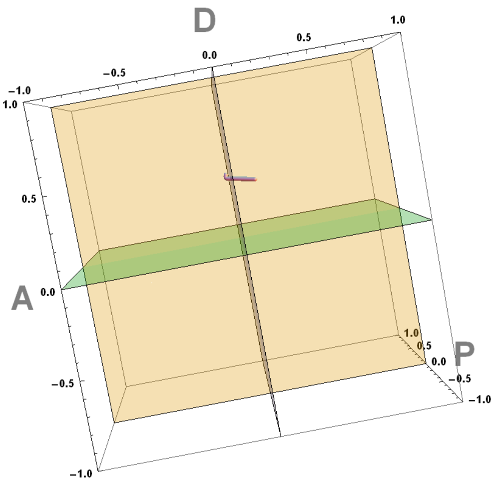
GO view 1



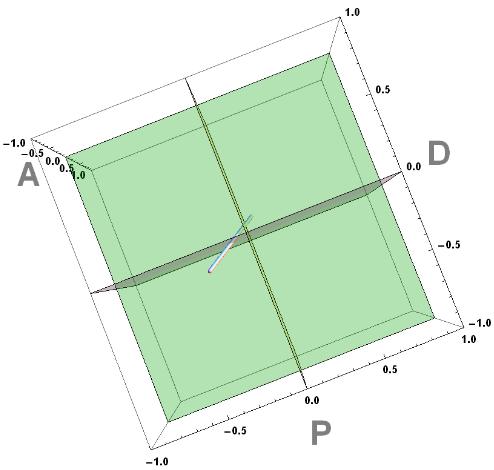
GO view 2



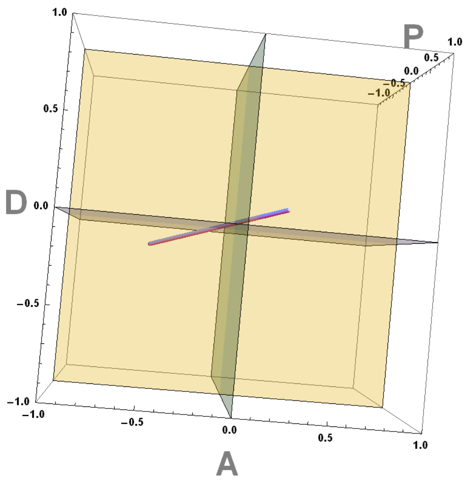
JR view 1



JR view 2



TO view 1



TO view 2

Figure 5.12: Various views of all agents results for test B.

The agent MP started with Disdainful mood ($-P, -A, +D$) took fifty minutes to change for a Hostile mood ($-P, +A, +D$), and then after twenty five minutes achieved Exuberant as the final state. Agent FB took one hour and fifty minutes to achieve the final state, before that it passed by the state Bored ($-P, -A, -D$) and Anxious ($-P, +A, -D$) taking thirty minutes, and passed in Hostile state about seventy minutes.

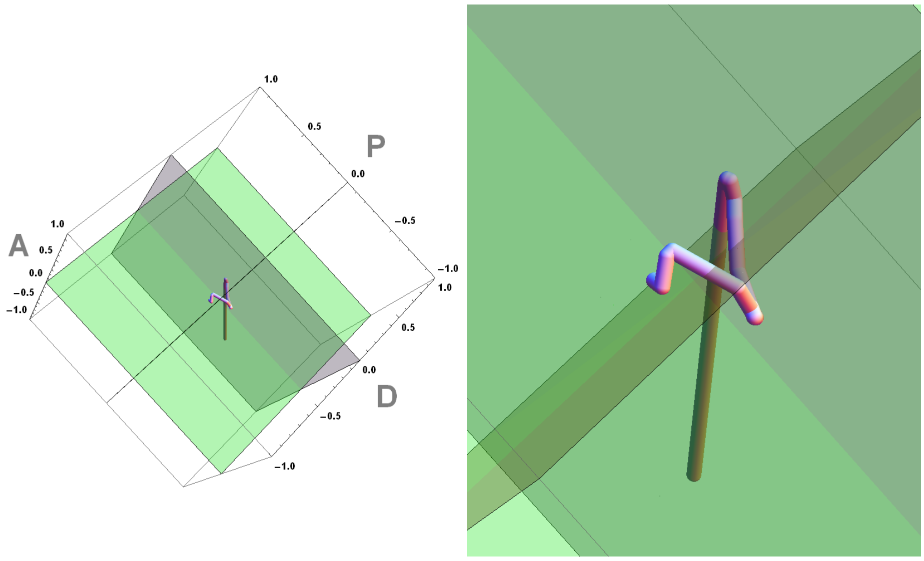
Similar to the previous test, the agent GO takes about thirty one rounds ($155minutes$) to complete the goal of achieve Exuberant, remaining in mood Dependent ($+P, +A, -D$). The agent JR was the faster to achieve the objective, it took about fifteen minutes to leave the Dependent state and entered in the Exuberant field.

The last agent in the charts, the TO agent, began in the state Bored and it took about forty five minutes to change to Disdainful, in this state it remained twenty minutes, until it reached the Hostile state. Then, it took forty five minutes to enter in the final state.

After all agents achieve the Exuberant state they remained constant in the same state until the end of the test. Each "worm", drawn in the graphics, shows different sizes, this fact explains the velocity that each agent achieves the final state. Also the almost perfect shape of the "worms" is explained by the constant values of the acquired conditions of environment. The velocity in JR agent is because its personality has the higher trend to express positive feelings, this means that it has the higher value of e. The agent MP and TO have a similar constitution, the difference is that the personality values of agent TO are more extreme, for example, it has a higher negative degree of extraversion and therefore it lasted more to achieve the final point than MP.

5.5.3 Analysis Simulator

To analyse the impact of simulation under a personality, in this case, the simulator test in the previous section 5.4 uses the personality MP. The present section shows the three-dimensional graphic of all the states of mood.



MP general view MP Zoom in

Figure 5.13: View of the MP mood paths under the simulation

It is possible to see a mood not so straight like the in the real tests. The agent started in mood Disdainful ($-P, -A, +D$), took nine turns and then entered in the Relaxed ($+P, -A, +D$) state only three turns before become Exuberant ($+P, +A, +D$). This initial steps represent the mood related with Acceptable temperature and sound, and Light for illuminance, after the temperature increases to Low Hot, and sound to Noise, this makes a decay for negative feelings and therefore the mood becomes Hostile ($-P, +A, +D$) and after Anxious ($-P, +A, -D$). Then twenty four turns later the temperature droped to Acceptable and then Low Cold, and illuminance decreased to an Acceptable state, this makes the mood Dependent ($+P, +A, -D$).

Comparing to negative feelings MP agent converges more quickly and prevails longer in Hostile, Anxious, Disdainful than to positive feelings like Exuberant and Relaxed.

5.6 Discussion

The main focus of attention in this context of results and analysis is to celebrate the union of the concepts studied in the first chapters with the work developed, giving meaning to the first ones, and validating the last one.

Objectively tests were made to realize the importance of the study of human psychology applied to a platform for the management sustainability and how personality increases or decreases the emotions impact of environmental features. The first test was a basic test to verify the mood changes through time, in this case the temperature discretization created a small group of values and the temperature weight was too high and so it controlled the final mood state, removing impact on other features such noise and illuminance.

This led to the other test, with different temperature configuration and different weight. Other particularity is that in this test B, the turn time was increased to extend the update step to approximate the calculation with real life, because the manifestation of changes on mood in human beings takes time, in other words, the mood is seen as a medium term emotion that takes minutes or even days to change (chapter 2.3 section 2.3.4). Therefore, it makes sense to reproduce test in a longer period of time than test A, this permits also, in a superficial level, to observe the performance of the application knowing if communication among all agents is preserved.

The problem lies on the lack of variation on environment acquired data, this issue created an handicap on validation of all constructed rules that relate sensor's values and emotion. This disability was overtaken by defining a simulator module for an user to insert "what if" values, for example increase or decrease temperature, light or sound without wait by real values. The mood passes by several states relating their emotions associated with the simulated values.

Also, it was possible to test the graphical interface that gives visual meaning to the processes that are updating in real time, such mood, values from sensor.

To conclude this chapter of results it has to be mention the potential that could have such system in a platform for supporting sustainability. Acknowledge that there is a change in the emotional state of a user, or to have the ability to provide a prediction for a potential alteration in behavior, could be used as a power supply to readjust the sustainability indicators. For example, notice that certain temperature controlled automatically via electronic appliances mechanisms can cause adverse reactions in people and thereby realizing Apriori, without the user need to expose their discontent, would be easier to adjust temperature, balancing costs with psychological costs.

Chapter 6

Conclusion

This last chapter aims to present the main conclusions from this work. Therefore, presents the main advantages and what could be done differently. It also presents its main contributions in scientific community. In addition, it presents the future work that is putted in perspective from the actual point and other decisions which may be considered.

6.1 General Conclusion

The first conclusion is that the objectives of this project were achieved. The initial drawn plan was held as scheduled, however some initial goals had to be prioritized, for example, like in section 1.3 the goal for making tests under the systems was delayed, because it was necessary to increase the effort in developing process.

The investigation of the literature was an interesting work (chapters 2 and 3) because Affective Computing (AC) and Ambient Intelligence (AmI) are gaining more and more importance both in Information Technology and Electronic fields. The capacity to generate a virtual emotional response from a digital system or mechanism is possible, as well as the capacity to understand human relation with his surroundings and with that increasing his quality of life and the environment quality.

This effective reality requests a thorough knowledge of human psychology to help both areas AC and AmI to manage their resources and provide better decisions. In addition, there was a lack of detailed information that relates environment conditions in terms of Big Five Factor and also in terms of PAD space.

In order to implement a system that could assign a grade to emotional events that occur in the world, a multi-agents platform was made, that had an agent with a mental structure and other to communicate with a platform for manage sustainability indicators that also had the ability to retrieve information of the world, using a sensing layer. Thereby, it was necessary to apply the agent with the mental structure, one personality and a mood and also it was necessary to model the events from the world.

To have a real perspective of the actual emotional state, a graphical interface was designed. This step permits to visualize the actual emotions that are calculate through time.

A factor that it is needed to observe is the TPB framework, that has the objective to calculate the value of intention of the human behavior on his daily action. There wasn't found information of computational systems that apply this questionnaire. In fact there wasn't found any work that uses this same questionnaire or a Big Five Inventory to assess the five personality traits which throws questions to users in sparse moments in time, for slowly construct a mental structure on virtual agents avoiding a long period of configuration at the beginning of the installation of a system like the one presented in this project. This means that in the beginning it would be necessary to assess negative action from users and then all at once using the TPB framework to know the intentions of repeat the same behavior. For example, to have a precise information about personality it would be necessary a extensive survey with at least two hundred and fifty questions for the user to fill, and forty minutes, at least, to analyse the results of it.

There was an initial plan to collect accurate data on personality using more extensive questionnaires, and to relate them to the questionnaire used, but this task would take some time, and the lack of knowledge in the field of psychology suggested the removal of the idea. So it was left to the background but with perspectives for future.

The creation of a database of the habits was also sent to a later phase because it would required the user's presence factor and concrete data about the user's actions in a house. So for this thesis, it was done the treatment of general information of environmental conditions.

In this work, the temperature, noise and luminosity were analysed, the values of these characteristics appear in infinite domains, therefore they have been mapped to groups of value, because, for example, a difference of half degree on temperature does not make a great difference on emotions. And then these groups were related with OCC to achieve a possible emotions. Once again the emotions needed to be defined by literature statements, that they weren't precise and this could trigger the inaccuracy of the final result. The decisions of these emotions were taken relating information of psychological articles and ergonomics measured in technical sites.

The results were as expected, it was worth noting the difference in mood for several personalities based on real people, and the time necessary to achieve the emotional state related with environment condition. With this step, it becomes accessible that the main objective of the project was fulfilled. When simulated emotions based on real people are calculated, it is possible to decrease the non-determinism of decision making in systems based on artificial intelligence. Therefore when a software has the ability to know what the user, that interacts with it, feels, it can make appropriated decisions

6.2 Relevant Work

Like it had been previously defined in the thesis objectives, there was the intention to submit one article to the scientific community. Two articles were published in collaboration with all those involved in the project PHESS in two different conferences and journal.

- Silva, F., Analide, C., Rosa, L., Felgueiras, G., Pimenta, C. "Ambient Sensorization for the Furtherance of Sustainability", in International Symposium on Ambient Intelligence 2013 (ISAmI'13)
- Silva, F., Analide, C., Rosa, L., Felgueiras, G., Pimenta, C. "Social Networks Gamification for Sustainability Recommendation Systems", in International Symposium on Distributed Computing and Artificial Intelligence 2013 (DCAI'13)
- Silva, F., Analide, C., Rosa, L., Felgueiras, G., Pimenta, C. Gamification, Social Networks and Sustainable Environments in the International Journal of Interactive Multimedia and Artificial Intelligence (IJIMAI'13).

The first is related to the sensors that are presented in an environment for the calculation of sustainability indicators. The second refers a possible social network based on gamification theory to improve action between users for their self indicators for sustainability. All of the works make reference to the use of emotional state of users, and how emotional system could help in decision making process.

Moreover, an introductory course on sustainability in Coursera was taken, that is a massive open online courses platform, promoted by the University of Illinois at Urbana-Champaign with Jonathan Tomkin as teacher. This was done to better understand the principles of sustainable behavior.

In addition, meetings were performed to validate the solution. There was a validation with Carlos Silva, expert in the field of psychology and psychology in computing field.

6.3 Future Work

As a natural step, some ideas had emerged during the course of the project, some ideas (not to compromise the implementation of the main objectives they stayed in the background for a future implementation). However some possible approaches were presented during the sketch architecture section in the developed work chapter, in fact that section is an approximation of what was possible with the results of the literature review.

Thereby, for future work, the implementation of a structure to save the habits of users of the platform will be done. That can, perhaps, use a ranking system, predict the strength of habits and how it can be treated, if an action that has a negative impact on sustainability indicators is done repeatedly.

Relating cognitive and mental structures of the virtual agent based with its own user, also, can be useful to create data structures that keep information about users desires, beliefs and motivations of sustainable main aspects, such environment, economics and social that can be related with external stimulus. One problem could be how to map the events of the world to these aspects, because of the dimension of non-specific acts on world from user. The system can be feed with data from other users, measuring the distance between their mental structures, calculating similarities between them, and predicting the actions that were done by other users in time.

Other task that will be made in the near future will be the improvement of the graphical interface, adding more information about the mental and cognitive states and including a three dimensional face with the manifestation of expressions. Also, it would be interesting to add information about the historic of actions and habits, as well as presenting, graphically, the differences between past emotional content and current status for different contexts such environmental, social, and economics.

A task to analyse will be the inclusion of questions to the user through time and with this the information about the intention to perform certain actions and would be aggregated and also it would increase the precision of personality. With this way it is intended to not cause discomfort to the user and also to help him to get interaction with the system.

Another future mission will be the validation and adjustment of the present model along various tests performed with the help of experts in psychological matters, activating synergies so that this platform can also be useful to them.

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Appendix

This appendix shows the NPA questionnaire used on tests.

		Very unlikely	Moderately unlikely	Neither likely or unlikely	Moderately likely	Very likely
1	Starting a Conversation with a stranger					
2	Making sure others are comfortable and happy					
3	Creating an artwork or a music piece					
4	Preparing for things well in advance					
5	Felling blue or depressed					
6	Planning parties or social events					
7	Insulting people					
8	Think about philosophical questions					
9	Letting things get into a mess					
10	Feeling stressed or worried					
11	Use complex words					
12	Sympathizing with others' feelings					

Table 6.1: NPA summarized [55]