Universidad del Norte
Department of Electrical and Electronics Engineering

Intelligent Management of Hierarchical Behaviors Using a NAO Robot as a Vocational Tutor

By
Selene Sol Goenaga Silvera

MASTER THESIS

Advisor
Dr. Christian G. Quintero M.

Barranquilla, Atlántico, Colombia
June 2017

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A dissertation presented to the Universidad del Norte in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE

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ABSTRACT

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This thesis focuses on the development of an intelligent system which manages hierarchical behaviors using a NAO robot as a Vocational Tutor. This scenario allows a suitable interaction between the robot and the human being to evaluate the different personality traits managed by the intelligent system.

Therefore, it is necessary to characterize common behaviors used by people during vocational tutor sessions (e.g., movements or robot's body postures), in order to create an intelligent system which can hold an interview, similar to humans. In this context, 20 behaviors are selected, which were classified and categorized into five personality profiles. Each of these profiles is based on a theory of personality traits called the "*Five Factor Model*".

The testing results show how the intelligent management of hierarchical behaviors can be successfully achieved through the proposed approach, making the Human-Robot interaction friendlier. For future work, refinement of each behavior will allow an improvement in the Human-Robot interaction, and therefore greater fluency in conversation and brought closer the NAO as a vocational tutor.

Acknowledgments

First I would like to thank our God for giving me the strength to finish this study and for giving me the opportunity to see this great dream culminated.

To my parents, whom I thank for their deep love, support and confidence.

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Special thanks to my advisor Christian G. Quintero. Without their assistance and dedicated involvement in every step throughout the process, this thesis would have never been accomplished.

Finally, I would like to thank to those people who somehow contributed to the creation of this document. Thank you all for your contributions and support, so important to the success of this project.

To my God, mother, family and friends

General Contents

PART I: INTRODUCTION AND RELATED WORK

Motivation, objectives, main contributions and an overview of general concepts used in this thesis dissertation.

A review of relevant related work used as reference and inspiration to develop the proposed approach.

PART II: PROPOSED APPROACH

General considerations and implementation of the proposed intelligent system approach that allows the management of hierarchical behaviors using a NAO robot as a vocational tutor.

PART III: EXPERIMENTAL RESULTS AND CONCLUSIONS

Analysis and discussion of the experimental results, final conclusions and future research related to the management of hierarchical behaviors in robots based on intelligent systems.

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PART I
INTRODUCTION AND RELATED WORK

Chapter 1

Introduction

This chapter provides an introduction to the work presented in this thesis. Specifically, the motivation for the research area, the pursued aims and the main contributions are briefly described. Finally, the chapter concludes with an overview of the structure and contents of the thesis.

1.1. Motivation

Currently, we have machines in our everyday life, we use and interact with them on a daily basis in our work, home and in public places. So Human-Robot-Interactions (HRI) play an important role in our lives. Research in HRI field has made interaction between humans and technology friendlier. Now we can see humanoid robots in several universities and other research places around the world. This field is creating advantages in shopping malls, train stations, schools, streets and museums (Hayashi & Sakamoto, 2007), (Złotowski et al., 2011), personal assistants (Finke et al., 2011) , health (Shamsuddin et al., 2012), rescue operations (Robinson, 2014), among others.

This research aims at developing an intelligent system on the NAO platform (Gouaillier et al., 2009) that allows the intelligent management of different behaviors during a vocational guidance session. NAO is a humanoid programmable robot platform developed by the French company *Aldebaran Robotics*. This platform has worked as a study object for research on voice (Smolar et al., 2011), object (Nguyen et al., 2015) and face recognition (Ismail et al., 2011). The complexity of its movements is given by the implementation of defined algorithms.

A *behavior* is then a set of instructions that we can program in the robot with an application called Choregraphe. An application of this robot technology has been teaching it to play soccer (Coltin et al., 2010) like humans in the famous world

RoboCup. The management of behaviors during the game, like running to the ball, kicking it, or just passing it to another robot, is the main focus of this challenge.

Another application is using NAO for teaching in schools and universities, which is an innovative way of engaging young students in their studies, Fig. 1.1-1.

Fig. 1.1-1. Humanoid Robot NAO as an Educational Tool.

NAO is also used by researchers in many different fields for taking part in experiments of conceptual or theory models[1]. They can also simulate behaviors with Webots framework, or Choregraphe from Aldebarans suite platform. Choregraphe is an excellent tool for creating complex movements like dance, or programming the robot for face recognition, object detection, and other difficult tasks.

One of the main focus of behavior management is understanding human emotions and how the robot can respond to them. So researchers are working on programs and databases of behaviors (Dalibard et al., 2012; Le et al., 2011) that simulate emotions in the robot in order to have interactions with it more naturally, like if it were talking about conversations between humans. For instance, the use of NAO as an assistant in the therapies for treating children with disabilities such as autism in order to help them in learning and other activities, using facial recognition techniques and improving the HRI by experimentation (Keizer et al., 2014; Meena et al., 2012; Mitsunaga et al., 2008).

To further support human and robot interactions, the intelligent management of those behaviors is the main goal of this thesis to use the robot as a vocational tutor. In this context, all the elements that play a role in this process, such as motion behaviors, voice and recognition modules and processing modules have to be

[1] More information available from www.active-robots.com/aldebaran

characterized, in order to create an intelligent system which can hold a vocational guidance session, similar to humans.

Also, this research contributes with a HRI implementation of an intelligent management system of behaviors with effective communication between a human and a robot. Behaviors management is performed by implementation of a system based on neural networks.

1.2. Objectives

This work is focused on the development of an intelligent system which manages hierarchical behaviors using a NAO Robot as a vocational tutor.

- **Problem**: Intelligent Management of Hierarchical Behaviors to achieve effective interaction between a human and a robot.
- **General Objective**: Develop an intelligent management of behaviors using a NAO robot as a vocational tutor.
- **Goals:**
  - ✓ Identify and characterize common behaviors used by people during vocational guidance sessions.
  - ✓ Design and implement an intelligent system that can properly manage those behaviors.
  - ✓ Evaluating the performance of the developed system at being the robot capable to establish a conversation with users and be capable to emit a recommendation about user vocation according to the parameters necessary to take into account in the career selection process.

1.2.1. Thesis Question

The principal question addressed in this dissertation is:

Could a computational intelligence system according to a pre-established personality and the response given by the user to the question posed during a vocational guidance session make the choice of the appropriate behavior to be executed by the NAO robot?

1.2.2. Approach

In this research is proposed the design of an intelligent system on the NAO platform for executing a vocational tutor role. This proposal looks for an implementation of an intelligent management system of behaviors with effective interaction between a human and a robot.

Behaviors on the robot, such as the gestural patterns, hand positions and other actions involving a block of memory for execution must be defined. This means that each position or gesture has to be classified within a library or directory, using the Choregraphe application for later use. The degree of elaboration and refinement of behavior is directly related to better interaction of the robot with its environment.

Thanks to the management of the selected behaviors, the robot will be able to choose the most appropriate way to behave during the vocational guidance session. Therefore, the goal of the management of behaviors is to increase the appeal of the robot and its interaction to the user.

The HRI has focused on endowing robots with personality. In particular, this need has inspired a trend towards developing robotic systems capable of embodied communication through use of non-verbal cues that convey intentions, emotions, and personality. Therefore, personality is essential to creating socially interactive robots.

How would personality affect the behavior of a robot during vocational tutor sessions? In this research, it is necessary to make coincide the behavior to be executed by the robot and the personality chosen by the experimenter. For instance, a robot with an introverted personality will almost never get angry, so this personality trait (anger) will probably be presented in a lesser proportion than a cordial behavior during the development of the interview.

1.3. Contributions

This thesis makes the following contributions with an HRI implementation of an intelligent management system of behaviors with effective interaction between a human and a robot.

- ✓ *An intelligent approach for managing a set of behaviors towards finding effective interaction between the robot and the person.*
- ✓ *To improve the interaction between humans and machines in a particular environment. This will allow to take a step forward in the field of HRI, which has a marked tendency worldwide with this type of humanoid robots.*

1.4. Reader's Guide to the Thesis

Following is a general description of the contents of this dissertation. This master thesis is organized in three main parts distributed by chapters.

Part I: Introduction and Related Works

Chapter 1 presents a motivational introduction to the main topics, objectives and contributions regarding this dissertation.

Chapter 2 gives a general overview of background information regarding management of hierarchical behaviors, vocational guidance and personality theory criteria which are required to develop the proposed approach described in chapter 4.

Chapter 3 provides a general survey of the most relevant work related to the research addressed in this thesis.

Part II: Proposed Approach

Chapter 4 describes the formal aspects of the intelligent management of behaviors model presented in this thesis. The chapter also contributes to complete the description of such proposal. The proposed intelligent system and its implementation are described.

Part III: Results and Conclusions

Chapter 5 provides experimental results of the implemented approach. An experimental design is presented to evaluate the performance of several criteria of the intelligent system which manages hierarchical behaviors.

Chapter 6 discusses and analyzes the results, summarizes the conclusions and contributions of the thesis and outlines the most promising directions for future work.

Chapter 2

Background Information

This chapter explains the main features of the robotic platform chosen to be connected to the intelligent system. Additionally, a psychological theory of personality that supports the choice of common behaviors used by interviewer during vocational guidance sessions is explained. Generalities are introduced about of vocational guidance processes, concepts necessary to issue a recommendation about the vocational preference of the interviewee. Finally, this chapter introduces and reviews general concepts of computational intelligent system required for developing the proposed approach.

2.1. Humanoid Robot NAO Specifications

The humanoid Robot NAO (Gouaillier et al., 2008; Gouaillier, 2009) is an autonomous robot developed by a French Company called *Aldebarans-Robotics*[2]. This robot has the appealing appearance of a human toddler as shown in Fig. 2.1-1[3]. It is an open platform where the user can change all the embedded system software or just add some applications to make the robot adopt specific behaviors.

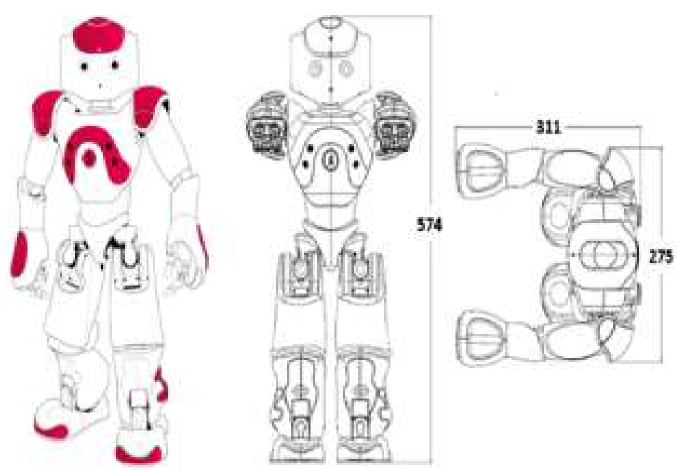


Fig. 2.1-1. Humanoid Robot NAO.

[2] Aldebaran-Robotics is a French company founded in 2005 by chief executive Bruno Maisonnier.
[3] Image available from https://www.ald.softbankrobotics.com/en

Technical specification details of NAO can be summarized in Table 2.1-1.

<table>
<tr><th>Description</th><th colspan="3">Specification</th></tr>
<tr><td>Dimension (HxDxW)</td><td colspan="3">574x275x311mm</td></tr>
<tr><td>Weight</td><td colspan="3">5.4 kg</td></tr>
<tr><td>Autonomy</td><td colspan="3">90 min (Normal use)
60 min (Active use)</td></tr>
<tr><td>Programming languages</td><td colspan="3">C++ / Python / .NET / Java.</td></tr>
<tr><td>Mother board</td><td colspan="3">CPU processor (ATOM Z530)
Cache memory (512KB)
Clock speed (1.6GHz)
RAM (1GB)
Flash memory (2 GB)
Micro SDHC (8 GB)</td></tr>
<tr><td>Connectivity</td><td colspan="3">Ethernet, Wi-Fi</td></tr>
<tr><td>Compatible OS</td><td colspan="3">Windows, Mac OS, Linux</td></tr>
<tr><td>Audio</td><td colspan="3">Loud Speakers (x2 lateral)
Microphones (x4 on the head)</td></tr>
<tr><td>Vision</td><td colspan="3">Cameras (x2 on front) 1280×960px</td></tr>
<tr><td>FSR (Force Sensitive Resistors)</td><td colspan="3">×4 per feet</td></tr>
<tr><td>IR</td><td colspan="3">x2 on front</td></tr>
<tr><td>Sonar</td><td colspan="3">Emitters (×2 on front)
Receivers (×2 on front)</td></tr>
<tr><td>Inertial unit</td><td colspan="3">Gyrometer (x1)
Accelerometer (x1)</td></tr>
<tr><td rowspan="6">LEDs</td><td>Placement</td><td>Quantity</td><td>Description</td></tr>
<tr><td>Tactile Head</td><td>×12</td><td>16 Blue levels</td></tr>
<tr><td>Eyes</td><td>2×8</td><td>RGB Full Color</td></tr>
<tr><td>Ears</td><td>2×10</td><td>16 Blue levels</td></tr>
<tr><td>Chest button</td><td>×1</td><td>RGB Full Color</td></tr>
<tr><td>Feet</td><td>2×1</td><td>RGB Full Color</td></tr>
<tr><td rowspan="5">Degree of freedom</td><td>Head</td><td>x2</td><td rowspan="5">25 dof</td></tr>
<tr><td>Arm(in each)</td><td>x5</td></tr>
<tr><td>Pelvis</td><td>x1</td></tr>
<tr><td>Leg (in each)</td><td>x5</td></tr>
<tr><td>Hand (in each)</td><td>x1</td></tr>
<tr><td>Contact sensor</td><td colspan="3">Chest Button, Foot Bumper,
Tactile Head and Tactile Hand</td></tr>
<tr><td>Text to speech& Automatic speech Recognition</td><td colspan="3">Danish, Dutch, English, French, German, Italian, Japanese, Korean, Portuguese, Spanish, Swedish, Russian, Chinese.</td></tr>
</table>

Table 2.1-1. Technical Specification of the Humanoid Robot NAO.

2.1.1. Humanoid Robot NAO Hardware

The Humanoid Robot NAO is 574 mm in height, 5.4 kg in weight. It has voice recognition and is powered by a LiPo battery with an autonomy of 90 minutes. Fig. 2.1-2 shows the location of inputs and outputs devices.

2.1.1.1. Input devices

NAO is equipped with two cameras and four microphones on its head. Microphones are very important sensors because voice should be the most natural interface between NAO and its users. The inertial unit consist of one gyroscope and one accelerometer and four Force Sensitive Resistors under each foot that give NAO the ability to estimate its current state.

NAO is equipped with a position sensor, contact sensor, sonar and IR. Sonars give a measurement of the distance between the robot and its environment. Bumpers on the feet detect collisions with obstacles on the ground. The head tactile device gives a way to communicate with the robot by, for instance, caressing NAO as a reward gesture.

2.1.1.2. Output devices

NAO offers two loudspeakers and programmable LEDS around the eyes. A Wi-Fi connection links the robot to any local network and to other NAOs if needed.

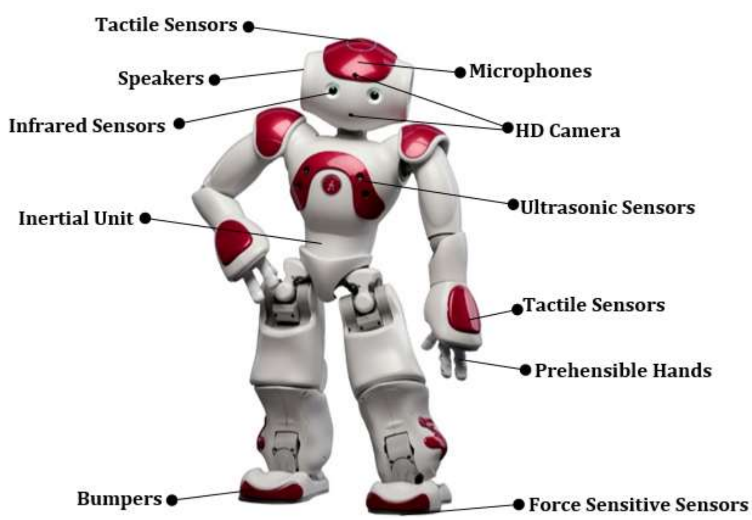


Fig. 2.1-2. NAO Key Features.

2.1.1.3. Kinematics

- ✓ NAO has a total of 25 degrees of freedom (DOF), 11 DOF in the lower part that includes legs and pelvis, and 14 DOF in the upper part that includes trunk, arms and head. Fig. 2.1-3 gives the kinematics details, and Table 2.1-2 lists the joints with their range.

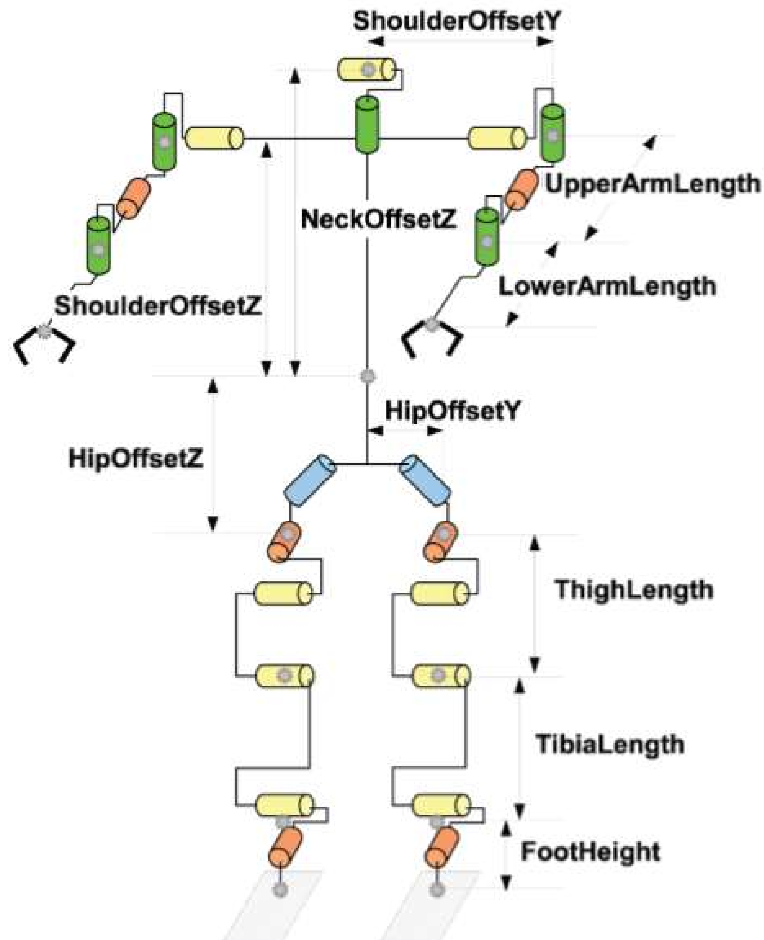


Fig. 2.1-3. Detailed kinematics of NAO. Wrist joint not represented. *(Gouaillier, 2009)*

Part	Motion	Range (°)	Actuator type
Leg (left)	hip twist (45°)	-68 to 44	M1R11
	hip roll	-25 to 45	M1R11
	hip pitch	-100 to 25	M1R12
	knee pitch	0 to 130	M1R12
	ankle pitch	-75 to 45	M1R12
	ankle roll	-45 to 45	M1R11
Arm (left)	shoulder roll	0 to 95	M2R22
	shoulder pitch	-120 to 120	M2R21
	elbow roll	-120 to 120	M2R22
	elbow yaw	0 to 90	M2R21
Head	yaw	-90 to 120	M2R21
	pitch	-37 to 31	M2R22

Table 2.1-2. Joints type, range and type. *(Gouaillier, 2009)*

2.1.2. Humanoid Robot NAO Software

NAO can be programmed by using visual programming, C and C++ languages, and Python language. NAO is compatible with Windows, Mac OS and Linux. The robot can be connected to a computer or laptop by using an Ethernet connection or WiFi connection. NAO has an embedded software called NAOqi.

The NAOqi is the programming framework used to program NAO. NAOqi is a distributed environment which allows several distributed binaries, each containing several software modules to communicate together. NAOqi defines five (5) main modules that allow interaction with the hardware elements on the robot:

- ✓ **NAOqi Core:** It are responsible for the primary functions of robot operation.
- ✓ **NAOqi Audio:** Contains the software elements related to the audio of the robot.
- ✓ **NAOqi Motion:** is the main tool allowing the robot to move.
- ✓ **NAOqi Vision:** It contains software elements related to the robot's vision.
- ✓ **NAOqi Sensors:** This module contains software elements that serve to interact with the sensors on the robot.

2.1.2.1. Choregraphe

Choregraphe is an intuitive graphical programming environment. When the software is launched, the graphic interface displayed in Fig. 2.1-4 appears on the screen. The application window is divided into three zones described in Table 2.1-3.

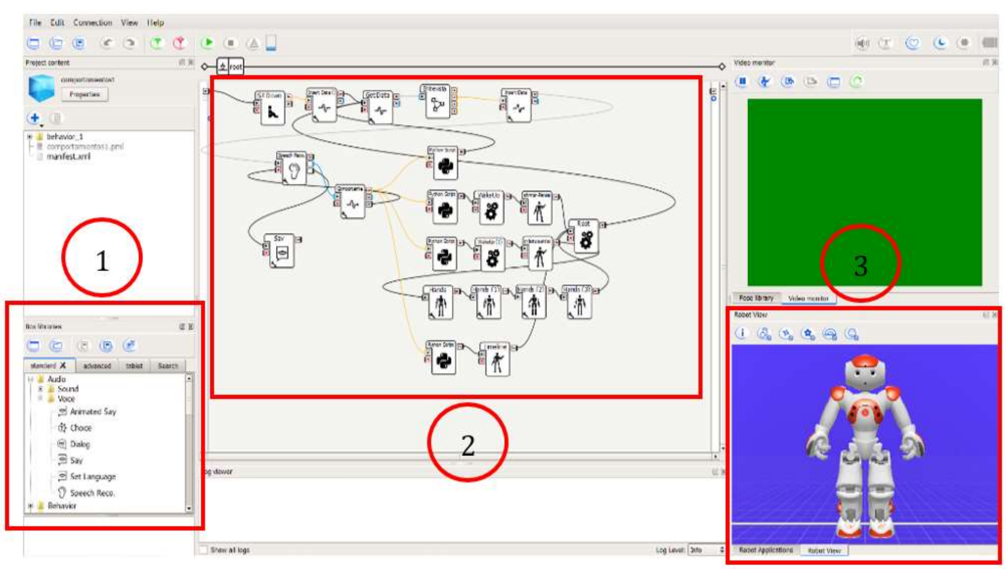


Fig. 2.1-4. Graphical User Interface of Choregraphe.

Zone	Name	Description
1	Box Library	It groups the list of available behaviors.
2	Flow Diagram	This zone allows the user to graphically lay out behaviors composed of library boxes and links between them.
3	Graphical representation	It is a graphical representation of NAO able to execute the implemented behavior.

Table 2.1-3. The Choregraphe Graphic Interface: zones.

Choregraphe is a multi-platform desktop application that allows[4]:

- Creating new animations, behaviors and dialogs.
- Testing on a simulated robot, or directly in the real one.
- Monitor and control NAO.
- Choregraphe allows to create very complex behaviors (e.g., interaction with people, dance, send e-mails, etc), without writing a single line of code. In addition, it allows to add original Python code to a Choregraphe behavior.

A set of classical pre-programmed behaviors are designed from high level functions (walk, dance, turn, speech synthesis, speech recognition, etc) to very low level ones (reading sensors, turning LEDS on and off) (Pot et al., 2009). By assembling these basic behaviors, it is possible to create an original behavior. Anybody can create their own boxes that can be added to the existing library. Assembly of behaviors is performed in the zone 2. By "dragging and dropping" icons of behaviors from Box Library to Flow Diagram, it is possible to implement the behaviors on NAO.

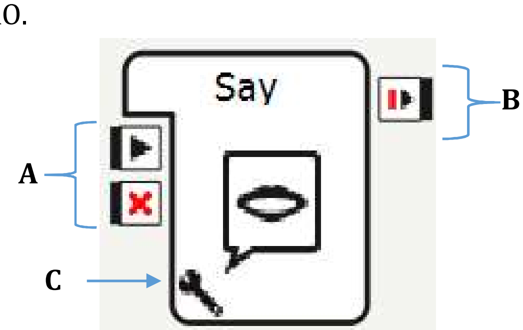


Fig. 2.1-5. Connectors of a Box in Choregraphe.

A Behavior contains boxes which are sequentially or simultaneously executed. A Box is the basic element of the Behaviors. A behavior is represented as an icon

[4] More information available from http://doc.aldebaran.com/1-14/software/choregraphe/choregraphe_overview.html

equipped with small squares on the left (entry boxes) and small squares on the right (output boxes).

Fig. *2.1-5* shows the main connectors of a Box. The inputs (A) receive events in order to start or stop the box. The outputs (B) send events and/or data during box execution or when the box execution is stopped. The Parameters boxes (C) receive data used by the box. A Box may contain a simple elementary action (Say box for example), as well as a very complex application (room exploration for example).

Programming simple behaviors for NAO: Connecting the output box of one behavior to the input box of another one allows to define the sequence of action to perform. On the top left of zone 2, the global "entry box" represents the starting point of the behavior. On the top right, the global "output box" represents the end of the behavior. The principle of programming NAO is to connect sequential, or parallel, behaviors between the "entry box" and the "output box"(Pot, 2009). Fig. 2.1-6 shows a behavior in which the robot is dancing while moving its head. When the dance is finished, the robot stops nodding and walks.

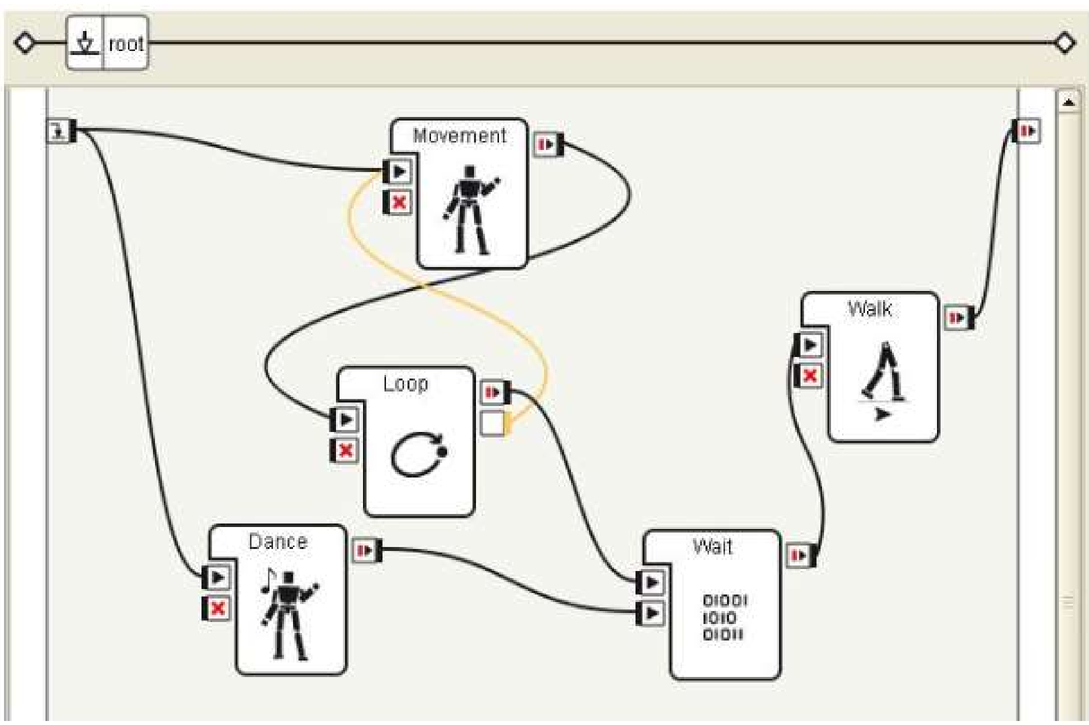


Fig. 2.1-6. Example of Complete Application with Sequential Behaviors. *(Pot, 2009)*

2.2. Vocational Guidance

Vocational Guidance is the process of assisting a person to choose, prepare for, and enter an occupation for which he or she shows aptitude. It helps to an individual in solving problems related to vocational planning and to occupational choice. It responds to questions such as: *who you are?* and *what do you want?.*

Vocational Guidance allows an individual by providing assistance in solving problems relating to choice of career, occupational change and adjustments. It is made up of three phases: self-knowledge (recognize interests, likes, abilities, skills, weaknesses); Information (on occupations and professions); the time of the election. (Holland, 1997).

2.2.1. Theory of Vocational Personalities and Work Environments

John L. Holland's theory of vocational personalities and work environments transformed vocational assistance worldwide (Gottfredson, 2009). Holland's greatest contribution and his most well-renowned work pertains to his theory of vocational personalities and work environments. This theory consists of a set of rules and definitions that can be used to understand people in their environments, especially those who have different occupations and different working environments. Holland changed the way many of us think about the influences of higher education and the accomplishments of talented people. The main objective of the theory is to explain vocational behavior and to suggest some practical ideas that help people to choose jobs, to change occupations and to achieve professional satisfactions (Nauta, 2010). The theory consists of several simple ideas and the concepts or corollaries that derive from it:

- ✓ The theory's core idea is that most people resemble a combination of six personality types: Realistic (R), Investigative (I), Artistic (A), Social (S), Enterprising (E), and Conventional (C) (commonly abbreviated with the acronym RIASEC). Each type is characterized by a constellation of interests, preferred activities, beliefs, abilities, values, and characteristics (Einarsdóttir et al., 2002). The RIASEC personality types are defined by both preferences and aversions that influence the choice of a work environment, and the environments are defined by typical work activities and other demands placed on individuals.

- ✓ The environments in which people live can be classified by their similarity to six model environments: realistic, research, artistic, social, business and conventional (Armstrong et al., 2008; Armstrong & Vogel, 2009).
- ✓ Associating people and environment types leads to results that we can predict and understand from our knowledge of personality types and environmental models. The degree of fit between an individual's personality type and the work environment type is theorized to be a determinant of several important outcomes, including job satisfaction, stability, and performance (Wille et al., 2015).

2.2.1.1. Vocational Personalities

As explained in section 2.2.1, it is supposed that types represent common people that have arisen in our culture. Each type is describe according to a theoretical model called *Orientation Model* (Gottfredson, 2009; Holland, 1997). Likeness of person with each one of orientation models indicates his personality pattern. That model to which the person most resembles is his personality type.

Realistic Type (R)

Person with this orientation enjoy activities requiring physical strength, motor coordination and skill. They use their skills to solve problems at work and in other situations. They prefer dealing with concrete, well-defined problems as opposed to abstract, intangible ones (Wille, 2015).

Investigative Type (I)

Persons of this orientation have marked needs to organize and understand the world. They avoid interpersonal problems which require interpersonal relations with groups of people. They concentrate on their work, are introverts and unsociable (Wille, 2015).

Artistic Type (A)

In general, person of this orientation prefer dealing with environmental problems though self-expression in artistic media. They avoid problems requiring interpersonal interaction, a high degree of structuring, or physical skills (Wille, 2015).

Social Type (S)

They prefers therapeutic or teaching roles, which may reflect a desire for attention and socialization. They avoid solving intellectual problems and physical activity. They prefer deal with problems through feelings and interpersonal manipulation of others (Wille, 2015).

Enterprising Type (E)

Characteristic for the enterprising type is the preference for activities that entail the manipulation of others to attain organizational goals or economic gain. Person of this class prefer to use their verbal skills in situations which provide opportunities for dominating, selling, or leading others (Wille, 2015).

Conventional Type (C)

They prefer structures verbal and numerical activities, and subordinate roles. They have a strong preference for activities that entail the explicit, ordered, systematic manipulation of data. They avoid the conflict and anxiety aroused by ambiguous situations or problems involving interpersonal relationships and physical skills (Wille, 2015).

Each personality type exhibits specific behavioral characteristics according to the evidence obtained in the research literature (Armstrong, 2008; Darcy & Tracey, 2007; Holland, 1997). These are: a) Vocational preferences, b) Goals and values, c) Favorite activities, d) Aversions e) Self-evaluation and f) Personal traits (see Table 2.2-1).

REALISTIC	INVESTIGATIVE	ARTISTIC	SOCIAL	ENTERPRISING	CONVENTIONAL
VOCATIONAL PREFERENCES					
Someone who tend to prefer agricultural, technical, specialized trade vocations.	Someone who tend to prefer scientific and engineering vocations.	Someone who tend to prefer artistic vocations (musical, literary, dramatic, ect).	Someone who tend to prefer educational, therapeutic and religious vocations.	Someone who prefers to work in sales, supervision and leadership.	Someone who prefers to work in office and computing tasks.
GOALS AND VALUES					
Someone who has the highest regard for concrete things or tangible personal characteristics: money, power, social position.	Someone motivated by the search for truth, is critical and rational. The honesty value identifies this type person.	People who are motivated towards aesthetic values, such as harmony and beauty. Their life experiences are associated with innovation, creation, inspiration and expression.	Social type values generosity, in themselves and others. They believe we should all help each other as much as possible.	People who are motivated towards power, influence and recognition. They develop actions in which they can lead, manage and govern.	Someone who gives great importance to the economic, and identifies with utilitarian and practical values.
FAVORITE ACTIVITIES					
Realistic types tend to prefer working with things, may have mechanical and athletic abilities, and may like working outdoors.	Investigative types prefer to work independently, without giving or receiving any help.	Artistic types want to be an independent artist and creator.	Social types tend to prefer activities that involve religious, social and aesthetic vocation.	Enterprising types prefer roles of power and leadership.	Conventional types prefer subordinate supervisor positions and want to work as an expert or adviser.
AVERSIONS					
Realistic type avoids social situations that require independent self-expression (artistic roles).	Situations that require social capacity or difficult social interactions.	Activities that require motor capacity, use of tools and machines or that involve physical danger.	Writing technical reports or poems. Mechanical drawing, car repair.	Activities that require motor capacity, use of tools and machines or that involve physical danger.	Restrictive, manual and non-social activities (Crafts, automotive mechanics, ect).
SELF-EVALUATION					
They conceive of themselves as strong, practical, conventional, constant, unsociable, pro-change and with a limited field of interests.	They conceive of themselves as original, non-exhibitionist, unwilling to help, unpopular.	They conceive of themselves as impulsive, irresponsible, originals.	They conceive of themselves as responsible, impulsive, and sociable.	They overestimate their oral and leadership skills.	They conceive of themselves as cultured, very responsible, and meticulous.
PERSONAL TRAITS					
Someone who is practicality, physical, conformist, materialistic, persistent.	Someone who is intellectual, introvert, original, unpopular, analytical, explorative.	They are creative, original, independent, and chaotic/random.	They are cooperative, supporting, nurturing, helpful, healing.	They are organized, adventuress, ambitious, controller, impulsive.	They are conformist, scrupulous, efficient, obedient, and persistent.

Table 2.2-1. Characteristics that define each vocational group. Adapted from *(Armstrong, 2008; Darcy, 2007; Holland, 1997).*

2.3. Personality Theory: Five-Factor Model

"Personality is the set of **psychological traits** and mechanisms within the individual that are organized and relatively enduring, and that influence his interactions, and adaptations to the intrapsychic, physical and social environment."(Larsen, 2005a).

Psychological traits are characteristics that describe ways in which people differ from one another. These characteristics can be described by the use of adjectives, and are called **trait-descriptive adjectives**. All personalities are a mixture of traits, with a greater preponderance of some more than others. The union of different traits is what determines personality characteristic of a person.

If personality is seen as a strictly behavioral phenomenon, then all robots have a certain personality. Therefore, personality that will be assumed by NAO robot during the vocational guidance session will be based on a theory of personality traits called the **"Five Factor Model" (FFM)** (Larsen, 2005b; Zhao & Seibert, 2006)**.** This theory evaluates personality according to its characteristics. The premise of FFM is that human personality traits can be described along five dimensions or factors: **O**penness, **C**onscientiousness, **E**xtroversion, **A**greeableness and **N**euroticism; often listed under the acronyms OCEAN. FFM is the most clearly defined, and behavioral-oriented personality model. Therefore, it is the most susceptible to computational implementation.

I. Extraversion (E): (outgoing/energetic vs. solitary/reserved). Extraversion is characterized by the tendency to seek stimulation in the company of others, talkativeness and assertiveness. People who are high in Factor E are generally energetic, fun loving and highly sociable. They tend to be enthusiastic and action-oriented individuals. They possess high group visibility, like to talk, and assert themselves. In contrast, people who are low in this factor are reserved, introverted, quiet, aloof or self-absorbed.

II. Agreeableness (A): (friendly/compassionate vs. analytical/detached). It is a measure of one's trusting and helpful nature, and whether a person is generally well-tempered or not. People who are high in Factor A tend to withdraw from social conflict. They are helpful, forgiving, and altruistic. However, people who are low in Factor A are aggressive, aloof, contrary, suspicious and unfriendly.

III. Conscientiousness (C): (efficient/organized vs. easy-going/careless). Hard working, punctuality, and dependable behavior are characteristic of personality Factor C. People who are high in the Factor C plan carefully and are highly motivated in achieving their goals. Low conscientiousness personalities can be seen as disorganized, easily discouraged, reliable and unpredictable.

IV. Neuroticism (N): (sensitive/nervous vs. secure/confident). Neuroticism refers to the tendency to experience unpleasant emotions easily, such as anger, anxiety, depression, and vulnerability. People with high Factor N tend to experience unpleasant emotions very easily. They are anxious, depressed, insecure and susceptible to stress. People who have low Factor N can be seen as uninspiring and unconcerned. They are calm, resistant to stress, secure and stable.

V. Openness to experience (O): (inventive/curious vs. consistent/cautious). Openness reflects the degree of intellectual curiosity, creativity and a preference for novelty and variety a person has. People who are high in Factor O are creative curious, insightful and intellectual. However, closed individuals, those who have low O, are bored, intolerant, routine-oriented and uninterested.

2.3.1. Inventory of Personality Adjectives

The most important elements of personality variation can be represented, in any human language, by a large number of similar but distinct words (generally adjectives). When a large and diverse bank of these adjectives has been collected, statistical approach is applied to identify groups or dimensions (Ashton et al., 2004). The most commonly used procedure for identifying these dimensions is **factorial analysis**. Factor analysis identifies groups of adjectives occurred together more often than another set of adjectives (Larsen, 2005b).

Lewis R. Goldberg has carried out the most systematic and thorough research about the Big Five factors using a list of useful words (adjectives) to describe any person's personality (Ashton, 2004; Larsen, 2005b; Saucier & Goldberg, 1996).

The paper (Ashton, 2004) analyses an inventory of adjectives related to personality. The structure of the English personality lexicon was investigated and used to characterize personality of a large group of people. It should be noted that this paper is based on work carried out by Saucier and Goldberg (Saucier, 1996), the findings of which describe an inventory of 435 personality adjectives. The resulting list in this research was used to characterize personality of a large sample of individuals (N = 899) and provides the factor loadings of the 435 adjectives on each of the five factors; the order reflects the relative size (variance) of the factors (e.g., Factor II is largest). Correlation scores for a selection of adjectives are show in Table 2.3-1.

Order	Adjective	I	II	III	IV	V
1	Sympathetic	0,02	**0,62 ***	-0,05	0,07	0,03
19	Agreeable	-0,07	**0,46 ***	-0,01	-0,16	0,03
24	Thoughtful	-0,07	**0,42 ***	0,2	-0,03	0,15
29	Cheerful	0,38	**0,4 ***	0,03	-0,22	-0,06
61	Rude	0,08	**-0,5 ***	-0,15	0,01	0,06
100	Critical	-0,01	**-0,32 ***	0,06	0,31	0,17
118	Obstinate	0,03	**-0,26 ***	-0,05	0,24	0,09
136	Enthusiastic	**0,5 ***	0,29	0,02	-0,03	-0,01
147	Merry	**0,44 ***	0,38	-0,02	-0,15	-0,09
189	Quiet	**-0,64 ***	0,15	0,15	-0,09	0,12
192	Bashful	**-0,59 ***	0,22	0,05	0,03	-0,02
200	Dull	**-0,46 ***	-0,03	-0,05	-0,02	-0,05
217	Serious	**-0,31 ***	0,03	0,31	0,04	0,17
227	Apathetic	**-0,23 ***	-0,08	-0,04	-0,01	-0,18
263	Alert	0,16	0,11	**0,36 ***	-0,09	0,2
316	Moody	-0,17	-0,13	-0,07	**0,53 ***	0,04
330	Grumpy	-0,19	-0,27	-0,03	**0,4 ***	-0,07
383	Insightful	-0,04	0,11	0,01	-0,1	**0,42 ***
385	Analytical	-0,12	-0,08	0,27	-0,02	**0,42 ***
411	Curious	0,13	0,05	0,02	0,05	**0,23 ***

Note: (*) indicates the factor on which each adjective has its highest loading.

Table 2.3-1. Factor loadings of the adjectives selected in each of the five factors.
(Ashton, 2004; Saucier, 1996)

The adjective *Merry* strongly correlates (0.44) with the factor I (Extroversion) as well as with the factor II (Agreeableness) at 0.38, while *Cheerful* also correlates with I (0.38) but even less with III (Conscientiousness) with 0.03 as well as negatively (-0.22) with IV (Neuroticism) and V (Openness) with -0.06.

2.4. Computational Intelligent System

2.4.1. Artificial Neural Networks (ANN)

The Artificial Neural Network (ANN), or neural network, is a machine learning method based on the functioning of biological neural networks, therefore, an ANN is a construction inspired by some aspect on how the human brain works.

An ANN uses a set of processing units called neurons, cells or nodes, interconnected by several direct communication links, in order to receive input signals, process them and send an output. Each connection is associated with a weight, representing the information used by neurons to solve a problem (Zou et al., 2009).

In most cases, an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase (D'Addona, 2014). Back propagation (BP) is a method of training the neural network, whose architecture consists of different interconnected layers. This algorithm, through an interactive method, will update the values of the weights in such a way that the outputs are similar to the set of target output.

The use of artificial neural networks (ANNs) for recognizing patterns will allow the classification of the selected behaviors. In this way, the system is capable to choose the most appropriate behavior to be executed by the robot during a vocational guidance session.

Chapter 3

Related Work

This chapter presents an overview of the main works focused on the topics addressed in this dissertation.

3.1. Introduction

There are several companies dealing with the marketing of prototypes for home, technologies with robotic features and research in the area of Human-Robot interaction. In recent years, this vision has started to become reality, with the development and commercialization of social robotic products. Sony was one the companies in to have a prototype for sale to the general public. This prototype, called AIBO[5] participated in several competitions of the RoboCup. This quadruped robot based on its own platform for programming, called AIBOLife software was designed for human interaction in the home. On the other side is *Aldebaran Robotics*, which is one of the companies leading the current market, which has three prototypes starting with NAO launched in 2006, PEPPER[6] recently launched in 2015 and ROMEO[7] project is being developed from the 2009.

These robots are useful platforms for research based on Linux. NAO is one of the models used in the RoboCup, given its humanoid form and easy programming capabilities. It has become one of the most popular technologies for research in this important event. PEPPER is the second prototype of the company which has been oriented more substantially than its predecessor, to the interaction with humans and the study of emotions in communicating with people. ROMEO is intended to be a genuine personal assistant and companion and this research platform is now being used to validate the possible service uses for a larger robot.

[5] More information available from http://www.sony-aibo.com/aibos-history/
[6] More information available from https://www.aldebaran.com/en/cool-robots/pepper
[7] More information available from https://www.aldebaran.com/en/cool-robots/romeo

3.1.1. Robot Locomotion

Humanoid Walk: Walk is defined as robot movement with desired speeds in forward, sideways and even rotational directions. Research in this field has been extensively developed and interesting results have been achieved (Shamsuddin et al., 2011). For example, the robot is able to walk straight and follow paths without falling. The motion algorithms used for the NAO robot have been the subject of research in several papers. These investigations have allowed to develop algorithms capable to:

- ✓ Generate paths for a biped walk, through which the robot is able to walk on many common surfaces found in a typical home environment. (Gouaillier et al., 2010; Lutz et al., 2012; Palyart Lamarche et al., 2011; Fei Wang et al., 2012)
- ✓ Modeling early infant walking, in particular the onset of independent walking. (G. Lee et al., 2011; Li et al., 2011)
- ✓ Optimize walk techniques for the robot, in terms of improving the walk speed and efficiency. (Kulk & Welsh, 2011)
- ✓ Generate locomotion patterns, with the goal of providing to animators and artists easy and intuitive tools to design expressive motions for humanoid robots. (Dalibard, 2012)
- ✓ Allow the robot to maintain its balance even after being pushed by external forces. (Bavani et al., 2011; Xu Tao & Chen Qijun, 2011; Yun & Goswami, 2012)

Motion Imitation: Imitate complex whole-body motions of humans in real time is the goal of the motion imitation. For recording the human motions, any sensor system capable of inferring the joint angle trajectories can be used. In (Koenemann & Bennewitz, 2012) they capture the human data with an Xsens MVN motion capture system consisting of inertial sensors attached to the body.

In the works developed in (Boboc et al., 2013; Filiatrault & Cretu, 2014) they use Microsoft Kinect to track and imitate human motion. The robot learns new skills from users by imitating their movements. By applying inverse kinematics through an optimization process, the human motion is divided into critical frames and represented by a list of robot joint angles. For example, in (Mukherjee et al., 2015) and (Fan Wang et al., 2012) the Kinect sensor was used to obtain coordinates of the shoulder, elbow and wrist joints of the robot. The results show that human actions were well imitated by the robot and that the systems are robust and flexible enough to imitate various human motions.

3.1.2. Robot Vision

The studies that had been undertaken in this area involve using a combination of camera hardware and computer algorithms to allow the robot to process visual data from the world. For example:

- ✓ In (Peña et al., 2013) techniques are developed that allow to determine the orientation of the objects located in the field of view of the NAO robot to perform the task of screw a nut.
- ✓ The work involved in (Ariffin, 2015) aims to develop a four (4) wheel mobile platform that can be used by NAO to avoid obstacles and navigate without collisions. The results show that the system can be tuned to get suitable performance.
- ✓ In (Song et al., 2015), the proposed system comprises of two (2) cameras: a ceiling camera which is placed overhead of NAO and by the robot's own camera. The ceiling camera provides global vision and the robot's camera gives local vision. Global vision and local vision are integrated to improve the vision localization effect. To test the proposed system, they designed an experiment, in which robot NAO moves to a place, avoids collisions and performs a grasp task.
- ✓ In (Guan & Meng, 2012) a study is carried out to find the most appropriate way to measure the accurate distance between NAO and a certain object, since the robot is not equipped with a depthsensing device which can offer the distance information directly.
- ✓ By using a vision system in (Gong & Oh, 2014), the NAO robot is able to place its hand at any desired position and orientation in order to play a board game. The results show that the robot can reliably reach the game piece.

3.2. Human-Robot Interaction

This review summarizes data from the documents presented in recent years on HRI to provide recent trends in application and methodologies in this field. A total of twenty eight (28) papers were analyzed, with each individual paper classified across four (4) categories according to the methods and approaches used within them. This process provides insights into current approaches and emerging trends in the field of HRI.

3.2.1. Imitating Human Emotions with Behaviors

The transmission of emotional states through behaviors has been investigated in (Park et al., 2010). This paper focuses mainly on the design of a behavior generation framework based on the combination of motion sets according to sentence types and emotions that appear in human-robot communication scenarios. Therefore, the robot's behaviors are classified into typical behaviors that represent its intentions or emotions. A behavior is made by combinations of multi-modal motion sets. Motion sets are classified into seven (7) different modalities (e.g., facial expressions, gestures, sound effects) and each modality is made up by basic actions (e.g., raise hand, moves backward etc.). Behaviors are generated from common sentences (e.g., How are you today?), which are categorized into four (4) groups, such as a question or a comment. Each sentence according to its type has an emotion that is related to it. Finally, they use humans' behavior patterns (characteristic traits of each type of personality) to generate behaviors according to personality assumed by the robot.

The study in (Shen et al., 2015) has developed a system that allows NAO convey emotions (such as anger, disgust, sadness, fear, happiness and surprise) through pre-programmed behaviors. By using a game called Mimic-Me, NAO mimics the human player's facial expression through a combination of body gestures and audio cues. The results obtained shows that NAO's ability to understand player's sentiment makes the HRI experience more engaging, and as a result, the participant's willingness to spend more time playing with NAO.

The work described in (Miskam et al., 2016) explores the benefits to develop an application to teach simple emotional gestures to autistic children. In this research, they used the NAO robot to physically show nine (9) emotional poses and conduct a simple guessing game with children. The different emotions (angry, disgusting, happy, hungry, loving, sad, scared, shy and tired) were choreographed using the robot's body postures and LED lights of the robot's eyes and ears. The results show that the robot can help children understand the emotions of others by demonstrating the emotions using its posture and voice intonation. A similar study is carried out in (Shamsuddin, 2012). A total of seven (7) modules are executed by

NAO to analyze reaction and interaction from children. Each of these modules is composed different behaviors such as: NAO speaks a given text by default, nods or shakes its head, sings a song etc. In research carried out in (Chevalier et al., 2015) they also use emotional poses to express four (4) emotions (i.e., anger, happiness, fear, and sadness).

In (Manohar & Crandall, 2014), they study the ability of people to create robot behaviors that express recognizable emotions using existing programming interfaces and methods for NAO and PLEO robots. The results show that the ability of participants to create recognizable behaviors was almost exclusively tied to the ability of users to create good verbal expressions. Nonverbal expressions created by users had low discernibility.

Imitating human emotions with artificial facial expressions is investigated in (Johnson et al., 2013). In this research is proposed how the led patterns of NAO's eyes can be used to imitate human emotions. They examined the LED color, intensity, frequency, sharpness, and orientation that humans associate with different emotions. Based on the results, 12 LED patterns were created. The results show that humans can recognize LED patterns as imitated emotions.

3.2.2. Management of Behaviors

The goal of the JAMES project[8] - **J**oint **A**ction for **M**ultimodal **E**mbodied **S**ocial **S**ystems - is to develop the core cognitive capabilities that enable a robot to interact with humans in a socially-appropriate manner, and demonstrate this behavior in a bartending scenario. Multiple investigations were developed as a result of this project. Reference (Keizer et al., 2013) presents an implementation of a JAMES robot as a Bartender. This project was focused on the communication abilities with clients in a bar, experimenting in a real scenario and examining better ways of attending customers. Fig. 3.2-1 shows the proposed system. The system is able to engage in, maintain and close interactions with customers, take a user's order by means of a spoken conversation, and serve their drinks.

[8] More information available from http://james-project.eu/

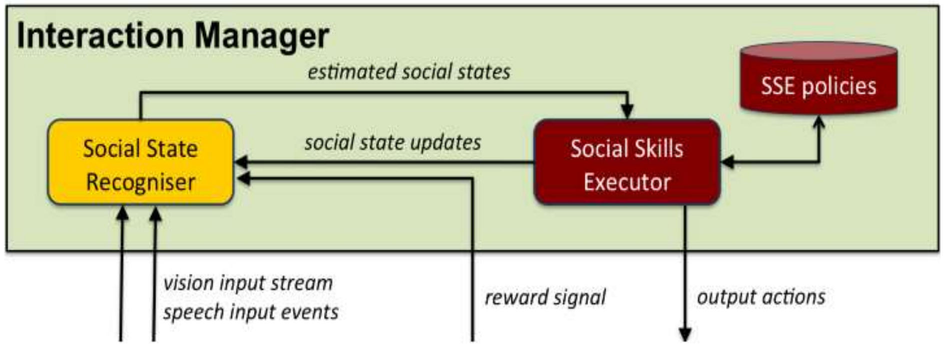


Fig. 3.2-1. Architecture of the system: Social State Recognition and Social Skills Execution. *(Keizer, 2013)*

The system maintains a model of the social context and decides on effective and socially appropriate responses in that context, this model is called Social State Recognizer (SSR). The robot is equipped with vision and speech input processing modules, as well as modules controlling two (2) robot arms and a talking head. The vision module tracks the location, facial expressions, gaze behavior, and body language of all people in the scene in real time. The speech input processing modules combine speech recognition with a natural language analyzer to create symbolic representations of the speech produced by all users. Therefore all these social states (or input variables) are processed by the SSR. The SSR provides a query interface to allow other system components access to the relations stored in the state, and also publishes an updated state to the SSE every time there is a change which might require a system action in response. Behaviors of the robot as bartender are controlled and selected by the Social Skills Executor (SSE). This control is based on the social states updates it receives from the SSR. The decision making process consists of three stages: 1) **social multi-user coordination**: customers are served in the same sequence that they make their requests, and the robot interacts with new customers in a socially acceptable manner, by acknowledging their arrival but completing the existing transactions before dealing with a new request, 2) **single-user interaction**: In the order in which customers appeared in the scene, a response is generated in the form of a behavior (e.g., greeting the user or serving him a drink), and 3) **multi-modal fission**: selecting a combination of modalities for realizing a chosen response (e.g., a greeting can be realized through speech and/or a nodding gesture).

An alternative embodiment of the system explained above is also available on the NAO platform (Keizer, 2014). For the bartender NAO, they implemented versions of the vision system and the robot behavior controller - developed in the JAMES project - making use of the robot's torso and Microsoft Kinect for vision. The vision module developed for this project allows tracks the location and orientation of all customers. Although the features tracked are a subset of those handled by the full system, the information it provides is still sufficient for the SSR to estimate the social state of customers. A set of behaviors was developed for the bartender domain, based on those supported by the full JAMES robot. For practical reasons, the NAO serves drinks "symbolically".

The NAO platform has also been used in experiments in the context of a human-robot dialog, in order to studying the realization of engagement rules in a multi-party setting. In (Klotz, 2010) is developed a system for the management of multiple conversations through a scenario consisting of social interaction where a robot introduces multiple persons to each other[9]. The developed system includes components for the perception (e.g., accessing audio from robot's microphones), for generating actions or behaviors (e.g., a greeting with hands and/or through speech), a dialog system and a memory system for connecting these diverse components. The dialogue system is a framework called PaMini (which is short form "Pattern-based Mixed-Initiative Interactions"). This framework is based on a model -called Located Multiparty Commitment Model- which has the goal of making it easier to model dialog situations and to integrate that dialog with the rest of the system. The PaMini dialog framework combines a collection of generic interaction patterns with an interface to submit and receive tasks to and from different components in the system. The patterns model the interaction between the robot and the human interaction partner as a set of states the dialog can assume and a set of valid transitions between those states. When a transition becomes active, it can then in turn produce a dialog act of the robot as an output. A research based on this system

[9] In this context, *engagement* is defined as a process involving rules on how communication channels are managed and includes ways to open and close these channels using verbal cues (like greetings) or non-verbal behavior (often connected to the way mutual attention is signaled between the participants).

is (Klotz et al., 2011), in which NAO is used in experiments in the context of a multi-user quiz game.

In (Meena, 2012) is developed a system that allows synchronization of non-verbal gestures, while NAO gives a speech. These gestures enhance its communicative behavior not just with verbal feedback, but also with non-verbal gestures (e.g., hand and head movements). The set of gestures includes gestures to mark topic, the end of a sentence or a paragraph, beat gestures and head nods. WikiTalk[10] is used in order that NAO may talk about an unlimited range of topics. Fig. 3.2-2 provides an overview of NAO's Multimodal Interaction Manger (MIM).

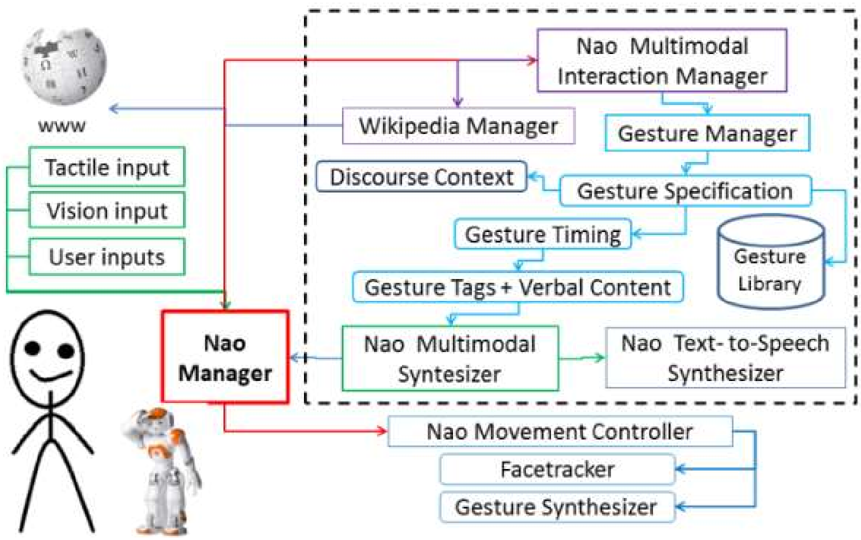


Fig. 3.2-2. NAO's Multimodal Interaction Manager. *(Meena, 2012)*

The MIM processes the user input (e.g., after NAO finishes a paragraph of its speech, the user is expected to signal interest by making explicit requests such as 'enough', 'continue', 'stop', etc.) and interacts with the Wikipedia manager to obtain the content and the structural details of Wikipedia. The Gesture Manager chooses right gesture from the Gesture Library according to the Discourse Context. Next, the duration parameter of this gesture is calculated (Gesture Timing) and used for placing the gesture tag at the appropriate place in the text to be spoken.

[10] WikiTalk is an open-domain knowledge access system that talks about topics using Wikipedia articles as its knowledge source.

3.2.3. Personality-Based Robot Behaviors

Personality-based robotic behavior is essential for the development of this thesis, since personality is fundamental to creating socially interactive robots. Robots with personality are more attractive.

In (Sohn et al., 2012) they have developed a model of Artificial Personality (AP) that they implemented on a robotic platform called Modroid. Emotions, motivation and perception of the robot are explicitly represented as probabilities. However, robot's personality is not explicitly represented and it is encoded into Bayesian rules, which are generated by a program called "Behavior Generator". The behavioral generator was derived from a psychological test used to evaluate personality, where each question is related to a personality trait (based on the Five Factor Model). Each trait is codified as an action for the robot, therefore the generator translates a description of robot's personality into Bayesian rules. The factor loadings obtained through the Five Factor Model are used to compute the probability that the robot will choose a particular action.

The benefits of combining verbal and non-verbal behaviors to generate the different types of robot's personalities when interacting with a human is the subject of research in the work described in (Aly & Tapus, 2013). Fig. 3.2-3 shows the different sub-systems that make up of the proposed system. First, the Dragon Toolkit Dictation module is responsible for making the voice to text translation; then the Personality Recognizer module estimates the personality traits through a psycho-linguistic analysis of the spoken language; the PERSONAGE module determines a personality type according to the traits provided by the previous module; finally the BEAT module translates the generated text (personality type) into a verbal or non-verbal behaviors. The results showed that the person preferred to interact more with the robot that had a personality like his own. Participants also expressed their preference to the mixed speech-gesture behavior of the robot, saying that the robot's speech was more engaging and more effective when accompanied by appropriate gestures than when no gestures were present.

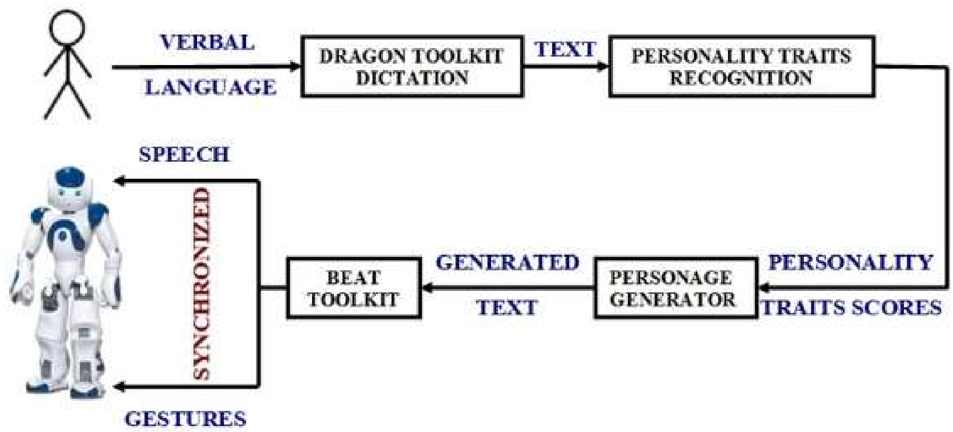


Fig. 3.2-3. Behavior Based on Personality Traits. *(Aly, 2013)*

In (Tapus et al., 2008) a work is carried out to assist in rehabilitation of patients after a cardiovascular accident. A robot monitors, assists, encourages, and socially interacts with post-stroke users engaged in rehabilitation exercises. This paper examined the effects of robot's personality on patients' motivation. They use Eysenk's PEN personality model, specifically the Extroversion dimension. The study showed that users preferred working and interacting with a robot with a similar personality as theirs during the therapy: extroverted users preferred the robot that challenged them during the exercises, while introverted users preferred the robot that praised them.

The study in (K. M. Lee et al., 2006) uses an AIBO robot - a social robotic pet developed by Sony - to interact with different people and demonstrate if it can manifest a personality through behaviors. This robot can use its eyes, tail, ears and lights to express a great amount of emotions, consequently projecting a certain type of personality. With its speech recognition capacity and touchable sensors, it is able to communicate with humans in a variety of autonomous ways. Therefore, verbal and non-verbal cues are used to model two (2) personality types for the AIBO: an introvert personality and an extroverted personality. Participants were randomly assigned to interact with either an extrovert or an introvert AIBO. The results show that participants could accurately recognize a robot's personality based on its verbal language and nonverbal behaviors. The results also suggested that participants enjoyed interacting with a robot more when the robot's personality was complementary to their own personalities.

The study in (Andrist et al., 2015) has developed a system that allows to match a robot's personality— expressed via its gaze behavior—to that of its users. The developed system is implemented on the MEKA robot platform. In this study, they focus on the extroversion dimension of the Big Five personality model, to generate two models of robot's gaze behavior, one to express an extroverted personality and the other to express an introverted personality. For example, in an expression of the extroverted model, the robot gazes into the face of the user more, while the introverted model generates more gaze toward the task space. The results confirm that the robot's gaze behavior can successfully express either an extroverted or introverted personality. In addition, the results demonstrate the positive effect of personality matching on a user's motivation to engage in a repetitive task.

3.2.4. Other research in the field of HRI

One of the main focus of this research is understanding human emotions and how the robot can respond to them. So researchers are working on systems that simulate emotions in the robot in order to have interactions with it more naturally. The system performed in (Le, 2011) has aimed at equipping the humanoid robot NAO with the capacity of performing expressive communicative gestures while telling a story. The body of the robot is therefore, the main medium through which its emotions are conveyed. Reference (Lim et al., 2011) proposes an emotional telepresence framework to transfer emotional voice to robot gesture. This system can convey four (4) the basis emotions: happiness, sadness, anger, and fear. Reference (Cohen et al., 2011) also investigates about of the construction of emotional postures for NAO. Dynamic body postures to convey emotions were created. The results show that a mobile robot without facial expressions, like NAO, can express emotions with its body effectively.

In (Smolar, 2011) different experiments are carried out in the field of artificial intelligence. The tests performed are object recognition, voice commands recognition and human-robot interaction. The experiments carried out in the HRI field are particularly interesting. A system built up by the Microsoft Kinect box and the NAO robot, which can mimic full body human motion in real time is presented. First, the robot is taught some initial moves and then the developed algorithm calculates positions of each joint of human and maps it to the robot's joint.

A project that also uses Microsoft Kinect is described in (Cheng et al., 2012). Kinect is used to recognize different body gestures of NAO and generate a Human-Robot interaction interface. The control signals of different body gesture modules are sent via WiFi to NAO, which can stimulate NAO to complete different tasks. This type of system aims to enrich the interaction between robots and humans and help non-expert users to control the robot freely, so human-robot interaction is much friendlier.

The transmission of non-verbal cues by the robot, such as gestures, body language, kinetics, signals, gaze and tactile communication are investigated in (Vircikova et al., 2011). This paper describes new ways to communicate humans and multi-robot systems in an effective way. They propose a dance choreography design aid system for humanoid robots, a project developed in an effort to create a Human-Robot Interactive System where a user freely cooperates with robots in such way to the robot learns to recognize its verbal and non-verbal cues. Similarly, (Han et al., 2012) carried out a set of pilot experiences with NAO using non-verbal cues. Several cameras and microphones were placed on and around the robot. People were asked to interact with the NAO robot with some instructions of how to use the commands and they were asked a series of specific questions for feedback and evaluation. The results show that non-verbal cues help the Human-Robot Interaction since people use a wide range of non-verbal communication channels in their natural communication.

Other application in the field of HRI have been the use of NAO as an assistant in the therapies for treating children with disabilities such as autism. In (Ismail, 2011), a face detection method is proposed for tracking the faces of children with autism in a robotic assistance therapy. The face detection tools in Choregraphe is used in this study. The non-verbal interaction between the humanoid robot and autistic children is recorded using two (2) inner chambers on the robot head.

Finally, with the development of technology, humanoid robots gradually enter our life and are present in fields such as education, helping people with housework and many other tasks. For instance:

- ✓ NAO has been used in educational field for teaching children at schools how to write and draw simple shapes appearing on a computer screen (El-Barkouky et al., 2013).
- ✓ Companion of a hospitalized children to cheer them and break their daily routine with different games and exercise (Csala et al., 2013).
- ✓ Painter assisted by a human to help children with disabilities (Gurpinar et al., 2012).

3.3. Final Remarks

The systems developed for the management of behaviors are a coordination between several sub-systems that allow an efficient interaction and promote a high satisfaction/enjoyment of the user towards the task performance carried out by the robot. In all approaches discussed above selected behaviors are consistent with the role played by the robot. Therefore, the robot's behaviors – verbal and non-verbal behaviors - are classified into typical behaviors that represent its intentions or emotions.

The primary purpose of using personality is to provide the robot with a behavior which allows it to interact efficiently with people. In related works, the application of personality allows to produce a consistent and predictable robot behaviors by human users. The construction of these behaviors is based on two fundamental aspects:

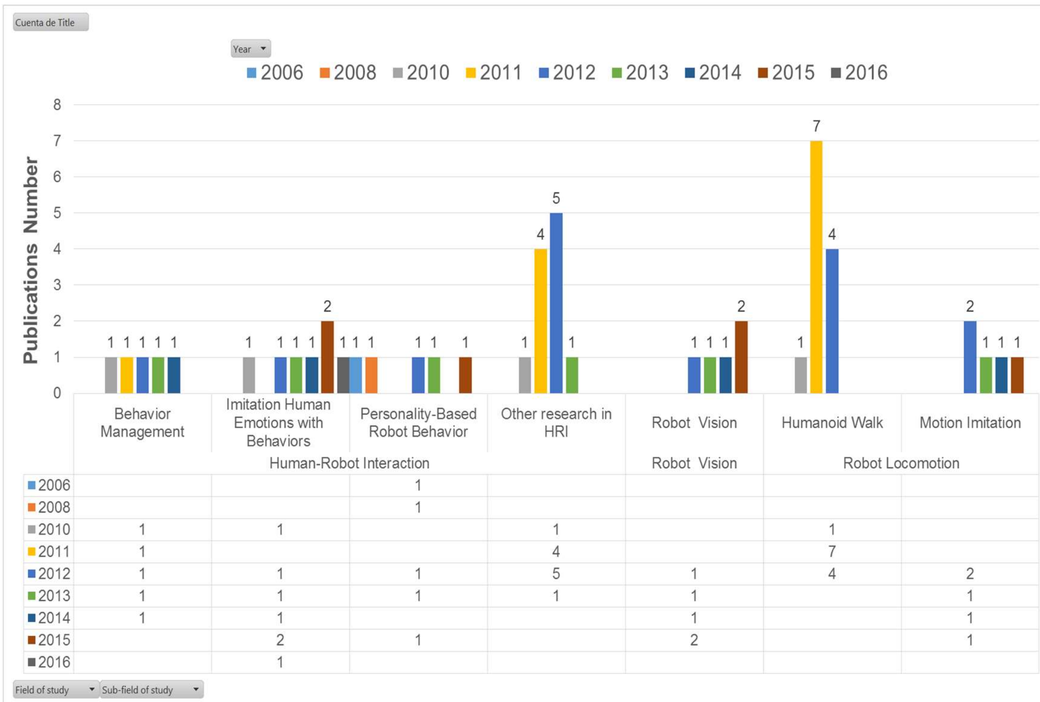
- ✓ A pre-established personality based on any personality model endorsed by the international scientific community.
- ✓ Correlation of several behaviors with a personality.

The review of the related work presented above has allowed the identification of the contribution of this thesis. This work proposes the development of a system capable of managing different behaviors. In this sense, the proposed system contributes with a HRI implementation of an intelligent management system of behaviors with effective interaction between a human and a robot.

In addition, the proposed scenario for the implementation of the intelligent system allows to perform a contribution in the field of vocational orientation processes, since no research were found that implemented systems to determine the vocation of a person through the use of a humanoid robot specifically during an interview.

Chapter 4 provides more information about behaviors and different personality types needed on the development of an intelligent system which manages hierarchical behaviors of the NAO robot as a vocational tutor.

Finally, Fig. 3.3-1 shows a summary of the related works.



Field of study	Publications number
Human-Robot Interaction	**28**
Behavior Management	5
Imitating Human Emotions with Behaviors	7
Personality-Based Robot Behavior	5
Other research in HRI	11
Robot Vision	**5**
Robot Vision	5
Robot Locomotion	**17**
Humanoid Walk	12
Motion Imitation	5
Grand Total	**50**

Fig. 3.3-1. Summary of the Related Works.

PART II
PROPOSED APPROACH

Chapter 4

Implementation of the IBM Approach

*This chapter presents the approach proposed for the behaviors management model applied to vocational orientation processes. The main definitions and general considerations for the **I**ntelligent **B**ehaviors **M**anagement (IBM) using a NAO robot as a vocational tutor are introduced in this chapter. The following sections describe what was technically done to implement the proposed approach and the components that were created to provide a bridge between the management system and the robotic control software of the NAO platform. The chosen scenario (vocational guidance session) serves as a suitable basic proof of the proposed approach. This scenario and its realization allows the intelligent management of the selected behaviors.*

4.1. Problem Statement

With the growing use of robots in human-centered environments, there is an increased need for the design and development of social robots able to interact with humans in an appealing and intuitive manner. In particular, this need has inspired a trend towards developing robotic systems capable of embodied communication through use of verbal and nonverbal signals that convey intentions, emotions, and personality to human users.

In addition, given the research on personality-based robot behavior and of having the NAO platform for experimentation, this research aims to develop an intelligent system that manages coherent and easily predictable behaviors for all users. The design of these behaviors will be based on a theory of personality traits called the "*Five Factor Model*".

The selected behaviors will be managed in the particular scenario of a vocational guidance session. A predefined set of questions will be asked by the robot according to a theoretical model called "*Orientation Model*”. Based on the answers to these questions, the vocational profile of the person and the score of the response are established.

Therefore, all the systems of the robot that interact during the vocational guidance session are analyzed. The main problem lies in the selection and implementation of the correct computational intelligence method for the management of all the blocks of behaviors created and that allow the robot to effectively emulate a human expert in vocational guidance.

4.2. Scenario for Intelligent Management of Behaviors

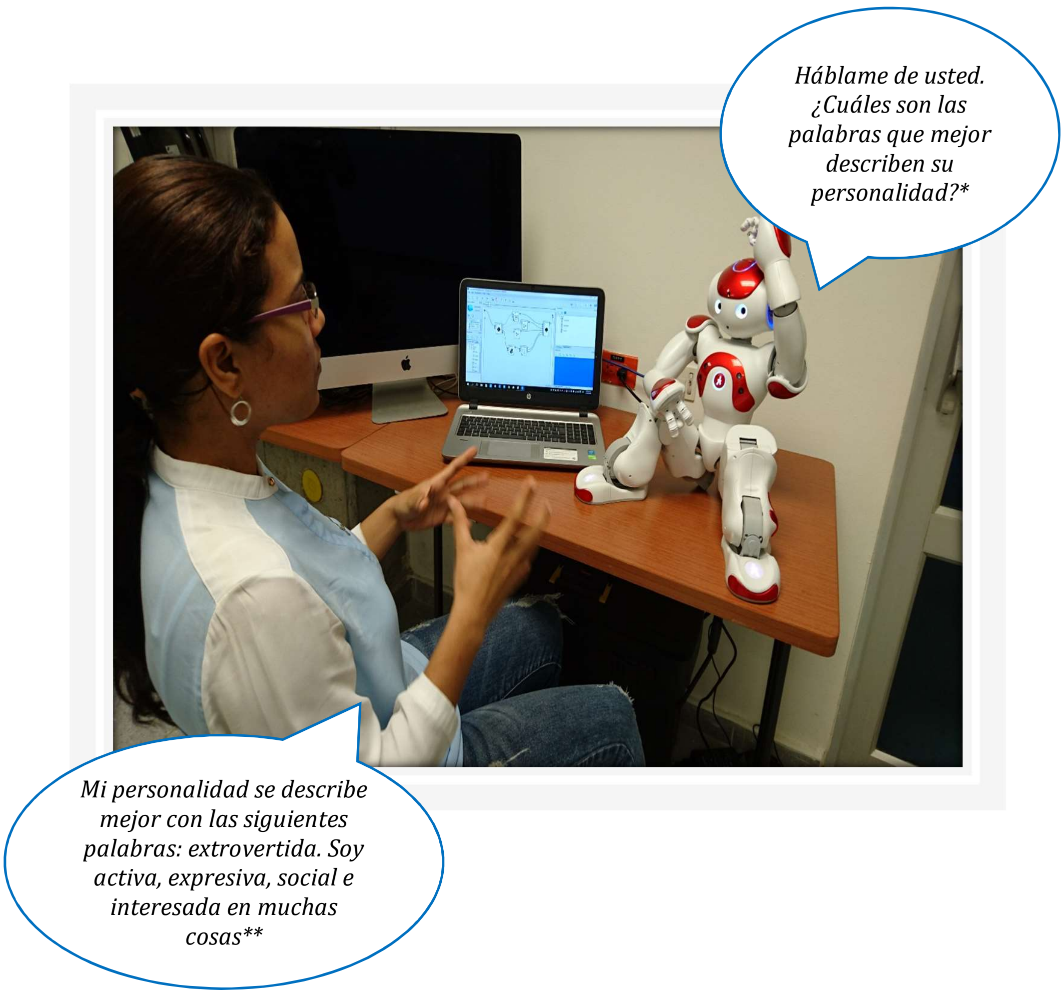


Fig. 4.2-1. Person Interacting with NAO in the Vocational Guidance Scenario.

* Tell me about yourself. Which are the personal characteristics that best describe your personality?
** My personality is best described with the following words: extravert. I am active, expressive, social and interested in many things.

The chosen scenario includes a specific type of human-robot interaction to make it interesting to study the management of behaviors selected. As a basic requirement, it involves the interaction of the person with the robot so that behaviors can be triggered by some type of stimulus. This, in order that behaviors assumed by the robot are a direct consequence of this interaction. It should also allow the robot to choose the most appropriate way to behave and react according to a previously established personality.

To demonstrate it, a scenario was chosen, consisting mainly of the social interaction between a person and an NAO robot in a session of vocational guidance. This type of tutoring is used to help the person in choosing an occupation or profession. Interviews are one of the activities carried out during this type of process.

Therefore, this type of interview involves the exchange of information between an interviewee and an interviewer to identify the vocational interests. The robot - who assumes the role of vocational tutor - asks the person for his vocational preferences and according to the rating of the response and its personality type can react as conveniently as possible. See Fig. 4.2-1 for an example interaction in this scenario.

Only native Spanish speakers were selected to ensure speech recognition accuracy.

4.3. Scenario Configuration: System Schema

The following sections describe the modules connected to the intelligent system for the management of the selected behaviors in NAO as a vocational tutor. These modules are described individually in next sections.

To connect the intelligent system with the robotic platform provided by NAO, some additional software was developed.

Fig. 4.3-1 shows a schematic overview of the different modules and the communication paths between them. The gray boxes show modules running on the robot and the white boxes show the components running on a connected computer.

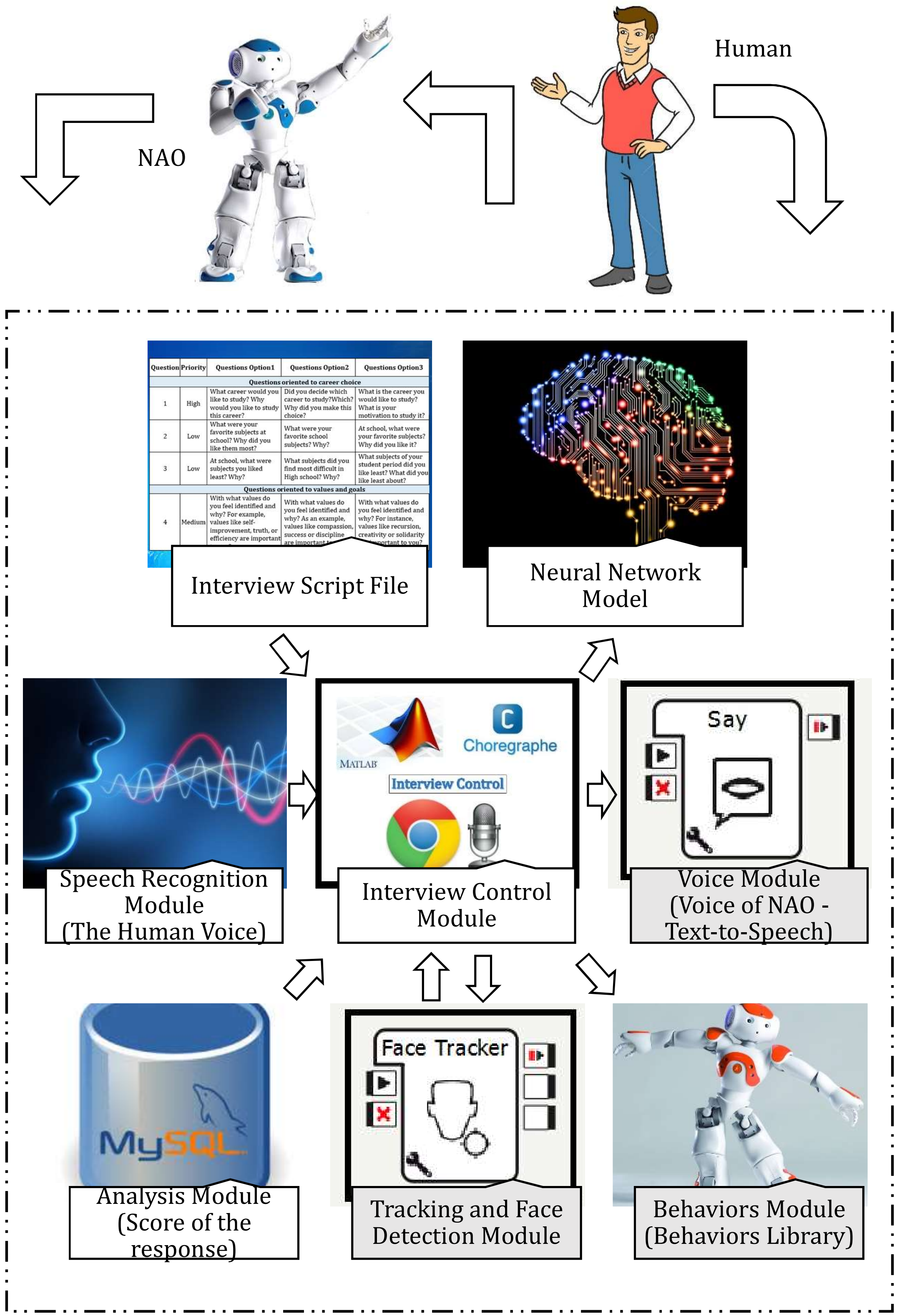


Fig. 4.3-1. Functional Diagram: Modules Developed for this Thesis.

4.3.1. Interview Control Module

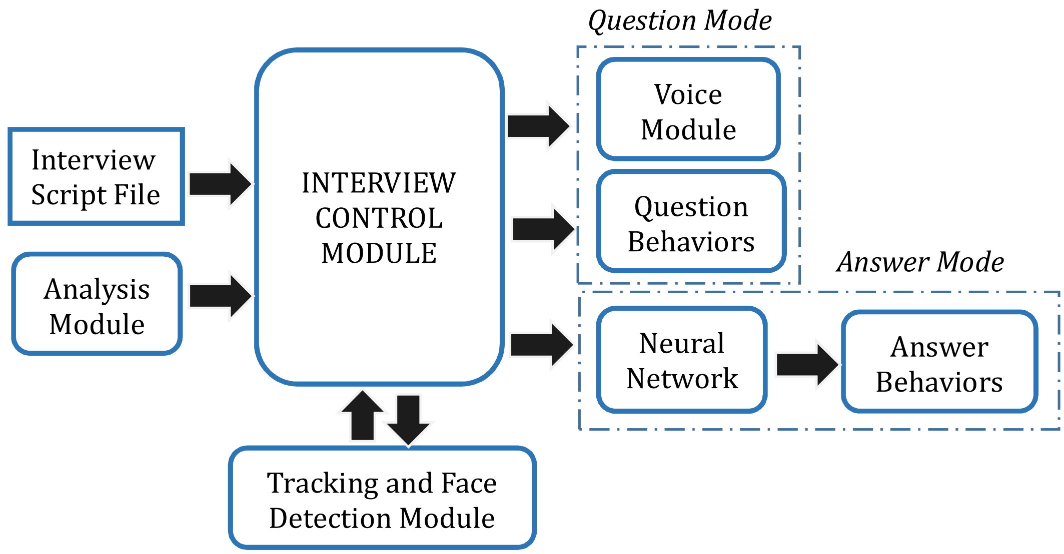


Fig. 4.3-2. Interview Control Module.

Interview control module is connected to the interview script file containing all questions, greetings or farewells categorized within the framework of the vocational guidance session. This module executes the interview process, delivering the text of each question determining the questions that will be performed.

In addition, it controls the behaviors module and sends the behavior that must be executed by NAO taking into account whether to activate the question or answer behaviors. For the calculation of the type of answer behavior that must be executed by the robot, the module connection to the neural network is established sending the necessary signals for the realization of this calculation to Matlab.

Fig. 4.3-2 shows the different modules of the system that interact with the interview control module.

4.3.2. Speech Recognition Module

This module is responsible for making voice-to-text translation. For this purpose, the Google API voice recognition (Google Dictation) is used. This is an Application Programming Interface (API) that allows developers to access Google's voice recognition service for development and personal use. This service can recognize quite a few languages including Spanish and internally uses the built-in speech recognition engine of Google Chrome to transform the voice into digital text[11].

Taking advantage of these functions, an interface to connect the NAOqi system with the recognized voice messages is created. For this case, it is use an APACHE server on the main computer that will receive and send the recognized messages between the Java script code page in an AJAX message and the programming language (Python) of the NAO robot. The output of this module is a text string block.

Fig. 4.3-3 shows the functional diagram for this module.

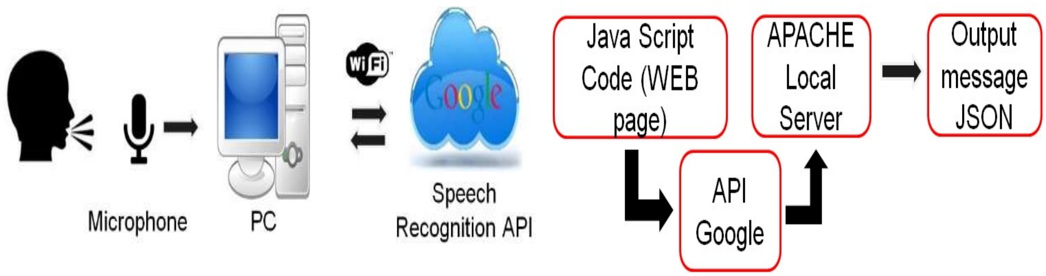


Fig. 4.3-3. Functional Voice Recognition Module and Components Speech Recognition Module.

4.3.3. Tracking and Face Detection Module

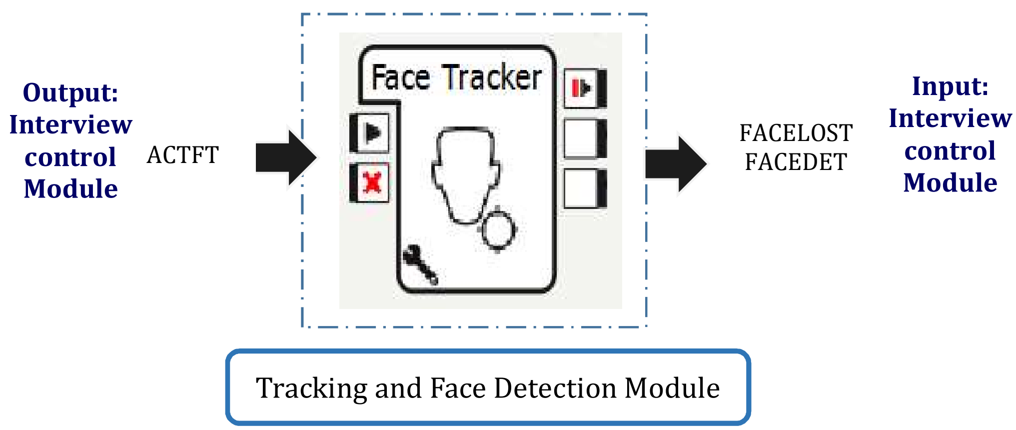


Fig. 4.3-4. Choregraphe Detection and Face Recognition Box.

The robot is able to identify and track the faces of the people who are being interviewed using recognition tools and the Choregraphe face detection box.

[11] More information available from https://dictation.io/

Fig. 4.3-4 shows the signals that are sent or received by this module. The Box starts when a signal is received on this input (ACTFT) from Interview control module. The Box sends a signal when the target is lost (FACELOST) or is detected (FACEDET). The input and output signals are Boolean data type.

4.3.4. Voice Module

The robot will be able to speak and make the questions using the voice playback tool of Choregraphe. Fig. 4.3-5 shows the signals that are sent or received by this module. The Box starts when a signal is received on this input (TEXT) from Interview control module. The input of this module is a text string block. The Box sends a signal when the robot finishes talking (VOICE_END). The output signal is Boolean data type.

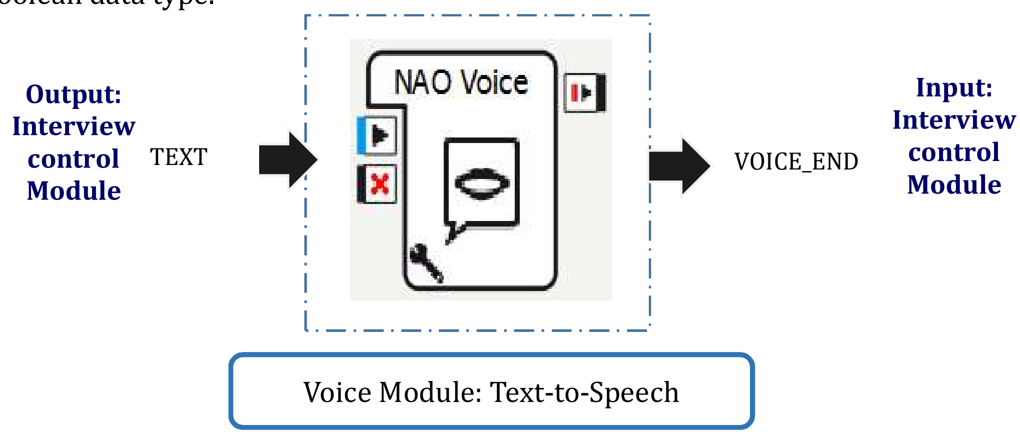


Fig. 4.3-5. Choregraphe Voice Module.

4.3.5. Interview Script File

The vocational guidance session is divided into three parts (Greeting protocols, Interview session and Endings protocols) and each of them has an associated script. Each script includes the texts to be reproduced by NAO. These scripts are stored in a MySQL database. The system will load these files and can access this information as needed.

4.3.5.1. Greeting protocols

In this part NAO greets and welcomes the vocational guidance session. The script for this session consists of three options that serve as text for the voice of the robot (executed by the voice module). The system randomly chooses any of these three greetings, which allows the robot not always greet the same way when starting a session. Table 4.3-1 shows these greetings.

Item	Greetings
1	Hello my name is NAO. Let's start the interview.
2	I'm NAO, it's nice to meet you. Let us begin!
3	Hi, I'm NAO, welcome to the vocational guidance session.

Table 4.3-1. Script: Greeting Protocols.

4.3.5.2. Interview session

Table 4.3-2 shows the interview script containing all questions categorized within the framework of the vocational guidance session.

Three options are presented for the formulation of each question by NAO, so it is possible to vary the questions between one interview and another. The system makes this choice randomly. Questions 4 to 8 include examples that allow the interviewee to understand what type of information the robot is requesting.

The number of questions was limited to eight (8) taking into account the theory explained in section 2.2.1.1.

Question	Priority	Questions Option1	Questions Option2	Questions Option3	T.L	Rat.
Questions oriented to career choice						
1	High	Which career would you like to study? Why would you like to study this career?	Did you decide which career to study? Why did you make this choice?	Which is the career you would like to study? What is your motivation to study it?	30	25
2	Low	Which were your favorite subjects at school? Why did you like them most?	Which were your favorite school subjects? Why?	At school, which were your favorite subjects? Why did you like them?	30	5
3	Low	At school, which were subjects you liked least? Why?	Which subjects did you find most difficult in High school? Why?	Which subjects of your student period did you like least? What did you like least about?	30	5
Questions oriented to values and goals						
4	Medium	Which values do you feel identified with? Why? For instance, values like self-improvement, truth, or efficiency are important to you?	Which values do you feel identified with? Why? For instance, values like compassion, success or discipline are important to you?	Which values do you feel identified with? Why? For instance, values like recursion, creativity or solidarity are important to you?	40	10

Question	Priority	Questions Option1	Questions Option2	Questions Option3	T.L	Rat.
Questions oriented to favorite activities						
5	High	Which kinds of activities do you like to do? For instance, do you like to collect stamps? Participate in a volunteer program? Do you like dance?	Which types of activities do you usually participate in? Why? For example, Do you practice any sport? Do you like to read? Do you like mechanics?	Which kinds of activities do you like to do? For instance, Do you like to write reports? Do you like music? Participate in a spelling contest?	40	15
Questions oriented to aversions						
6	Medium	Which kinds of activities do you dislike to do? For example, practice a sport, work in sales or study math.	Which kind of activities do you enjoy less? Why? For instance, Do you dislike artistic activities? Don't you like to read? Don't you like to do scientific projects?	Which kind of activities do you enjoy less? Why? For example, Don't you like writing reports? Don't you like dancing or painting?	40	10
Questions oriented to opinion of oneself and personality traits						
7	High	Tell me about yourself. Which are words that best describe your personality? Why? For instance, are you an ambitious, scrupulous, imaginative or sociable person?	Which words would you use to describe your personality and why? For example, do you consider yourself a kind, intelligent, orderly or creative person?	Tell me about yourself, Which are words that best describe your personality? Why? For instance, are you a shy, introverted or materialistic person?	40	20
8	Medium	Which words wouldn't you use to describe your personality? Why? For example, wouldn't you describe yourself as someone persistent, curious, adventurous, or idealistic?	Which words wouldn't you use to describe your personality? Why? For instance, wouldn't you describe yourself as a generous, conceited, creative, or independent person?	Which words wouldn't you use to describe your personality? Why? For example, wouldn't you describe yourself as a thrifty, emotional, friendly or optimistic person?	40	10

Note: T.L= Timeout, Rat. = Rating of the question.

Table 4.3-2. The Interview Script

Timeout: Timeout allows the system to establish when the robot finishes talking and a question behavior is terminated. For this purpose, a comparison is made between the moment the behavior starts until it ends. The speech recognition module is enabled when the timeout is less than or equal to the end runtime of the behavior.

Rating of the question: In each of the eight questions, a score is assigned to each answer. The final rating is 100 points. The high-priority questions will play a more important role in the final rating that the low-priority questions. The final rating of the interview allows to determine the person's vocational profile.

4.3.5.3. Ending protocols

In this part NAO emits a recommendation about user vocation according to the parameters necessary to take into account in the career selection process (see section 2.2). In addition, the robot says goodbye and ends the vocational guidance session.

For each of the vocational groups the key letters (R, I, A, S, E, C)[12] will be used. The rating obtained for each vocational group[13], allows to determine different sets that will describe the person's vocational profile. The vocation with the maximum rating is ranked first and so on until the last position, which represents the vocation with the minimum rating. For example, the IRACSE key means that in the first place the person looks like people from investigative occupations, secondly he looks a bit less like people from realistic occupations and so on until the last position corresponding to enterprising occupations. In this way, the keys provide a brief summary of the person's vocational interests and show his degree of similarity with the six vocational groups.

The sentences of the text to be reproduced by the robot are organized according to the order of the key letters. Only the first three key letters are taken into account so that the resulting text is not very extensive.

The first sentence of the text represents the vocational group with the maximum rating, the second one symbolizes the vocational group with the second-highest rating and the third one denotes the vocation with the minimum rating. Finally, a fourth phrase is used as farewell text. Therefore, the text to be reproduced by the robot is composed of four different sentences.

[12] Vocational groups are: Realistic (R), Investigative (I), Artistic (A), Social (S), Enterprising (E), and Conventional (C).

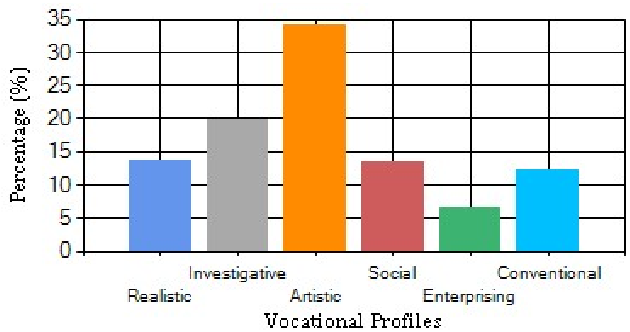
[13] During the vocational guidance session, the questions asked by the robot allow to collect relevant information about the individual's aspirations, interests and abilities. In this way, the system can establish the person's vocational profile by giving a rating for each vocational group. The analysis module is in charge of performing this score. This process is explained in section 4.3.7.2.

Table 4.3-3 shows the sentences associated with each vocation. In addition, the script containing the farewell texts is displayed. The system randomly chooses any of the three options presented.

Sentences for each vocational group	
First Sentence	Firstly, I recommend you study a career
Second Sentence	Secondly, I suggest you study a career
Third Sentence	Finally, I advise you to study a career
Realistic (R)	related to use of tools or the realization of manual tasks, for example mechanic or farmer.
Investigative (I)	related to the scientific part, research or intellectual activities, for example biologist or engineer.
Artistic (A)	where you can express your ideas, feelings and your creativity through art, for example, architect or musician.
Social (S)	which requires contact with people, and where you carry out actions that improve their quality of life, for example a doctor or a teacher.
Enterprising (E)	related to leadership and business, for example lawyer or administrator.
Conventional (C)	where you can work in administrative tasks, office and economic affairs, for example economist or accountant.
Item	**Farewell Texts**
1	We finished, thank you very much.
2	That's it, it was a pleasure to talk to you.
3	The interview is over, thank you for your time.

Table 4.3-3. Script: Ending Protocols.

Fig. 4.3-6 shows an example of the construction of a text to be reproduced by the robot. The example is based on results obtained during a vocational guidance session.



Key words: AIRSCE

<< Firstly, I recommend you study a career where you can express your ideas, feelings and your creativity through art, for example, architect or musician. Secondly, I suggest you study a career related to the scientific part, research or intellectual activities, for example biologist or engineer. Finally, I advise you to study a career related to use of tools or the realization of manual tasks, for example mechanic or farmer. That's it, it was a pleasure to talk to you. >>

Fig. 4.3-6. Example of the construction of a text to be reproduced by NAO: Ending Protocols.

4.3.6. Behaviors Module

The different behaviors associated with the vocational guidance session were divided and prioritized as shown in Fig. 4.3-7.

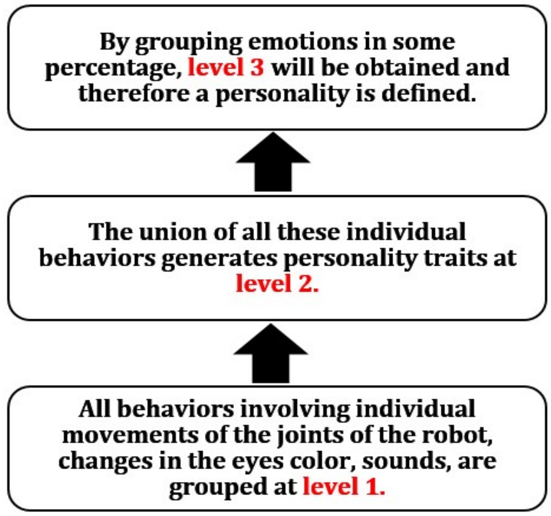


Fig. 4.3-7. Hierarchical Behaviors.

4.3.6.1. Behaviors at Level I: Individual Movements

Behaviors involving individual movements of the joints of the robot, head movements, changes in the eyes color, sounds, opening and closing hands, are grouped at level 1. This level is also made up of the set of pre-programmed behaviors from Choreographe (see section 2.1.2.1) such as: Wake Up, Play Sound, Motor on/off, among others. Level 1 is divided into five (5) categories which group behaviors according to body part of NAO in which the behavior is being executed:

4.3.6.1.1. Facial Expressions

Behaviors involving changes in eye color are used to convey information about the emotional state of the NAO robot. The NAO robot, like other humanoids, does not possess facial features to convey emotion. Therefore, emotions are conveyed through LED patterns around the eyes of the robot and are used to show NAO's "emotion" about what it is feeling at a given moment. The eyes of the NAO robot are composed of eight partitions (see Fig. 4.3-8), each partition containing a Red, Green, and Blue LED that can be programmed for different colors, intensity, and duration (i.e., LED pattern). The LED pattern associated with each emotion is based in (Johnson, 2013) and Table 4.3-4 shows the behaviors designed.

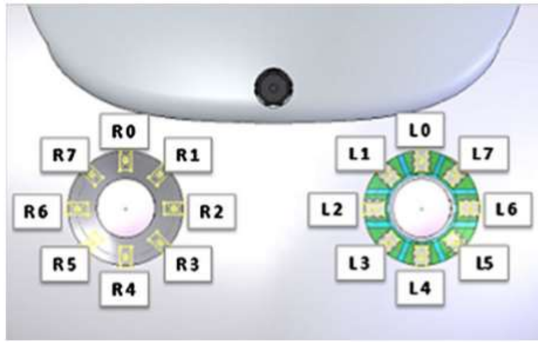
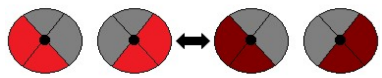
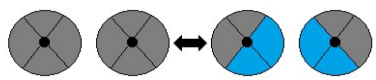
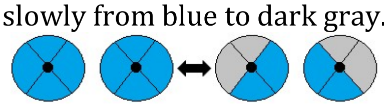
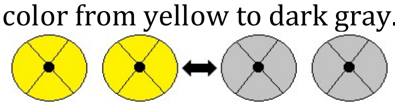
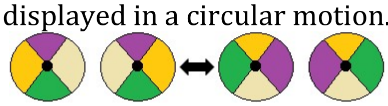


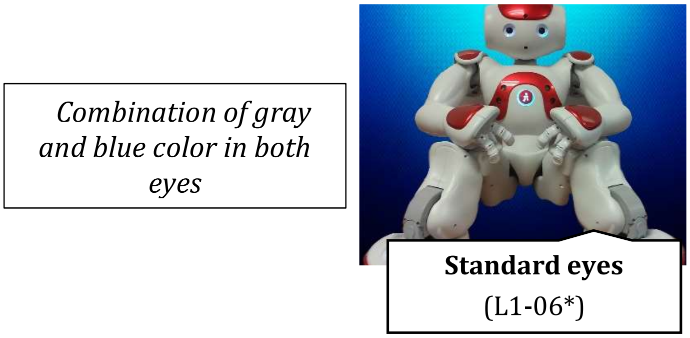
Fig. 4.3-8. The eyes of the NAO robot.

Emotion	Name	Description and LED Pattern	Picture
Anger	Red-Black eyes (L1-01*)	The combination of black and red color in both eyes are used to imitate an angry look by changing the color from red to dark. 	
Boredom	Grays-blue eyes sequence (L1-02*)	Gray and blue color in both eyes are displayed in a circular motion. 	
Interest	Blue eyes sequence (L1-03*)	Both eyes are displayed in color blue and then the lower partitions of the eyes change slowly from blue to dark gray. 	
Surprise	Yellow-gray eyes sequence (L1-04*)	The entire eye is changing the color from yellow to dark gray. 	
Joy	Multicolored eyes sequence (L1-05*)	Combination of purple, orange and green color in both eyes are displayed in a circular motion. 	

Note: (*) indicates a numeric code by each behavior.

Table 4.3-4. Facial Expressions: Behaviors at Level 1.

A LED pattern was designed to accompany the behaviors during the interview questions. Fig. 4.3-9 shows this behavior.

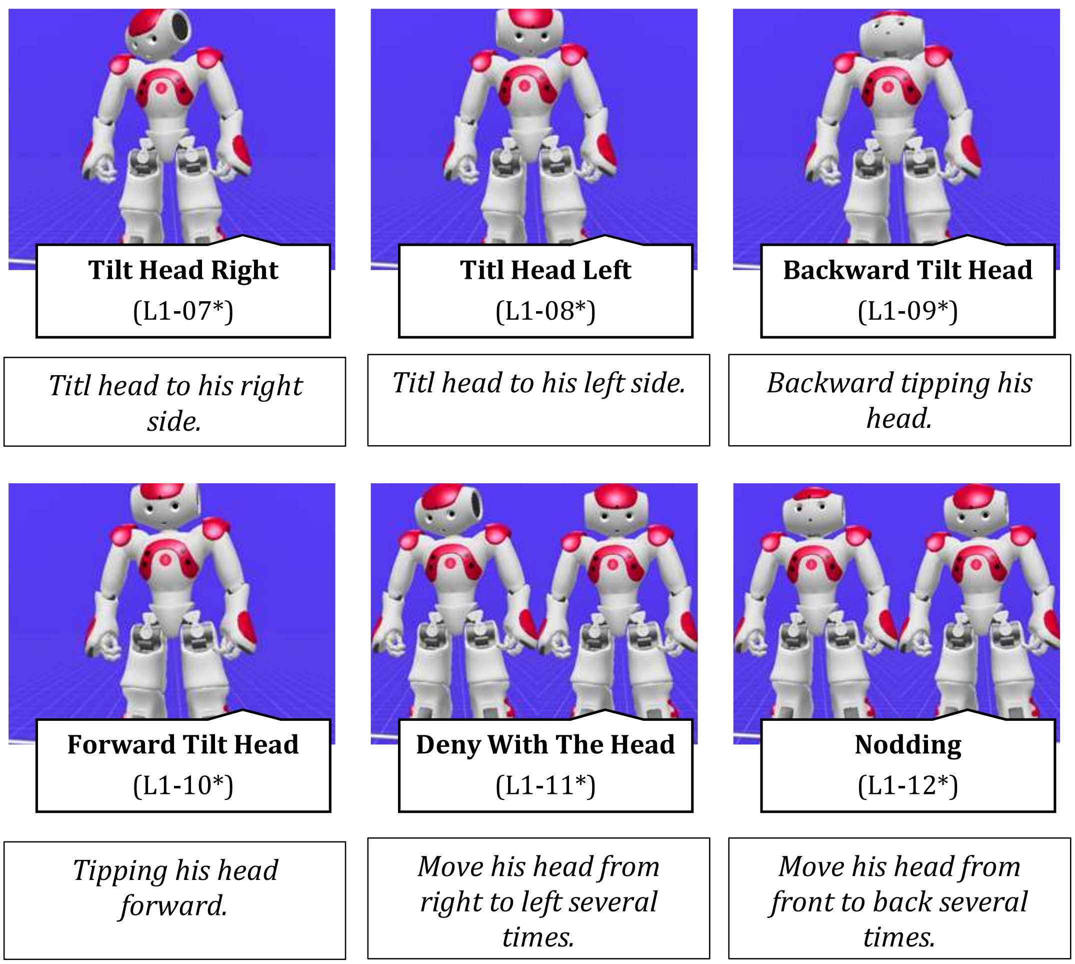


Note: (*) indicates a numeric code by each behavior.

Fig. 4.3-9. Facial Expressions: Standard Eyes.

4.3.6.1.2. Head Position

Movements like: NAO nods or shakes its head, titl head to his right side, backward tilt head, etc. Fig. 4.3-10 shows the behaviors designed.



Moving-Laugh
(L1-13*)

Move his head quickly from front to back.

Note: (*) indicates a numeric code by each behavior.

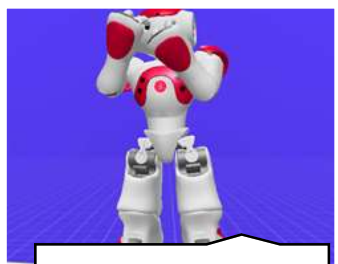
Fig. 4.3-10. Head Position: Behaviors at Level 1.

4.3.6.1.3. Arms Position

Behaviors involving movements with the robot's hands, such as cover its mouth, cover its eyes, crossing arms, etc. Fig. 4.3-11 shows the behaviors designed.

Cover Its Mouth.
(L1-14*)

Raise his left arm to his face to cover his mouth while tipping his head.



Cover Its Eyes
(L1-15*)

Raise both arms to cover his eyes while tipping his head

Put Its Hand On Its Mouth.
(L1-16*)

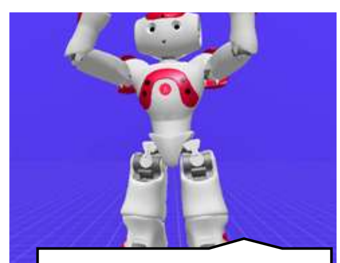
Put Its Hand On Its Mouth.

Move Right Hand To Face.
(L1-17*)

Raise his right arm to cover his face.

Move Left Hand To Face
(L1-18*)

Raise his left arm to cover his face.

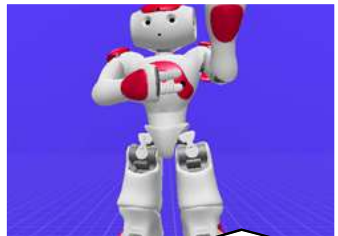


Rising both arms
(L1-19*)

Raise and open its arms.

Crossing Arms
(L1-20*)

Raise both arms and puts the left arm over the right arm to the chest level.



Crossing An Arm Forward
(L1-21*)

Cross the right arm and place it forward to his left arm.

Open the Arms
(L1-22*)

Open his arms.

Put Hands Over The Head
(L1-23*)

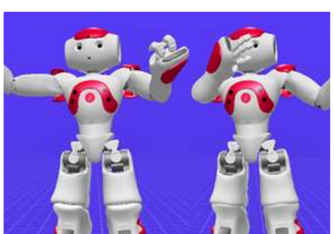
Raise both arms to his head level.

Hands on the hips
(L1-24*)

Put its hands on its hip.

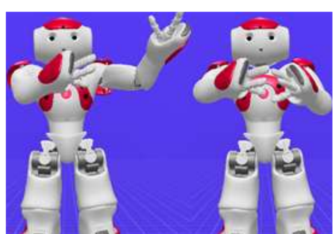
Hands on the Face
(L1-25*)

Raise his arms and puts them close to his face.



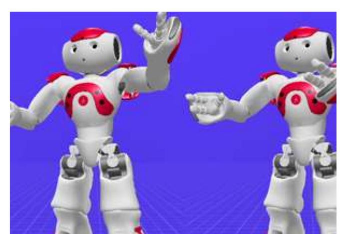
Movement 1
(L1-26*)

Random open and close both arms.



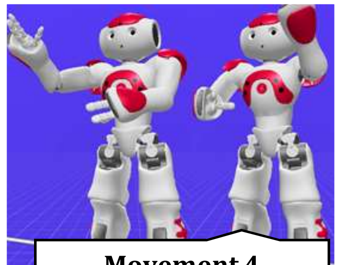
Movement 2
(L1-27*)

Random open and close both arms.



Movement 3
(L1-28*)

Random open and close both arms.

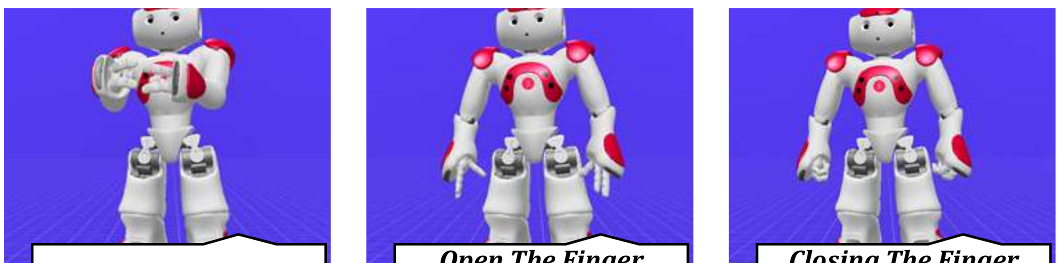


Note: (*) indicates a numeric code by each behavior.

Fig. 4.3-11. Arms Position: Behaviors at Level 1.

4.3.6.1.4. Hands Position

Movements like: Random open and close both arms, hands on the face, joint the fingertips, etc. Fig. 4.3-12 shows the behaviors designed.



Note: (*) indicates a numeric code by each behavior.

Fig. 4.3-12. Hands Position: Behaviors at Level 1.

4.3.6.1.5. Sounds

NAO speaks the given text by default. Table 4.3-5 shows the sounds (text) included in each of behaviors developed at level 2 (see section 4.3.6.2.1).

Code	***Sounds*: (Text)**	**Code**	***Sounds*: (Text)**
L1-33	It was not a good answer	L1-37	Yawn-1* (Mmmm)
L1-34	Your answer was not the right one	L1-38	Yawn-2* (Mmmm)
L1-35	You have responded inappropriately	L1-39	Yawn-3* (Mmmm)
L1-36	No, very bad	L1-40	Yawn-4* (Mmmm)
Code	***Sounds*: (Text)**	**Code**	***Sounds*: (Text)**
L1-41	Let me think of it.	L1-45	Woa!-1* (Woa!)
L1-42	I'll think about it!	L1-46	Very good answer! **
L1-43	Interesting!	L1-47	Good answer! **
L1-44	I will consider it!	L1-48	Woa!-2* (Woa!)

Code	*Sounds*: (Text)	
L1-49	Excellent answer**	* Only audio file. ** Includes audio file and text.
L1-50	Fantastic! **	
L1-51	Oh! Wonderful **	
L1-52	Fabulous! **	

Table 4.3-5. Sounds: Behaviors at Level 1.

4.3.6.2. Behaviors at Level II: Answer and Question Behaviors

The different behaviors developed at level 2 are executed by NAO during the development of the vocational guidance session. These are divided into *Question Behaviors* (i.e., behaviors executed when the robot asks a question, greets someone or says goodbye to the person) and *Answer Behaviors* (i.e., behaviors that are triggered depending on the answers to the questions posed).

4.3.6.2.1. Answer Behaviors

The union of several behaviors level 1 generates **personality traits** at level 2. The selection of personality traits is carried out according to the theory explained in section 2.3. These traits are what are known as *Behaviors* at Level 2.

Five basic emotions are considered from a set of possible emotions (Gratch et al., 2004): **Anger**, **boredom**, **interest**, **surprise** and **joy**. The set of 20 personality-descriptive adjectives (personality traits), selected in Table 2.3-1, are grouped according to these five different emotions. Each emotion has associated four adjectives shown in Table 4.3-6.

Emotion	Anger	Boredom	Interest	Surprise	Joy
Behavior *(Personality traits)*	Rude (L2-01)*	Quiet (L2-05)*	Critical (L2-09)*	Thoughtful (L2-13)*	Sympathetic (L2-17)*
	Serious (L2-02)*	Bashful (L2-06)*	Insightful (L2-10)*	Obstinate (L2-14)*	Agreeable (L2-18)*
	Moody (L2-03)*	Dull (L2-07)*	Analytical (L2-11)*	Enthusiastic (L2-15)*	Cheerful (L2-19)*
	Grumpy (L2-04)*	Apathetic (L2-08)*	Curious (L2-12)*	Alert (L2-16)*	Merry (L2-20)*

Note: (*) indicates a numeric code by each behavior.

Table 4.3-6. Summary Behaviors at Level 2.

The set of body postures designed for this type of behavior is based on work carried out by (Erden & Tapus, 2010; Miskam, 2016) in which different postures are determined by means of which NAO can convey these emotions effectively.

During the design of the level 2 behaviors, many of the movements of the robot are limited in comparison to of human movements. This is because the range of joint angles of the NAO robot (see section 2.1.1.3) is not as large as in the human body. In addition, the difference in mass distribution throughout the robot body does not allow it to remain stable since the ratio of the mass of the head to body is larger in NAO.

The movement of each personality trait is pre-programmed using Choregraphe in combination with the different level 1 behaviors. The behaviors designed in Choregraphe are shown in Fig. 4.3-13 to Fig. 4.3-37. The level 1 behaviors that make up each of these behaviors are illustrated by images in every category involved. The sounds (text) are included and each of them has one sound associated.

- **Emotion: Anger:**

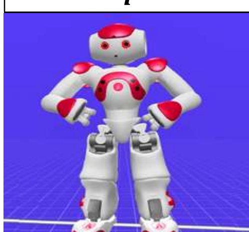
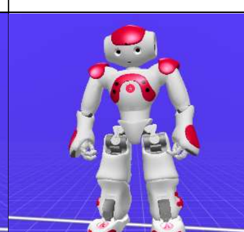
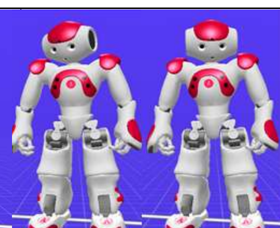
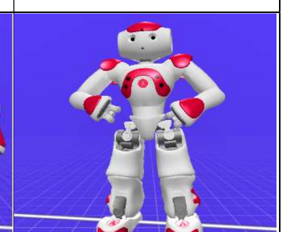
Facial Expressions	***Head Position***		***Arms Position***
			
L1-01	*L1-10*	*L1-11*	*L1-24*
Sounds *(L1-33): It was not a good answer.*			

Fig. 4.3-13. Answer Behavior (Rude): Behavior at Level 2.

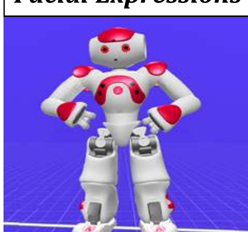
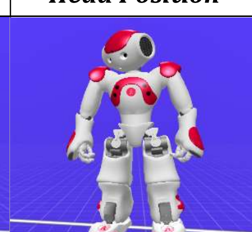
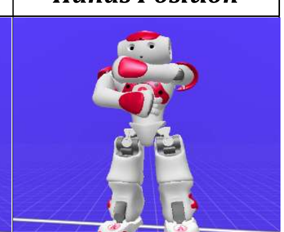
Facial Expressions	***Head Position***	***Hands Position***
		
L1-01	*L1-07*	*L1-20*
Sounds *(L1-34): Your answer was not the right one.*		

Fig. 4.3-14. Answer Behavior (Serious): Behavior at Level 2.

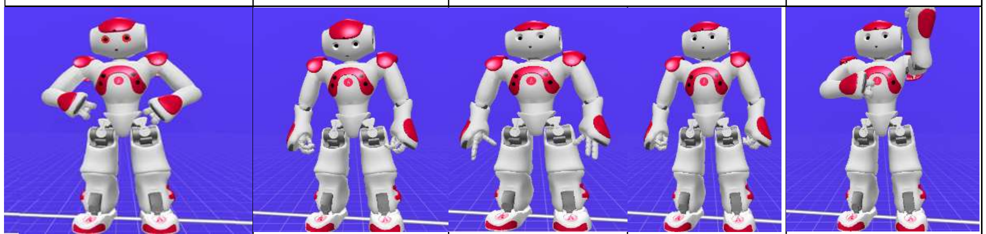
Facial Expressions	***Head Position***	***Hands Position***		***Arms Position***
				
L1-01	*L1-10*	*L1-31*	*L1-32*	*L1-21*
Sounds *(L1-35): You have responded inappropriately.*				

Fig. 4.3-15. Answer Behavior (Moody): Behavior Level 2.

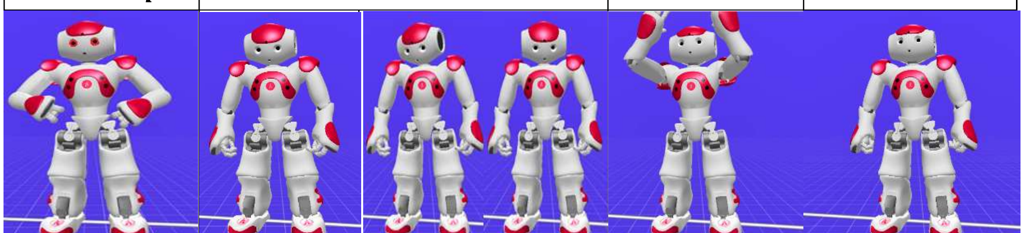
Facial Exp.	***Head Position***		***Arms Position***	***Hands Position***
				
L1-01	*L1-10*	*L1-11*	*L1-19*	*L1-32*
Sounds *(L1-36): No, very bad.*				

Fig. 4.3-16. Answer Behavior (Grumpy): Behavior Level 2

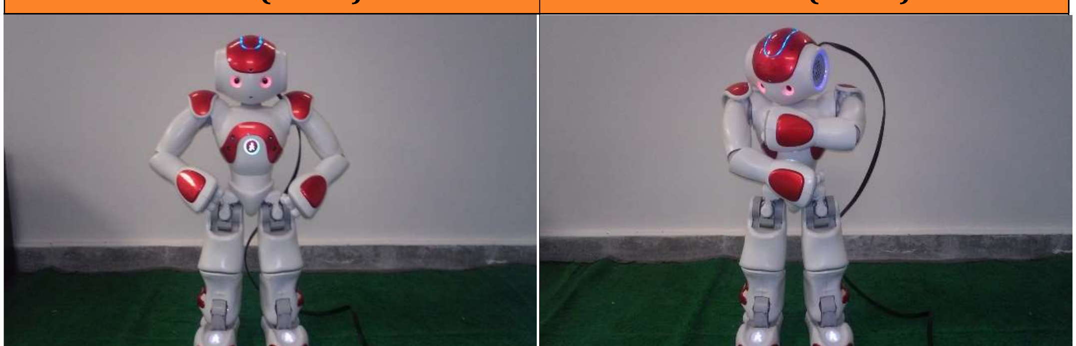
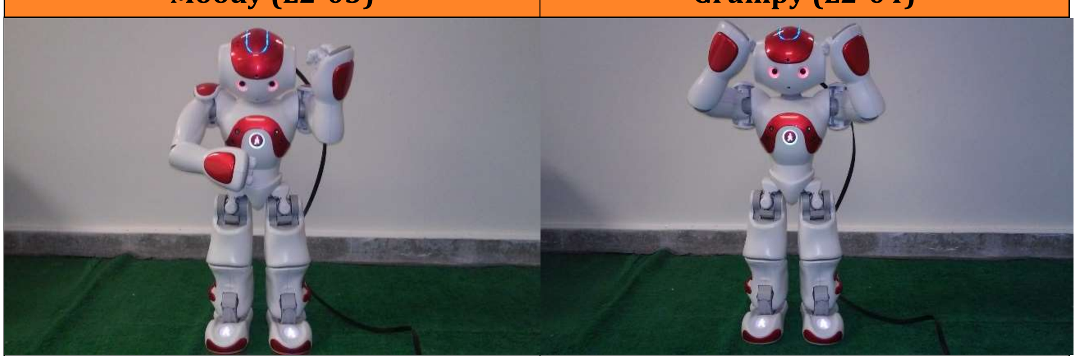
Rude (L2-01)	**Serious (L2-02)**
	
Moody (L2-03)	**Grumpy (L2-04)**
	

Fig. 4.3-17. Anger Emotion: Behavior at Level 2.

- **Emotion: Boredom**

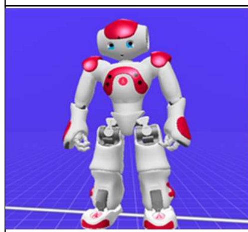
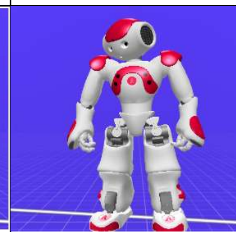
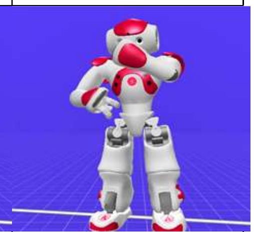
Facial Expressions	***Head Position***	***Arms Position***
		
L1-02	*L1-07*	*L1-14*
Sounds *(L1-37):* Audio file (Yawn-1: *Mmmm*)		

Fig. 4.3-18. Answer Behavior (Quiet): Behavior at Level 2.

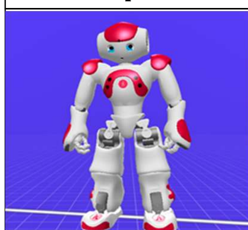
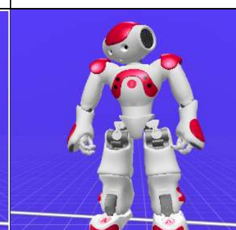
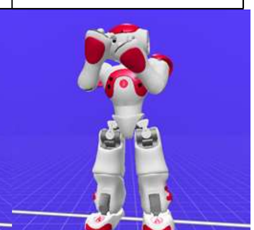
Facial Expressions	***Head Position***	***Arms Position***
		
L1-02	*L1-07*	*L1-15*
Sounds *(L1-38):* Audio file (Yawn-2: *Mmmm*)		

Fig. 4.3-19. Answer Behavior (Bashful): Behavior at Level 2.

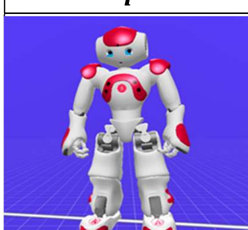
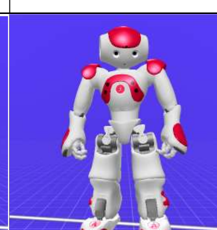
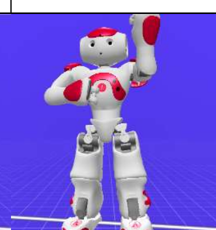
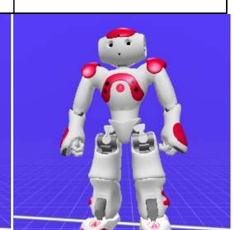
Facial Expressions	***Head Position***	***Arms Position***	***Hands Position***
			
L1-02	*L1-08*	*L1-21*	*L1-32*
Sounds *(L1-39):* Audio file (Yawn-3: *Mmmm*)			

Fig. 4.3-20. Answer Behavior (Dull): Behavior at Level 2.

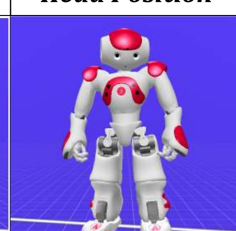
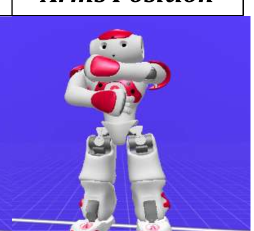
Facial Expressions	***Head Position***	***Arms Position***
		
L1-02	*L1-08*	*L1-20*
Sounds *(L1-40):* Audio file (Yawn-4: *Mmmm*)		

Fig. 4.3-21. Answer Behavior (Apathetic): Behavior at Level 2.

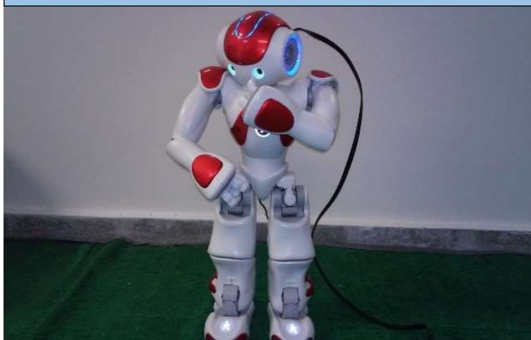
Quit (L2-05)	Bashful (L2-06)
	
Dull (L2-07)	**Apathetic (L2-08)**
	

Fig. 4.3-22. Boredom Emotion: Behavior at Level 2.

- **Emotion: Interest**

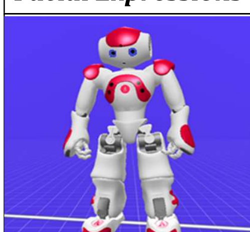
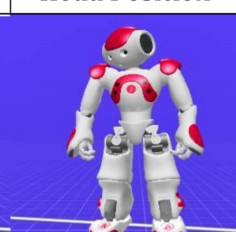
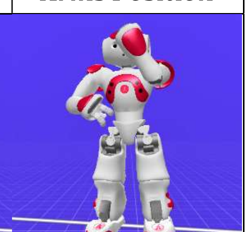
Facial Expressions	*Head Position*	*Arms Position*
		
L1-03	*L1-07*	*L1-18*
***Sounds** (L1-41): Let me think of it.*		

Fig. 4.3-23. Answer Behavior (Critical): Behavior at Level 2.

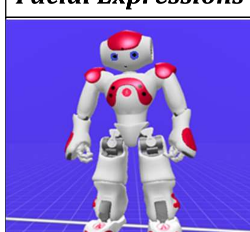
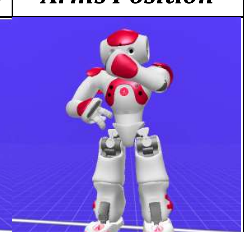
Facial Expressions	*Arms Position*
	
L1-03	*L1-14*
***Sounds** (L1-42): I'll think about it!*	

Fig. 4.3-24. Answer Behavior (Insightful): Behavior at Level 2.

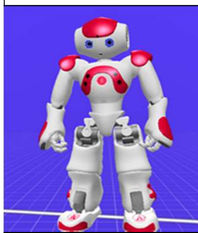
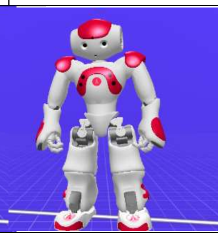
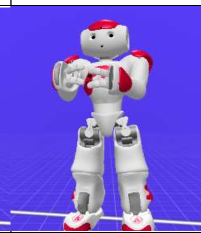
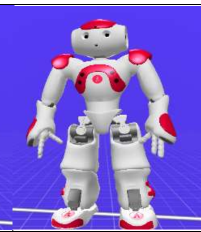
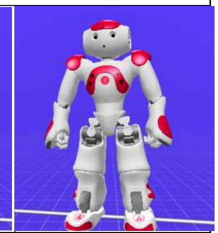
Facial Exp.	***Head Position***	***Hands Position***		
				
L1-03	*L1-10*	*L1-30*	*L1-31*	*L1-32*
***Sounds** (L1-43): Interesting!*				

Fig. 4.3-25. Answer Behavior (Analytical): Behavior at Level 2.

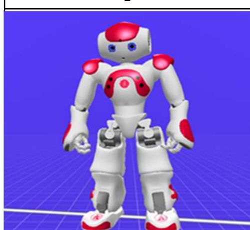
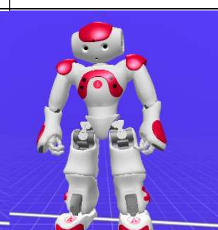
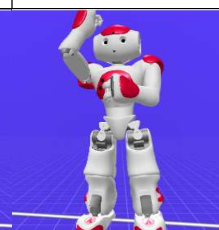
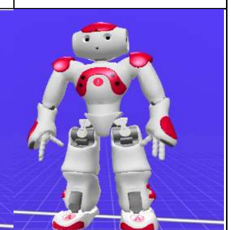
Facial Expressions	***Head Position***	***Arms Position***	***Hands Position***
			
L1-03	*L1-10*	*L1-17*	*L1-31*
***Sounds** (L1-44): I will consider it!*			

Fig. 4.3-26. Answer Behavior (Curious): Behavior at Level 2.

Critical (L2-09)	**Insightful (L2-10)**
	
Analytical (L2-11)	**Curious (L2-12)**
	

Fig. 4.3-27. Interest Emotion: Behavior at Level 2

- **Emotion: Surprised**

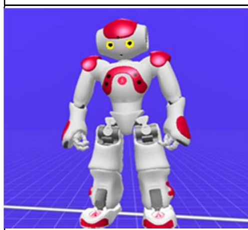
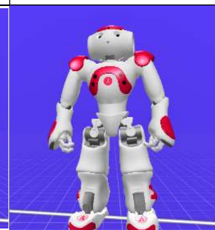
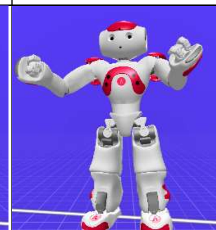
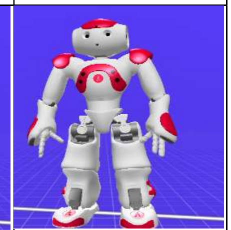
Facial Expressions	***Head Position***	***Arms Position***	***Hands Position***
			
L1-04	*L1-09*	*L1-22*	*L1-31*
***Sounds** (L1-45):* Audio file (Woa!-1: *Woa!)*			

Fig. 4.3-28. Answer Behavior (Thoughtful): Behavior at Level 2.

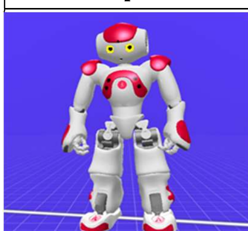
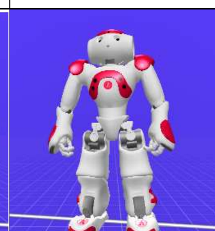
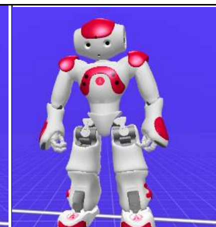
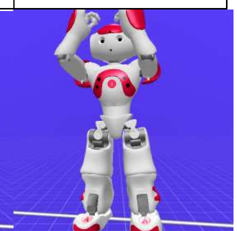
Facial Expressions	***Head Position***		***Arms Position***
			
L1-04	*L1-09*	*L1-10*	*L1-23*
***Sounds** (L1-46): Very good answer!* (Includes audio file)			

Fig. 4.3-29. Answer Behavior (Obstinate): Behavior at Level 2.

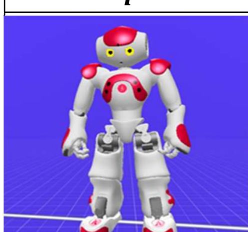
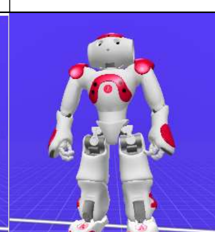
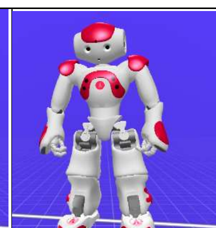
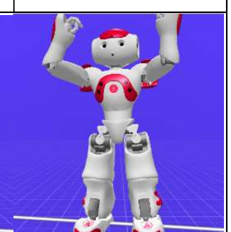
Facial Expressions	***Head Position***		***Arms Position***
			
L1-04	*L1-09*	*L1-10*	*L1-19*
***Sounds** (L1-47): Good answer!* (Includes audio file)			

Fig. 4.3-30. Answer Behavior (Enthusiastic): Behavior at Level 2.

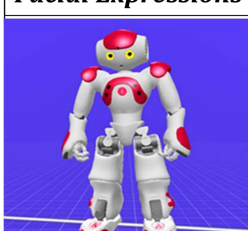
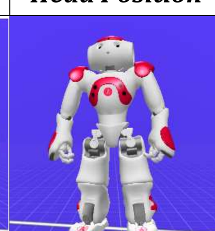
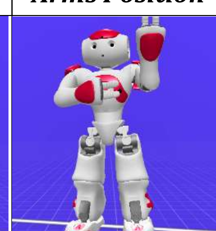
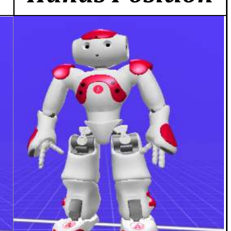
Facial Expressions	***Head Position***	***Arms Position***	***Hands Position***
			
L1-04	*L1-09*	*L1-21*	*L1-31*
***Sounds** (L1-48):):* Audio file (Woa!-2)			

Fig. 4.3-31. Answer Behavior (Alert): Behavior at Level 2.

Thoughtful (L2-13)	Obstinate (L2-14)
	
Enthusiastic (L2-15)	**Alert (L2-16)**
	

Fig. 4.3-32. Surprised Emotion: Behavior at Level 2.

- **Emotion: Joy**

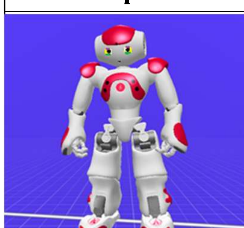
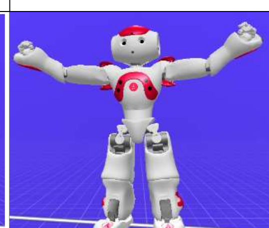
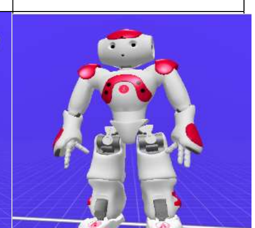
Facial Expressions	*Arms Position*	*Hands Position*
		
L1-05	*L1-22*	*L1-31*
Sounds *(L1-49): Excellent answer!* (Includes audio file)		

Fig. 4.3-33. Answer Behavior (Sympathetic): Behavior at Level 2.

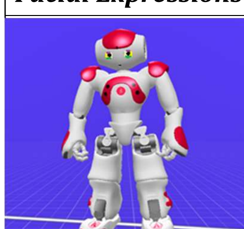
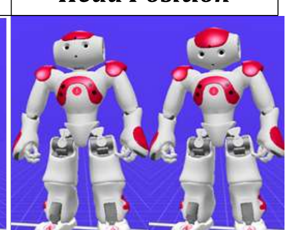
Facial Expressions	*Head Position*
	
L1-05	*L1-12*
Sounds *(L1-50): Fantastic!* (Includes audio file)	

Fig. 4.3-34. Answer Behavior (Agreeable): Behavior at Level 2.

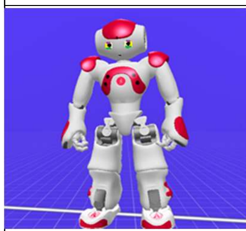
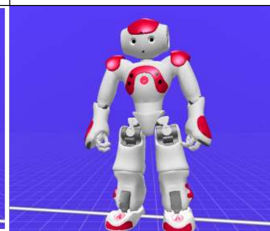
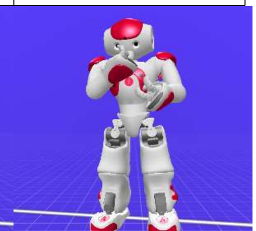
Facial Expressions	***Head Position***	***Arms Position***
		
L1-05	*L1-13*	*L1-16*
Sounds *(L1-51): Oh! Wonderful* (Includes audio file)		

Fig. 4.3-35. Answer Behavior (Cheerful): Behavior at Level 2.

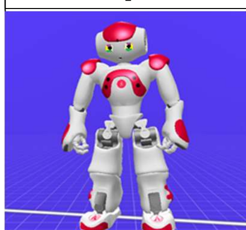
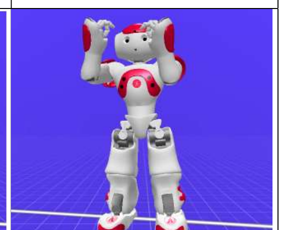
Facial Expressions	***Arms Position***
	
L1-05	*L1-25*
Sounds *(L1-52): Fabulous!* (Includes audio file)	

Fig. 4.3-36. Answer Behavior (Merry): Behavior at Level 2.

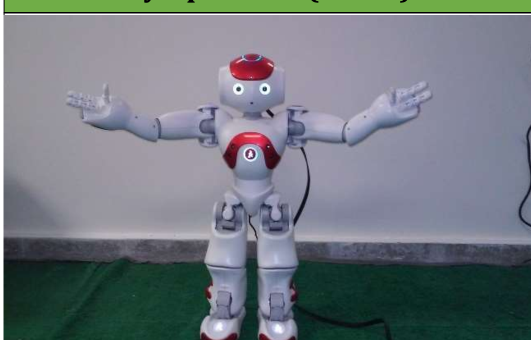
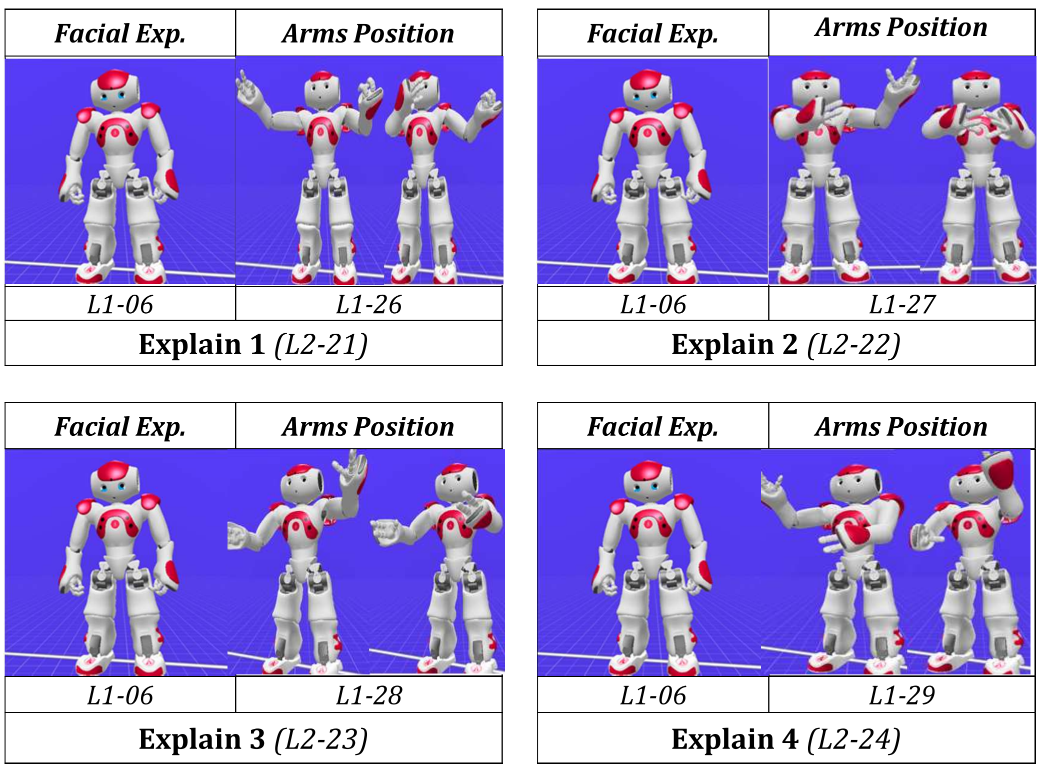
Sympathetic (L2-17)	**Agreeable (L2-18)**
	
Cheerful (L2-19)	**Merry (L2-20)**
	

Fig. 4.3-37. Joy Emotion: Behavior at Level 2.

4.3.6.2.2. Question Behaviors

Behaviors involving movements with the robot's arms, randomly executed (see Fig. 4.3-11, codes L1-26 to L1-29), are used to accompany the voice of the robot during a question, greeting or farewell of the vocational guidance session, and thus give emphasis to what it is saying. In addition, the length of texts for the voice of the robot is different in each question, greeting, or farewell (see section 4.3.5) and the time for the execution of the same varies from one to another. Therefore, each of them has an associated Question Behavior. Fig. 4.3-38 shows the distribution of each behaviors designed.



State[14]	Question Behavior
Greeting Protocols	Explain 1
Interview Session (Question 1,2 and 3)	Explain 2
Interview Session (Question 4,5,6,7 and 8)	Explain 3
Ending Protocols	Explain 4

Fig. 4.3-38. Question Behavior: Behavior at Level 2.

[14] Each of the parts (state) into which the vocational guidance session is divided.

4.3.6.2. Behaviors at Level III: Personality

On level 3, each of the behaviors associated to level 2 has a variable that determines the frequency with which they appear during the interview. This variable is called *Frequency Weight.* By grouping emotions in some percentage, level 3 will be obtained and therefore a **personality** is defined.

As explained in section 2.3, it is possible to determine different personality types according to characteristic traits from each of them. The frequency weights values are determined taking into account the *Factor Loadings* (FL) and correlation shown in Table 2.3-1. In addition, the frequency weights values are established in a range of 0-100 for every level 2 behavior.

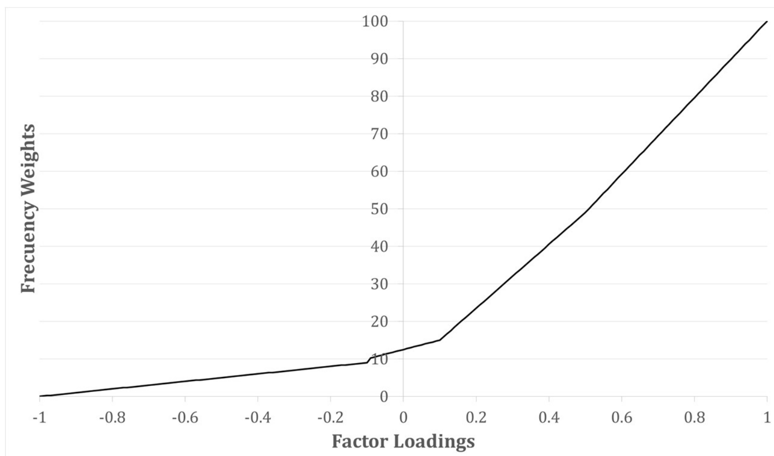


Fig. 4.3-39. Proposed curve for calculating the Frequency Weights in each behavior Level 2.

Fig. 4.3-39 shows the proposed curve to determining the frequency weights and Fig. 4.3-40 shows the relationship between the factor loadings and the frequency weights. The values in green represent the frequency weights by adjective (behavior).

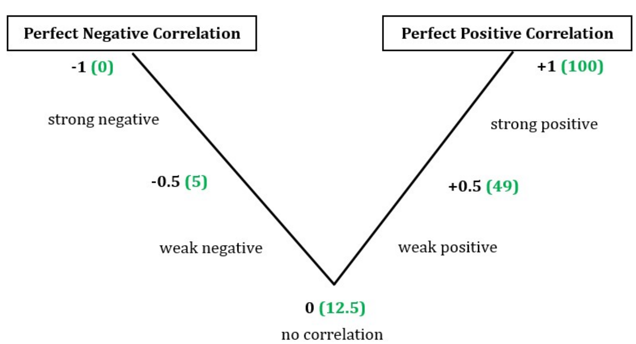
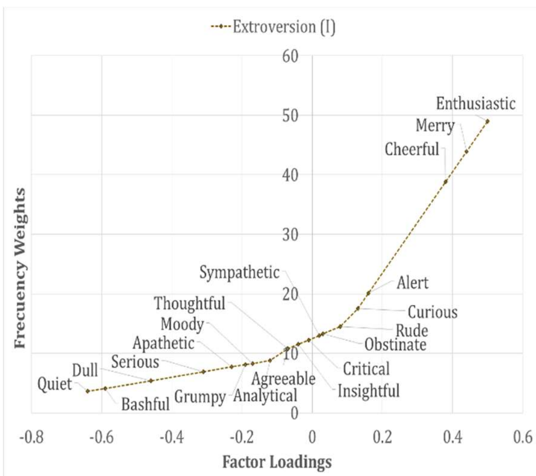
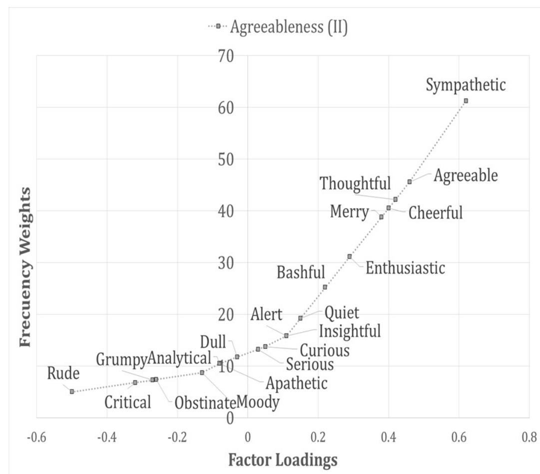


Fig. 4.3-40. Relationship between the Factor Loadings and the Frequency Weights in each behavior.

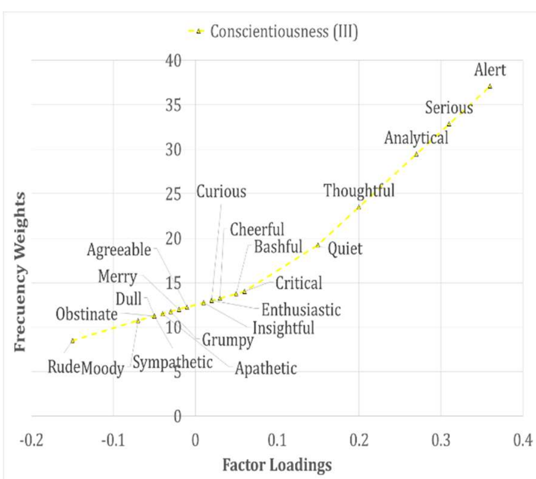
A correlation of -1 (perfect negative correlation) is represented by the frequency weight value 0. Non-correlation is determined at a value of 12.5 in order to reserve the interval of 0-12.5 to represent negative correlations. When the factor loadings value is close to zero, between -0.1 and +0.1, the relationship between the adjective and the factor is very weak. Therefore, negative correlations will be less than positive correlations in this interval, since negative correlations approach a correlation equal to zero, and positive correlations moves away from this value. The frequency weight values will increase linearly with respect to positive correlations. Finally, a frequency weight value of 100 represents a correlation of +1 (perfect positive correlation). Fig. 4.3-41 shows the curves obtained to each Factor according to the graph shown in Fig. 4.3-39:



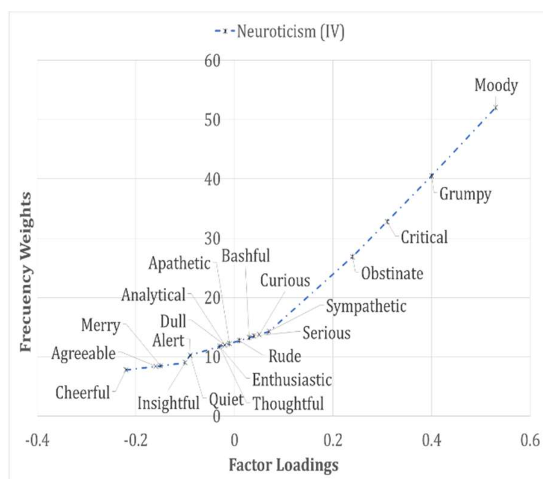
(a) Factor I: Extroversion



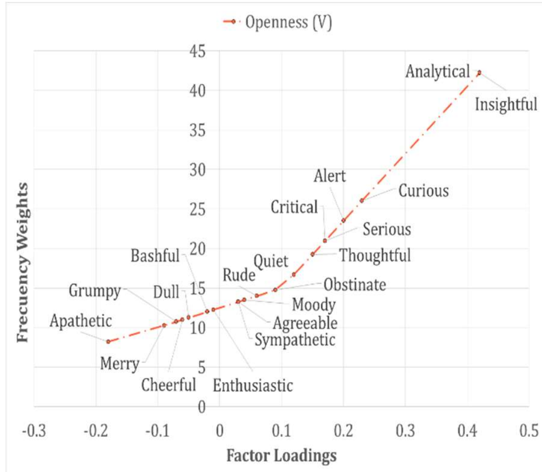
(b) Factor II: Agreeableness



(c) Factor III: Conscientiousness



(d) Factor IV: Neuroticism



(e) Factor V: Openness

Fig. 4.3-41. Frequency Weights vs Factor Loadings graphs to each Factor.

For example, the adjective *Sympathetic* has the following factor loadings [0.02 0.62 -0.05 0.07 0.03] corresponding to Extraversion (E), Agreeableness (A), Conscientiousness (C), Neuroticism (N), and Openness to experience (O), respectively. This adjective strongly correlates with the Factor II, therefore its frequency weight will be a high value (61.24). In addition, *Sympathetic* is negatively correlated with the Factor III at -0.05, which is a value very close to zero and therefore its frequency weight will be a low value (11.25), even lower than the frequency weights from the Factors I, IV and V (13, 14.25 and 13.25 respectively). These factors are positively correlated with *Sympathetic*, but its factor loadings are very close to zero, therefore its frequency weights will be a low values.

Based on the factor loadings Table 4.3-7 shows the frequency weights obtained on each of the five factors:

Adjective	**I**		**II**		**III**		**IV**		**V**	
	FL	**FW**	**FL**	**FW**	**FL**	**FW**	**FL**	**FW**	**FL**	**FW**
Sympathetic	0,02	13	0,62	61,24	-0,05	11,25	0,07	14,25	0,03	13,25
Agreeable	-0,07	10,75	0,46	45,6	-0,01	12,25	-0,16	8,4	0,03	13,25
Thoughtful	-0,07	10,75	0,42	42,2	0,2	23,5	-0,03	11,75	0,15	19,25
Cheerful	0,38	38,8	0,4	40,5	0,03	13,25	-0,22	7,8	-0,06	11
Rude	0,08	14,5	-0,5	5	-0,15	8,5	0,01	12,75	0,06	14
Critical	-0,01	12,25	-0,32	6,8	0,06	14	0,31	32,85	0,17	20,95
Obstinate	0,03	13,25	-0,26	7,4	-0,05	11,25	0,24	26,9	0,09	14,75
Enthusiastic	0,5	49	0,29	31,15	0,02	13	-0,03	11,75	-0,01	12,25
Merry	0,44	43,9	0,38	38,8	-0,02	12	-0,15	8,5	-0,09	10,25
Quiet	-0,64	3,6	0,15	19,25	0,15	19,25	-0,09	10,25	0,12	16,7

Adjective	I		II		III		IV		V	
	FL	**FW**	**FL**	**FW**	**FL**	**FW**	**FL**	**FW**	**FL**	**FW**
Bashful	-0,59	4,1	0,22	25,2	0,05	13,75	0,03	13,25	-0,02	12
Dull	-0,46	5,4	-0,03	11,75	-0,05	11,25	-0,02	12	-0,05	11,25
Serious	-0,31	6,9	0,03	13,25	0,31	32,85	0,04	13,5	0,17	20,95
Apathetic	-0,23	7,7	-0,08	10,5	-0,04	11,5	-0,01	12,25	-0,18	8,2
Alert	0,16	20,1	0,11	15,85	0,36	37,1	-0,09	10,25	0,2	23,5
Moody	-0,17	8,3	-0,13	8,7	-0,07	10,75	0,53	52,06	0,04	13,5
Grumpy	-0,19	8,1	-0,27	7,3	-0,03	11,75	0,4	40,5	-0,07	10,75
Insightful	-0,04	11,5	0,11	15,85	0,01	12,75	-0,1	9	0,42	42,2
Analytical	-0,12	8,8	-0,08	10,5	0,27	29,45	-0,02	12	0,42	42,2
Curious	0,13	17,55	0,05	13,75	0,02	13	0,05	13,75	0,23	26,05

Note: FW= Frequency Weights, FL= Factor Loadings, II= Agreeableness, I= Extroversion, III= Conscientiousness, IV= Neuroticism and V= Openness.

Table 4.3-7. Frequency weights: Behaviors at Level 3.

The set of twenty (20) personality-descriptive adjectives are grouped according to five (5) different emotions (see section 4.3.6.2.1). Table 4.3-8 shows the different personalities obtained according to this distribution. The percentages in red represent the total frequency by emotion. Each factor is assigned a name according to its characteristic traits. For example, frequency weights obtained for Factor II allow to describe the following personality:

Optimistic Personality: *"Someone who is sympathetic, agreeable, enthusiastic, never loses his composure and almost never gets angry".*

Emotion	Behavior	Reserved Personality (I)		Optimistic Personality (II)		Gloomy Personality (III)		Grumpy Personality (IV)		Analytical Personality (V)	
		FW	**PE**	**FW**	**PE**	**FW**	**PE**	**FW**	**PE**	**FW**	**PE**
Anger	*Rude*	14,5	12%	5	8%	8,5	20%	12,75	36%	14	17%
	Serious	6,9		13,25		32,85		13,5		20,95	
	Moody	8,3		8,7		10,75		52,06		13,5	
	Grumpy	8,1		7,3		11,75		40,5		10,75	
Boredom	*Quiet*	3,6	7%	19,25	15%	19,25	17%	10,25	14%	16,7	14%
	Bashful	4,1		25,2		13,75		13,25		12	
	Dull	5,4		11,75		11,25		12		11,25	
	Apathetic	7,7		10,5		11,5		12,25		8,2	
Interest	*Critical*	12,25	16%	6,8	11%	14	21%	32,85	20%	20,95	37%
	Insightful	11,5		15,85		12,75		9		42,2	
	Analytical	8,8		10,5		29,45		12		42,2	
	Curious	17,55		13,75		13		13,75		26,05	

Emotion	Behavior	Reserved Personality (I) FW	Reserved Personality (I) PE	Optimistic Personality (II) FW	Optimistic Personality (II) PE	Gloomy Personality (III) FW	Gloomy Personality (III) PE	Grumpy Personality (IV) FW	Grumpy Personality (IV) PE	Analytical Personality (V) FW	Analytical Personality (V) PE
Surprised	*Thoughtful*	10,75	30%	42,2	22%	23,5	26%	11,75	18%	19,25	20%
	Obstinate	13,25		7,4		11,25		26,9		14,75	
	Enthusiastic	49		31,15		13		11,75		12,25	
	Alert	20,1		15,85		37,1		10,25		23,5	
Joy	*Sympathetic*	13	35%	61,24	43%	11,25	15%	14,25	12%	13,25	13%
	Agreeable	10,75		45,6		12,25		8,4		13,25	
	Cheerful	38,8		40,5		13,25		7,8		11	
	Merry	43,9		38,8		12		8,5		10,25	

Note: FW= Frequency Weights, PE= Emotion Percentage (%anger, %boredom, %interest, %surprised and %joy)

Table 4.3-8. Different Personalities: Behaviors at Level 3.

Fig. 4.3-47 to Fig. 4.3-46 show all personality curves obtained.

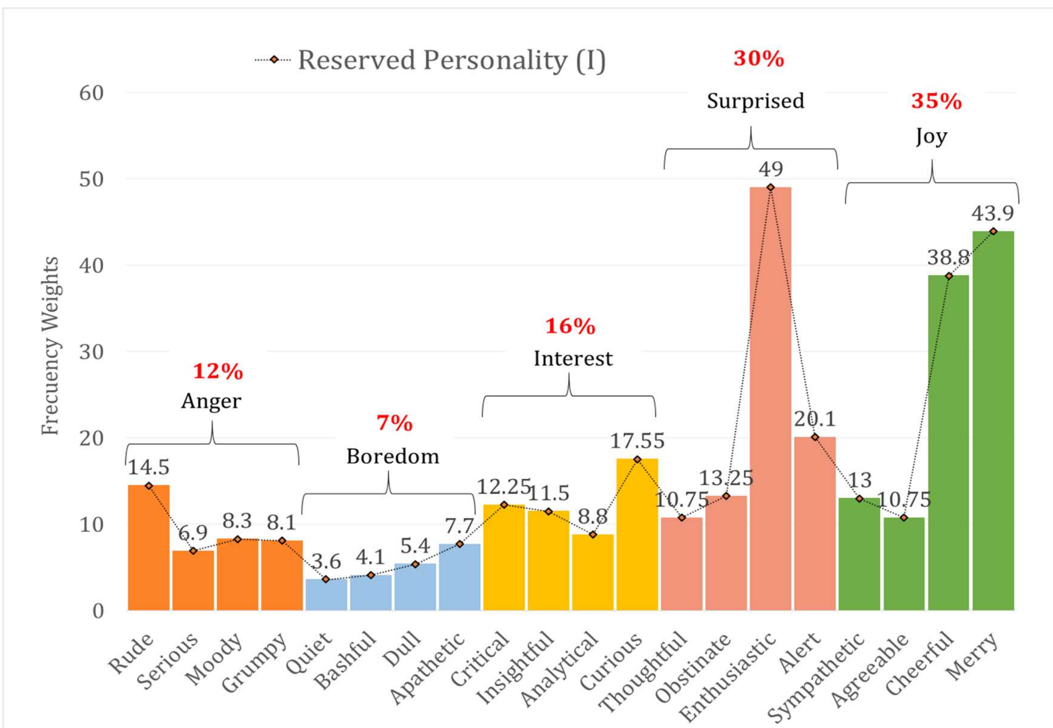


Fig. 4.3-42. Reserved Personality (I): Behaviors at Level 3.

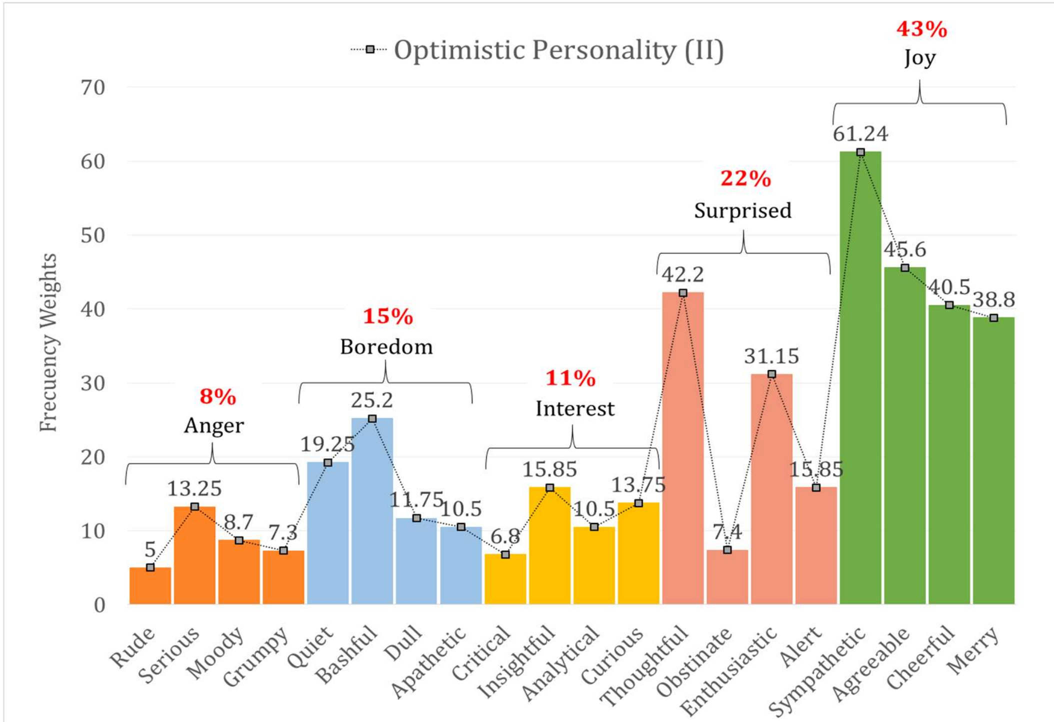


Fig. 4.3-43. Optimistic Personality (II): Behaviors at Level 3.

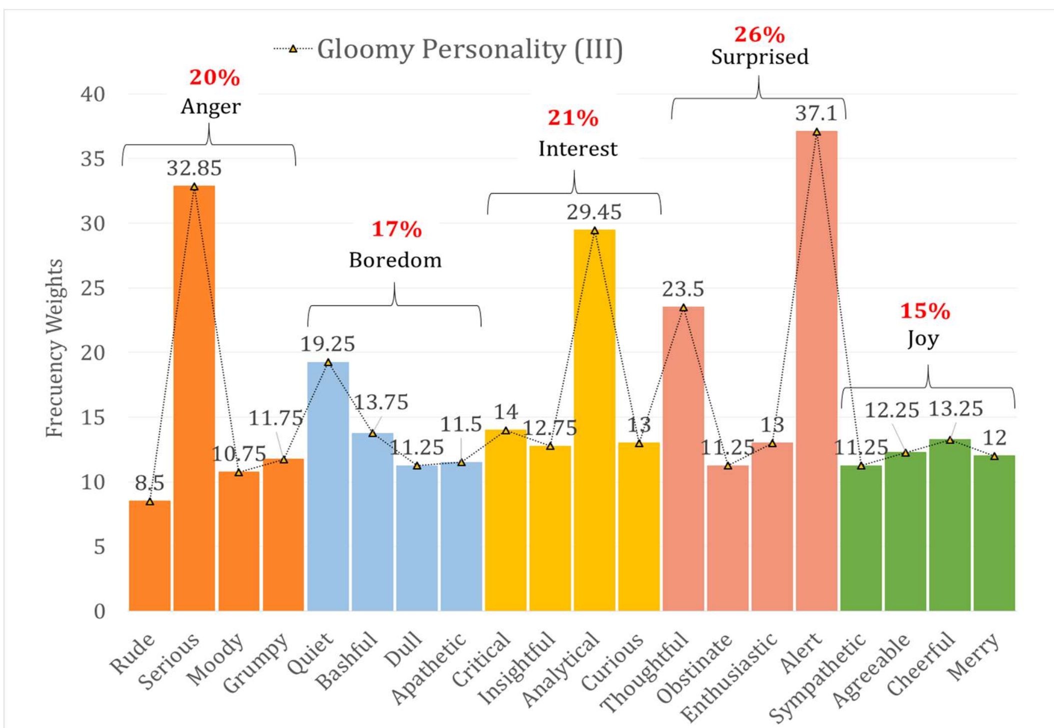


Fig. 4.3-44. Gloomy Personality (III): Behaviors at Level 3.

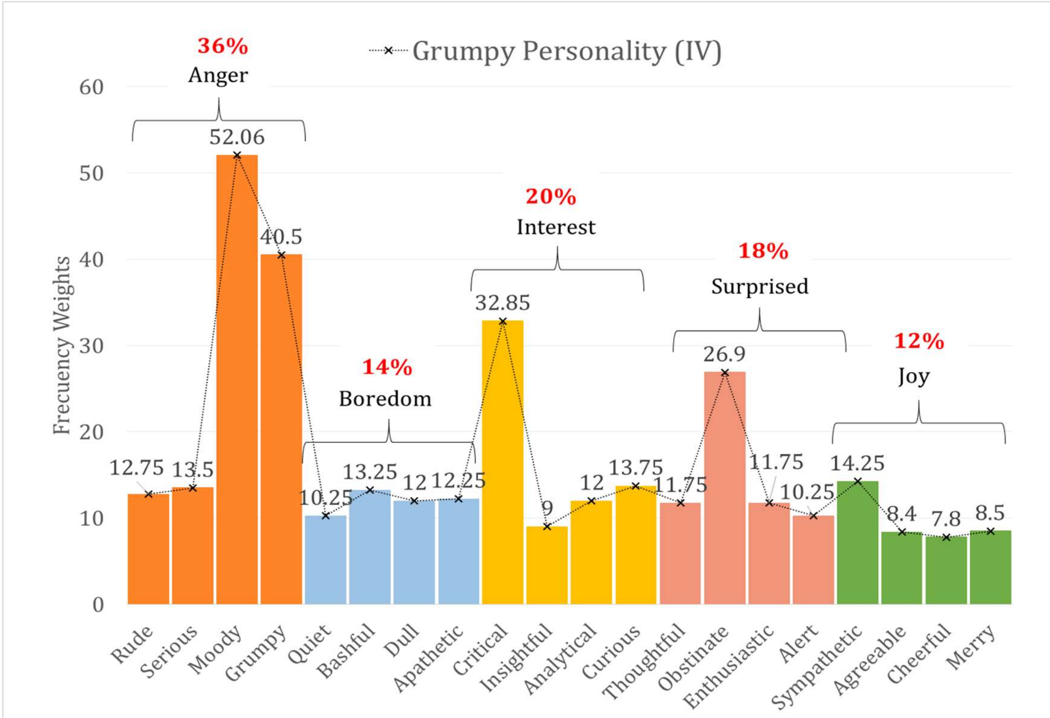


Fig. 4.3-45. Grumpy Personality (IV): Behaviors at Level 3.

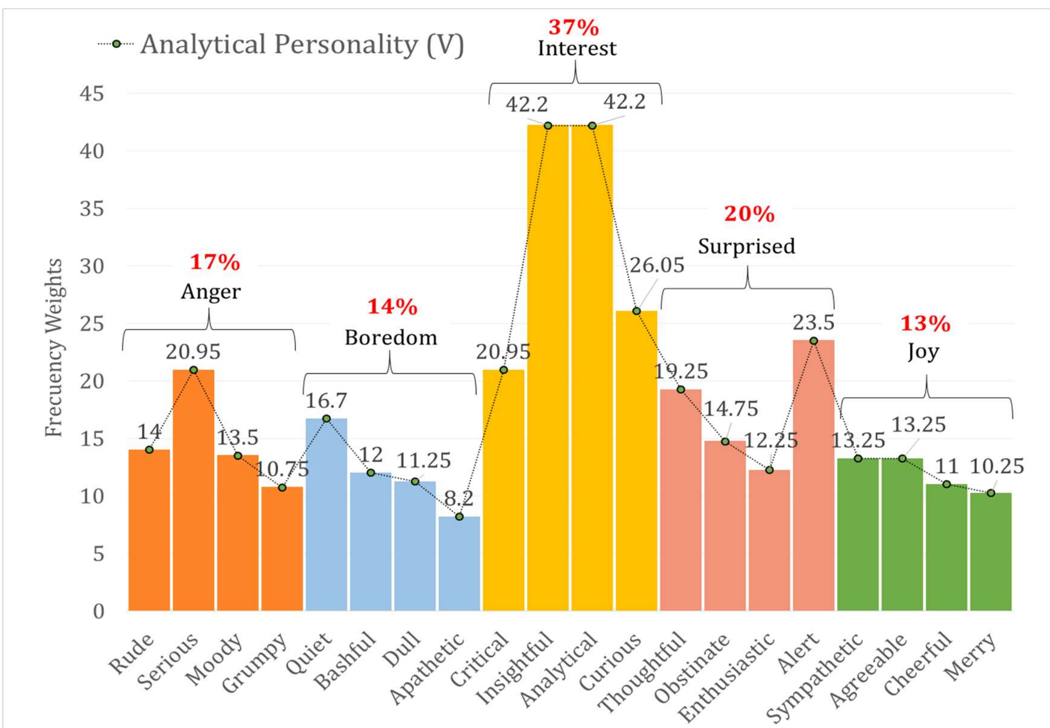


Fig. 4.3-46. Analytical Personality (V): Behaviors at Level 3.

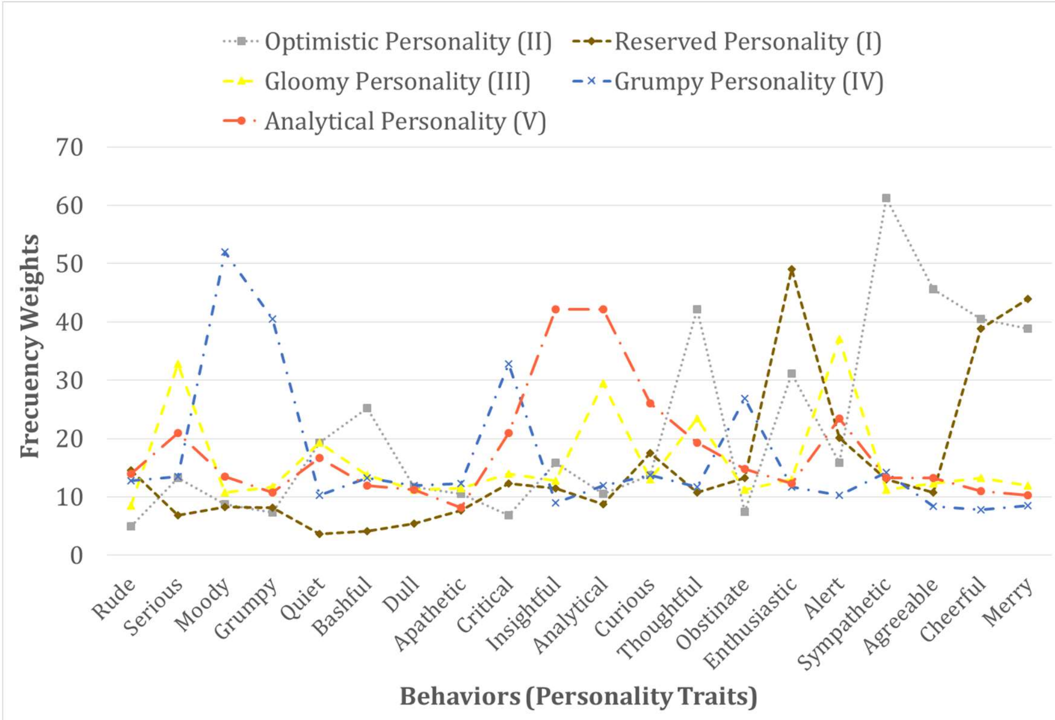


Fig. 4.3-47. All personality curves obtained: Behaviors at Level 3.

4.3.7. Analysis Module

This module has two main functions:

1. Calculate the *Score*, which is a numeric value that indicates when the question was well answered or not. The rating (score) of the response will be in a range of 0-100%.
2. To emit a recommendation about *person's vocational profile*.

Fig. 4.3-48 shows the components for this module. The module receives as input a text string block from the speech recognition module.

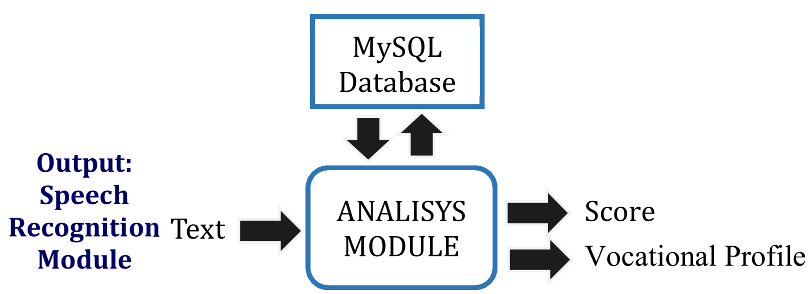


Fig. 4.3-48. Components Analysis Module.

Text Normalization: The text string block is normalized in order to eliminate accent marks or diacritic marks. In addition, capital letters are converted to lowercase.

Match Search: A *matches search* is performed between the words that make up the normalized text string block and a set of words stored in a MySQL database. This database is made up of eight different tables, one for each question posed by NAO during the interview (see section 4.3.5). Each table contains a set of words related to the question to which it belongs (***Descriptor***). For example, Table No. 1 in the database (corresponding to Question 1) consists of a list of occupations and careers related to each of the vocational profiles. Therefore, a descriptor is defined as all those words that are contained in the response given by the user and make direct reference to what the robot is asking and that allow the system to evaluate the vocational profile of the person. In addition, all tables store a common set of words that are used to evaluate the ***Interest*** and ***Cohesion*** of the answer given to question.

Cohesion: Cohesion establishes the number of connectors which appear in the text. Connectors are words or expressions used to establish different types of relationships between words or sentences. They are used to achieve a correct coherence by connecting the parts of a text, sentences or paragraphs. Through them we can be continue with the same argument of an idea, give examples, purposes, among other functions. By establishing the number of connectors in the text we can have an idea of the number of ideas that the person wants to convey in the answer provided.

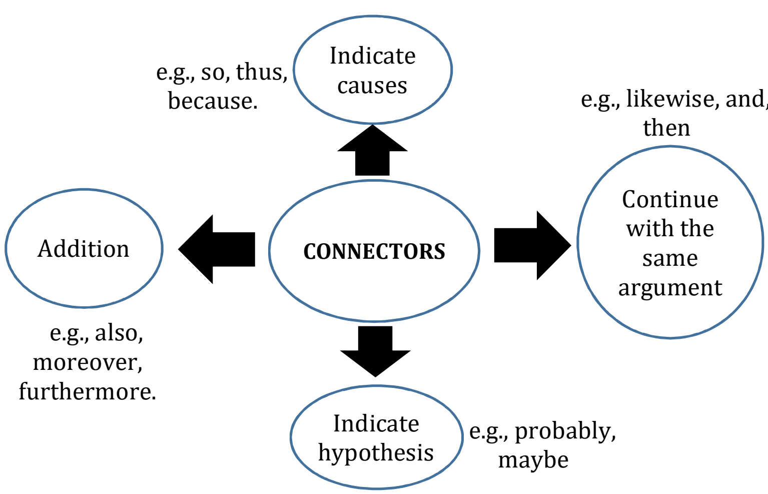


Fig. 4.3-49. Example of Connectors: Analysis Module.

Fig. 4.3-49 shows examples of some connectors and the type of relationship that can be established when using them. A total of 82 connectors are used to calculate the score of the answer.

Interest: It is evaluated according to the number of matches found with words that indicate that the person has an inclination or predisposition towards a particular situation (e.g., liked, interest, interesting or predilection).

The analysis module performs the *matches search* for these three aspects. Therefore the Score of the response is directly related to the number of Descriptors, Interest and Cohesion in the text block.

Each of the tables in the MySQL database will be composed of different fields, which are shown in Table 4.3-9. It is included the type of data of each field.

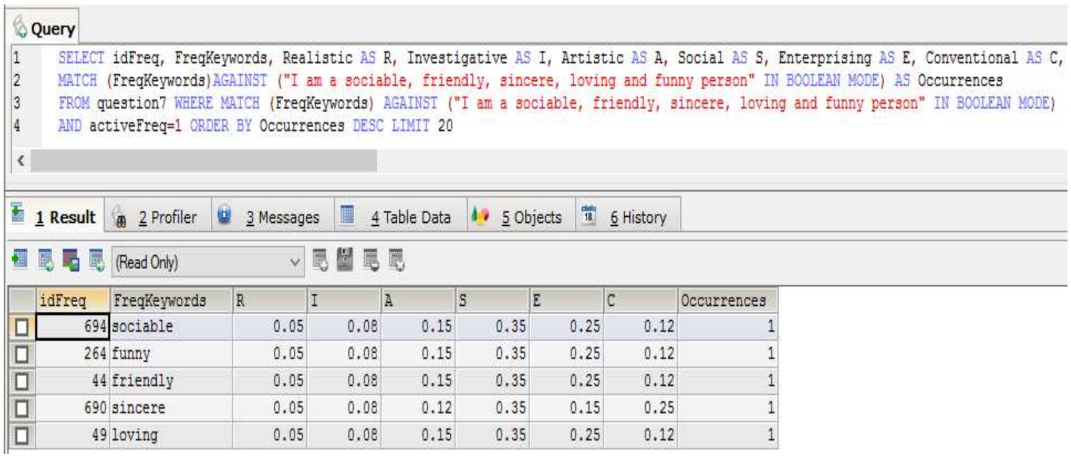
Field	Type	Description
idFreq	Int	Item corresponding to each of the rows in the table.
FreqKeywords	Varchar	List of words referring to Descriptors, Connectors or words that indicate Interest. It is in this field that the match search will be performed.
Keywords Type	Text	Indicates whether the words are a Descriptor, Connector, or word that indicates Interest.
Realistic	Double	Percentage of the total rating of the question assigned to each vocational group (see section 4.3.7.2)
Investigative	Double	
Artistic	Double	
Social	Double	
Enterprising	Double	
Conventional	Double	
activeFreq	TinyInt	By default, the value of this field is equal to 1. Allows the sum of the matches found during the matches search between the normalized text string block and the words stored in the FreqKeywords field.

Table 4.3-9. Fields in the Database MySQL: Analysis Module.

The MySQL database is managed from an interface designed in Microsoft Visual Studio (see section 4.4). The SQL statement that is sent through this interface to the MySQL server is as follows:

"SELECT idFreq, FreqKeywords, Realistic AS R, Investigative AS I, Artistic AS A, Social AS S, Enterprising AS E, Conventional AS C, MATCH (FreqKeywords) AGAINST (' Text = {0}' IN BOOLEAN MODE) AS Coincidences FROM Table name WHERE MATCH (FreqKeywords) AGAINST (' Text = {0}' IN BOOLEAN MODE) AND activeFreq=1 ORDER BY Coincidences DESC LIMIT 20"

The search string (Text) is given as an argument to AGAINST (). For each row in the table, MATCH () returns a match value and therefore, a list of records is obtained within which the search string appears in the field defined in MATCH.



idFreq	FreqKeywords	R	I	A	S	E	C	Occurrences
694	sociable	0.05	0.08	0.15	0.35	0.25	0.12	1
264	funny	0.05	0.08	0.15	0.35	0.25	0.12	1
44	friendly	0.05	0.08	0.15	0.35	0.25	0.12	1
690	sincere	0.05	0.08	0.12	0.35	0.15	0.25	1
49	loving	0.05	0.08	0.15	0.35	0.25	0.12	1

Fig. 4.3-50. Example of a query in the MySQL database: Analysis Module.

Fig. 4.3-50 shows the results obtained in a *matches search*. This search was made from an answer given to Question 7 (NAO asks about the person's personality traits) during a vocational guidance session. Results are displayed directly from SQlyog[15]. The answer to the question was: << *I am a sociable, friendly, sincere, loving and funny person*>>. In this answer five (5) different personality traits are mentioned (*Descriptors*).

4.3.7.1. Score of the Answer

Question 1 *(Career choice)*

With this question, NAO asks about vocational preferences the person. As explained in section 2.2 this allows to establish the vocational group to which the person most resembles. Table 2.2-1 lists the types of occupations that each vocation prefers. (Armstrong, 2008; Darcy, 2007; Holland, 1997) establish a list of occupations distributed in the six vocational groups (Realistic, Investigative, Artistic, Social, Enterprising and Conventional). This listing can be expanded from published information by the U.S. Department of Labor's Bureau of Labor Statistics[16]. Therefore, a list with 416 occupations in which all the vocational

[15] Graphical interface designed to work with the MySQL database server.
[16] The U.S. Department of Labor's Bureau of Labor Statistics publishes an Occupational Outlook Handbook that discusses which type of jobs are likely to be most in demand. This publication

profiles are included is established. According to the number of matches in the *Descriptor* (Career), *Interest* and *Cohesion*, the score of the answer (score_1) is calculated as shown in Table 4.3-10 and equation (4.3-1).

70%	
CAREER	
Matches	SC
=1	100
=2	75
=3	50
=4	25
>=5	5
=0	0

15%	
INTEREST	
Matches	SI
>=3	100
=2	67
=1	33
=0	0

15%	
COHESION	
Matches	SCO
>=7	100
=6	86
=5	71
=4	57
=3	43
=2	29
=1	14

Note: SC= Rating of the career descriptor, SI = Rating for the interest, SCO= Rating for the cohesion.

Table 4.3-10. Score of the Question 1: Analysis Module.

$$\textbf{SORE\_1} = 0.7 \times \mathrm{SC} + 0.15 \times \mathrm{SI} + 0.15 \times \mathrm{SCO} \qquad (4.3\text{-}1)$$

Question 2 and 3 *(Career choice)*

As described in the previous question, the list of school subjects related to each vocational group is made according to the work developed in (Armstrong, 2008; Darcy, 2007; Holland, 1997).

According to the number of matches in the *Descriptor* (Subjects), *Interest* and *Cohesion*, the score of the answer (score_2 or score_3) is calculated as shown in Table 4.3-11 and equation (4.3-2).

SUBJECT		**INTEREST**		**COHESION**	
Mat.	SS	Mat.	SI	Mat.	SCO
>=1	100	>=3	100	>=7	100
				6	86
				5	71
				4	57
				3	43
				2	29
				1	14
				0	0

SUBJECT		**INTEREST**		**COHESION**	
Mat.	SS	Mat.	SI	Mat.	SI
>=1	75	=2	67	>=7	100
				6	86
				5	71
				4	57
				3	43
				2	29
				1	14
				0	0

describes the nature of the work, working conditions, the training and education needed, earnings, and expected job prospects for hundreds of occupations. It is used the official Spanish version of the *2010 Standard Occupational Classification System (SOC)* (ISBN # 978-1-935239-04-8 in English language). The new version of this manual will be published in 2018. More information available from https://www.bls.gov/soc/soc_2010_Spanish_Version.pdf.

SUBJECT		INTEREST		COHESION	
Mat.	SS	Mat.	SI	Mat.	SCO
>=1	50	=1	33	>=7	100
				6	86
				5	71
				4	57
				3	43
				2	29
				1	14
				0	0
==0	0	>=0	0	>=7	100
				6	86
				5	71
				4	57
				3	43
				2	29
				1	14
				0	0

SUBJECT		INTEREST		COHESION	
Mat.	SS	Mat.	SI	Mat.	SI
>=1	25	=0	0	>=7	100
				6	86
				5	71
				4	57
				3	43
				2	29
				1	14
				0	0

Note:
Mat. = Number of matches in the *Descriptor* (Subjects), *Interest* and *Cohesion*, SS= Rating of the descriptor (subject), SI = Rating for the interest, SCO= Rating for the cohesion.

Table 4.3-11. Score of the Question 2 and 3: Analysis Module.

$$\textbf{SORE\_2,3} = (SS + SI + SCO) / 3 \qquad (4.3\text{-}2)$$

Question 4 *(Values and goals)*

Question 5 *(Favorite activities)*

Question 6 *(Aversions)*

Question 7 and 8 *(Opinion of oneself and personality traits)*

As in the previous questions, the list of values, activities, aversions and personality traits (corresponding to Questions 4, 5, 6, 7 and 8 respectively) related to each vocational group is made according to the work developed in (Armstrong, 2008; Darcy, 2007; Holland, 1997). According to the number of matches in the *Descriptor* - corresponding to question 4 to 8 -, *Interest* and *Cohesion*, the score of the answer (score_4 to score_8) is calculated as shown in Table 4.3-12 and equation (4.3-3).

70%	
DESCRIPTOR	
Matches	SD
>=4	100
=3	80
=2	50
=1	25
=0	0

10%	
INTEREST	
Matches	SI
>=2	100
=1	85
=0	0

20%	
COHESION	
Matches	SCO
>=7	100
=6	86
=5	71
=4	57
=3	43
=2	29
=1	14
=0	0

Note: SD= Rating of the descriptor, SI = Rating for the interest, SCO= Rating for the cohesion.

Table 4.3-12. Score of the Question 4 to Question 8.

$$\textbf{SORE\_4-8} = 0.7 \times SD + 0.10 \times SI + 0.20 \times SCO \qquad (4.3\text{-}3)$$

4.3.7.2. Vocational Profile Evaluation

During the vocational guidance session, the questions asked by the robot (see section 4.3.5) allow to collect relevant information about the individual's aspirations, interests and abilities. In this way, the system can establish the person's vocational profile.

In particular, it is highly unlikely that a person has only one vocational interest, in general we all have a vocational profile or combination of interests (Nauta, 2010). If the person says "*My favorite subject in school was Math*" in response to the Question 2 can be classified within an investigative vocation, but can also be classified within a conventional vocation, because in both cases, this subject is really interesting for both vocational groups.

Therefore, the relationship between the different vocational groups must be determined (see theory explained in section 2.2.1).

The six vocational group (Realistic, Investigative, Social, Artistic, Enterprising and Conventional) are organized according to degree of interest they have shown in a specific behavioral characteristic. A behavioral characteristic refers to information requested when the robot asks a question during the vocational guidance session. For example in the Question 5, NAO asks the person about his preferred activities and in the Question 7 asks about his personality traits.

Continuing with the example mentioned above, the interest in mathematics for every vocational group can be organized as follows: Investigative (6), Conventional (5), Enterprising (4), Artistic (3), Social (2) and Realistic (1) (see Fig. 4.3-51). The number in parentheses indicates the order in which a characteristic appears within all vocational groups, with 1 being the least value (i.e., the vocation with the inferior characteristic) and 6 being the maximum (i.e., the vocation with the dominant characteristic).

The order in which a characteristic appears within all vocational groups is determined according to the work developed by (Gottfredson, 2009; Holland, 1997). When it creates a table in the MySQL database, a percentage of the total rating of the question is assigned to each vocational group. These percentages have been assigned taking into account the order in which a characteristic appears within all vocational groups (see Table 4.3-13).

Order	1	2	3	4	5	6
Rating	5%	8%	12%	15%	25%	35%

Table 4.3-13. Percentage of the total rating of the question for each vocational group.

Fig. 4.3-51 shows an example of responses to Questions 2, 3, 7 and 8 (only the *Descriptors* associated with each of them are included). For example, in the Question 7 shows that the Artistic group is the most creative. This is inverted in the Question 8 because this one is geared to finding out the personality traits that define the vocational group to a lesser extent, in this case the Conventional group is the least creative within the six vocational profiles.

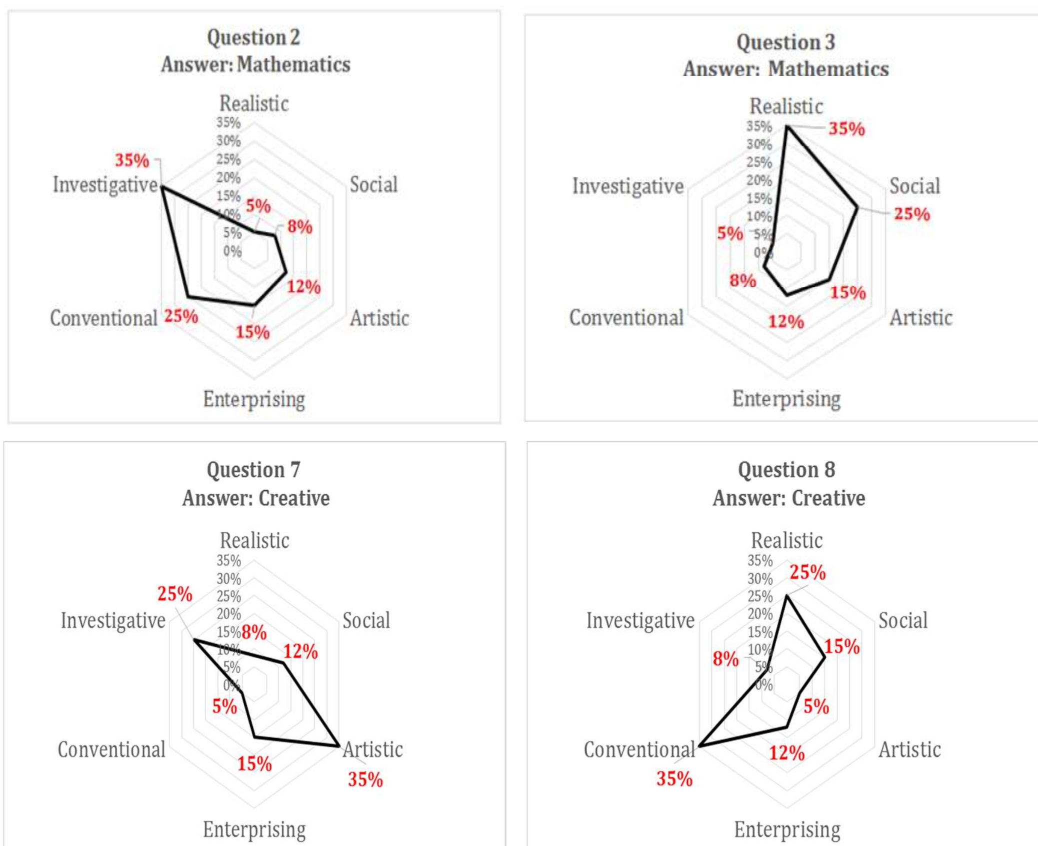
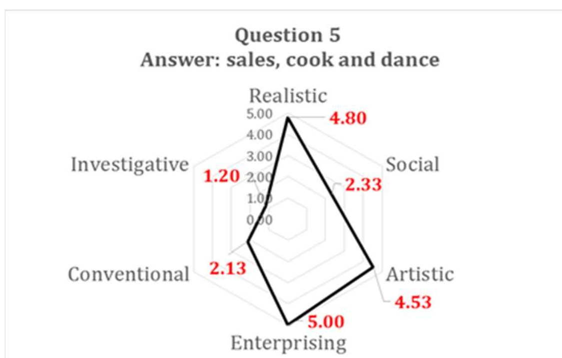


Fig. 4.3-51. Example of the relation of each vocational profile with the given response.

The answer given to a question may include several *Descriptors*, therefore the rating associated with each vocational group can be determined from the equation (4.3-4). Where **n** is the number of *Descriptors* in the answer, $\mathbf{W}(\boldsymbol{vc})_{\boldsymbol{i}}$ is a percentage of the total rating of the question for each vocational group ($\boldsymbol{vc}$ is the vocational group), $\mathbf{Q_{question}}$ is the rating of the question in the general interview, and $\boldsymbol{i}$ represents each of the *Descriptors.* The summation of the results of each vocation corresponds to the rating of the question in the general interview. (Table 4.3-2 shows the rating of each question of the interview).

$$\mathbf{Q_{vocation}} = \left(\sum_{i=1}^{n} \mathrm{W}(vc)_i\right) \times \left({}^{100}/_{n}\right) \times \mathrm{Q_{question}} \tag{4.3-4}$$

Fig. 4.3-52 shows an example of the results obtained when carrying out the calculation of the rating associated with each vocational group. These calculations are based on the results obtained from an answer given to the Question 5 (NAO asks the person about his preferred activities). Three different activities (*Descriptors*) were mentioned in the response. The person's vocational profile can be calculated from the order in which the vocational groups are organized. The profile obtained is ERASCI, which indicates that the interests of the person in relation to his favorite activities are: Enterprising, Realistic, Artistic, Social, Conventional and Investigative.



Question No. 5
$Q_{question}$ = 20%
n = 3

Descriptor	W_R	W_I	W_A	W_S	W_E	W_C
Sales	25%	5%	8%	12%	35%	15%
Cook	35%	5%	25%	8%	15%	12%
Dance	12%	8%	35%	15%	25%	5%
$Q_{vocation}$	**4.8**	**1.2**	**4.5**	**2.3**	**5.0**	**2.1**

Fig. 4.3-52. Calculation of the rating associated with each vocational profile: Example.

4.3.8. Neural Network Model

4.3.8.1. Pattern Recognition with Neural Networks.

The intelligent management of hierarchical behaviors is based on Pattern Recognition and Classification with Artificial Neural Networks (ANN).

<u>INPUT DEFINITION</u>**:** The inputs of the neural network are listed as follows:

- **Answer rating (score):** rating of the response issued by the answer to the question asked (see section 4.3.7.1). (*input1:* score).
- **Question rating:** rating the question asked by the robot according to the interview script shown in Table 4.3-2. (*input2:* low priority question, medium priority question or high priority question).
- **Emotion percentage:** percentage by emotion for each of the robot's personalities (see section 1). (*input3:* %anger, *input4:* %boredom, *input5:* %interest, *input6*: %surprise, *input7*: %joy).

Input data will be represented by the vector $[X_1, X_2, \cdots, X_7]$

Two models are proposed according to the outputs of the neural network for the management of the selected behaviors.

4.3.8.2. Neural Network Model 1

<u>OUTPUT DEFINITION</u>**:** The outputs of the neural network are the emotions described in section 4.3.6.2. (*output1:* anger emotion, *output2:* boredom emotion, *output3:* interest emotion, *output4:* surprise emotion, *output5:* joy emotion).

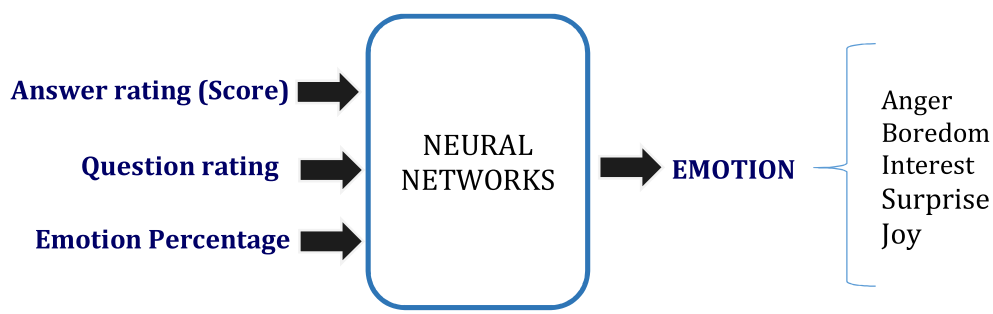


Fig. 4.3-53. Representation of the input and output data for the selection of five different emotions: ANN Model 1.

The output data allow to know whether an input element has been recognized by the ANN. As in this case it is desired to recognize five (5) emotions (Anger, Boredom, Interest, Surprise and Joy), a dimension vector (1, 5) represented as $[Y_1, Y_2, \cdots, Y_5]$ will be sufficient. Therefore, the neural network model for recognizing the five emotions can be represented as shown in Fig. 4.3-53, where the input data will be represented by the vector $[X_1, X_2, \cdots, X_7]$ and the output data will be represented by the vector $[Y_1, Y_2, \cdots, Y_5]$.

4.3.8.3. Neural Network Model 2

OUTPUT DEFINITION: The outputs of the neural network are the set of behaviors described in section 4.3.6.2. (*output1:* rude behavior, *output2:* serious behavior, *output3:* moody behavior, *output4:* grumpy behavior, *output5:* quit behavior, *output6:* bashful behavior, *output7:* dull behavior, *output8:* apathetic behavior, *output9:* critical behavior, *output10:* insightful behavior, *output11:* analytical behavior, *output12:* curious behavior, *output13:* thoughtful behavior, *output14:* obstinate behavior, *output15:* enthusiastic behavior, *output16:* alert behavior, *output17:* sympathetic behavior, *output18:* agreeable behavior, *output19:* cheerful behavior, *output20:* merry behavior).

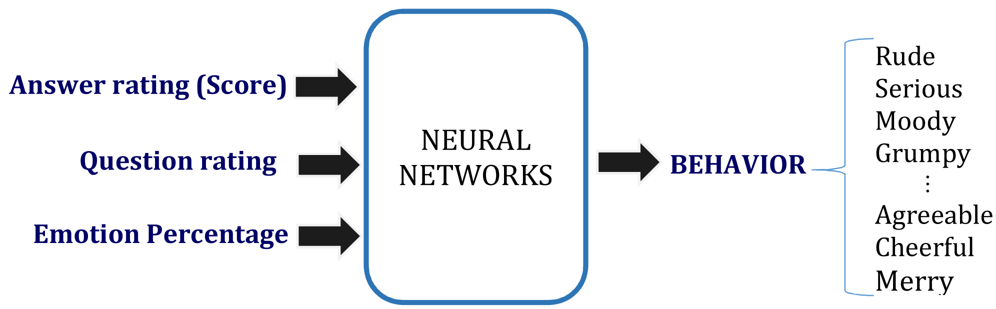


Fig. 4.3-54. Representation of the input and output data for the selection of twenty different behaviors: ANN Model 2.

The neural network model for recognizing the twenty (20) behaviors can be represented as shown in Fig. 4.3-54, where the input data will be represented by the vector $[X_1, X_2, \cdots, X_7]$ and the output data will be represented by the vector $[Y_1, Y_2, \cdots, Y_{20}]$. It selects the right behavior according to the personality parameters set, when an answer is given by the interviewee. This answer has to be qualified with a score before it enters to the neural network.

4.3.8.4. Training Data

Table 4.3-14 shows how the five (5) emotions are organized according to the priority of the question and the score of the answer. This organization is made according to how a person (interviewer) could react to a response given by another person (interviewee) to a question posed during the interview.

Answer Rating (Score: 0-100%)	Question Rating Priority		
	Low	***Medium***	***High***
Excellent answer	Surprise	Happiness	Happiness
Good answer	Interest	Surprise	Happiness
Acceptable answer	Boredom	Interest	Interest
Insufficient answer	Boredom	Boredom	Anger
Deficient answer	Boredom	Anger	Anger

Table 4.3-14. Emotions organized according to the priority of the question and the score of the answer.

For instance, a deficient answer to a question with a low priority can trigger a behavior corresponding to boredom emotion. This same rating (deficient) but when the question priority is medium triggers a behavior corresponding to anger emotion, because the question priority is greater.

To calculate the upper limits for each score by priority, as shown in Table 4.3-14, first, it has to be determined the proportion of each emotion within the complete set of emotions using equation (4.3-5).

$$X_i = p_i / m_i \tag{4.3-5}$$

Where $\mathbf{p_i}$ is equal to the percentage by emotion for each personality (see section 4.3.6.2), $\mathbf{m_i}$ is the number of times the emotion is repeated as shown in Table 4.3-14 and $\boldsymbol{i}$ represents each of the five emotions. Secondly, each priority has a number of emotions associated with it, so it has to be calculated the total of existing $\mathbf{X_i}$ in that priority. For each of the priorities this value is determined as shown equations (4.3-6) to (4.3-8).

$$W_{Low} = X_{Boredom} + X_{Boredom} + X_{Boredom} + X_{Interest} + X_{Surprise} \tag{4.3-6}$$

$$W_{Medium} = X_{Anger} + + X_{Boredom} + X_{Interest} + X_{Surprise} + X_{Joy} \tag{4.3-7}$$

$$W_{High} = X_{Anger} + + X_{Anger} + X_{Interest} + X_{Joy} + X_{Joy} \tag{4.3-8}$$

To find the ranges of each qualifier for the answer (score) is calculated as shown equations (4.3-9) to (4.3-23).

- ***Low Priority***

$$AR(D)_{Low} = (X_{Boredom} / W_{Low}) \times 100 \quad (4.3\text{-}9)$$

$$AR(I)_{Low} = (X_{Boredom} / W_{Low}) \times 100 + AR(D)_{Low} \quad (4.3\text{-}10)$$

$$AR(A)_{Low} = (X_{Boredom} / W_{Low}) \times 100 + AR(I)_{Low} \quad (4.3\text{-}11)$$

$$AR(G)_{Low} = (X_{Interest} / W_{Low}) \times 100 + AR(A)_{Low} \quad (4.3\text{-}12)$$

$$AR(E)_{Low} = (X_{Surprise} / W_{Low}) \times 100 + AR(G)_{Low} \quad (4.3\text{-}13)$$

- ***Medium Priority***

$$AR(D)_{Medium} = (X_{Anger} / W_{Medium}) \times 100 \quad (4.3\text{-}14)$$

$$AR(I)_{Medium} = (X_{Boredom} / W_{Medium}) \times 100 + AR(D)_{Medium} \quad (4.3\text{-}15)$$

$$AR(A)_{Medium} = (X_{Interest} / W_{Medium}) \times 100 + AR(I)_{Medium} \quad (4.3\text{-}16)$$

$$AR(G)_{Medium} = (X_{Surprise} / W_{Medium}) \times 100 + AR(A)_{Medium} \quad (4.3\text{-}17)$$

$$AR(E)_{Medium} = (X_{Joy} / W_{Medium}) \times 100 + AR(G)_{Medium} \quad (4.3\text{-}18)$$

- ***High Priority***

$$AR(D)_{High} = (X_{Anger} / W_{High}) \times 100 \quad (4.3\text{-}19)$$

$$AR(I)_{High} = (X_{Anger} / W_{High}) \times 100 + AR(D)_{High} \quad (4.3\text{-}20)$$

$$AR(A)_{High} = (X_{Interest} / W_{High}) \times 100 + AR(I)_{High} \quad (4.3\text{-}21)$$

$$AR(G)_{High} = (X_{Joy} / W_{High}) \times 100 + AR(A)_{High} \quad (4.3\text{-}22)$$

$$AR(E)_{High} = (X_{Joy} / W_{High}) \times 100 + AR(G)_{High} \quad (4.3\text{-}23)$$

Where **AR** represents the *Answer Rating* for each answer qualifier, ***E*** is an excellent qualifier, ***G*** is a good qualifier, ***A*** is an acceptable qualifier, ***I*** is an insufficient qualifier and ***D*** it is a deficient qualifier for response. AR calculations for each of robot's personalities are shown Table 4.3-15 to Table 4.3-19.

Answer Rating (Score: 0-100%)	Low Priority			Medium Priority			High Priority		
	Xi	AR	Emotion	Xi	AR	Emotion	Xi	AR	Emotion
Excellent answer	0.15	**42-100%**	**Surprise**	0.12	**70-100%**	**Joy**	0.12	**70-100%**	**Joy**
Good answer	0.05	**21-41%**	**Interest**	0.15	**30-69%**	**Surprise**	0.12	**37-69%**	**Joy**
Acceptable answer	0.02	**14-20%**	**Boredom**	0.05	**16-29%**	**Interest**	0.05	**22-36%**	**Interest**
Insufficient answer	0.02	**8-13%**	**Boredom**	0.02	**11-15%**	**Boredom**	0.04	**12-21%**	**Anger**
Deficient answer	0.02	**0-7%**	**Boredom**	0.04	**0-10%**	**Anger**	0.04	**0-11%**	**Anger**
	0.26	W_{Low}		*0.38*	W_{Medium}		*0.37*	W_{High}	

Table 4.3-15. AR calculations: Reserved Personality (I)

Answer Rating (Score: 0-100%)	Low Priority			Medium Priority			High Priority		
	Xi	AR	Emotion	Xi	AR	Emotion	Xi	AR	Emotion
Excellent answer	0.11	**58-100%**	**Surprise**	0.14	**60-100%**	**Joy**	0.14	**63-100%**	**Joy**
Good answer	0.04	**44-57%**	**Interest**	0.11	**29-59%**	**Surprise**	0.14	**24-62%**	**Joy**
Acceptable answer	0.04	**30-43%**	**Boredom**	0.04	**19-28%**	**Interest**	0.04	**15-23%**	**Interest**
Insufficient answer	0.04	**16-29%**	**Boredom**	0.04	**8-18%**	**Boredom**	0.03	**8-14%**	**Anger**
Deficient answer	0.04	**0-15%**	**Boredom**	0.03	**0-7%**	**Anger**	0.03	**0-7%**	**Anger**
	0.26	W_{Low}		*0.36*	W_{Medium}		*0.38*	W_{High}	

Table 4.3-16. AR calculations: Optimistic Personality (II)

Answer Rating (Score: 0-100%)	Low Priority			Medium Priority			High Priority		
	Xi	AR	Emotion	Xi	AR	Emotion	Xi	AR	Emotion
Excellent answer	0.13	**61-100%**	**Surprise**	0.05	**87-100%**	**Joy**	0.05	**84-100%**	**Joy**
Good answer	0.07	**39-60%**	**Interest**	0.13	**50-86%**	**Surprise**	0.05	**68-83%**	**Joy**
Acceptable answer	0.04	**27-38%**	**Boredom**	0.07	**31-49%**	**Interest**	0.07	**44-67%**	**Interest**
Insufficient answer	0.04	**14-26%**	**Boredom**	0.04	**19-30%**	**Boredom**	0.07	**23-43%**	**Anger**
Deficient answer	0.04	**0-13%**	**Boredom**	0.07	**0-18%**	**Anger**	0.07	**0-22%**	**Anger**
	0.33	W_{Low}		*0.36*	W_{Medium}		*0.30*	W_{High}	

Table 4.3-17. AR calculations: Gloomy Personality (III)

Answer Rating (Score: 0-100%)	Low Priority			Medium Priority			High Priority		
	Xi	AR	Emotion	Xi	AR	Emotion	Xi	AR	Emotion
Excellent answer	0.09	**66-100%**	**Surprise**	0.04	**89-100%**	**Joy**	0.04	**91-100%**	**Joy**
Good answer	0.07	**41-65%**	**Interest**	0.09	**64-88%**	**Surprise**	0.04	**80-90%**	**Joy**
Acceptable answer	0.04	**28-40%**	**Boredom**	0.07	**45-63%**	**Interest**	0.07	**63-79%**	**Interest**
Insufficient answer	0.04	**14-27%**	**Boredom**	0.04	**35-44%**	**Boredom**	0.12	**32-62%**	**Anger**
Deficient answer	0.04	**0-13%**	**Boredom**	0.12	**0-34%**	**Anger**	0.12	**0-31%**	**Anger**
	0.27	W_{Low}		*0.35*	W_{Medium}		*0.38*	W_{High}	

Table 4.3-18. AR calculations: Grumpy Personality (IV)

Answer Rating (Score: 0-100%)	Low Priority			Medium Priority			High Priority		
	Xi	AR	Emotion	Xi	AR	Emotion	Xi	AR	Emotion
Excellent answer	0.10	**70-100%**	**Surprise**	0.04	**88-100%**	**Joy**	0.04	**87-100%**	**Joy**
Good answer	0.12	**32-69%**	**Interest**	0.10	**60-87%**	**Surprise**	0.04	**74-86%**	**Joy**
Acceptable answer	0.03	**22-31%**	**Boredom**	0.12	**26-59%**	**Interest**	0.12	**36-73%**	**Interest**
Insufficient answer	0.03	**11-21%**	**Boredom**	0.03	**16-25%**	**Boredom**	0.06	**18-35%**	**Anger**
Deficient answer	0.03	**0-10%**	**Boredom**	0.06	**0-15%**	**Anger**	0.06	**0-17%**	**Anger**
	0.32	W_{Low}		*0.35*	W_{Medium}		*0.32*	W_{High}	

Table 4.3-19. AR calculations: Analytical Personality (V)

Fig. Fig. 4.3-55 shows an example of the graphical representation of the input and output data for a reserved personality (I).

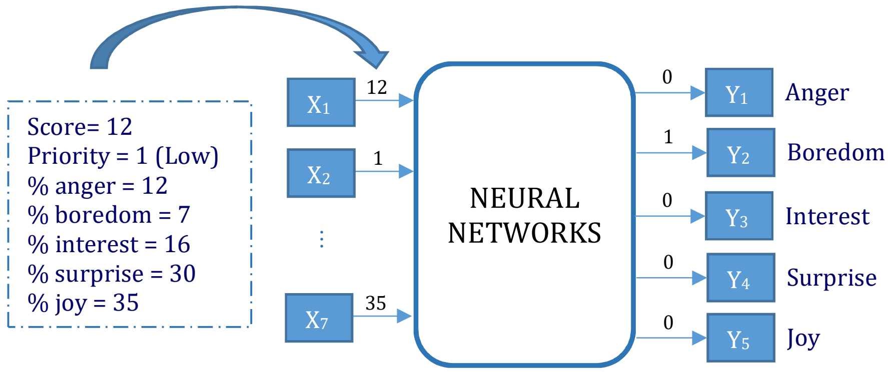


Fig. 4.3-55. Example of a representation of the input and output data for recognizing the five different emotions: ANN Model 1.

In the case of the ANN Model 1, the training data are constructed as explained above. Subsequently, the selection of the answer behavior is performed as explained in section 0. The ANN Model 2 calculates the appropriate answer behavior directly. Therefore, the training data are constructed as explained above and as explained in section 0.

The training data contains in matrix form all the different values that can be given to the vectors X and Y, in order to represent various models of the elements to be recognized. To train the network covering all possibilities, 303 different data are needed for each personality. Two vectors are generated in this case with 1515 types of samples, each one with one behavior for seven inputs.

A feed-forward back-propagation neural network with five neurons in the hidden layer was used for the ANN Model 1. In the case of the ANN Model 2 twenty neurons in the hidden layer was used. The metrics used are Cross-Entropy (to measure performance) and Percent Error (to evaluate the percentage of misclassification). *Data for training:* 70% (1061 samples), *validation:* 15% (227 samples) and *testing:* 15% (227 samples). The training of the neural network (Model 1 and 2) is realized using the MATLAB Neural Network Toolbox.

4.3.8.4.1. Selection of the Answer Behavior

The selection of the appropriate behavior that the robot must assume is calculated from the results obtained with equations (4.3-9) to (4.3-23) for calculating the upper limits for each score by priority (AR). For example, for a low priority of the question and a reserved personality (Type I) the upper limits of the score are as shown in Fig. 4.3-56.

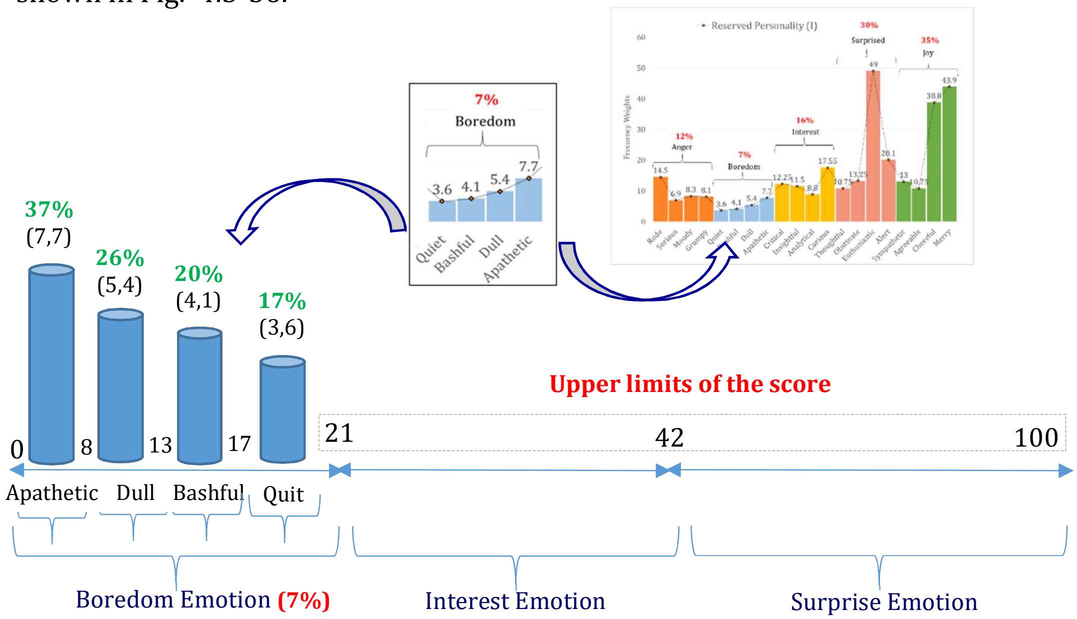


Fig. 4.3-56. Example of the calculation of the limits of each behavior within an emotion.

Any score of the response between 0-21 should trigger a behavior corresponding to boredom emotion. Therefore, values closer to zero correspond to questions answered in worse form than answers with a score that moves away from this value. The higher the score value, the robot's tendency to may become bored will be lower than in values close to zero, for example. This behavior is presented in inverse way for surprise and interest emotions. In this way, the five emotions can be divided into negative emotions (anger, boredom) and positive emotions (interest, surprise, joy).

The frequency weights values of each of the behaviors (see section 4.3.6.2) allow us to calculate the limits at which each of them can be selected considering to the score of the response. In the case of positive emotions, these weights are organized in ascending order and for negative emotions are organized in descending order. The limits for the four behaviors that making up each emotion, are calculated with the equations (4.3-24) to (4.3-27).

$$Lim_{BEH\_1} = (\%BEH\_1 / 100) \times AR_{Emotion} \quad (4.3\text{-}24)$$

$$Lim_{BEH\_2} = (\%BEH\_2 / 100) \times AR_{Emotion} + Lim_{BEH\_1} \quad (4.3\text{-}25)$$

$$Lim_{BEH\_3} = (\%BEH\_3 / 100) \times AR_{Emotion} + Lim_{BEH\_2} \quad (4.3\text{-}26)$$

$$Lim_{BEH\_4} = (\%BEH\_4 / 100) \times AR_{Emotion} + Lim_{BEH\_3} \qquad (4.3\text{-}27)$$

Where **%BEH** is equal to the percentage of frequency weights for each behavior within an emotion, $\mathbf{AR_{Emotion}}$ is the sum the upper limits for each score by priority within the same emotion.

Continuing with the example mentioned above, Fig. 4.3-56 shows the results for these calculations. The percentages in red represent the total frequency by emotion and the values in green represent the percentage of frequency weights for each behavior.

4.3.8.4.2. Confusion Matrix

The confusion matrix shows the percentages of correct and incorrect classifications. Therefore, it can determine how well the classification of the data was performed. This matrix is an indicator of how well they are doing the classification. The percentage of overall classification is 96.2% for the ANN Model 1 (see Fig. 4.3-58) and 91.2% for the ANN Model 2 (see Fig. 4.3-57).

Output Class \ Target Class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	43 2.8%	1 0.1%	0 0.0%	1 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	95.6% 4.4%
2	2 0.1%	74 4.9%	0 0.0%	2 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	94.9% 5.1%
3	1 0.1%	3 0.2%	76 5.0%	8 0.5%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	86.4% 13.6%
4	0 0.0%	0 0.0%	1 0.1%	53 3.5%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	98.1% 1.9%
5	0 0.0%	0 0.0%	0 0.0%	0 0.0%	55 3.6%	2 0.1%	3 0.2%	2 0.1%	0 0.0%	2 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	85.9% 14.1%
6	4 0.3%	0 0.0%	0 0.0%	0 0.0%	4 0.3%	57 3.8%	2 0.1%	3 0.2%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	81.4% 18.6%
7	0 0.0%	0 0.0%	0 0.0%	0 0.0%	2 0.1%	3 0.2%	38 2.5%	2 0.1%	1 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	82.6% 17.4%
8	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 0.1%	4 0.3%	44 2.9%	3 0.2%	0 0.0%	1 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	83.0% 17.0%
9	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	64 4.2%	0 0.0%	3 0.2%	6 0.4%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	2 0.1%	0 0.0%	85.3% 14.7%
10	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 0.1%	0 0.0%	1 0.1%	0 0.0%	1 0.1%	69 4.6%	4 0.3%	3 0.2%	0 0.0%	2 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	85.2% 14.8%
11	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 0.1%	0 0.0%	0 0.0%	0 0.0%	3 0.2%	2 0.1%	80 5.3%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	93.0% 7.0%
12	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	6 0.4%	2 0.1%	2 0.1%	66 4.4%	1 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	85.7% 14.3%
13	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	85 5.6%	1 0.1%	1 0.1%	1 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	96.6% 3.4%
14	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 0.1%	0 0.0%	2 0.1%	63 4.2%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 0.1%	0 0.0%	94.0% 6.0%
15	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 0.1%	0 0.0%	111 7.3%	2 0.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	97.4% 2.6%
16	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	3 0.2%	2 0.1%	0 0.0%	93 6.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	94.9% 5.1%
17	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	77 5.1%	1 0.1%	0 0.0%	4 0.3%	93.9% 6.1%
18	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	5 0.3%	62 4.1%	1 0.1%	2 0.1%	88.6% 11.4%
19	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 0.1%	1 0.1%	85 5.6%	0 0.0%	97.7% 2.3%
20	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 0.1%	2 0.1%	2 0.1%	1 0.1%	86 5.7%	93.5% 6.5%
	86.0% 14.0%	94.9% 5.1%	98.7% 1.3%	82.8% 17.2%	87.3% 12.7%	90.5% 9.5%	79.2% 20.8%	86.3% 13.7%	82.1% 17.9%	92.0% 8.0%	87.9% 12.1%	88.0% 12.0%	92.4% 7.6%	92.6% 7.4%	99.1% 0.9%	95.6% 4.1%	90.6% 9.4%	93.9% 6.1%	94.4% 5.6%	93.5% 6.5%	91.2% 8.8%

Fig. 4.3-57. Confusion Matrix: ANN Model 2.

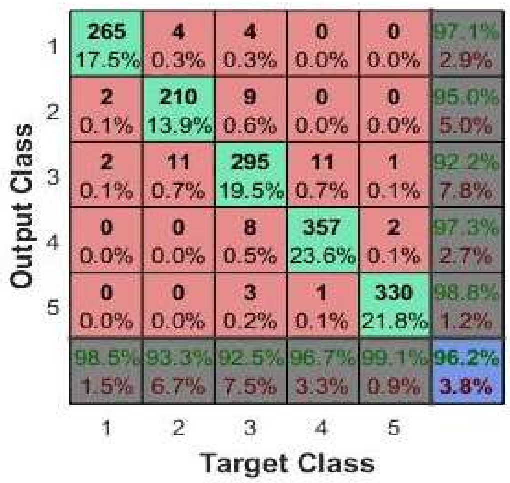


Fig. 4.3-58. Confusion Matrix: ANN Model 1.

4.4. Interface with the Real World

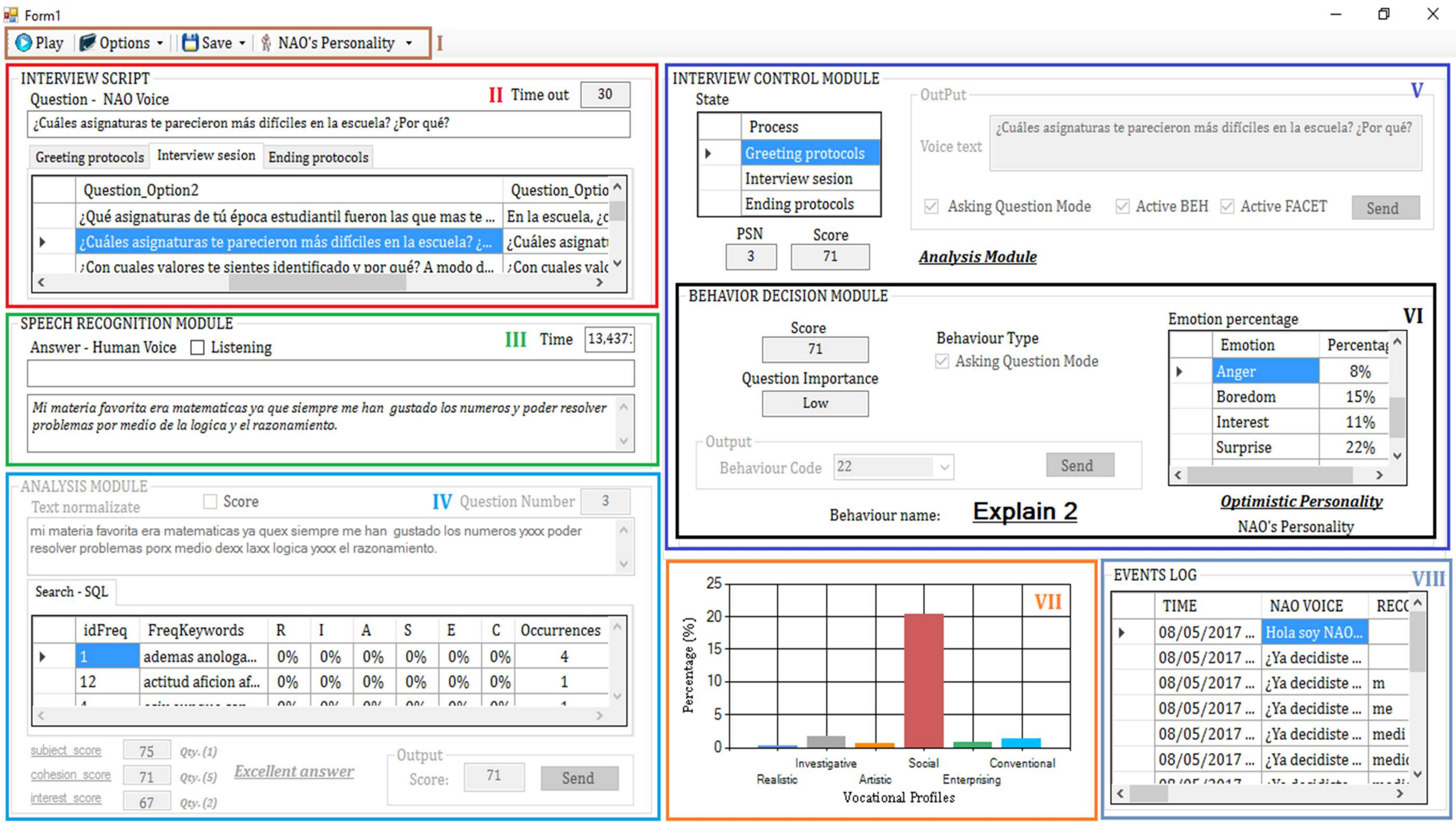


Fig. 4.4-1. Interface for Management of Behaviors.

The connection of the various system modules with the NAO robot, is developed through an interface designed in Microsoft Visual Studio. The programming language used is C #.

4.4.1. Interface Overview

The interface shown in Fig. 4.4-1 has eight (8) functional parts:

Part I: This section contains the following buttons and drop-down lists:

- The **Play** button allows to start the vocational guidance session.
- The **Save** drop-down list has two (2) functions:
  a) Save a file in format (.*xlsx) called *Event Log*, which contains the status of all signals sent or received by the interface during the entire vocational orientation process. In the interface these signals are visualized in **Part VIII**.
  b) Save a file in format (.*csv) called *Management Behaviors,* which contains information such as: score, recognized audio (voice of the person), behavior code, robot's personality and the rating obtained for each vocational group (Realistic, Investigative, Artistic, Social, Enterprising and Conventional). This file is saved according to the records stored in a table in MySQL with this information.
- Using the **Options** drop-down list, the behavior module is independently manipulated to perform tests such as the execution of a specific answer behavior by NAO. In addition, we can *restart* all the system variables and *delete* the different records stored in the *Management Behaviors* table in MySQL.
- **NAO's Personality** drop-down list allows to choose between the different personalities that can be assumed by robot during the vocational guidance session.

Part II: In this session, the scripts corresponding to each of the parts into which the vocational guidance session is divided (Greetings protocols, Interview session and Ending protocols) is loaded. These files are loaded directly from a database in MySQL.

Part III to Part VI: The signals corresponding to the speech recognition module (Part III), analysis module (Part IV), interview control module (Part V) and behaviors module (Part VI) are displayed.

Part VII: The results of the ratings for each vocational group are shown through a bar chart. These results are updated during each of the questions asked by the robot.

4.4.2. Signals sent and/or received by the Interface

The interface is responsible for sending and/or receiving the necessary signals to carry out the entire process of vocational guidance.

Three (3) classes were created in Visual Studio for this purpose. The set of signals that make up each of these classes are shown in Table 4.4-1.

CLASS DATA		
Signal	**Type**	**Description**
SDR	Boolean	Sending data between the interface and the modules that make up the system is activated when SDR is equal to true.
TEXT	String	Text for the voice of the robot.
BEHCODE	Int	Numeric code by each behavior.
BEHTYPE	Boolean	True = Question Behaviors, False = Answer Behaviors
ACTFT	Boolean	The face tracking is activated when ACTFT is equal to true.
ACTB	Boolean	The selected behavior is activated when ACTB is equal to true.
RESET	Boolean	The reset of the signals is activated when RESET equals true.
CLASS MONITOR_DATA		
Signal	**Type**	**Description**
VOICE_END	Boolean	When the robot finishes speaking VOICE_END is equal to true.
BEHA	Boolean	When the robot completes a answer behavior BEHA is equal to true.
BEHQ	Boolean	When the robot completes a question behavior BEHQ is equal to true.
FACELOST	Boolean	Face not found. (FACELOST = true)
FACEDET	Boolean	Face detected. (FACEDET = true)
RECOG	String	Recognized voice messages (text string block) by the Google Voice Recognition API.
CLASS BEHAVIOR		
Signal	**Type**	**Description**
SCORE	Double	Numeric value that indicates when the question was well answered or not.
PRIORITY	Int	Numeric value that indicates the importance of a question within the interview. (Low =1, Medium=2, High = 3).
P_ANGER	Int	Total frequency for anger emotion.
P_BOREDOM	Int	Total frequency for boredom emotion.
P_INTEREST	Int	Total frequency for interest emotion.
P_SURPRISE	Int	Total frequency for surprise emotion.
P_JOY	Int	Total frequency for joy emotion.

CLASS BEHAVIOR		
Signal	**Type**	**Description**
CALCULATE MODE	Boolean	Bit to control whether data sent from Visual Studio to Matlab should be used to calculate the output of the neural network or not.
BEHAVIOR	Int	Numeric code by each behavior. (It is the output of the neural network).
OUTPUT	Boolean	Verification bit of the response. It must be true so that BEHAVIOR to be the value calculated by the intelligence (neural network).
FINALIZE	Boolean	When FINALIZE is equal to true, the communication between the interface and Matlab ends.

Table 4.4-1. Signals sent and/or received by the interface for communication between the various system modules and NAO.

The DATA class allows to send to Choreographe the necessary signals to perform actions in NAO (e.g., SDR enables the voice module so the robot can ask a question). By means of the MONITOR_DATA class, the process state variables in NAO are received from Choreographe (e.g., VOICE_END establishes when the robot finishes talking). In addition, this class sends the recognized voice messages by the Google Voice Recognition API to the interface. Finally, the BEHAVIOR class allows to send to Matlab the necessary signals to calculate the answer behaviors to be executed by NAO during the interview. In turn, Matlab sends to the interface the answer behavior code established by the neural network.

The exchange of information between Visual Studio and the different programs (Choreographe, Matlab and Google API Voice Recognition) is achieved through the reading and/or writing of three files in JSON format. The directory for these files is "C:\\comNAO\\". The syntax for each of the files is as follows:

- ✓ OUTPUT.json (Corresponding to the class DATA)

{"RESET": false, "__module__": "__main__", "SDR": true, "TEXT": "Hello my name is NAO. Let's start the interview", "__class__": "data", "BEHTYPE": true, "BEHCODE": 23, "ACTB": true, "ACTFT": true}

- ✓ MONITORDATA.json (Corresponding to the class MONITOR_DATA)

{"RECOG": "I am a sociable, friendly, sincere, loving and funny person", "__module__": "__main__", "BEHA": false, "__class__": "monitor_data", "FACEDET": true, "BEHQ": false, "VOICE_END": false, "FACELOST": false}

- ✓ BEHAVIORDATA.json (Corresponding to the class BEHAVIOR)

{"SCORE": 2.8, "PRIORITY": 3, "P_ANGER": 12, "P_BOREDOM": 7, "P_INTEREST": 16, "P_SURPRISE": 30, "P_JOY": 35, " CALCULATEMODE": false, "BEHAVIOR": 1, "OUTPUT": true, "FINALIZE": false}.

4.4.3. Program developed in Microsoft Visual Studio

Table 4.4-2 shows the necessary variables to develop programming in Visual Studio.

Variable	Type	Description
PSN	Int	Status variable within each process (greetings protocols, interview session or ending protocols).
ST	Int	Variable that defines which process is running (greetings protocols, interview session or ending protocols).
ejecModules	Int	This variable controls the module that is active at each runtime.
greeting	bool	When it is equal to true it activates the greetings protocols.
interview	bool	When it is equal to true it activates the interview session.
ending	bool	When it is equal to true it activates the endings protocols.
change_process	bool	When it is equal to true this variable allows the change to a new process.
ReadRow	bool	When it is equal to true this variable allows the change to a new process.
comBehModule	bool	This variable contains the two states of communication with the neural network: false to write data and true to read.
Timeout	Int	Minimum time for the robot to finish talking and a question behavior is terminated.
Time_beh	Int	Runtime of a question behavior

Table 4.4-2. Variables of the program developed in Visual Studio.

When the interface opens, the MONITOR_DATA class is automatically read from the "C: \\ comNAO \\ MONITORDATA.json" directory. This is because a timer is added to the form, which allows to repeat this procedure within a set interval of 300 milliseconds. Consequently, this interval determines the time that passes before performing a new reading of this class. The flowcharts in Fig. 4.4-2 to Fig. 4.4-4 show a graphical representation of the algorithm executed by this timer.

Fig. 4.4-6 to Fig. 4.4-9 show the code corresponding to the execution of the different system modules. The code to start the vocational guidance session is included (by pressing the Play button on the interface), because through the activation of the signals shown in Fig. 4.4-5 the interview can be started. Fig. 4.4-10 shows the graphical representation of the algorithm developed for reading and / or writing of the necessary signals to calculate the answer behavior in Matlab.

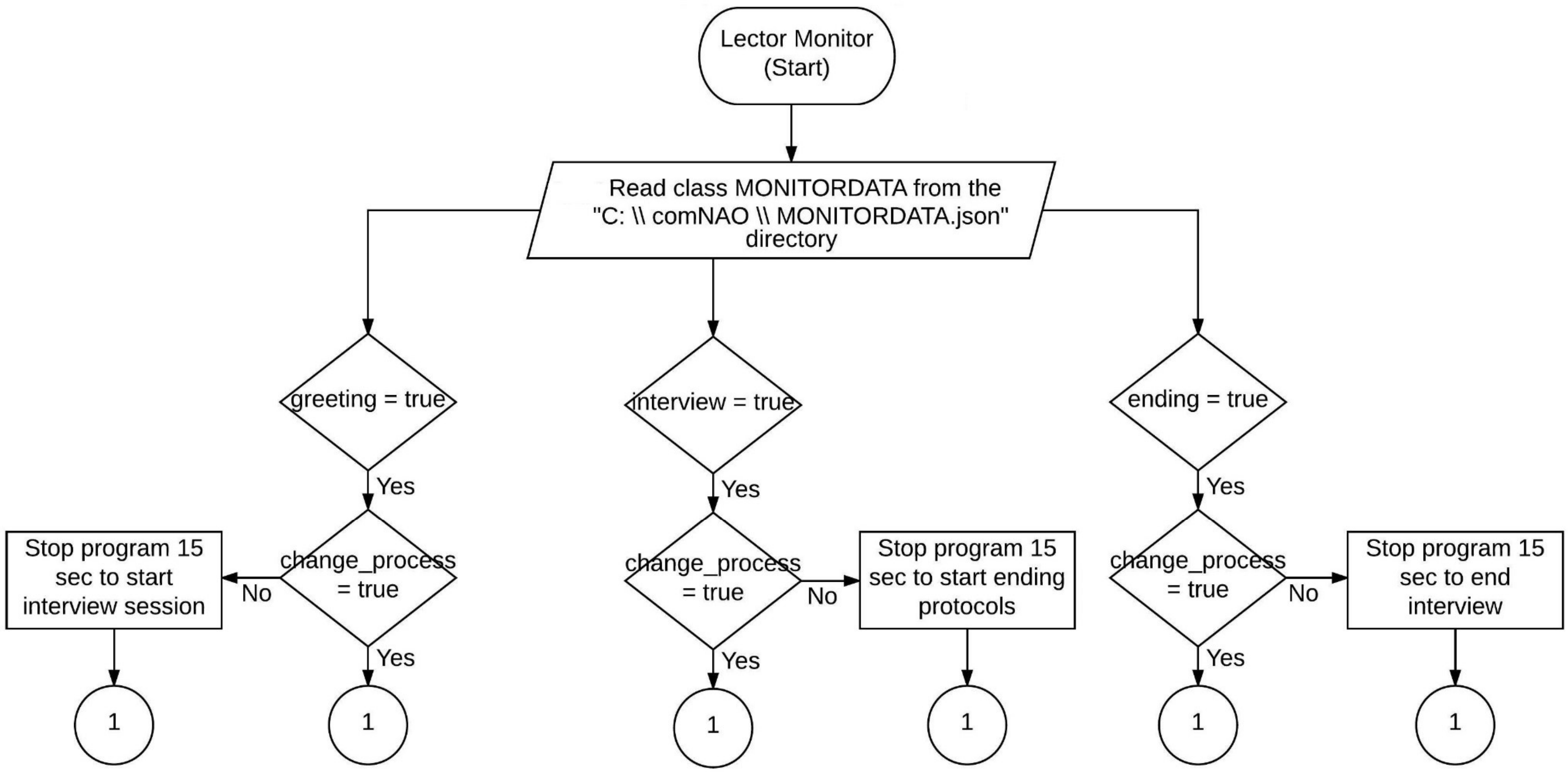


Fig. 4.4-2. Flowchart: Program developed in Visual Studio (Part 1)

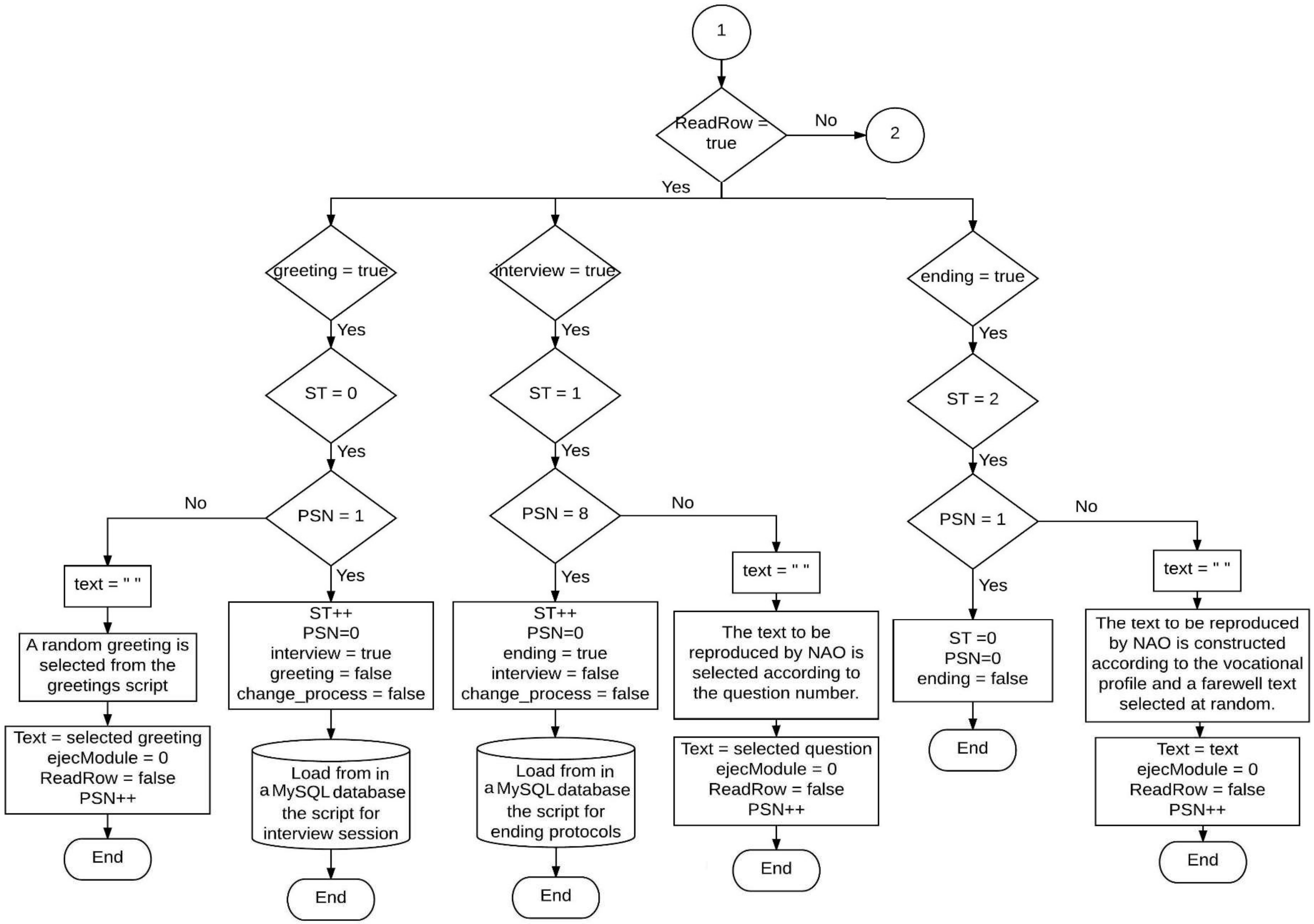


Fig. 4.4-3. Flowchart: Program developed in Visual Studio (Part 2)

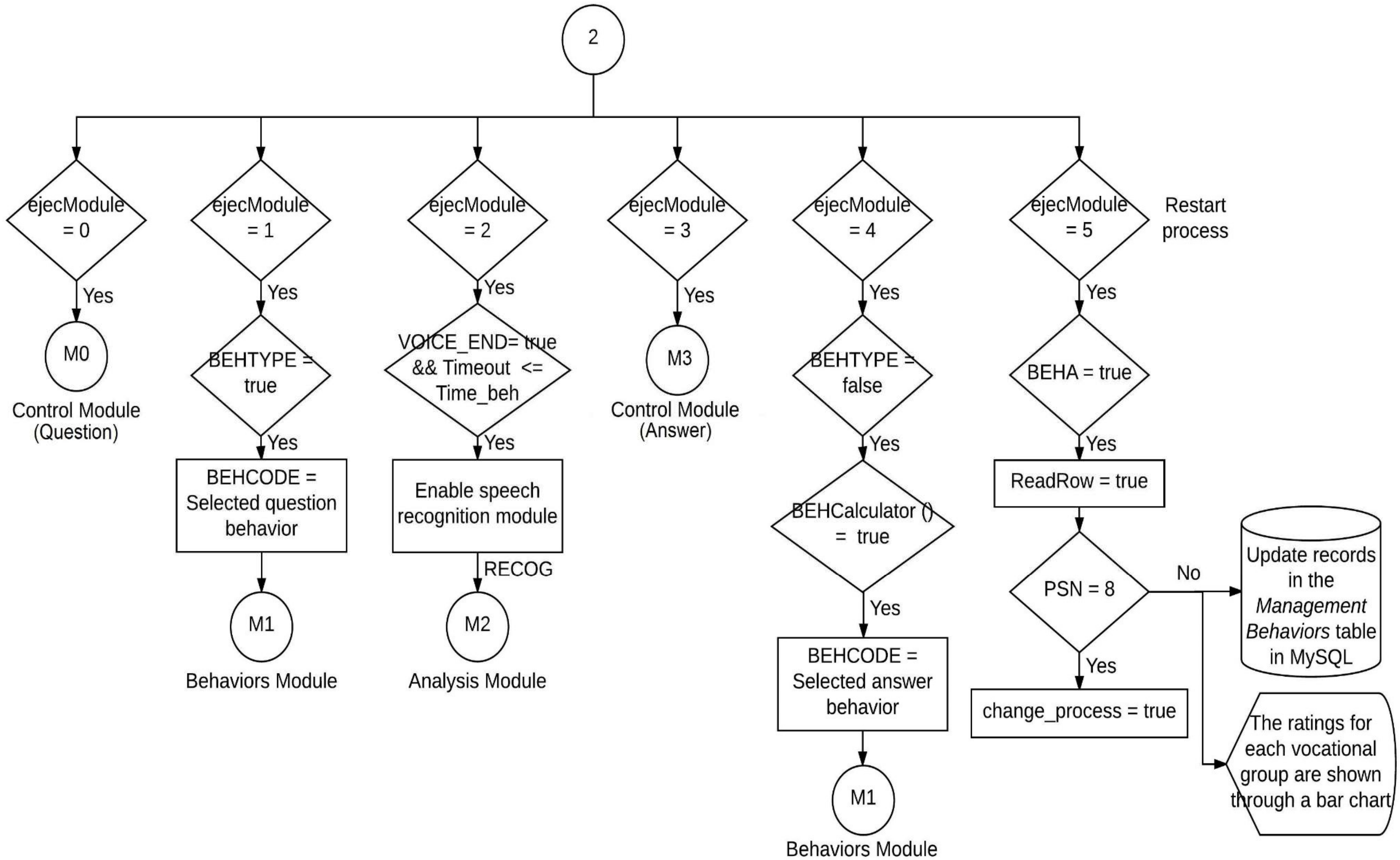


Fig. 4.4-4. Flowchart: Program developed in Visual Studio (Part 3)

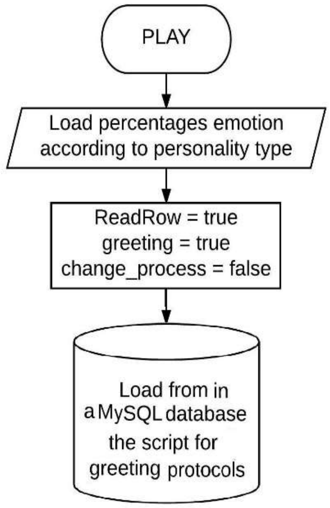


Fig. 4.4-5. Flowchart: Start the Vocational Guidance Session.

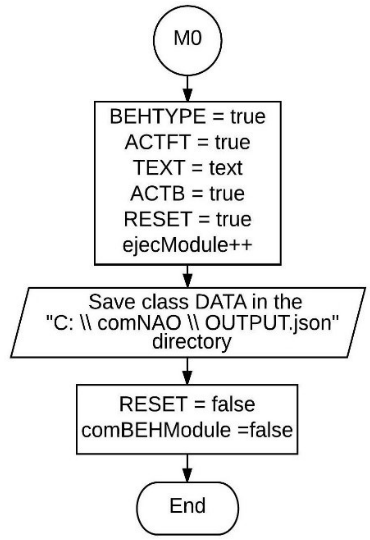


Fig. 4.4-6. Flowchart: Control Module (Questions).

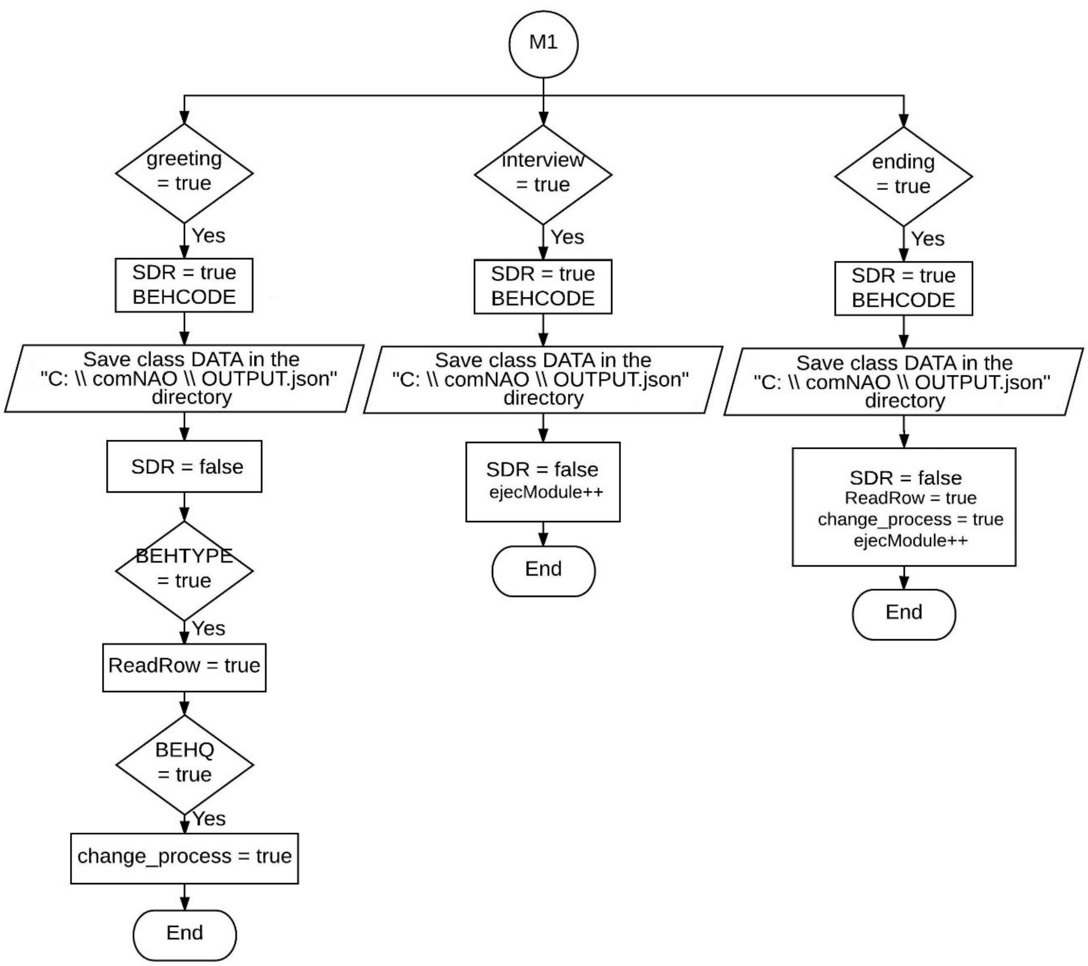


Fig. 4.4-7. Flowchart: Behaviors Module.

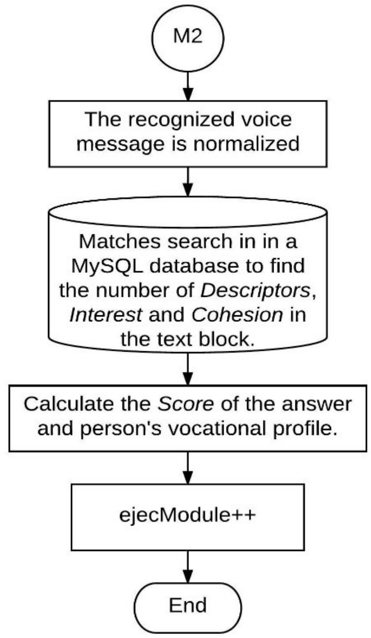


Fig. 4.4-8. Flowchart: Analysis Module.

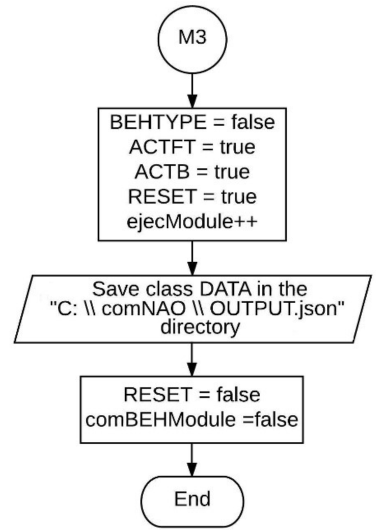


Fig. 4.4-9. Flowchart: Control Module (Answers).

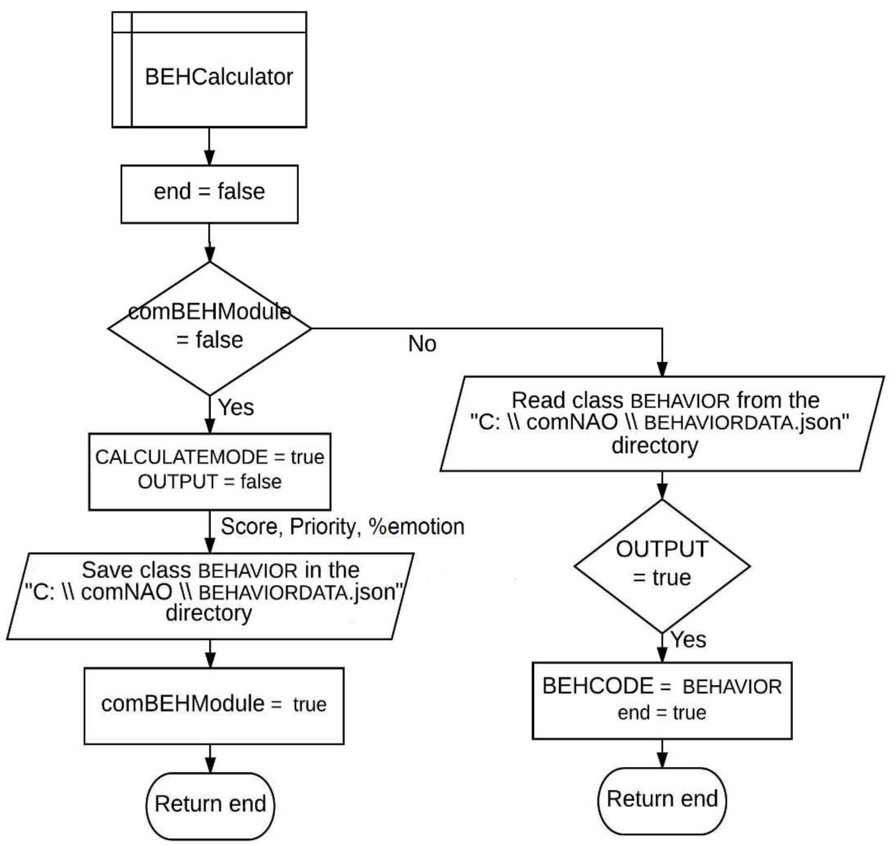


Fig. 4.4-10. Flowchart: Function that allows the reading and/or writing of the necessary signals to calculate the answer behavior in Matlab.

4.4.4. Program developed in Choregraphe

Add features to NAOqi (Creation of a new module): As noted in the section 2.1.2 the framework NAOqi is the programming framework used to program NAO. This one defines different modules that allow interaction with the hardware elements on the robot (e.g., elements related to the audio or the vision of the robot).

For the execution of the vocational guidance process, it is necessary to create a new module in NAOqi that allows the exchange of information between Visual Studio and the different programs (Choreographe and Google API Voice Recognition). The programming required for the creation of this new module is developed using the Python programming language. The module (a .pyproj file) is managed within Visual Studio.

The created module is made up of two (2) different classes. The set of signals that make up each of these classes are the same as those declared in Visual Studio (DATA and MONITOR_DATA).

Program developed:

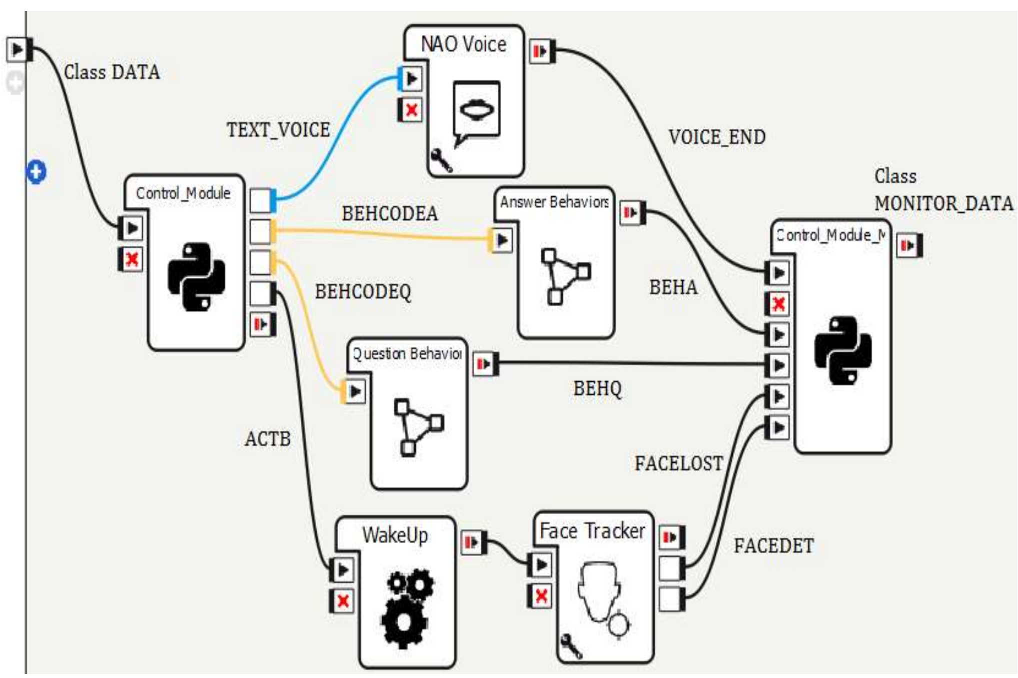


Fig. 4.4-11. Program developed in Choregraphe for Management of Behaviors.

Fig. 4.4-11 shows the program developed in Choreographe and the input signals (set of variables belonging to the DATA class) and the output signals (set of variables belonging to the MONITOR_DATA class).

The flowchart in Fig. 4.4-12 shows a graphical representation of the algorithm developed in Python for the control of the input signals received from the interface.

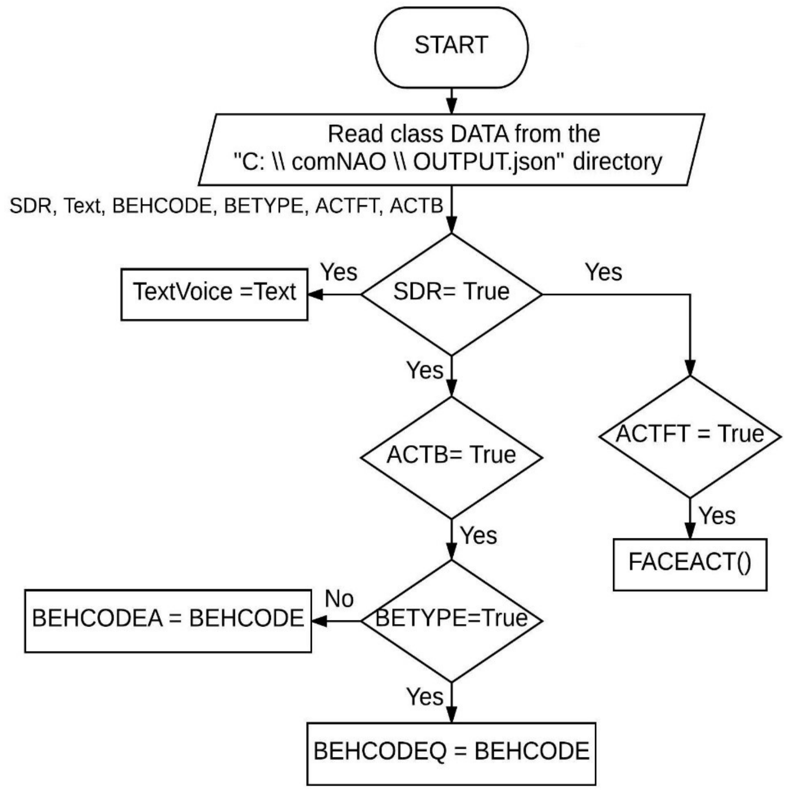
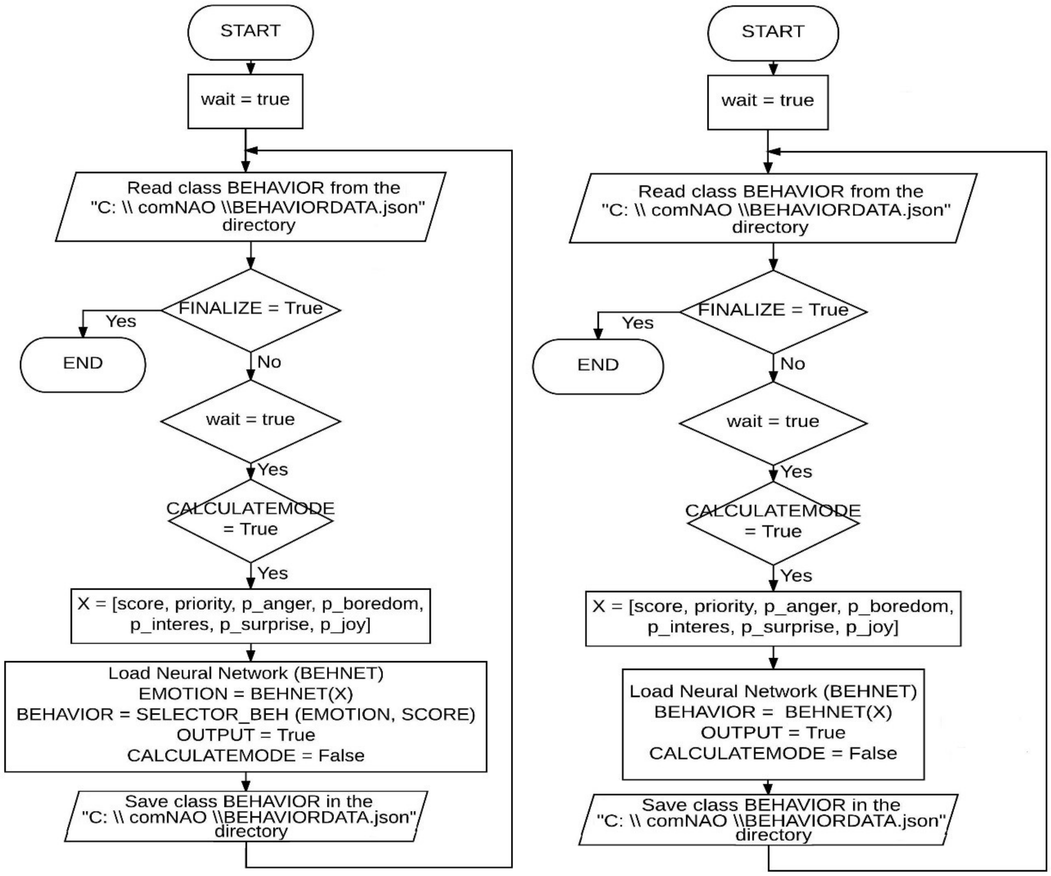


Fig. 4.4-12. Flowchart: Control of input signals (class DATA) sent from Visual Studio to Choreographe.

4.4.5. Program developed in Matlab

The flowchart in Fig. 4.4-13 shows a graphical representation of the algorithm developed in Matlab for the control of the signals received from the interface. These signals are used to perform the calculation of the behaviors to be executed by the robot.



ANN Model 1 ANN Model 2

Fig. 4.4-13. Flowchart: Control of input signals (class BEHAVIOR) sent from Visual Studio to Matlab.

PART III
EXPERIMENTS RESULTS AND CONCLUSIONS

Chapter 5

Analysis of the Experimental Results

This chapter presents the discussion and analysis of the experiments and testing that have been carried out for the proposed test beds. The results depicted in this chapter demonstrate the feasibility and reliability of the overall proposed approach presented in the previous chapters.

5.1. Experimental Design

This section presents a hypothesis about the matching between the robot's personality, the answer given by the user to the question posed by NAO and the answer behavior to be executed during the vocational guidance session. Validation is performed through a series of experiments, where each of the questions asked by NAO during the interview corresponds to a one system test.

Taking in account the above, it defines the following characteristics to the experiment design:

Hypothesis:

Could a computational intelligence system according to a pre-established personality and the response given by the user to the question posed during a vocational guidance session make the choice of the appropriate behavior to be executed by the NAO robot?

Case Study:

The answers given by the person can be rated with the following qualifiers: *Excellent (E)*, *Good (G)*, *Acceptable (A)*, *Insufficient (I)* and *Deficient (D).* These qualifiers vary depending on the robot's personality as explained in section 4.3.8.4.

With this in mind, three (3) case studies were created for analysis of the results.

Case 1: The answers are rated as E, G, A, I or D.

Case 2: The answers are rated as A, I or D.

Case 3: The answers are rated as E or G.

Response variable:

Every case is evaluated for the different personality types. It is expected that the response of the intelligent system be the trend defined by the selected personality (i.e., the answer behavior).

Number of experiments:

Calculating the number of experiments necessary to evaluate the performance of the system is based on equation (5.1-1).

$$n = (Z_a^2 \times p \times q) / e^2 \tag{5.1-1}$$

Where **n** is the *number of experiments*, $\mathbf{Z_a}$ corresponds to the *confidence level*, **p × q** represents the population variance (**p** is the *probability of success*, and **q** is the *probability of failure*) and **e** is the desired *accuracy* (error accepted).

It is worked with a confidence level of 95%, which corresponds to a z = 1.96 *sigma* or *typical errors.* The greater diversity of responses occurs when p = q = 0.50 (half of the behaviors can be correctly recognized and the other half not) so in equation (5.1-1) **p × q** is always equal to 0.25 (it is a constant). This value allows maximizing the sample size.

The number of experiments (questions) was established in 384 with a confidence level of 95%, a proportion of the total population of 50% and an accuracy of 5%. Therefore, for each of robot's personalities, forty-eight (48) interviews of eight (8) questions each were conducted. Table 5.1-1 shows the distribution of the interviews conducted taking into account all robot's personalities.

Reserved Personality (I)		**Optimistic Personality (II)**		**Gloomy Personality (III)**		**Grumpy Personality (IV)**		**Analytical Personality (V)**	
ANN Model 1	**ANN Model 2**	**ANN Model 1**	**ANN Model 2**	**ANN Model 1**	**ANN Model 2**	**ANN Model 1**	**ANN Model 2**	**ANN Model 1**	**ANN Model 2**
Interview 1	Interview 6	Interview 11	Interview 16	Interview 21	Interview 26	Interview 31	Interview 36	Interview 41	Interview 45
Interview 2	Interview 7	Interview 12	Interview 17	Interview 22	Interview 27	Interview 32	Interview 37	Interview 42	Interview 46
Interview 3	Interview 8	Interview 13	Interview 18	Interview 23	Interview 28	Interview 33	Interview 38	Interview 43	Interview 47
Interview 4	Interview 9	Interview 14	Interview 19	Interview 24	Interview 29	Interview 34	Interview 39	Interview 44	Interview 48
Interview 5	Interview 10	Interview 15	Interview 20	Interview 25	Interview 30	Interview 35	Interview 40		

Table 5.1-1. Distribution of the interviews conducted taking into account all robot's personalities.

The answers given in the different interviews should be evaluated for all robot's personalities (e.g., Interview 3 should also be evaluated taking into account personality types II, III, IV and V), in order to ensure that the score at the input of the neural network is the same regardless of the personality type chosen. Therefore, the selection of the answer behavior by the neural network (model 1 and 2), is performed through simulations with Matlab software.

Metrics:

Minkowski distance is used to measure the similarity between the results, being zero the best value for a comparison. The Minkowski distance of order p between two points $\mathrm{X} = (x_1, x_2, \cdots, x_n)$ and $\mathrm{Y} = (y_1, y_2, \cdots, y_n) \in \mathbb{R}^n$ is given by equation (5.1-2).

$$d(X,Y) = \left(\sum_{i=1}^{n} |X_i - Y_i|^p\right)^{1/p} \tag{5.1-2}$$

5.1.1. Results for Behavior Management

To make a comparison of the results is necessary to calculate the percentage of each behavior by case study over total experiments performed, and the same for the personality graphs. Taking in account the above, the following are the results obtained for each of the robot's personalities (see Fig. 5.1-3 to Fig. 5.1-15).

RESERVED PERSONALITY (I)

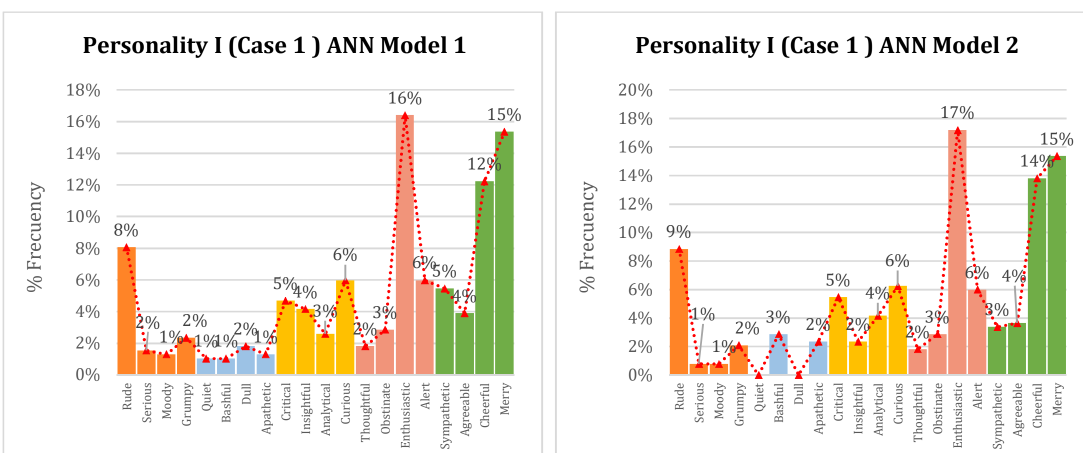


Fig. 5.1-1. Results Case 1 for a Reserved Personality (I)

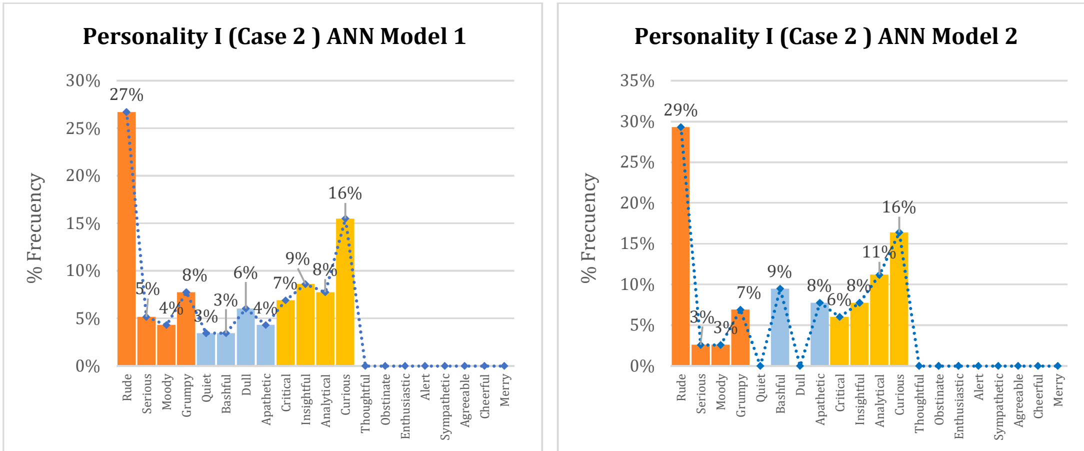


Fig. 5.1-2. Results Case 2 for a Reserved Personality (I)

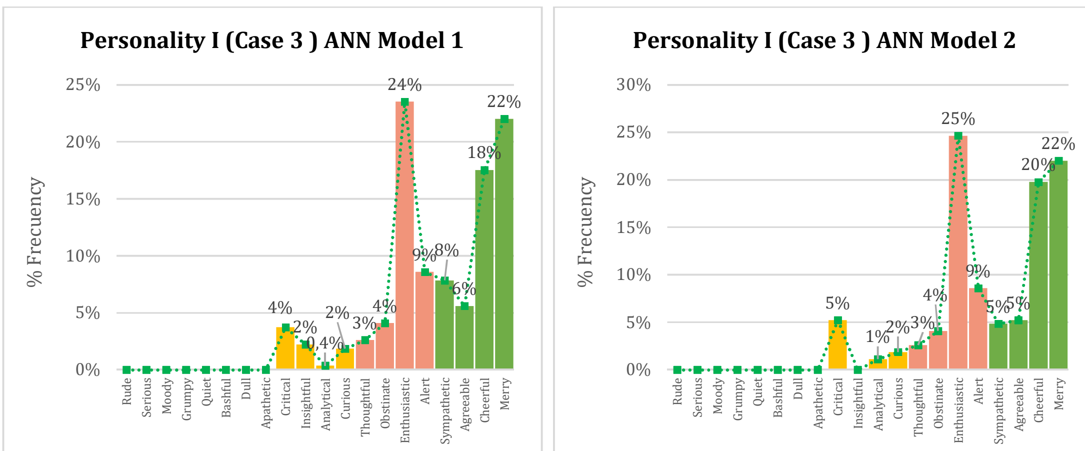


Fig. 5.1-3. Results Case 3 for a Reserved Personality (I)

Optimistic Personality (II)

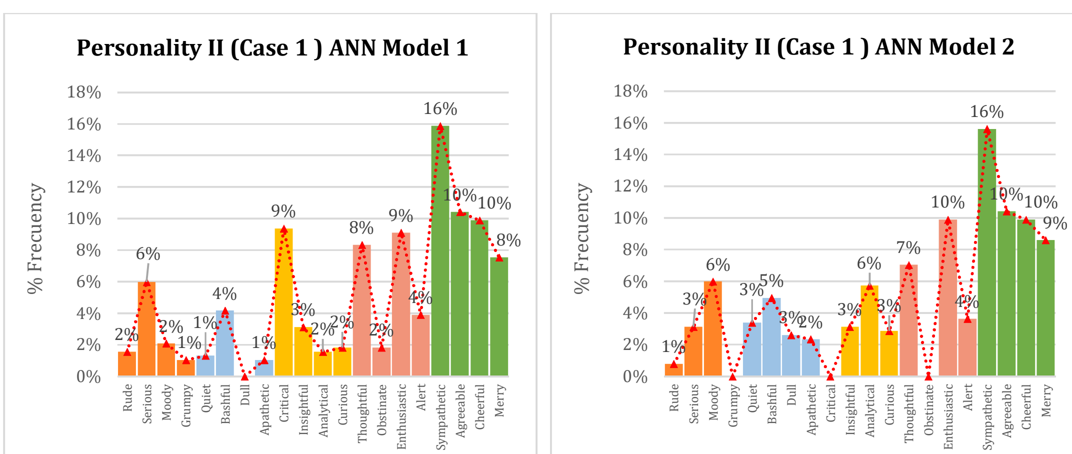


Fig. 5.1-4. Results Case 1 for an Optimistic Personality (II)

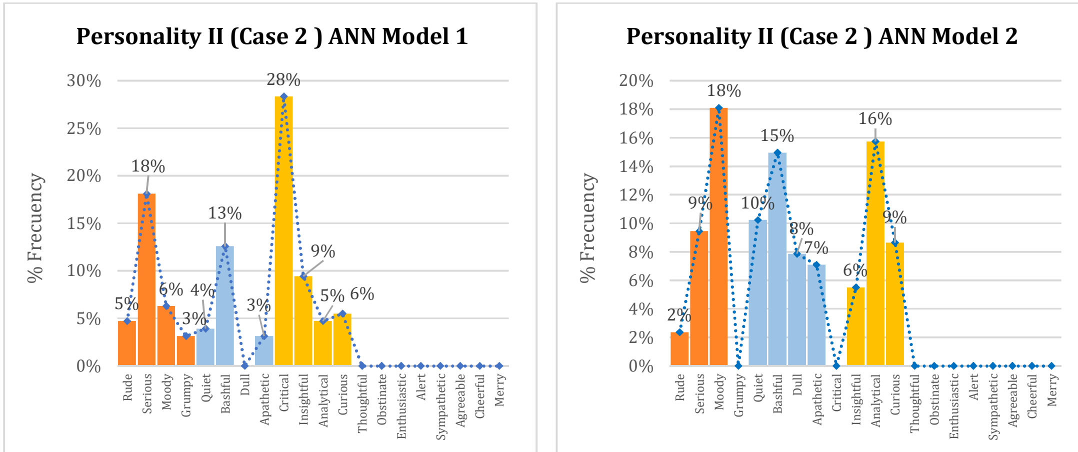


Fig. 5.1-5. Results Case 2 for an Optimistic Personality (II)

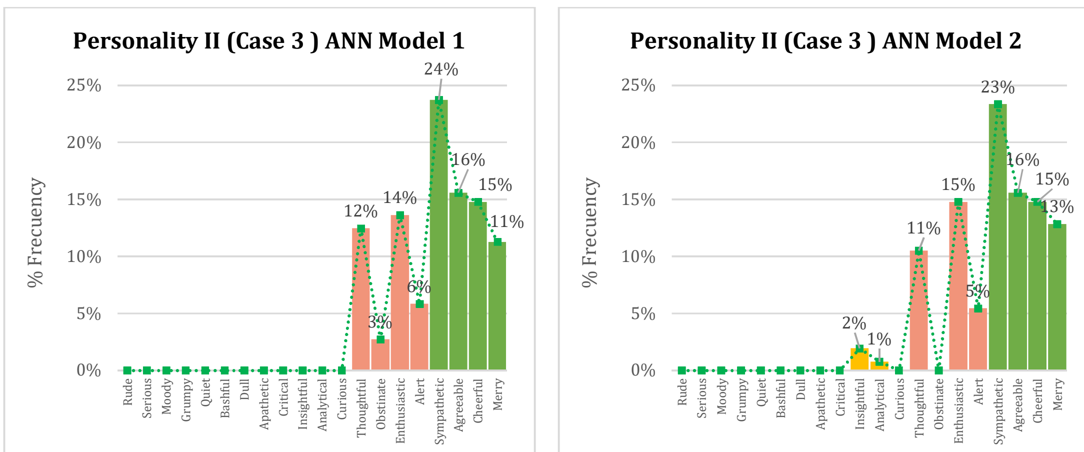


Fig. 5.1-6. Results Case 3 for an Optimistic Personality (II)

GLOOMY PERSONALITY (III)

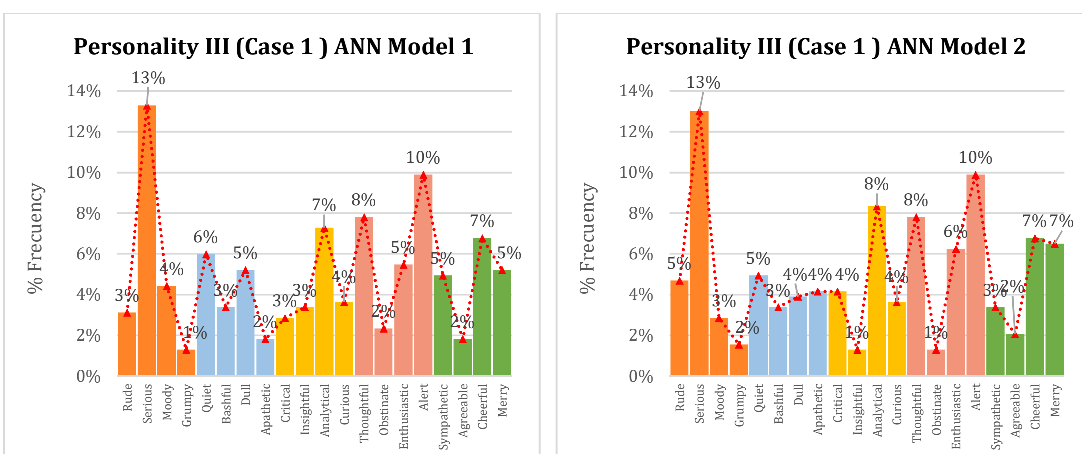


Fig. 5.1-7. Results Case 1 for a Gloomy Personality (III)

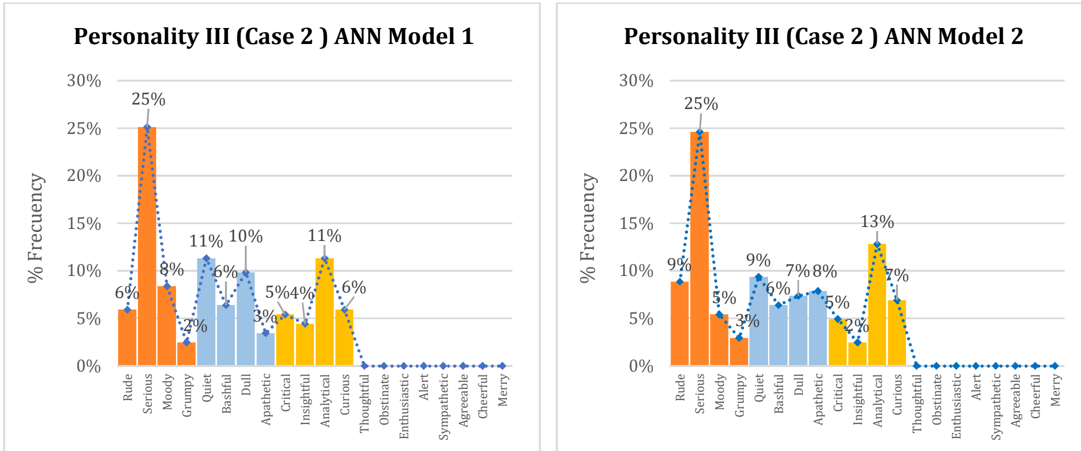


Fig. 5.1-8. Results Case 2 for a Gloomy Personality (III)

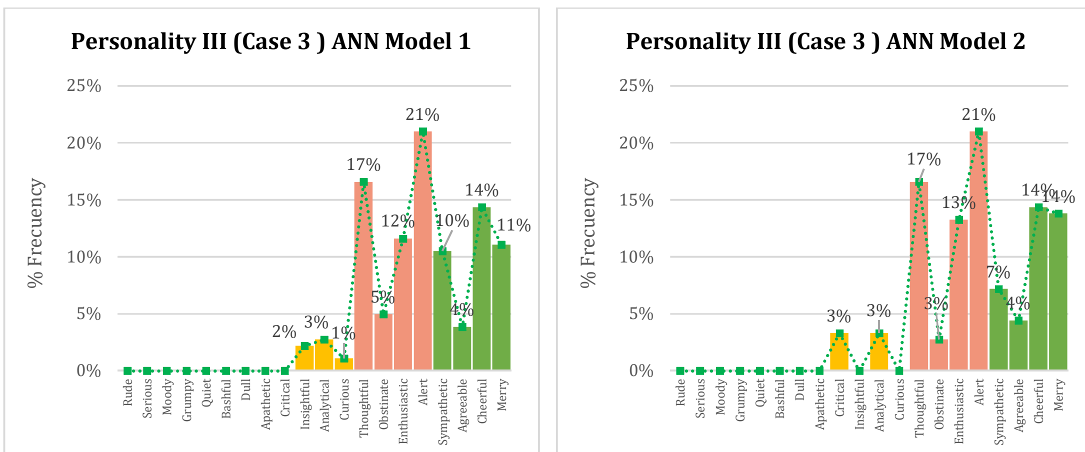


Fig. 5.1-9. Results Case 3 for a Gloomy Personality (III)

GRUMPY PERSONALITY (IV)

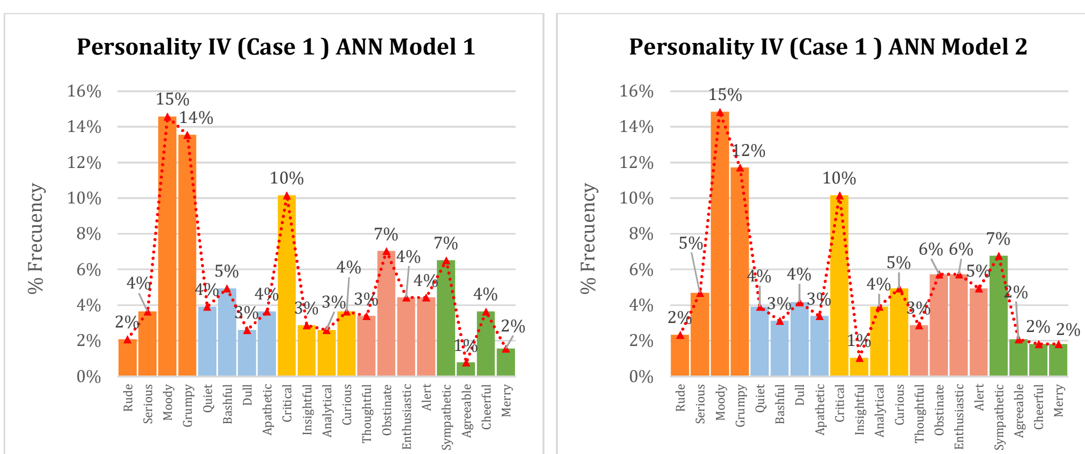


Fig. 5.1-10. Results Case 1 for a Grumpy Personality (IV)

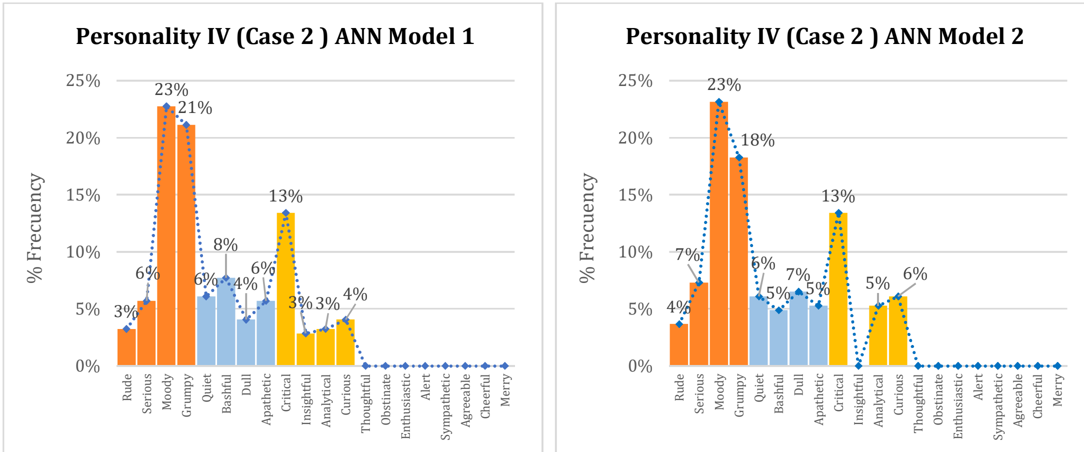


Fig. 5.1-11. Results Case 2 for a Grumpy Personality (IV)

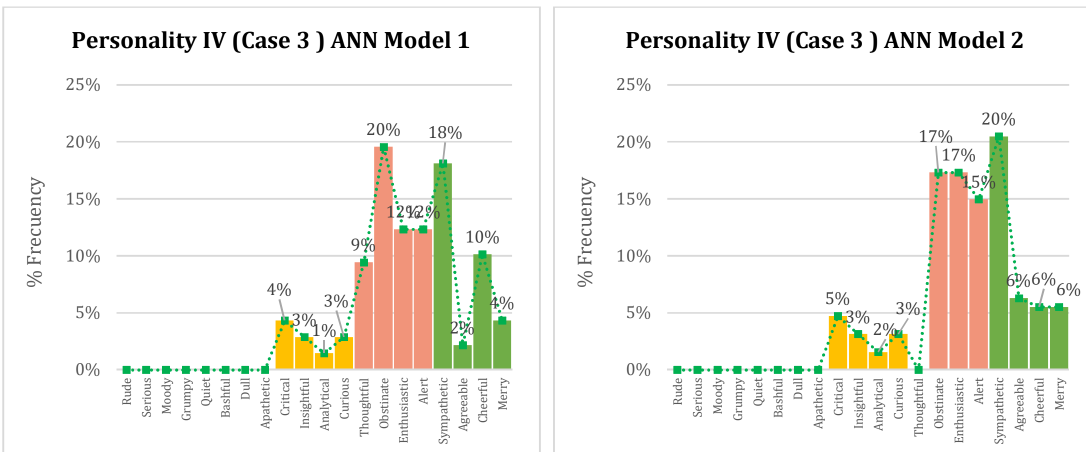


Fig. 5.1-12. Results Case 3 for a Grumpy Personality (IV)

ANALYTICAL PERSONALITY (V)

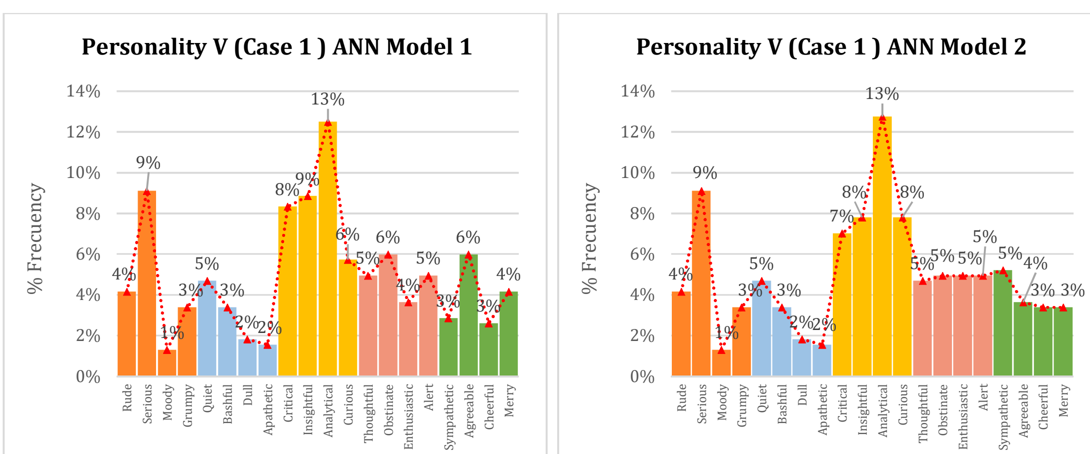


Fig. 5.1-13. Results Case 1 for an Analytical Personality (V)

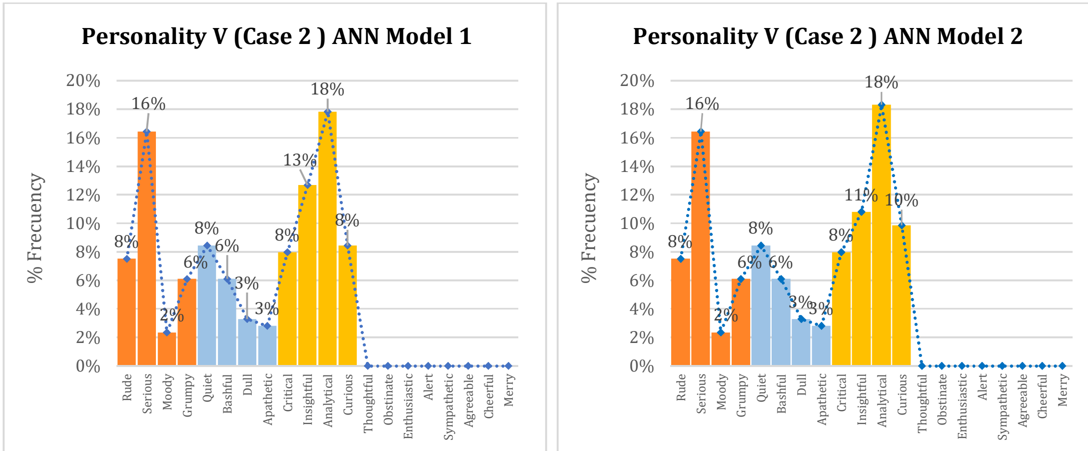


Fig. 5.1-14. Results Case 2 for an Analytical Personality (V)

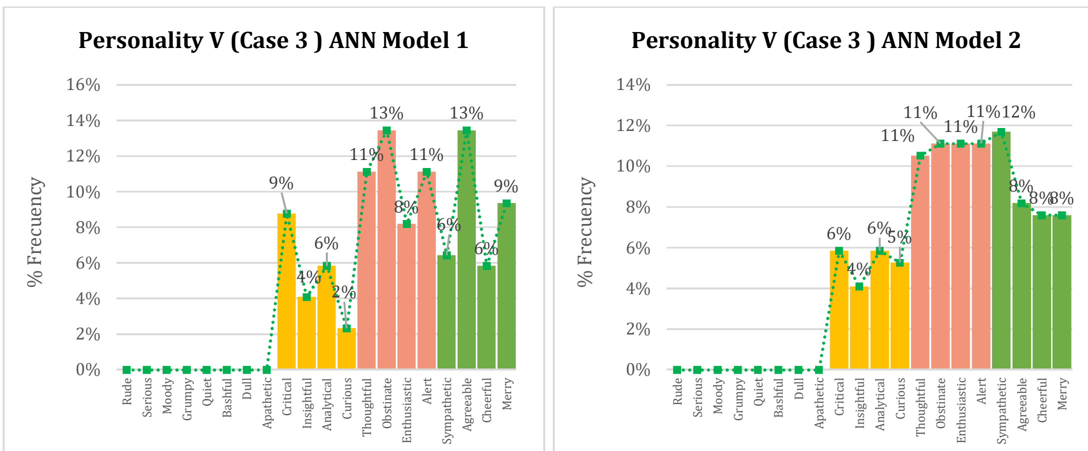


Fig. 5.1-15. Results Case 3 for an Analytical Personality (V)

Table 5.1-2 shows the Minkowski distance obtained for each personality type.

	Reserved Personality (I)		Optimistic Personality (II)		Gloomy Personality (III)		Grumpy Personality (IV)		Analytical Personality (V)	
	ANN 1	ANN 2	ANN 1	ANN 2	ANN 1	ANN 2	ANN 1	ANN 2	ANN 1	ANN 2
Case 1	0.034	0.042	0.078	0.04	0.031	0.03	0.022	0.025	0.033	0.040
Case 2	0.22	0.246	0.268	0.162	0.149	0.144	0.091	0.082	0.106	0.101
Case 3	0.08	0.088	0.095	0.091	0.107	0.108	0.157	0.165	0.099	0.083

Table 5.1-2. Minkowski Distance.

Fig. 5.1-16 to Fig. 5.1-25 show a comparative graph between the results obtained for the different case studies and each personality curve.

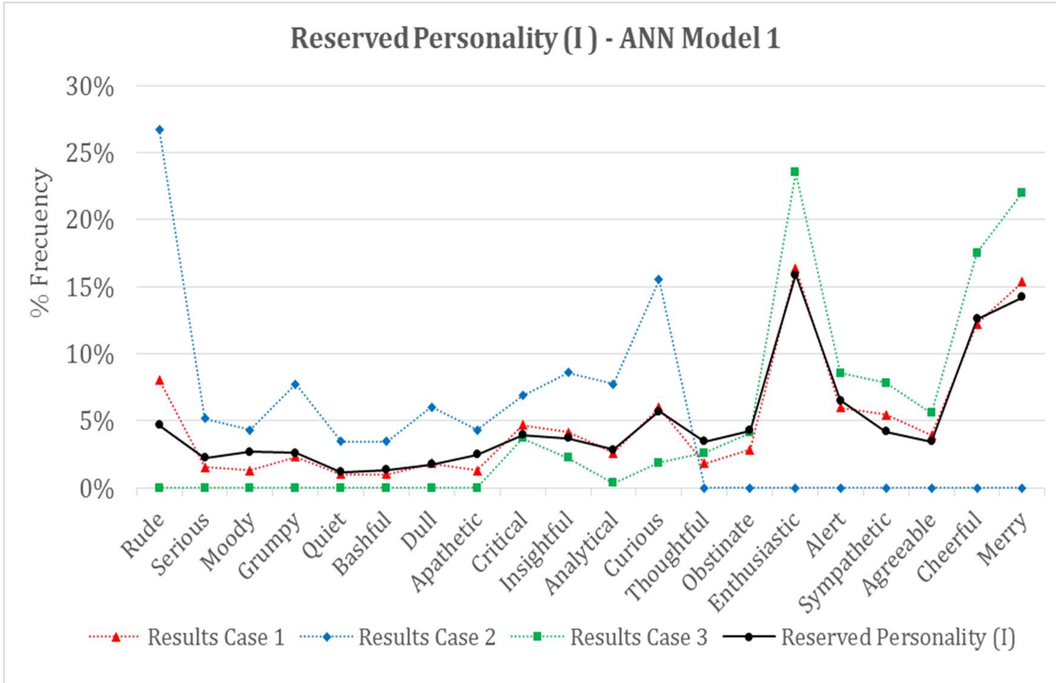


Fig. 5.1-16. Comparison of the results Case 1, Case 2 and Case 3 for a Reserved Personality (I) - ANN Model 1.

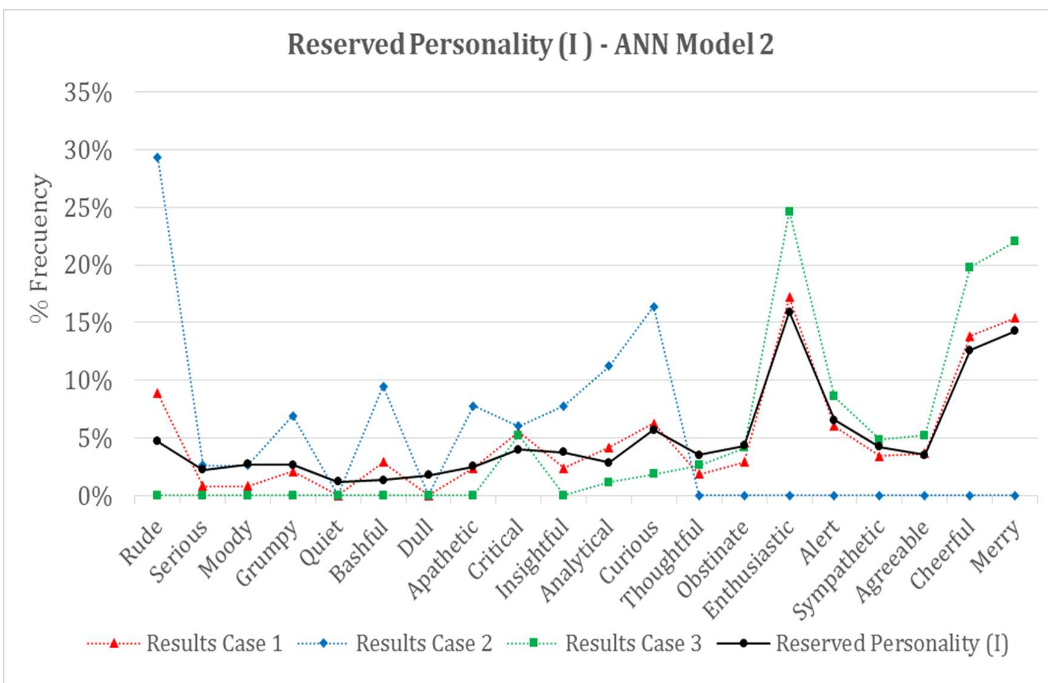


Fig. 5.1-17. Comparison of the results Case 1, Case 2 and Case 3 for a Reserved Personality (I) - ANN Model 2.

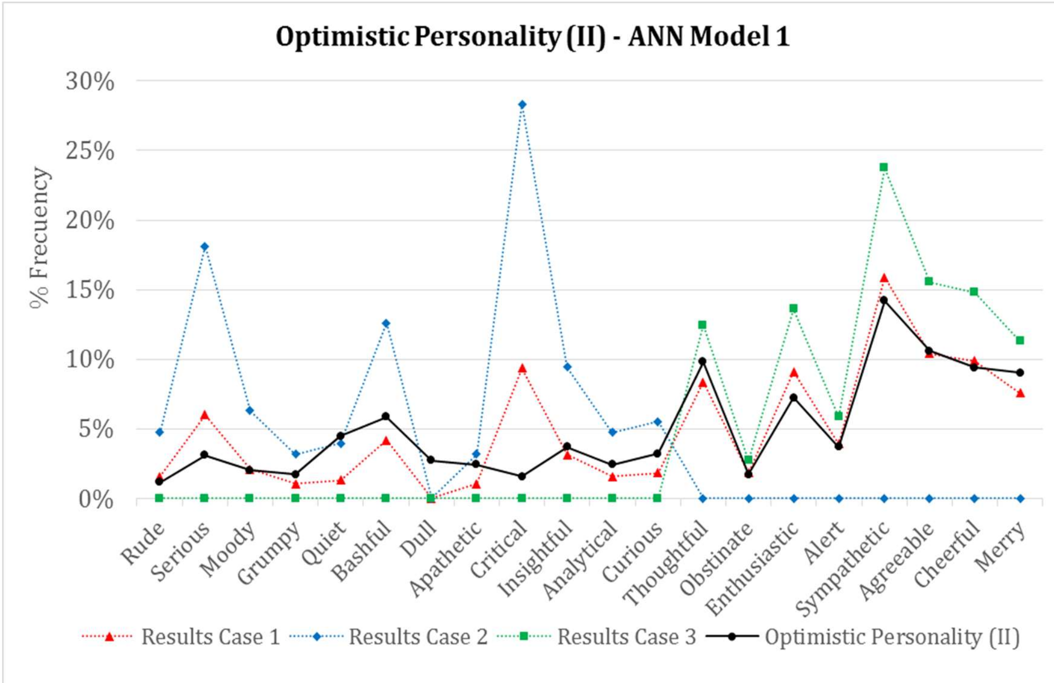


Fig. 5.1-18. Comparison of the results Case 1, Case 2 and Case 3 for an Optimistic Personality (II) - ANN Model 1.

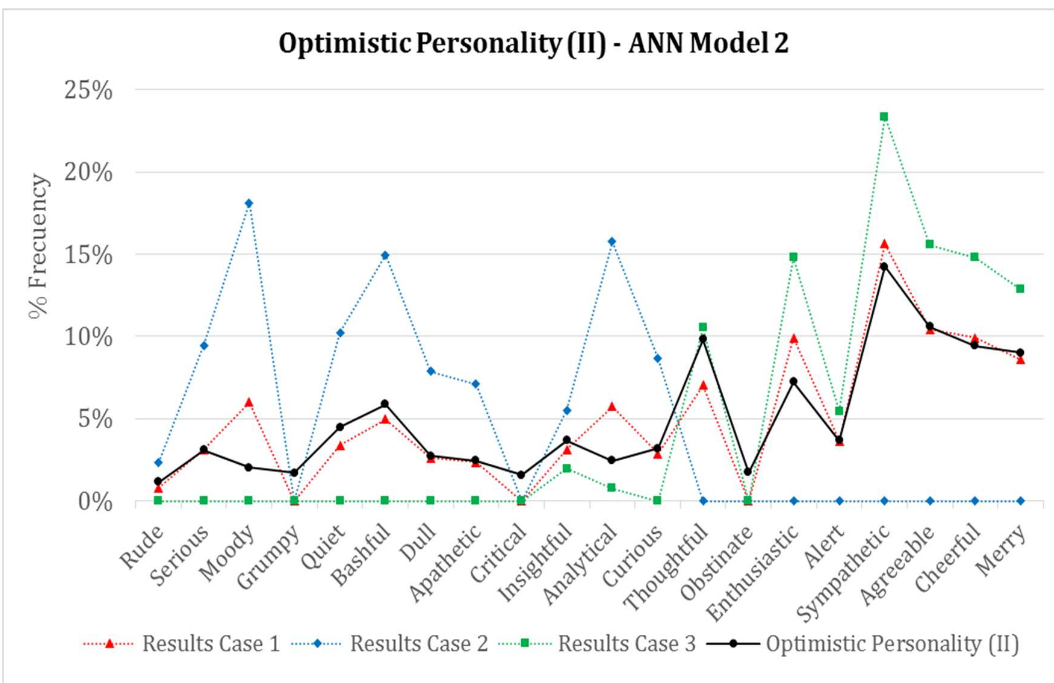


Fig. 5.1-19. Comparison of the results Case 1, Case 2 and Case 3 for an Optimistic Personality (II) - ANN Model 2.

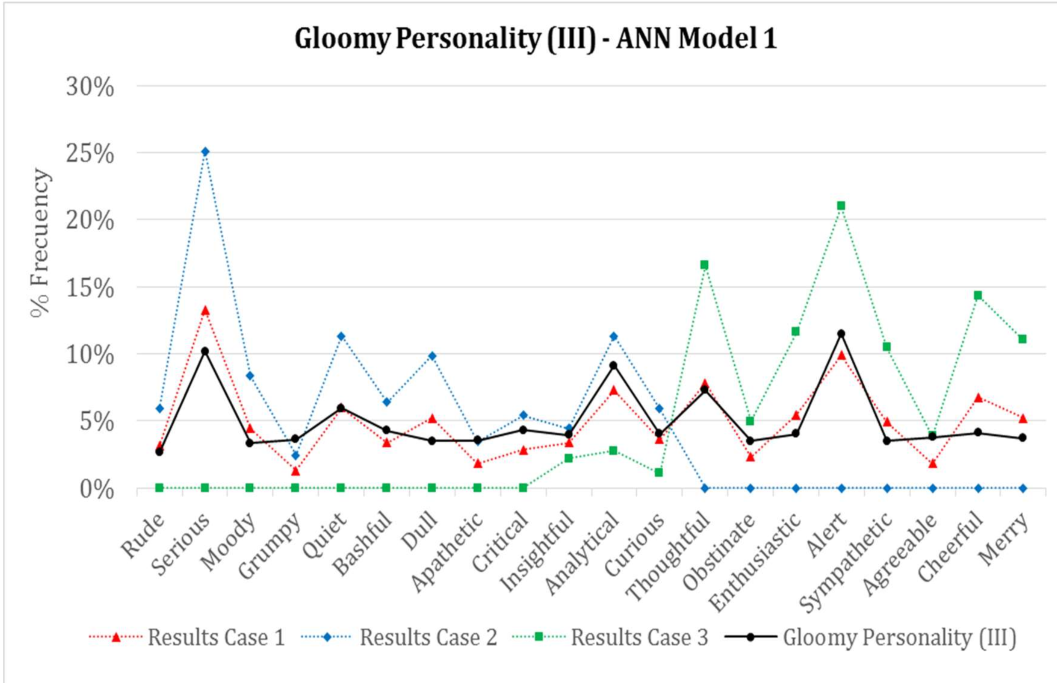


Fig. 5.1-20. Comparison of the results Case 1, Case 2 and Case 3 for a Gloomy Personality (III) - ANN Model 1.

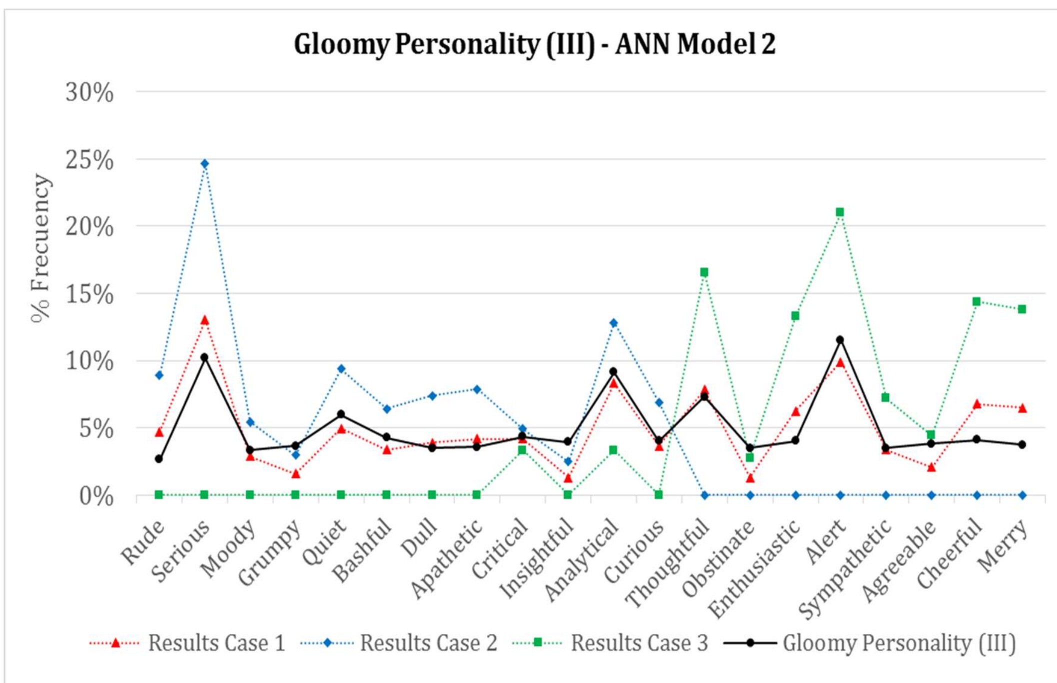


Fig. 5.1-21. Comparison of the results Case 1, Case 2 and Case 3 for a Gloomy Personality (III) - ANN Model 2.

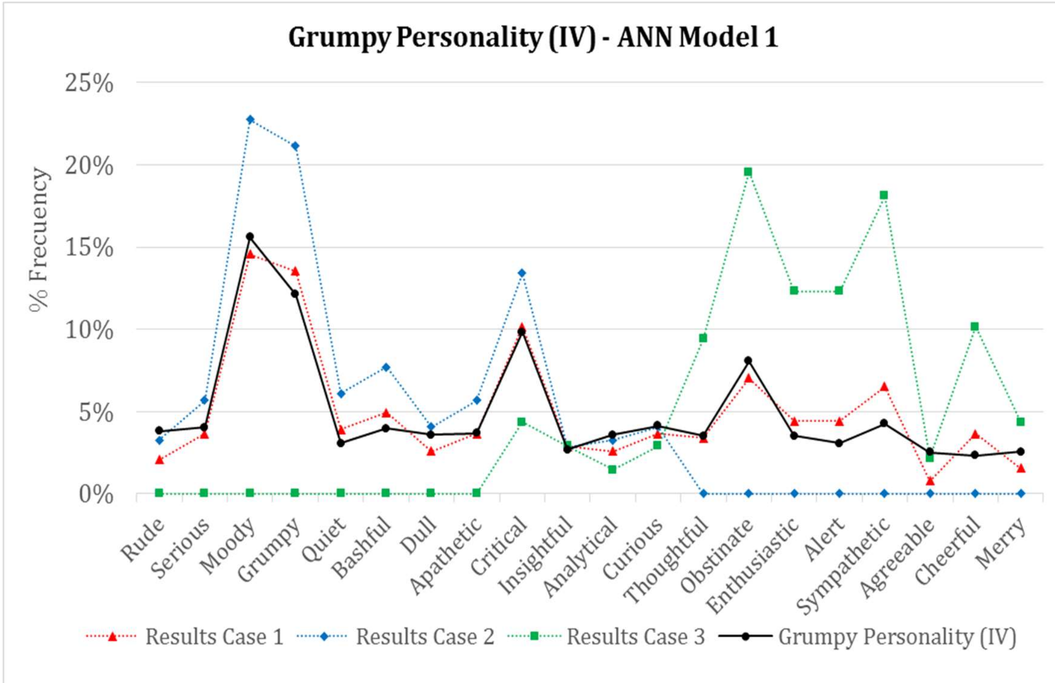


Fig. 5.1-22. Comparison of the results Case 1, Case 2 and Case 3 for a Grumpy Personality (IV) - ANN Model 1.

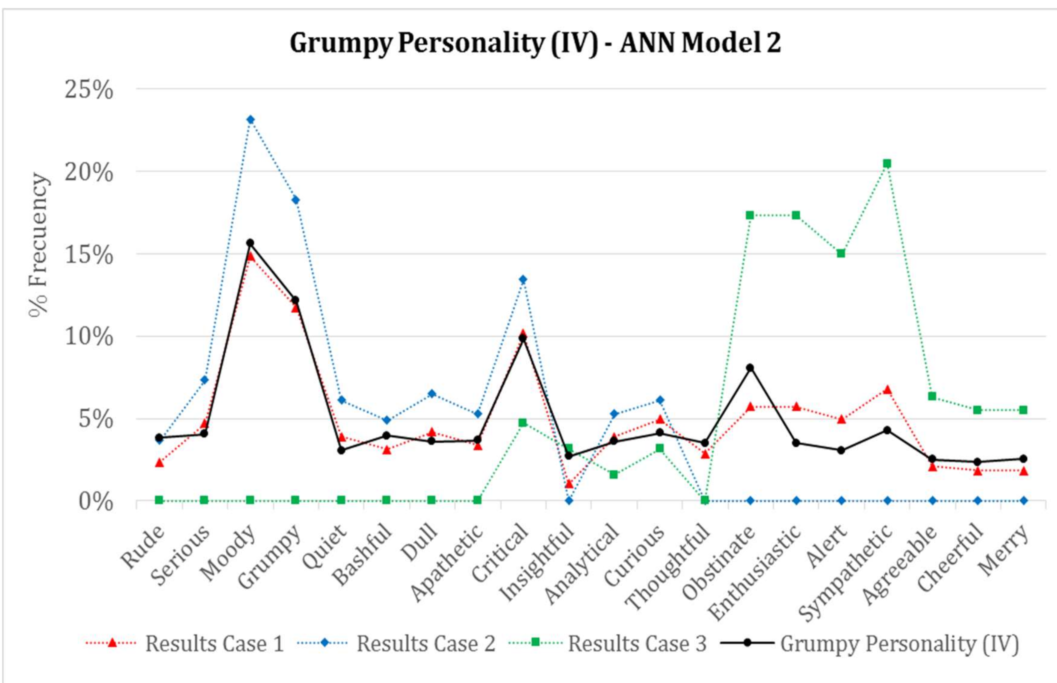


Fig. 5.1-23. Comparison of the results Case 1, Case 2 and Case 3 for a Grumpy Personality (IV) - ANN Model 2.

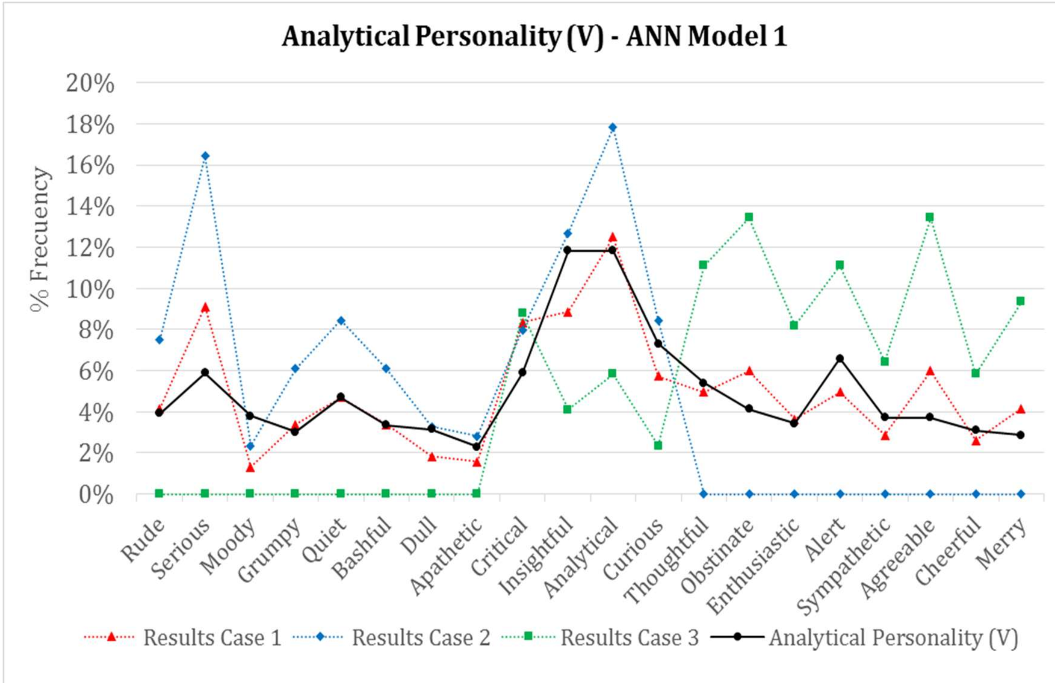


Fig. 5.1-24. Comparison of the results Case 1, Case 2 and Case 3 for an Analytical Personality (V) - ANN Model 1.

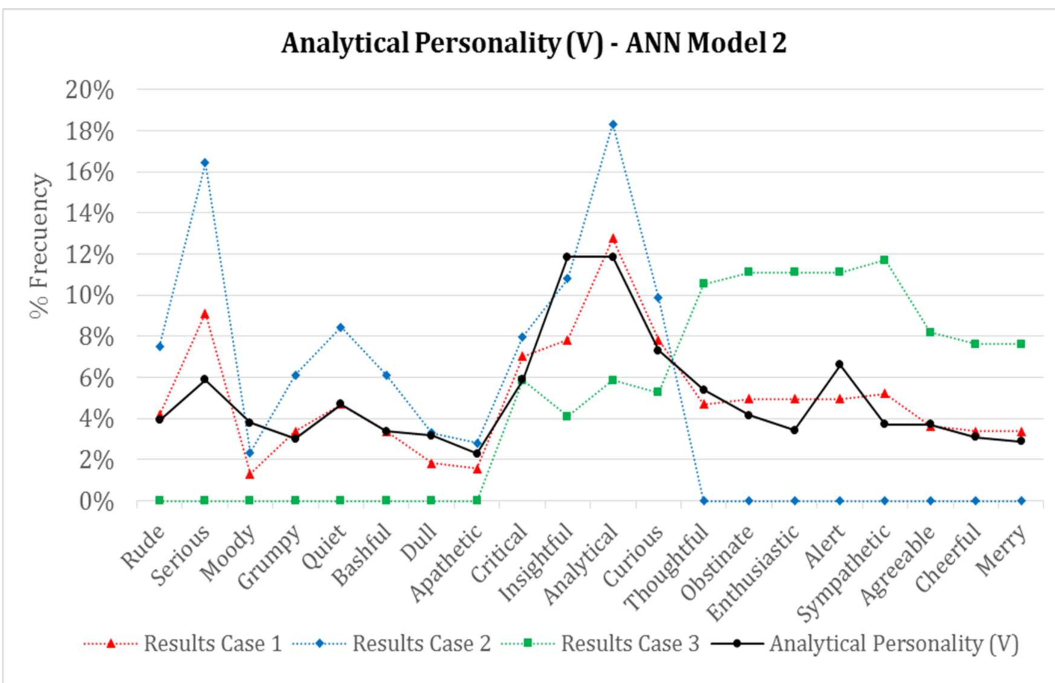


Fig. 5.1-25. Comparison of the results Case 1, Case 2 and Case 3 for an Analytical Personality (V) - ANN Model 2.

5.1.2. Results for Vocational Profile Evaluation

As an additional result are presented the calculations carried out to evaluate the person's vocational profile. For this, three (3) different vocational profiles were selected, which were obtained from information provided by the person in the interviews conducted by NAO. The key letters (R, I, A, S, E, C) represent each of the vocational groups[17]. The order in which they are organized determines the degree of interest that the person presents by the six vocational groups. The vocation with the maximum rating is ranked first and so on until the last position, which represents the vocation with the minimum rating (see Fig. 5.1-26 to Fig. 5.1-28).

VOCATIONAL PROFILE: **SERACI**

Question	Answer	R	I	A	S	E	C
1	I don't know.	0	0	0	0	0	0
2	Sports was the only subject I really liked.	1.25	0.4	0.6	1.75	0.75	0.25
3	I didn't like art education.	1.25	0.75	0.25	0.4	0.6	1.75
4	Nothing comes to my mind at this moment.	0	0	0	0	0	0
5	I like to do exercise and practice outdoor sports.	5	1.6	2.4	7	3	1.0
6	I don't know.	0	0	0	0	0	0
7	I see myself as a cheerful, kind person, and very loyal to my friends.	0.99	1.58	2.77	6.27	5.61	2.57
8	I am not a rude person, unfriendly or cruel.	0.8	1.5	2.5	3.5	0.5	1.2
SERACI (*Vocational Profile*)		**9.3**	**5.8**	**8.5**	**18.9**	**10.5**	**6.8**

Table 5.1-3. Results for vocational profile evaluation: Example 1.

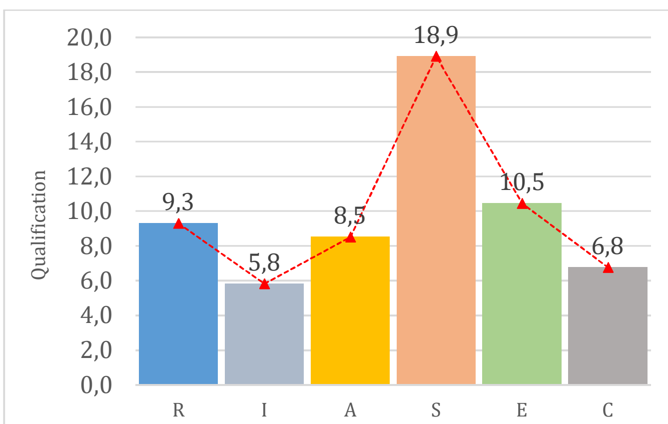


Fig. 5.1-26. Graphical representation of the results obtained for vocational profile evaluation: Example 1.

[17] Vocational groups are: Realistic (R), Investigative (I), Artistic (A), Social (S), Enterprising (E), and Conventional (C).

VOCATIONAL PROFILE: **IRCASE**

Question	Answer	R	I	A	S	E	C
1	I want to study a technical career, it could be electricity, mechanics or electronics. I would also like to study gastronomy, be a famous chef and cook for everyone.	6.7	13.3	0	0	0	0
2	I liked electronics and robotics a lot because I love to develop new projects. Through these subjects I had the opportunity to know this vocation that was unknown to me.	1.3	1.8	0.8	0.4	0.3	0.6
3	I didn't like music and dance. I can't dance because I can't coordinate the music rhythm with body movements and I was very embarrassed to do it.	1.3	0.8	0.3	0.4	0.6	1.8
4	The quality and all that has to do with the intellectual part is important for me.	0.5	3.5	2.5	1.3	1.0	1.2
5	I like electronics and mechanics. Besides, I love cooking which is for me an excellent opportunity to relax.	6.9	3.6	2.3	2.1	2.0	2.8
6	I don't like dancing, singing, painting or anything that involves the artistic part.	2.1	2.5	0.5	0.9	1.1	2.8
7	I think I'm humble, supportive, peaceful and very courageous in any situation that may arise in my life.	3.8	2.5	4.4	5.5	1.5	2.4
8	I'm not a traditionalist or a religious person but I like to respect others' beliefs, I'm very tolerant. Besides, I don't consider myself an adventurer.	3.1	1.2	1.2	0.7	2.1	1.6
IRCASE (*Vocational Profile*)		**25.7**	**29.0**	**11.8**	**11.3**	**8.6**	**13.0**

Table 5.1-4. Results for vocational profile evaluation: Example 2.

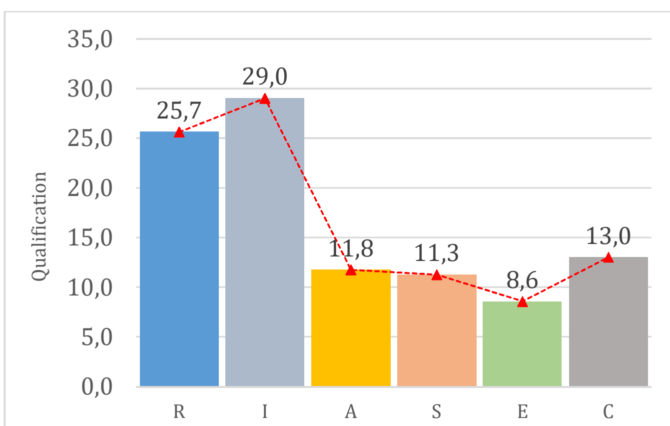


Fig. 5.1-27. Graphical representation of the results obtained for vocational profile evaluation: Example 2.

VOCATIONAL PROFILE: **CRSIEA**

Question	Answer	R	I	A	S	E	C
1	I will study accounting.	0	0	0	0	0	20
2	My favorite subject was computer science, I like to work with computers.	0.4	1.25	0.25	0.6	0.75	1.75
3	Chemistry was very difficult and I didn't like it at all. It took a while for me to understand many of the lessons taught by teacher. Besides, I didn't like physics for the same reasons.	1.17	0.25	1.0	0.82	1.17	0.57
4	I can totally identify with the values of obedience and tolerance. It is important for me to respect other people, treating them the same as I would like them to treat me.	2.0	1.1	0.75	1.57	1.32	3.25
5	I like all that has to do with computer science, repair computers and learn about new changes in the field of information technologies.	4.48	5.61	1.84	2.37	1.65	3.82
6	I wouldn't like to work in something related to chemistry, physics or mathematics.	2.7	0.49	1.81	1.91	1.94	1.02
7	I'm an organized, patient, sincere, loving and fun person. I can be radical in my decisions.	2.56	1.66	1.82	5.12	3.42	4.6
8	I certainly don't see myself as a lazy, disorderly or rude person.	2.0	1.75	1.0	1.07	1.25	2.92
CRSIEA (*Vocational Profile*)		**15.3**	**12.1**	**8.5**	**13.5**	**11.5**	**37.9**

Table 5.1-5. Results for vocational profile evaluation: Example 3.

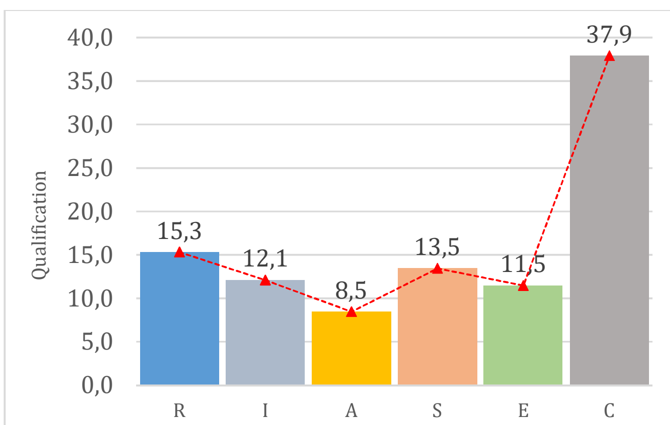


Fig. 5.1-28. Graphical representation of the results obtained for vocational profile evaluation: Example 3.

Three (3) equal profiles (vocational profile: ASEIRC) were chosen but originating from three types of interviews whose ratings (success) were different.

Table 5.1-6 to Table 5.1-8 show the answers given by the person to the questions formulated by NAO, the rating for each vocational group and the vocational profile obtained. Fig. 5.1-29 to Fig. 5.1-31 graphically display these results.

INTERVIEW WITH A LOW TOTAL RATING: (30 POINTS OUT OF 100)

Question	Answer	R	I	A	S	E	C
1	I would like to study many things, since I'm curious about many careers, but I haven't been able to identify my true vocation.	0	0	0	0	0	0
2	I don't know.	0	0	0	0	0	0
3	I don't know what to say, I don't remember.	0	0	0	0	0	0
4	I can't think of a value now.	0	0	0	0	0	0
5	Play the guitar, swim and go out for a run at times.	3	3.3	4.7	5	2.7	1.3
6	I don't like mechanics or electronics.	0.5	0.8	3.5	1.5	2.5	1.2
7	I don't know.	0	0	0	0	0	0
8	I don't know how to answer that question. It's hard to put it into words.	0	0	0	0	0	0
ASEIRC (*Vocational Profile*)		**3.5**	**4.1**	**8.2**	**6.5**	**5.2**	**2.5**

Table 5.1-6. Results for vocational profile evaluation: Example of an interview with a low total rating.

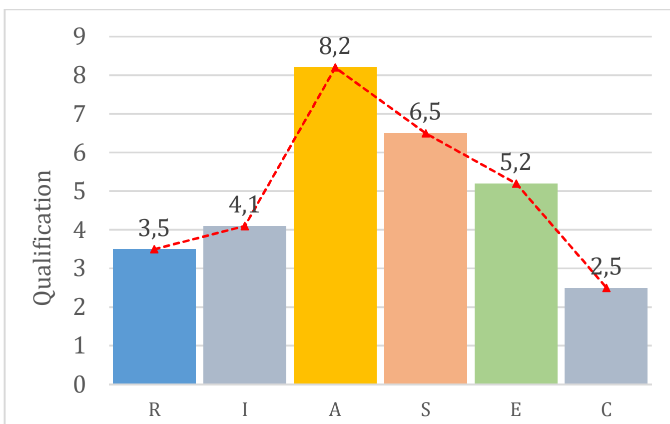


Fig. 5.1-29. Graphical representation of the results obtained for vocational profile evaluation: Example of an interview with a low total rating.

INTERVIEW WITH A MEDIUM TOTAL RATING: (61POINTS OUT OF 100)

Question	Answer	R	I	A	S	E	C
1	I want to be a radio announcer and the career that I want to study is social communication and journalism. Since journalism is a career that allows us to know many cultures and travel around the world which is something that I have always liked. Moreover, I would also like to be a famous actress.	0	0	20	0	0	0
2	I loved all the subjects that had to do with art.	0.4	0.6	1.8	1.3	0.8	0.3
3	I didn't like chemistry because the subjects were very complex and I had a hard time understanding them.	0.6	0.3	1.3	0.4	1.8	0.8
4	I don't know.	0	0	0	0	0	0
5	I really enjoy reading because I like to find out new things and letting my imagination run free. I also sometimes like to write my own stories. Sometimes I like to paint and take walks around my neighborhood.	2.3	3.7	4.7	5.0	3.2	1.2
6	Right now, I wouldn't know what to answer to this question.	0	0	0	0	0	0
7	I don't know.	0	0	0	0	0	0
8	I don't think I'm a materialistic, boring, or reckless person.	2.3	1.2	1.5	2.6	2.1	1.3
ASEIRC (*Vocational Profile*)		**5.6**	**5.7**	**29.2**	**9.2**	**7.8**	**3.4**

Table 5.1-7. Results for vocational profile evaluation: Example of an interview with a medium total rating.

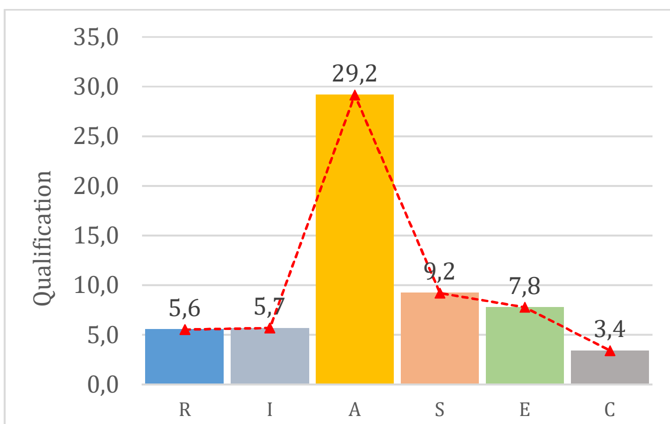


Fig. 5.1-30. Graphical representation of the results obtained for vocational profile evaluation: Example of an interview with a medium total rating.

INTERVIEW WITH A HIGH TOTAL RATING: (99 POINTS OUT OF 100)

Question	Answer	R	I	A	S	E	C
1	I think I would enjoy studying a career related to the artistic part, for example I would like to become a famous painter. I really like drawing.	0	0	20	0	0	0
2	Artistic education, with a wide difference over the rest of subjects. Painting really grabs my imagination and inspires me to do more.	0.4	0.6	1.75	1.3	0.8	0.3
3	It was hard for me chemistry and geometry, I did not like them much because I had to study a lot to pass the exams and almost always failed.	1.2	0.3	1.0	0.8	1.2	0.6
4	Originality is fundamental for me because I always seek to excel and innovate in the things I do. Also, I can totally identify with the elegance and ingenuity to do new things. Spontaneity also characterizes me and I like being like this.	0.9	1.6	3.25	1.2	2.3	0.9
5	I like painting, I love to experience the state of peace, relaxation and isolation when drawing. When I draw my brain stops thinking and focuses entirely on what I'm doing. I also like to watch TV and go to movies occasionally.	2.3	2.2	5.85	4.7	3.0	2.0
6	I don't like activities like mechanics, bricolage, or gardening.	0.5	0.8	2.14	2.8	2.5	1.2
7	I'm a genuine person and very original, I can be introverted sometimes. I'm very faithful and loyal to my principles and values.	1.6	3.7	4.6	3.6	3.6	2.0
8	I'm not a very tidy and responsible person, but I strive to improve. Besides, I'm not narrow-minded.	1.2	2.0	3.5	1.5	1.2	0.6
ASEIRC (*Vocational Profile*)		**8.0**	**11.1**	**42.1**	**15.8**	**14.4**	**7.5**

Table 5.1-8. Results for vocational profile evaluation: Example of an interview with a high total rating.

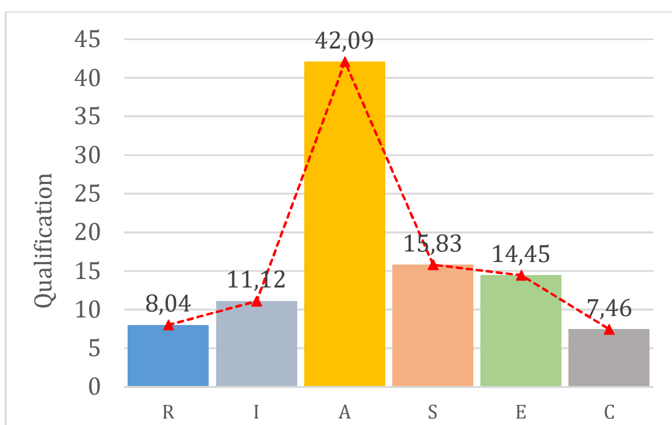


Fig. 5.1-31. Graphical representation of the results obtained for vocational profile evaluation: Example of an interview with a high total rating.

5.2. Analysis of Results

CASE 1

From the behaviors determined by the system (see Fig. 5.1-1, Fig. 5.1-4, Fig. 5.1-7, Fig. 5.1-10 and Fig. 5.1-13) the curve obtained in this case is very similar to the personality established in each outcome. Consequently, the system allows the robot to choose the most appropriate way to behave and react according to the established personality. Minkowski distance is very close to zero (see Table 5.1-2) therefore, the approximation between the robot's personality and the results issued by the system are very close.

By means of the results shown in Fig. 5.1-16 to Fig. 5.1-25 it can be seen that the ANN model 1 and the ANN model 2 exhibit a similar behavior when selecting answer behavior.

CASE 2

Case 2 shows the system's behavior when the answers given to questions were rated in an acceptable, insufficient or deficient manner (see Fig. 5.1-2, Fig. 5.1-5, Fig. 5.1-8, Fig. 5.1-11 and Fig. 5.1-14). Accordingly, the answer behaviors are concentrated in greater proportion where they are produced by negative or acceptable responses and according to the established personality profile.

For instance, for personality type I (Reserved) a large proportion of the behaviors are concentrated in the interest emotion, that is, 61% the answer behaviors for the ANN model 1 are grouped in this emotion and for the case of the ANN model 2 this percentage is of 41%. The opposite happens for personality type IV (Grumpy) where the majority of behaviors are grouped in the emotions anger and boredom. The behaviors concentrated in the interest emotion are only 24% for the ANN model 1 and 25% for the ANN model 2. Therefore, personality type has an impact on the results and the way in which the system reacts to the same input.

The difference in amplitude between the curve for Case 2 and the personality curve occurs for the reasons explained above, since the data are concentrated only in three (3) of the five (5) emotions, so when calculating the percentages by behavior it end up being higher than curve for Case 1 that has not any concentration of the data. This is evident with the Minkowski distance for this case, as it shows in Table 5.1-2, being further away from zero than Case 1.

CASE 3

Case 3 shows a similar behavior between the results obtained and the results explained for Case 2. The only difference is that the system behavior is evaluated when the answers given to questions are were rated in a good or excellent manner and thus the behaviors are grouped in positive emotions and not in negative emotions as in Case 2. The interest emotion can occur in any rating assigned to the response[18] because the personality profile has an effect over the results to react this way. Therefore, this emotion appears in both Case 2 and Case 3.

VOCATIONAL PROFILE EVALUATION

According to the interviews performed, it can be determined that regardless of the value of the score of the answer, the person's vocational profile can be evaluated if at least one *descriptor* (see definition in section 4.3.7.1) is contained in the answer given by the person. Moreover, regardless of personality type the results for these calculations are the same.

The number of *descriptors* in the answer influences the rating given to each vocational group, since the more information is given in the answer, the vocational profile obtained (rating of the interview) is higher. This is evidenced through the results shown in the Fig. 5.1-29 to Fig. 5.1-31, where the same vocational profile is obtained in each of the interviews conducted, but the ratings assigned to each vocational group vary according to the rating obtained in the general interview.

[18] *Excellent (E)*, *Good (G)*, *Acceptable (A)*, *Insufficient (I)* or *Deficient (D).*

Chapter 6

Conclusions and Future Works

This chapter summarizes the main conclusions arisen of the analysis and discussion of the results reported in this work. The chapter also reviews the dissertation's scientific contributions and then discusses promising directions for future research and applications in certain topics in which the work of this thesis can continue. Finally, some concluding remarks are drawn.

6.1. Conclusions

The proposed system manages correctly the behaviors selected according to priority and score of the answer to each question posed by the robot. The case studies were based on situations in which the person's response were well or not. With this, the matching between the robot's personality and the answers given by the user during the interview is verified. Thanks to the management of the selected behaviors, the robot is able to choose the most appropriate way to behave during the vocational guidance session.

The results and analysis carried out during this proposal show how the intelligent management of hierarchical behaviors can be successfully achieved through the proposed approach, making the Human-Robot interaction friendlier.

6.2. Main Contributions

This thesis presents a computational system oriented to evaluate how the intelligent management of a set of behaviors allows a robot to behave in the most appropriate way during a vocational guidance session. In this case, the suitability of the proposed management system is evaluated according to the matching between the robot's personality and the variables presented in section 5.1.

This thesis makes the following contributions with an HRI implementation of an intelligent management system of behaviors with effective interaction between a human and a robot.

- ✓ *An intelligent approach for managing a set of behaviors towards finding effective interaction between the robot and the person. The developed system allows through experimentation to give sufficient information to relate how the implemented computational intelligence complies or not with their target effectively and which parameters can intervene positively or negatively in processing. Evaluating the performance of the developed system can determine how the algorithms developed can help a robot emulates an Intelligent Vocational Tutor effectively.*
- ✓ *To improve the interaction between humans and machines in a particular environment. This will allow to take a step forward in this area, which has a marked tendency worldwide with this type of humanoid robots. The findings and results of this research will be significantly useful for the following investigations. By developing an intelligent system capable of imitating a vocational tutor, it expects to encourage the participation of more researches by approaching the community with these technologies.*

6.3. Future Research and Directions

According to the results presented in this thesis, can be considered the following future works:

- ✓ Refinement of the behaviors developed to achieve an improvement in the Human-Robot interaction, and therefore greater fluency in conversation.
- ✓ Use of intelligent algorithms with the aim that the robot can make decisions appropriately from different stimuli of the environment that surrounds it and not only from previously programmed behaviors. Therefore, these behaviors will be more elaborate since they can be generated from computational intelligence techniques and from the interaction of the robot with the person and/or with its environment.

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