# How linguistic descriptions of data can help to the teaching-learning process in higher education, case of study: artificial intelligence

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# Abstract

Artificial Intelligence is a central topic in the computer science curriculum. From the year 2011 a project-based learning methodology based on computer games has been designed and implemented into the intelligence artificial course at the University of the Bío-Bío. The project aims to develop software-controlled agents (bots) which are programmed by using heuristic algorithms seen during the course. This methodology allows us to obtain good learning results, however several challenges have been founded during its implementation.

In this paper we show how linguistic descriptions of data can help to provide students and teachers with technical and personalized feedback about the learned algorithms. Algorithm behavior profile and a new Turing test for computer games bots based on linguistic modelling of complex phenomena are also proposed in order to deal with such challenges.

In order to show and explore the possibilities of this new technology, a

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web platform has been designed and implemented by one of authors and its incorporation in the process of assessment allows us to improve the teaching learning process.

Keywords: Computational Intelligence, Linguistic Descriptions of Data,Linguistic Modelling of Complex Phenomena, Computer Game Bots,Turing Test, Computer-assisted Assessment

# 1. Introduction

Feedback is an indispensable component of an effective teaching and learning environment in education [17, 23, 33, 40]. Additionally, its personalization offers possibilities to deliver feedback that is the most appropriate for the user's expertise, cognitive abilities and to their current moods and attentiveness [16]. However, providing students with personalized and immediate feedback is a complex task and it is usually a standardized process (every student receives the same feedback, e.g., knowledge of correct response) due to the large number of students [16]. In writing skill, for example, truly immediate feedback is impractical [20].

A possible solution to solve this limitation is to employ computer-assisted assessment (CAA). CAA is a longstanding problem that has attracted interest from the research community since the sixties and has not been fully resolved yet [24]. The main aim is to study how the computer can help in the evaluation of students' learning process [21]. The literature has exposed several advantages:

- It provides educators with didactic advantages [40].
- It provides students with immediate information in a timely manner and it is particularly useful when the number of students is high and resources are scarce [16].
- It is a quick way of providing feedback and it reduces the teacher's workload [20]
- It can be personalized, hence allowing the process of assessment to be enhanced from both teacher's and students' points of view

Automatic assessment methods can be grouped into five main categories: statistical, natural language processing (NLP), information extraction (IE), clustering and integrated-approaches [22]. Several examples of successful applications can be found in the literature:

- Automatic creation of summaries assessment for intelligent tutoring systems [24];
- Automatic generation of formative feedback in the university classroom for specific concept maps scaffold students' writing [19]
- A framework to provide students with feedback on algebra homework in middle-school classrooms [13];
- Automatic test-based assessment of programming [11];
- Automatic assessment of free text answers using a modified BLEU algorithm [22].
- Feedback for serious computer games to provide learners with useful

and immediate information about the player's performance [4].

The use of CAA in an undergraduate course of artificial intelligence can be very beneficial when a project-based learning is employed as teachinglearning methodology. An important skill to be acquired by undergraduate students of artificial intelligence courses is to get a better understanding of the different kind of heuristic algorithms existents for implementing computer games bots. In such project, each student individually <sup>1</sup> must design and implement a computer game by programming the artificial intelligence of the various agents (bots) acting in the virtual world. This kind of project can be seen as a real computer game-based learning [26].

Computer Game-based learning <sup>2</sup>, which is a type of CCA tool, was selected as a learning strategy because video-games are now used as new and powerful platforms for teaching and learning. In fact, the development of video games is currently a very motivational topic for the computer science students.

In this context, the classical assessment of a computer game-based learning project consists in checking if the bots developed by the students are correctly designed and implemented. This process has important flaws:

<sup>&</sup>lt;sup>1</sup>For us, the projects must be individually developed because team-based learning could has certain limitations when it is applied for acquiring programming skills, however this discussion is out of the scope of this paper

<sup>&</sup>lt;sup>2</sup>Note that, we do not use computer games for learning, students design and implement a computer game, that is, the computer game is the result, it is not used as a pedagogical resource

- It is a time-wasting task, mainly due to the excessive time required by the teacher to check the project's functionality. This becomes a serious problem when the number of students is high and there is only one teacher.
- 2. It is a complex task mainly due to the difficulty of evaluating a lot of important details about the implementation, which are usually missed in an execution trace: quantity (memory occupied, iterations performed, data structure used, etc.) and quality (how the artificial intelligence agent is good at capturing coins in the virtual world: is it fast, brave, intelligent?). Additionally, both of them -quantity and quality- are difficult to capture due to the nature of the computer algorithm: they are running very fast, the debugger generates a lot of information which is difficult to understand, also large amount of data generated in the execution of a program.
- Impossibility (or very difficult) of performing individual project-based learning.

In the literature, some works have been proposed to provide learners and/or teachers with a CAA tool based on linguistic descriptions of data generated into the learning process: Automatic Textual Reporting in Learning Analytics Dashboards [27], Feedback reports for students based on several performance factors [14] and Reports describing the learner's rating in a specific learning activity [34].

In [31] linguistic descriptions were used for improving player experience in

a computer game called YADY (Your actions define you). There are remarkable differences with respect to the present work. While in [31] the feedback aims to improve player experience, now the feedback aims to support the teaching-learning process.

In this paper, we propose a methodology and a data-driven software in order to automatically generate personalized and technical feedback from the data generated during the heuristic algorithm execution. A combination of three computational techniques is proposed, namely: bot's behaviour analysis, computational perception networks and natural language generation based on templates. The idea is that each student can gets immediate, technical and personalized feedback about their faults committed during the development of the project and they can learn about the heuristic algorithms employed for programming computer games bots.

On the other hand, this approach is very beneficial to the teachers since allows them to:

- 1. Save time for evaluating others aspects of the projects what implies a better understanding of them.
- 2. Enhance the classical process of assessment providing students with personalized and technical feedback.
- 3. Support individual project-based learning in order to get a more closed tracing of the projects and the opportunity of focusing on the weak skills of the students and its strengthening.

In order to show and explore the possibilities of this new technology a web platform has been designed and implemented by one of the authors following the phases and steps indicated in the methodology and the software specification (see User's Manual in Appendix). Additionally, this portal has been incorporated into the teaching learning process, now each student can consult the feedback in any time he/she wants and compare different kind of algorithms for programming computer games bots, also he/she can establish his/her own plan work for learning. Additionally, behavior profiles for computer game bots and human players allow to compare the quality of the algorithms designed by students by using an adaptation of the Turing test which will be presented at [18].

The structure of the paper is as follows. Section 2 introduces several general concepts regarding project-based learning in artificial intelligence and provides a very brief review of the state of art on the different involved disciplines. Then, in section 3 a methodology for incorporating linguistic description of data is proposed and incorporated into the AI projects. Section 4 details the software architecture for providing teacher and students with personalized and technical feedback. Afterwards, section 6 explains the experimentation and evaluation carried out on the projects of the student by employing an adaptation of the Turing test. Finally, section 7 provides some concluding remarks.

### 2. Preliminary Concepts

### 2.1. Linguistic Descriptions of Data and Natural Language Generation

Linguistic Description of Data (LDD) intends to automatically produce expressions that convey the most relevant information contained (and usually hidden) in the data. It uses a number of modelling techniques taken from the soft computing domain (fuzzy sets and relations, linguistic variables, etc.) that are able to adequately manage the inherent imprecision of the natural language in the generated texts [29]. LDD models and techniques have been used in a number of fields of application for textual reporting in domains such as: Deforestation Analysis [7], Big Data [8], Advices for saving energy at home [9], Self-Tracking Physical Activity [35], cosmology [36, 1], driving simulation environments [12], air quality index textual forecasts [28], weather forecasts [30]. It is a subfield of Artificial Intelligence (AI) which allows us to produce language as output on the basis of data input.

NLG models and techniques have been applied for textual reporting in various domains, such as meteorological data [15, 6], care data [25], project management [42], air quality [5]

# 2.2. Restricted Equivalent Functions

A restricted equivalent function (REF) [2] is a function which allows to establish a similarity between the elements of a domain. A REF can be formally defined as follows:

**Definition 2.1.** A REF, f, is a mapping  $[0,1]^2 \longrightarrow [0,1]$  which satisfies the following conditions:

- 1. f(x,y) = f(y,x) for all  $x, y \in [0,1]$
- 2. f(x,y) = 1 if and only if x = 1
- 3. f(x,y) = 0 if and only if x = 1 and y = 0 or x = 0 and y = 1
- 4. f(x,y) = f(c(x), c(y)) for all  $x, y \in [0,1]$ , c being a strong negation.
- 5. For all  $x, y, z \in [0, 1]$ , if  $x \le y \le z$ , then  $f(x, y) \ge f(x, z)$  and  $f(y, z) \ge f(x, z)$

For example, g(x, y) = 1 - |x - y| satisfies conditions (1)-(5) with c(x) = 1 - x for all  $x \in [0, 1]$ . A similarity measure based on REFs between linguistic terms has been recently proposed in order to enhance the inference engine of Bousi Prolog [32].

# 2.3. Project-based learning in Artificial Intelligence

From the year 2011 a project-based learning methodology based on computer games is applied into the intelligence artificial course at the University of the Bío-Bío. This methodology aims to provide students with a better understanding of the heuristic algorithms which can be employed in real world applications. To this end, the project aims to develop a computer game in which the bot's ability should be like that of the human players, being the programming skills and the abilities for incorporating them in the computer game very important competencies to be achieved as well.

In the year 2017 the project consisted in the development of a set of computer game bots which should be designed and implemented by using the Java programming language. A computer game bot aims to remain itself

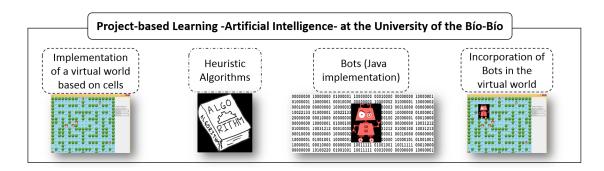


Figure 1: Project-based learning employed in the course of Artificial Intelligence at the University of the Bío-Bío

inside of a scenario based on cells during the most time possible. The student must take into account that the bots can lose energy in each movement performed (1 point of energy each five seconds). Three Bots opponent (also programmed by the students) will treat to stole its energy and a set of rewards will be distributed at the scenario which for providing bots with additional energy.

The first competence to be acquired for students in this project is the well-known algorithm thinking competence which is a pool of abilities for construction, analysis, specification and understanding of algorithms for solving given problem. Additionally, improving and adapting algorithms for given problems is an important ability to be acquired as well. In particular, the learning methodology employed in the artificial intelligence course at the University of the Bío Bío is as follows (see Figure 1):

1. **Theoretical explanation** of the Heuristic algorithm is provided to students in order that they can get a better understanding of them

from a theoretical point of view.

- 2. Implementation of the algorithms must be performed by the students by using a particular programming language (Java is currently used) in order that programming skills can be acquired by the students.
- 3. Understanding behavior of the algorithm in a real-life context. The implementation performed by the student is incorporated into the computer game.
- 4. Evaluation of the Bots created by the students is performed by checking if the bots is acting in a similar way than human expert players.

We are going to pay attention on the third and the fourth items because an important question here is how a student of an artificial intelligence course can be sure that his/her designed and implemented bots is correctly working when it is incorporated in the computer game. An informal way to get it is by observing to the bot and to check that it is performed all the functionalities.

A limitation of this process is that some details about the design and the implementation could be lost due to the large amount of data generated during the execution of the algorithm. This fact makes difficult to get an optimal assessment of the projects turning the pedagogical monitoring of the students into a complex task.

In order to address this flaw the concept of "algorithm behavior profile" is proposed. This profile is formed by the linguistic descriptions automati-

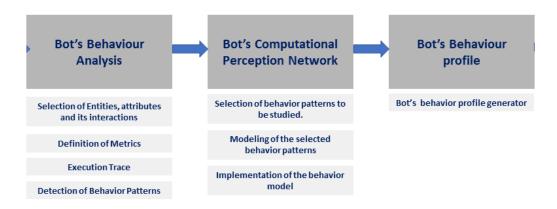


Figure 2: General methodology for automatically generated personalized feedback by using linguistic reports

cally generated by analyzing the data generated during its execution, then "computer game bot behavior" is defined as the behavior of a bot which has been implemented by using heuristic algorithms.

Then, as LDD allows us to automatically generate a human behavior player profile [31], algorithm behavior profile can be obtained. By using this idea, the students can check if the designed computer game bot has a similar behavior than the human player one. In order to formally define this comparison a Turing test based on LDD and REF for comparing profiles is proposed and explained in detail in section 3.3.

# 3. Methodology for incorporating linguistic description of data in AI projects

This methodology aims is to provide us with a guide for creating a datato-text system which transforms data in linguistic descriptions about the behavior of the computer bots implemented by using heuristic algorithms. First, data generated by the movements of the computer games bots will be grouped in metrics. The values captured for each metric will be clustered in linguistic terms. Next, a set of if-then rules will be generated by aggregating these linguistic terms. The final result is a bot's behavior profile report automatically generated.

The proposed methodology is formed by three phases: Bot's Behaviour Analysis, Linguistic Descriptions of Data and Evaluation (see Figure 2).

# 3.1. Phase 1. Bots's Behaviour Analysis

The aim of this phase is to analyze actions performed by the intelligent agents in order to get a set of behavior patterns. In order to do that, the following steps can be followed:

1. Selection of Entities, attributes and interactions the main features of the entities which are acting in the virtual world must be selected in order to capture useful information about which entities must be taken into account in the process of assessment. To this end, entities, interactions and attributes must be identified and well-established.

In our case, four entities have been identified: agent, opponents, rewards and obstacles. The agent has three important attributes: position x and y, energy and time employed to capture each reward. The rest of the entities and its attributes are shown in the Figure 3.

Entity	Attriibute	Description	Interactions and its effects
Agent (1)	Agent_x	Position $x$	Opponents (stole energy),
			Obstacles (protection), Re-
			wards(gain energy)
	Agent_y	Position y	
	Agent_e	Energy e	
Opponent(3)	$Opponent\_x$	Position $x$	Obstacles,Rewards
	Opponent_y	Position $y$	
Reward(4)	Reward_x	Position $x$	Obstacles,Rewards
	Reward_y	Position y	
Obstacle (M)	Obstacle_x	Position $x$	Obstacles, Rewards
	Obstacle_y	Position $y$	Obstacles,Rewards

Figure 3: Entities, attributes and interactions. The number (i) is indicating the number of entities in the scenario. An agent, three opponents, four rewards and M obstacles are the entities of the computer game

- 2. Definition of Metrics (Quantity and Quality). From the entities selected in the previous step, a set of metrics can be defined in order to analyze its behavior. We are going to split between quantity metrics and quality ones. Quantity provides us with information about the performance of the algorithms (memory occupied and iterations performed). On the other hand, quality provides us with information about the behavior of the heuristic algorithms, that is, how good an algorithm is for implementing a computer game bot which should act like a human player. These metrics are defined from the entities and attributes identified in the previous item. The Figure 4 shows these metrics and the corresponding descriptions.
- 3. Definition of a Computational Procedure to capture numerical data. We are going to design and implement a procedure for capturing

Metric	Description
Protection	Number of obstacles between the agent and the $opponent_i$ , a rect-
	angular area is created from the position of the agent and the
	$opponent_i$ , respectively
Distance	Distance between two entities $E_1$ and $E_2$ $d(E_1, E_2) =$
	$\sqrt{(x-x')^2+(x-x')^2}$ , being $(x,y)$ the position of $E_1$ and $(x',y')$
	the position of $E_2$
Energy	Energy of the player in an instant of time during the play session
Time	Time registered from the start of the play session to the end of it
Reward	True or false if a reward was captured at this instant of time
Iterations	Number of iterations performed for the execution of the heuristic
	algorithm (It is executed in each move)
Memory	Amount of memory required for the execution of the heuristic
	algorithm (It is executed in each move)

Figure 4: Metrics defined for analyzing the behavior of the heuristic algorithms

the data and it assigns values captured during a play session to the metrics defined in the previous task. A simple algorithm for capturing data can be performed in order to put them into a data structure which allows us to handle data in an efficient way.

In our case, traces of execution (Figure 6) have been employed as computational procedure for capturing and storing data. Tracing recording, or tracing is a commonly used technique useful in debugging and performance analysis. Concretely, trace recording implies detection and storage of relevant events during run-time, for later off-line analysis. We use a trace recording which stores the metrics defined in the previous item. The result is stored in a text file contained values for each metric defined in Figure 4. A set of execution traces can be found at the portal web (see User's Manual in Appendix).

Behavior Pattern	Description of the actions	Metrics related
Attitude	How the agent acts with respect to the reward,	Distance
	the distance between opponent and reward must	
	be evaluated.	
Situation	How the agent acts with respect to the opponent,	Protection and
	the energy and the protection must be evaluated	Distance
Kind of move	Which is the result of a movement, distance be-	Distance and
	tween the agent and the reward and opponents	Energy
	must be evaluated	
Performance	Which is the performance of each movement, time	Memory and It-
	and memory must be measured	erations

Figure 5: Behavior Patterns created from the metrics defined in Figure 4

4. Detection of Behaviour Patterns. Basic behaviour patterns can be established on the input data captured. An agent behavior pattern is associated with actions, that is, when a set of actions (act<sub>1</sub>, act<sub>2</sub>,..., act<sub>n</sub>) are produced then a set of effects (effect<sub>1</sub>, effect<sub>2</sub>,..., effect<sub>n</sub>) are trigged, e.g., when the opponent is close to the player then the player goes far away from he/she, so player and opponent are related and could provide us with some interesting behaviour pattern. Note that, patterns are related with the metrics defined in the previous item and they should created from them.

This phase provides us with a complete set of behavior patterns from actions performed by entities in the virtual world (see Figure 4). It has been designed and implemented by using a computational perception network (see Figure 8).



Figure 6: Trace of execution created from the values captured during the execution of the algorithms

3.2. Phase 2. Linguistic Descriptions of Data in a 2D virtual world for automatically generating behavior profiles

The aim of this phase is to establish a cognitive model from the previously behavior patterns identified and to generate linguistic descriptions about it. In order to do that the following step can be followed:

- 1. Selection of behavior patterns to be studied. The behavior patterns defined in the previous module are analyzed and selected according with our particular interest in them, that is, which behavior patterns are important in order to create the "algorithm behavior profile". For example, a particular sequence of movement is not relevant for us, but the reason for performing it, it is really important.
- 2. Modeling of the selected behavior patterns. A cognitive model for treating the patterns computationally is established. Taxonomies,

ontologies, linguistic terms, if-then rules or a combination of them could be used in this item without giving details about the implementation.

- 3. Implementation of the behavior model. The aim of this task is to implement a computational solution for representing the behavior model of our problem. Details about the implementation should be given. For example an "Ad-hoc" implementation could be employed or a package for automatically generating linguistic descriptions could be used [10]. It will depends on the kind of application to be developed. In our case, the PHP programming language has been employed because our ojective was the developement of a web platform and, in this context, PHP is a good alternative.
- 4. Linguistic Descriptions Generator. A linguistic description generator is designed and implemented providing us with textual messages from the execution of the computational perception network. In our case, linguistic summaries of data based on fuzzy quantifiers have been employed which allows us to summarize the data generated in the process.

This phase provide us with the behavior profile which is a graphical and textual describing the most relevant information about the behavior of the computer game bot during the execution of the algorithms used for its implementation.

# 3.3. Evaluation: A Turing Test for Computer Game Bots based on LLD and REFs

The analysis of algorithms for computer games is quite different that in others IA topics, while in the classical approach the aim is to simulate near-optimal intelligent behaviour, in computer games the aim is to provide interesting opponents for human players, not optimal ones [37].

As we mentioned the key in the evaluation in our artificial intelligence course is to develop computer game bots whose ability must be similar to the ability shown by a human player.

How it could be formally evaluated? In [18] was proposed a variation of the Turing Test, designed to test the abilities of the computer game bots to impersonate a human player. The Turing test for (computer game) bots is as follows: "Suppose we are playing an interactive video game with some entity. Could you tell, solely from the conduct of the game, whether the other entity was a human player or a bot? If not, then the bot is deemed to have passed the test"

This kind of Turing test is adapted to our methodology by using LLD and REF. The aim of this new Turing test is to establish a formal and effective method of comparison between the human behavior profile generated for a human expert player and the behavior bots profiles generated by a computer game bot implemented by using some heuristic algorithm. Therefore, a heuristic algorithm is near-behavioral (for us it is an "optimal" algorithm) when its associated profile is similar to the human expert profile. This novel process of assessment for heuristic algorithms will be detailed in the section 5.

# 4. A data-driven software architecture based on Linguistic Modelling of Complex Phenomena

The software architecture proposed is formed for four modules which implements the phases and steps described in the methodology previously detailed:

- 1. Tracing module
- 2. Computational Perception Network module
- 3. Behavior Profile Report Generation module
- 4. Evaluation module

# 4.1. Tracing module

The tracing module aims to implement the functionality explained in the phase 1 once data have been, selected, captured and stored. The output of this module is a file contained the needed data captured during the execution of the algorithms implemented in the project (see portal web for more detail).

# 4.2. Computational Perception Network module

A computational perception network allows to implement the functionality explained in the phase 2. We use here the concept of Declarative Computational Perception(DCP) network which is inspired by the definition of CP network proposed [39] and it allows to model the problem in a declarative way. A declarative CP can be recursively defined as follows:

- Base case. A CP=(A,(u<sub>1</sub>,...,u<sub>k</sub>)), being A=(a<sub>1</sub>,...,a<sub>n</sub>) a vector of linguistic expressions that represents the whole linguistic domain of CP whose values are calculated by aggregating each u<sub>i</sub> to either one or several elements of A.
- Inductive case. A  $CP = (A, (CP_1, \ldots, CP_k))$ , being  $A = (a_1, \ldots, a_n)$  a vector of linguistic expressions whose values are calculated by aggregating each  $CP_i$  to either one or several elements of A.

Note that, the base case is produced when a CP is defined in terms of a real numbers set which belongs to a particular domain; i.e., a 1CP.

The recursive case is produced when a CP is defined in terms of linguistic terms from a set of CPs; i.e., 2CP. We say that a set of sub-CPs  $\{CP_1, \ldots, CP_k\}$  completely define a CP or that a CP can be defined in terms of a sets of sub-CPs  $\{CP_1, \ldots, CP_k\}$ .

The computational perception presented in [31] is enhanced for the problem previously presented in section 2.3. In this case, additional variables must be considered and hence the computational perceptions network must be enhanced, rules and templates must be also updated for these new requirements.

Currently, a computer game bot can stay in a safe, easy, dangerous or risky situation, it depends on three factors, its protection (low,normal,high) with respect to the opponent, the distance (close,normal,far) to the opponent and the energy (low,normal,high) that the bot has in this moment. Four attitudes can be detected for a computer game bot: wise, brave, cautious and passive. This depend on two factors, the distance between the bot and the closest reward and the distance between the opponent and the closest reward. A computer game bot can perform four types of movements: good, bad, scare, kamikaze. This depend on three factors, the distance between player and the closest reward, the distance between the bot and the opponent and the energy of the bot. The ability of a computer game bot depends on its attitude, kind of movement performed and the time. The skill of a computer game bot depends on its attitude, kind of movement performed and situations detected. The resources (time and space) required for the execution of the algorithm used for implementing the artificial intelligence of the bot. More formally, the computational network can be declaratively defined as follows (see Figure 8 and appendix for more details).

- $CP_{Situation} = ((Safe, Easy, Dangerous, Risky), (CP_{Protection}^{player, opponent}, CP_{Distance}^{player, opponent}, CP_{Energy}^{player})).$
- $CP_{Attitude} = ((Wise, Brave, Cautious, Passive), (CP_{Distance}^{player, R*}, CP_{Distance}^{opponent, R*}))$
- $CP_{Movement} = ((Good, Bad, Scare, Kamikaze), (CP_{Distance}^{player, R*}, CP_{Distance}^{player, opponent}, CP_{Enery}^{player}))$
- $CP_{Ability} = ((\text{Expert, Intermediate, Basic, Dummy}), (CP_{Attitude}, CP_{Movement}, CP_{Time}))$
- CP<sub>Skill</sub>=((Very\_Skilled, Skilled, Improvable, Very\_Improvable), (CP<sub>Attitude</sub>, CP<sub>Movement</sub>, CP<sub>Situation</sub>))
- $CP_{Resources} = ((Very\_Efficient, Inefficient, Very\_Inefficient), (CP_{Iterations}, CP_{Memory}))$

#### 4.3. Behavior Profile Report Generation module

The system selects, among the available possibilities, the most suitable linguistic expressions in order to describe the input data.

We use  $\Sigma CPs = ((a_1, w_1), \dots, (a_n, w_n))$  in order to generate a summa-

rization of vector of linguistic expressions that represents the whole linguistic domain. These kind of CP allows us to obtain the total number of times in which a value  $(a_1, \ldots, a_n)$  occurred during the execution.

These kind of CP provides us with a set of variables, its associated value and a degree  $\alpha$ , which indicates the fuzzy average for a particular value. For example, a value for CP Situation could be Safe with 0.8 at an instant i and X = safe with 0.7 at instant i + 1, and so on. Therefore, at the end of the execution, we will have that  $a_i$  (in the example "safe") has been given N times with N different degrees  $\beta_1, \ldots, \beta_n$  (of course, some of these degrees could be equals). Thus, the final degree is calculated as follows:  $\alpha_i = ((\beta_1 + \ldots + \beta_n)/N)$ . For example, the following summaries can be obtained from different  $\Sigma CP$  (see Figure 8).

The generation of the report is performed by using the set of  $\Sigma CP$ . For each CP a linguistic description is created in function of the pair  $(a_i, w_i) \in$  $\Sigma CP$ . Percentages are calculated for each  $\Sigma CP$ . The percentage  $p_i$  is then transformed in a linguistic term of quantity as follows: few is when  $p_i \in$ [0, 1/3]; several when  $p_i \in [1/3, 2/3]$  or many when  $p_i \in [2/3, 1]$ . Then, we are going to consider four cases:

- 1. There exists a pair  $(a_i, p_i) \in \Sigma CP$  whose  $p_i$  is greater than 66 percent
- 2. There exists a pair  $(a_i, p_i) \in \Sigma CP$  whose  $p_i$  is greater than 33 percent
- 3. There are two pair  $(a_1, p_1), (a_2, p_2) \in \Sigma CP$  whose  $p_i$  is greater than 33 percent
- 4. There not exists any pair  $(a_i, p_i) \in \Sigma CP$  whose is greater 33 percent

A complete example of behavior profile generation from data execution is detailed in Example 1.

**Example 1.** Suppose a raw of the execution trace described in the Figure 6.

The data are processed and grouped. In the Figure 7 is shown the result. The second column represents data captured and the third one terms linguistic created from these data. Linguistic terms are implemented by using using fuzzy sets (trapezoidal functions), membership degrees are also shown in the Figure 7 with  $P=Position \ Player(1,13) \ O1=Position \ Opponent1(3,16),$  $O2=Position \ Opponent \ 2(4, 12) \ and \ O3=Position \ O3(2, 12).$ 

Name	Data	Linguistic Term Generated
Distance (P,o1)	3.60	Close $(3.69, 0, 0, 4, 7) = 1$
Distance (P,o2	3.16	Close $(3.16, 0, 0, 4, 7) = 1$
Distance (P,o3)	1.41	Close $(1.41, 0, 0, 4, 7) = 1$
Energy(P)	17	High $(17, 10, 13, 100, 100) = 1$
Protection (P,o1)	5.0	High $(5.0, 4, 6, 380, 380) = 0.5$
Protection (P,o2)	2.0	Normal $(2.0, 1, 3, 3, 5) = 0.5$
Protection (P,o3)	1.0	Low $(1.0, 0, 0, 0, 2) = 0.5$
Distance (P,R*)	15.26	High $(15.26, 13, 16, 38, 38) = 0.75$
Distance (o1,R*)	17.08	High $(17.08, 13, 16, 38, 38) = 1$
Distance $(o2, R^*)$	13.0	Normal $(13.0, 6, 9, 11, 14) = 0.33$
Distance (o3,R*)	13.89	High $(13.89, 13, 16, 38, 38) = 0.29$
Time	15995	Small $(15995, 0, 0, 90000, 150000) = 1$
Iterations at this move-	42	Normal $(42, 18, 30, 42, 54) = 1$
ment		
Memory occu-	924	Low $(924, 0, 0, 768, 1280) = 0.69$
pated(Bytes)		

Figure 7: Data captured during a trace execution and the linguistic terms associated

Then each CP is instantiated with the values of the linguistic terms and if-then fuzzy rules are computed by using the average as t-norm of aggregation for computing computational perceptions as follows (Obtained after processing and computing data in Figure 7):

$$\frac{Distance(A, R^*) = (High, 0.29)}{Attitude = (Cautious, 0.54)} \frac{Distance(P, R) = (Normal, 0.33)}{Energy = (High, 1)}$$

$$\frac{Protection = (Low, 0.5)}{Situation = (Dangerous, 0.83)} \qquad Energy = (High, 1)$$

 $\frac{Distance(J,R^*) = (Normal, 0.33)}{Movement = (Bad, 0.91)} \frac{Distance(P,O) = (Close, 1)}{Energy = (High, 1)}$ 

$$\frac{Memory=(Low, 0.69)}{Resources=(Efficient, 0.76)}$$

Finally, the  $\Sigma CP$  are computed:

- $\Sigma CP_{Attitude} = \{ (wise, 17.53), (brave, 101.55), (cautious, 14.05), (passive, 10.78) \}$
- $\Sigma CP_{Situation}$  { (risky,24.44), (dangerous,651.39), (safe,32.26), (easy,0) }
- $\Sigma CP_{Movement}$  { (good, 24.21), (scared, 0), (kamikaze, 94.82), (bad, 48.01) }
- ΣCP<sub>Ability</sub>{(skillful, 7.56), (little skilled, 0.72), (improvable, 122.2), (very improvable, 31)}
- $\Sigma CP_{Skill}$ {(expert, 38.48), (intermediate, 0), (basic, 31.93), (dummy, 94.88)}
- $\Sigma CP_{Resources}$ {(very efficient, 41.42), (efficient, 121.86), (inefficient, 0), (very inefficient, 15.33)}

From these  $\Sigma CP$  and using the case established in a template, the instantiation is produced. An example of template and its instantiation is showed in the Figure 8. The rest of the sentences for each CP are detailed in the appendix and a complete example is detailed in Figure 8

Template	Instantiation after Bots play session
The bot showed $d_{Attitude} a_{Attitude}$ attitudes.	The bot showed <b>several brave</b> attitudes.
Definitely, $d_{Situation} a_{Situation}$ were safe. The	Definitely, <b>many</b> situations were <b>safe</b> . The
bot proved capable of performing <i>degree value</i>	bot proved to be capable of performing sev-
movements. The bot displayed an <i>value</i> skill	eral good movements. The bot displayed an
level <i>degree</i> times. The bot proved to be <i>value</i>	expert skill level several times. The agent
degree times. During most of the execution,	proved to be <b>skillful several</b> times. During
the measured use of resources demonstrates an	most of the execution, the measured use of
operation that is <i>degree</i> times <i>value</i> .	resources demonstrates an operation that is
	many times very efficient

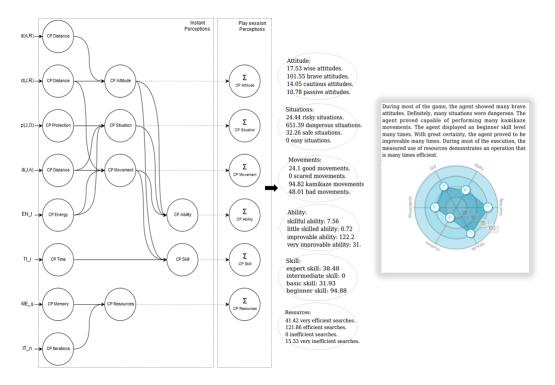


Figure 8: Automatic generation of a bot behavior profile: from trace of execution to linguistic descriptions

# 5. Experimentation and Evaluation

As we mentioned one the most important objectives in AI is to create an agent that simulates the human ability. The bots behavior profile is compared with the human expert player profile (see Figure 9) by using a similarity measure based on REFs. The human player profile was created after that an expert human player played to the computer game with the following result:

- Attitude is mainly brave during the most part of the time.
- Situation is mainly safe during the most part of the time.

- Movements were mainly good during the most part of the time.
- The player is expert.
- The player is skilled.
- The use of computational resource is efficient in time and space

The final grade (from 1 to 7) is computed by using the similarity between the human behavior profile and the bot one. The equation for calculating the final grade is as follows:

$$FG = G_{Min} + S_{Attitude} + S_{Situation} + S_{Movement} + S_{Ability} + S_{Skill} + S_{Efficiency}$$
(1)

- 1.  $G_{Min}$ : 1 point (all the students have 1 point as a minimum score it is mandatory at the University of the Bío-Bío)
- 2.  $S_{Attitude} = S_{REF}(\Sigma CP_{Attitude}^{Human}, \Sigma CP_{Attitude}^{Bot})$  is the similarity between human player and bot attitude.
- 3.  $S_{Situation} = S_{REF}(\Sigma CP_{Situation}^{Human}, \Sigma CP_{Situation}^{Bot})$ : is the similarity between human player and bot situation.
- 4.  $S_{Movement} = S_{REF}(\Sigma CP_{Movement}^{Human}, \Sigma CP_{Movement}^{Bot})$ : is the similarity between human player and bot movements.
- 5.  $S_{Ability} = S_{REF}(\Sigma CP_{Ability}^{Human}, \Sigma CP_{Ability}^{Bot})$ : is the similarity between human player and bot ability.
- 6.  $S_{Skill} = S_{REF}(\Sigma CP_{Skill}^{Human}, \Sigma CP_{Skill}^{Bot})$ : is the similarity between human player and bot skill.
- 7.  $S_{Efficiency} = S_{REF}(\Sigma CP_{Efficiency}^{Human}, \Sigma CP_{Efficiency}^{Bot})$ : is the similarity be-

tween human player and bot efficiency.

where  $S_{REF}$  is a similarity measure between computational perceptions.

The following definition formalizes this measure.

**Definition 5.1.** Given two  $\Sigma CP_i$ ,  $\Sigma CP_j$  whose percentage linguistic vectors  $\{(a_1, p_1) \dots, (a_n, p_n)\}$  and  $\{(b_1, q_1) \dots, (b_n, q_n)\}$  respectively. A similarity measure between  $\Sigma CP_i$  and  $\Sigma CP_j$  is defined as:

$$S_{REF}(\Sigma CP_i, \Sigma CP_i) = \sum_{i=0}^{n} (REF(p_i, q_i))/n$$

being  $REF(p_i, q_i) = 1 - |p_i - q_i|$ 

**Example 2.** Let  $CP^{Human}_{Attitude}$ ,  $CP^{Bot}_{Attitude}$  be two summation computational perceptions for the human player and the computer game bot, respectively:

- $\Sigma CP_{Attitude}^{Human} = \{ (wise, 122.35), (brave, 289), (cautious, 87.59), (passive, 8.75) \}$
- $\Sigma CP_{Attitude}^{Bot} = \{ (wise, 17.53), (brave, 101.55), (cautious, 14.05), (passive, 10.78) \}$

Then, the percentages linguistic vectors are calculated for each  $\Sigma CP$  by using their totals  $Total_{\Sigma CP_{Attitude}}^{But}(507.69)$  and  $Total_{\Sigma CP_{Attitude}}^{Bot}(143.61)$ , respectively:

- $\Sigma CP_{Attitude}^{Human} = \{ (wise, 0.240), (brave, 0.569), (cautious, 0.172), (passive, 0.017) \}$
- $\Sigma CP_{Attitude}^{Bot} = \{ (wise, 0.122), (brave, 0.709), (cautious, 0.097), (passive, 0.075) \}$

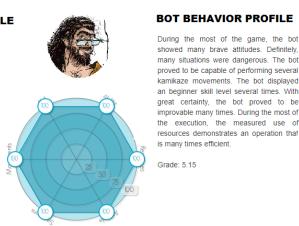
Now, the similarity  $S_{REF}(\Sigma CP_{Attitude}^{Human}, \Sigma CP_{Attitude}^{Bot})$  can be calculated:

- REF(0.240, 0.122) = 1 |0.240 0.122| = 0.882
- REF(0.569, 0.172) = 1 |0.569 0.172| = 0.882
- REF(0.172, 0.097) = 1 |0.172 0.097| = 0.925

#### **HUMAN BEHAVIOR PROFILE**

The human player showed several brave attitudes. Definitely, many situations were safe. The human player proved to be capable of performing several good movements. The human player displayed an expert skill level several times. The human player proved to be skillful several times. During the most of the execution, the measured use of resources demonstrates an operation that is many times very efficient.

Grade: 7



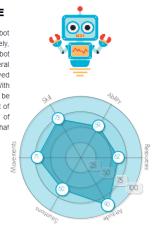


Figure 9: Similarity between hehavior profiles reports: human player versus bots

• REF(0.017, 0.075) = 1 - |0.017 - 0.075| = 0.942

Hence,  $S_{REF}(\Sigma CP_{Attitude}^{Human}, \Sigma CP_{Attitude}^{Bot}) = \frac{3.402}{4} = 0.838$ . The rest of the similarities is computed in a similar way. The final grade together with the linguistic reports generated for the human player and the bot designed by an anonymous student are shown in the Figure 9.

### 6. Conclusions

In this paper a novel and promising technology for automatically generating behavior profile reports and immediate feedback from the traces of execution of the heuristic algorithms has been presented.

The concepts of the algorithm behavior profile has been proposed as a pedagogical tool for evaluating computer game bot quality. A Turing test based on the similarity between bot behavior profile and human player has been defined and implemented. These pedagogical resources provide teachers with an useful tool for getting information about the quality of the heuristic algorithm designed by the students what allows to improving the teaching and the learning process. The project created by the students can be evaluated in any time from two point of view: quantity (performance of the algorithm -space and time-), quality (kind of situations, movements, attitudes, abilities, skills).

As future work we would like to incorporate our technology in other high educational disciplines in order to obtain personalized feedback.

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# Appendix A. Definition of the Computational Perceptions

# Appendix A.1. CP Situation

This CP is defined as follows:  $CP_{Situation} = ((Safe, Easy, Dangerous, Risky), (CP_{Protection}^{player, opponent}, CP_{Distance}^{player, opponent}, CP_{Energy}^{player, opponent} = ((low, intermediate, high), (0,1,...,380))), with low(0,0,0,2), intermediate(1,3,3,5) and high(4,6,380,380); <math>CP_{Distance}^{player, opponent} = ((close, normal, far), (0,1,...,38)), with close(0,0.4,7), normal(6,9,11,14) and dar(13,16,38,38)$ 

Consecuent (Situation)	Antecedent (Protecction, Distance, Energy)
Risky	Intermediate, Close, Normal
Dangerous	Low, Close, Normal
Safe	Intermediate, Normal, Normal
Easy	Low, Normal, Normal
Dangerous	Low, Normal, Low
Dangerous	Normal, Close, Low
Dangerous	Normal, Normal, Low

Cases for CP Situation	Sentence
1	Definitely, degree situations were value
2	degree situations were value
3	$degree situations were value_1$ , although $degree situation also were$
	$value_2$
4	Diverse situations were detected during the most part of the play
	session

# Appendix A.2. CP Attitude

This CP is defined as follows:  $CP_{Attitude} = ((Wise, Brave, Cautious, Passive), (CP_{Distance}, CP_{Distance}))$  and  $CP_{Distance}^{Oponnet,R*} = ((close, normal, far), (0,1,..., size(scenario)))$  with close(0,0.4,7), normal(6,9,11,14) and far(13,16,38,38), being R\* the closest reward to the agent;  $CP_{Distance}^{player,R*} = ((close, normal, far), (0,1,..., size(scenario)))$  with close(0,0.4,7), normal(6,9,11,14) and far(13,16,38,38), being R\* the closest reward to the agent;  $CP_{Distance}^{player,R*} = ((close, normal, far), (0,1,..., size(scenario)))$  with close(0,0.4,7), normal(6,9,11,14) and far(13,16,38,38), being R\* the closest reward to the agent

Consecuent(Attitude)	Antecedent (Distance,Distance)
Wise	Close, Normal
Brave	Close, Close
Cautious	Normal, Close
Passive	Normal, Normal

Cases for CP Attitude	Sentence
1	During the most part of the play session, the bot showed <i>degree</i>
	attitudes value
2	The bot showed <i>degree</i> attitudes <i>value</i>
3	The bot showed degree attitudes $value_1$ , but also it showed degree
	attitudes $value_2$
4	The bot does not show a particular attitute during the play ses-
	sion'

# Appendix A.3. CP Movement

This CP is defined as follows:  $CP_{Movement} = ((Good, Bad, Scare, Kamikaze), (CP_{Distance}^{player,R*}, CP_{Distance}^{player,opponent}, CP_{Enery}^{player}))$ , with  $CP_{Distance}^{player,R*} = ((close, normal, far), (0, 1, ..., size(scenario)))$  with close(0,0.4,7), normal(6,9,11,14) and far(13,16,38,38), being R\* the closest reward to

the agent;  $CP_{Distance}^{player,opponent} = ((close, normal, far), (0,1,..., size(scenario)))$  with close(0,0.4,7), normal(6,9,11,14) and far(13,16,38,38), ;  $CP_{Enery}^{player} = ((low, normal, high), (0,1,..., size(scenario)))$ 

Consecuent(Movement)	Antecedent(Distance,Distance,Energy)
Good	Close, Mormal, Normal
Good	Close, Close, Low
Scare	Normal, Normal, Normal
Kamikaze	Close, Close, Normal
Bad	Normal, Close, Normal

Cases for CP Movement	Sentence
1	Certainly, <i>degree</i> of the movements performed by the bot were
	value
2	The bot proved to be capable of performing <i>degree</i> movements
	value
3	The bot proved to be capable of performing <i>degree</i> attitudes
	$value_1$ , but also performed <i>degree</i> movements $value_2$
4	The bot performs indistinctly several movements during the play
	session

Appendix A.4. CP Ability

This CP is defined as follows:  $CP_{Ability} = ((\text{Expert, Intermediate, Basic, Dummy}),$  $(CP_{Attitude}, CP_{Movement}, CP_{Time}))$  with  $CP_{Time} = ((\text{little,normal,large}), (0, 1, max\_time))$  with little, normal, and large

Consecuent(Ability)	Antecedent(Attitude,Movement,Time)
Expert	Wise, Good, Small
Intermediate	Brave, Good, Normal
Basic	Passive, Bad, Much
Dummy	Passive, Scare, Much

Cases for CP Ability	Sentence
1	Clearly, the bot displayed a/an value player degree times
2	The bot displayed a/an value player degree times
3	The displayed a/an value player $degree_1$ times, however $degree_2$
	times it acted as $a/an \ value_2$
4	No kind of player has been identified

# Appendix A.5. CP Skill

This CP is defined as follows:  $CP_{Skill} = ((Very\_Skilled, Skilled, Improvable, Very\_Improvable),$  $(CP_{Attitude}, CP_{Movement}, CP_{Situation}))$ 

Consecuent(Skill)	Antecedent(Attitude,Movement,Situation)
Very_Skilled	Wise, Good, Easy
Skilled	Cautious, Good, Safe
Improvable	Brave, Bad, Dangerous
Improvable	Passive, Bad, Risky

Cases for CP Skill	Sentence	
1	Certainly, the bot proved to be <i>value degree</i> times	
2	The agent proved to be <i>value degree</i> times	
3	The agent proved to be $value_1 \ degree_1 \ times$ , nevertheless $degree_2$	
	times proved to be $value_2$	
4	No kind of skill can be proved at the current play session	

# Appendix B. User's Manual

This section aims to explain in detail the use of the web platform for automatically generating human player and bot behaviour profiles from execution traces. A quick test of the application can be performed by downloading examples of traces at the following URL:

# http://youractionsdefineyou.com/assess/web/examples\_traces

First, the user must access to the URL:

### |\protect\vrule widthOpt\protect\href{http://www.youractionsdefineyou.com/assess}{http://www.you

The main window shows two options: log in and register. The register of a user consists in introducing email, user name, full name, RUT and password. A confirmation via email will be sent to the user if the registration was correct. The log in of a user consists in introducing the user name and the password. Second, behaviour profile report can be obtained by selecting and loading an execution trace file, then the behavior profile report is automatically generated. Additionally, the report can be exported in PDF (see Figure B.10)

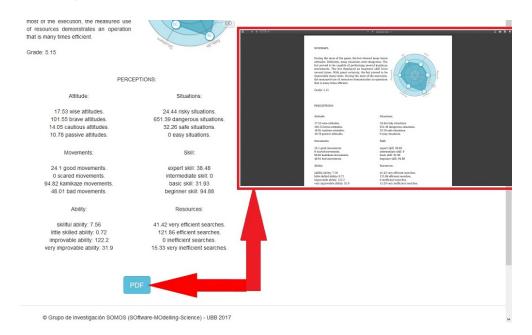


Figure B.10: Linguistic Report obtained from a trace of execution of a human expert player

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