

# AGENT-BASED MODEL FOR THE CONTROL AND MONITORING OF KPI IN A CURRICULUM: CIVIL ENGINEERING DEGREE IN INFORMATION TECHNOLOGY

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## ABSTRACT

The present work proposes an intelligent agent model for the control and monitoring of KPI (key performance indicator) that impacts on the profile of professional exit. The intelligent agent allows to verify the performance of KPIs that impacts on professional performance in a civil engineering career in computing at UC Temuco, Chile. It can be seen that the development of KPIs obeys the integral control panel where the agent behaves. In this work we have worked with 8 KPI for the control and monitoring in a curriculum of undergraduate training.

## KEYWORDS

Intelligent Agent, Control, KPI, Curriculum, Professionals

## 1. INTRODUCTION

Training by competencies, why? These are the questions asked by the team of academics of the Civil Engineering degree in Computer Science at the Catholic University of Temuco in Chile during the years 2008 - 2009 (Lévano et al, 2016; Herrera et al, 2009) with a focus on the need to answer challenges that lead to the training of professionals with tools in computing. It was enough a series of participatory works in cloisters, work meetings, attendance to congresses, consultations to the student medium, business environment, consultations to specialists and graduates, that allowed to build the paths to develop the formation of computing in the career of Computer Engineering. Responding like this, to the current challenges of the new millennium. Where it seeks to promote and intend the graduation profile, to respond to the demands and demands of the labor market with respect to computer technologies based on general and specific competences (Lévano and Herrera, 2012; Tobón, 2007; Lévano, 2020).

UCT Educational Model: In our university, we define competence as: “to know how to behave, using our own means and outside resources in order to solve real problems in an effectively and ethically responsible manner”. We also distinguish two kinds of competences or skills, the generic competences, which are shared among all the programs and the specific competences which are directly related to the areas of study of each program. The educational model in our university (Lévano and Albornoz, 2016; Lévano, 2020), is based on five axes.

### 1.1 Problem

Decision makers have to adapt to the constant problems of dynamic complex context in the development of a University. Changes as for example: why the approval rate in such level, of such generation has fallen in this year?, Why the students do not manage to be titled opportunely ?, Why the students defect in the initial process ?, Why the do students drop out by the third year? How can we achieve quality according to the demands of the education ministry? How do we monitor that the learning outcomes are being achieved?, among others.

## 1.2 Proposal

Through this work we propose an intelligent agent model for the control and monitoring of KPI (key performance indicator) (Kovacevic and Reynoso, 2017; Porter, 1987; Norton and Kaplan, 2000; Medne, Lapina and Zeps, 2022; Leiber, 2022), in a curriculum for an undergraduate degree, such as the Civil Engineering degree in Computer Science at the Catholic University of Temuco (Lévano and Herrera, 2012; Lévano and Albornoz, 2016).

This work is composed of the following sections, the introduction that exposes the context, the problem, the proposal and the fundamentals of agents, section 2 describes the hypotheses proposed, section 3 describes the architecture of the agent-based model, the strategic map of agent behavior, KPI's integral scorecard that allow to measure the behavior of the agent, in section 4 the results are exposed, then the conclusions and references.

## 1.3 Agent-Based Model

Agent-based models (ABMs) are particularly suitable for studying. Complex adaptive systems (CAS) (Banks, 2002a; Canessa, 2002). In general terms, a CAS is one where numerous elements, parties or agents. (homogeneous or not) interact in a non-linear way. The one with the other and with its environment, such that its properties can be modified as a result of these interactions (Canessa and Riolo, 2003). Traditional approaches to studying CAS (Canessa and Riolo, 2003) often limit our ability to understand the complete complexity of these systems, in part because the CAS characteristics (eg, dependent on the dynamic route) violate many of the presumptive statistics needed to use those approaches (ie, survey research, controlled experiments, game theory) (Bonabeau, 2002).

The distinctive feature of ABMs is that they are constructed “from the bottom up”, defining the model in terms of entities and dynamics at the micro level, that is, at the level of individual actors and their interactions with each other and with the environment. (Banks, 2002a; Canessa, 2002).

An ABM consists of one or more types of agents, and possibly a non-agent environment (for example, in a prey predator ABM, the environment could be the food of the prey, example: if the prey is sheep and predators are the wolves The environment could be the grass. Agent definitions include the specification of their capabilities to determine particular behaviors, as well as the decision-making norms and other mechanisms that agents use to choose their own behaviors.

## 2. HYPOTHESIS

In this section, we expose two hypotheses related to KPI (key performance indicator) (Kovacevic and Reynoso, 2017; Porter, 1987; Norton and Kaplan, 2000; Medne, Lapina and Zeps, 2022; Leiber, 2022), organizational climate and demand according to labor market competencies, seeing how it impacts the decisions of the university organization at lower levels.

### 2.1 Effect of Organizational Climate on the KPI

The KPIs (Kovacevic and Reynoso, 2017; Porter, 1987; Norton and Kaplan, 2000; Medne, Lapina and Zeps, 2022; Leiber, 2022) are the key business indicators that help to account for the efficiency and productivity of the actions, thus responding to the tasks planned in the set of projects designed to achieve the objectives based on goals and the realization of the strategic plan (Norton and Kaplan, 2000).

Regarding the organizational climate we can specify it as an organizational climate (CO)  $i$  with dimension  $N$ , where we define that there is a greater increase in CO if the variability is lower, otherwise the CO degree will be smaller and the variability is greater or distant. Thus, we can observe how the KPI is disturbed in its performance. Therefore we can summarize the following hypothesis:

*H1: The higher the organizational climate, the greater the wealth of KPI performance.*

## 2.2 Effect of Competency Demands on the Labor Market in the KPI

The demand for requirements in skills or abilities come from the labor market, leading to unique attributes that are grouped in soft skills, hard competition or semi-hard competitions. The demand obeys to the different areas of computing in technical and scientific knowledge.

The current behavior in the case of Chile, the demand for programmers at different levels with focus on the line of software development. There is also the line of information and communication technologies very highly demanded. We can specify that the demand of labor market competences (ECML) and with dimension N, where we define that there is a higher degree of ECML, if the variability is lower and in another case the ECML degree will be lower and the variability is greater or distant.

In this way, a KPI achieves its expected value  $E(KPI)$ , if the ECML is of lesser degree and remains in time. On the other hand, a KPI does not achieve its expected value  $E(KPI)$ , if the ECML is of a higher degree and does not remain in time.

*H2: Greater demand for skills in the labor market, the lower the wealth of the KPI's performance.*

## 3. INTELLIGENT AGENT DIAGRAM

This section describes the conceptual framework and mechanisms as a physical problem, and the hypotheses are described in sections 1 and 2 (Figure 1).

The representation of our organizational system, which is a university educational entity, is treated as a conceptual scheme that connects the business perspectives (such as customer, financial, process, growth, and innovation) with a focus on quality in teaching and learning.

The system can be treated as a case of data clustering in an n-dimensional space (Lévano and Nowak, 2009). The objective is to find optimal clusters that represent a strong interaction between the effective communication (*ce*) of the agents, and for this there are  $x_i$  agents (data) and  $y_j$  points called nodes. Clusters are sought by minimizing the quadratic distance between data and nodes, which will be called energy,

$$E_{ij} = \frac{1}{2} |x_i - y_j|^2$$

The total energy of the system will be given by,

$$E = \sum_i \sum_j P_{ij} E_{ij}$$

Where  $P_{ij}$  is an unknown probability of finding a given data point  $i$  with node  $j$  at position  $y$ . How do we find the node positions and the probability that minimizes the energy  $E$ ? This is solved by putting the system in a thermal reservoir at different temperatures. This contact maximizes for a given temperature the entropy or minimizes the Helmholtz free energy (Nowak and Haeussler, 2013; Lévano and Nowak, 2009).

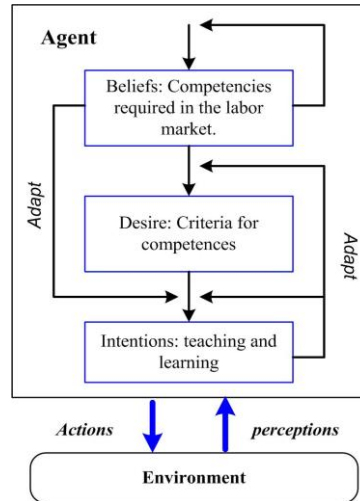


Figure 1. Agent-based model schema

### 3.1 Strategic Map of the Career Where the Agent Behaves

Strategic focus: Academic excellence in the training of computer professionals, with an identity in the assessment and respect for diversity and social responsibility.

Therefore, based on the strategic career map, the following perspectives are formulated, reflecting the agent's performance.

Perspective of client (PC): in this perspective the objectives are to strengthen the extension and link with other public and private institutions (C1). Improve the student's bond (C2).

KPI performance measures are:

- a) KPI 1: Impact activities related to the career  $N^{\circ}$  activities with impact evaluation in the middle. # (unit of measurement)
- b) KPI 2: Institutional positioning of the career. Percentage of participation of subjects related to computing. % (unit of measurement)

Financial perspective (FP): In this perspective, the objectives are, Manage the resources to support the planned activities, allowing sustainability (F1).

- a) KPI 3: Retention rate  $(A/B)*100$ , A= number of students admitted in the year they enrolled, B= number of students admitted in the year by admission cutoff. % (unit of measurement)
- b) KPI 4: Timely Graduation Rate  $(\text{Number of students who graduated in 5 or 6 years}) / (\text{Total number of admissions court})$ , % (unit of measurement)

Process perspective (PP): in this perspective the objectives are to strengthen the curricular program for student development (P1).

- a) KPI 5: Support workshops for critical courses Cumulative Nominal. # (unit of measure)
- b) KPI 6: Annual percentage of wellness service coverage.  $(A/B)*100$ , A= wellness services coverage B= Wellness service. % (unit of measurement)

Perspective of learning and growth (PA): in this perspective the objectives are, To consolidate the formation of the educational development in the undergraduate (A1).

- a) KPI 7: percentage of self-evaluations applied in the career to teachers.  $(A / B) * 100$ , A = N° of self evaluations carried out, B = Number of teachers evaluated planned. % (unit of measurement)
- b) KPI 8: Accreditation of the race  $A = A + X$ , A = number of successful years of accreditation in the race X = No of years of accreditation. # (unit of measurement)

## 4. DISCUSSION AND RESULTS

To check the behavior of the agent, a descriptive statistical study of qualitative aspects was carried out. For the discussion of H1 hypothesis, the following sample of 24 graduates from a population of 82 professionals graduated at the national level, Observation Year 2014, was designed. Among the questions that were consulted were:

- Did the degree from which he graduated and the Catholic University of Temuco have a good placement policy and graduates? What he gave as a result: that 14% strongly disagree, 29% said they disagreed, 43% agreed, and 14% strongly disagreed.
- There an efficient process of the university or career to track graduates and graduates? What resulted was that 27% strongly disagreed, 32% said they disagreed, 27% said they agreed, and 14% strongly disagreed.
- Does the university currently offer alternatives for improving or updating its graduates and graduates? What resulted was that 26% strongly disagree, 36% said they disagreed, 32% said they agreed, and 9% strongly disagreed.

It can be observed from the race that the tools taught during the race are well valued and that they are adapted to face the labor field. The weakness is in improving the process of monitoring the graduate. In the part A, regarding the performance of KPIs against H1 hypothesis, we can have evidence of the behavior of the agent according to the architecture (Figure 1).

### 4.1 Behavior of the Agent Against Hypothesis H1

Case 1: The higher the organizational climate, the greater the wealth of the KPI performance, if only when the time is shorter, where CO is higher and the variance is lower, then E (KPI) has good performance, but because of the short time the KPI must change, which implies that the agent must adapt.

Case 2: The greater the organizational climate, the greater the wealth of the performance of the KPI, if only when the time is less, where CO is lower and the variance is greater then the E (KPI) does not perform well.

Case 3: The greater the organizational climate, the greater the wealth of the performance of the KPI, if only if, when the time is greater, where CO is greater and the variance is lower then the E (KPI) has good performance.

Case 4: The higher the organizational climate, the greater the wealth of the KPI performance, if only when the time is longer, where CO is lower and the variance is greater then the E (KPI) has a regular performance.

This shows that the KPI indicators that the agent model has are key to the performance of teaching in the career, so much so that it demonstrates the effectiveness and productivity of the actions carried out, thus responding to the tasks planned in the set of projects designed to achieve the objectives based on the goals and improvement plan. For this agent, they show that with a lower variance, the organizational climate is higher or indicates a good performance of the KPIs (part A). In other cases there is no good performance or performance is not achieved, or there is a good performance but short durability, which leads to generate new reformulations of KPI, resulting in economic losses and redesigns in operational activities in an organization.

Regarding the hypothesis H2, to check the behavior of the agent, a descriptive statistical study of qualitative aspects was carried out. For the discussion of hypothesis H2, the following sample of 16 employers from a population of 37 employers at national level was designed, the year of observation was 2014. Among the questions that were consulted were respects in criteria referring to the specific and general competences of the career of civil engineering in computer science, such questions were:

- You. Do you think that the abilities related to applying engineering sciences are observable and demonstrate that they apply deductive logical reasoning to address problems of technological systems? What he gave as a result: that 7% said regular, and 93% said good.
- You. Do you believe that the capabilities related to modeling and applying compilation science procedures are observable and demonstrate that they apply computer science procedures to address problems of technological systems in information technologies and software development? What he gave as a result: that 13% said regular, and 83% said good.
- You. Do you believe that the capabilities related to the management of information technologies are observable and are demonstrated in that it manages systems that involve the use of hardware and software in an organization for the automation of management systems and production processes? What he gave as a result: that 6% said regular, 6% said bad, and 88% said good.
- You. Do you think the capabilities related to software development are observable and are shown in developing software solutions appropriate to one or more application domains using an engineering approach? What he gave as a result: that 13% said regular, and 87% said good.
- You. Do you believe that the capacities related to the assessment and respect for diversity are concerned with the development of the other in its human dimension, understanding that social, religious, gender, cultural and capacity differences enrich coexistence? What he gave as a result: that 25% indicates regular, and 75% indicates good.
- You. Do you believe that the capacities related to ethical action, is demonstrated ethical sense based on principles, values of justice, common good and the absolute dignity of the human person that translates into attitudes and actions at the service of society? What he gave as a result: that 13% indicates bad, 25% indicates regular, and 63% indicates good.

It can be observed that the general and specific competences (Lévano and Herrera, 2012) taught during the career are well valued, and they are adapted to face the labor field. The weakness lies in improving the process of monitoring the behavior of the labor market according to the economy of the country and the world. In the part B, regarding the performance of the KPIs versus the H2 hypothesis, we can have evidence of the behavior of the agent according to the architecture (figure 1).

## 4.2 Behavior of the Agent Against Hypothesis H2

Case 1: Greater demand for skills in the labor market, the lower the wealth of the performance KPI, if and only if, the time is constant, where labor market competition demand (ECML) is lower and the variance is lower then the E(KPI) presents good performance.

Case 2: Greater demand for labor market skills, less wealth of the performance of the KPI. If and only if, the time is constant, where labor market competition (ECML) is lower and the variance is higher, then the E(KPI) presents good performance.

Case 3: Greater demand for skills in the labor market, less wealth is the performance of the KPI., If and only if, the time changes, where demand labor market competition (ECML) is higher and the variance is lower, then the E(KPI) does not achieve performance.

Case 4: Greater demand for skills in the labor market, less wealth will be the performance of the KPI. If and only if, the time changes, where demand labor market competition (ECML) is higher and the variance is higher, then the E(KPI) does not achieve performance.

## 5. CONCLUSIONS

The training of professionals in a training model by competences leads to generate a series of KPI as part of the teaching and learning process in order to validate the specific and general competences in training.

We believe that the analyzes made possible by an ABM can provide a guide for empirical research efforts and to support hypotheses about the relationships between variables associated with KPI, which can then be evaluated using other research methods.

We can also conclude that when it is not possible to obtain the wealth of the KPI in its expected value, this leads to an instability in the system, which causes losing focus and generating downtime and economic losses.

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