An approach towards the integration of Adaptive Business Intelligent and Constraint Programming

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Abstract

Adaptive Business Intelligence is the discipline that combines prediction, optimization and adaptability into a system answering two important questions: What would probably happen in the future? and What is the better decision now? To build such system, first of all we must understand methods and techniques that provide prediction, optimization and adaptability. Hundreds of authors have already investigated about business intelligence, data mining and prediction methods and optimization techniques. However, none of them has explained how to combine these concepts into a system that is able to predict, optimize and adapt. In this article we propose a working framework, which allows incorporate constraint programming as adaptive business intelligence, in the development of adaptive business intelligence software.

1. Introduction

Business Intelligence is a technology for business management, which covers aspects of data management for decision making. It includes data management in terms of its extraction from systems, cleansing, transformation, data structures design or special data store forms for the exploitation of data through business tools. The technology which supports Business Intelligence is based on the following concepts: Online Analytic Processing (OLAP), Data warehousing and Data mining.

To implement Adaptive Business Intelligence (ABI) the available data should be prepared, to allow its analysis, also should develop modules containing a prediction model based in data mining results, in turn requires an optimization module that helps to choose the best alternative, and an adaptation module that allows the prediction model is adapted to the changing environment. Using this framework, there are three important modules, prediction, optimization and adaptation.

Constraint Programming (CP) is a software technology used for solving large complex problems, which has a wide range of applications. There are ramifications of this technology, for example constraint satisfaction programming (CSP), that consist to find solution with a configuration that respects all restrictions, finding also the optimal solution, CSP turns into Constraint Satisfaction Optimization Problem.

In this paper raises the possibility of merge ABI with CP, in a context of possible applications for ABI at the Pontifical Catholic University of Valparaíso (PUCV) School of Computer Engineering. The strategic guidelines are several, but the study will focus on the hard problem of reformulates curricular mesh of professional career and balancing academic burden. The proposal involved in optimization module incorporated within, CSOP technology.

The paper is structured as follows: in section 2 describes what is Business Intelligence. In section 3 is showed the structure of an Adaptive Business Intelligence system. Section 4 describes what is Constraint Programming. Section 5 describes the proposal, and the last section presents the conclusions and further work.

2. Business Intelligence

It’s called Business Intelligence to the set of strategies and tools focused on creation and management of knowledge through the analysis of existing data in an organization or company.

This set of tools and methods have in common the following characteristics:
- Accessible information: Data is the primary source of this concept. The first thing that must ensure this type of tool and techniques will be user access to data regardless of the source of these.
- Support in decision-making: It seeks to go beyond the presentation of the information, so users have access to analysis tools that enable them to select and manipulate data only those of interest to them.
- Guidance to final user: It searches independence among user’s technical knowledge and their ability to use these tools.

According to their level of complexity Business Intelligence can be classify in:
- Queries and reports
- OLAP cubes
- Data Mining
- Enterprises projection systems

To being a competitive company, the people who make decisions needs a quickly and easily access
information from the company and this is done through Business Intelligence. The organizational intelligence is the process of analyzing data from the company in order to extract knowledge from them. With BI can: create a customer database, provide sales and rebates, sharing information between different departments and improving customer service. Organizational Intelligence comprises at least:

- **Multidimensionality:** This information is found in spreadsheets, databases, etc. Gathering scattered information throughout the company and various sources to provide to departments of accessibility, power and flexibility they need to analyze information.
- **Data Mining:** Companies often collect information about production, markets and customers, but in fact the success of the business depends on the vision to intuit changes or new trends. Data mining applications identify trends and behaviours to extract information and discovering relationships in databases that reveals behaviours little obvious.
- **Agents:** They are programs that realizes basics task without human intervention.

Also BI can be marked as an e-business component. According [1] the concept of e-business was originally coined by IBM in 1997, within its business strategy and consultants for their clients. Define as: “A sure, flexible and integrated way to achieve a differentiated value by combining systems and processes that govern the basic business operations with the simplicity and scope enables Internet technology”.

The concept surpasses IBM inspiration, and today has become a widely used generic, which can be described in the following formula [1]:

\[ \text{eB} = (\text{e-c + CRM + PS + BI + VO + SCM}) \times \text{IT} \]  \hspace{1cm} (1)

- **e-c:** Electronic Commerce
- **CRM:** Customer Relationship Management
- **PS:** Payment System
- **BI:** Business Intelligence
- **VO:** Virtual Organization
- **SCM:** Supply Chain Management
- **IT:** Information Technology

### 3. Adaptive Business Intelligence

The need to create an Adaptive Business Intelligence, which comes that today’s organizations operate in a changing environment and constantly adapting and making adjustments. An ABI system contains three important components, Prediction Module, Optimization Module and Adaptation Module [2].

Figure 1 show the structure of an Adaptive Business Intelligence system.

- **Prediction Module:** Its function is to create an output (a prediction), based on a given information. Order to make functional Prediction Module, prediction models are trained, through historical inquiries, which will use to learn.
- **Optimization Module:** It should recommend the best answer, using as input the outputs delivered by the prediction module. Optimization module generates a distribution solution that serves as input data for the prediction module. The optimization module then uses the predicted to gauge the quality of the input data.
- **Adaptation Module:** Its aim is the predictions made can be modifying if environment changes, so prediction module can learn and adapt to change. The adaptation module should compare the predictions made with reality. If there are differences, adaptation module reconfigures prediction module to reduce the differences.

### 4. Constraint Programming

Constraint Programming (CP) is a software technology used for description and further resolution of large and complex problems, particularly combinatorial, which may have many applications in real life.

Among the recent applications can appoint those such as [3]:

- **Computer graphics** (to express geometric consistency on scene analysis).
- **Natural language processing** (to build efficient analysis programs).
- **Databases systems** (to ensure and restore data consistence).
- **Operation research problems** (for optimization problems).
- **Molecular biology** (to order DNA).
- **Business applications** (business options).
• Electric engineering (to detect fails).
• Circuit design (to compute provisions).

4.1. Definition of a CSP

A constraint satisfaction problem (CSP) can be defined as a tuple \(<X, D, C > [4]\):
\[\begin{align*}
X &= \text{a set of n variables } x_1, ..., x_n. \\
D &= \text{an array of domains. The ith component } D_x \text{ is the domain that contains all possible values that can be assigned to the variable } x_i. \\
C &= \text{a set of finite restrictions. Each nth restriction } (C_n) \text{ is defined on a set of variables } x_1, ..., x_n \text{ restricting values that variables can take simultaneously.}
\end{align*}\]

In this paper there is a proposal to merge ABI with CP, for this intervene in optimization module of figure 1, in the next sections are given more details of the proposal. By using CP techniques for the optimization module that is responsible for providing the best answer, is how to deal with solving a CSOP (Constraint Satisfaction Optimization Problem).

4.2. Definition of a CSOP

A CSOP can be defined as a tuple \([4] <X, D, C, f >\) where:
\[\begin{align*}
<X, D, C, f> \text{ define as CSP } <X, D, C> \text{ along with a function } f \text{ value that allows a mapping of each } S \text{ solution with a numerical value.}
\end{align*}\]

Wanted find \(S\), which minimizes or maximizes the value of \(f(S)\) depending on the results of the problem requirements.

5. ABI Implementation at PUCV’S School of Computer Engineering

The educational system in Chile and in particular the university sector have experienced a significant qualitative and quantitative change, which has led to rethink how to tackle the current challenges that modern society demand. In this way each university has embarked on reforms that provide for actions in its internal management, academic planning, and links with the means and generally rethinking the educational role compared to the needs and requirements of our country and the global environment.

For our university and especially for the School of Computer Engineering this reality has led to sustained growth that has seen the number of students between the two careers Enforcement Computer Engineering and Civil Computer Engineering, as well as emphasizing the creation of a Master program, begun last year, and has positioned the School of Computer Science as an entity of the area's most renowned and scope.

The previous background, require the establishment of a Strategic Plan, which allows guide the development of the School of Computer Engineering, and allow it to successfully confront the challenges of the coming years. This plan provides a set of proposals to make, which are based on the analysis of past and present, which allow projecting and positioning of PUCV’s School of Computer Engineering in the educational field. Thus Strategic Planning has become a necessity to face the future, the challenges and changes that will determine the ability of developments that give competitive differences in this new educational arena.

The School of Computer Engineering, understands that an efficient implementation of the Strategic Plan arranged passes by availability of financial resources as human resources. That is why it is essential to explain under this perspective, the strategic guidelines governing its operation.

The successful implementation of the Strategic Plan for PUCV’s School of Computer Engineering, requires an adaptive capacity that allows adjusting actions and mechanisms raised according to the constant changes that are suffering the educational process and society in general, by product aside from technological innovations and on the other to a higher level of expertise in the professional development and maturity in the acquisition of knowledge.

Thus, the strategic lines presented in the plan, describes the current work of the School of Computer Engineering and its future on the horizon, with the understanding that working together and responsible commitment to the proposed actions, will enable move forward and develop internally, what inevitably affect the quality in the process of training of professionals and hence to national development and also international development.

In this way, are raised to develop strategic objectives, but also presents itself as a core activity reviewing and adapting of the Strategic Plan, which will be evaluated periodically in accordance with the needs and requirements identified in its operation. For this it is essential the implementation of technical and business intelligence tools to monitor compliance with the plan by analyzing their performance indicators.

5.1. Strategic Planning Process

The process of Strategic Planning for the School of Computer Engineering is conceived as a mechanism that guides the actions of the different branches and allowing for a progressive and efficient advance in pursuit of academic excellence, professional and operational. From this perspective the graphic model of figure 2 shows which corresponds to the process of Internal Strategic
Planning, which regularly rises and restructuring to adjust to the realities required.

In this context, the Functional Strategic Orientations are: (1) Strengthen Quality and Excellence in Education Process, (2) Improvement and Increase Academic Plant, (3) Enhance activities for Research and Innovation and Development Program for Advanced Studies, (4) Increase Efficiency of Internal Management in the School and (5) Promoting Linkages with the External Environment and Internationalization.

5.2. Evaluation Mechanisms and Performance Indicators

The establishment of evaluation mechanisms, is required to conduct a management control for each of the action plans proposed (see [5]) in the Strategic Plan. For the development of this proposal we will focus on the first functional strategic direction: Strengthen the Quality and Excellence of the educational process, it is clear in the plan the need for indicators. The Table 1 shows some indicators.

5.3. Constraint Programming Application

It is proposed incorporating constraint programming techniques in the optimization module. To perform the analysis of this proposal are considered results of two indicators: the amount of updated programs and the amount of courses incorporated based on competency focus per semester.

As explained in section 3, it is required the development of an optimization module able to recommend the best answer, which this "best answer" is based on the output prediction module. For example, to evaluate the success of updating curricula and the incorporation of focus based on competency, we have to predict the number of students who successfully complete their studies and the rate of disapproval by subject. Relationships between prediction and optimization modules are shown in figure 3.

A key factor to consider when assessing the academic success of students is the academic burden they have in each semester. The usual way of measuring this burden is allocated for each course, a number of credits that represent the amount of effort required to successfully continue the course. Thus, the academic burden of each period is given by the sum of the credits for each course inscribed in the period. Usually, it is explicitly imposed several restrictions when developing the curriculum. For example, it must define a burden maximum period to prevent overloading and to establish several relationships precedence over some courses.

In the proposed scheme, the optimization module generates a solution of balanced curriculum mesh which serves as input to prediction module. These inputs provide an allocation of subjects for each semester, and the prediction module should generate the prediction success rate students. The optimization module then uses this information (i.e., data output) to gauge the quality of input data: More high success rates for students, improved data entry and therefore the quality of the program studies.

To maximize the quality of the curriculum, the optimization module trying many combinations of different input data to the problem of balancing curriculum meshes and then evaluates the data output. Many programming techniques with different restrictions can build an efficient optimization module, more detail regarding these can be found in [3, 4].

Table 1: Some Indicators
The BACP (Balanced Academic Curriculum Problem), initially proposed in [6], is to design a balanced academic curriculum by assigning periods courses in a way that the academic burden for each period will be balanced, that is, as similar possible. The curriculum must comply with the following administrative and academic regulations:

- Academic Curriculum: an academic curriculum is defined for a range of courses and a set of prerequisites associated with these.
- Number of Periods: courses must be allocated within a maximum number of academic periods.
- Academic Burden: each course has a number of credits or units which represents the effort required for academic success.
- Prerequisites: several courses have other courses as prerequisites.
- Minimum Academic Burden: requires a minimum number of credits for time to consider a full-time student.
- Academic Maximum Load: a maximum number of credits for that period should not be exceeded.

The goal is to assign a time for all courses so as to satisfy the restrictions of minimum and maximum number of courses for each period, and prerequisites relations.

An optimal balanced curriculum minimizes the maximum academic burden from all periods. You can consider other criteria of balancing such as minimize the amount of the academic burden from all periods. It assumes that a balanced academic burden favours habits and facilitates academic success of students.

An Integer Programming model for the problem of balancing an academic curriculum can be seen in [7].

The proposed adaptive scheme is based on 4 components exchanging information [8] (see Figure 4).

The SOLVE component runs a generic CSP solving algorithm performing a depth-first search by alternating constraint propagation with enumeration phases. SOLVE has a set of basic enumeration strategies (could be include local search heuristic), each one characterized by evolving a priority for the resolution: the other components assess these strategies and update these priorities. For each enumeration, the dynamic strategy resolution selects the basic strategy to be used based on the attached priorities. SOLVE is also able to perform meta-backtracks (jump back of a sequence of several enumerations and propagation phases) to repair a "desperate" state of resolution, for example, when changing strategies is not enough due to several very bad previous decisions. The OBSERVATION component aims at observing and recording some information about the current search tree, i.e., it spies the resolution process in the SOLVE component. These observations (called snapshots) are not performed continuously, and they can be seen as an abstraction of the resolution state at a time t. Taking a snapshots consists in extracting (since search trees are too large) and recording some information from a resolution state. The ANALYSIS component examines the snapshots taken by the OBSERVATION: it evaluates the different strategies, and provides indicators to the UPDATE component. Indicators can be extracted, calculated or deducted from one or several snapshots from the database of snapshots. The component UPDATE makes decisions using the indicators. It interprets the indicators, and then updates the enumeration strategies.
priorities and requests, if necessary, some meta-backtracks in the SOLVE component.

Figure 4: Framework approach to a dynamic strategy resolution.

6. Conclusions and Future Work

Over the past few decades, organizations have the ability to improve their decision-making capacity of collecting and storing more data. The need to convert the raw data into usable knowledge has fuelled the growth of industry of intelligence business, which provides software tools to retrieve summarize and interpret data to final users. Most of these business intelligence systems can: (a) accessing data from a variety of sources, (b) facilitate the transformation of data into knowledge, (c) show this knowledge through a variety of graphics reports. But this does not seem to be enough.

Today, besides the prediction and optimization, the concept of adaptability is also central to the Adaptive Business Intelligence. Adaptability has already been introduced to many consumer products, including transmissions of vehicles, television sets, and sneakers. As these products manufactured in series can be adapted to the preferences of a unique proprietorship, they quickly gain popularity with consumers around the world. The logical extension of this trend is adaptive software: a software system manufactured in series that can be adapted to the daily operation of any organization, in our case, in the field of education.

Another level of adaptability that is presented in section 5.6 for solving the problem of balancing curriculum meshes. Here, special emphasis should be placed on modelling and resolution through strategies listing of variables and values and spreading restrictions, in a dynamic way, moving so quickly to exploit the most promising areas of trees search for a solution to this kind of problems and therefore optimize memory requirements.

The aim is to validate this approach to the implementation of business intelligence model proposed 5 in monitoring the strategic plan of PUCV’s School of Computer Engineering introduced in section 5.1 [5].

7. References