

Introduction to Computational Intelligence Business Applications

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Abstract. Computational intelligence business applications have been developed since the early days of computing and are now commonly found in many aspects of modern society. This paper briefly surveys historic applications of computational intelligence in different business contexts. In addition, it describes this type of application from a business point of view, where computational intelligence is used as a source of competitive advantage. It concludes with an analysis of how organizations may create the proper environment and effectively use computational intelligence to improve their business.

1 Introduction

The problem of teaching a computer how to acquire knowledge and exhibit intelligent behavior has been explored since beginnings of computing [1]. Following Alan Turing's famous questioning [2, 3] of whether a machine can actually *think*, precocious and overly optimistic predictions stated that soon (i.e. before the year 2000), computers would match or exceed human-level intelligence [4].

Imagining of the impact in society of such tremendous advancements is as amusing as it has been to watch all the science fiction created around the topic. Despite the frustration of still not being able to pass the now quasi-folkloric Turing test, computers did manage to acquire *some* level of intelligence, at least enough to find their way onto our daily lives.

From its early days, the development of computational intelligence has been driven - and funded - by governmental and private institutions that shared the generally acknowledged perception that these models and techniques have great potential in numerous practical and commercial applications. Indeed, many such applications have been developed and deployed ever since [5].

The first model of an artificial neuron was introduced by McCulloch and Pitts in 1943 [6]. The birth of the artificial neural network was followed by a development period with several important contributions such as Hebb's learning rule [7], Widrow and Hoff's training method [8], and Rosenblatt's *Perceptron* [9]. Despite the Perceptron initial practical applications in linearly-separable classification problems, nearly 10 years of lack of interest followed after Minsky and Papert criticisms of the model in 1969 [10].

The connectionist school only regained attention in the 1980s with new works such as Hopfield's [11] and Rumelhart's popularization of the *back-propagation* training algorithm [12]. This *renaissance* of the field was characterized by not only a great deal of development in theories and models, but also by a widespread utilization of neural networks in various applications, particularly in finance [13]. Many reviews on artificial neural network business applications [14, 15] report assorted uses in marketing, customer relationship management, risk assessment, fraud detection, operations research, among others.

Artificial neural networks enable one to solve learning problems proposed under different paradigms, notably supervised and unsupervised learning. With supervised learning, among other uses, one is able to induce a general learning rule using historical data and later use it to deduct labels or real values forecasted for unknown situations. For a business manager, whenever there is business value in predicting the outcome of a given process based on its own history, there is potential for an artificial neural network business application. With supervised learning, also among other uses, one is able to detect information patterns in the data. In a business context, managers are able to analyze data and infer patterns of behavior, enabling them to take advantage of opportunities that otherwise would go unnoticed.

A new wave of research in connectionism in the 1990s led to what Vapnik referred to as the return to the origins of statistical learning theory [16]. Several new theories and models were proposed aiming at improving the performance and robustness of learning machines. Notably, the support vector machine was introduced [17, 18], and has since gained a lot of attention as a powerful ally to artificial neural networks in practical applications based on classification and regression problems [19].

Expert systems, or knowledge-based systems, first appeared in the 1960s. With a number of implementations especially in the 1970s and 1980s [20, 21], expert systems are considered to be some of the first CI techniques commercially applicable [5]. As the design of expert systems is usually specific to a particular problem domain, their applicability is also restricted. Still, expert systems have been used in assorted business applications, from operations research and process control to financial services and human resources. Nowadays, many of the concepts behind expert systems such as rule-based inference and knowledge encoding are commonly found in many contemporary software products and corporate information systems.

Evolutionary algorithms, inspired in biological evolution and natural selection, emerged in the 1970s with the introduction of genetic algorithms [22, 23]. Many other ramifications and specializations were developed in the following decades, for instance genetic programming [24] in the 1990s. Evolutionary algorithms have been quickly adopted in many practical optimization problems where the explicit elicitation of the search space or objective function is troublesome, including applications in engineering, scheduling, timetabling, bioinformatics, and other domains [25, 26]. Since their introduction, evolutionary algorithms have received a great deal of attention from the research community. Meanwhile,

a similarly great number of practical business and management applications involving solving search and optimization problems have been successfully designed using different variations of evolutionary algorithms.

The methods and techniques described in this introduction are but a sample of the vast myriad of developments that took place in CI since the 1940s. From fuzzy logic to artificial immune systems, including hybrid systems combining more than one technique, CI not only progressed in the development of new tools but also on their application in business problems. More and more, computational-intelligence-based products and technologies are seen in everyday situations. Although a lot of ground has already been covered, it is arguable that there is still great potential for new CI business applications, possibly far greater than all the progress made so far.

2 Business Applications

The definition of what characterizes a business application is not entirely uniform throughout the CI literature. The root of the misconceptions are often in the interpretation of the concept of *business*, a word sometimes abused of and with many different singular translations from English depending on the language. In this work, the broad definition of *business* is used, anchored at generally accepted management concepts. First, consider the classic management tools of business mission and vision for an organization [27]. The mission of an organization is a declaration of its purpose and contribution to society; it is *what* it does. The vision of an organization describes its ultimate objectives and aspirations; it is the *direction* to where it is headed. In a broad sense, a business application of CI is the practical employment of the field's models and techniques to help the organization *realize its mission while moving towards its vision*.

Second, consider the different types of business applications often seen in the literature. One may classify a business application according to the vertical market segment where the organization operates, for instance financial services, manufacturing, telecommunications, etc. Another common classification dimension is the area of the organization where the application is in fact utilized. Porter describes an organization using a value chain model [28], classifying business activities as *primary* or *support*, as shown graphically in Figure 1. In its original version, primary activities are those relating to the execution of the *core-business* (realization of the mission) of the organization, with activities such as inbound logistics, operations, outbound logistics, marketing and sales, and service. Support activities are procurement, technology (e.g. processes, research and development), human resource management, and firm infrastructure (e.g. finance, legal, corporate management). It is important to discriminate these two classification dimensions, something that often is cause for confusion. For instance, there are many so-called *financial applications* reported in the literature. Many of these applications (in trading, retail banking, etc) are applicable to organizations in these market segments, while others may be generally applicable in the finance support activity to a wider variety of organizations (e.g. audit-

ing, risk management). Although all of these are usually labeled as *financial*, the distinction is determinant to the adoption (and further development) of the application by other users. Another common label found in applications is *management*. There are indeed corporate management applications of CI (e.g. in strategic planning), but the term *management* is often mistaken for the whole set of support activities of the organization, sometimes even its marketing practice (a primary activity closely related to the core-business).

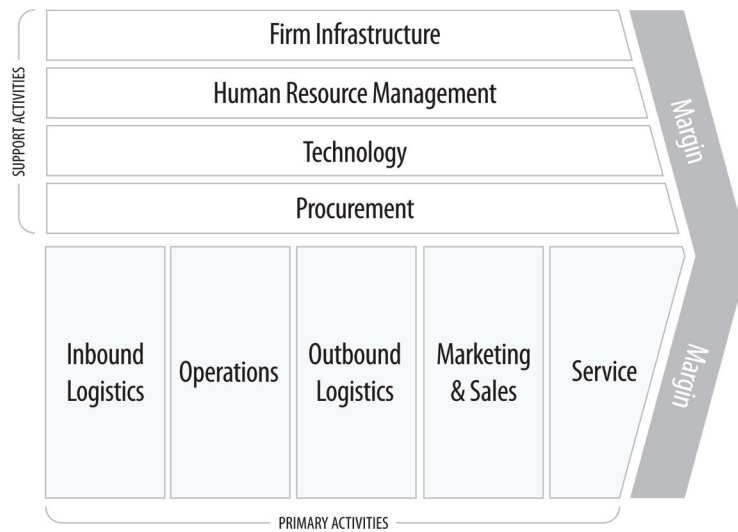


Figure 1: Porter's description of an organization using a value chain.

3 CI as a Source of Competitive Advantage

Today's businesses face challenges unmatched in history. Globalization and unstoppable economic forces are constantly rising the level of competition in virtually every market segment across the planet. The pace of technology advancements accelerate this process, creating a business environment where strategy and management practices that drove the development of the 20th century will likely soon disappear [29]. More and more, a scenario of hypercompetition is developing [30], where competitors move quickly to build new advantages and erode the advantages of their rivals [31].

Within this context, many businesses are starting to use computational intelligence as a tool to build, extend, and sustain their competitive advantage. Consider the pressure and the numerous forces that different businesses are subject to according to their strategic positioning and value discipline [32]. Businesses focused on *operational excellence* must strive to lower costs below those of the competition while keeping a reasonable quality, offering more value to its customers for less money. The emphasis is on efficiency, volume, and execution.

These businesses may develop applications to improve their inbound and outbound logistics, areas less subject to the specificities of particular businesses, as well as their operations. There are many works in the literature on operations applications for CI, from transformation business with complex production process to stock trading (which is at the heart of the operations of investment fund management organizations). The greater the pressure for lower costs against the competition, the more opportunity to employ CI in the various cost-sensitive aspects of an organization's primary business activities.

Businesses focused on *product leadership* must differentiate their products through strong branding and innovation. The emphasis is on research and development, design, and time-to-market. These businesses have the opportunity to enhance their products by embedding CI in them. This is a trend in high-technology firms. Several CI techniques are part of everyday products performing functions such as speech recognition, face recognition, natural language processing, among others. As these features become the new standards, tomorrow's products will have to bear newer features, and these have a substantial chance of being based on or utilizing CI techniques.

Finally, businesses focused on *customer intimacy* must be closer to its customers than the competition, offering exceptional service quality while meeting individual demands. The emphasis is on quality, service, and customization. These businesses may extend the use of CI to improve the relationship with their customers. Today's modern customer relationship management packages already offer several features based on CI, from consumer preference mapping to intelligent pipeline management. For example, virtually every major online retailer today offers some sort of automated suggestions system based on customer history. Increasing competition in this and other vertical segments will demand not only more knowledge of a firm's market, but also the tailoring of its products and services at the individual customer level.

4 ESANN 2010 Special Session

This paper introduces the Special Session on Computational Intelligence Business Applications of the 18th European Symposium on Artificial Neural Networks.

Burattin et al. present a time-interval-aware process mining algorithm in the paper *Heuristics Miner for Time Intervals* [35]. Although relatively new, this type of technique is gradually attracting more attention from academia and from the business community. New business process management (BPM) platforms now include technologies such as business activity monitoring (BAM), a correlated technology also based on extracting relevant information from business event logs. The ability to harvest business logs from underlying corporate systems to monitor (BAM) or infer patterns and organization (process mining) is of great value to improving any business process, so much so it is already a trend in next-generation corporate management systems.

In the paper entitled *Machine Learning Analysis and Modeling of Interest*

Rate Curves [33], Kanevski et al. describe an application based on Gaussian Mixture Models for the analysis and forecasting of the Swiss Franc interest rate curve (IRC). IRC models have a direct application in financial organizations (i.e. retail banks, central banks, etc) where borrowing transactions take place. The ability to understand and forecast IRCs improve the efficiency of financial managers when swapping debt contracts, a common operation in financial markets. In addition, IRCs are important economic indicators, so virtually everyone inserted in the marketplace may indirectly use IRC models to help forecasting economic scenarios and planning for the future.

Mazzieri et al. describe a new knowledge management model based on the identification of contexts using hierarchical clustering in the paper *Modeling Contextualized Textual Knowledge as a Long-Term Working Memory* [34]. Efficient knowledge management is a cross-industry management trend. As information technology favors the production of vast amounts of information, being able to organize and extract value from this information is of paramount importance. Common benefits of intelligent knowledge management include more effective staff training, shorter time-to-market of new products and services, streamlined problem solving, among others.

5 Conclusion

The efforts in research and development of CI over the last decades have led to a collection of mature models and techniques with plenty of applications reported in the literature. In the future, CI will most definitely continue to evolve, and as expected so will the capabilities of its new models and techniques. This further development of the field will enhance the applicability of CI in different business contexts. As more applicability will likely contribute to a wider adoption of CI in practical applications, it is not the envelope of science that has been restraining its utilization in larger scale. Many practical, technical issues must be solved in the application of CI to business problems. Availability and quality of data always demand special care, so does the careful proposition of the problem along with the selection of the best-suited models and techniques to solve it. As hard as these issues may be, they usually lie well within the capabilities of competent researchers and the existing body of knowledge of the field. Recognizing the applicability of CI techniques in business contexts, though, is a multidisciplinary effort. It requires technical background to understand the potential and limitations of each tool as well as the business acumen to recognize the opportunities. This merger between technical CI knowledge and business skills can be done in two ways. First, business analysts and business-intelligence-focused information-technology analysts may acquire the sufficient CI knowledge to apply its techniques, even if abstracting the inner workings of each method. There are many commercially available business intelligence packages in the market today that pack many CI methods (under particular names such as *business analytics*), readily available for use outside academia. This approach not only works, but it is the most common way for business

organizations to have CI applied to their problems.

Another way to do the same knowledge merger is to bring people with solid technical background to the business world. Although the amount of new explicit business knowledge to be absorbed is far smaller than the amounts required for a solid background in CI, acquiring the tacit business knowledge and skill is somewhat of a challenge. Regardless of being an easier or harder move, this type of merger yields the highest benefits, as the outcome is one who can fully appreciate the potential of CI in different business situations. The very application of CI in business contexts remounts to the definition of innovation adopted in the academic business literature following Schumpeter [36], where invention is said to be an idea made manifest, while innovation is an idea successfully applied in practice. A recent study suggests that this hybrid profile of one with a solid academic, technical background, combined with business skills and market insight is the most effective way to drive innovation in knowledge-intensive medium enterprises [37]. Having one or more business leaders with such profile was a common trend in the whole population of firms researched where innovation was found to be nurtured and to have substantial positive impact on the business. This hybrid set of skills, assuming CI is understood and not just utilized as a black-box, therefore creates the proper scenario to bolster CI innovation and produce new *CI business applications*.

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