Juan R. Rabuñal and Julián Dorado

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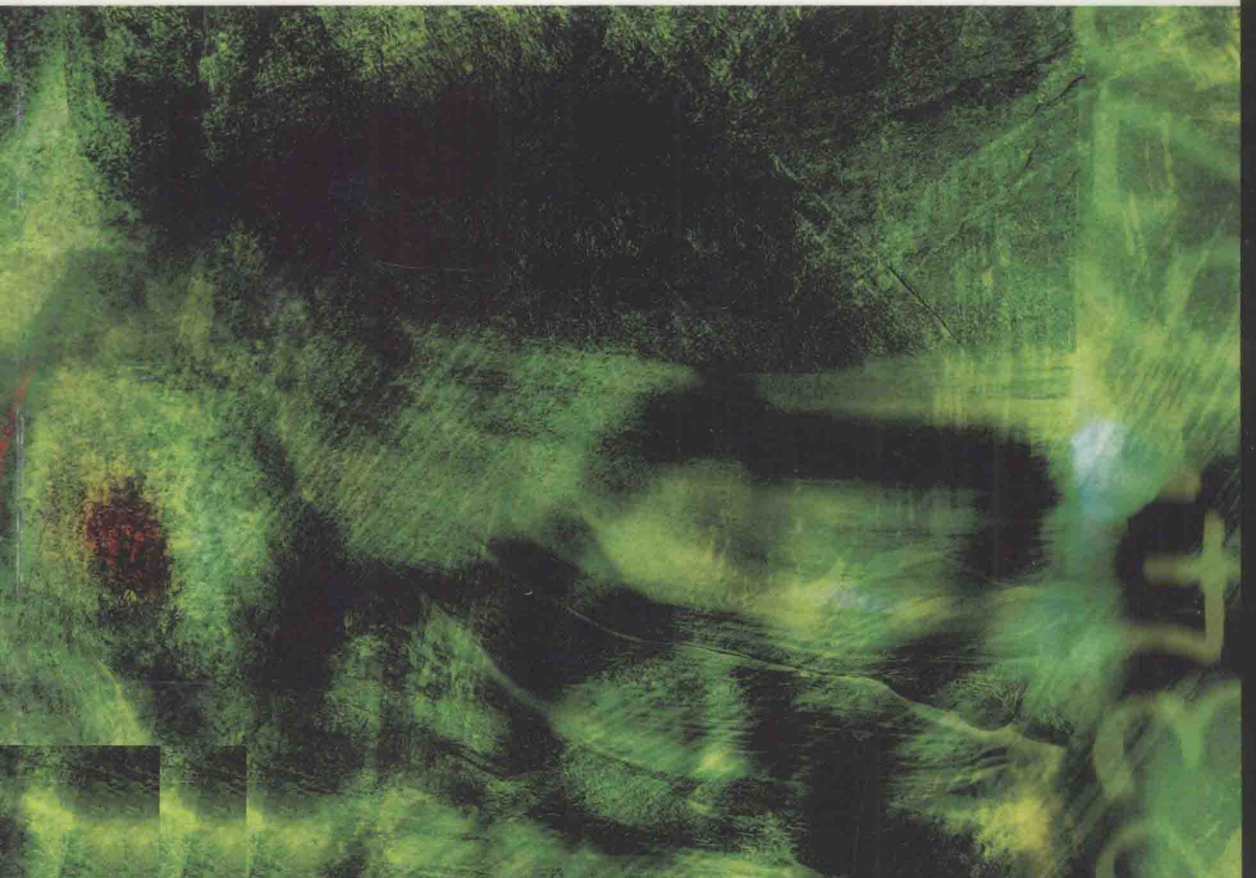

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Preface

Evolution and Development

Throughout the past, human beings have been concerned with how to acquire tools that might increase their potentialities, not only regarding the physical or intellectual aspect but also the metaphysical one.

At the physical aspect, the use of wheels, levers, or cams, among others, finally reached the point of elaborating hominids and automats that in their most sophisticated creations consisted of animated statues that generally reproduced daily movements. Heron of Alexandria constructed some artificial actors which represented the Trojan War, where the idea of automats reached a high level of development as it was established that: (a) the mechanisms would act depending on the internal structure; (b) the action comes from an accurate organisation of motor forces, both natural and artificial; (c) the mobile ones are the most improved, since they are able to move completely. Ultimately, they are only the expression of the unavoidable human wish to increase their possibilities in all the aspects of their lives. In this line, some of the most remarkable creations include "The Dove" by Archytas de Tarente, Archimedes' "Syracuse Defensive Mechanisms" (developed to face the Roman fleet), "The Mechanical Lion" by Leonardo Da Vinci, the clock creations of the Droz brothers at the Cathedrals of Prague and Munich, and "The Transverse Flute Player" by Vaucanson. "The Madzel Chess Automaton" by Hungary's Von Kempelen was able to play chess with the best players of its time and impressed Empress Maria Theresa of Austria. Edgar Allan Poe built a logical test trying to prove that this automaton was not authentic, but failed as he considered that the machine was not able to change its strategy as the game went on (Elgozy, 1985; Poe, 1894).

At the metaphysical aspect, the creations along time also have been numerous. The main concern in this case was "ex nihilo," the idea of a motionless-based creation of beings similar to humans that might act as substitutes to humans during the performance of the most tedious, dangerous, or unpleasant tasks. The Hephaistos (God of the Forge) androids were the first known reference to creation of artificial intelligence.

As Tetis told her son Achilles during their visit to the workshop of the god, "They were made of solid gold and they had understanding in their mind." In the modern age, "The Golem" by Loew, XVI century Prague Rabbi (Meyrink, 1972; Wiener, 1964), "The Universal Robots" by Rossum (Capek, 1923), and "Frankenstein" (Shelley, 1818) should be highlighted as well.

But what is really interesting is the third of the mentioned aspects: the attempt to reproduce and promote the intellect. Multiple mechanical devices, specifically the abacus, were designed in order to improve the capability of calculation. In the Middle Ages, the Majorcan Ramón Llul developed the Ars Magna, a logical method that exhaustively and systematically tested all the possible combinations. Later, in the Modern Age, some of the most noticeable devices are "The Pascal Machines" and the works of several authors such as Leibnitz, Freege, or Boole. Ada Lovelance, Charles Babbage's co-worker at the analytic machine, established "The Lovelance Regime," where she states that "machines only can do those things we know how to tell them to do, so their mission is helping to supply or to obtain what is already known.". Other important contributions of the second half of 20th century in this field include "The Logical Theoretical" by Bewel, "The General Problem Solver" by Shaw, Newell, and Simon, the program for draughts play by Samuel, and the developments of the first computers by Zuse and Sreyers (Samuel, 1963; Erns, 1969).

The appearance of computers and computer software is the key point in the real development of certain characteristics of intelligent beings such as the capabilities of memory or calculus, although most of these characteristics still are merely outlined when replicated in artificial systems. In this way, and despite the high rhythm of advances during the last decades, we are still too far from artificially reproducing something that is so inherent to human beings, such as creativity, criticism capability (including self-criticism), conscience, adaptation capability, learning capability, or common sense, among others.

Artificial intelligence (AI) is an area of multidisciplinary science that comes mainly from cybernetics and deals with the deeper study of the possibility — from a multidisciplinary, but overall engineering, viewpoint — of creating artificial beings. Its initial point was Babbage's wish for his machine to be able to "think, learn, and create" so that the capability for performing these actions might increase in a coextensive way with the problems that human beings deal with (Newel & Simon, 1972). AI — whose name is attributed to John McCarthy from the Dormouth College group of the summer of 1956 — is divided into two branches known as symbolic and connectionist, depending on whether they respectively try to simulate or to emulate the human brain in intelligent artificial beings. Such beings are understood as those who present a behaviour that, when performed by a biological being, might be considered as intelligent (McCorduck, 1979; McCarthy, 1958).

The main precursor of connectionist systems from their biological fundaments was from Spanish Nobel Award-winning Dr. Santiago Ramón y Cajal who, together with Sherringon, Williams y Pavlov, tried to approach the information processes of the brain by means of an experimental exploration and also described the first connectionist system with the statement: "When two brain procedures are active at the same time or consecutively, one tends to propagate its excitation to the other" (Ramón y Cajal, 1967; Ramón y Cajal, 1989).

In the dawn of cybernetics, and within that field, three papers published in 1943 constituted the initiation of the connectionist systems (Wiener, 1985). The first of these works was written by McCulloch and Pitts. Apart from revealing how machines could use such concepts as logic or abstraction, they proposed a model for an artificial neuron, named after them. This model, together with the learning systems, represented the foundations of connectionist systems. Most of the mentioned systems derive from the Hebb Rule, which postulates that a connection between neurons is reinforced every time that this connection is used (McCulloch & Pitts, 1943).

The second work was by Rosemblueth, Wiener, and Bigelow, who suggested several ways of providing the machines with goals and intentions (Rosemblueth, Wiener, & Bigelow, 1943). In the last work, Craik proposed the use of models and analogies by the machines for the resolution of problems, which established that the machines have certain capabilities of abstraction (Craik, 1943).

These three contributions were added to some others: "The Computer and the Brain" by Von Neumann;, "The Turing Machine" by Turing — a theory that preceded actual computers; and "The Perceptron" by Rosemblatt — the first machine with adaptable behaviour able to recognise patterns and provide a learning system where stimulus and answers are associated by means of the action of inputs (Turing, 1943; Von Nuemann, 1958).

During the second half of the 20th century, numerous authors made important contributions to the development of these types of intelligent systems. Some of the most remarkable are Anderson, who made the first approaches to the Associative Lineal Memory, Fukushima, Minsky, Grossberg, Uttley, Amari, McClelland, Rumelhart, Edelman, and Hopfield. They contribute with different cell models, architectures, and learning algorithms, each representing the basis for the most biological AI systems, which eventually resulted in the most potent and efficient ones (Raphael, 1975; Minsky, 1986; Minsky & Papert, 1968; Rumelhart & McClelland, 1986).

These systems are quite interesting due, not only to their ability for both learning automatically and working with inaccurate information or with failures in their components, but also because of their similarities with the neurophysiologic brain models, so that the advances in both disciplines might be exchanged for their reinforcement, indicating a clear symbiosis between them.

Present and Future Challenges

All these studies and investigations have achieved spectacular results, although they are still far from the daily performance of biological systems. Besides, during the last decades, the expectation for these type of systems has broadened due to the miniaturisation of computers coupled with the increment of their capacities for calculus and information storage. In this way, more complex systems are being progressively implemented in order to perform already demanded functions as well as those that will be coming soon and are unforeseen.

The efforts made so far represent two sides: On the one hand, they are the basis for all the advances achieved up to this moment in order to reinforce or reproduce the characteristics that define the intelligent beings; on the other hand, they also reflect the poor — although spectacular — advances achieved with regards to the creation of truly intelligent artificial beings. While the connectionist systems are the most advanced ones in the field of emulation of biological intelligent systems, certain restrictions are present. These limitations are mainly referred to the need to reduce the time for training and to optimise the architecture — or network topology — as well as to the lack of explanation for their behaviour and to the approach to more complex problems. For the two first restrictions, there is a new technique based on genetics, known as genetic algorithms (GA) (Holland, 1975), proposed by Holland and developed until genetic programming in the last decade by Koza (1992) among others. These techniques have proved to be useful for the extraction of new knowledge from the system, using the data mining process.

The two other restrictions might be palliated by incoming solutions such as those suggested with the incorporation of artificial glia cells to the Artificial Neural Networks (ANN). This adventurous proposal is currently being elaborated by our research group of La Coruña University, co-working at the neuroscience aspects with Professors Araque and Buño, of the Santiago Ramón y Cajal Scientific Research Institute.

It seems necessary to look again toward nature, such as it was done when the wider steps were taken along this track, looking for new guides and new information for the search of solutions. And the nature, as it has been mentioned, contributes again with solutions.

Technology also tries to provide solutions. In this line, it is intended to integrate different disciplines under a common label: MNBIC (Micro and Nanotechnologies, Biotechnology, Information Technologies, and Cognitive Technologies) Convergent Technologies. The MNBIC promise to be a revolution at the scientific, technologic, and socioeconomic fields because they contribute to help make possible the construction of hybrid systems: biological and artificial.

Some of their possibilities consist on the use of micro or nano elements that might be introduced into biological systems in order to substitute dysfunctional parts of it, whereas biological particles might be inserted into artificial systems for performing certain functions. According to a recent report of the U.S. National Science Foundation, "The convergence of micro and nanoscience, biotechnology, information technology, and cognitive science (MNBIC) offers immense opportunities for the improvement of human abilities, social outcomes, the nation's productivity, and its quality of life. It also represents a major new frontier in research and development. MNBIC convergence is a broad, cross-cutting, emerging, and timely opportunity of interest to individuals, society, and humanity in the long term."

There is a scientific agreement with regards to the fact that the most complex part for being integrated with the rest of the convergent technologies is the one that represents the cognitive science. The part that has to do with technologies of knowledge has a best level of integration through models of knowledge engineering. It is remarkable that the interaction of the connectionist branch with other disciplines such as the GAs and the introduction of other elements, representing the cells of the glial system, are different from neurons.

Book Organization

This book is organized into six sections with 16 chapters. A brief revision of each chapter is presented as follows:

Section I presents recent advances in the study of biological neurons and also shows how these advances can be used for developing new computational models of ANNs.

- Chapter I shows a study that incorporates, into the connectionist systems, new elements that emulate cells of the glial system. The proposed connectionist systems are known as artificial neuroglial networks (ANGN).
- Chapter II expands artificial neural networks to artificial neuroglial networks in which glial cells are considered.

New techniques such as connectionist techniques are preferred in cases like the time series analysis, which has been an area of active investigation in statistics for a long time, but has not achieved the expected results in numerous occasions. Section II shows the application of ANNs to predict temporal series.

- Chapter III shows a hybrid evolutionary computation with artificial neural network combination for time series prediction. This strategy was evaluated with 10 time series and compared with other methods.
- Chapter IV presents the use of artificial neural networks and evolutionary techniques for time series forecasting with a multilevel system to adjust the ANN architecture.

In the world of databases the knowledge discovery (a technique known as data mining) has been a very useful tool for many different purposes and tried with many different techniques. Section III describes different ANNs-based strategies for knowledge search and its extraction from stored data.

- Chapter V describes genetic algorithm-based evolutionary techniques for automatically constructing intelligent neural systems. This system is applied in laboratory tests and to a real-world problem: breast cancer diagnosis.
- Chapter VI shows a technique that makes the extraction of the knowledge held by previously trained artificial neural networks possible. Special emphasis is placed on recurrent neural networks.
- Chapter VII shows several approaches in order to determine what should be the most relevant subset of variables for the performance of a classification task. The solution proposed is applied and tested on a practical case in the field of analytical chemistry, for the classification of apple beverages.

The advances in the field of artificial intelligence keep having strong influence over the area of civil engineering. New methods and algorithms are emerging that enable civil engineers to use computing in different ways. Section IV shows two applications of ANNs to this field. The first one is referred to the hydrology area and the second one to the building area.

- Chapter VIII describes the application of artificial neural networks and evolutionary computation for modeling the effect of rain on the run-off flow in a typical urban basin.
- Chapter IX makes predictions of the consistency of concrete by means of the use of artificial neuronal networks

The applications at the economical field, mainly for prediction tasks, are obviously quite important, since financial analysis is one of the areas of research where new techniques, as connectionist systems, are continuously applied. Section V shows both applications of ANNs to predict tasks in this field; one of them is for bond-rating prediction, and the other for credit-rating prediction:

- Chapter X shows an application of soft computing techniques on a high dimensional problem: bond-rating prediction. Dimensionality reduction, variable reduction, hybrid networks, normal fuzzy, and ANN are applied in order to solve this problem.
- Chapter XI provides an example of how task elements for the construction of an ANN can be automated by means of an evolutionary algorithm, in a credit rating prediction.

Finally, section VI shows several applications of ANNs to really new areas, demonstrating the interest of different science investigators in facing real-world problems.

As a small sample of the areas where ANNs are used, this section presents applications for music creation (Chapter XII), exploitation of fishery resources (Chapter XIII), cost minimisation in production schedule setting (Chapter XIV), techniques of intruder detection (Chapter XV), and an astronomy application for stellar images (Chapter XVI).

- Chapter XII explains the complex relationship between music and artificial neural networks, highlighting topics such as music composition or representation of musical language.
- Chapter XIII approaches the foundations of a new support system for fisheries, based on connectionist techniques, digital image treatment, and fuzzy logic.
- Chapter XIV proposes an artificial neural network model for obtaining a control strategy. This strategy is expected to be comparable to the application of cost estimation and calculation methods.

- Chapter XV shows a novel hybrid method for the integration of rough set theory, genetic algorithms, and an artificial neural network. The goal is to develop an intrusion detection system.
- Finally, Chapter XVI describes a hybrid approach to the unattended classification of low-resolution optical spectra of stars by means of integrating several artificial intelligence techniques.

Relevance and Conclusions

As can be observed, this book tries to offer an outlook of the most recent works in the field of the connectionist AI. They include not only theoretical developments of new models for constitutive elements of connectionist systems, but also applications of these systems using intelligent characteristics for adaptability, automatic learning, classification, prediction, and even artistic creation.

All this being said, we consider this book a rich and adventurous, but well-based, proposal that will contribute to solving old problems of knowledge-based systems and opening new interrogations which, without doubt, will make the investigations advance through this field.

This is not a book of final words or definitive solutions, rather it contributes new and imaginative viewpoints, as well as small — or big — advances in the search of solutions for achieving truly intelligent artificial systems.

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2005

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