Artificial Intelligence and Intelligent Systems Research in Chile

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Abstract Worldwide Artificial Intelligence research has witnessed fast and growing advances. These contributions mainly came from first-world nations as other research priorities and needs have been undertaken by less-developed countries. Nevertheless some Latin American countries have put significant efforts into AI research so as to advance in the state-of-the-art at international levels. This paper describes the history, evolution and main contributions of Chile to AI research and applications.

1 Introduction

In 1947 Alan Turing predicted that there would be intelligent computers by the end of the century. Hence he proposed an intelligence test which allows us to assess a machine as intelligent in his classic 1950 article "*Can a machine think?*". The term Artificial Intelligence (AI) arose for the first time in a conference at Dartmouth College in 1956 on machine intelligence which gathered the most renowned scientists such as John McCarthy, Marvin Minsky, Claude Shannon, Allen Newell and Herbert Simon. One of these, Herbert Simon predicted in 1965 that by 1985, machines will be capable of doing anything a man can do. At the same time Dreyfus argued against the possibilities of AI. Furthermore, Marvin Minsky from MIT predicted in 1967 that within a generation, the problem of creating AI will be substantially solved.

In the early sixties, neural network research started to spread across the most important laboratories and universities in the world. Despite the significant efforts and funding provided by public and private institutions, the famous 1969 monograph entitled *Perceptrons* [10] showed that it was impossible for these classes of neural network to learn an XOR function. Minsky and Papert conjectured incorrectly that a similar result would hold for a Perceptron with three

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or more layers. Three years later Stephen Grossberg published a series of papers introducing neural networks capable of modeling differential, contrast-enhancing and XOR functions. Nevertheless the often-cited Minsky & Papert paper caused a significant decline in interest and funding of neural network research. Thus, the first twenty years of AI research worldwide was characterized by high expectations in a short time.

Developing countries were not supposed to get involved in AI research in a timely fashion as renowned researchers claimed the majority of the open problems may be solved in a too short period of time. Fortunately, it was not so as a couple of South American countries such as Brazil and Chile got involved in AI in the early 80s. In Chile, the eighties witnessed the beginnings of research and development in AI. Early applications included contributions of AI in diagnostic systems in the mining industry and significant achievements on practical applications in engineering and science. In particular, strategic areas for the country were given high priority including mining, forestry and industrial automation.

A resurgence of neural networks research worldwide in the 1980s also encouraged national researchers to pursue advanced research and applications of neuro-mimetic systems. Some of these milestones had a significant impact on the economic resources a developing country is willing to spend on Research and Development (R&D). Since then, Computer Science (CS) research in Chile has been reinforced aiming to hire more researchers, enroll more graduate students, improve and spread research initiatives throughout the country, and increase the number of R&D projects. In the scientific area, Chilean CS shows an increase in scientific production by papers published in high quality indexed journals, renowned conferences, and ACM & IEEE conferences, etc. Most of the funding for R&D in Chile comes from the government and a few research contracts with private industries (27% of the money spent in R&D). Nevertheless, the major research funding institutions are public, including CONICYT (The Chilean NSF equivalent), FONDEF (CONICYT's funding unit for technological research in industry), CORFO (Ministry of Economy's Production Development Corporation) and MIDEPLAN (Ministry of Planning).

In this chapter, the evolution of R & D activity on AI by Chilean scientists and developers is briefly discussed and the main impacts are highlighted.

2 The Beginnings of Research and Development in AI in Chile

As for the majority of the AI activity worldwide, Chilean research on AI has historically had two main working focuses: Foundations and Engineering. The first stream involved seminal work by biologists, psychologists, mathematicians and linguistics on the basis of cognition, knowledge acquisition and perception. A second stream included researchers and developers, mainly from universities and research centers, working on AI applications in industry and science.

On the AI applied side, research has mainly been carried out in universities, where several paradigms can be found including *Artificial Intelligence* (mainly in CS departments), *Computational Intelligence* (mainly in Electrical and Electronic Engineering departments) and others (linguistics, psychology). A good exception outside the academic world is a project which aimed to apply AI and Cybernetic theory to the government. In 1971, an innovative system of cybernetic information management and transfer began developing in Chile during the government of President Salvador Allende; the CYBERSYN project, cybernetic synergy, information and control system. In Chilean State owned companies a system for capturing, processing and presenting economic information to be managed in "quasi" real time, based on a convergence of science, technology, politics and cybernetics, became an absolute pioneer in the application of a cybernetic model in mass socio-economic contexts, and. The economic system of the Allende Government, after annexing and nationalizing diverse State companies, was faced with the necessity to coordinate information regarding state companies and those that had been recently nationalized, so it required the creation of a dynamic and flexible system for proper management of the companies. In 1970 Fernando Flores was appointed Technical Director General of CORFO, and was responsible for the management and coordination between nationalized companies and the State. He had known the theories and solutions proposed by British scientist Stafford Beer since he was an engineering student, and subsequently in the course of his professional relationship with SIGMA, the Beer consultancy firm. He wrote to Stafford Beer inviting him to implement in Chile VSM (the Viable System Model), which had been developed in Beer's "The Brain Of The Firm". Beer accepted immediately, and the project entered its development stage in 1971.

In the early eighties, the Chilean scientist Dr. Fernando Flores working with Terry Winograd from Stanford University, proposed a new approach to understanding what computers do and how their functioning is related to human language, thought, and action. His influential work entitled "*Understanding Computers and Cognition*" [20] was a worldwide contribution to understand social networks and commitment nets in companies. This is based on the *Speech Acts* theory and has impact on designing intelligent systems, effective human communications, etc. It is a broad-ranging discussion exploring the background of understanding in which the discourse about computers and technology takes place. It represents an important contribution to the research about what it means to be a machine, and what it means to be human. Software systems using his research were marketed as The *Coordinator* (`http://www.actiontech.com/`).

Although practical applications of AI in Chile started in the early 80s, some underlying research on origins of intelligence (and its biological basis) was long before then. Research on origins of intelligence and language use (*languaging*) is due to the world renowned Chilean Scientist *Humberto Maturana*. Biologist Maturana is best known for his (re)definition of Autopoiesis [9] which has a significant impact on the understanding of natural and artificial autonomous systems. Autopoiesis theory featured two referents: a set of interconnected ideas aimed to provide definitions and explanations for life and biological phenomena.

(aka. “Autopoietic theory”), and a central concept in this set of ideas; the defining property of living systems.

With roots in Cybernetics, Maturana’s work influenced various fields; hot topic in *Artificial Life and embodied* dynamical approaches to cognitive science. Its basic axioms involved two key principles:

- *Structural determinism*. The dynamics of a system are determined only by its own structural composition, following operational laws (the laws of physics).
- *Everything said is said by an observer*. It is not possible to do science without a point of view and a language that influences what the observer chooses to distinguish in her/his observations.

Maturana’s theory applies science, especially what is known of neural systems, to philosophical questions about human perception and understanding (Autopoiesis and Cognition). This addresses the origin of life and continues through the development of language in humans [9]. Furthermore, A Maturana’s colleague, Francisco Varela provided the biological basis for designing complex systems, artificial life and embodied intelligence. For Varela, the core of intelligence and cognitive abilities is the same as the capacity of living which gives rise to modern *Artificial Life* [18, 19] with applications to control theory, robotics and the shift towards biologically inspired notions of viability and adaptation, situatedness, etc. He addressed *bottom-up theories of artificial intelligence* and explored what can be learned from simple models such as insects about the cognitive processes and characteristic autonomy of living organisms. Dr. Varela first introduced the notion of “*Emergence*” (connectionism): many cognitive tasks (such as vision and memory) seem to be handled best by systems made up of many simple components, which, when connected by the appropriate rules, give rise to global behaviours.

3 AI at Universities

An interesting feature of AI research in Chile was that this aimed to solve practical problems in industry. For example, early development of expert systems in Chile was applied to the mining industry (one of the most important in the World), process control, and medicine. The first expert system (ES) outside the mining area was capable of diagnosing faults in motor pumps for paper companies, other applications included an expert controller for Semi-Autogenous Grinding [11]; a configuration system for climatic testings [16], and Fuzzy ES for automation. Later, a group of Chilean researchers pioneered the foundations for essential hypertension treatment using AI techniques [8].

In the middle 80s, several Chilean experts pursuing graduate studies returned to the country. They were mainly specialized in ES, neural network systems, evolutionary computation and heuristic optimization. This drove the development and application of AI technology in the Chilean industry. The first Chilean

graduates were from Georgia Tech (USA), King's College London (UK), UFRJ in Brazil, University of Toronto (Canada), etc. In the last five years, graduates returning to the country came from INRIA (France), University of Edinburgh (UK), University of Cambridge, Carnegie Mellon University (USA), etc.

Currently, CS departments of all major universities in the country have a research area in AI. There is no common thematic or central AI organization in the country, but most of the researchers are members of the Chilean Computer Science Society. An overview of the main activities in some of the major institutions are highlighted including those by Catholic University of Chile (PUC), Universidad de Concepción (UCO), Universidad de Santiago de Chile (USACH), Universidad de Chile (UChile) and Universidad Técnica Federico Santa Maria (UTFSM).

3.1 AI at PUC

The main research activities in AI at PUC focus on machine learning, computer vision and autonomous robotics. In the early 80s, a significant development of logics and theorem solving was carried out by [5, 6, 7]. Furthermore, PUC pioneered the use and application of ES technology in industry. This led to the first Expert System company in the early 80s: *SOLEX*, and the development of applications in industrial planning, optimization, and heuristics. By the early 90s, milestones included influential work on logic for knowledge representation by Professor Leopoldo Bertossi (now at Carleton University, Canada), and *Situation Calculus* by Professor Javier Pinto (RIP) [14, 15]. Some other recent developments included Robotics and Probabilistic Reasoning, Agent planning under uncertainty using logic-based programming, Dynamic Surveillance using Unmanned Aerial Vehicles and Planning visual navigation for mobile robots. Applied machine learning has also been a recent focus for detecting rare objects in huge astronomical databases using data mining technologies.

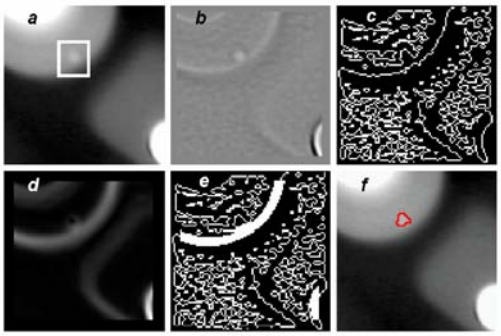

Fig. 1: Flaw Detection in uncalibrated sequence of images

An example of computer vision research is the automated inspection using uncalibrated image sequences. This technology integrates state-of-the-art image processing and pattern recognition techniques (see Fig. 1).

3.2 AI at UCO

Early AI research was marked by applied work on ES in medium-size companies and knowledge representation theories for adaptive ES. Recent work has contributed significantly to advancing applied AI on areas such as Natural Language Processing (NLP), Multi-agent systems, evolutionary computation, pattern recognition and intelligent optimization. The work at UCO is the Chilean leader on NLP and language technology including text mining, natural-language dialogue systems and semantic processing. Some of this work has been published in the most prestigious international journals [1, 2, 3, 4]. NLP work has been pursued jointly with researchers in the Department of Linguistics for the last 10 years. A current worldwide contribution [3] involves a new model to filter information from the Web using natural-language dialogue systems (see Fig. 2).

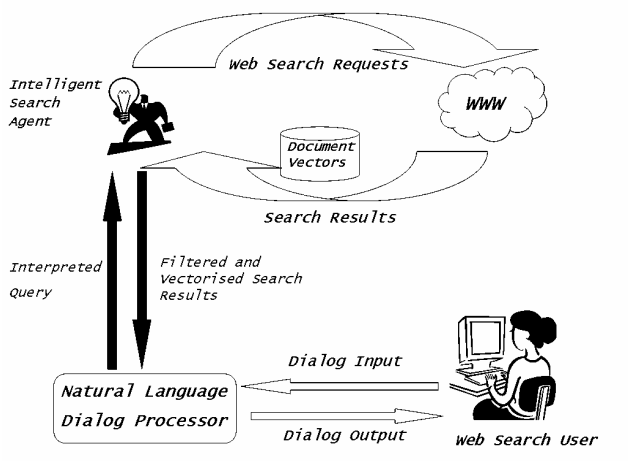

Fig. 2: A New Natural-Language Dialogue Model for Filtering information from the Web.

In the new paradigm, users do not get overloaded with information when searching on the web. Instead, they interact with a dialogue system which attempts to understand their requests. Dialogue goes on until most of the user's communication goals have been met. The model is then capable of filtering information from the web that is of specific interest to the user. Multiple experiments have shown that this new filtering model outperforms state-of-the-art search systems.

Autonomous agents and multi-agent systems research has carried out work on intelligent search on the web, negotiation strategies for dynamic formation of agents, and multi-agent simulation. Furthermore, the Department of Computer Sciences has one of the two Chilean robotic soccer teams participating in the world robotic soccer competition *RoboCup*. A recent achievement is in intelligent robotic soccer in which team formation strategies are dynamically generated by using neural networks learning from the game conditions and the policy provided by a human coach.

The University has also contributed influential work on AI applications in foreign language learning and intelligent tutoring systems. Recent work focuses on automatic feedback generation using NLP technology for intelligent tutoring of language learning. Significant research has also been pursued on pattern recognition and its applications in Bioinformatics. In particular, new clustering and recognition methods for microarray image analysis and DNA processing.

3.3 AI at USACH

Current research has mainly focused on AI applications in medicine and practical optimization in industry. Research groups at USACH along with other universities pioneered a national effort to advance research and applications of neural network based methods in industry in the middle eighties. Significant applied AI work has also been in autonomous robotics applications for the Chilean mining industry. Recently, an important effort has concentrated on using machine learning techniques for Business Intelligence applications.

In Heuristics and Optimization, the focus is on solving hard problems in engineering and industry [12, 13]; Metaheuristics (i.e., Genetic Algorithms) for NP-hard problems; approaches to optimization using parallel and distributed computing technology [17]. Optimization using other techniques such as neural networks includes influential applied work on neural network models for pattern recognition, time-series prediction, metal image recognition and Intelligent Signal Processing. The Department of Computer Science Engineering has a key national role in biomedical applications in different areas such as data mining in the health area, biological systems analysis, neural nets and Bayesian methods for assessing health technologies.

3.4 AI at UChile

The Computer Science Department at University of Chile has no significant research contributions in AI. However, a small research group spread over several departments (electrical engineering, computer science, and industrial engineering)

has been engaged on AI related research. For example, some significant work has been developed in the areas of dynamic data mining and feature selection using machine learning methods. Furthermore, important research on formal Logic and the Semantic Web including a metadata model for describing and querying on the semantic web have been pursued by researchers in logic, mathematics and computer science. Recently, the Department of Electrical Engineering has led the application of AI techniques on intelligent robotic systems.

In addition to the academic AI research in universities some nationwide milestones have been witnessed across universities and companies. For example, Chile was the first South American country to introduce ES technology for fault diagnosis and knowledge acquisition into the Mining industry (80s). The first experimental and practical Natural Language Interfaces for business purposes were developed in early 80s. The first International Symposium on Artificial Intelligence in South America was held in Valparaiso, Chile (early 80s) in cooperation with the French Government. In early 90s the first practical mobile robotics applications for mine operations were deployed. In the middle 90s, a consortium of Universities brought Neural Nets Engineering into the productive area funded by FONDEF. Results included applications in pattern classification; Automatic Visual inspection; Robotic Manipulation; and Financial analysis. Recently, the government granted a million US dollar project to develop the first national University-Industry consortium for designing Unmanned Aerial Vehicles for surveillance and monitoring applications (2005).

3.5 AI at UTFSM

AI work at UTFSM has been conducted in the Department of Computer Science and Department of Electronic Engineering. Main research areas have focused on pattern recognition, evolutionary computation and heuristic optimization and neural networks. New ensemble machine learning techniques have been developed to deal with data-intensive tasks such as image processing, climate analysis, etc. Statistically-motivated methods have also been designed to improve the parameter setting task in evolutionary computation methods. Recently, important ongoing work has been developed for intelligent robotics in order to provide evolutionary mechanisms of navigation and object tracking.

4 Conclusions

Chilean AI basic and applied research has shown important contributions in industry, science and technology both at national and international levels. Keeping in mind the population of Chile (a 16 million people country), its activities are

even comparable in term of *per capita* activities to other bigger developing countries such as Brazil.

However, massive introduction of AI technology into private companies is still in its early stages. Data mining technologies, fraud detection, industrial-strength optimization, etc are some exceptions. As biotechnology, and in particular, bioinformatics becomes more popular, AI techniques for processing massive genomic data, image sequence and DNA information are a must. There are huge gaps in education as being recognized by educational authorities. Designing and applying AI systems for improving the learning/teaching process can address the main issues.

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