

Computational intelligence

The Centre for Intelligent Systems (CSI) is a multidisciplinary research and development centre, founded in 2001, in a very young university, the University of Algarve, in the south of Portugal. The Centre's mission is to promote fundamental research in Computational Intelligence (CI) methodologies (not forgetting their synergy with traditional methodologies), and to apply these techniques mainly in the areas of control systems and biomedical signal processing.

There is not a universally accepted definition of an intelligent system. Perhaps the most common one is a system that employs, in different degrees, methodologies coming from the big umbrella of CI, which embraces a series of techniques and paradigms, which have in common the fact they can be biologically or linguistically motivated. Although not restricted to, the most important techniques are artificial neural networks, fuzzy systems and evolutionary algorithms.

An artificial neural network, as the name indicates, is a mathematical model (or a computational model) that is based on biological neural networks, or, at least, shares some common properties with them. Nowadays, artificial neural networks are recognised tools for function approximation (they have the ability to approximate any function to an arbitrary degree of accuracy) and classification. Moreover, as artificial neural networks share with their biological counterpart the properties of learning and adaptation, they can be applied in changing environments.

Artificial neural networks (and fuzzy systems) have been found in applications in almost every area of science: two of the most important being control systems and signal

processing. CSI has organised, in 2003, the first IFAC Conference on Intelligent Control and Signal Processing (ICONS 2003), and, in 2005, the IEEE Symposium on Intelligent Signal Processing (WISP 2005).

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At CSI, we are interested in both fundamental research and applications of neural networks. In the former, a long-standing research line is pursued on methods to construct 'better' approximators and classifiers. Past work by several researchers enables the Centre to have available a proven methodology and algorithms, which obtain excellent results using off-line data. Current and future research is focused on improving the performance of online learning algorithms.

Due to their universal approximation capability, neural networks can be employed as non-linear predictive models of, for instance, weather variables, such as solar radiation, temperature, wind velocity, etc. The advantages of using these models compared with 'conventional' predictors are their superior performance (particularly for long-range prediction) and their applicability to model complex systems, not requiring a predefined model structure. These predictive models have been applied in renewable energy

Intelligent systems for energy and medical diagnosis support systems...

applications, enabling a more efficient energy usage/conversion/storage. In a more indirect way, reliable predictions allow the use of anticipatory or predictive control, where control actions are computed not only with the current measured or stored data, but also taking into account their predicted evolution. We have shown that the use of this scheme for Heating, Ventilation and Air Conditioning (HVAC) systems maintains thermal comfort with important energy savings. This is important as in EU countries primary energy consumption in buildings represents about 40% of total energy consumption and, depending on the country, half of this energy is spent for indoor climate conditioning. As energy (particularly fossil) will be a scarcer and more expensive resource, it can be forecasted that intelligent systems will have an important role in renewable energy and climate control applications.

Another area where intelligent systems have been employed, and where increasing use can be expected, is biomedical signal processing, in particular diagnosis support systems. Here, typically, neural networks are used as classifiers.

Ischemic Cerebral Vascular Accidents (ICVA) are the third cause of death in developed countries and the first in Portugal. Computerised Tomography (CT) scans have already proved to be the first line of diagnosis of ICVAs, helping to identify haemorrhages or infarcts. To minimise morbidity or even patient death, diagnosis should be done in quick time. The reduced number of radiologists associated to the increasing number of individual examinations, may contribute to a delayed final report. In addition, some institutions do not have full-time expert radiologists. These facts constitute the motivation to create an

intelligent system capable of assisting the radiologist in the analysis of CT scan images, and, in the future, enabling a preliminary trigger of a pathologic occurrence in the absence of the expert radiologist. Work done so far has reported no false positives and a very small number of false negatives, indicating that neural networks are suitable for automatic identification of ICVAs. Another related area of interest is the detection and classification of circulating cerebral emboli using blood flow ultrasonic signals. The first system achieving success rates better than 90% were achieved by us in 2001.

Another clinical application of intelligent systems is on hyperthermia and diathermia. CSI has also developed ultrasonic experimental models supported by computational neurogenetic techniques to obtain a non-linear spatial-temporal model of tissue temperature estimation, when subject to therapeutic ultrasound. The proposed model was also the first ultrasound model to obtain, in a multi-layered tissue phantom, a temperature estimation error less than the gold standard value of 0.5°C per cm³, a value only achievable using expensive Magnetic Resonance Techniques. This innovation leads to the development of other thermal applications on localised areas with high focused ultrasound signals, namely on oncology treatments.

Evolutionary algorithms are computational methods for search and optimisation that are inspired in the processes of natural selection and biological evolution, and have found many important applications in science and engineering. In evolutionary computation, problems play the role of an environment in which a number of individuals, representing candidate solutions, compete for survival and for the opportunity to reproduce. As in nature, reproduction introduces variability in the population, leading to the discovery of, potentially better, solutions to the problem considered. Under selection, badly performing offspring die, whereas fitter offspring become the parents of the next generation of solutions.

Following its inception in the late sixties, both in the USA and in Germany, evolutionary computation developed more or less quietly during the seventies and the eighties, and became increasingly popular in the nineties and the current decade. In particular, the development of evolutionary algorithms for multi-criterion optimisation, or the optimisation of problems involving more than one measure of solution quality, found strength in the nineties, having received, and continuing to receive, strong European input. In 2001, an International Conference on Evolutionary Multi-Criterion Optimisation took place in Zurich, Switzerland, and became the first of a successful series. The second conference in this series was organised by CSI, and was held in Faro, in April 2003.

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Evolutionary multi-criterion optimisation (EMO) has been precisely one of the main focal points of evolutionary computation research at CSI, with special emphasis on the development of methods and tools for the experimental assessment of evolutionary multi-objective optimiser performance, the articulation of preference information in evolutionary optimisation, and the application of EMO techniques to engineering and management problems such as resource allocation and scheduling, neural network structure selection, the optimisation of polymer processing equipment, and power distribution network optimisation. A more recent line of theoretical work concerns the study of the dynamical behaviour of evolutionary optimisers.

Work at CSI is not limited to artificial intelligent systems. To understand how the brain accomplishes meaningful processing of structured sequences of information is a generic problem of central importance in human cognition. Human language and literacy are paradigmatic examples of this and specific difficulties in reading and writing; dyslexia is a condition characterised by a specific problem with structured sequence processing. We have proposed that implicit acquisition of structured sequence knowledge can serve as a laboratory model for language and literacy acquisition. Ultimately, the capability for structured sequence processing is closely related to questions about the nature of the neural code and its adaptive characteristics. In addition, because of important recent mathematical breakthroughs, it has become possible to explore how structured sequence processing can be achieved in biological neural networks. The main objective is to investigate these topics at neurofunctional, behavioural-cognitive, and theoretical-computational levels. The results will contribute to: a fundamental integration of research on dyslexia, implicit learning, and the effects of literacy on human cognition; a comprehensive understanding of the cognitive deficits underlying reading disorders; and a comprehensive theoretical framework for the acquisition/processing of structured sequences in biologically realistic neural networks.



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