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Computational intelligence: A primer

Matthew NO Sadiku[1], Sarhan M Musa[2], Osama M Musa[3]
[1] Roy G Perry College of Engineering, Prairie View A&M University, Prairie View, Texas, United State
[2, 3] Ashland INC, Bridgewater, Texas, United State

Abstract
Computational intelligence (CI) refers to the ability of a computer to learn a specific task from experimental observation. It is an emerging discipline which provides powerful tools for modeling and analyzing complex systems. Some regard CI as a branch of artificial intelligence that comprises algorithms inspired by nature to address complex real-world problems. This paper provides a brief introduction to computational intelligence.

Keywords: computational intelligence, artificial intelligence, soft computing

1. Introduction

Computational intelligence (CI) techniques are computational systems that try to mimic human behavior, such as perception, reasoning, learning, evolution, and adaptation. It is concerned with discovery of structures in data and recognition of patterns. It involves using an algorithm to capture hidden knowledge from data and use it to train "intelligent machines" to make complex decisions without human intervention [1]. It encompasses techniques such as neural networks, fuzzy logic, and evolutionary computation which derive rules, patterns, and develop complex mappings from the data.

The concept of computational intelligence was first used in 1990 by the IEEE Neural Networks Council, which later became the IEEE Computational Intelligence Society. CI provides knowledge engineers with a set of robust techniques and intelligent tools for various applications. CI methods provide the ability to learn from experience and extract knowledge. Although Artificial Intelligence (AI) and Computational Intelligence (CI) seek a similar long-term goal, they are different. While AI is based on hard computing methods, CI is based on soft computing methods, which enable adaptation to many situations. One may regard AI as human-based, and CI as nature-based. Some consider CI as a subfield of AI; while others consider them as parallel disciplines.

Concept of computational intelligence

CI approaches aim at creating intelligent systems by using innovative and nature-inspired algorithms. Traditionally CI therefore uses a combination of three main techniques: Neural Networks, Fuzzy Systems and Evolutionary Computation. They are briefly explained as follows [2, 3] and illustrated in Figure 1.

- Neural Networks: These are the most popular artificial learning tools. Artificial neural network (NN) is a CI method that mimics the neural system of a human brain. NNs are parallel distributed networks that have the ability to learn and generalize from examples. NNs includes feedforward NNs, recurrent NNs, self-organizing NNs, deep learning, and convolutional neural networks. An NN architecture typically consists of an input layer, one or more hidden layers, and an output layer. With large numbers of input variables, it can be difficult for the user to understand the logic represented in this mapping of inputs to output.
- Fuzzy Systems: Fuzziness refers to the inexact or imprecise nature of common terms. It constitutes a form of "approximate reasoning." This area of research includes fuzzy sets and systems, fuzzy clustering and classification, fuzzy controllers, linguistic summarization, and fuzzy neural networks. Fuzzy algorithms attempt to capture the uncertainty and imprecision in rule-based representations that are not easily quantified by other methods. They are very powerful for modeling systems where the descriptors or inputs do not cleanly separate into discrete values or are subjective.
- Evolutionary Computation: Evolutionary computation (EC) is a CI model used to mimic the biological evolution phenomenon. EC solves optimization problems by generating, evaluating, and modifying a population of possible solutions. EC currently includes five algorithms: genetic algorithm (GA), evolutionary programming (EP), evolution strategies (ES), genetic programming (GP), and swarm intelligence (SI). EC is very useful for optimizing the connections and weightings between the input layer, the hidden layer(s), and the output layers for an NN model.

However, CI is an evolving field. In addition to the three main constituents, it encompasses computing paradigms like ambient intelligence, swarm intelligence, artificial immune systems, cultural learning, data mining, natural language processing, and artificial intelligence. The common characteristics of these techniques are their collective intelligence and adaptability to a changing environment. Due to their efficiency and simplicity, the algorithms have been employed successful for problem solving across social and natural sciences [4].

Applications

CI plays a major role in developing successful intelligent systems, including games and cognitive developmental systems. It provides solutions to complex real-world problems to which mathematical or traditional modelling does not perform well. Successful applications of CI have been found in computer science, engineering, data analysis, business, marketing, medical, e-government, and manufacturing domains.

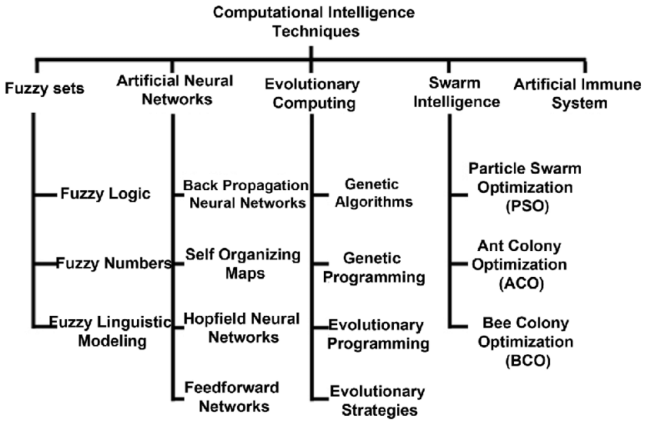
- *Wireless sensor networks (WSNs):* These are networks of distributed autonomous devices that can sense or monitor environmental conditions. WSNs face many challenges, mainly caused by communication failures, storage and computational constraints and limited power supply. Computational intelligence has been successfully applied to address various challenges such as data aggregation and fusion, energy aware routing, task scheduling, security, optimal deployment and localization. CI provides adaptive mechanisms that exhibit intelligent behavior in complex and dynamic environments like WSNs [5].
- *Finance and Economics*: The financial sector is crucial to the economical and social organization of modern society. The number of applications of CI in this area is huge and could cover anything from asset pricing or game analysis to time series forecasting. The range of approaches that have already been used in economics and finance includes fuzzy systems, neural networks, evolutionary computation, support vector machines, and ant algorithms. The techniques have been used in financial economics, games and industrial organizations, macroeconomics, and econometrics [6].
- *Control*: CI methodologies are currently applied to all areas of control. Application of CI in control leads to neural network control, fuzzy control, reinforcement learning, and brain machine interfaces. Neural network has been successfully applied to system control with its universal approximation and adaptation capabilities [7].
- *Medicine*: Computational intelligence can be useful for medical purposes. CI models can analyze large amounts of data in order to predict healthcare outcomes for individual patients. They can handle the imprecision and uncertainty which is typically apparent in clinical and biological data. They are suitable for clinical predictions as they are efficient in finding patterns in data which contain noisy features, and which traditional statistical models alone often fail to handle [8].

Other applications include production electronics, games, hydrology, drug discovery and development, HVAC (Heating Ventilating and Air-Conditioning) systems, power systems, transfer learning, sports, bioinformatics, intrusion detection, and logistics and supply chain management. The combination of big data and computational intelligence provides a powerful tool, has the potential to influence modern societies, businesses, and the public [9].

Benefits and challenges

CI techniques can solve real-world complex problems in which traditional approaches are ineffective. They perform efficient approximations within reasonable computation time because they often use non-deterministic techniques. Nonlinear characteristics of the optimization models and 3D problems pose challenge for traditional mathematical programming methods. CI techniques perform well in nonlinear optimization problems and allow modeling systems of different complexity [10]. Other advantages of CI methods are that they often work efficiently, that they are fault-tolerant, and that they are mostly well-suited for parallelization.

On the other hand, the biggest disadvantage of CI, compared to deterministic methods, is that the optimal solution(s) can generally be neither proved nor guaranteed to be found [11]. Attempt to combine different CI methods is a challenge.



***Source*:** https:// www.researchgate. net/ figure/ Type-of-computational- intelligence-9_fig2_317263278

Fig 1: Computational intelligence methods

Conclusion

CI develops intelligent systems with the ability to learn, to deal with new situations, and to reason. The major goal of researchers in CI is mimicking Nature with artificial technologies. The growing interest in CI research can perhaps best be illustrated by the increasing number of journals, books, and articles published on CI in the recent years. However, CI is yet to reach maturity as a discipline in its own right.

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