Chapter 1
Computational Intelligence Paradigms:
An Overview

El-Sayed M. El-Alfy
King Fahd University of Petroleum and Minerals, Saudi Arabia

Wasan Shaker Awad
Ahlia University, Bahrain

ABSTRACT

The evolution of communication networks and information systems, to support wireless access, cloud and grid computing, and big data, provides great business opportunities. However, it also generates a new trend of sophisticated network threats and offers several challenges in securing information and systems confidentiality, integrity and availability. The traditional techniques used by security experts are mostly static and lack the much needed characteristics of adaptation and self-organization, computational efficiency and error resilience to deal with evolving attacks. The inherent characteristics of computational intelligence (CI) paradigms provide a promising alternative that has gained popularity resulting in significant applications in information security. There is a plethora of CI paradigms commonly used in this domain including artificial neural networks, evolutionary computing, fuzzy systems, and swarm intelligence. This chapter provides an overview of the widely-recognized CI paradigms and shades the light on some of their potential applications in information security.

INTRODUCTION

There are several problems encountered in the field of information security and cryptography that can be handled using computational intelligence paradigms, e.g. (Laskari et al., 2005, Wu & Banzhaf, 2013). These problems require optimization, adaptation, self-organization, parallelizability, fault tolerance, error resilience, and computational efficiency. According to Papadimitriou and Steiglitz (1982), a combinatorial optimization (CO) problem $P = (S, f)$ is an optimization problem in which we are given a finite set of objects S (search space) and an objective function $f: S \rightarrow \mathfrak{R}$ that assigns a positive cost value to each

DOI: 10.4018/978-1-4666-9426-2.ch001

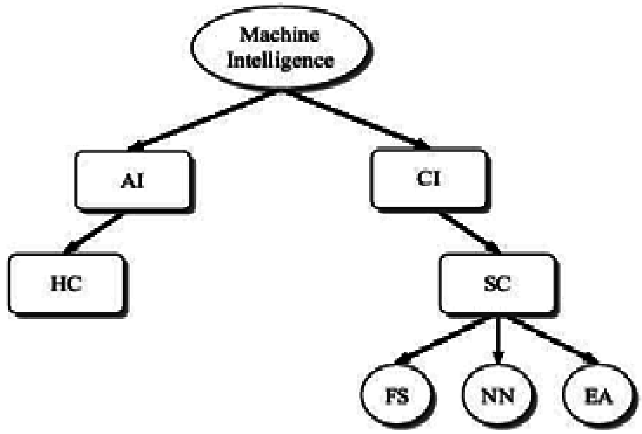
of the objects $s \in S$. The goal is to find an object that has the minimal cost value. CO problems can be modeled as discrete optimization problems in which the search space is defined over a set of decision variables with discrete domains. Therefore, the terms combinatorial optimization and discrete optimization can be used interchangeably.

Due to the practical importance of CO problems, many algorithms to solve them have been proposed. These algorithms can be classified as either complete or approximate algorithms. Complete algorithms are guaranteed to find, for every CO problem instance, an optimal solution in polynomial time, but for CO problems that are *NP*-hard (Garey & Johnson, 1979), no polynomial time algorithms exist. Therefore, complete methods might need exponential computation time in the worst case. Thus, the development of approximate methods including CI techniques has received a growing attention where finding optimal solutions cannot be guaranteed but getting good solutions in a significantly reduced amount of time is desirable.

Computational intelligence is used to solve problems that only humans and animals can solve, i.e., problems requiring intelligence (Chen et al., 2001). Artificial Intelligence (AI) has been already established since the mid 1950s, addressing problems that require intelligence in order to be solved. Thus, one may ask, what is the difference between AI and CI? Zadeh (1994, 1998) distinguishes hard computing techniques based on AI from soft computing techniques based on CI. In hard computing, imprecision and uncertainty are undesirable features of a system whereas these are the foremost features in soft computing. Figure 1 shows the difference between AI and CI along with their relationship to hard computing (HC) and soft computing (SC). Zadeh defines soft computing as "a consortium of methodologies that provide a foundation for designing intelligent systems".

Many attempts have been made by different authors and researchers to define CI. Bezdek (1994) first proposed and defined the term CI as follows: "a system is called computationally intelligent if it deals with low-level data such as numerical data, has a pattern-recognition component and does not use knowledge in the AI sense; and additionally when it begins to exhibit computational adaptivity, fault tolerance, speed approaching human-like turnaround and error rates that approximate human performance" (Bezdek, 1994). He argues that CI is a subset of AI. Since then there has been much explanation published on the term CI. The IEEE Computational Intelligence Society (formerly the IEEE Neural Networks Council) defines its subject of interest as Neural Networks (NN), Fuzzy Systems (FS)

Figure 1. Artificial intelligence (AI) versus computational intelligence (CI)



Related Content