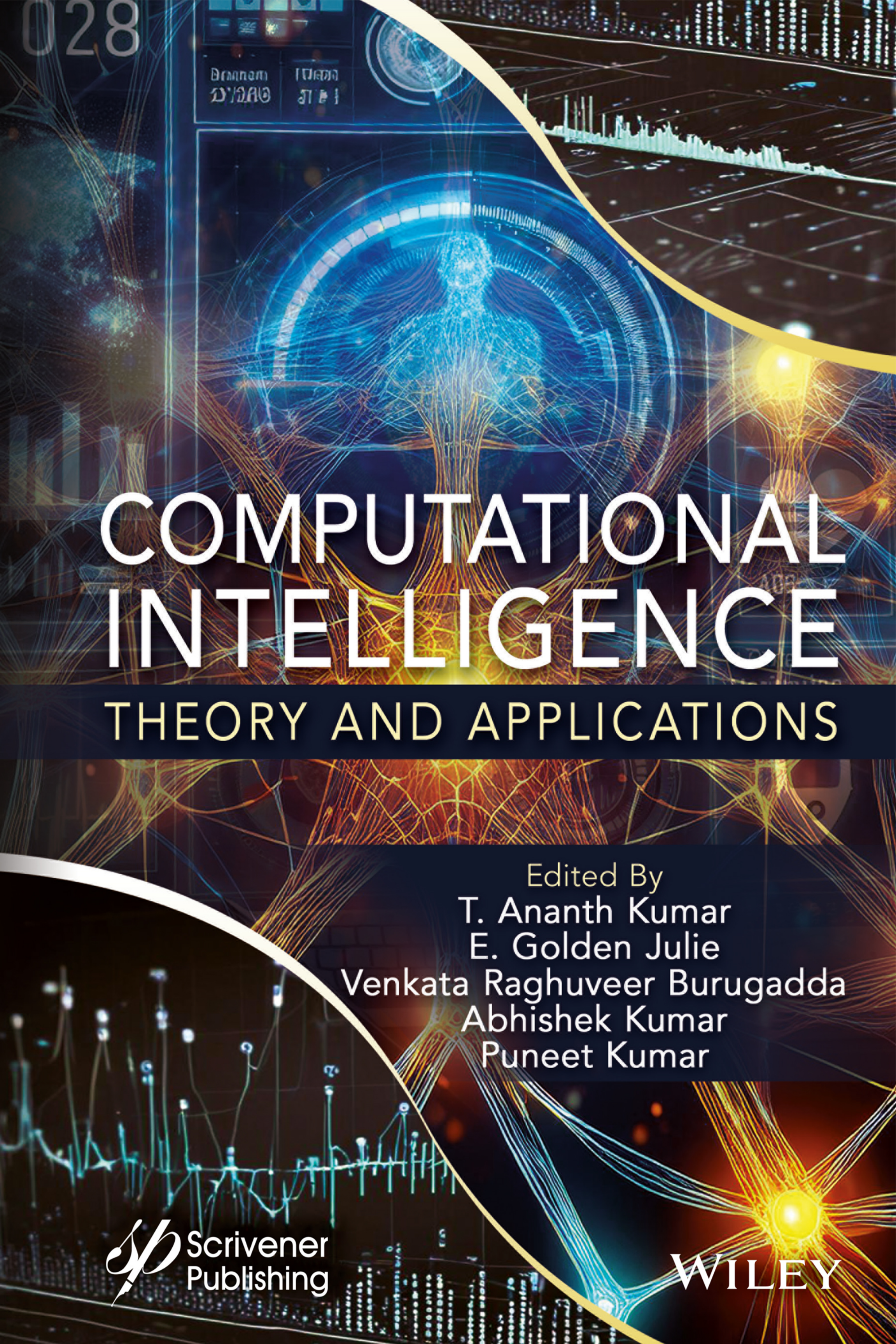

COMPUTATIONAL INTELLIGENCE

THEORY AND APPLICATIONS

Edited By
T. Ananth Kumar
E. Golden Julie
Venkata Raghuveer Burugadda
Abhishek Kumar
Puneet Kumar

Scrivener Publishing

WILEY

Computational Intelligence

Scrivener Publishing
100 Cummings Center, Suite 541J
Beverly, MA 01915-6106

Publishers at Scrivener
Martin Scrivener (martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

Computational Intelligence

Theory and Applications

Edited by

T. Ananth Kumar

E. Golden Julie

Venkata Raghuveer Burugadda

Abhishek Kumar

and

Puneet Kumar

Scrivener Publishing

WILEY

This edition first published 2024 by John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA and Scrivener Publishing LLC, 100 Cummings Center, Suite 541J, Beverly, MA 01915, USA

For more information about Scrivener publications please visit www.scrivenerpublishing.com.

Wiley Global Headquarters
111 River Street, Hoboken, NJ 07030, USA

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Library of Congress Cataloging-in-Publication Data

ISBN 978-1-394-21422-8

Front cover images supplied by Adobe Firefly
Cover design by Russell Richardson

Set in size of 11pt and Minion Pro by Manila Typesetting Company, Makati, Philippines

Printed in the USA

10 9 8 7 6 5 4 3 2 1

Contents

Introduction

Chapter 1 encompasses computing paradigms inspired by nature and cognition, rooted in evolution, fuzzy systems, and neural networks. Computational intelligence (CI) underpins potent AI systems, notably deep learning, a cornerstone of modern AI technology. It is the bedrock of highly effective AI systems, driving advancements like video games and cognitive development.

Chapter 2 handles merging evolutionary computation, neural networks, and fuzzy systems decades ago. Nature-inspired algorithms have evolved, proving more adaptable for optimization. Various types of these algorithms, particularly those centered on self-organizing natural communities, are actively developed. This article compares state-of-the-art optimization techniques with established gradient-based and gradient-free methods. It also identifies unresolved issues in optimization and meta-heuristics for future research.

Chapter 3 demotes AI's significance in modern industries for its robust computing capabilities, which process extensive data, yielding valuable insights and aiding decision-making. AI customizes experiences through user data analysis. Computational intelligence research benefits individuals and society, enhancing data processing for intelligent AI systems. This chapter explores various dimensions of computational intelligence, driving societal development and economic progress. It delves into hybrid models, ensemble techniques, and practical AI applications, offering insights for future researchers and scholars in advancing computational intelligence.

Chapter 4 delves into an AI system based on cognitive mechanisms for visual data processing. It explores the relationship between this model and cognitive processes, focusing on selective attention. AI is viewed as a transformative force in human–machine interaction, impacting organizational dynamics, communication, and ecosystems. While AI research can be complex, the information systems field is pivotal. The paper suggests that AI technology may surpass human instructors within a decade.

Chapter 5 deals with groups of spatial co-location patterns. This work introduces a computational intelligence method employing a grid clustered technique, enhancing pattern detection. The Top-K co-location technique is used for generating highly co-located spatial patterns. Implemented on the MapReduce framework, it accelerates the processing of large spatial datasets, improving efficiency. Experimental results confirm the algorithm's effectiveness across various data sizes.

Chapter 6 introduces an efficient method for early detection and classification of plant illnesses using machine learning. Early detection of plant diseases is crucial in agriculture for increased profitability and yield protection. The approach involves capturing leaf images with a camera sensor, extracting essential features through segmentation, and utilizing SVM for disease categorization. The system's effectiveness is evaluated for both detection and classification.

Chapter 7 predicts that protein structure, a deep learning challenge, has seen notable progress, yet room for improvement remains. Deriving tertiary, secondary, and quaternary structures from the primary is complex. Convolutional neural networks (CNNs) model interactions using features like amino acid sequences. Employing data from a protein data bank, we developed CNN-CA-P, augmenting cellular automata. Achieving high accuracy (96.56% secondary, 91.2% tertiary, and 86.32% quaternary), it outperforms baseline methods, evaluated on parameters like accuracy, AUC, precision, F1 score, and recall.

Chapter 8 explores the application of artificial intelligence techniques, specifically artificial neural networks (ANNs) and expert systems (ES), in modeling and forecasting renewable energy effectiveness. It presents various problems in renewable energy engineering to showcase how these systems operate. The research demonstrates the potential of AI as a design tool across different aspects of renewable energy engineering, affirming the efficacy of neural networks in this domain.

Chapter 9 presents health informatics and a surge in data analytics driven by diverse multimodal data. This has sparked interest in tailored machine learning (ML) models. Deep learning (DL), rooted in neural networks, has emerged as a potent tool in AI, promising transformative impacts. Its capacity for complex feature enhancement and semantic analysis, coupled with computational advancements, fuels its prominence. This chapter comprehensively assesses DL's advantages, potential limitations, and prospects, particularly in health-related contexts. The investigation focuses on critical applications, spanning bioinformatics, continuous sensing, medical imaging, and public health.

Chapter 10 tackles real-world issues using nature-inspired methods, distinct from formal models. CI plays a crucial role in human activity recognition (HAR), capturing activities via sensors and processing them. HAR holds vital information on identity, personality, gestures, and more, impacting interpersonal interactions. This chapter delves into CI paradigms for HAR, like fuzzy logic, artificial neural networks, swarm intelligence, evolutionary computing, and artificial immune systems. Researchers are advancing HAR with CI algorithms, showcasing CI's versatility and discussing its benefits and drawbacks in various research contexts.

Chapter 11 deals with AI with healthcare. Biomedical image processing employs image analysis, machine learning, and cloud technology. Fuzzy logic, Bayesian inference, and statistics aid medical disease detection. Overcoming challenges of high dimensionality, class imbalance, and limited databases, modern technology provides superior results. Cloud computing enables global accessibility for data storage and processing, improving diagnostic accuracy for connected diseases. AI strives for precise, comprehensive solutions in biomedical processing.

Chapter 12 deals with computational intelligence (CI) methods, including sample augmentation, feature extraction, categorization, indexing, fusion, normalization, and anti-spoofing, which are crucial in creating biometric identities and addressing dataset challenges. CI enables complex nonlinear calculations and model development from training data, employing supervised and unsupervised training. This chapter explores CI-based biometric recognition methods.

Chapter 13 deals with hyperspectral imaging (HSI), which has gained prominence, especially in biomedical fields like cancer detection. Breast cancer (BC) is a significant global health concern, with over 1.3 million cases in India. Early detection improves survival rates. Various optical techniques are employed, each with its advantages and drawbacks. Biopsies, the current validation method, are invasive. Non-invasive methods like HSI show promise. This chapter comprehensively reviews HSI for breast cancer detection, covering advanced deep-learning frameworks for automated diagnosis.

Chapter 14 also deals with healthcare and AI. Oral cancer (OC) is particularly prevalent in India, accounting for a significant percentage of cases and deaths. Early detection is crucial for survival. Various imaging techniques exist, with drawbacks. Emerging methods like hyperspectral imaging (HSI) show promise for non-invasive, safe, and precise diagnosis. HSI combined with deep learning techniques like CNNs and 3DCNNs holds potential for early OC detection. This chapter outlines these advancements and suggests future research directions.

Chapter 15 deals with image processing, which plays a crucial role in human eye recognition. Prolonged computer use can lead to visual problems. Optic disc (OD) is vital for diagnosing retinal diseases. It is characterized by high fractal dimensions due to blood vessels. OD's location helps diagnose conditions like glaucoma. This screening system aids in glaucoma detection through OD segmentation. Glaucoma is a chronic eye disease causing irreversible vision loss. Retinal image features like OD, optic cup (OC), and neuro retinal rim (NRR) are crucial for disease identification. This work aims to enhance OD detection using multiple segmentation algorithms. The method involves directional matched filtering, vessel detection, and cup boundary assessment for OC segmentation. Machine learning algorithms further aid in glaucoma diagnosis. This method shows promising potential with a solid correlation to ground truth segmentation results.

Chapter 16 revolutionized AI in marketing, providing innovative ways to engage customers. It processes vast data, offering insights for tailored marketing strategies. Social media and placement automation streamlines operations, saving time and enhancing plans. AI-powered chatbots handle basic inquiries, freeing marketers. Predictive analytics use client data to forecast behavior and refine products and services. Embracing AI ensures a competitive edge in the digital landscape, enabling customized, effective marketing tactics. This chapter explores AI's role in marketing, presenting opportunities and challenges. It is a valuable resource for marketing professionals, educators, and students keen on understanding AI's impact in the field.

1

Computational Intelligence Theory: An Orientation Technique

S. Jaisiva[1*], C. Kumar[2], S. Sakthiya Ram[3], C. Sakthi Gokul Rajan[1] and P. Praveen Kumar[4]

[1]Electrical and Electronics Engineering, Sri Krishna College of Technology, Coimbatore, Tamil Nadu, India
[2]Electrical and Electronics Engineering, Karpagam College of Engineering, Coimbatore, Tamil Nadu, India
[3]Electronics and Instrumentation Engineering, Bannari Amman Institute of Technology, Sathyamangalam, Tamil Nadu, India
[4]Department of Information Technology, Sri Manakula Vinayagar Engineering College, Pondicherry, India

Abstract
The ability of a system to change its behavior to reach its objective in a variety of settings is intelligence. In reality, a different definition of computational intelligence (CI) is that it entails real-world adaption in challenging and shifting situations. In other words, it serves as a precise illustration of a notion. Adaptation and computational intelligence are intimately linked concepts. The concept, design, implementation, and advancement of computing paradigms driven by natural and cognitive motivations is known as CI. Evolutionary computation, fuzzy systems, and neural networks have historically been the three major foundations of CI. However, over time, various computing models that were inspired by nature have emerged. Sustainable smart information system, such as the creation of video games and cognitive developmental systems, heavily relies on CI. Deep learning study, especially that on deep convolutional neural networks, has exploded in recent years. Deep learning is currently the main approach for artificial intelligence. Deep learning has become the main technology for AI. In reality, CI is the foundation of some of the most effective AI systems.

**Corresponding author*: jaisiva1990@gmail.com

T. Ananth Kumar, E. Golden Julie, Venkata Raghuveer Burugadda, Abhishek Kumar and Puneet Kumar (eds.) Computational Intelligence: Theory and Applications, (1–24) © 2024 Scrivener Publishing LLC

***Keywords*:** Computational intelligence, artificial intelligence, biological intelligence, neural networks, fuzzy systems, optimization, evolutionary computation

1.1 Computational Intelligence

Intelligence is a trait shared by all decision-makers with a goal. An analysis paradigm known as an artificial neural network (ANN) is loosely framed on the basis of the human brain massively parallel architecture [1]. It replicates a massively parallel, linked computing framework with a large number of very straightforward individual processing components (PEs). The phrases artificial neural network and neural network will now be used equally throughout this chapter. Fuzzies are non-statistical inexactitude and ambiguity in info, as used in this article. The majority of notions used or expressed in the real world are hazy. For instance, the sentence "It's somewhat misty outdoors right now" combines the notions of being pretty and, even before, a long period of time. (One may even contend that the term is ambiguous and inaccurate enough to be hazy.) Fuzzy sets simulate the characteristics of estimation, ambiguity, and inaccuracy. Fuzzy membership values in a fuzzy set represent the membership dimensions (or grades) of the set's components. It will be demonstrated that the fundamental concept of fuzzy set theory is a membership function, which is the same as a fuzzy set [2].

Crossover, mutations, and the survival of the fittest are examples of natural evolutionary phenomena that are incorporated into genetic algorithms, which are search algorithms. They are utilized for categorization as well as optimization more frequently. While genetic algorithms incorporate crossover, evolutionary programming approaches do not. Instead, they depend on mutation and the survival of the fittest. Comparable to genetic algorithms, evolution tactics frequently employ a distinct kind of mutation in addition to using combination to share data across members of population rather than crossover [3]. Computer programs can evolve using a technique called genetic programming. Hierarchical tree topologies are frequently used to manipulate structures. Potential solutions are dispersed throughout the problem space by particles in particle swarm optimization. The issue space's chosen locations where prior fitness values have been high are where the particles are pushed. The term "computational intelligence" refers to a computing-based methodology that gives a system the capability to gain knowledge of novel situations, giving the system the appearance of possessing one or more rational qualities including generalization, discovery, connection, and abstraction. They are frequently made to resemble one or more characteristics of natural intelligence. In the illustration of a neural network paradigm is back-propagation, which presupposes a particular set of characteristics, such as the design and the learning algorithm [4]. A certain collection of options for each characteristic constitutes a paradigm. Introducing a separate paradigm includes putting together a group of characteristics that describe the desired behavior of the CI tool.

There are some words that should only be used with care. One such instance is neural networks, where it is important to be clear if we are taking about analytical tools for artificial neural network wetware. Let us explore the conceptual and technological underpinnings of computational intelligence tools and component approaches after providing the fundamental definitions [5]. We utilize and mention the caveat mentioned before. The creation of algorithmic models to address ever-more-complex issues is a key focus of algorithmic innovation. These clever algorithms are a subset of artificial intelligence, along with deductive reasoning, expert systems, case-based reasoning, and symbolic machine learning systems (AI). AI can be seen as a synthesis of various scientific areas, such as computer science, physiology, philosophy, sociology, and biology, just by looking at the broad range of AI methodologies [6].

Yet what exactly is intelligence? Definitions of intelligence continue to spark heated discussion. Dictionary definitions of intelligence include the capability for cognition and reason, as well as the capacity to perceive, comprehend, and benefit from experience (especially to a high degree). Innovation, ability, awareness, empathy, and instinct are other terms used to characterize characteristics of intelligence.

Can computers think for themselves? Even now, there is more disagreement over this issue than over how to define intelligence. Alan Turing gave this issue a lot of study in the middle of the 20th century. He thought it was possible to build devices that could duplicate the functions of the human brain. Turing firmly felt that a well-designed computer could perform every task that the brain was capable of. His predictions are still prophetic more than fifty years later. Smaller biological neural system components have been successfully modeled, but the complicated task of modeling is an essential component of mankind intelligence and remains unsolved [7].

The Turing test, created by Turing in 1950, is a measurement of computing intelligence. The test involved asking questions of both a person and a machine using a keyboard. The computer might be thought to be smart if the interviewer was unable to tell the computer from the person.

Turing anticipated that by the year 2000, a system will be able to compete with the testing and training of 70% chance. Has his conviction been realized? In order to avoid jumping into yet another argument, the reader is left to choose the solution to this issue. However, the information in this book may help to clarify some aspects of the response [8].

The IEEE Neural Networks Council of 1996 gave a more modern version of artificial intelligence as the research of how to get computers to perform tasks that people are good at. These processes include the AI paradigms that can generalize, synthesize, discover, and connect as well as learn novel contexts. While specific approaches and techniques from various CI paradigms have been effectively used to address issues in the real world, the current trend is to create hybridization of models because no one model is always better than the others. By doing this, we strengthen the areas where each component of the hybrid CI system excels and do away with those where it falls short. Swarm intelligence is a category of the CI concepts, despite the fact that many investigators believe they should only fall within the category of synthetic biology [9].

1.2 Application Fields for Computational Intelligence

There are applications for which every computational intelligence element technique is particularly well suited. A particular problem might be solvable by either a neural network or a fuzzy system, but at varying standards of achievement; therefore, consider the fact that main applications may intersect. It might not even be typical of all the important application fields. It is intended to give some insight into the variety of issues that have been addressed by using CI's component techniques.

1.2.1 Neural Networks

Generally speaking, neural networks are best suited for five types of applications. The first three have a connection.

1.2.1.1 Classification [10]

This section examines which of a number of predefined classes most accurately captures an input sequence. Usually, there are not many classes compared to the quantity of inputs. One illustration determines whether a specific EEG data section represents an epileptiform spike waveform. Another type of clustering is the creation of nonlinear mappings between high-dimensional spaces by neural networks. This application area includes several forms of video image processing (such as tumor diagnosis).

1.2.1.2 Clustering or Compression

Although categorization is a part of this field, compression algorithm can also be used to describe it. Think of natural language processing as an example of how the complexity of a source is considerably decreased. Lowering the number of bits necessary to represent a data block within a specific allowed error range is another. In other words, less bytes than in the source information can be used to reproduce the original block of data within the allowed mistake.

1.2.1.3 Generation of Sequences or Patterns

In contrast to the first three, this fourth area does not entail any classification. Using examples as training data, a network creates these patterns [11]. At an instant, to duplicate a particular kind of harmonious progression, the network may be able to create "original" renditions of that style of music. Another option is to train a neural network to emulate or model anything. There may not be any "correct" solutions because the system being replicated has inherent unpredictability, yet the system can perhaps be quantitatively defined. These statistical characteristics can then be incorporated into the network simulation.

1.2.1.4 Control Systems

Among the quickest-evolving application areas for neural networks is control systems. It is being used extensively for a number of reasons. An ANN-based control system can first handle all sets of nonlinear effects. (An approximate linearity of the system is not required.) Second, when building the control system, the chaotic system can be modeled using a network. Third, compared to other, more conventional methods, developing a neural network control system often takes a lot less time. For each of the five uses, there appear to be more and more emerging every day. Some implementations are unique to a field of study [12]. EEG waveform classification and appendicitis diagnosis are two examples of fields such as medicine. Neural networks are used in accounting and commerce to process loan applications from financing companies and to trade options on commodity futures contracts. Neural networks are able to govern the locations of several cars on an interstate at once in the automotive sector.

1.2.1.5 Evolutionary Computation

Optimization and categorization are the two basic applications of evolutionary algorithms. Since optimization is the subject of the majority of engineering disciplines for evolutionary computation, optimization is the main topic of discussion in this theme.

1.2.2 Fuzzy Logic

Numerous engineering fields, including robotics and control, modeling, and geotechnical sciences, use fuzzy logic in a variety of applications. Medicine, management, decision analysis, and computer science are further application fields. Similar to neural networks, new applications pop up practically every day. Fuzzy expert networks and adaptive logic are two of the key application domains [13].

1.2.2.1 Fuzzy Control Systems

Fuzzy control systems have been used in traffic signal circuits, household appliances, video cameras, metro systems, cement kilns, and a number of automotive subsystems, along with the gearbox and emergency systems. The circuitry within a video camera that stabilizes the image despite the user's shaky hand placement is one technology that many people are familiar with. Fuzzy expert systems have been used in a variety of fields, including corporate strategy selection, industrial automation, medical diagnosis, planning, and currency trading.

1.2.2.2 Fuzzy Systems

According to conventional set theory, a component may either be a member of a set or it cannot. Similar restrictions apply to the results of an implicit learning procedure in binary-valued logic, which calls for model parameters to be either 0 or 1. Unfortunately, human logic is rarely this precise. Normally, there is a level of ambiguity in both our perceptions and thinking [14].

Probabilistic thinking is made possible by fuzzy sets and fuzzy logic. When using fuzzy sets, an element can be quite assured that it conforms to a range. Fuzzy logic enables inference of actual revelations from these ambiguous facts, each of which has a degree of certainty attached to it. In a way, rational thinking can be modeled using fuzzy sets and reasoning.

Fuzzy systems have been effectively used to regulate traffic lights, lifts, cog shifting and brake mechanisms in automobiles, and many other systems.

1.2.2.3 Behavioral Motivations for Fuzzy Logic

Fuzzy systems are lacking a physiological rationale or foundation at the subcellular and cellular levels. It manifests itself in the way the creature behaves, or in how the creature engages with its surroundings. The methodologies before have a strong biological foundation, but fuzzy logic mostly works with uncertainty and vagueness. We do not exist in a universe of truth and untruth, ones and zeros, black and white, or other objective facts. Our emotions, interactions, and perceptions almost always contain a significant amount of unpredictability [15].

There are two primary categories of ambiguity. One is quantitative and is based on the probabilistic laws. The other kind of uncertainty is nonstatistical and relies on ambiguity, inaccuracy, or both. Fuzziness is a term used to describe nonprobability unpredictability. Fuzzy logic's capacity to effectively collect and manage these hazy, disorganized thoughts is one of its key characteristics.

A system's essential characteristic is fuzziness. By inspection or measurement, it is neither changed nor resolved. The representation of a complicated system can be made more tractable to analysis by accounting for some unpredictability. Thus, fuzzy logic offers a structure for the definition, description, and analysis of descriptive unpredictability. According to him, fuzziness results from a verbal lack of precision [16].

1.3 Computational Intelligence Paradigms

Artificial neural networks (NN), evolutionary computation (EC), swarm intelligence (SI), artificial immune systems (AIS), and fuzzy systems are the five basic paradigms that computational intelligence (CI) takes into account (FS). Figure 1.1 illustrates how deterministic methods are typically combined with CI approaches in addition to CI paradigms. The arrows show how different paradigm approaches can be merged to create architectures. Every CI paradigm has biochemical pathways at its foundation.

1.3.1 Artificial Neural Networks

A sophisticated, chaotic, and simultaneous computer is the nervous system. Even if events happen in the range of nanoseconds for semiconductor

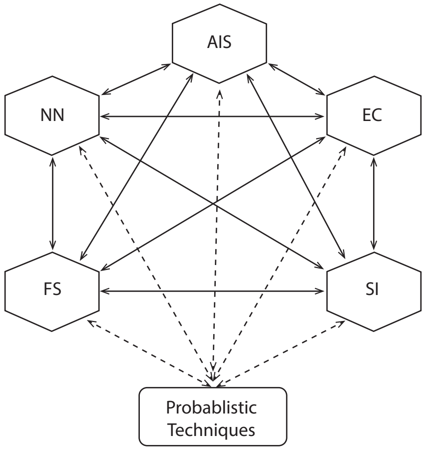

Figure 1.1 Computational intelligence paradigms.

gates and milliseconds for brain systems, it can accomplish tasks like analytical thinking, vision, and motor control much more quickly than any computer. Investigation into algorithmic modeling of biological brain systems, also known as artificial neural networks, was stimulated by these traits as well as others like the capacity to learn, memorize, and still generalize (NN) [17].

The cerebral cortex is thought to contain 60 trillion interconnections and between 10 and 500 billion axons. Each of the 1000 primary modules that make up the arrangement of the neurons has about 500 neural networks. The most successful artificial neural networks (NNs) used in neural modeling today are tiny, task-specific NNs. As long as you are limited by the limits of current processing capacity and memory size, challenges are handled rather feasible with reasonable NNs. Conversely, the intellect has the capacity to solve many issues at once by utilizing different brain regions.

Neurons, often known as nerve cells, are the fundamental components of biological brain networks. A neuron comprises of an axon, dendrites, and the cell body as represented in Figure 1.2. Neurons are incredibly linked, with connections often occurring in between axon and dendrite of two different neurons. The term "synapse" refers to this link. From the synapses, signals travel to the axon and cell body, from where they spread to all associated filaments. When a nerve cell fires, a signal travels to the axon of the unit. A pulse can be either excited or inhibited by a cell. The following Figure 1.3 shows the representation of an artificial neuron, which