AI Searching Techniques

Computational Intelligence

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Last-Time

- The Local-Global Principle for Similarity Measures
- Graph Representations and Graph Similarities
- Taxonomic Similarities

Learning Objectives

- Introduce the students to the theory of computational intelligence.
- Learn about the different computational intelligence paradigms
- Understand how to apply CI paradigms to solve different problems

Outlines

Computational Intelligence

Computational Intelligence Paradigms

Computational Intelligence: Definition

What is computational Intelligence?

- Is a branch of AI, that focus on building machine intelligence by using a set of nature-inspired algorithms and approaches that address complex real-world problems to which mathematical or traditional modeling is inefficient.
- Computational Intelligence achieve intelligence by modeling biological and natural intelligence.
- The study of adaptive mechanisms to enable or facilitate intelligent behavior in complex and changing environments.

Computational Intelligence: Main Paradigms

1. Artificial Neural Networks (ANN)
2. Evolutionary Computation (EC)
3. Swarm Intelligence (SI)
4. Artificial Immune Systems (AIS)
5. Fuzzy Systems (FS)

Computational Intelligence: Main Paradigms

- Each of the CI paradigms has its origins in biological systems:
  - ANNs model biological neural systems
  - EC models natural evolution (including genetic and behavioral evo-
  - lution)
  - SI models the social behavior of organisms living in swarms or colonies
  - AIS models the human immune system
  - FS attempts to resemble human reasoning in decision making

Computational Intelligence: Definition

- Computational Intelligence and Soft Computing
  - The term coined by Lotfi Zadeh. Soft computing techniques resemble biological processes more closely than traditional techniques.
  - It is a different grouping of CI paradigms. It include support vector machine and bayesian networks.
  - There is no a general agreement on what is computational intelligence

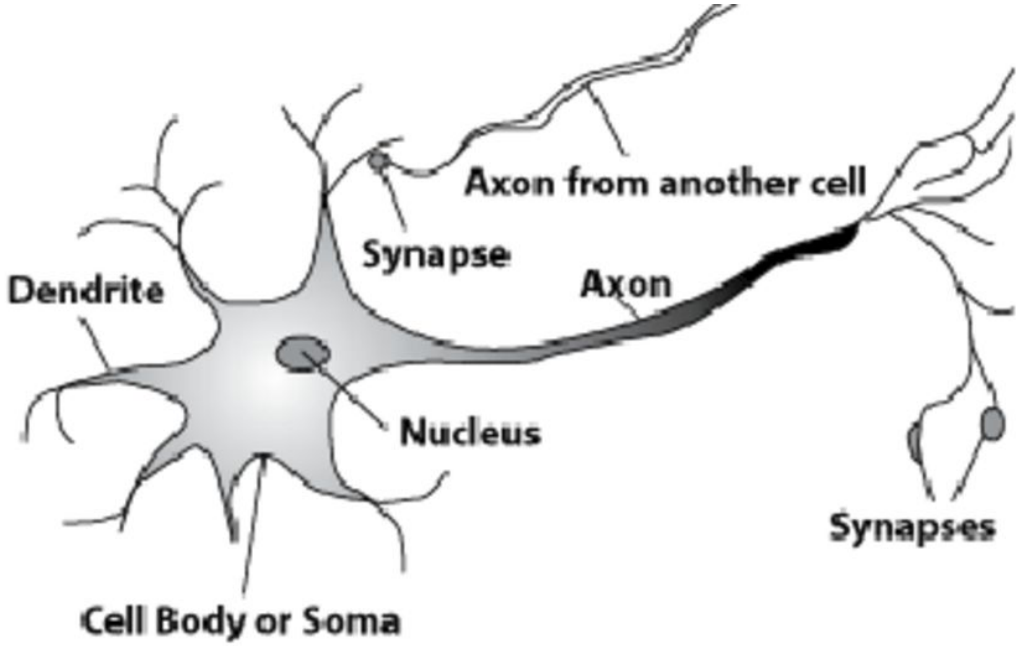
Artificial Neural Networks (ANN)

The ability of the human brain to perform complex tasks such as pattern recognition, perception and motor control, learn, memorize, generalize and reuse knowledge prompted research in algorithmic modeling of biological neural systems.

It is estimated that there is in the order of 10-500 billion neurons in the human cortex, with 60 trillion synapses. The neurons are arranged in approximately 1000 main modules, each having about 500 neural networks.

Artificial Neural Networks (ANN)

The basic building blocks of biological neural systems are nerve cells, referred to as neurons.



Artificial Neural Networks (ANN)

Neurons are massively interconnected, where an interconnection is between the axon of one neuron and a dendrite of another neuron. This connection is referred to as a synapse. This connection is referred to as a synapse.

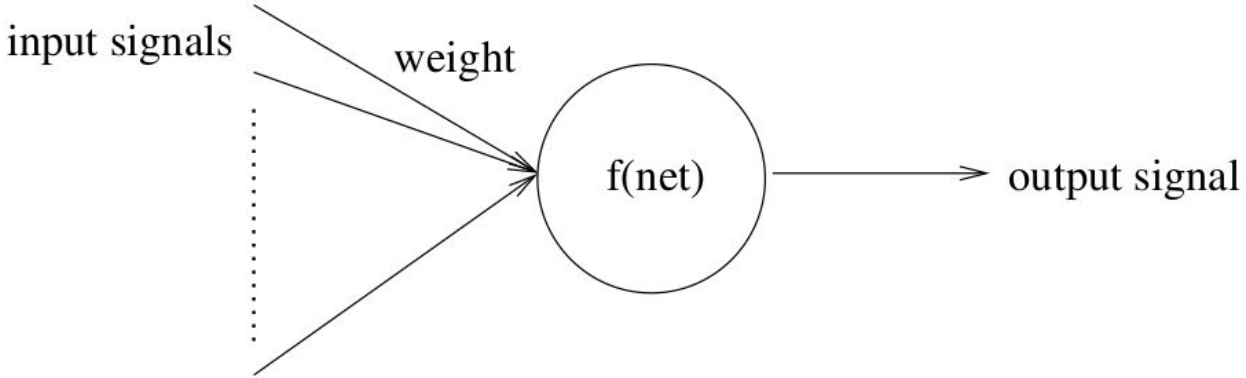
Signals propagate from the dendrites, through the cell body to the axon; from where the signals are propagated to all connected dendrites.

A signal is transmitted to the axon of a neuron only when the cell “fires”. A neuron can either inhibit or excite a signal.

Artificial Neural Networks (ANN)

An artificial neuron (AN) is a model of a biological neuron (BN).

Each AN receives signals from the environment, or other ANs, gathers these signals, and when fired, transmits a signal to all connected ANs.



Artificial Neural Networks (ANN)

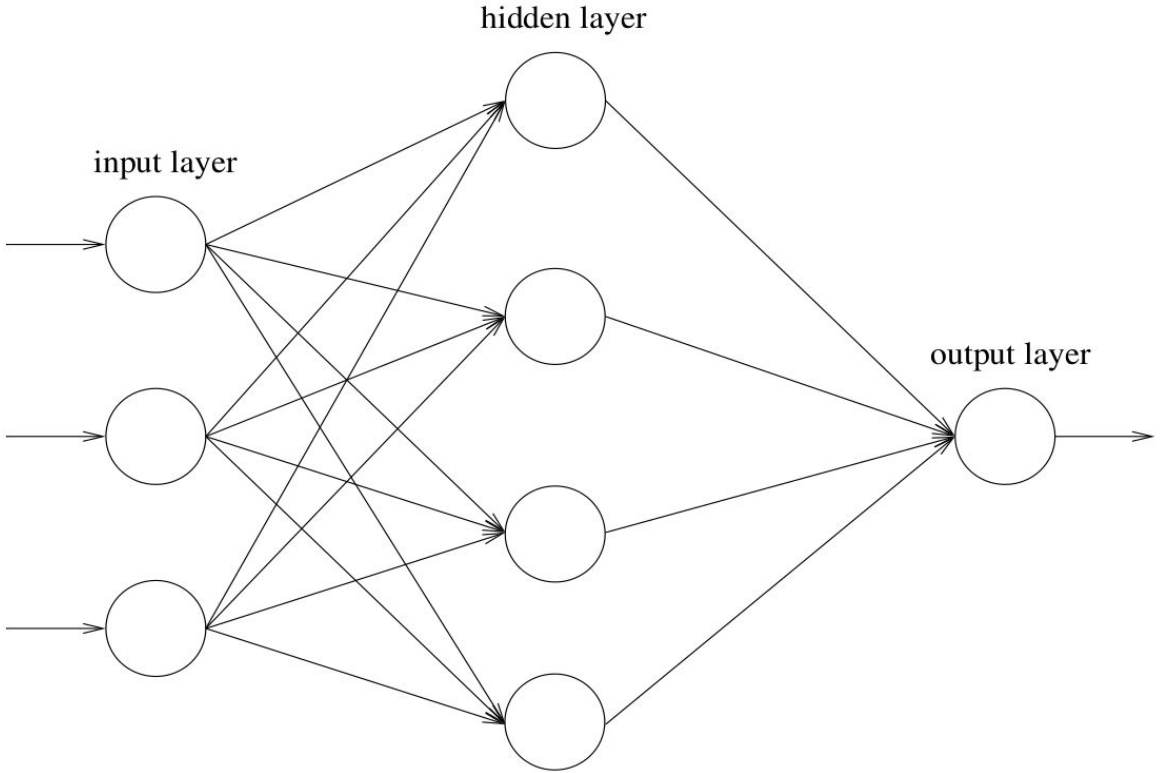
- Input signals are inhibited or excited through negative and positive numerical weights associated with each connection to the AN.
- The firing of an AN and the strength of the exiting signal are controlled via a function, referred to as the activation function.
- The AN collects all incoming signals, and computes a net input signal as a function of the respective weights.
- The net input signal serves as input to the activation function which calculates the output signal of the AN.

Artificial Neural Networks Structure

What is an ANN?

- An artificial neural network (NN) is a layered network of ANs.
- An NN may consist of an input layer, hidden layers and an output layer.
- ANs in one layer are connected, fully or partially, to the ANs in the next layer.
- Feedback connections to previous layers are also possible.

Artificial Neural Networks (ANN)



Artificial Neural Networks (ANN)

Several different NN types have been developed:

- Single-layer NNs, such as the Hopfield network
- Multilayer feedforward NNs (backpropagation NNs)
- Temporal NNs, such as the Elman and Jordan simple recurrent networks as well as time-delay neural networks.
- Self-Organizing NNs, such as the Kohonen self-organizing feature maps and the learning vector quantizer

Artificial Neural Networks (ANN)

Current successes in neural modeling are for small artificial NNs aimed at solving a specific task.

NN types have been used for a wide range of applications, including diagnosis of diseases, speech recognition, data mining, composing music, image processing, forecasting, robot control, credit approval, classification, pattern recognition.

Evolutionary Computation: Definition

It mimics processes from natural evolution. The key concept in EC is is survival of the fittest.

In natural evolution, survival is achieved through reproduction.

Offspring, reproduced from two parents, contain genetic material of both parents – hopefully the best characteristics of each parent.

Those individuals that inherit bad characteristics are weak and lose the battle to survive.

Evolutionary Computation

- Uses a population of individuals, where an individual is referred to as a chromosome.
- A chromosome defines the characteristics of individuals in the population.
- Each characteristic is referred to as a gene.
- The value of a gene is referred to as an allele.
- For each generation, individuals compete to reproduce offspring.

Evolutionary Computation

- Offspring are generated by combining parts of the parents, a process referred to as crossover.
- Individual in the population can also undergo mutation which alters some of the genes of the chromosome.
- The survival strength of an individual is measured using a fitness function which reflects the objectives and constraints of the problem to be solved.
- After each generation, individuals may undergo culling, or individuals may survive to the next generation.

Evolutionary Computation

Different classes of evolutionary algorithms (EA) have been developed:

- Genetic algorithms which model genetic evolution.
- Genetic programming which is based on genetic algorithms, but individuals are programs (represented as trees).
- Cultural evolution which models the evolution of culture of a population and how the culture influences the genetic and phenotypic evolution of individuals.
- Coevolution where initially “dumb” individuals evolve through cooperation, or in competition with one another, acquiring the necessary characteristics to survive.

Evolutionary Computation

Evolutionary computation has been used successfully in real-world applications:

- Data mining
- Combinatorial optimization
- Fault Diagnosis
- Classification
- Clustering
- Scheduling

Swarm Intelligence

- Artificial Swarm Intelligence → Many minds are better than one
- Social creatures (birds, bees, fish, wolfs, ants, spiders) can work together as a unified, decesterizled, self-organized, and dynamic system to accomplish specific goals.
- Originated from the study of colonies, or swarms of social organisms.
- Studies of the social behavior of organisms (individuals) in swarms prompted the design of very efficient optimization and clustering algorithms.
- Collaborative behaviors of swarms and colonies are achieved via subtle connections that establish real-time feedback-loops among members

Swarm Intelligence

Examples of Artificial Swarm Intelligence

- Particle Swarm Optimization.
- Ant Colony Optimization.
- Bees Algorithm.
- Wolf Pack Algorithm.
- Social Spider Swarm Optimization.
- Fish School Search.

Artificial Immune Systems

Human Immune System has an amazing pattern matching ability, used to distinguish between foreign cells entering the body (referred to as non-self, or antigen) and the cells belonging to the body (referred to as self).

Different computational models are inspired from HIS:

- Positive and Negative Selection
- Clonal Selection Theory
- Danger Theory

Artificial Immune Systems

Applications of Artificial Immune System

- Pattern Recognition
- Anomaly Detection
- Classification
- Computational Optimization

The challenge when building AIS is how we can model the task as an immune process.

Fuzzy Systems

- Introduced by Lotfi Zadeh in 1965 (fuzzy set theory)
- An element belongs to a set to a certain degree of certainty.
- Model the human reasoning process, where the decisions are not simply binary decisions (true or false)
- Fuzzy sets and logic allow the modeling of common sense and can handle uncertainty
- Fuzzy sets and fuzzy logic allow what is referred to as approximate reasoning.
- The challenge is how to design and select fuzzy function

Fuzzy Systems

Fuzzy systems are usually implemented a set of IF-THEN rules

- If temperature is very cold turn off fan
- If temperature is cold turn down fan
- If temperature is normal maintain fan speed
- If temperature is hot speed up fan

Applications of Fuzzy Systems include:

- Control systems, Automotive, Defense , Cyber Security,

Questions