Computational Intelligence

An Introduction

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  - In classical AI, human experts would manually encode rules and knowledge into the AI system.
  - The focus was on symbolic reasoning and logic to process information and make decisions.
  - Conventional AI lacked the ability to learn from data and adapt to new situations, as it primarily relied on explicit rules and pre-defined knowledge.

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  - Conventional AI lacked the ability to learn from data and adapt to new situations, as it primarily relied on explicit rules and pre-defined knowledge.
  - It had limitations in handling complex and real-world problems due to the rigid nature of rule-based systems.

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Computational Intelligence

- Modern AI: It is also known as Computational Intelligence. It shifted the focus from rule-based systems to data-driven approaches, where AI models learn patterns and relationships directly from data.
    - It has the ability to learn from experience, adapt to new data, and improve its performance over time, making it more versatile and flexible.

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  - The development of advanced algorithms and computational power enabled the rise of Machine Learning, Deep Learning, and other statistical techniques.
  - Modern AI can handle large amounts of data and identify complex patterns that may not be easily discernible by human experts.

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- In summary, Conventional AI was characterized by rule-based systems and expert knowledge, while Modern AI relies on data-driven approaches and the use of algorithms to learn from data.
- Computational Intelligence has led to significant advancements in various applications, such as natural language processing, computer vision, speech recognition, and robotics, and has become an integral part of many industries and technologies in the present era.

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Formal Computing

- The concept of computing refers to the process of using computers or computational systems to perform various tasks, solve problems, and process information.

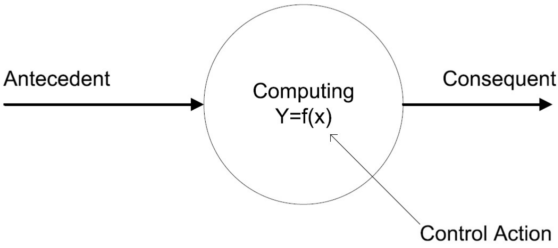

Figure: Basic of computing

- $y = f(x)$, f is a mapping function. f is also called a formal method or an algorithm to solve a problem.

Important characteristics of computing

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- Suitable for problem, which is easy to model mathematically.

Hard Computing

In 1969, Prof. Lotfi Zadeh introduced the term hard computing. According to him, term computing as "Hard" computing, if following conditions are satisfied.

- Precise result is guaranteed

Example:

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- Control action is formally defined (i.e. with mathematical model)

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- Searching and sorting techniques
- Solving graph problems (e.g. Shortest tour in Graph theory, Finding closest pair of points, etc.)

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- Network optimization

Soft Computing

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- The main goal of Soft Computing is to develop intelligent machines and to solve nonlinear and mathematically unmodelled system problems.
- The applications of Soft Computing have proved two main advantages. First, it made solving real world complex nonlinear problems, in which mathematical models are not available.
- Second, it introduced the human knowledge such as cognition, recognition, understanding, leaning, and others into the fields of computing.

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- Algorithms are adaptive (i.e. it can adjust to the change of dynamic environment)
- Use some biological inspired methodologies such as genetics, evolution, Ant's behaviors, particles swarming, human nervous systems etc.

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Methodologies of Soft Computing

Soft computing is a collection of computing techniques and methodologies that aim to deal with complex and uncertain problems by tolerating the notions of imprecision, vagueness, and partial truth.

- Fuzzy System: Imprecision and reasoning

In summary, hard computing relies on precise algorithms and exact models to find optimal solutions in well-defined problems, whereas soft computing leverages approximate methods and adopts uncertainty to handle complex and uncertain problems.

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- Evolutionary Computation: Searching and optimization

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- The fuzzy set for representing the linguistic variable human age is partitioned into three fuzzy subsets, namely, young middle-age, old. Each fuzzy subset is characterized by an MF.
- A linguistic variable is a variable whose values are linguistic terms in a natural or artificial language. For example, the size of an object is a linguistic variable, whose value can be small, medium, and big.

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Fuzzy sets representation of crisp data

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- The membership functions can take various shapes, such as triangular, trapezoidal, Gaussian, or sigmoidal, depending on the nature of data and application.

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A fuzzy partition of human age

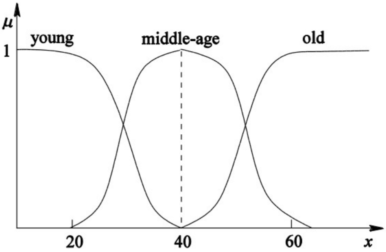
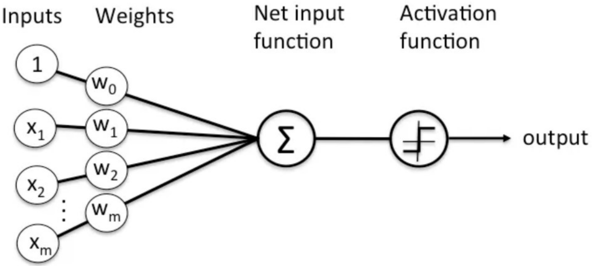


FIGURE 1: A fuzzy partition of human age. The fuzzy set for representing the linguistic variable *human age* is partitioned into three fuzzy subsets, namely, *young*, *middle-age*, *old*. Each fuzzy subset is characterized by an MF.

Introduction to Neural Networks

- Neural networks are machine learning models inspired by the structure and functioning of the human brain.



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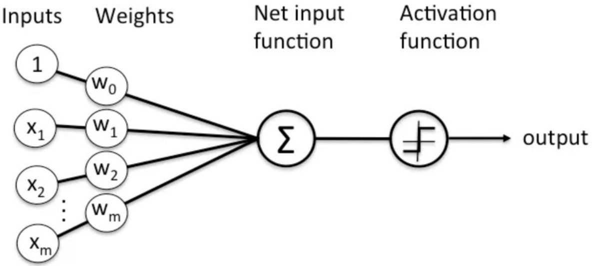
- We can express a neural network as, it consists of interconnected artificial neurons, also known as nodes or units, organized into layers.
- The fundamental building block of a neural network is the neuron, which takes inputs, performs a computation, and produces an output.



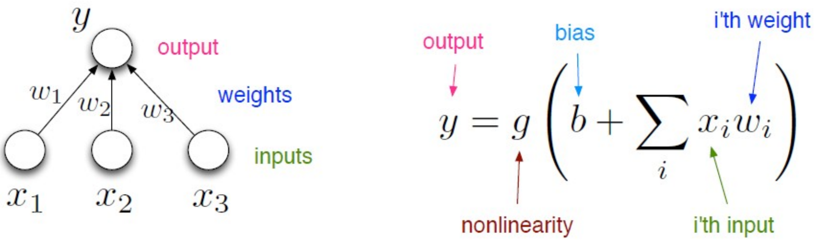


Figure: Mathematical representation of Neural Network

Working principle of Neural Networks

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- A **learning phase**: an appropriate architecture is chosen for the neural network and a activation function for each neuron. A subset of samples or observations is used to train the network by means of a suitable algorithm.
- A **generalization phase**: unseen samples (not used in the training) are tested with the neural networks model and a performance index is computed. This index characterizes the quality of the model.

Neural Networks Training Procedure

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- Continue same process for number of epochs until error is minimized

Evolutionary Computation

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- However it requires a smooth differentiable cost function, it is unable to deal with sudden, discontinuous change.
- But engineering problems' cost or loss functions are mostly complex and discontinuous in nature.
- However, evolutionary algorithms can handle these issues because it is derivative free and randomized optimization.

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- Evolutionary algorithms are efficient at exploring a wide search space, making them well-suited for finding global optima in complex and multi-modal optimization problems.

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- By combining/hybridizing two or more methodologies such as fuzzy logic, neural networks, and evolutionary algorithm methodologies together, Computational model provides powerful tools for tackling complex and dynamic challenges in diverse domains.
- Truly intelligent machines - Computers that can learn on their own and take decision as human being.