Computational Intelligence (CI)

Introduction

[Module 1]

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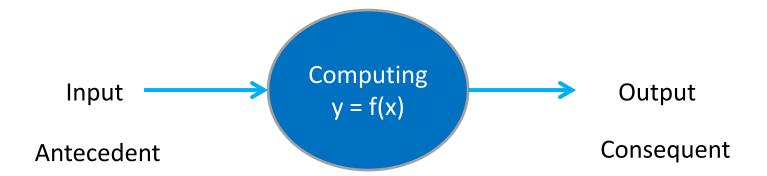
Motivation

New world of computation:

- Mobility: Computation is everywhere

- Dynamic: Computation for everything

- Adaptation and Improvement: Computation in every environment

- Uncertainty and Noise

- Missing Information

Computing ?

Input → Computing $y = f(x)$ → Output

Antecedent   Consequent

$y = f(x)$,   f is a mapping function/algorithm to solve a problem

Computing is a mapping function.

It is basically the algorithm to solve a problem.

Characteristics of Computing

- ➢ Should provide **precise** solution

- ➢ Control action should be **unambiguous** and **accurate**

- ➢ Control action is **formally defined** (with mathematical model or algorithm)
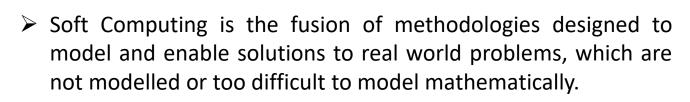
Hard Computing

➢ In 1996, Lotfi A. Zadeh introduces the term **hard computing.**

➢ According to Zadeh, a computing is called hard computing if

      o **Precise result is guaranteed.**

      o **Control action is unambiguous.**

      o **Control action is formally defined.**

What is Soft Computing?

➢ The Term Soft Computing (SC) was proposed by the inventor of fuzzy logic, Lotfi A. Zadeh, 1992.

➢ The idea of soft computing was initiated in 1981 when Lotfi A. Zadeh published his first paper on soft data analysis "What is soft computing", soft computing Springer-Verlag Germany/USA 1997.

➢ Zadeh, defined Soft Computing into one multidisciplinary system as the fusion of the fields of **Fuzzy Logic, Neuro-Computing, Evolutionary and Genetic Computing, and Probabilistic Computing**.

Lotfi A. Zadeh

➢ Soft Computing is the fusion of methodologies designed to model and enable solutions to real world problems, which are not modelled or too difficult to model mathematically.

What is Soft Computing?

➤ Lotfi A. Zadeh describes Soft Computing (SC) as follows.

Soft computing is an emerging approach to computing which parallels the remarkable ability of the human mind to reason and learn in an environment of uncertainty and imprecision.

It is characterized by the use of inexact solutions to computationally hard tasks.

Terminology

Approximation: similar to the real ones, but not the same.

Uncertainty: lack of sureness.

What will happen next, this is an example of uncertainty.
Outcome of tossing a coin – head or tail (not sure/doubt)

Imprecision/Vagueness: lack of clarity

Is hot? Vague as there is no particular temp that represents hot.
Tall? Vague as there is no well defined boundary that represents tall

Ambiguity: more than one interpretation/inexactness

Bank – can refer to a financial institution or riverside

Characteristics of Soft Computing

- ➢ Soft computing is tolerant of imprecision, uncertainty and approximation

- ➢ Algorithms are adaptive (i.e. it can adjust to the change of dynamic environment)

- ➢ Uses evolutionary computing (biologically inspired methodologies) to find optimal solution

Soft Computing Paradigms?

$$SC = EC + NN + FL$$

Soft Computing	**Evolutionary Computing**	**Neural Network**	**Fuzzy Logic**
Zadeh 1981	Rechenberg 1960	McCulloch 1943	Zadeh 1965

Soft Computing Paradigms/Constituents

Soft computing consists of several computing paradigms mainly:

➢ **Fuzzy Systems-** for knowledge representation via fuzzy If Then rules.

➢ **Neural Networks-** for learning and adaptation

➢ **Genetic Algorithms-** for evolutionary computation for search and optimization

Sometimes, Hybridization of these three fields increases the strength of the system.

Example 1

- ➢ How a student **learns** from his teacher?
  - o Teacher asks questions and tells the answers.
  - o Teacher puts questions and hints answers and asks whether the answers are correct or not
  - o student thus learns a topic and stores in his memory
  - o Based on the knowledge the student solves new problems

- ➢ This is the way how human brain works.

- ➢ **Artificial Neural Network** is used to solve problems.

Ability to learn, memorize and still generalize
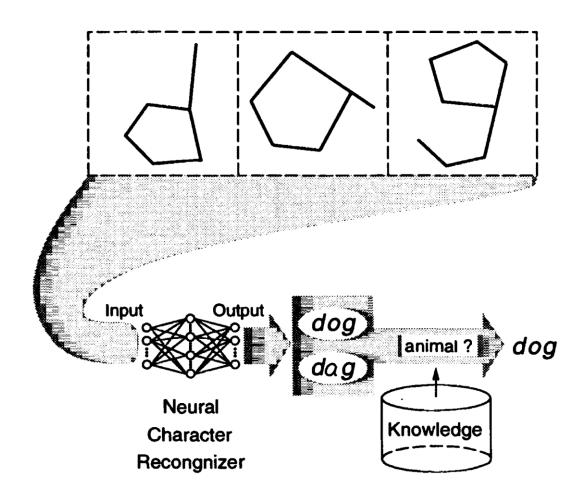
Example 2

➢ How world **selects the best?**

 o It starts with a random population

 o Reproduces another population (next generation)

 o Rank the population and selects the best

➢ **Genetic Algorithm** is based on this natural phenomena.

 o Population is synonymous to solutions.

 o Selection of best solution is synonymous to finding the optimal solution.

Example 3

➢ How a doctor treats his patient ?

    o   Doctor asks the patient about suffering.

    o   Doctor find symptoms of diseases.

    o   Doctor prescribed tests and medicines.

➢ This is how **fuzzy logic** works.

    o   Symptoms are correlated with diseases with **uncertainty**.

    o   Doctor prescribes tests/medicines **fuzzily**

Example

*A neural character recognizer and a knowledge base responding
to three hand-written characters that form a word "dog."*

Soft Computing vs. Hard Computing

Hard Computing	Soft Computing
Conventional computing that requires a precisely stated analytical model.	Soft Computing is tolerant of imprecision and uncertainty.
Often requires a lot of computation time for real-world problem.	Can solve some real-world problems in reasonably less time.
Not suited for real-world problems for which ideal model is not present.	Suitable for real-world problems.
It requires full truth.	Can work with partial truth.
It is precise and accurate	Imprecise
It is known for Conventional AI.	It is known for Computational Intelligence

Soft Computing Strength

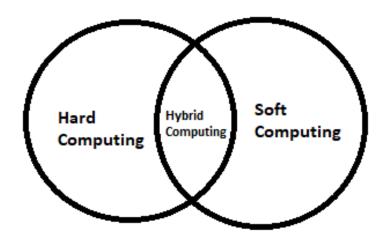| Methodology	Strength	
Neural network	Learning and adaptation	CI
Fuzzy set theory	Knowledge representation via fuzzy if-then rules	CI
Genetic algorithm and simulated annealing	Systematic random search	CI
Conventional AI	Symbolic manipulation	AI

Hybrid Computing

It is a combination of conventional hard computing and emerging soft computing.

Intelligence

- ability to learn or understand the environment.

- **ability to solve complex problems or make decisions.**

Artificial intelligence (*AI*) is the intelligence of machines or software.

Motivation for CI: Nature Inspired

- Nature for Computation: CI

- Computation for nature: Computational Biology
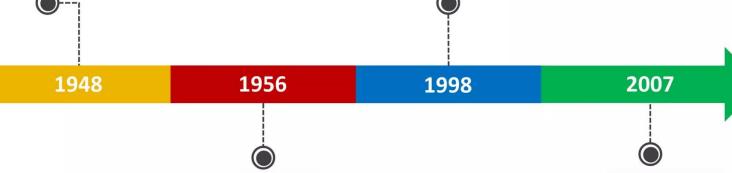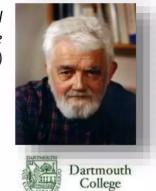
History

"You cannot make a machine to think for you."
(Turing, 1948)

Hard versus soft computing
(Zadeh, 1998)

1948   1956   1998   2007

Dartmouth Artificial Intelligence Conference
(McCarthy, 1956)

Dartmouth College

Computational Intelligence: An Introduction
(Engelbrecht, 2007)

5

Definition

Computational Intelligence (CI):

- Is a sub-branch of AI.

- Is a set of nature-inspired computational methodologies and approaches.

- Solves complex real-world problems to which traditional approaches are ineffective or infeasible.

- Study of adaptive mechanisms to enable or facilitate intelligent behavior in complex and changing environments. (Engelbrecht, 2007).

Pseudonym of CI

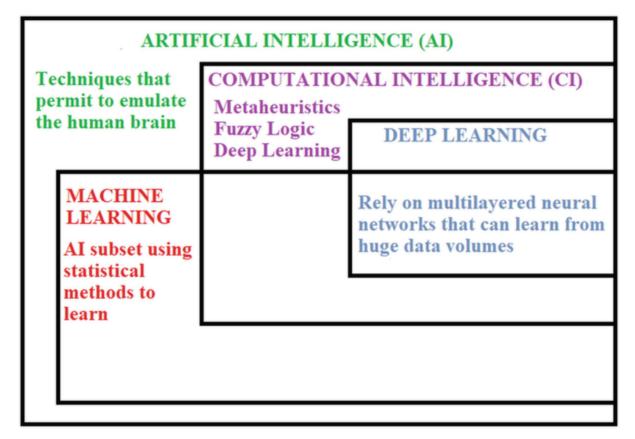**Pseudonym :** a fictitious name, especially one used by an author.

- Soft Computing

- Natural Computation

- Nature-Inspired Computing

- Adaptive Systems

Note# Even though it is commonly considered a synonym of soft computing, there is still no commonly accepted definition of computational intelligence.

AI vs CI

Artificial Intelligence (AI) is an area of computer science which focuses on the development of intelligent machines, and **Computational Intelligence (CI) is a sub-field within AI that focuses on creating systems capable of performing complex tasks**.

Source: https://link.springer.com/chapter/10.1007/978-3-030-67921-7_1

AI vs CI

CI is a specific subset of AI, but while AI focuses on the outcome, CI focuses on the mechanism.

May 11th, 1997
Computer won world champion of chess
(Deep Blue)   (Garry Kasparov)

(Reuters = Kyodo News)

General Intelligence
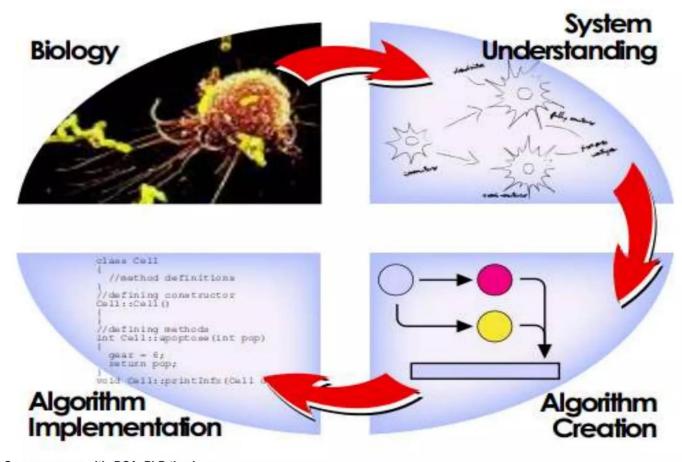
General Intelligence: to perform intellectual task that a human can.

CI Modeling Methodology

Source: greensmith, DCA, PhD thesis

Applications of CI

Few applications are listed below

- Real-time water treatment process control with ANN (Zhang et al., 1999);

- Classification and diagnostic prediction of cancers (Khan et al., 2001);

- Hybrid approach to solve the team allocation problem (Britto *et al.*, 2012);

- Regression testing prioritization based on FIS (Neto *et al.*, 2012);

- Classification of social network users (Lima; Machado, 2012);

- Power system harmonics estimation (Holanda *et al.*, 2013);

- Hydrothermal Power Systems Operation Planning (Antunes *et al.*, 2014);

- Sentiment Classification (Anchieta et al., 2015);

- Improving the Performance of IoT Applications (Sobral et al., 2015);
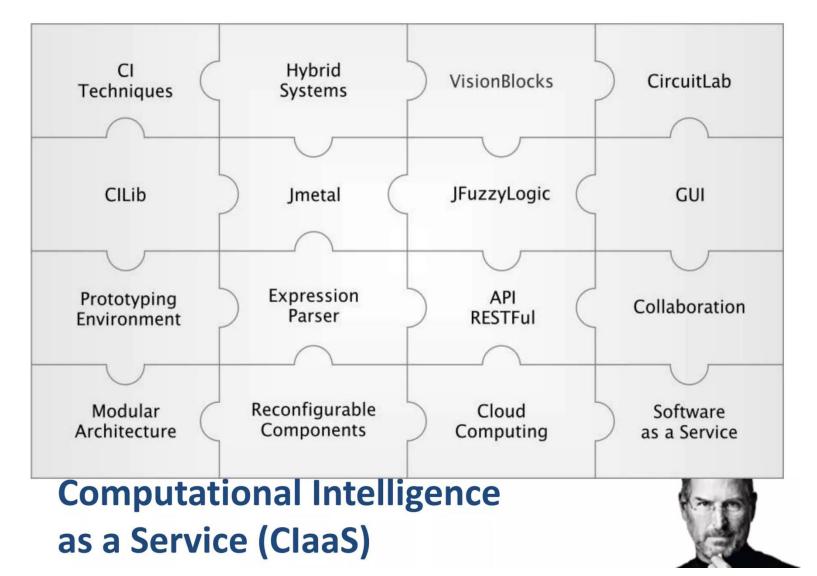
Application Domain of CI

Some application domains are

- Robotic;

- Natural Language Processing;

- Facial and speech recognition;

- Game playing;

- Healthcare;

- Finance & Banking;

- Machine Learning;

- Military Equipment;

CI as a Service

CI Techniques | Hybrid Systems | VisionBlocks | CircuitLab

CILib | Jmetal | JFuzzyLogic | GUI

Prototyping Environment | Expression Parser | API RESTFul | Collaboration

Modular Architecture | Reconfigurable Components | Cloud Computing | Software as a Service

Computational Intelligence as a Service (CIaaS)

Future of CI

- Hybrid Systems

- New techniques/algorithms

- Ubiquitous and pervasive computing

- Smart IoT device

- And others..

Each of your actions will have an impact on your future.

Once you know who is walking with you on your path. you will never be afraid.

Thank you