Soft Computing

An introduction

Aparajita Ojha

PDPM IIITDM Jabalpur

Introduction

The World we are living in

12+ TBs **of tweet data every day**

TBs of data every day

25+ TBs **of log data every day**

30 billion RFID tags today (1.3B in 2005)

4.6 billion camera phones world wide

100s of millions of GPS enabled devices sold annually

76 million smart meters in 2009… 200M by 2014

3.2+ billion people on the Web by end 2015

Image source: http://www.cs.kent.edu/~jin/BigData/index.html

Introduction

- *The World we are living in*
- *Exploding data* and *internet based services* throw enormous challenges in providing solutions to real life problems.
- Computing methods have been continuously evolving, but present challenges are like never before !!

Major Challenges

- Real time and internet data processing
- Extracting useful information
- Devising solutions
- Selecting right techniques for solutions
- Big challenges in the modern era of Big Data

Major Scientific & Technological Developments

- Internet of Things
- Big Data Analytics and Data Science
- New Artificial Intelligence Techniques (Deep Learning)
- A related development
  - Industry 4.0 Revolution

Data Analytic Challenges

- From the gigantic size data find a key pattern that indicates a situational change
  - Could be a single event or a sequence of events.
- The key pattern could be an earlier observed one or could also be a new pattern.
- Predict the next event based on the current pattern
- Identify relevant data fragments from a multitude of data sources.
- Example: Find a few packets in billions of packets flowing through different networks *that carry a virus or malware.*
- Problem: We need new methods to deal with larger, more complex data and problems!

Source: Presentation by Kaisler, Armour, Espinosa, Money, Kogod School of Business, Washington

Some Grand Challenges

- Modeling Our Planet's Systems:
  - Assessing global warming and determining mitigating actions
- Confronting Existential Risk:
  - Assessment of impact of a dangerous genetically modified pathogen
- Exploring Transhumanism:
  - Predicting the impact of embedded nanotechnology, genetic therapy, and "smart" prosthetics?
- Empowered Machines Challenge
  - When computing systems surpass the level of human intelligence? Emotional intelligence?
- Dealing Effectively with Globalism:
  - Modeling the interconnected human societies/organizations.

Source: Martin, The Meaning of the 21st Century: A Vital Blueprint for Ensuring Our Future, 2007

Wicked Problems !!!

- In 1973, Horst Rittel and Melvin Webber formally described the concept of wicked problems.
- Conventional problem solving methods, rooted in 18th century physics, economics and engineering *focused on efficiency*.
- Societal and real life problems are fundamentally different from the types of problems that are solved using the conventional mathematical computing approaches.
- *Societal problems are wicked problems*.

Source: Presentation by Kaisler, Armour, Espinosa, Money, Kogod School of Business, Washington, 2016

Wicked Problems !!!

- Definition
- A wicked problem is a problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize.

- The use of the term "wicked" here has come to denote resistance to resolution, rather than evil.
- Another Definition
- A problem whose social complexity means that it has no determinable stopping point.
- Moreover, because of complex interdependencies, the effort to solve one aspect of a wicked problem may reveal or create other problems.

Source: Wikipedia

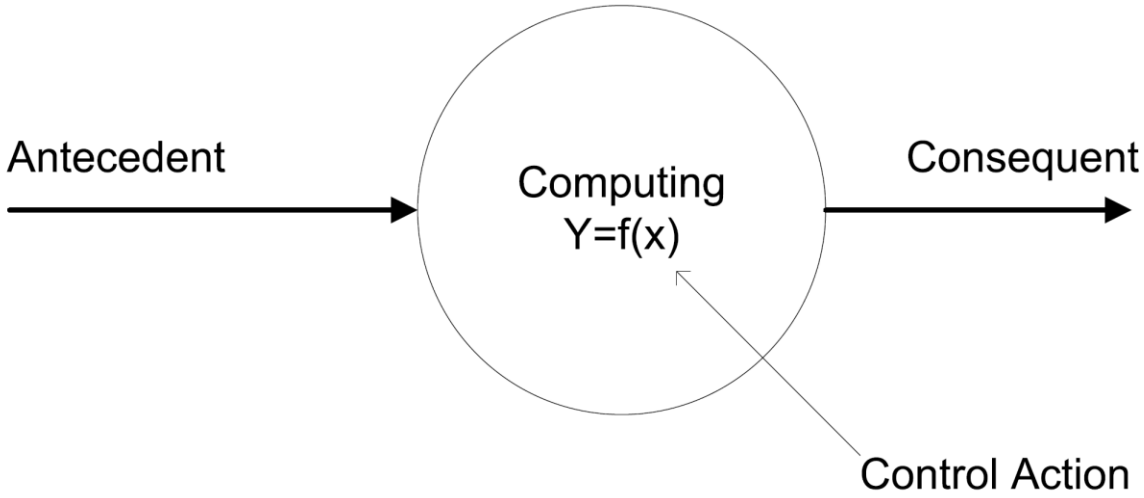
Some Examples

- Climate Change
- "Peaking" Oil or Coal: When does it run out?
- The "Long War": Is there an end to terrorism?
- Sustainable Cities and Ecosystems
- Sustainable Development in the Third World
- Affordable Health Maintenance for an Aging Society
- Biological and Genetic Threats and Opportunities
- Discover drugs that minimize disease-resistant micro-organisms

Source: Presentation by Kaisler, Armour, Espinosa, Money, Kogod School of Business, Washington, 2016

Problem Solving and Computing

- Concept of computing
- Solutions exist: How to find them
- For given inputs, find a method or an algorithm that provides solution to the a problem



Source: Prof. Simanta, NPTEL Lecture notes on Soft Computing

Important Characteristics

- The method or algorithm should provide precise solution.
- Control action should be unambiguous and accurate.
- Easy to model mathematically.

Hard Computing

- Hard computing or conventional computing (Zadeh's 1996 paper)

- *Requires a precisely stated mathematical or analytical model.*
- *Control action is unambiguous: : Same output for the same input every time.*
- *Many analytical models are valid for ideal cases.*

- Real world problems are never posed in an ideal environment.

Hard Computing Examples

- Given an input of data values (x, y)
  - (0,2), (1, 3), (2, 11), (3, 29)
- Find the value of y when x = 1.5.
- A solution using cubic interpolation is $y = x^3 + 2$.

Hard Computing Limitations

- Conventional weather forecasting techniques use rigorous mathematical models such as time series analysis, multivariate regression.
- Need comprehensive and complete datsets to analyse data.
- Apply exhaustive computations to arrive at solutions.
- May fail when the dataset is not available in some locations or is available with some noise.

Hard Computing Limitations

- Do hard computing based solutions exist for wicked problems ?
- Do there exist solutions for grand challenges using conventional computing methods ?
- Some common problems of current relevance –
  - Medical diagnosis
  - Object detection in images
  - Hand written character recognition
  - Weather forecasting
  - VLSI design
  - Network flow optimization: internet, rail network etc.

Source: Prof. Simanta, NPTEL Lecture notes on Soft Computing

Soft Computing

- The guiding principle of soft computing –
- Exploit the tolerance for imprecision, uncertainty, partial truth, and approximation to achieve tractability, robustness and low solution cost in solving problems that involve information processing.
- Use of approximate calculations to provide imprecise but usable solutions to complex computational problems.
- The approach enables solutions for problems that may be either unsolvable or just too time-consuming to solve with current hardware.
- Soft computing is sometimes referred to as computational intelligence.
- Origin :
  - Zadeh's 1965 paper on fuzzy sets
  - 1973 paper on the analysis of complex systems and decision processes
  - 1979 report (1981 paper) on possibility theory and soft data analysis.

Soft Computing Characteristics

- It does not require any mathematical modeling for problem solving
- Solutions may not be precise
- Algorithms are adaptive
  - it can adjust to the change of dynamic environment.
- Uses methodologies that are inspired by human intelligence and nervous system, genetics, evolution processes, particles swarming etc.

Source: Prof. Simanta, NPTEL Lecture notes on Soft Computing

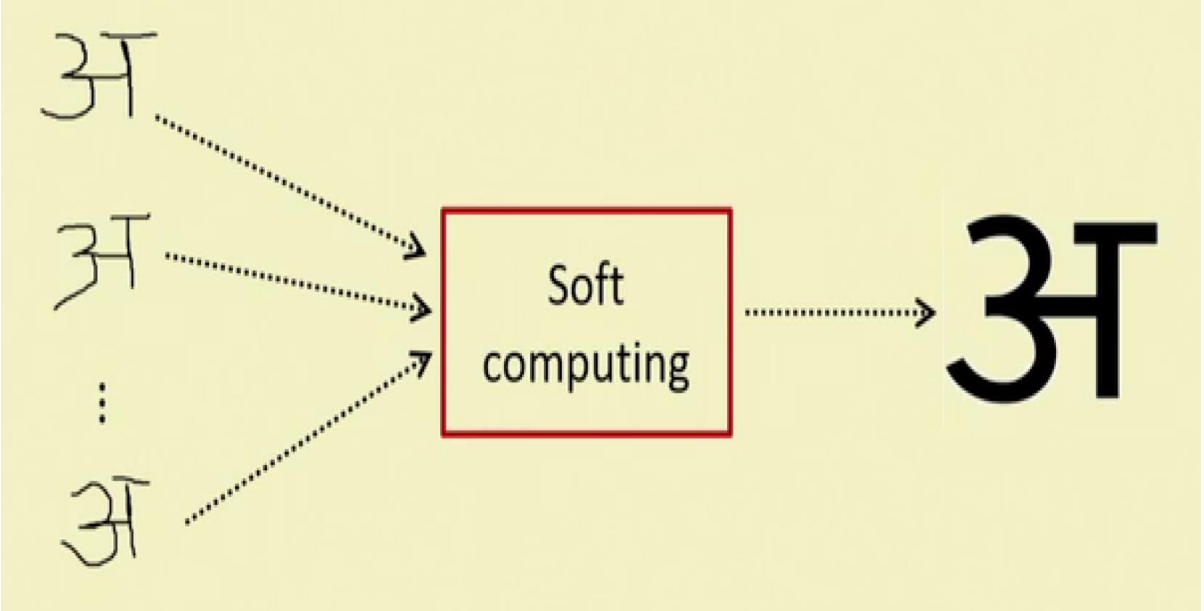
Soft Computing Methodologies

- The principal constituents

- Fuzzy Logic,
- Neural Networks,
- Support Vector Machines,
- Evolutionary Computation,
- Machine Learning and
- Probabilistic Reasoning.

Examples

- Handwritten documents: character recognition

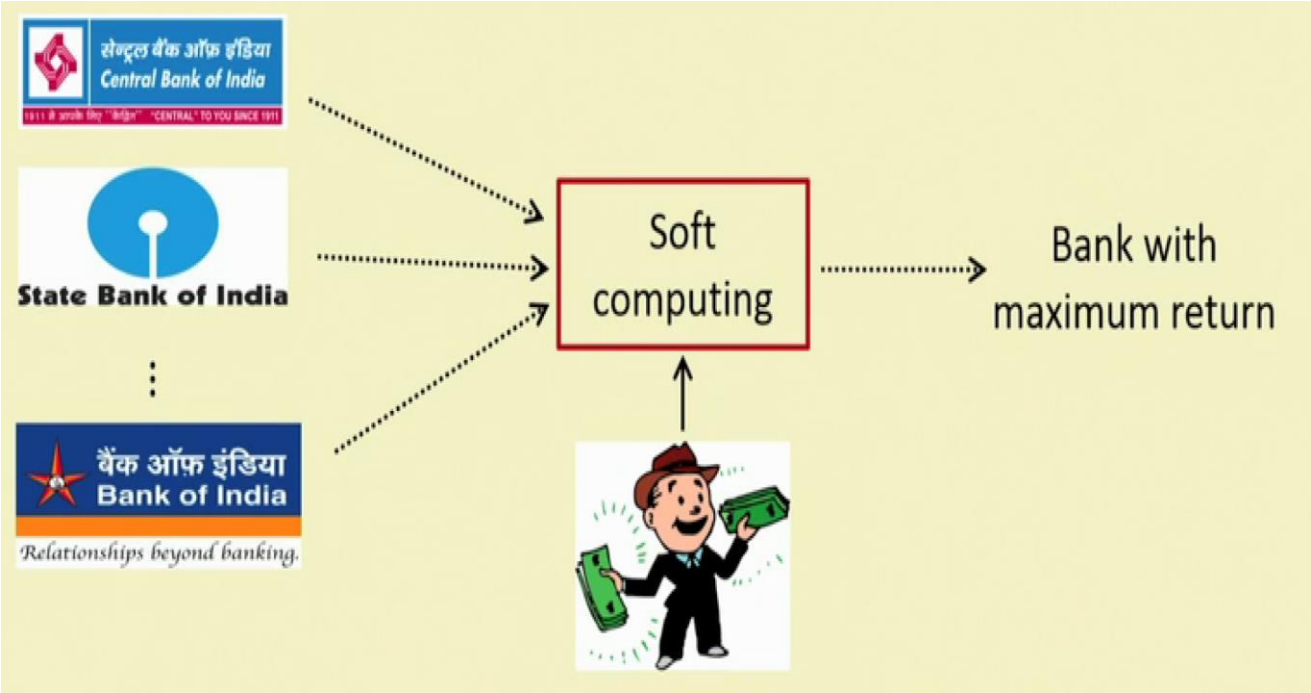


Neural network based solution

Image Source: Prof. Simanta, NPTEL Lecture notes on Soft Computing

Examples

- Banks with maximum return on term deposits

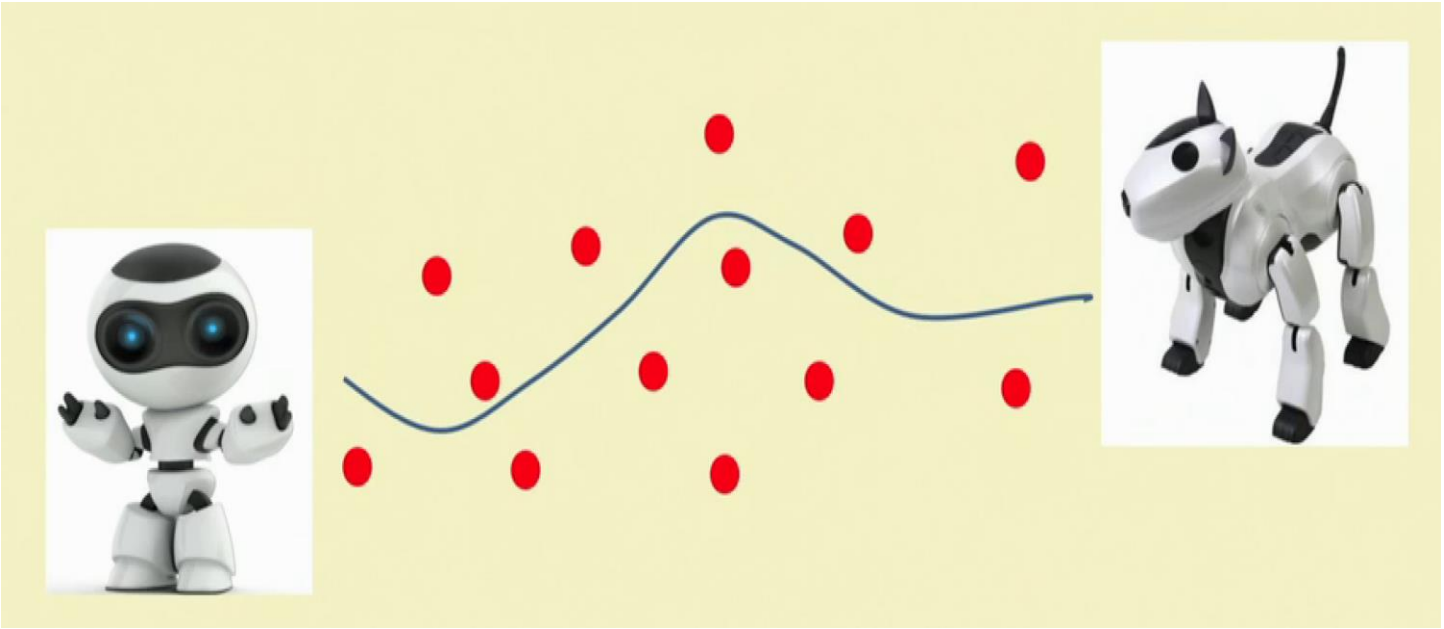


Evolutionary Algorithms

Image Source: Prof. Simanta, NPTEL Lecture notes on Soft Computing

Examples

- Robot Motion Planning

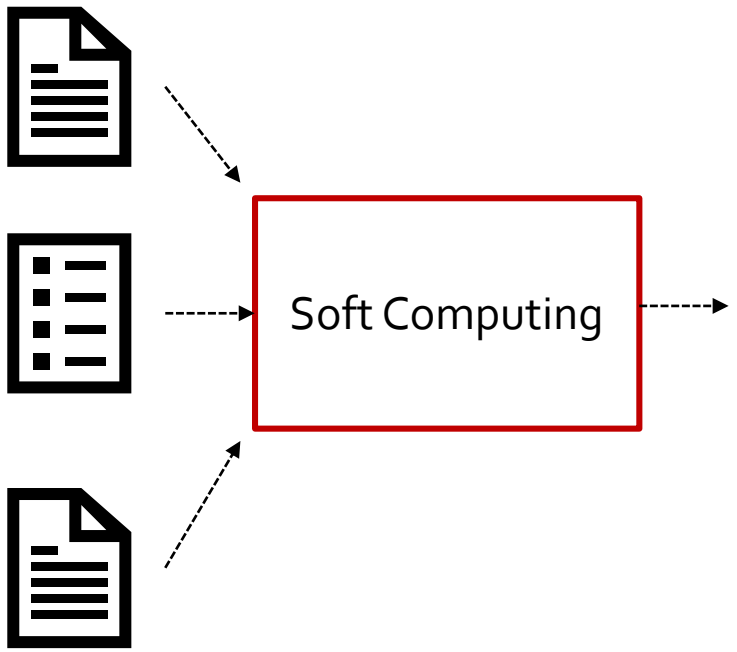


Fuzzy logic based controller design

Image Source: Prof. Simanta, NPTEL Lecture notes on Soft Computing

Examples

- Text Summarization

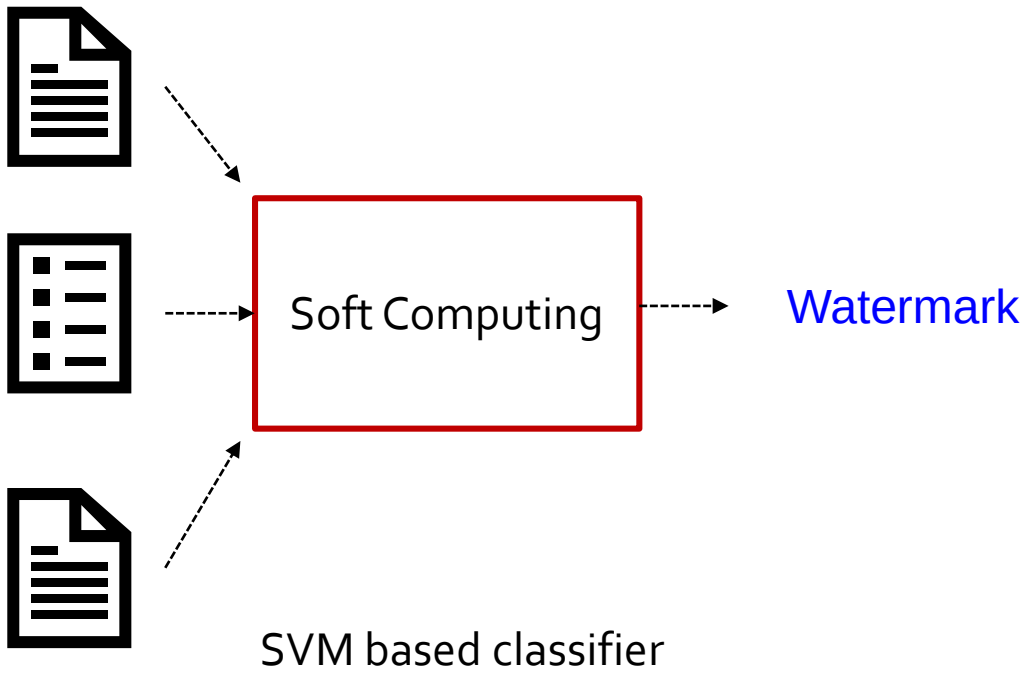


Summary
Soft computing is the use of approximate calculations to provide imprecise but usable solutions to complex computational problems.

Machine learning and probabilistic reasoning

Examples

- Watermark Detection and Extraction



Soft Computing: Main Features

- Learning from experimental data
- Techniques derive their power of generalization from approximation or interpolation to produce outputs from previously unseen inputs by using outputs from previous learned inputs
- Generalization is usually done in a high dimensional space.

Hard Computing \vs Soft Computing

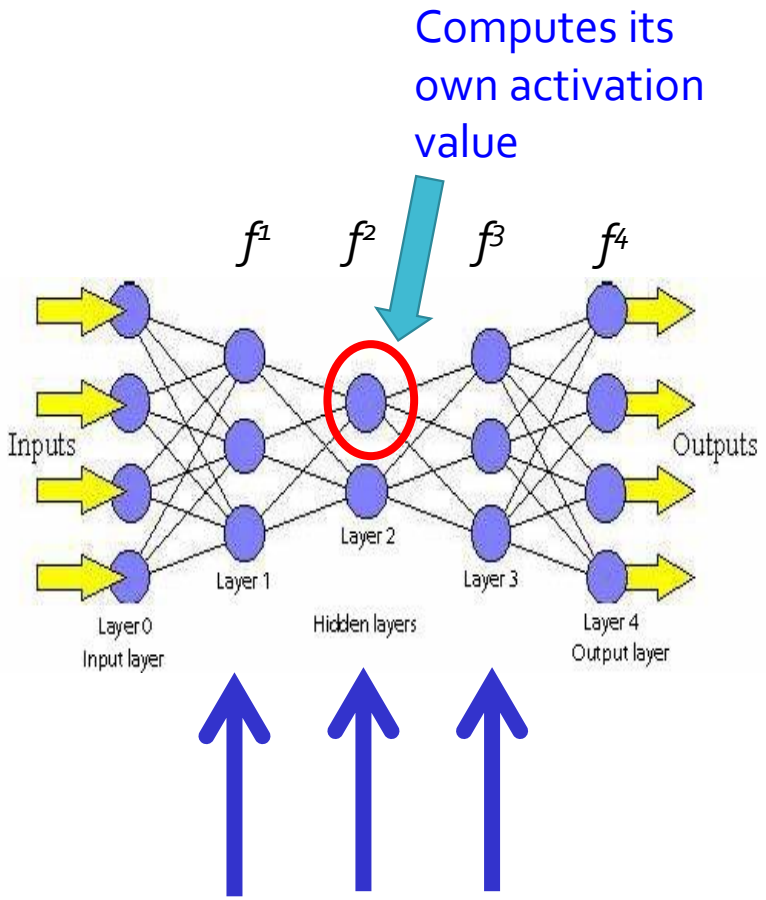
Hard Computing	Soft computing
Precisely stated analytical model required.	Imprecision is tolerable.
High amount of computation required for complex problems.	Involves intelligent computation steps, reduces computational time for complex problems.
Involves binary logic, crisp systems and numerical analysis.	Involves nature inspired systems, fuzzy logic, neural approximation.
Imprecision and uncertainty are undesirable.	Imprecision and uncertainty are tolerable and are exploited to arrive at a better solution.
Outcome is deterministic.	Outcome is stochastic or random in nature.
Requires exact input data.	Can handle ambiguous and noisy data.
Strictly follows the sequence of computation	Allows parallel processing and computation

Source: Prof. NP Padhy, Soft Computing Book

Overview of Soft Computing Approaches

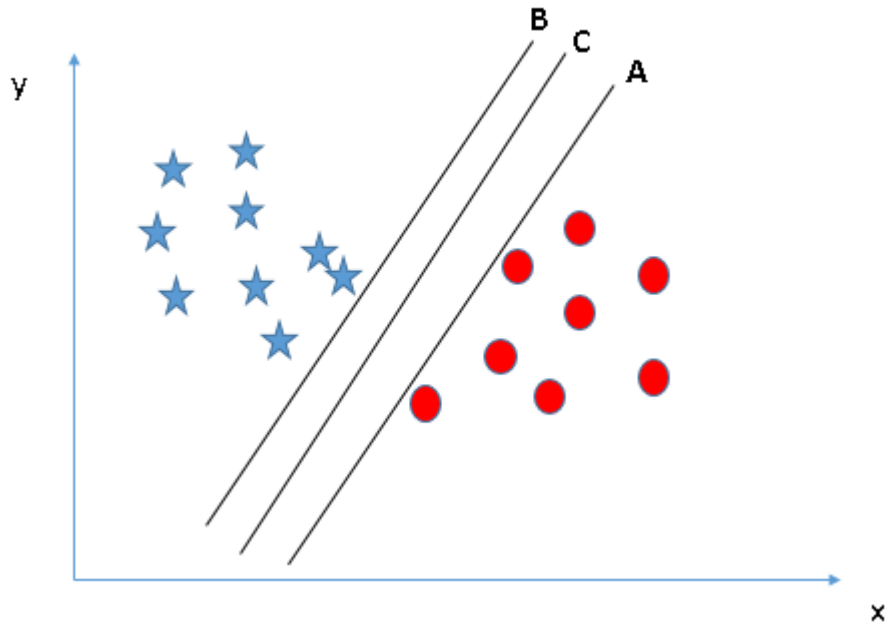
- Neural Network
  - A neural network is a system composed of many simple processing elements operating in parallel whose function is determined by network structure, connection strengths, and the processing performed at computing elements or nodes.
  - They are physical cellular systems which can acquire, store, and utilize experiential knowledge.

Artificial Neural Network



Support Vector Machine

- A discriminative classifier defined by a separating hyperplane.
- Given a labeled training data, the algorithm outputs a hyperplane that optimally classifies new examples.
- Derived from statistical learning theory by Vapnik and Chervonenkis (1992).



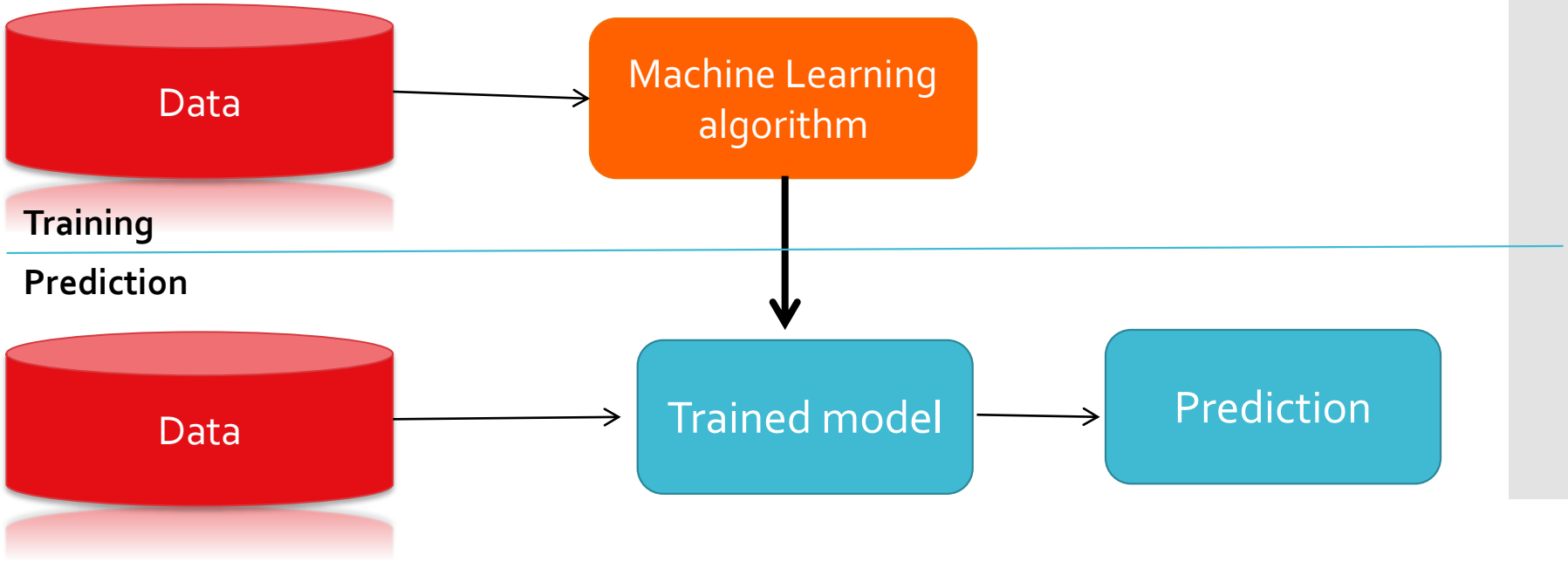
Fuzzy Logic

- Fuzzy Logic (FL) is a method of reasoning that resembles human reasoning.
- The approach of FL imitates the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO.
- The conventional logic block that a computer can understand takes precise input and produces a definite output as TRUE or FALSE, which is equivalent to human's YES or NO.
- Unlike computers, the human decision making includes a range of possibilities between YES and NO, such as –
  - CERTAINLY YES
  - POSSIBLY YES
  - CANNOT SAY
  - POSSIBLY NO
  - CERTAINLY NO

Machine Learning

- Machine learning is a field of computer science that gives computers the ability to automatically learn without being explicitly programmed.

- Learning from experience on data to make predictions.



Hybrid Approaches

- Combine the hard and the soft computing approaches to improve accuracy of solutions.

Thank you!