Introduction to CI

In this collected lecture notes, computational Intelligence covers a wide range of issues that developed in parallel with, or in competition to, symbolic AI. The major constituents of the field are bio-inspired computing – which deals with an ever-expanding number of biologically related techniques – and fuzzy logic – which deals with reasoning under conditions of vagueness.

In this course we will explore several topics that are core to Computational Intelligence (e.g., neural nets and evolutionary computing) and these will lead into some state-of-the-art approaches (such as fuzzy model-based reasoning and learning).

Objectives:

1.To understand the fuzzy inductive reasoning methodology for modelling systems and predicting their behavior.

2.To apply the fuzzy inductive reasoning methodology to the simulation of environmental, biomedical, industrial or economical processes.

3.To understand the different ways of designing computational intelligence hybrid techniques by integrating fuzzy logic, neural networks and evolutionary algorithms.

4.To apply computational intelligence hybrid techniques to solve complex data mining problems in real scenarios.

5.To understand some of the most advanced and recent techniques in the field of neural networks (e.g. recurrent neural nets, extreme learning machines, deep neural nets).

6.To apply neural network advanced techniques to solve complex data mining problems in real scenarios.

Lecture Outline

- Artificial / Computational intelligence
- CI models

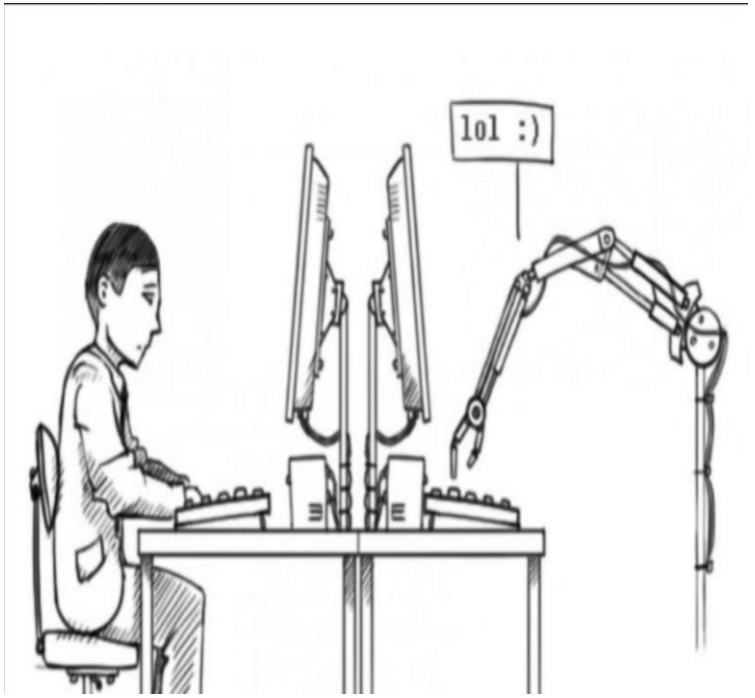
Computational Intelligence

- What's it all about?
  - The Turing test
  - An alternative definition

What is the Turing Test?

It is an intelligent behavior as the ability to achieve human-level performance in all cognitive tasks, sufficient to fool an interrogator.

Roughly speaking, the test proposed that the computer should be interrogated by a human via a teletype, and *passes the test if the interrogator cannot tell if there is a computer or a human at the other end*.



The Turing Test

- Proposed by Alan Turing in 1950
- Deals with the question: “Can machines think?”
- Turing thought this question absurd
- How to define ‘think’?
- Dealt with it with a thought experiment

In Turing Test the computer would need to possess the following capabilities:

Natural language processing to enable it to communicate successfully in English (or some other human language);

Knowledge representation to store information provided before or during the interrogation;

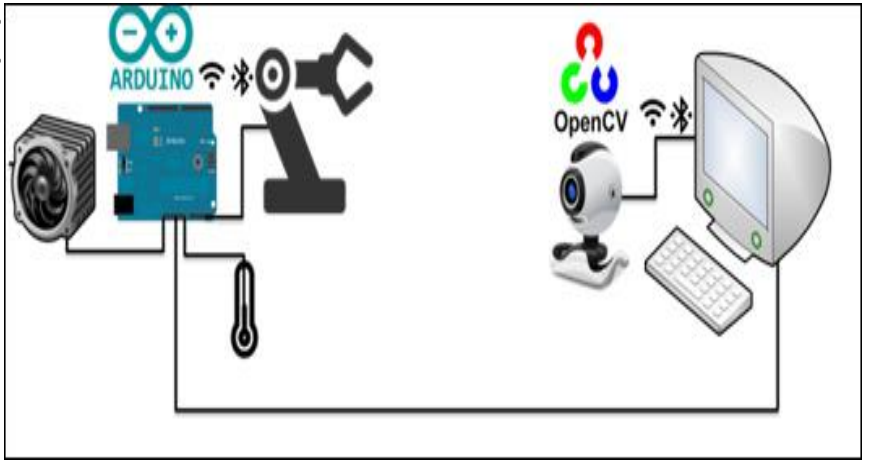
Automated reasoning to use the stored information to answer questions and to draw new conclusions;

Machine learning to adapt to new circumstances and to detect and extrapolate patterns.

To pass the total Turing Test, (features)

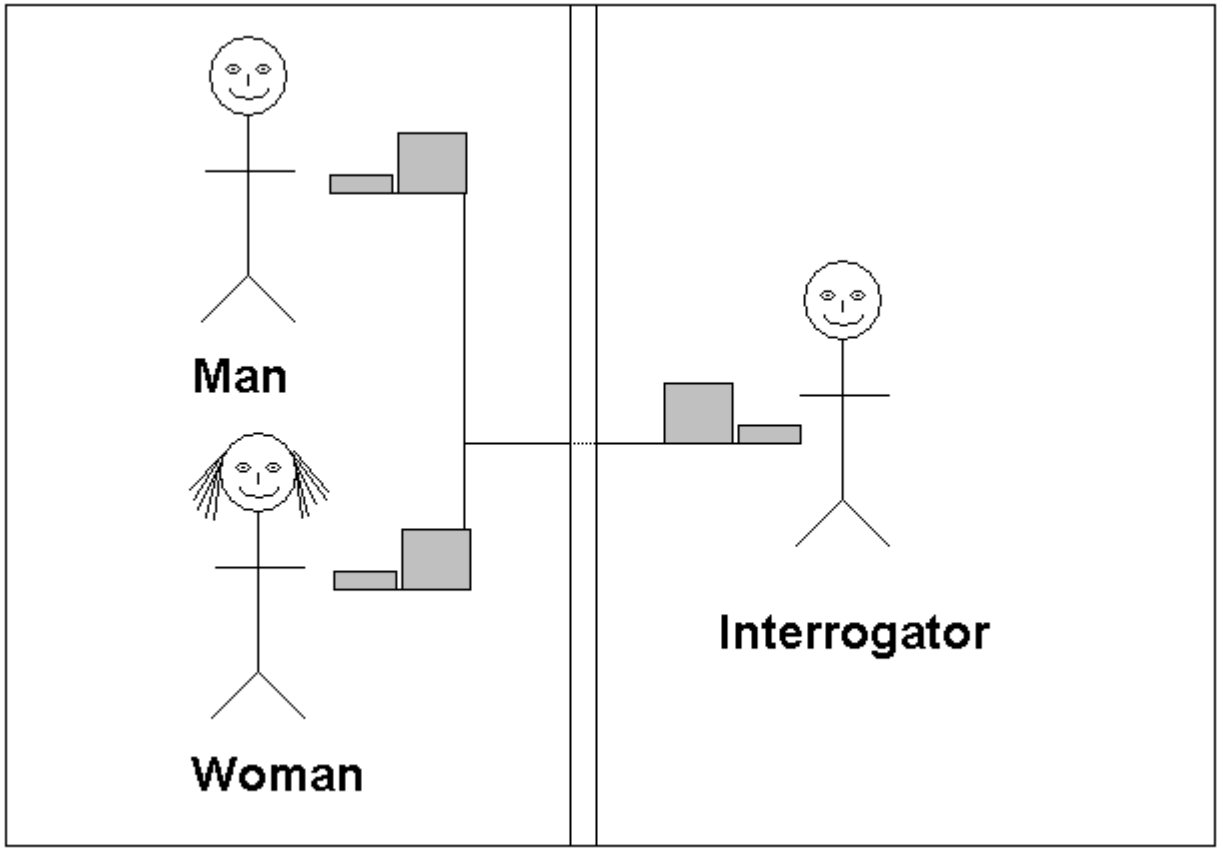
the computer will need:

Computer vision: to perceive objects.



- **Robotics: to move them about.**

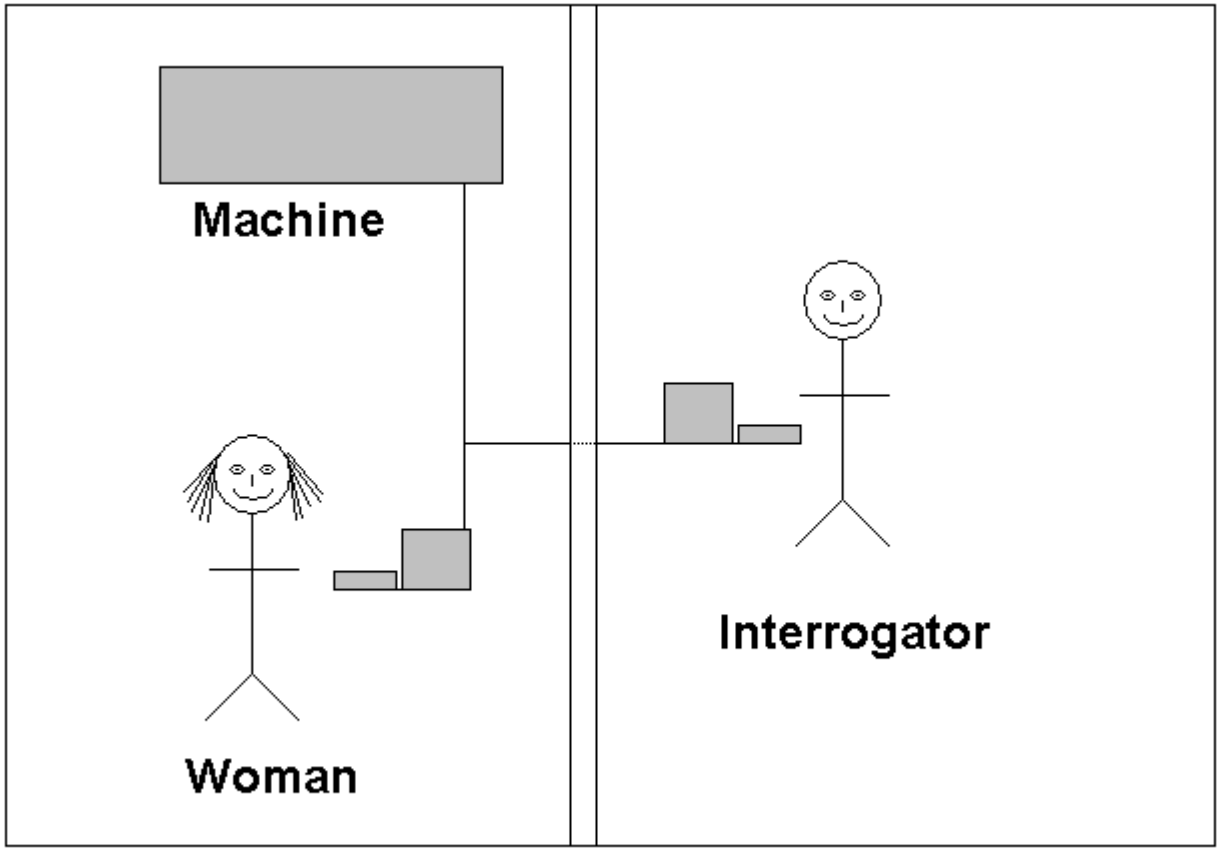
The Turing Test



The Turing Test

- Man’s objective is to convince interrogator that he is a woman
- Woman’s objective is to help the interrogator
- After a while, the interrogator must decide which is which
- Now, replace the man with a computer

The Turing Test



The Turing Test

- Will the interrogator decide wrongly as often as before?
- In other words, can the machine convince the interrogator that it is human as often as a man can pass as a woman?

The Turing Test

- "The Turing Test is no more a test for intelligence than it is a test for femininity… A man doesn't become a woman because he can fool you into thinking that he's a woman. By the same token, a machine doesn't become…an intelligent machine, just because it can fool you into thinking that it's thinking"

– David B. Fogel, *Blondie24: Playing at the Edge of AI* pg 11

An Alternative Definition

- "Intelligence is the capability of a decision-making system to adapt its behavior to meet its goals in a range of environments"

–David B. Fogel, *Blondie24: Playing at the Edge of AI* pg 14

Computational Intelligence

- Artificial Intelligence is now called Computational Intelligence
- Why the change?
  - Fashion?
  - Politics?
  - More accurate?

CI Models

- We will be studying three general paradigms of CI
  - Rule based and fuzzy systems (FS)
  - Artificial Neural Networks (ANN)
  - Evolutionary Computation (EC)

CI Models

- Why cover different models?
- No Free Lunch Theorem
  - If there is a problem A on which the algorithm performs well, there will be a problem B on which the algorithm performs poorly
  - Nothing is good at everything

Rule-Based Systems

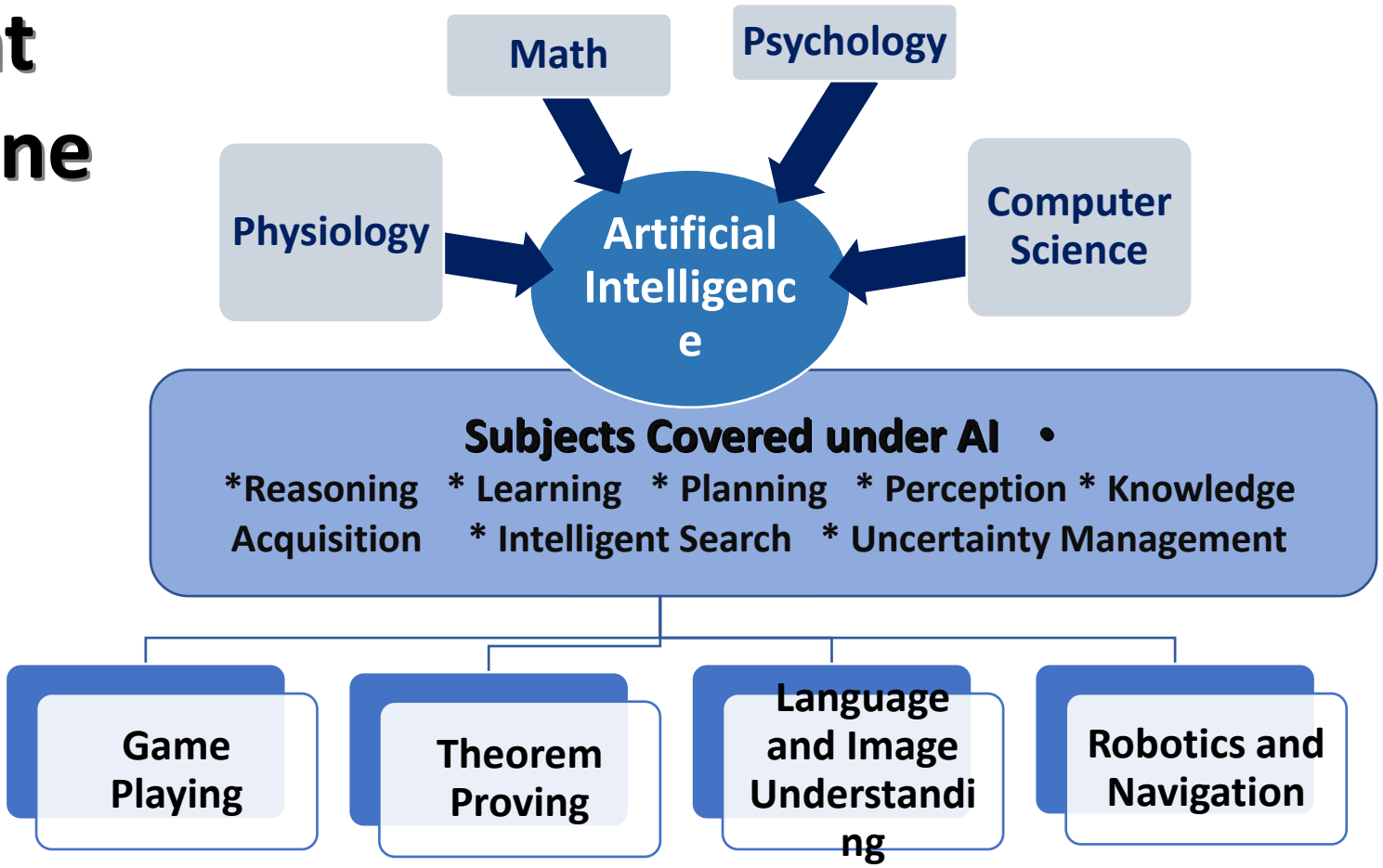
- Systems that make decisions based on rules
- Used when the rules can be stated
- Crisp rules
  - When the numbers dealt with are always exact
  - Can be a pain in the neck to program, though
- Fuzzy rules
  - deals with inexact concepts – ‘bigger’, ‘smaller’, ‘faster’
  - easier to state rules
  - Optimisation can be difficult

Rule-Based Systems

- First, define the rules
- Easier said than done
- Are the rules consistent?
- Are the rules complete?
  - Cover all possibilities
- Fuzzy systems
  - define the fuzzy membership functions

Before proceeding in studying Artificial Intelligence in details, we need to know what is the **Discipline** of AI?

Parent Discipline of AI



The Subject of AI

1- Learning Systems

Learning denotes changes in a system that enable the system to do the same task more efficiently next time.

A computer program is said to learn from experience **E** with respect to some class of tasks **T** and performance measure **P**, if its performance at tasks in **T**, as measured by **P**, improves with experience **E**. (Mitchell 1997)

This means :

Given : A task **T**

A performance measure **P**

Some experience **E** with the task

Goal : Generalize the experience in a way that allows to improve your performance on the task.

2- Knowledge Representation and Reasoning

In a reasoning problem, one has to reach a pre-defined goal state from one or more given initial states.

So, the ***lesser the number of transitions*** for reaching the goal state, the ***higher the efficiency of the reasoning system***.

(Ex. When travelling, assume there is some ways to get from the airport to hotel. Thus,

the goal is reaching hotel.

The initial state: airport,

reasoning problem: select one of the available ways to go.)

Increasing the efficiency of a reasoning system thus requires minimization of intermediate states, which indirectly calls for an organized and complete knowledge base.

Organization of knowledge, therefore, is of paramount importance in knowledge engineering.

There many knowledge representation techniques are in use in Artificial Intelligence:

Production rules

Semantic nets

Frames

Filler and slots

Predicate logic.

The selection of a particular type of representational scheme of knowledge depends both on the nature of applications and the choice of users.

Now we will display a knowledge representation technique (**Semantic Net**)

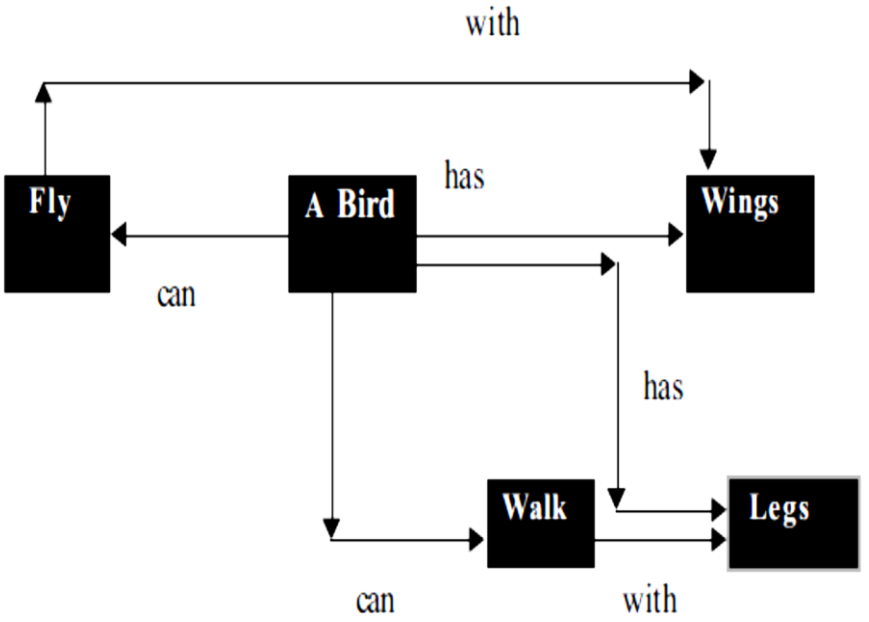
Knowledge Base:

A bird has wings.

A bird can fly with wings.

A bird has legs.

A bird can walk with legs.



3- Planning

Reasoning and Planning share many common issues:

The reasoning problem is mainly concerned with the testing of the ***satisfiability of a goal*** from a given set of data and knowledge.

The planning problem deals with the ***determination of the methodology*** by which a successful goal can be achieved from the known initial states.

4- Knowledge Acquisition

It includes generation of new pieces of knowledge from given knowledge base, setting dynamic data structures for existing knowledge, learning knowledge from the environment and refinement of knowledge.

It is equally hard process for machines as it is for human beings.

Automated acquisition of knowledge by machine learning approach is an active area of current research in Artificial Intelligence.

5- Intelligent Search

Search problems usually have deterministic nature, *i.e., the order of visiting the elements of the search space is known.* For example, First In first Out search algorithms (FIFO), one knows the sequence of visiting the nodes in a tree.

However, search problems, which we will come across in AI, are *non-deterministic* and the order of visiting the elements in the search space is completely dependent on data sets.

6- Logic Programming

Mathematicians and logicians were used to designing various tools to represent logical statements by symbolic operators.

One outgrowth of such attempts is ***propositional logic,*** which deals with a ***set of binary statements (propositions)*** connected by ***Boolean operators.***

The logic of propositions, which was gradually enriched to handle more complex situations of the real world, is called ***predicate logic***.

The most famous programming language for Logic programming is **PROLOG (PROgramming in LOGic)**

7- 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 a collection of computing tools and techniques such as

Fuzzy logic,

Artificial Neural nets,

Genetic Algorithms,

Inductive Logic Programming.

Soft Vs. Hard Computing ?

1- Fuzzy Logic

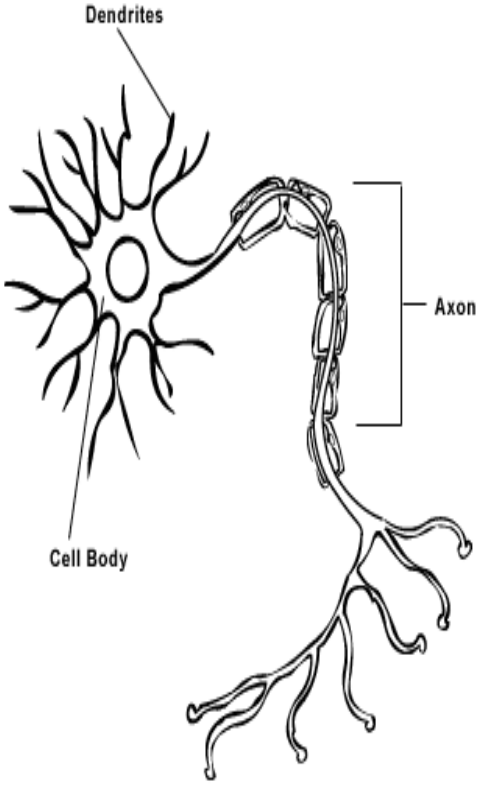
deals with fuzzy sets and logical connectives for modeling the human-like reasoning problems of the real world. A fuzzy set includes all elements of the universal set of the domain but with varying membership values in the interval [0,1].

The most common operators applied to fuzzy sets are AND (minimum), OR (maximum) and negation (complementation), where AND and OR have binary arguments.

2-Artificial Neural Nets

ANN are electrical analogues of the biological neural nets.

Biological nerve cells, called neurons, receive signals from neighboring neurons or receptors through dendrites, process the received electrical pulses at the cell body and transmit signals through a large and thick nerve fiber, called an axon.



An artificial neural net is a collection of such electrical neurons connected in different topology.

The most common application of an artificial neural net is in machine learning.

Artificial Neural Networks

- Based on models of the brain
- Consist of network of interconnected subunits
  - Neurons
- Used when the rules are not known
- ANN are learning structures
  - Don’t need to be told the answer to the problem

Artificial Neural Networks

- Many kinds in existence
- We will be covering only three
  - Perceptrons
  - Multi-layer Perceptrons (MLP)
  - Kohonen Self-Organising Maps (SOM)

Artificial Neural Networks

- Which networks are used depends on the application
- perceptrons useful for simple problems
  - linear separability
- MLPs handle problems perceptrons cannot
  - Non linearly separable

Artificial Neural Networks

- Perceptrons and MLPs both use supervised learning
  - Must know the target values the network is learning
- SOMs are unsupervised
  - capture clusters in the data
  - vector quantisers

Artificial Neural Networks

- Care must be taken with the data used to train the network
  - It is easy to badly train an ANN
- Other circumstances where ANN don’t function well

Evolutionary Algorithms

- Based on the mechanisms of natural selection and biological evolution
- Evaluates fitness of (initially) random solutions
- More fit individuals produce more offspring
- Search algorithms
- Used when brute-force (exhaustive) search is not feasible
- Useful for multi-parameter optimisation

Evolutionary Algorithms

- Several kinds exist
  - Genetic Algorithms (GA)
  - Evolution Strategies (ES)
  - Evolutionary Programming (EP)
  - Genetic Programming (GP)
- Require the following characteristics
  - representable
  - Fitness (objective) function

Representation

- Must be able to represent the problem in the algorithm
- some means of encoding candidate solutions

Evaluation

- some means of rating candidates must exist
  - binary ratings are no good
- right/wrong
  - fitness function must be objective
  - fitness function must separate good candidates from bad candidates
  - Most problem dependent component of EA