INTELLIGENT COMPUTING

(COMPUTATIONAL INTELLIGENCE)
Introduction

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WHAT IS COMPUTATIONAL INTELLIGENCE?

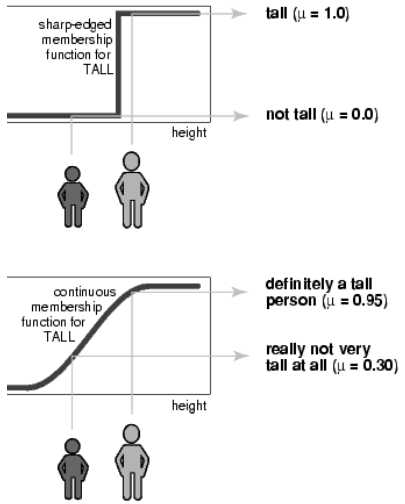
- Computational intelligence (CI) is a set of nature-inspired computational methodologies and approaches to address complex real-world problems to which traditional approaches are ineffective or infeasible.
- Many such real-life problems are not considered to be well-posed problems mathematically, but nature provides many examples of biological systems exhibiting the required functionality.
- Traditional models also often fail to handle uncertainty, noise and the presence of an ever-changing context. Computational Intelligence can provide solutions under the above conditions. It primarily includes artificial neural networks, evolutionary computation and fuzzy logic.
- In addition, CI also embraces biologically inspired algorithms such as swarm intelligence and artificial immune systems, which can be seen as a part of evolutionary computation.

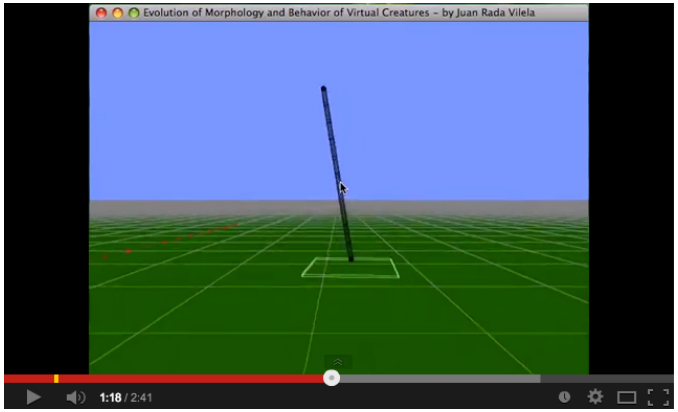
WHAT IS FUZZY LOGIC?

- Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. The idea of fuzzy logic was first advanced by Dr. Lotfi Zadeh of the University of California at Berkeley in the 1960s.
- Most activities in life are not easily translated into the absolute terms of 0 and 1. Whether everything is ultimately describable in binary terms is a philosophical question worth pursuing, but in practice most data we might want to feed a computer is in some state in between and so, frequently, are the results of computing.
- Fuzzy logic includes 0 and 1 as extreme cases of truth but also includes the various states of truth in between so that, for example, the result of a comparison between two things could be not "tall" or "short" but ".38 of tallness."

WHAT IS FUZZY LOGIC?

- A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1.
- Concept of tallness is a classic Fuzzy Logic example. In this case the concept corresponds to a curve that defines the degree to which any person is tall.
- The output-axis is a number known as the membership value, between 0 and 1. The curve is known as a membership function and is often given the designation of μ. This curve defines the transition from not tall to tall.
- Both people are tall to some degree, but one is significantly less tall than the other.





3D POLL BALANCING USING FUZZY LOGIC CONTROLLER

http://youtu.be/YOKk8G_5aRA

PRACTICAL APPLICATIONS

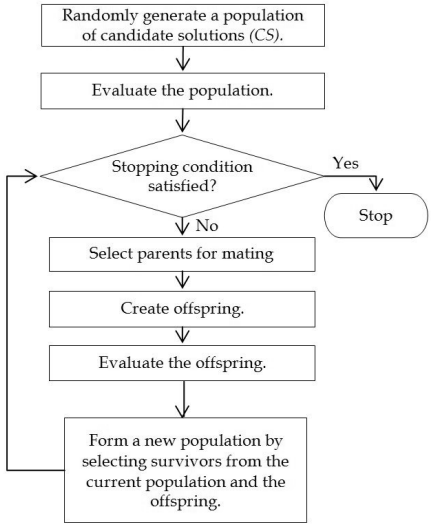
Fuzzy Logic rice cooker: http://home.howstuffworks.com/rice-cooker2.htm

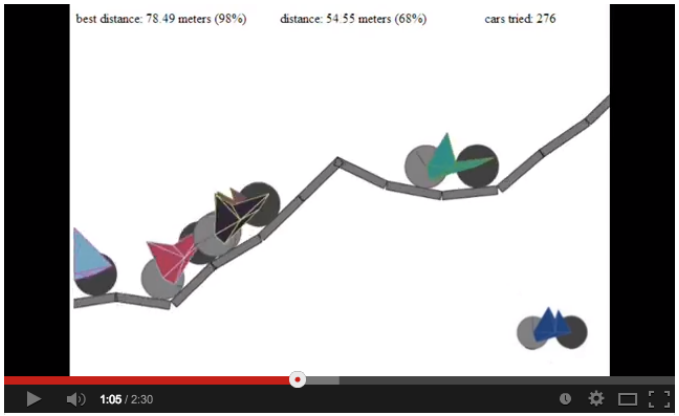
WHAT IS EVOLUTIONARY COMPUTATION?

- The use of Darwinian principles for automated problem solving originated in the 1950s. It was not until the 1960s that this idea started to be developed. Evolutionary programming was introduced by Lawrence J. Fogel in the US, while John Henry Holland called his method a genetic algorithm. These areas developed separately for about 15 years. From the early nineties on they unified as different representatives of one technology, called evolutionary computing.
- Evolutionary computation involves continuous optimisation and combinatorial optimisation problems. Its algorithms can be considered global optimisation methods and are mostly applied for black box problems (no derivatives known), often in the context of expensive optimisation.
- Evolutionary computation uses iterative progress, such as growth or development in a population. This population is then selected in a guided random search using parallel processing to achieve the desired end. Such processes are often inspired by biological mechanisms of evolution.

WHAT IS EVOLUTIONARY COMPUTATION?

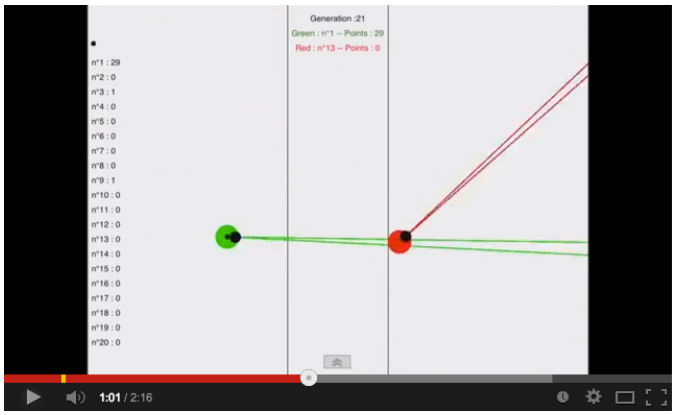
- Population of candidate solutions to an optimisation problem is evolved toward better solutions.
- Each candidate solution has a set of properties (chromosomes) which can be mutated and altered.
- The evolution usually starts from a population of randomly generated individuals, and is an iterative process, with the population in each iteration called a generation.
- In each generation, the fitness of every individual in the population is evaluated; the fitness is usually a function of the optimisation problem being solved.





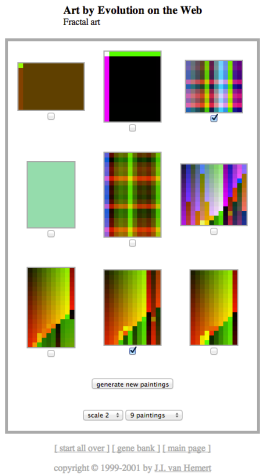
GENETIC EVOLUTION OF A WHEELED VEHICLE

http://youtu.be/uxourrlPlf8



GENETIC ALGORITHM LEARNS HOW TO FIGHT

http://youtu.be/u2t77mQmJiY



PRACTICAL APPLICATIONS

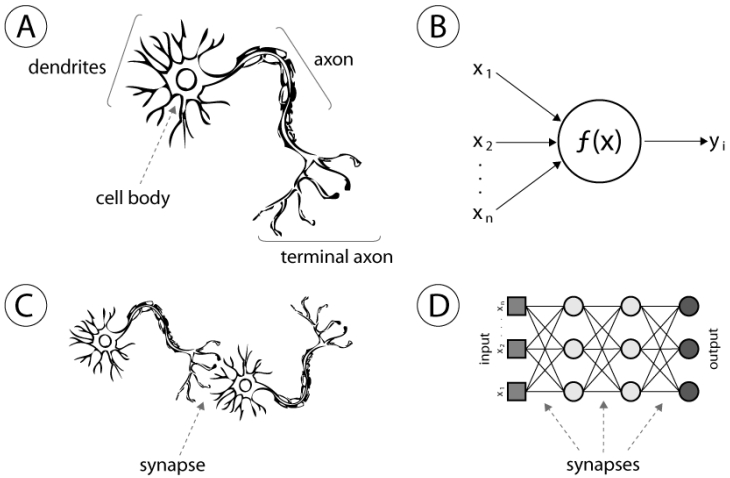
Art by Evolution: http://www.vanhemert.co.uk/eartweb/

WHAT ARE ARTIFICIAL NEURAL NETWORKS?

- Artificial neural networks (ANNs) are computational models inspired by the brain and are capable of machine learning and pattern recognition. They are usually presented as systems of interconnected "neurons" that can compute values from inputs by feeding information through the network.

- For example, in a neural network for handwriting recognition, a set of input neurons may be activated by the pixels of an input image representing a letter or digit. The activations of these neurons are then passed on, weighted and transformed by some function determined by the network's designer, to other neurons, etc., until finally an output neuron is activated that determines which character was read.

- ANNs can be trained in an unsupervised or supervised manner. For unsupervised training ANNs take input data and create an internal model of what the data might represent. In supervised training, a trainer must create a set of positive and negative examples of a concept in order for the network to make acceptable classifications.

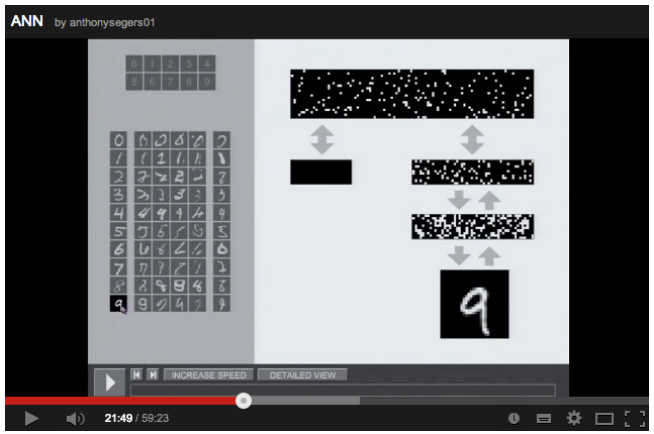


HUMAN BRAIN HAS AROUND 100BN NEURONS

Recent research by Dr Suzana Herculano-Houzel suggests that its more like 86bn - short by 14bn.

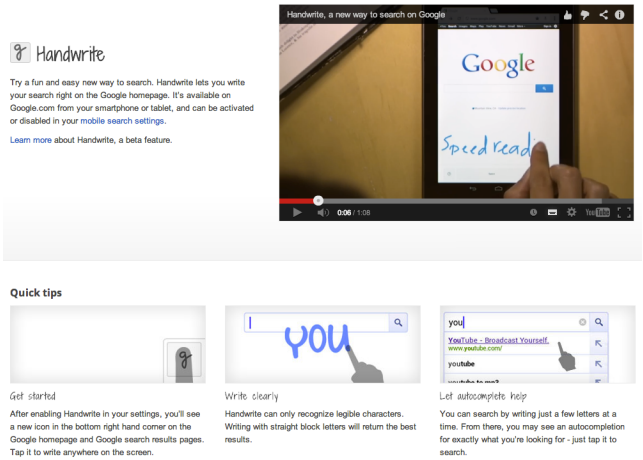
WHAT ARE ARTIFICIAL NEURAL NETWORKS?

- Warren McCulloch and Walter Pitts(1943) created a computational model for neural networks based on mathematics and algorithms. They called this model threshold logic. This model paved the way for neural network research.
- In the late 1940s psychologist Donald Hebb created a hypothesis of learning based on the mechanism of neural plasticity that is now known as Hebbian learning.
- Frank Rosenblatt(1958) created the perceptron, an algorithm for pattern recognition.
- Neural network research stagnated after a publication by Marvin Minsky and Seymour Papert(1969). They discovered that single layer neural networks could only solve linearly separable problems.
- Interest in the area did not peak again until the backpropagation learning algorithm was created by Paul Werbos(1975), which allowed artificial neural networks solve non linearly separable problems.
- In the 1990s, neural networks were overtaken in popularity by support vector machines and other, much simpler methods such as linear classifiers. Renewed interest in neural nets was sparked in the 2000s by the advent of deep learning.



ARTIFICIAL NEURAL NETWORK LEARNING HAND WRITTEN DIGITS (21:15)

http://www.youtube.com/watch?v=AyzOUbkUf3M&feature=share&list=PLD0p8RGTHoRe5-_-eqoBmFCIEdvj24w7f



PRACTICAL APPLICATIONS

Google handwrite: http://www.google.com/insidesearch/features/search/handwritinginput/

WHAT IS SWARM INTELLIGENCE?

- Swarm intelligence (SI) is the collective behaviour of decentralised, self-organised systems, natural or artificial. The expression was introduced by Gerardo Beni and Jing Wang in 1989, in the context of cellular robotic systems.

- SI systems consist typically of a population of simple agents or boids interacting locally with one another and with their environment. The inspiration often comes from nature, especially biological systems. The agents follow very simple rules, and although there is no centralised control structure dictating how individual agents should behave, local, and to a certain degree random, interactions between such agents lead to the emergence of "intelligent" global behaviour, unknown to the individual agents.

- Examples in natural systems of SI include ant colonies, bird flocking, animal herding, bacterial growth, and fish schooling. The definition of swarm intelligence is still not quite clear. In principle, it should be a multi-agent system that has self-organised behaviour that shows some intelligent behaviour.

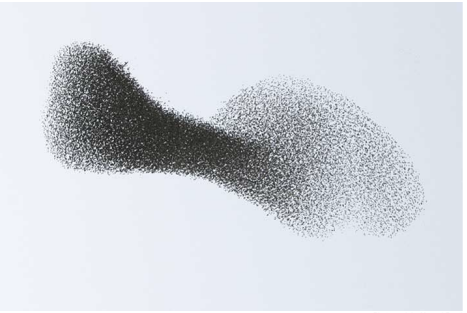
WHAT IS SWARM INTELLIGENCE?

- Control is distributed among a number of individuals(decentralisation).

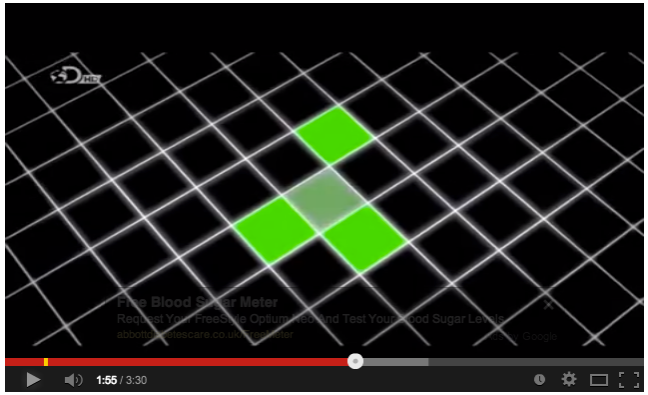
- Communications among individuals happen in a localised way.

- System-level behaviours seem to transcend the behavioural repertoire of a single individual (emergence).

- The overall response of the group is robust, flexible and adaptive with respect to changes in the environment (the group as an emergent object).



Photograph by Manuel Presti

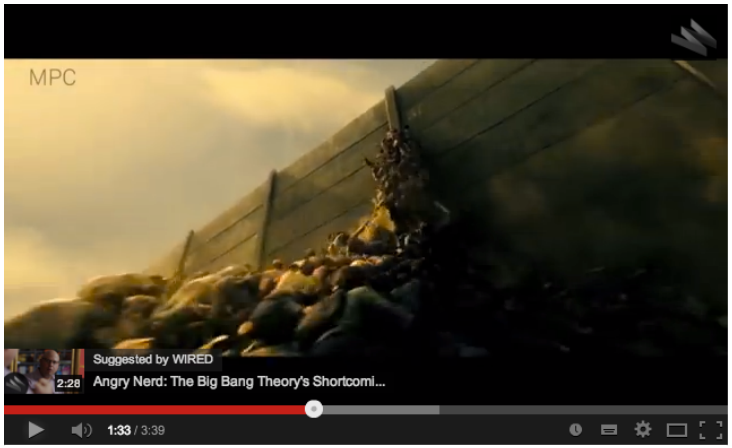


CONWAY'S GAME OF LIFE

http://youtu.be/CgOcEZinQ2I

CONWAY'S GAME OF LIFE

http://youtu.be/XcuBvj0pw-E



PRACTICAL APPLICATIONS

World War Z: http://youtu.be/tvoUMH9Ghpo

APPROACH & ASSESSMENT

- Lectures & lab based exercises
- 40% continuous assessment (2 pieces) programming based.
- 60% final written exam
- **COMP H4011** - Intelligent Computing MOODLE page enrolment key is "kismet"