UCD CASL

Complex & Adaptive Systems Laboratory

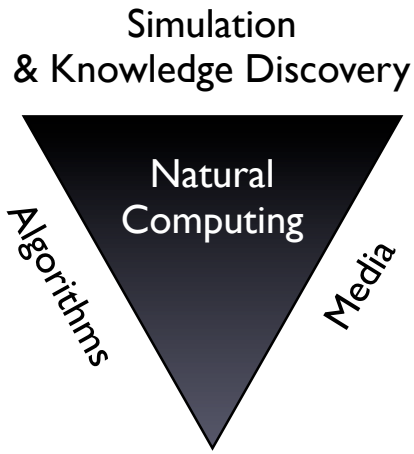
Dr. Michael O'Neill
Dr. Miguel Nicolau

Introduction to Natural Computing

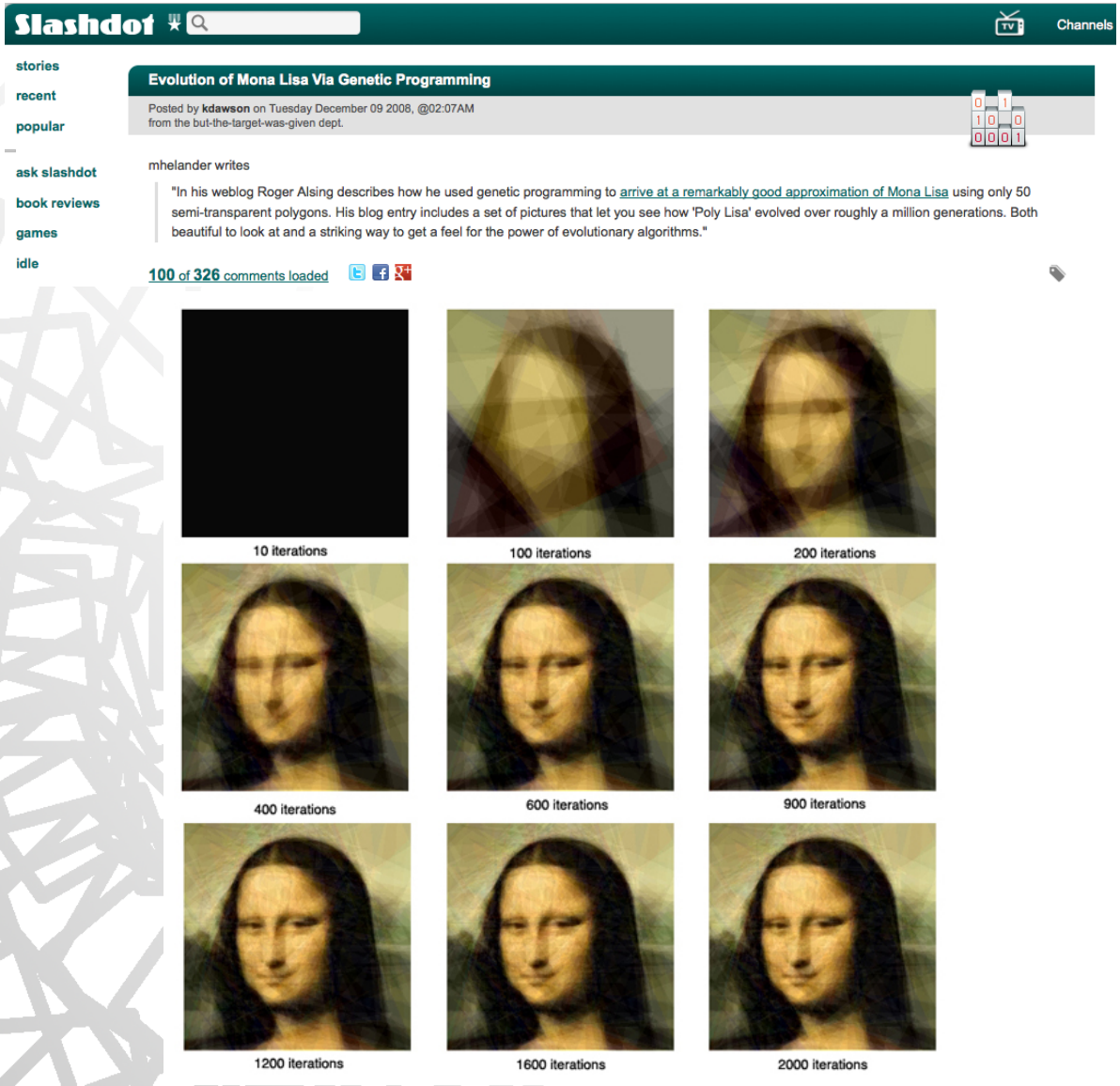
COMP30290 Natural Computing
COMP41190 Natural Computing and Applications

Natural Computing

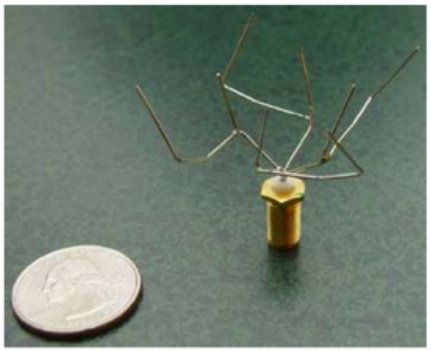
What is Natural Computing?

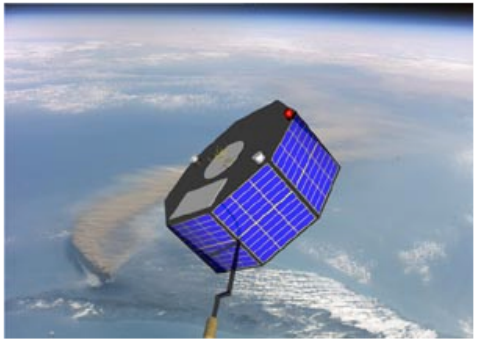


Natural Computing Algorithms



Natural Computing Algorithms





Simulation of Natural Systems

SCIENTIFIC AMERICAN™

IBM Simulates 4.5 percent of the Human Brain, and All of the Cat Brain

A special online-only addition to November 2011's Graphic Science

By Mark Fischetti | October 25, 2011 | 25

Supercomputers can store more information than the human brain and can calculate a single equation faster, but even the biggest, fastest supercomputers in the world cannot match the overall processing power of the brain. And they are nowhere near **as compact or energy efficient**.

Nevertheless, IBM is trying to simulate the human brain with its own cutting-edge supercomputer, called Blue Gene. For the simulation, it used 147,456 processors working in parallel with one another. IBM researchers say each processor is roughly equivalent to the one found in a personal computer, with one gigabyte of working memory.

So configured, Blue Gene simulated 4.5 percent of the brain's neurons and the connections among them called synapses—that's about one billion neurons and 10 trillion synapses. In total, the brain has roughly 20 billion neurons and 200 trillion synapses.

IBM describes the work in an intriguing paper (pdf) that compares various animal simulations done by its cognitive computing **research group** in Almaden, Calif. The group has managed to completely simulate the brain of a mouse (512 processors), rat (2,048) and cat (24,576). To rival the cortex inside your head, IBM predicts it will need to hook up 880,000 processors, which it hopes to achieve by 2019.

Simulation of Natural Systems

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Page last updated at 12:46 GMT, Wednesday, 22 April 2009 13:46 UK

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Simulated brain closer to thought

By Jason Palmer
Science and technology reporter, BBC News, Prague

A detailed simulation of a small region of a brain built molecule by molecule has been constructed and has recreated experimental results from real brains.

This result completes the first phase of the brain simulation project

The "Blue Brain" has been put in a virtual body, and observing it gives the first indications of the molecular and neural basis of thought and memory.

Scaling the simulation to the human brain is only a matter of money, says the project's head.

The work was presented at the European Future Technologies meeting in Prague.

The Blue Brain project launched in 2005 as the most ambitious brain simulation effort ever undertaken.

While many computer simulations have attempted to code in "brain-like" computation or to mimic parts of the nervous systems and brains of a variety of animals, the Blue Brain project was conceived to reverse-engineer mammal brains from real laboratory data and to build up a computer model down to the level of the molecules that make them up.

The first phase of the project is now complete; researchers have modeled the neocortical column - a unit of the mammalian brain known as the neocortex which is responsible for higher brain functions and thought.

"The thing about the neocortical column is that you can think of it as

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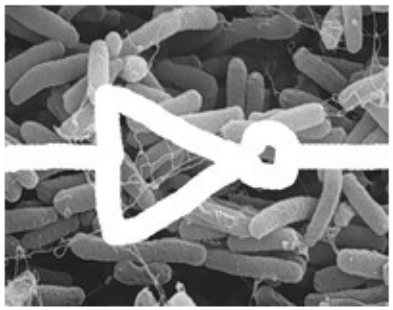
Synthesised Computing

FILED UNDER *Science*, *Alt*

Scientists build logic gates out of gut bacteria, then hopefully wash their hands

By Sharif Sakr posted Oct 24th 2011 1:42AM



Ever thought about upgrading your PC by breeding more cores? Or planting a few GBs of extra storage out in the yard? Us neither, until we heard that scientists at Imperial College in London have succeeded in building "some of the basic components of digital devices" out of genetically modified E.Coli. We've seen these germs exploited in a similar way before, but Imperial's researchers claim they're the first to make bacterial logic gates that can be fitted together to form more complex gates and potentially whole biological processors. Aside from our strange upgrade fantasies, such processors could one day be implanted into living bodies -- to weed out cancer cells, clean arteries and deliver medication exactly where it's needed. So much for Activia.

VIA *PhysOrg*
SOURCE *Imperial College London*

DISCUSS

TAGS *AND, bacteria, biological, biological computing, BiologicalComputing, biology, computing, E.Coli, germ, germs, gut, Imperial college, ImperialCollege, logic, logic gates, LogicGates, NAND, NOT, organic, organic computing, organic processor, OrganicComputing, OrganicProcessor, processor, stomach*

Synthesised Computing

The Economist

World politics | Business & finance | Economics | Science & technology | Culture | Blogs | Debate | The World in 2012 | Multimedia | Print edition

Technology Quarterly: Q1 2012

DNA computing

Computing with soup

Molecular computing: DNA is sometimes called the software of life. Now it is being used to build computers that can run inside cells

Mar 3rd 2012 | from the print edition

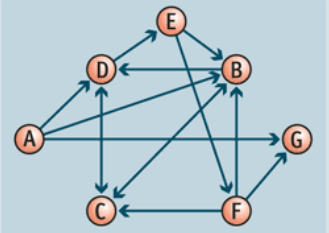
EVER since the advent of the integrated circuit in the 1960s, computing has been synonymous with chips of solid silicon. But some researchers have been taking an alternative approach: building liquid computers using DNA and its cousin RNA, the naturally occurring nucleic-acid molecules that encode genetic information inside cells. Rather than encoding ones and zeroes into high and low voltages that switch transistors on and off, the idea is to use high and low concentrations of these molecules to propagate signals through a kind of computational soup.

Computing with nucleic acids is much slower than using transistors. Unlike silicon chips, however, DNA-based computers could be made small enough to operate inside cells and control their activity. "If you can programme events at a molecular level in cells, you can cure or kill cells which are sick or in trouble and leave the other ones intact. You cannot do this with electronics," says Luca Cardelli of Microsoft's research centre in Cambridge, England, where the software giant is developing tools for designing molecular circuits.

At the heart of such circuits is Watson-Crick base pairing, the chemical Velcro that binds together the two strands of DNA's double helix. The four chemical "bases" (the letters of the genetic alphabet) that form the rungs of the helix stick together in complementary pairs: A (adenine) with T (thymine), and C

Showing the way

The experiment that launched DNA computing



1. Given a network of one-way roads linking seven towns, the aim is to determine if there is a route that starts in town A, finishes in town G and visits each town exactly once. First, short strands of DNA are made to represent the links in the road network. Because a road runs from town A to town B, AB strands are created. There are no roads between A and C, so no AC or CA strands are created. For each link in the network, about 100 trillion DNA strands are created

Natural Computing Algorithms

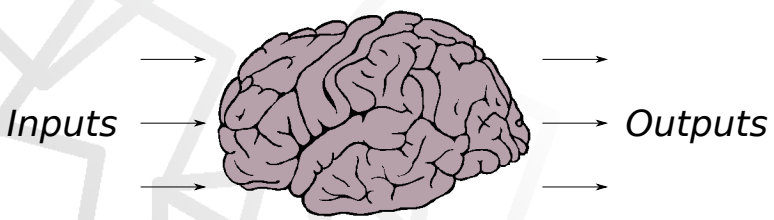
Natural Computing Algorithms

Sources of inspiration

- Central Nervous System (*Neurocomputing*);
- Evolution (*Evolutionary Computation*);
- Molecular Dynamics (*Physical and Chemical Computing*);
- Immune Systems (*Immunocomputing*);
- Social Interaction amongst organisms (*Social Computing*);
- Language and Developmental Biology (*Developmental and Grammatical Computing*).

Not perfect imitation - exploit salient computational features

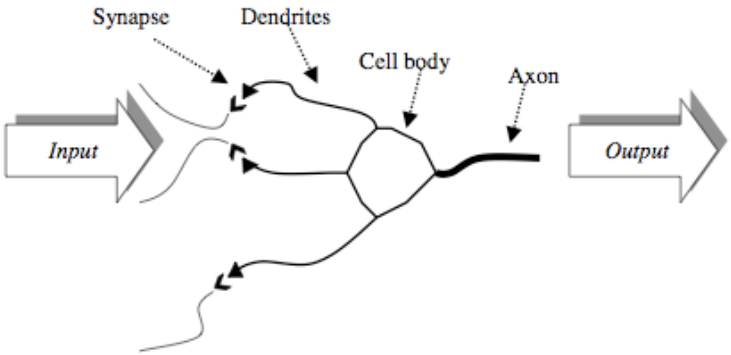
Neurocomputing

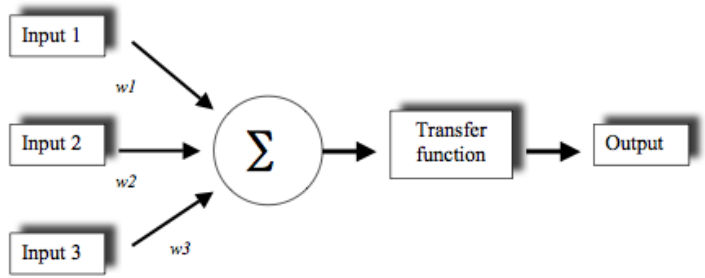


Artificial Neural Networks (ANN)

- Simplified model of workings of human brain;
- Neuron/Perceptron;
- Learn connection weights.

Neurocomputing



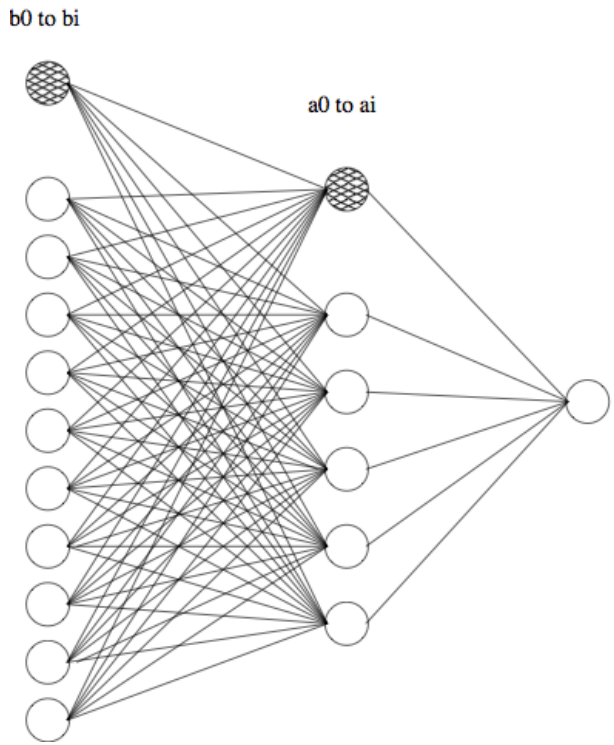


Artificial Neural Networks (ANN)

- Essentially a function approximator;
- *Classification* (pattern recognition, image matching, . . .);
- *Prediction* (extrapolation from historical data, . . .);
- . . .

Neurocomputing

$$z_t = L\left(a_0 + \sum_{j=1}^{x} w_j L\left(\sum_{i=0}^{y} b_i w_{ij}\right)\right)$$

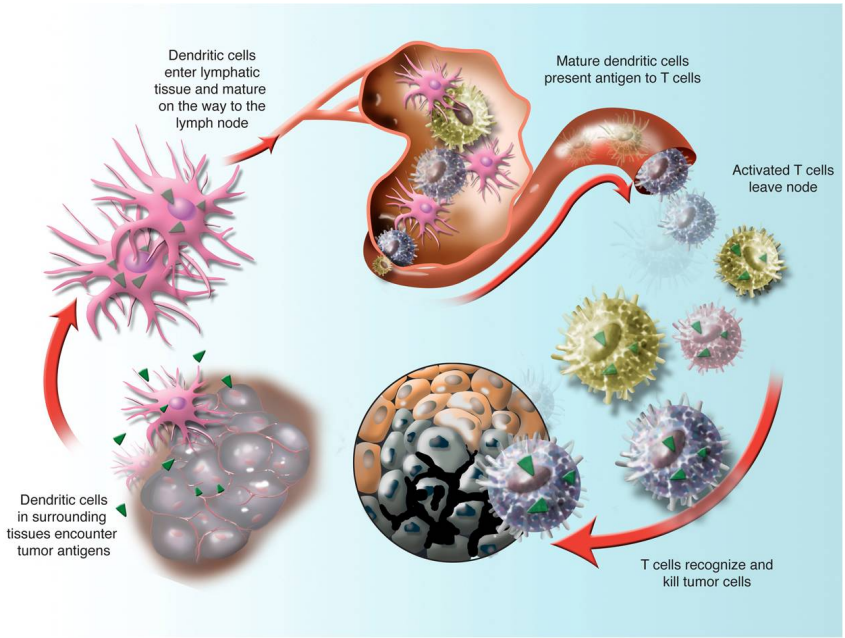


Neurocomputing

Variety of ANNs

- Activation function: linear, sigmoid;
- Type: Multi Layer Perceptron (MLP), Radial Basis Function Network (RBNF), Self Organising Map (SOM);
- Topology: fully connected, feedforward, recurrent;
- Training method: supervised, unsupervised;

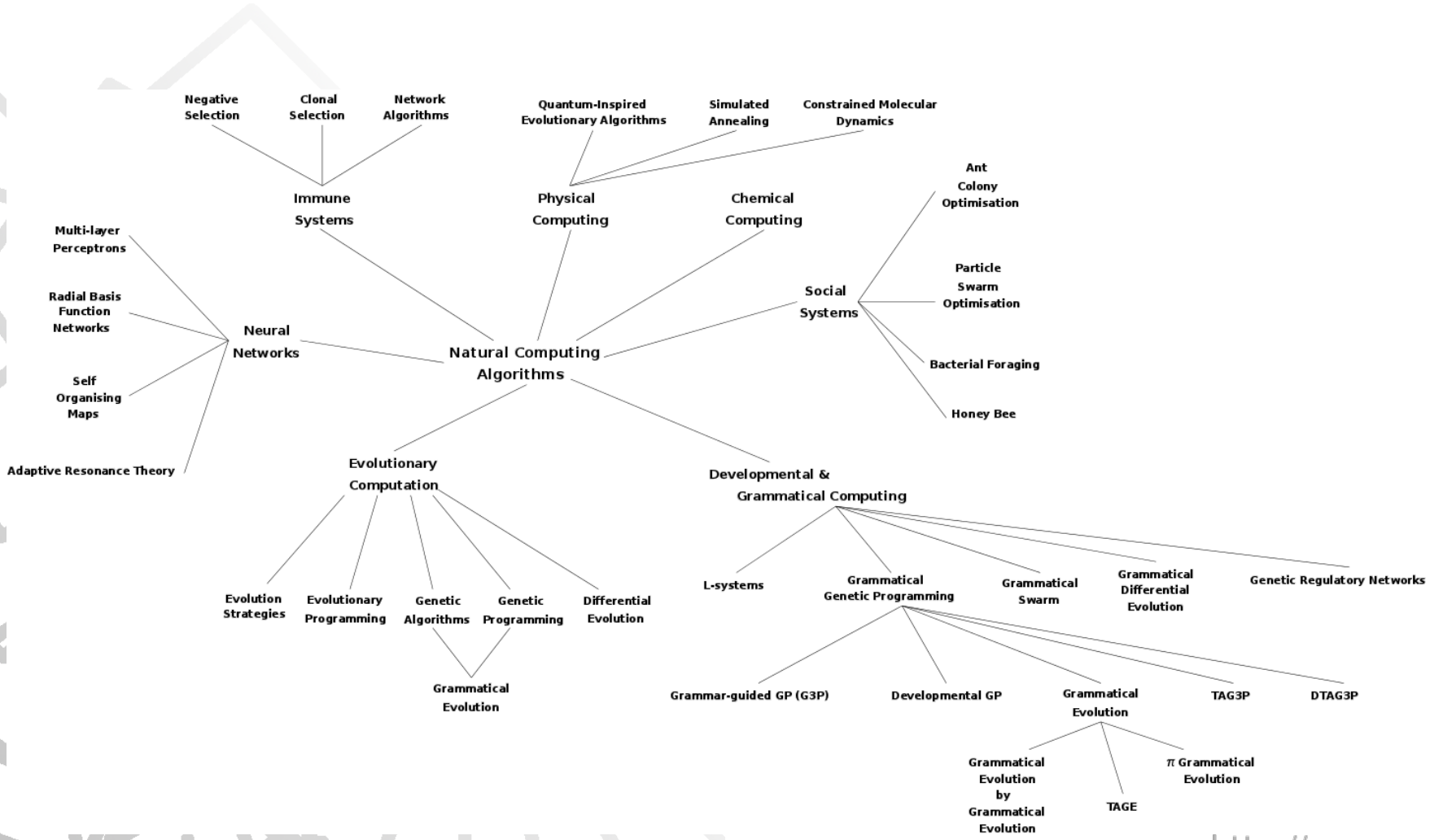
Immunocomputing



Artificial Immune Systems

- Immune system is an amazing classifier:
  - Almost unlimited number of foreign bodies;
  - Protect against our own misbehaving cells.
- AIS: fraudulent ccard transactions, financially *at-risk* companies, ...

Natural Computing Algorithms



Project

Ideas

- Apply a NC method to an *interesting* problem;
- Compare two or more methods on an *interesting* problem;
- Analyse behaviour of a NC algorithm/component;
- Propose/test new variant or a NC algorithm/component.

Project

Papers

- *"On the Genetic Evolution of a Perfect Tic-Tac-Toe Strategy"*;
- *"Using Genetic Programming to Evolve an Algorithm for Factoring Numbers"*;
- *"Influences of Function Sets in Genetic Programming"*;
- *"Evolving Musical Scores using a Genetic Algorithm"*;
- *"A simple approach to Protein Structure Prediction using a Genetic Algorithm"*;
- *"Using Genetic Programming to Perform Time-Series Forecasting of Stock Prices"*;
- *"Corporate Failure Prediction using an Artificial Immune System"*;
- *"A Genetic Algorithm Solver for Sudoku"*;
- *"Sound Synthesis using Particle Swarm Optimisation"*.

Next Class?

- Thur 12th September @3pm;