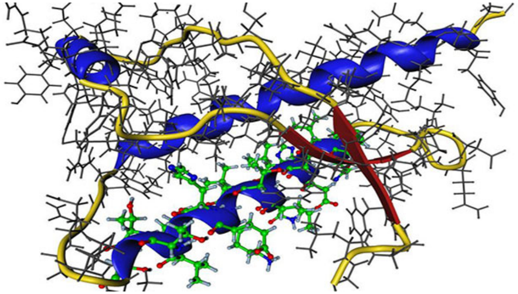
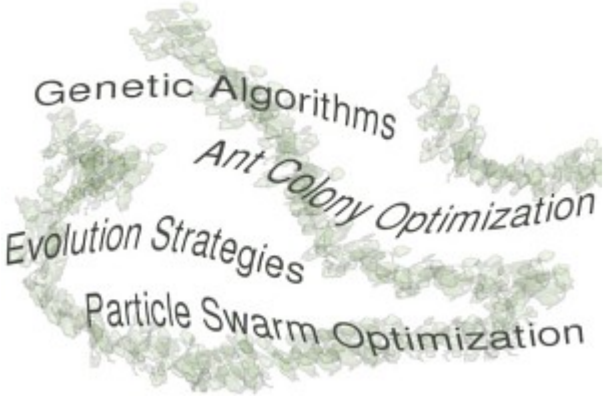
NTNU

Norwegian University of Science and Technology

Lecture 1

The NEW AI





Håken Jevne,
Pauline Haddow and Kazi Ripon

Outline

- What is the new AI?
- Traditional problem solvers
- What is Natural/Bio-inspired Computation?
  - Complexity
  - Emergent Systems
  - Adaptive Systems
- Bio-inspired vs Bio-plausible
- Bio-inspired Techniques

GOFAI -> New AI

- Early (1955 – 1980) GOFAI
  - tasks that humans find difficult
  - Human brains and cognitive reasoning
  - Challenge: easy tasks (computationally hard)
  - Computers lack common sense
- Later (1985 –) SEAI
  - Experience and survival -> common sense
  - Situated and Embodied AI (SEAI)
    - I am therefore I think
    - Low road to intelligence
    - Basic building blocks to intelligence are simple behaviours
  - 'Nouvelle AI'
    - Rodney Brooks pioneer

New AI

- 1990s Technology revolution
  - ↑ demand for automated complex problem solvers
  - Newer concepts
    - Real-time and embedded intelligence
    - Autonomous behaviour
    - Self-adaptation, self-organisation
    - Social awareness
- Fundamental aspects of biological intelligence

  -> survival in unknown and changing environments
- Look to Nature beyond the brain
  - The evolutionary process
  - Other biological processes / organisms

Top-down vs Bottom-up AI

- *Top-down – idealist approach*
  - *Looks at Cognition:*
    - *High-level phenomena independent of the low-level implementation ie brain*
  - *Knowledge intensive*
  - *What's necessary to implement this vision/goal?"*
  - *Break down knowledge*
    - *Symbols -> symbolic AI*
  - *Symbol processing*

- Bottom-up – pragmatic approach
  - *"What can we do with what we've got?"*
  - *Simple behaviours in building blocks*
    - *Create networks of building blocks*
    - *simple behaviours combine - > more complex behaviour*
    - *Sub-symbolic*
  - *Connectionist view*

Areas of the new AI: bottom-up AI

- Artificial Life
- Evolution
- Artificial Development
- Artificial Neural Networks
- Deep Learning
- Artificial Immune Systems
- Swarm Intelligence
- SEAI
- Incremental cognition

SEAI: Karl Sim's Evolving Creatures

Karl Sim's evolving creatures

1994

Evolving body and control

Provided artificial 3D environment and artificial goal

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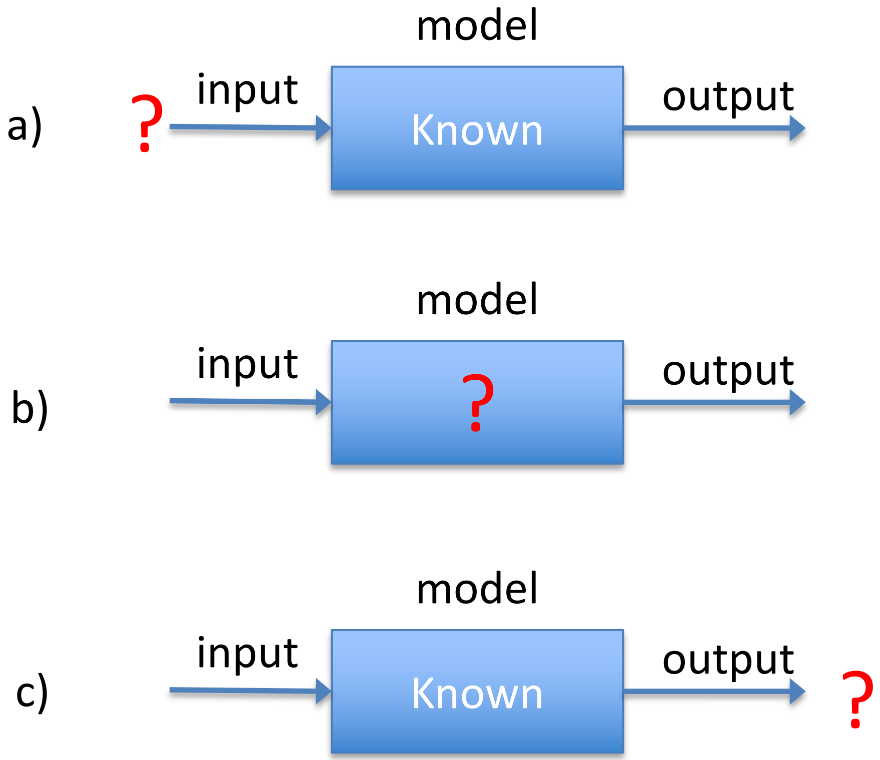
Problem Solvers

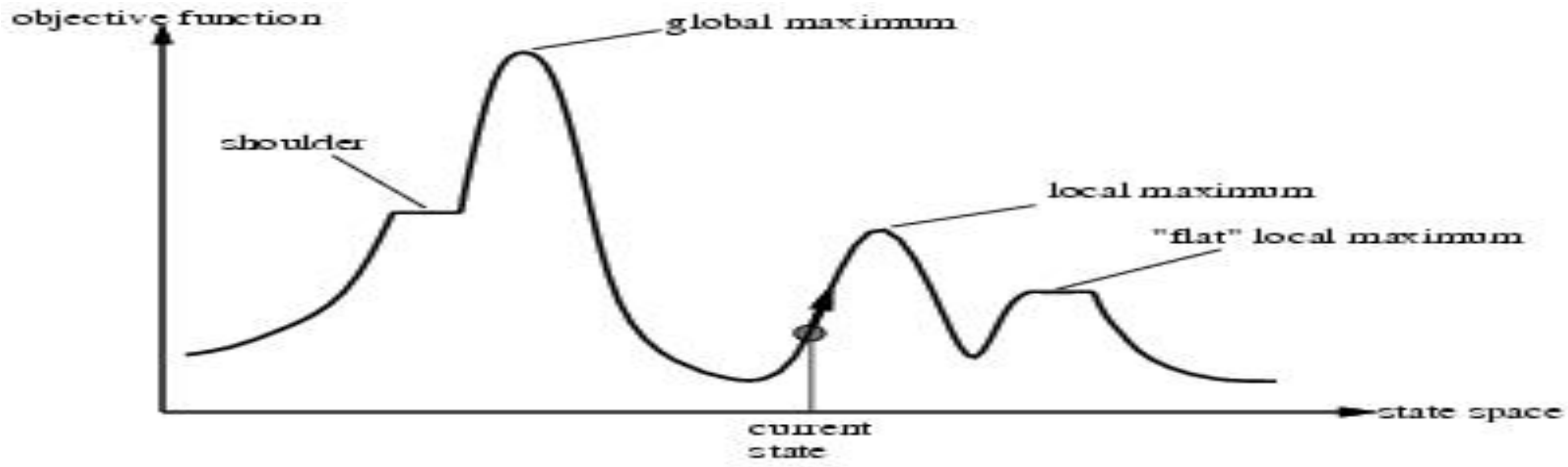


a) Optimisation
- Desired output/artificial goal
- TSP, shortest path (optimal)
- Portfolio optimisation

b) Modelling
- Sets of inputs -> outputs
- Economic system
- Correct model, prediction too

c) Simulation
- Test theories
- prototype

Non-linear problems- search landscape



Hill-climbing search

function *HILL-CLIMBING(problem)* ***return*** *a state that is a local maximum*

input: *problem, a problem*

local variables: *current*, ***a node.***

neighbour, ***a node.***

current ← *MAKE-NODE(INITIAL-STATE[problem])*

loop do

neighbour ← *a highest valued successor of current*

if *VALUE [neighbor]* ≤ *VALUE[current]* ***then return*** *STATE[current]*

current ← *neighbour*

- Continuous movement
- Increasing value - > peak
- Greedy local search

- Random?
  - Choose between set of best successors (best value)

- Variations exist providing improvements

Simulated Annealing

function SIMULATED-ANNEALING(*problem, schedule*) **return** a solution state
input: *problem*, a problem
schedule, a mapping from time to temperature
local variables: *current*, a node.
next, a node.
T, a "temperature" controlling the probability of downward steps

current ← MAKE-NODE(INITIAL-STATE[*problem*])
for t ← 1 to ∞ do
T ← *schedule*[*t*]
if *T* = *0* **then return** *current*
next ← a randomly selected successor of *current*
ΔE ← VALUE[*next*] - VALUE[*current*]
if $\Delta E > 0$ **then** *current* ← *next*
else *current* ← *next* only with probability $e^{\Delta E / T}$

– random new state
  +ve positive – move
  o/w – prob. move

– can be very slow,
  - slow fall in temp gradient
  - High T – prob. of locally bad move is higher

– theoretically will always find the global optimum

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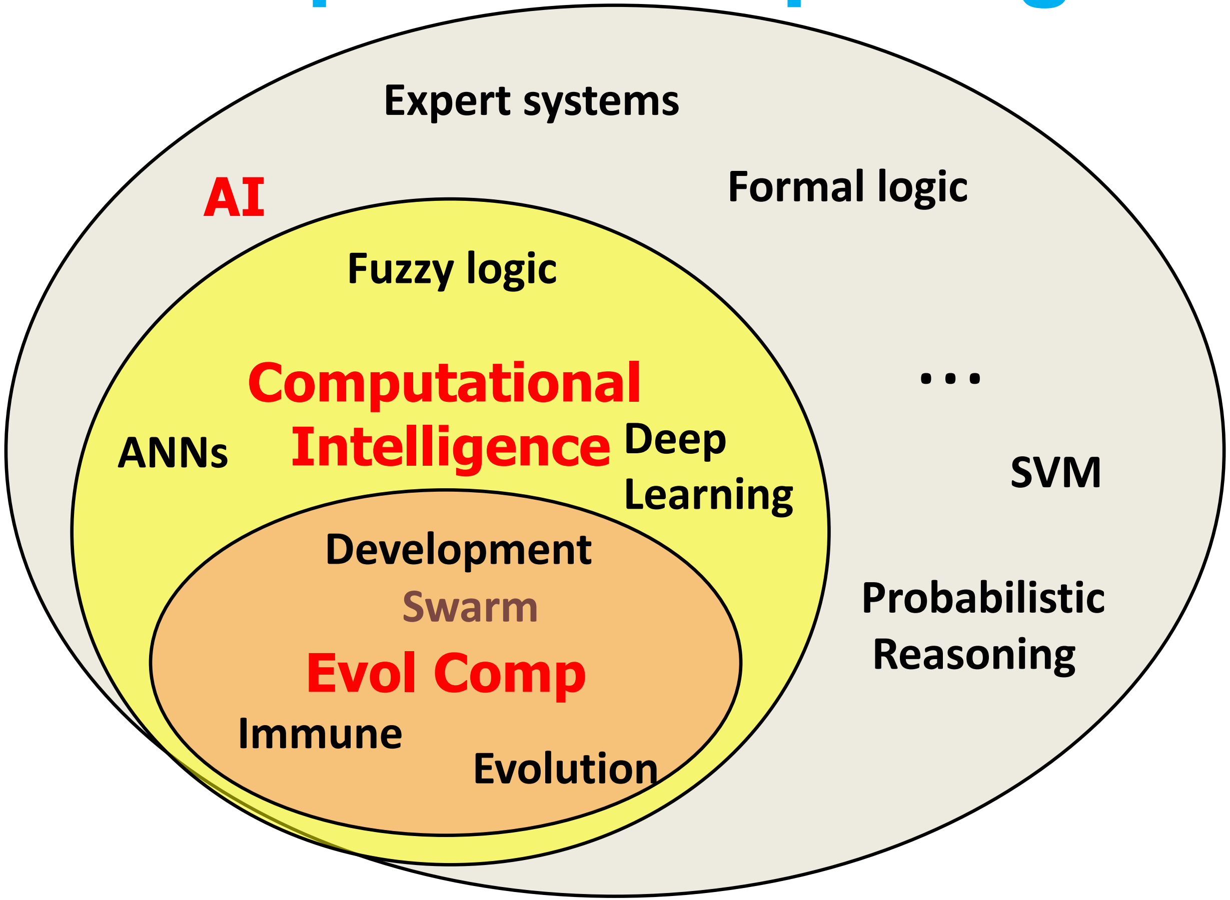
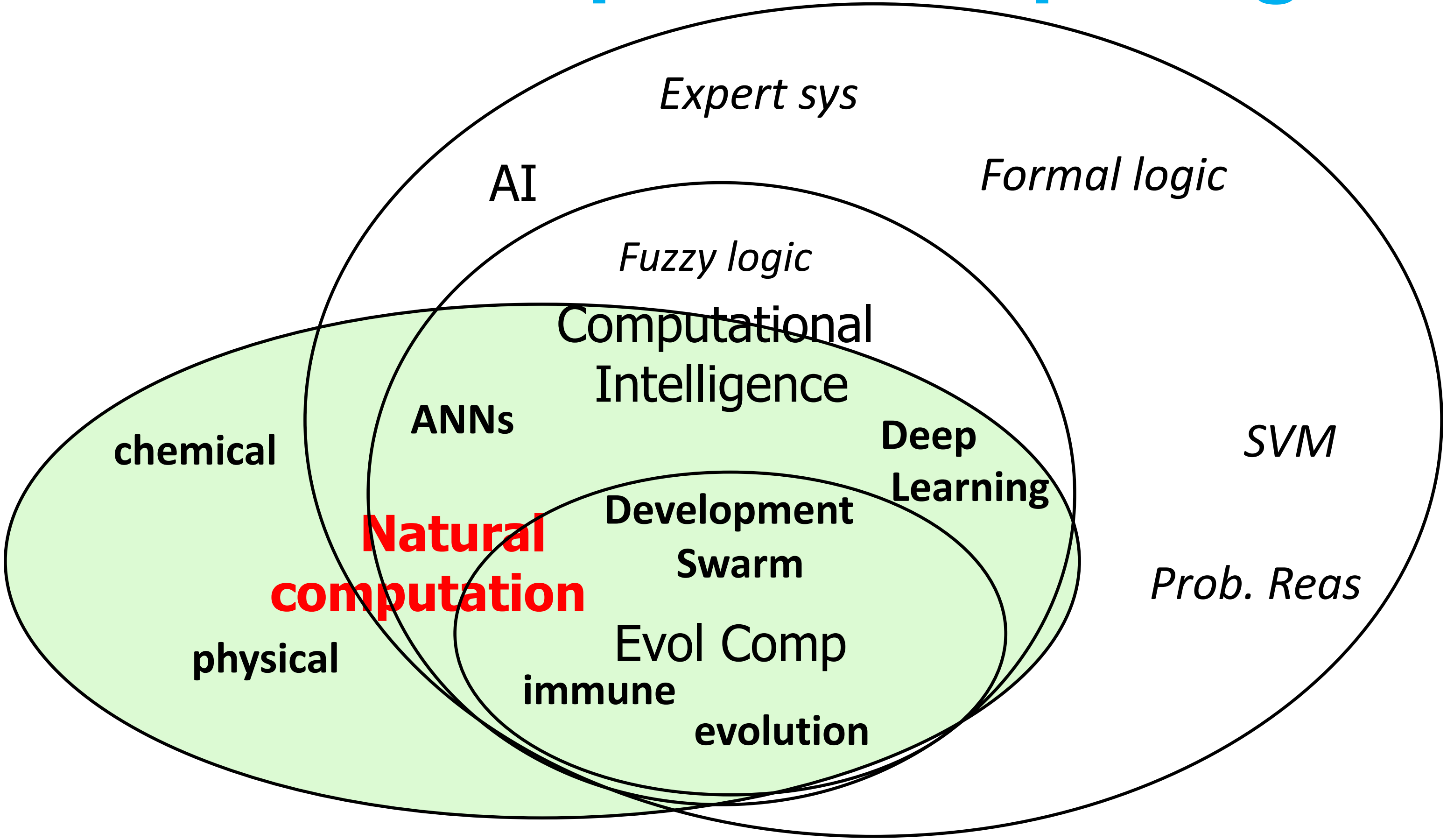
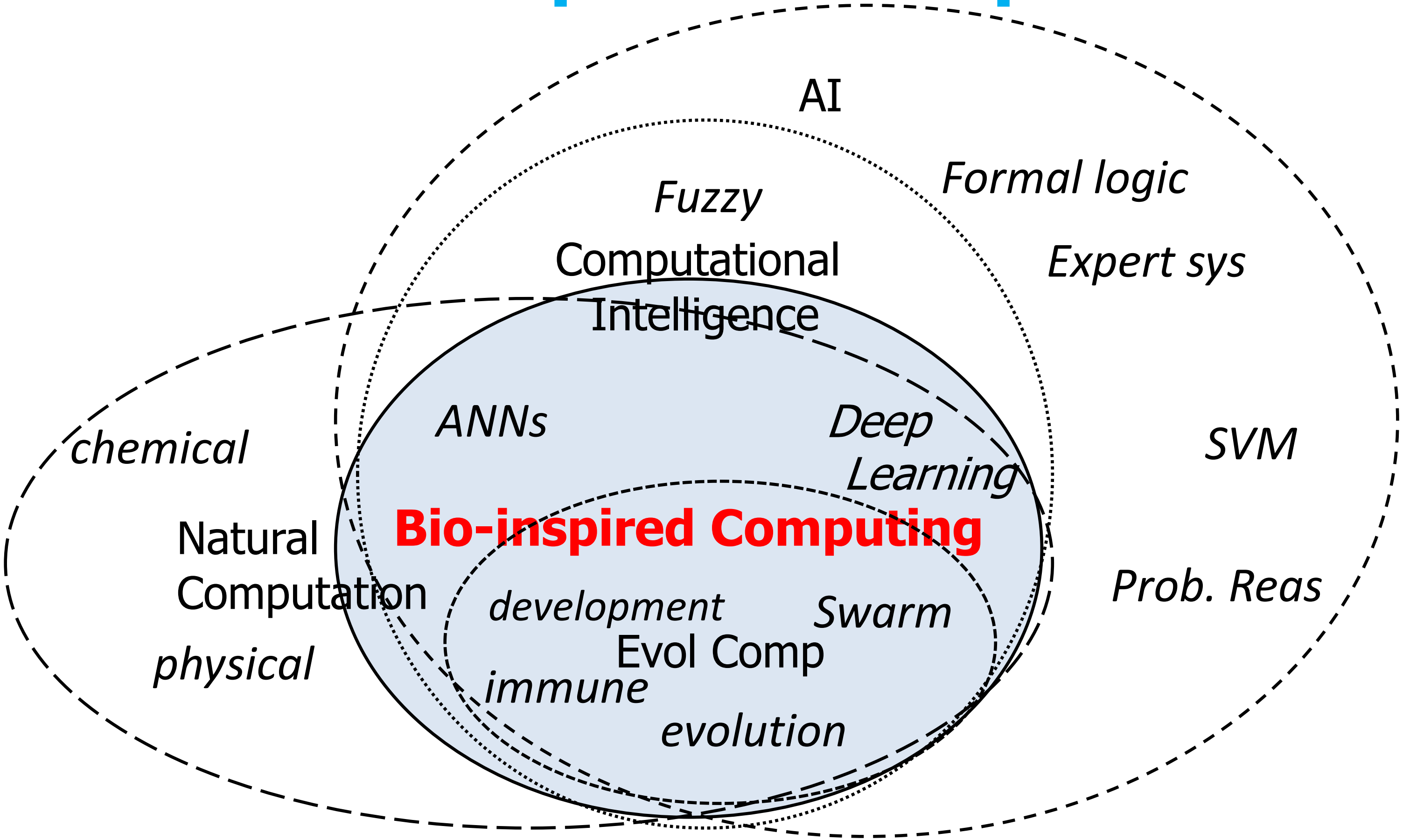
What is Bio-Inspired Computing?



What is Bio-Inspired Computing?



What is Bio-inspired Computation?



Natural Computation

- models of computation
- inspired by the functioning of natural systems
  - Biological, physical, chemical

1. Novel problem-solving techniques.
2. Synthesis of natural phenomena.
3. Employ natural materials (e.g., molecules) to compute.

Emergent Intelligent Behaviour

- Prominent behaviour of life

- Definition
- 'The arising of novel and coherent structures, patterns and properties during the process of self-organisation in complex systems'
  - [corning, 2002]

- intelligence is often in the eye of the observer
  - sees the global pattern,

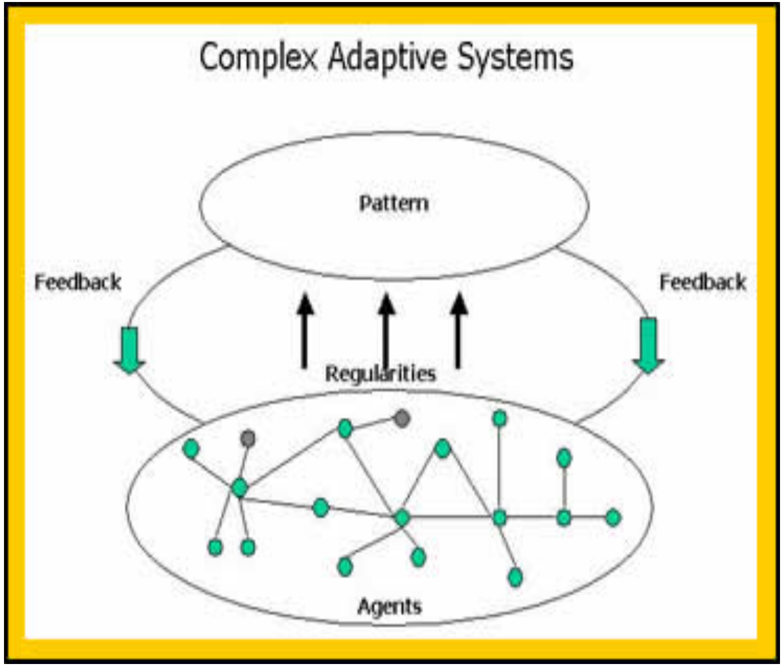
Nature as a Complex System

- Complex:

Difficulty of predicting the emergent whole from the interacting parts.

- Biological Principles
  - Global information
    - Patterns over the individual components
  - positive feedback
  - Randomness
  - Parallel
  - exploration and exploitation
  - Continuous interaction between bottom-up and top-down mechanisms

Complex Adaptive System



www.fractal.org

- Desired global pattern
- Bottom-up:
- Agents random actions – interactions
  - Regularities /emerging patterns
- Top-down:
  - Global behaviour affects individuals through feedback

Emergent Systems

:Stock market booms and busts

Pond ice formation

Stigmergy in Social insects

Orderly crowd movement

V-formation Flying birds

Adaptive System : Developmental process

Similar DNA – > adaption to environment

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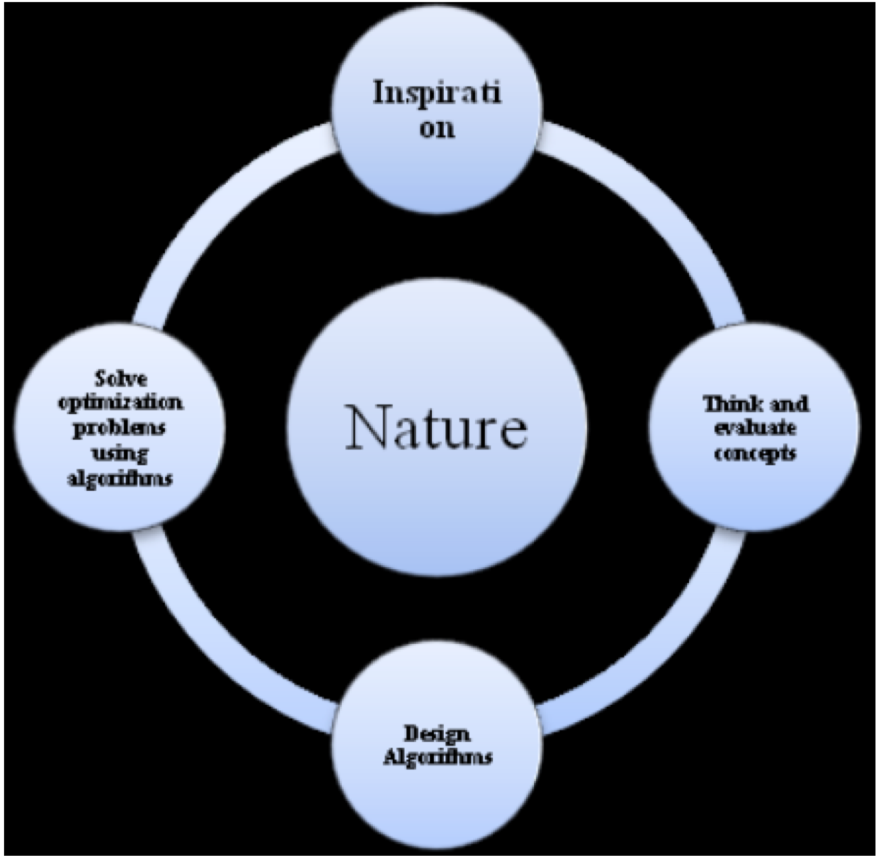
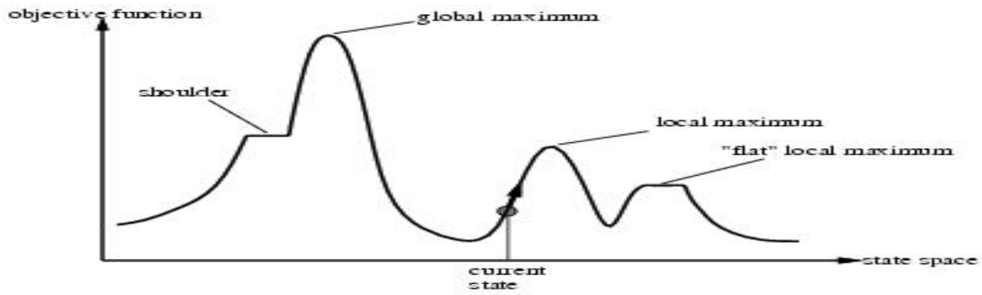
Nature/bio-inspired algorithms



Problem Solver

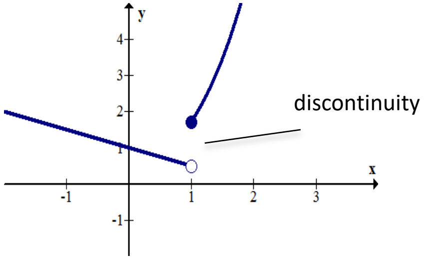
Traditional

- mostly local search
  - depend on the initial state
  - global optimality?
- Methods tend to be problem-specific
- Challenge
  - non-linear optimization
  - problems with discontinuity.

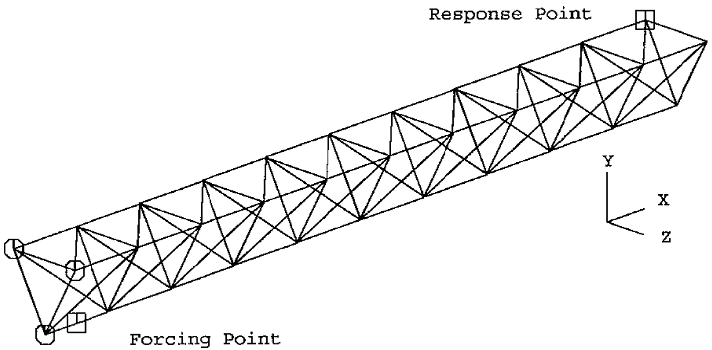


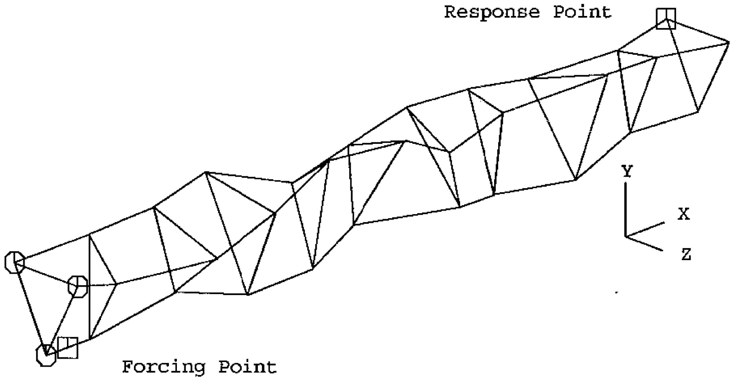
Bio-inspired

- Local and global search
  - Parallel search
  - Global optimality
- Black box approach
  - Wide range problems
- Efficient solver
  - Highly non-linear optimisation
  - Problems with discontinuity
  - NP hard combinatorial



Application example: Evolved satellite dish holder boom





- Optimisation task
  - Regular design (top)

- Evolved design (bottom)
  20,000% better
  Non intuitive
  Exhibits no symmetry

ADV:
- outwith human thinking

DISADV:
- outwith verification methods?

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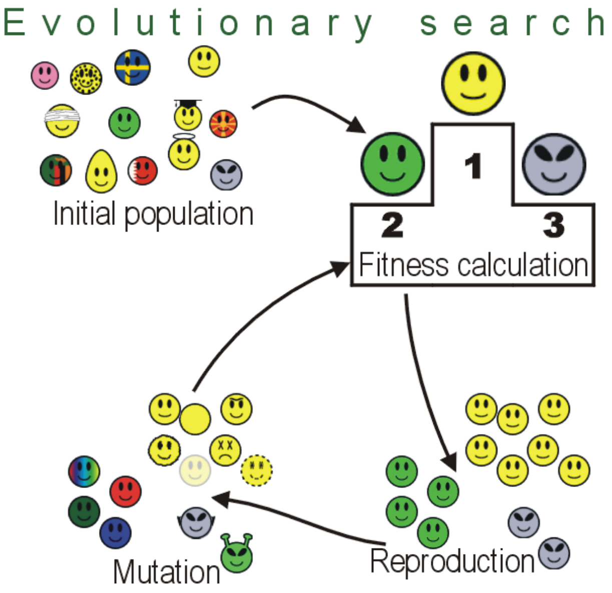
Natural/Bio-inspired computing

1. bio-inspired (but not SI-based).
2. swarm intelligence (SI) based.
3. physics/chemistry-based.

Evolution

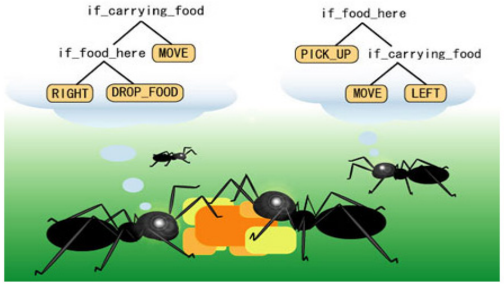
- Bio-inspired (not swarm-based)
  - Individuals (population based)
- Biological evolution.
- Survival of the fittest.
    - Genetic Algorithm (GA).
    - Evolutionary Strategies (ES)
    - Genetic Programming (GP).
    - Multi-objective Optimisation
    - Differential Evolution
- Other processes
  - Development
  - Immune

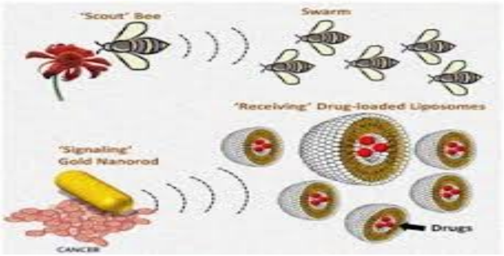


Swarm Intelligence

- collective emergent behaviour
  - multiple, interacting agents
  - simple rules.
  - social insects (…ants, bees)
  - animal societies (flocks of birds or fish)
- self-organization behaviour
- collective intelligence.

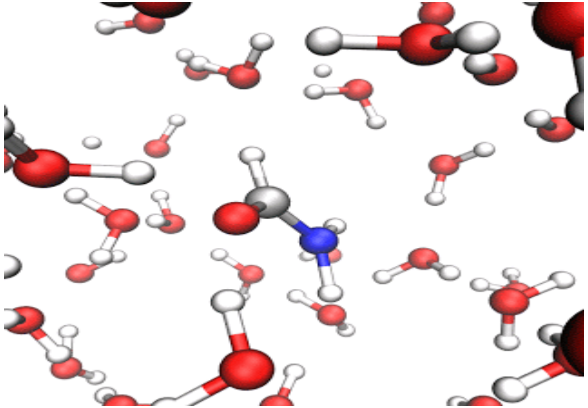
    Ant Colony Optimization (ACO)
    Particle Swarm Optimization (PSO).
    Bee Algorithm.
    Firefly algorithm
    Cuckoo search

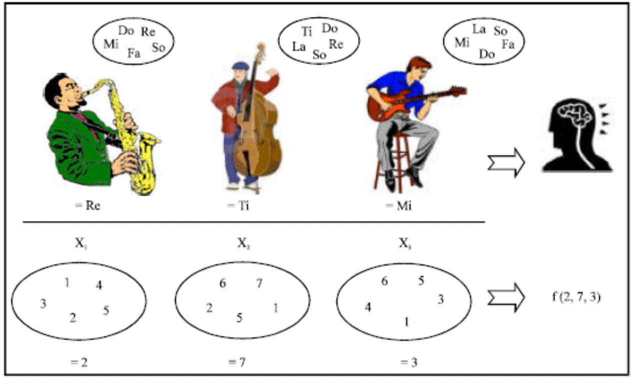




Classification: *Physics/Chemistry-Based*

- Mimicking physical and/or chemical laws
  - Chemical Reaction Optimization (CRO).
  - Harmony search.
  - Central force optimization.
  - Electro-magnetism optimization





Does nature have all the answers?

Bio-inspired vs Bio-plausible

Biological Plausible model

- What are the underlying mechanisms?
- How to apply?
- How do they work?
- How do they effect each other?
- How to implement – abstraction level

Bio-inspired model

- Which mechanisms to apply?
- How to allow them to interact

Are Bio-plausible models the way to go to achieve biological properties?

- Complexity, adaptivity, emergence

Artificial organism vs natural organism

Evolutionary Swarm Robotics

- Masters work:
  - Box pushing swarm behaviour