

Natural Computing

CS6800 Presentation I
Thap Panitanarak

Introduction

- ▶ Usefulness of computers in many applications/area
- ▶ Most computers are static
 - do whatever the order is
- ▶ Decades of research
- ▶ Evolve in time
- ▶ In past 2-3 decades, nature + computing

Natural Computing

- ▶ Natural science + Computing science
- ▶ Process of extracting ideas from nature to develop computational systems, or using natural materials to perform computation
- ▶ Three main goals
 - Find new problem solving techniques
 - Synthesize natural phenomena
 - Construct novel computing devices using natural materials (in addition to silicon)

Natural Computing

Three branches of natural computing

1. Computing inspired by nature
 - Nature inspiration for new computational techniques
2. Simulation and emulation of nature by means of computing
 - Synthetic process for creating patterns, forms, behaviors & organisms to mimic various natural phenomena
3. Computing with natural materials
 - Use natural materials, not silicon-based, to perform computation

Natural Computing

Require knowledge from various fields

- Physics
- Chemistry
- Biology
- Engineering
- Computer science
- Mathematics
- Etc

Natural Computing

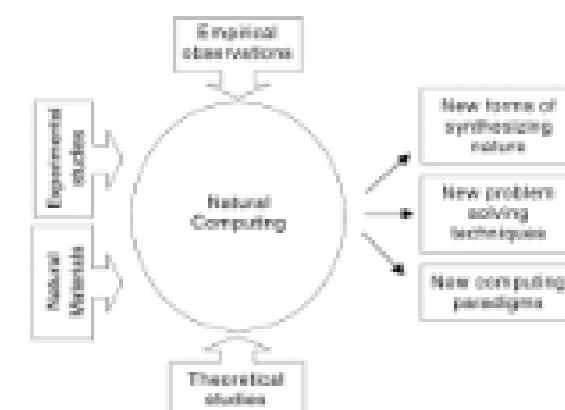


Fig. 1. Many approaches are used to develop natural computing and its main branches.

Natural Computing

- ▶ List of some well-known research
- ▶ Computing inspired by nature
 - Artificial neural networks
 - Evolutionary computing
 - Swarm intelligence
 - Artificial immune system
- ▶ Synthesis of natural phenomena
 - Fractal geometry
 - Artificial life
- ▶ Computing with new materials
 - DNA computing
 - Quantum computing

Computing Inspired by Nature

- Computing inspired by nature
- ▶ The oldest & most popular among three
 - ▶ Goals
 - Devise theoretical models & implemented in computers
 - Provide (alternative) techniques/algorithms for solving complex problems
 - ▶ Other terms
 - Bio-inspired computing
 - Biologically motivated computing
 - Computing with biological metaphors

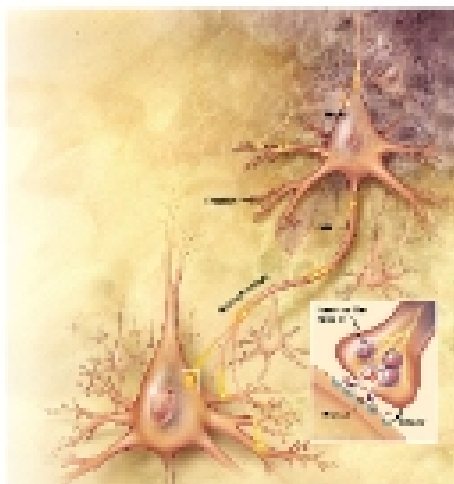
Computing Inspired by Nature Artificial Neural Networks

- Artificial neural networks
- ▶ MC Culloch & Pitts
 - ▶ First mathematical model of a neuron
 - ▶ Artificial Neural Networks - ANNs
 - ▶ Inspired by nervous system - human brain
 - ▶ Problem solving:
 - Input → Algorithms (?) → output
 - ▶ Different from 'computational neuroscience'

Computing Inspired by Nature Artificial Neural Networks

- Biological Motivation
- Brain - Connection between massive number of neurons - basic units used for computation (also in ANNs with simplified abstract models)
 - Connection
 - Synapse, a small junction
 - Forward / feedback forming networks
 - Cognitive abilities e.g. perception, thinking and inferring
 - Representation of information/knowledge in a distributed way with parallel processing
 - Concept of learning & experiencing
 - Abilities to modify & update itself

Computing Inspired by Nature Artificial Neural Network



Computing Inspired by Nature Artificial Neural Network

- Design Principles
- ▶ Neurons, nodes - processing elements
 - ▶ Receive / send stimuli - exchanging information
 - ▶ Neuron network - connection among neurons
 - ▶ Synapses - information transmitted between neurons
 - ▶ Strength, weight value - efficiency of a synapse
 - ▶ Learning - weight adjusting

Computing Inspired by Nature Artificial Neural Network

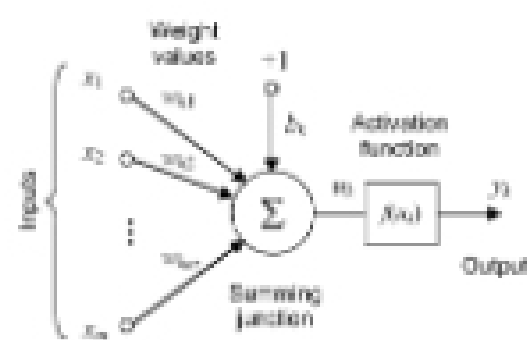


Fig. 2. Nonlinear model of a neuron.

Computing Inspired by Nature Artificial Neural Network

Characterized by Three Features

1. **Artificial neurons**
 - Weight, summing junction & activating function
2. **Architecture / structure of network**
 - Layers - input, hidden, output
 - Feed forward vs. recurrent
3. **Training / learning algorithms**
 - Supervised, unsupervised (self-organized) & reinforcement

Computing Inspired by Nature Artificial Neural Network

Scope & Applications

- ▶ (In principle,) compute any computable function
- ▶ Clustering
- ▶ Classification
- ▶ Pattern recognition
- ▶ Mapping problems

Computing Inspired by Nature Evolutionary Computing

Evolutionary Computing

- ▶ Evolutionary biology
- ▶ Search & optimization techniques for solving complex problems
- ▶ Population → reproduction → genetic variation → selection → new population
- ▶ Increasingly fitter to their environment

Computing Inspired by Nature Evolutionary Computing

Biological Motivation

- ▶ Charles Darwin - evolution & natural selection
- ▶ Evolutionary biology - diversity of life, differences & similarities, characteristics of organisms
- ▶ Evolving system - one generation after other
- ▶ Current generation → Reproduction & Evolution → Next generation → Natural selection → Survivors
- ▶ Next generation - Genetically changed, genes in chromosomes
- ▶ Evolution - Mutation & crossing-over
- ▶ Survivors - Fitted to environment & advantage over others (better)

Computing Inspired by Nature Evolutionary Computing

Design Principle

- ▶ Standard evolutionary algorithm
 - Population of individuals that reproduce with inheritance - allow to reproduce
 - Genetic variation - mutation & crossing-over
 - Natural selection - adaptability & fitness values
- ▶ Generic, iterative & probabilistic
- ▶ Maintain the same population size
- ▶ Individual = (encoded) potential solution
- ▶ Genetic algorithms