

Computational Intelligence

Unit # 1

Information

- Course Wiki
 - <http://cse659ci2012.wikispaces.com/>
- Text/Reference Books
 - Daniel Ashlock, Evolutionary Computation for Modeling and Optimization, 2005
 - Gusz Eiben and Jim Smith, Introduction to Evolutionary Computing, 2007
 - Andries Engelbrecht, Computational Intelligence: An Introduction, 2007
 - Kenneth DeJong, Evolutionary Computation A Unified Approach, 2006

Marks Distribution

- Midterms = 2 x 15 = 30%
- Final 40%
- Assignments (3-4) 15%
- Project 15%

Tentative Outline

- Evolutionary Computation
 - Evolutionary Algorithms
 - Genetic Algorithms
 - Evolutionary Strategies
 - Evolutionary Programming
 - Ant Colony Optimization
 - Particle Swarm Optimization
- Artificial Immune Systems
- Simulated Annealing
- Tabu Search
- Neural Networks
- Fuzzy Logic
- Other Algorithms
 - Harmony Search, Co-Evolution, Honey Bee Optimization, Artificial Life
- Hybrid Techniques

Definition (Source: Wikipedia)

- Computational intelligence (CI) is a set of Nature-inspired computational methodologies and approaches to address complex problems of the real world applications to which traditional methodologies and approaches are ineffective or infeasible.
- It primarily includes Fuzzy logic systems, Neural Networks and Evolutionary Computation.
- In addition, CI also embraces techniques that stem from the above three or gravitate around one or more of them, such as Swarm intelligence and Artificial immune systems which can be seen as a part of Evolutionary Computation.

IEEE Computational Intelligence Society's Scope

- The Field of Interest of the Society shall be the theory, design, application, and development of biologically and linguistically motivated computational paradigms emphasizing neural networks, connectionist systems, genetic algorithms, evolutionary programming, fuzzy systems, and hybrid intelligent systems in which these paradigms are contained.

Excerpts from Engelbrecht's Book

- It is necessary to state that there are different definitions of what constitutes CI.
- This book reflects the opinion of the author, and may well cause some debate. For example, swarm intelligence (SI) and artificial immune systems (AIS) are classified as CI paradigms, while many researchers consider these paradigms to belong only under Artificial Life.
- However, both particle swarm optimization (PSO) and ant colony optimization (ACO), as treated under SI, satisfy the definition of CI given above, and are therefore included in this book as being CI techniques. The same applies to AISs

Evolutionary Computation (Source: Wikipedia)

- In computer science, evolutionary computation is a subfield of artificial intelligence (more particularly computational intelligence) that involves combinatorial optimization problems.
- Evolutionary techniques mostly involve metaheuristic optimization algorithms such as:
 - Evolutionary algorithms (comprising genetic algorithms, evolutionary programming, evolution strategy and Genetic programming)
 - Swarm intelligence (comprising ant colony optimization and particle swarm optimization)
 - and in a lesser extent Artificial immune systems, Cultural algorithms, Differential evolution, Harmony search algorithm, etc.

Evolutionary Algorithms (Source: Wikipedia)

- In artificial intelligence, an evolutionary algorithm (EA) is a subset of evolutionary computation, a generic population-based metaheuristic optimization algorithm.
- An EA uses some mechanisms inspired by biological evolution: reproduction, mutation, recombination, and selection.
- Candidate solutions to the optimization problem play the role of individuals in a population, and the fitness function determines the environment within which the solutions "live" (see also cost function).
- Evolution of the population then takes place after the repeated application of the above operators.



Swarm Intelligence

- There are two popular swarm inspired methods in computational intelligence areas:
 - Ant colony optimization (ACO)
 - Particle swarm optimization (PSO)
- ACO was inspired by the behaviors of ants and has many successful applications in discrete optimization problems.
- The particle swarm concept originated as a simulation of simplified social system. The original intent was to graphically simulate the choreography of bird of a bird block or fish school. However, it was found that particle swarm model can be used as an optimizer.

Examples



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MASON Demo

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Global Optimization

- Global optimization is the branch of applied mathematics and numerical analysis that deals with the optimization of single or maybe even multiple, possible conflicting, criteria.
- These criteria are expressed as a set of mathematical functions $F = \{f_1, f_2, \dots, f_n\}$, the so-called objective functions.
- The result of the optimization process is the set of inputs for which these objective functions return optimal values.

Search vs. Optimization

- The difference between optimization algorithms and search algorithms is that when performing a search algorithm, we know the element x_i we are looking for and just want to find its position in a structured set.
- In global optimization algorithms on the other hand we do not even know the characteristics of the x_i beforehand and are only given some criteria which describe if a given configuration is good or not.

Local Maximum and Minimum

Definition 2 (Local Maximum). A (local) maximum $\hat{x}_l \in X$ of an objective function $f : X \mapsto \mathbb{R}$ is an input element with $f(\hat{x}_l) \geq f(x)$ for all x neighboring \hat{x}_l .

If $X \subseteq \mathbb{R}$, we can write:

$$\hat{x}_l : \exists \varepsilon > 0 : f(\hat{x}_l) \geq f(x) \forall x \in X, |x - \hat{x}_l| < \varepsilon \quad (1.1)$$

Definition 3 (Local Minimum). A (local) minimum $\check{x}_l \in X$ of an objective function $f : X \mapsto \mathbb{R}$ is an input element with $f(\check{x}_l) \leq f(x)$ for all x neighboring \check{x}_l .

If $X \subseteq \mathbb{R}$, we can write:

$$\check{x}_l : \exists \varepsilon > 0 : f(\check{x}_l) \leq f(x) \forall x \in X, |x - \check{x}_l| < \varepsilon \quad (1.2)$$

Definition 4 (Local Optimum). An (local) optimum $x_l^* \in X$ of an objective function $f : X \mapsto \mathbb{R}$ is either a local maximum or a local minimum (or both).

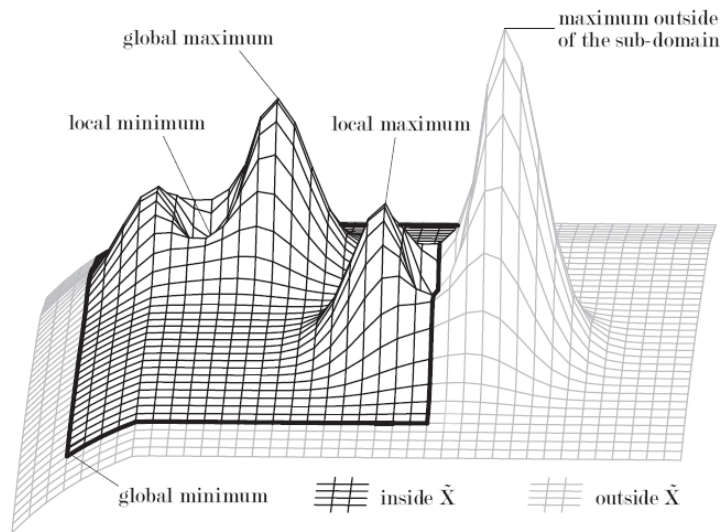
Global Maximum and Minimum

Definition 5 (Global Maximum). A global maximum $\hat{x} \in X$ of an objective function $f : X \mapsto \mathbb{R}$ is an input element with $f(\hat{x}) \geq f(x) \forall x \in X$.

Definition 6 (Global Minimum). A global minimum $\check{x} \in X$ of an objective function $f : X \mapsto \mathbb{R}$ is an input element with $f(\check{x}) \leq f(x) \forall x \in X$.

Definition 7 (Global Optimum). A global optimum $x^* \in X$ of an objective function $f : X \mapsto \mathbb{R}$ is either a global maximum or a global minimum (or both).

Global and Local Optima

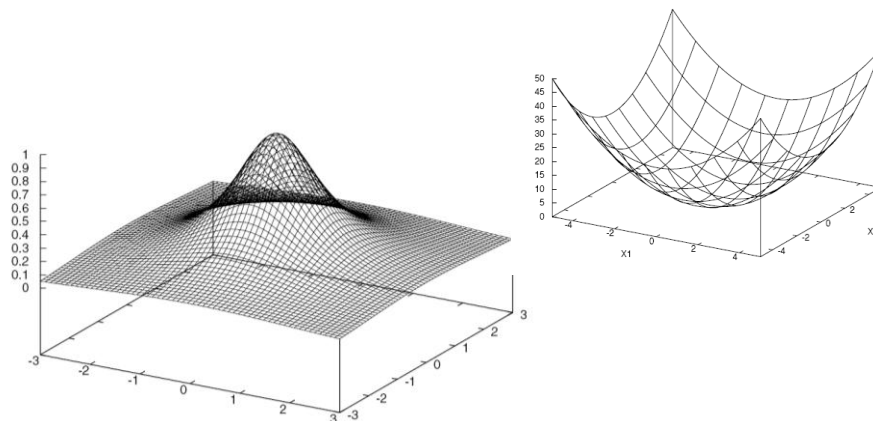


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Simple Functions

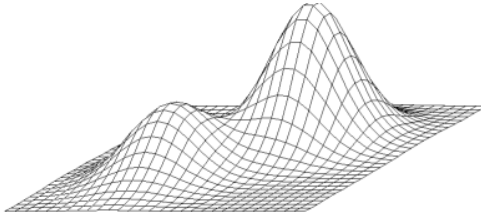


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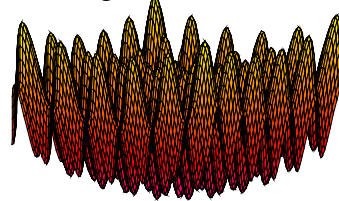
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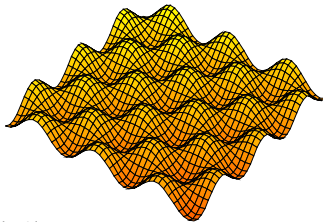
Complex Functions



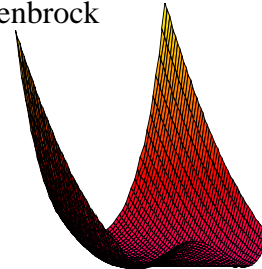
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