Chapter 6
Evolutionary Computation and Evolving Connectionist Systems

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Overview

- Evolutionary Computation (EC) – introduction
- EC for optimisation of off-line learning connectionist systems
- EC for optimisation of on-line learning systems

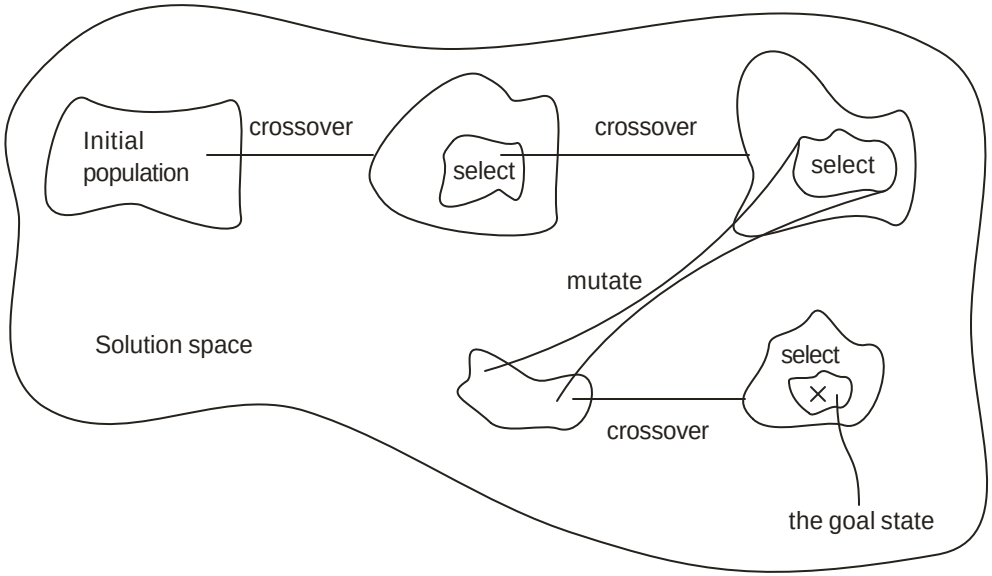
Introduction to EC

- Evolutionary computation (EC) is concerned with population-based search and optimisation of individual systems through generations of populations
- It has been applied so far to the optimisation of different structures and processes, one of them being the connectionist structures and connectionist learning processes
- Methods of EC include two stages:
  - » a stage of creating new population of individuals
  - » a stage of development of the individual systems, so that a system develops, evolves through interaction with the environment that is also based on the genetic material embodied in the system.

Genetic Algorithms (GAs)

- GAs are computational models used to solve complex combinatorial and organizational problems with many variants.
- The most important terms used in the GA are analogous to the terms used to explain the evolution processes.
  - gene
  - chromosome
  - population
  - crossover (mating) operation
  - mutation
  - fitness (goodness) function
  - selection

GAs

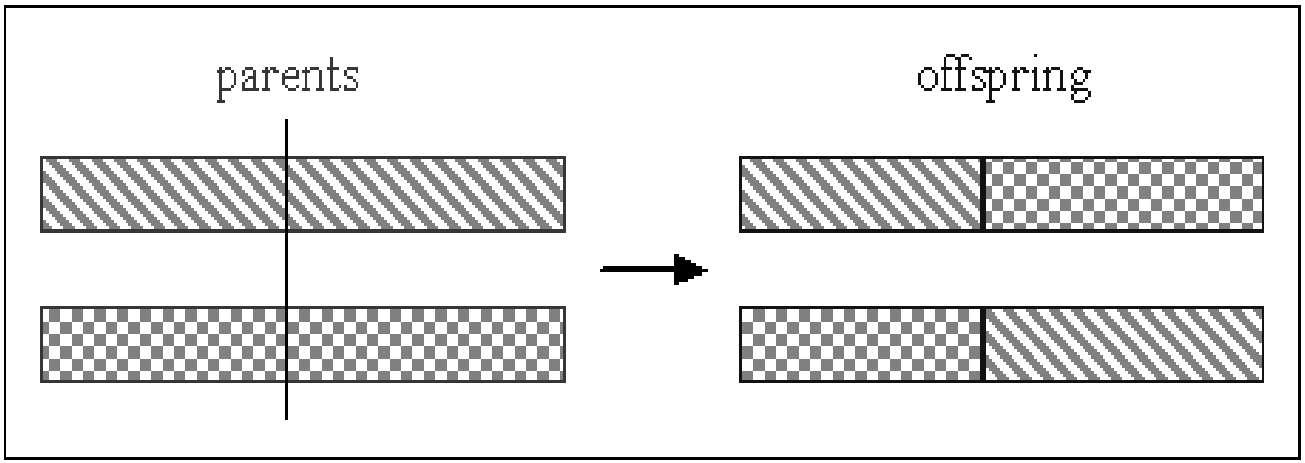


A schematic diagram of how a genetic algorithm (GA) works in time (fig. 6.1)

GAs

- When using the GA method for a complex multi-optional optimisation problem, a "fitness" or "goodness" criterion is needed for the selection of the most promising individuals (they are partial solutions to the problem).
- This criterion may require a mutation as well, which is a heuristic approach of a "trial-error" type.
- GAs are search heuristics for the "best" instance. Important issues for any genetic algorithm are:
  - *the encoding scheme*
  - *the population size*
  - *the crossover operations*
  - *the mutation heuristic*

GAs



One-point cross over operation (Fig 6.4)

Other EC techniques

- Evolutionary strategies. These techniques use only one chromosome and a mutation operation, along with a fitness criterion, to navigate in the solution (chromosomal) space.

- Evolutionary programming. These are EC techniques applied to the automated creation and optimisation of sequence of commands (operators) that constitute a program (or an algorithm) to solve a given problem (Koza, 1992).

EC for off-line learning systems

- EC optimisation methods:
  - NN topology determination by GA
  - Selection of control parameters by GA
  - Training of NN via GA
  - Neuro-Fuzzy Genetic Systems
  - Evolutionary Neuro-Genetic Systems and cellular automata

EC for on-line learning systems

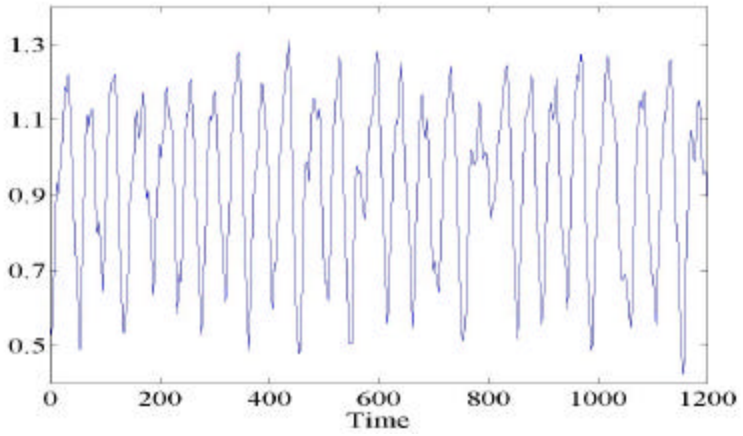
- ECOS have efficient learning algorithms that allow for on-line, life-long capturing of associations between input and output clusters, rules, statistics.
- Problems
  - » Large number of parameters and modes of operation need to be properly selected and optimised for a particular application

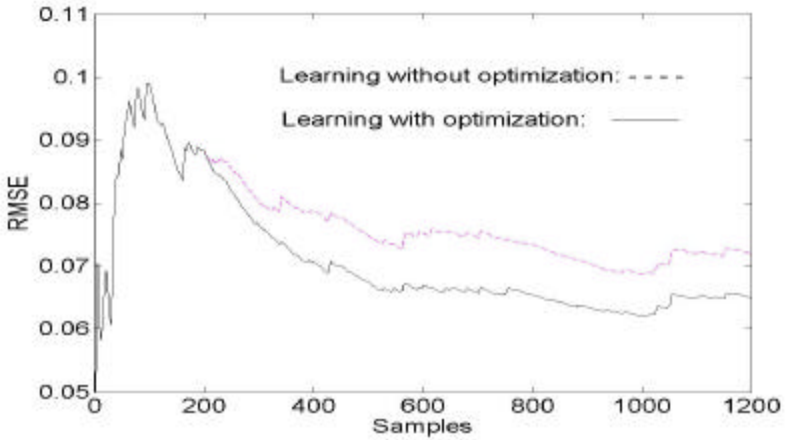
EC methods for optimisation

- Spawning
  - As new data is presented to the network, the system strives to find a better set of parameters, allowing the ECOS to better adapt and better solve the problem in current time interval.
  - An initial period of adaptation and training is followed by a period of evolutionary parameter optimisation.
- GAs
  - Goldberg's simple genetic algorithm (Goldberg, 1989) was used with the some modifications.
  - The proposed GA optimisation method is tested on the task of time series prediction when the dynamics of the series change at certain time moments.
  - The results show that the networks have adapted well to the new data.

On-line GA optimisation of EFuNN parameters

- Nature optimises its "parameters" through evolution
- Replication of individual ECOS systems and selection of:
  - The best one
  - The best *m* averaged





Summary

- Some issues that still need to be addressed in further research:
  - On-line optimisation of the fitness function.
  - Using individual fitness function for each ECOS.
  - EC help chose the parameter values of ECOS, but how to chose the optimal parameters for the EC method at the same time?
  - Interactions between individuals and populations that have different genetic make-ups.

Further Readings

- Generic material on evolutionary computation (Goldberg, 1989; Michaliewicz, 1992).
- Genetic programming (Koza, 1992).
- Evolutive Fuzzy Neural Networks (Machado et al, 1992).
- Using EC techniques for the optimisation of neural networks (Fogel, 1990; Yao, 1993 Schiffman et al, 1993).
- Using GA for the optimisation and training of fuzzy neural networks (Watts and Kasabov, 1998).
- The evolution of connectivity: Pruning neural networks using genetic algorithms (Whitley and Bogart, 1990).
- Neuro Darwinism (Edelman, 1992).
- GA for the optimisation of fuzzy rules (Furuhashi et al, 1994).
- Using EC for artificial life (Adami, 1998).