Evolutionary Computation : A Tutorial

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HIERARCHY OF THE FIELD

Natural Computation
- Artificial Life
- Fractal Geometry
- other Complex Systems Sciences

Computational Intelligence
- Fuzzy Systems
- Artificial Neural Networks

Evolutionary Computation

Evolutionary Computation

- Genetic Algorithms (GA),
- Evolutionary Programming (EP),
- Evolution Strategies (ES),
- Classifier Systems (CFS),
- Genetic Programming (GP)

PSEUDO CODE

```
Algorithm EA is
    t := 0;
    initpopulation P (t);
    evaluate P (t);
    while not done do
        t := t + 1;
        P' := selectparents P (t);
        recombine P' (t);
        mutate P' (t);
        evaluate P' (t);
        P := survive P,P' (t);
    od
end EA.
```

Brief history

1960

- Rechenberg (1965) Schwefel (1975) "evolutionary strategies" ,
- Fogel, Owens and Walsh (1966) "evolutionary programming"
- Holland (1960) "genetic algorithms"

GA (Mitchell 1996)

Formal study of the phenomenon of adaptation as it occurs in nature and to develop ways in which the mechanisms of natural adaptation might be imported into computer systems.

Adaptation -- to continue to perform well in a changing environment.

Genetic Algorithm/Programming

It is a general-purpose search algorithm that use principles inspired by population genetics to evolve solutions to problems.

GA is a method for moving from one population of "chromosomes" to a new population by using a kind of "natural selection" together with the genetics-inspired operators of crossover, mutation, and inversion.

Each chromosome consists of "genes",
each gene being an instance of a particular "allele".
The selection operator chooses those chromosomes in the population that will be allowed to reproduce, and on average the fitter chromosomes produce more offspring than the less fit ones.

Crossover exchanges subparts of two chromosomes, roughly mimicking biological recombination between two single-chromosome ("haploid") organisms;
mutation randomly changes the allele values of some locations in the chromosome; and
inversion reverses the order of a contiguous section of the chromosome, thus rearranging the order in which genes are arrayed.

Mathematical analysis of GA is based on "schemata theory".

Biological terminology

living organism
cells
chromosome (strings of DNA)
genes (functional blocks of DNA) each encodes a particular protein (trait such as eye colour)
allele, different possible trait
each gene is located at a particular locus (position) on the chromosome

genome, all chromosome
genotype, the particular set of genes contained in a genome.
phenotype, physical and mental characteristics of an individual.

chromosome
- diploid (human being 23 pairs)
- haploid

recombination -- exchange genes between parents
mutate -- single nucleotides (elementary bits of DNA) are changed.
fitness -- the probability that the organism wil live to reproduce (viability) or
the function of the number of offspring the organism has (fertility).

Search space

- collection of candidate solutions to a problem
- distance measure between candidates

Search methods

1. search for stored data : binary search
2. search for paths to goals : depth-first search, branch and bound, A*
3. search for solutions
   - genetic-inspired
   - hill climbing (gradient search)
   - simulated annealing

weak methods -- can work on a large variety of problems
strong methods -- specially designed to work on particular problems
genetic-inspired -- parallel population-based, stochastic selection, crossover and mutation

Applications

- automatic design of electronic circuits
- solving facility layout
- automatic generation of OOP
- image classification
- control laws for a network of traffic signals
- image and sound compression
- data mining
- optimizing local area network topology
- job shop scheduling

Examples

Prisoner's Dilemma (M. Flood & M. Dresher 1950)

Two individuals (Alice and Bob) are arrested and are held in a separate cells. Alice is offered the following deal : if she confesses and agrees to testify against Bob, she will receive a suspended sentence with probation, and Bob will be put away for 5 years. However, if at the same time Bob confesses and agrees to testify against Alice, her testimony will be discredited, and each will receive 4 years for pleading guilty. Alice is told that Bob is being offered precisely the same deal. Both Alice and Bob know that if neither testify against the other they can be convicted only on a lesser charge for which they will each get 2 years in jail.

Should Alice "defect" or "cooperate" ?

Player B

	Coop	Defect
Coop	3,3	0,5
Defect	5,0	1,1

Player A

Payoff matrix (get as many points as possible)
5 - num of year is prison

Two Tournament 1984 : 14, 63 programs :
winner TIT FOR TAT (Rapoport)

Axelrod (1987) GA to play this game.

four possibilities of a play : CC, CD, DC, DD
TIT FOR TAT
1. if CC then C
2. if CD then D
3. if DC then C
4. if DD then D
this strategy is encoded as CDCD,

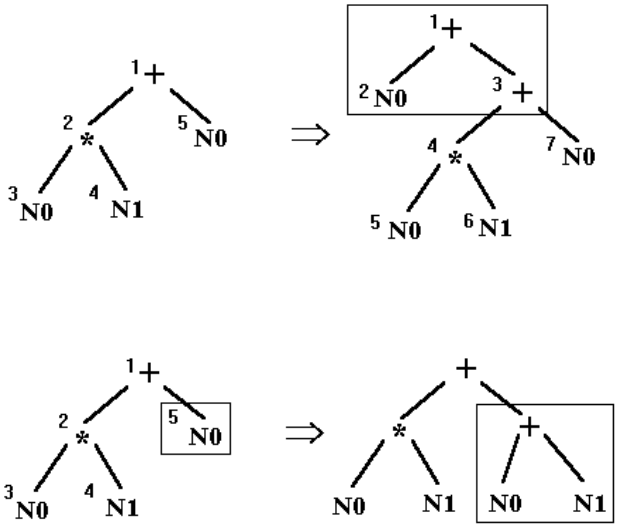
Algorithm
-- find the case number of the previous play, i.e. CD i = 2
-- select the letter in i th position in the strategy, i.e. D

64 possibilities of three plays :
CC CC CC, CC CC CD, ..., DD DD DD
64-letter string, Axelrod used 70, space 2^{70}

Experiment
GA has 20 strategies
GA played against 8 fixed strategies.
40 runs of 50 generations each.
= search 20 x 50 = 1000 out of a space 2^{70}
GA found strategies that scored substantially better than TIT FOR TAT
GA played against other individuals -- fitness landscape is a function of population.
-- initially uncooperative
-- around 10-20 generations trend started to reverse; reciprocated cooperation
-- co-evolution

Genetic Programming

Automatic Programming



Example : Synthesis of Logic Circuits

Manovit, C., Aporntewan, C., and Chongstitvatana, P., "Synthesis of Synchronous Sequential Logic Circuits from Partial Input/Output Sequences", Proc. of 2nd Int. Conf. on Evolvable Systems (ICES98), Lausanne, Switzerland, 1998, pp. 98-105.

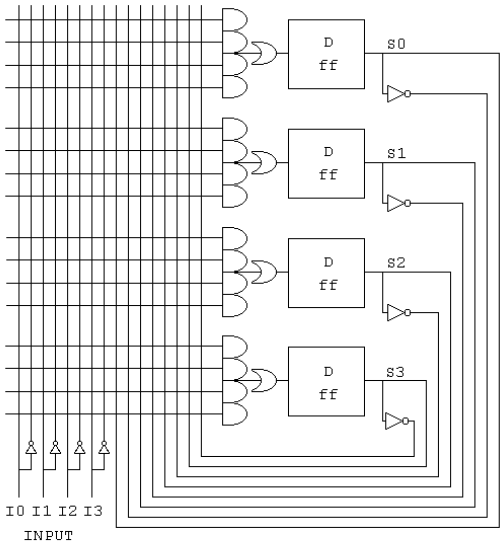


Fig. 1. GAL structure used in the experiment

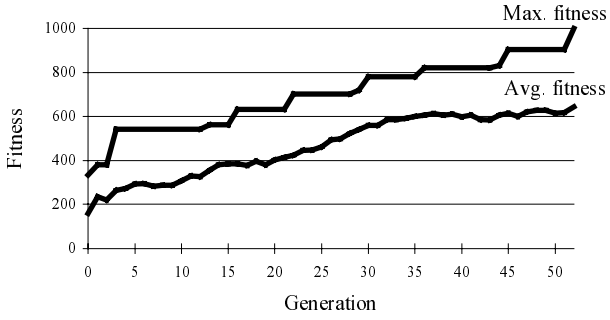


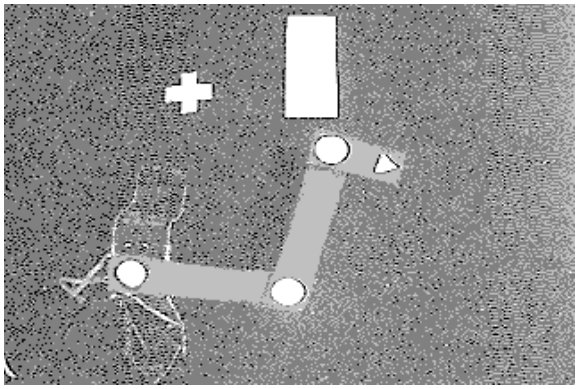
Fig. 2. Evolution of a Serial Adder

Table 1. The summary of computational effort

Circuit	Effort	
	Moore	Mealy
Frequency Divider	770	440
Odd Parity Detector	1,210	1,760
Modulo-5 Detector	87,967,440	7,018,000
Serial Adder	3,035,120	26,730

Example : Generate programs to control a robot arm

Polvichai, J., and Chongstitvatana, P., "Visually-guided reaching by genetic programming", Proc. of 2nd Asian Conf. on Computer Vision, Singapore, 1995.



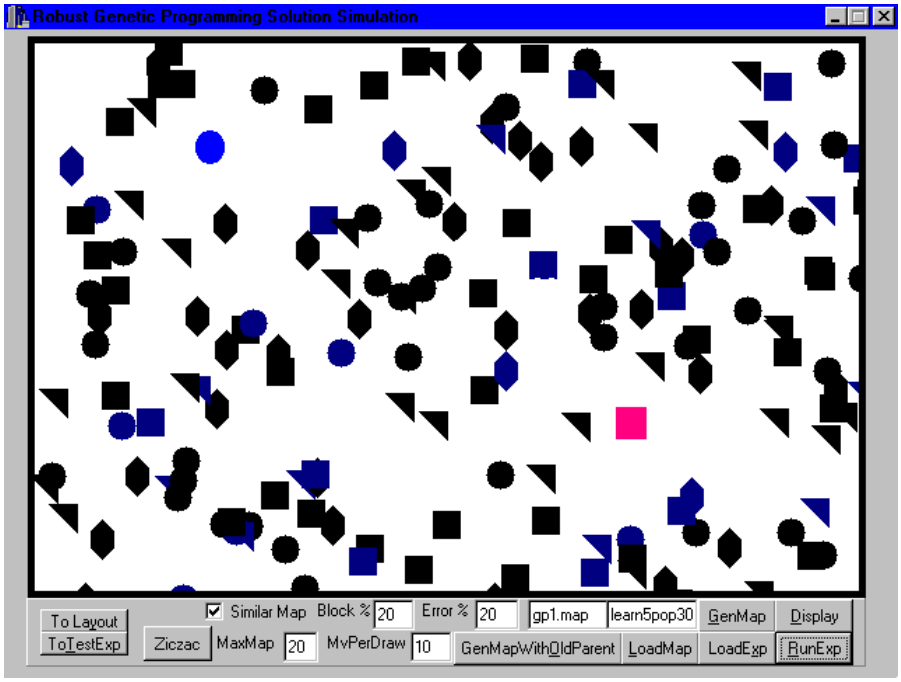
Terminal set = { s+, s-, e+, e-, w+, w-, HIT?, SEE?, INC?, DEC?, OUT?}.
Function set = { IF-AND, IF-OR, IF-NOT}.

```
(IF-AND w+ w+ e+ (IF-AND (IF-NOT (IF-NOT OUT? s-
w+) (IF-AND e+ s- e- (IF-OR (IF-NOT w+ s+ e+) s+ e- e-))
(IF-OR (IF-NOT SEE? w- e-) w+ e+ e+)) w- (IF-OR SEE?
(IF-OR e- (IF-OR (IF-OR HIT? e+ s+ e-) INC? w- e-) s+
w+) (IF-AND (IF-NOT w- e- e-) w- w- w+) s-) e+)))
```

Figure : A sample of computer program which is randomly generated.

Example : Generate Robust program for a mobile robot

Chongstitvatana, P., "Improving Robustness of Robot Programs Generated by Genetic Programming for Dynamic Environments", 1998 IEEE Asia Pacific Conference on Circuits and Systems (APCCAS '98)



The terminal set is { move, left, right, isnearer? }.
The function set is { if-and, if-or, if-not }