Multi-Layer Genetic Algorithm for Maintenance Scheduling in Power Systems

by

Michael Negnevitsky and Galina Kelareva

Centre for Renewable Energy and Power Systems

University of Tasmania

Contents

Introduction

- Maintenance scheduling problems are usually solved using a combination of search techniques and heuristics;
- These problems are complex and difficult to solve;
- They are NP-complete and cannot be solved by combinatorial search techniques ;
- Scheduling involves competition for limited resources, and is complicated by a great number of badly formalised constraints.

Genetic Algorithms as an Optimisation Tool

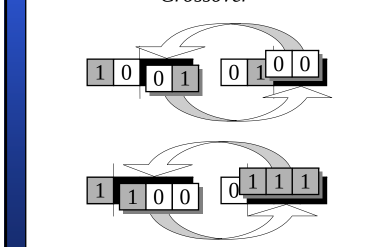
- John Holland introduces the concept in the 1970s;
- Genetic Algorithms (GA) use “natural” selection, crossover and mutation;
- GA works as follows:
  - create a population of individuals;
  - evaluate their fitness;
  - generate a new population by applying genetic operations;
  - repeat this process a number of times.

A 16-bit binary string representing a chromosome

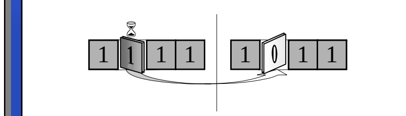
1	0	1	1	0	1	0	0	0	0	0	1	0	1	0	1

Crossover and mutation in 4-bit binary strings

Crossover



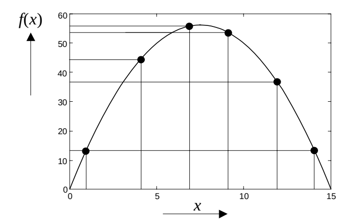
Mutation



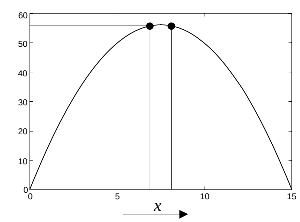
The fitness function and chromosome locations

$f(x) = 15\,x - x^2$

Chromosome label	*Chromosome string*	*Decoded integer*	*Chromosome fitness*	*Fitness ratio, %*
X1	1 1 0 0	12	36	16.5
X2	0 1 0 0	4	44	20.2
X3	0 0 0 1	1	14	6.4
X4	1 1 1 0	14	14	6.4
X5	0 1 1 1	7	56	25.7
X6	1 0 0 1	9	54	24.8

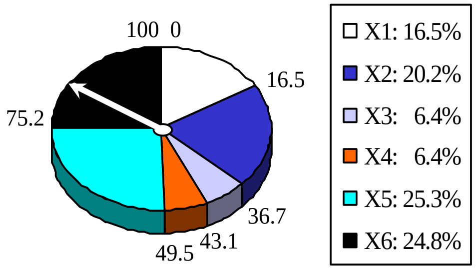


(*a*) Chromosome initial locations.

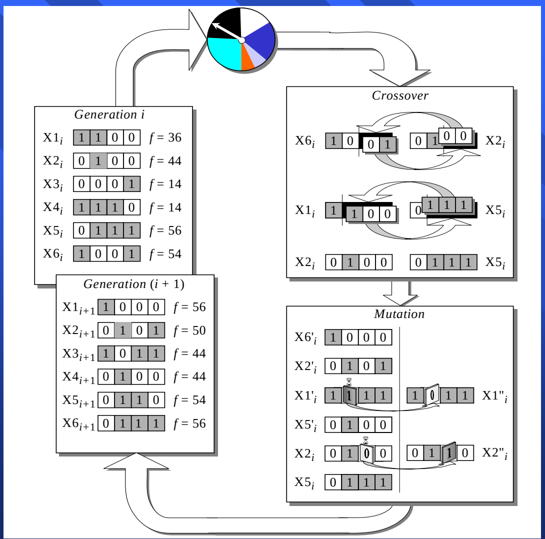


(*b*) Chromosome final locations.

Roulette wheel selection



The GA cycle



Steps in the GA development

1. Specify the problem, define constraints and optimum criteria
2. Represent the problem domain as a chromosome.;
3. Define a fitness function to evaluate the chromosome performance
4. Construct the genetic operators
5. Run the GA and tune its parameters

Case Study 1

Scheduling of 7 units in 4 equal intervals

The problem constraints:

- The maximum loads expected during four intervals are 80, 90, 65 and 70 MW;
- Maintenance of any unit starts at the beginning of an interval and finishes at the end of the same or adjacent interval. The maintenance cannot be aborted or finished earlier than scheduled;
- The nett reserve of the power system must be greater or equal to zero at any interval.

The optimum criterion is the maximum of the nett reserve at any maintenance period.

Case Study 1

Unit data and maintenance requirements

Unit number	*Unit capacity, MW*	*Number of intervals required for unit maintenance*
1	20	2
2	15	2
3	35	1
4	40	1
5	15	1
6	15	1
7	10	1

Case Study 1

Unit gene pools

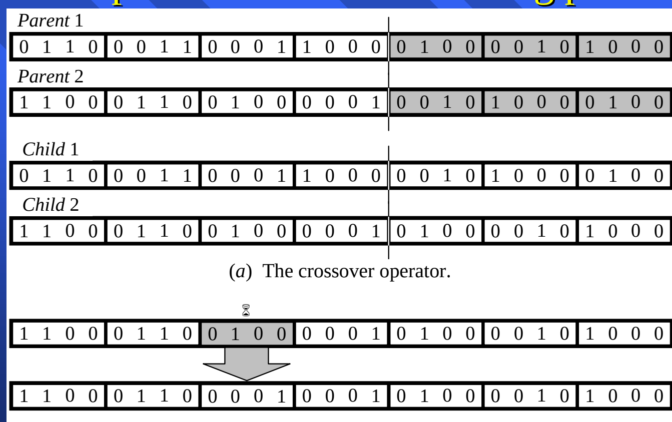
Unit 1:	1 1 0 0	0 1 1 0	0 0 1 1	
Unit 2:	1 1 0 0	0 1 1 0	0 0 1 1	
Unit 3:	1 0 0 0	0 1 0 0	0 0 1 0	0 0 0 1
Unit 4:	1 0 0 0	0 1 0 0	0 0 1 0	0 0 0 1
Unit 5:	1 0 0 0	0 1 0 0	0 0 1 0	0 0 0 1
Unit 6:	1 0 0 0	0 1 0 0	0 0 1 0	0 0 0 1
Unit 7:	1 0 0 0	0 1 0 0	0 0 1 0	0 0 0 1

Chromosome for the scheduling problem

Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
0 1 1 0	0 0 1 1	0 0 0 1	1 0 0 0	0 1 0 0	0 0 1 0	1 0 0 0

Case Study 1

Genetic operators for the scheduling problem

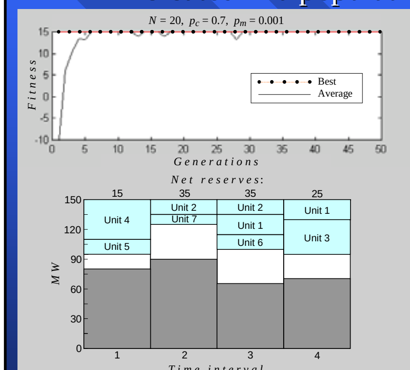


(*a*) The crossover operator.

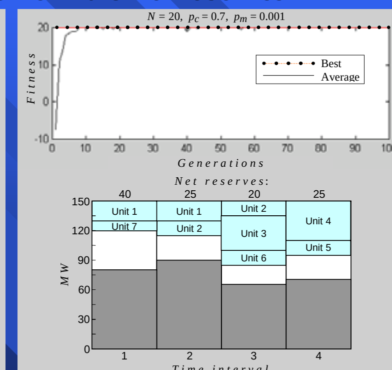
(*b*) The mutation operator.

Case Study 1

Performance graphs and the best maintenance schedules created in a population of 20 chromosomes



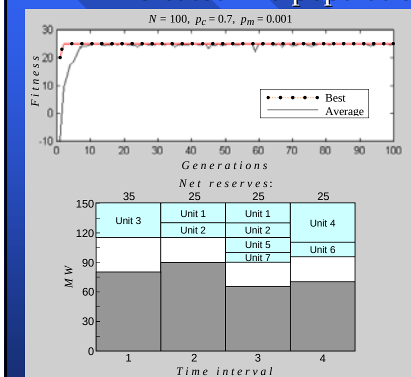
(*a*) 50 generations.



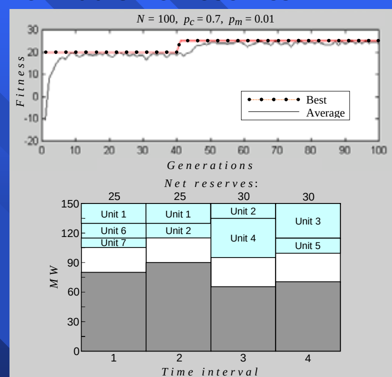
(*b*) 100 generations.

Case Study 1

Performance graphs and the best maintenance schedules created in a population of 100 chromosomes



(*a*) Mutation rate is 0.001.



(*b*) Mutation rate is 0.01.

Case Study 2

Scheduling of 62 units in 26 intervals

The problem constraints:

- Maintenance of any unit starts at the beginning of an interval and finishes at the end of the same or adjacent interval. The only exception is the maintenance of unit 62;
- Unit 62 is to be maintained in four intervals divided in two equal periods. The minimum operating period is 8 intervals;
- Units 61 and 62 are to be available for the winter period (intervals 21-26), units 56-60 are to be available in intervals 23-26;
- Units 1-5, 15-20 and 25 are to be available in the summer period (intervals 7-13).

Case Study 2
Expected maximum loads

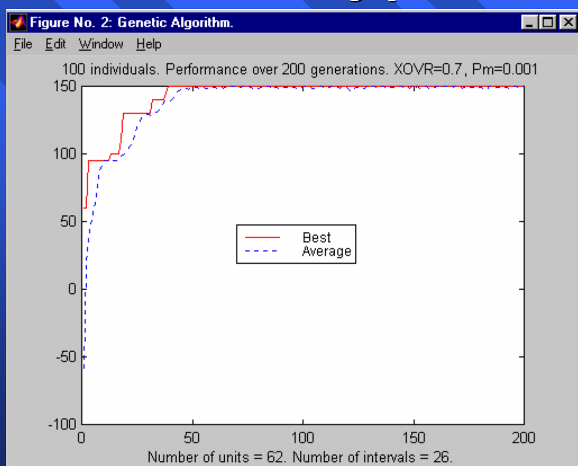
Interval number	*Predicted load, MW*
1,2	2100
3-4	1900
5-7	1750
8,9	1650
10-12	1600
13-15	1700
16-18	1900
19-21	2000
23,24	2200
25,26	2100

Case Study 2
Expected maximum loads

Interval	*Units scheduled for maintenance*	*Nett reserve*
1	10,22	210
2	15,19	210
3	2,6,45,62	290
4	1,3,31,45,62	250
5	31,58	340
6	13,18,38,58,61	365
7	7,38,56,58,61	325
8	41,46,49,56,61	285
9	14,28,41,46,49,54,56,61	275
10	32,37,46,49,54	450
11	26,32,36,37,51,52,54	420
12	24,36,51,52,53,54,60	370
13	39,42,51,52,53,60	410
14	35,39,42,51,52,53,55,60	210
15	8,9,17,25,34,35,47,53,55,62	235
16	29,30,34,47,55,59,62	275
17	4,42,47,50,55,59	150
18	22,40,43,48,50,59	150
19	21,40,48,50,57	200
20	16,44,48,57	155
21	11,27,44,57	180
22	12,20	310
23		150
24		150
25	33	210
26	5,33	200

Case Study 2

Performance graph



Conclusion

- Solving a problem using genetic algorithms involves defining constraints and optimum criteria, encoding the problem solutions as chromosomes, defining a fitness function to evaluate the chromosome performance, and creating appropriate crossover and mutation operators.
- Genetic algorithms represent a very powerful tool. However, coding the problem as a bit string may change the nature of the problem being investigated. There is always a danger that the coded representation represents a problem which is different from that desired to be solved.

Conclusion

- There are many potentially areas for applications of genetic algorithms in power systems. The application described in this paper demonstrates that one of the most successful areas may include problems concerned with scheduling resources.