THE SOLUTION OF CUTTING PLANS BY MEANS OF GENETIC ALGORITHMS

1. Introduction

There are problems that are necessary to solve in practice and cutting plans belong to them. See more [1 - 7]. The correct optimization of such problems enables us to minimize the scrap. The genetic algorithms can help us with such problems.

2. Cutting plan – one-dimensional task

The solution of one-dimensional cutting plan can be presented in the following case. We have pipes (logs, bars, etc.) of various lengths on the stock, for example 10 pieces of length 4 m and 20 pieces of length 5 m. The demand is 9 pieces of pipes of length 1 m, 14 pieces of length 2 m and 20 pieces of length 3 m. The demand is to find such a variant, which guarantees that the amount of scrap will be zero or minimum. The aim is to set up the number and length of the pipes needed from the stock and the form of their cut. It is necessary for the solution to determine the possible variants of cuts of the pipes, which are on the stock. The cut variants can be limited, for example by possible maximum scrap of 1m. See Tab.1. The optimization can be limited by the number of pipes on the stock, too.

Tab.1. must be optimized. The result of the optimization is setting up the number of pipes which are available on the stock, the determination of the variants of the cuts of the pipes and the fulfillment of the demand of zero or minimum amount of scraps. The calculated cutting plan need not fulfill the fact that the scrap will be zero and that the number of cut pipes will be exactly required, but the solution will lead to this demand. The imperfect fulfillment of the demands can be virtue of nonexistence of solution of this problem or the fact that the algorithm does not find the best solution. If we do not find the best solution, we can repeat the process of optimization with different set up of optimization algorithm, for example the population size, chromosome length, crossover rate, mutation rate. Tab.1. presents the situation after optimization, where the demand of zero scrap and exactly required pieces is fulfilled (there is neither surplus nor lack of demanded pipes).

Our case is solved by the need of 3 pieces of pipes of length 4 m (these 3 pieces will be cut on 1 one meter piece and 1 three meter piece) and 17 pieces of pipes of length 5 m (3 pieces will be cut on 2 one meter pieces and 1 three meter piece and 14 pieces will be cut on 1 two meter piece and 1 three meter piece). See Tab.1.

Variant	1m	2m	3m	Scrap
4a	4			
4b	3			1
4c	2	1		
4d	1	1		1
4e	1		1	
5a	5			
5b	4			1
5c	3	1		
5d	2	1		1
5e	2		1	
5f	1	2		
5g	1		1	1
5h		2		1
5i		1	1	

Variant	Pc.	1m	2m	3m
4a	**0**	0	0	0
4b	**0**	0	0	0
4c	**0**	0	0	0
4d	**0**	0	0	0
4e	**3**	3	0	3
5a	**0**	0	0	0
5b	**0**	0	0	0
5c	**0**	0	0	0
5d	**0**	0	0	0
5e	**3**	6	0	3
5f	**0**	0	0	0
5g	**0**	0	0	0
5h	**0**	0	0	0
5i	**14**	0	14	14

Shapes:

1m

2m

3m

Material:

4m

5m

Scrap:	0

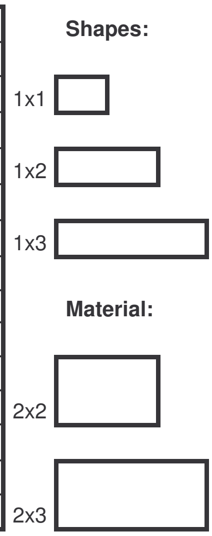
	Fact	Stock
Pipe 4m:	3	10
Pipe 5m:	17	20

Length:	1m	2m	3m
Real:	9	14	20
Demand:	9	14	20
Surplus(+):	0	0	0

Tab.1. Cutting plan – one-dimensional task

Variant	1x1	1x2	1x3	Scrap
(2x2)a	4			
(2x2)b	3			1
(2x2)c	2	1		
(2x2)d	1	1		1
(2x2)e		2		
(2x3)a	6			
(2x3)b	5			1
(2x3)c	4	1		
(2x3)d	3	1		1
(2x3)e	2	2		
(2x3)f	1	2		1
(2x3)g		3		
(2x3)h		2	1	1
(2x3)i			2	

Variant	Pc.	1x1	1x2	1x3
(2x2)a	**0**	0	0	0
(2x2)b	**0**	0	0	0
(2x2)c	**0**	0	0	0
(2x2)d	**1**	1	1	0
(2x2)e	**0**	0	0	0
(2x3)a	**1**	6	0	0
(2x3)b	**0**	0	0	0
(2x3)c	**0**	0	0	0
(2x3)d	**0**	0	0	0
(2x3)e	**7**	14	14	0
(2x3)f	**0**	0	0	0
(2x3)g	**0**	0	0	0
(2x3)h	**0**	0	0	0
(2x3)i	**5**	0	0	10



Scrap:	0

(2x2)	1	10
(2x3)	13	20
	Fact.	Stock

Size:	1x1	1x2	1x3
Real:	21	15	10
Demand:	20	15	10
Surplus(+):	1	0	0

Tab.2. Cutting plan – two-dimensional task

3. Cutting plan – two-dimensional task

The solution of two-dimensional cutting plans can be presented in the following case. We have sheets of various sizes on the stock, for example 10 pieces of the size 2x2 m^2 and 20 pieces of the size 2x3 m^2. The demand is 20 pieces of sheets of size 1x1 m^2, 15 pieces of sheets of size 1x2 m^2 and 10 pieces of sheets of size 1x3 m^2. The demand is to find such a variant, which guarantees that the amount of scrap will be zero or minimum. The aim is to set the number and size of the sheets needed from the stock and the form of their cut. It is necessary for the solution to determine the possible variants of cuts of the sheets, which are on the stock. The cut variants can be limited, for example by possible maximum scrap of 1 m^2. See Tab.2. The optimization can be limited by the number of sheets on the stock.

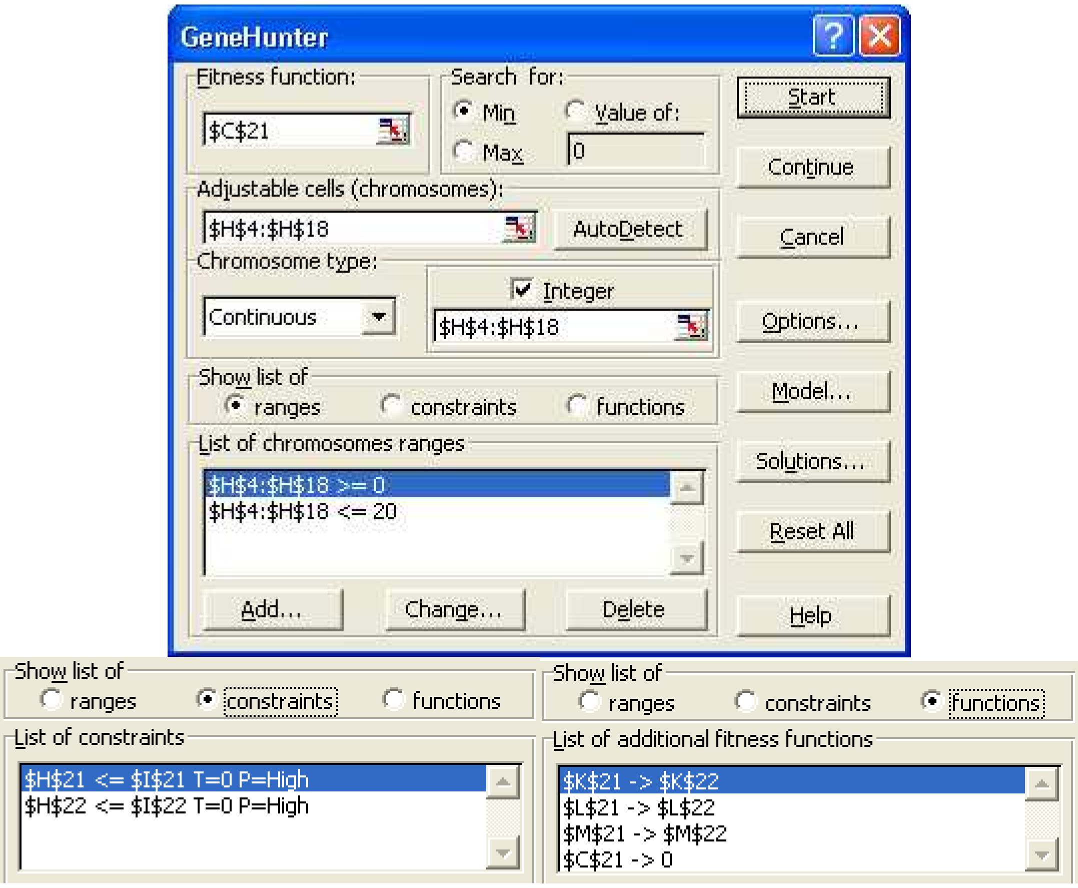
Tab.2. must be optimized. The result of the optimization is setting up the number of sheets which are available on the stock, the determination of the variants of the cuts of the sheets and the fulfillment of the demand of zero or minimum amount of scraps. The calculated cutting plan need not fulfill the fact that the scrap will be zero and that the number of cut sheets will be exactly required, but the solution will lead to this demand. The imperfect fulfillment of demands can be virtue of nonexistence of solution of this problem or the fact that the algorithm does not find the best solution. If we do not find the best solution, we can repeat the process of optimization with different set up of optimization algorithm, for example the population size, chromosome length, crossover rate, mutation rate. Tab.2. presents the situation after optimization, where the demand of zero scrap is fulfilled, but we will have a surplus of the sheet of size 1x1 m^2.

Our case is solved by need of 1 piece of sheet of size 2x2 m^2 (this 1 piece will be cut on 1 piece of size 1x1 m^2 and 1 piece of size 1x2 m^2 , 1 piece of size 1x1 m^2 will be a surplus) and 13 pieces of sheet of size 2x3 m^2 (1 piece will be cut on 6 pieces of the size 1x1 m^2, 7 pieces of sheets will be cut on 2 pieces of size 1x1 m^2 and 2 pieces of the size 1x2 m^2, 5 pieces of sheets will be cut on 2 pieces of size 1x3 m^2. See Tab.2.

The solution of three-dimensional cutting plans is similar as previous case.

4. Process of calculation

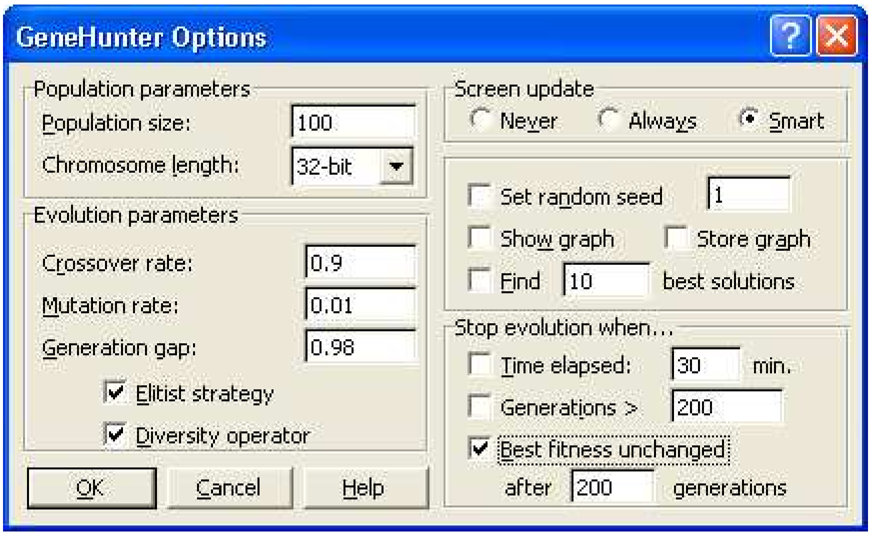
The process of calculation is as follows: At first it is necessary to fill in the data and formulas in Excel sheet (for example see Tab.1. or Tab.2.). The sheets represent the possible cutting variants of available material on stock, the number of variants is zero before the process of calculation.



Set up of input parameters

Further it is necessary to set up the position of cell, where the formula of fitness function is placed (the number of pieces of scrap), set the search for minimum, mark the area of adjustable cells (the number how many times the variants will be used for cutting), the type of chromosomes, set up the area of integer numbers (the number of use of variants must be integer). It is necessary to set up the chromosome ranges of three types: the range limits the number of variants, which could not be zero and bigger then 20; the constraints represent the fact that the number of demanded pieces on the stock is smaller or equal to the number of real pieces on the stock; the functions present the fact that the number of demanded and cut pieces should be the same and that the scrap should be zero.

The last step before the calculation is the set up of population size, chromosome length, value of crossover and mutation rate and generation gap. You can choose the elitist strategy and diversity operator. The other parameters set up the display parameters and the way of stop of the process of evaluation. The chosen parameters influence the process of evaluation and the quality of results.



Set up of options

The result of calculation is displayed in the Excel sheet after the process of evaluation. The calculated cutting plan should fulfilled the demand (the number and type of cutting variants should fulfilled the demand of needed number and shapes of materials).

5. Conclusion

The calculation has been done on the commercially sold software GeneHunter of Ward System Group Inc. The genetic algorithms enable us to solve complicated problems. The cutting plans belong to them. The correct optimization enables us to minimize the scrap and thus to contribute not only to minimization of the costs and increase of the profit, but also to saving the environment.