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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 9 (4): 710-714, 2010
ISSN 1812-5638

The Genetic Algorithm for Truck Dispatching Problems in Surface Mine

[1]Ming-Xiang He, [2]Jiu-Chuan Wei, [1]Xin-Ming Lu and [1]Bao-Xiang Huang
[1]College of Information Science and Engineering,
[2]College of Geosciences, Shandong University of Science and Technology, Qingdao, China

Abstract: At first, this study described the characteristics of truck transport in surface mine, then construct the model of truck dispatching and expound working principle and application of genetic algorithm. Finally, the typical experiment, by using the MATLAB genetic algorithm toolbox for calculation, showed that using genetic algorithm to optimize mine vehicle dispatching is feasible and effective.

Key words: Genetic algorithm, scheduling optimization, mine, MATLAB genetic algorithm toolbox

INTRODUCTION

The means of transportation about open-pit mine, according to topography, geology, the scale and scope of mining, mining way, mining equipment, climate conditions and combined with the characteristics of different ways of transport, mainly include: trucking, conveyor belt transport, railway transport, as well as intermodal transport which combined by a few modes of transport mentioned above. Truck transportation has a lot of advantages. For example, it has a high mobility, flexibility, climbing ability, a small turning radius, a short period of time and a low investment of infrastructure compared to train tracks railway transport. But, it also has some drawbacks, such as the high consumption of fuel and tires, the high operating costs, the short economic reasonable distance (Xian, 1987). It is given in open-pit mine production scheduling and vehicle scheduling model, but the lack of specific data to support (Huang and Qiao, 2006). In this study, as to defects of trucking, using the genetic algorithm to optimize the number of trucks in open-pit mine so that the whole truck transport system, without appearing to wait, meet production and quality requirements.

TRUCK DISPATCHING OPTIMIZATION MODEL IN OPEN-PIT MINE

The vehicle scheduling system, studied in this study, is based on an open-pit mining as an example to introduce. There are a number of open-pit shovel-bits. According to metal content, each shovel-bit is divided into the stone ore and rock, in addition, the output of ore and rock and the ore grade is known (Zhou and Zhang, 2007). The distribution of transport routes of trucking system is shown in Fig. 1. Assuming that there are n spade-bits in this system, trucks transport the ore and rock within each shovel bit to the appropriate disposal points. There are a total of five discharge points in which two flip-fields and ore leak belonging to ore unloading point, drain rock and rock field belonging to the rock unloading point. In this study, as to fixed transport routes, the distribution of the number of trucks is optimized by the genetic algorithm. That is to say that how to allocate the amount of trucks on each route, so that trucks meet the demand of discharge points, while making the cost of freight and maintenance minimum, which is a combinatorial optimization problem.

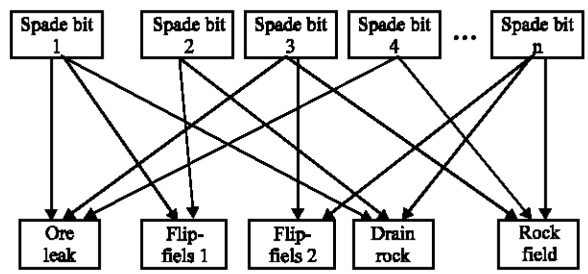

Fig. 1: Transport routes of trucking

The model established in this study is based on the least-cost of truck transportation and maintenance. In the open pit-mine, existing n-spade bits, ore leak, flip-fiels 1, flip-fiels 2, drain rock, rock field, is followed by numbered 1, 2, 3, 4, 5. During transport, trucks being all the work and, the mathematical model is established under the circumstances that no-load and full load speed is the same (Yao and Liu, 2008). The model is described as follows:

$$C = \mathrm{Min}(\alpha C_1 + \beta C_2), \quad \alpha + \beta = 1 \tag{1}$$

Corresponding Author: Ming-Xiang He, College of Information Science and Engineering, Shandong University of Science and Technology, Qingdao 266510, China

$$C_1 = \sum_{i=1}^{n} \sum_{j=1}^{5} X_{ij} d_{ij} c_{ij} N_{ij} \quad (2)$$

$$C_2 = \sum_{i=1}^{n} \sum_{j=1}^{5} X_{ij} M_{ij} \quad (3)$$

Constraint conditions:

$$\sum_{i=1}^{n} X_{ij} L \le P_j \qquad j = 1,...,5 \quad (4)$$

$$\sum_{i=1}^{n} X_{ij} \le M \qquad j = 1,...,5 \quad (5)$$

$$0 \le X_{ij} \le M \quad i = 1,2,..,n; \quad j = 1,2...,5 \quad (6)$$

where, C is the total cost of trucks, C_1 is the cost of truck transportation, C_2 is the cost of maintenance, M is the total number of truck in open-pit mine, α and β for the linear weighting factors, according to the actual conditions to determine their value.

With the use of trucks, the costs of maintenance and wear and tear are more and more, so in the later stage of truck running, maintenance costs should be considered more, so, β should be set more bigger.

X_{ij} is the number of trucks which spade bit i to unloading point j, the units are cars, i = 1, 2 … n; j = 1, 2...5, d_{ij} is distance which spade bit i to unloading point j, the units are km, i = 1, 2...n; j = 1, 2...5, N_{ij} is the largest transport times which spade bit i to unloading point j, the units are times, i = 1,2...n; j = 1, 2...5, c_{ij} is the cost of transportation which spade bit i to unloading point j, the unit is the yuan, i = 1, 2...n; j = 1, 2...5, M_{ij} is the cost of maintenance which spade bit i to unloading point j, the unit is the yuan, i = 1, 2. .. n; j = 1, 2. .. 5 and L is the truck load, the unit is t and P_j is the demand of spade bit j.

GENETIC ALGORITHM AND ITS TRUCK SCHEDULING OPTIMIZATION

Algorithm overview: Genetic algorithm, abbreviated as GA, is proposed by J.H. Holland, a professor in the University of Michigan, under the inspiration of biological evolution (Zhang and Zhang, 2008). Using the natural selection and natural genetic mechanism of biosphere for reference. The GA is a random global search and optimization algorithm. It can automatically acquire and accumulate of knowledge of the search space in the search process and adaptively control of the search process in order to achieve the optimal solution.

Genetic algorithm in truck scheduling: As the characteristics of vehicle scheduling, it gives the genetic algorithm with distinct genetic optimization characteristics of vehicles, in addition to the general distinguishing features, such as selection, crossover and mutation. Its characteristics are described below:

- Coding
- Initialize population
- Determination of fitness function
- The design of genetic operators
- Algorithm termination rules
- Work flow of algorithm

Coding: Coding is the first thing to solve for genetic algorithm to resolve vehicle scheduling problem. The role of genetic algorithm objects is not a problem in itself, but rather the issue of encoded string, usually expressed in binary. Each binary string constitutes an individual character, called chromosomes, each character is the gene and all individuals also constitute a population. Assuming that the number of trucks of each spade bit to unloading points within the eight, then right X_{i1}, X_{i2},, X_{i3}, X_{i4}, X_{i5} coding, you can use 3-bit binary to express the number of trucks on the route of the shovel bit to various unloading points, encoding format as shown in Table 1.

Each string, the third line in Table 1, is a different encoding method, representing different scheduling program. For fixed transport-routes vehicle scheduling, the length of string L is the number of shovel bits n the number of unloading points pthe number of binary bit on each fixed-line of truck. For example, when the spade bit is 2, unloading point is 5, the number of binary bit is 3, then the string length L = 2×5×3 = 30.

Initialize population: Initial population, genetic algorithms can handle the search space, is composed of the individuals randomly generated. Population size should be moderate. If too big, it will affect the speed of the search for algorithm; if too small, it will reduce the diversity of populations, which will make the algorithm converge to a local optimal solution rather than the global optimal solution, causing premature convergence. This

Table 1: Encoding format

Format	Spade bit 1					Spade bit 2					Spade bit 3					...	Spade bit n				
Coding	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{31}	X_{32}	X_{33}	X_{34}	X_{35}	...	X_{n1}	X_{n2}	X_{n3}	X_{n4}	X_{n5}
Chromosomes	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	...	xxx	xxx	xxx	xxx	xxx

initial population randomly generated, population size is 50, in each iteration, maintaining the same size of population.

Determination of fitness function: Fitness function is the criteria to evaluate the individual's good or bad, is the driving force for population evolution, but is also the basis for natural selection. Fitness function should be single-valued, continuous, non-negative, a small amount of calculation in order to reduce the computational complexity. As the objective function is desired to minimize transportation costs, so, the objective function take a negative for the fitness function, the text used in the fitness function as follows:

$$fit(X_{ij}) = -C = -\alpha C_1 - \beta C_2 \quad (7)$$

The design of genetic operators

Selection operator: Selection is the operation to make the fittest individual of populations to survival and then genetic individuals with high fitness to the next generation. Roulette wheel selection method used here (Nie and Liu, 2008), the individual probability of being selected depend on the individual's fitness. Supposing the size of population is M, then the selection probability of the individual i is P_i, $P_i = f_i / \sum_{j=1}^{M} f_j$, occasionally, individuals with poor quality will be copied to the next generation in order to increase the diversity of groups.

Crossover operator: Crossover is the main way of the genetic algorithm to generate new individuals. Two parents through mutual exchange of parts of individual genes, get a new generation of individuals, the new individual retains the characteristics of parents to make good genes combined together constantly to ensure the probability that search the global optimal solution. In this study, single-point crossover method is adopted and cross-location is a random set, in the part of individuals can be produced artificially remove inappropriate individual. In the part of individuals generated can be artificially removed the unsuitable ones. For example, the potential new entity represents the scheduling program that allocate vehicles on the absence of the line, then the new entity can be replaced by the parent individual in order to maintain the stability size of group. Generally, take 0.4~0.99 as crossover probability.

Mutation operator: Genetic algorithms can produce new individuals by mutation in order to maintain the diversity of population. Having a certain probability, it randomly changes the value of individual genes. For selected individuals, changing in a particular gene on the one, that is, 0 to 1, or 1 to 0. The general mutation probability is 0.0001~ 0.1.

Algorithm termination rules: Stopping operations of genetic algorithm are carried out by setting the stopping criterion. Through constant iteration, genetic algorithm gradually approach the optimal solution. When reaching a certain degree, the algorithm in the state of second-best solution, accompanied by the phenomenon of stagnation. Then the rules are needed to terminate the algorithm. In this study, the stop criteria of genetic algorithm are adopted (Lei and Zhang, 2005), then any one of them satisfied, the algorithm will stop running, stop criteria as follows:

- The algorithm stops running when running to the iterative required
- The current population is less than or equal to the best specified fitness value then stop running
- The algorithm stops running when running to a specified time
- The fitness function run to a certain iteration, it has not been improved all the time at the state of stagnation, then stop running
- The fitness function run to a certain time, there is no any improvement, then stop running

Work flow of algorithm: First, the genetic algorithm initializes population, and then determines the important parameters of the algorithm, Second, according to the fittest. Furthermore, excellent individual conducting fitness, it carries out the operation of survival of the

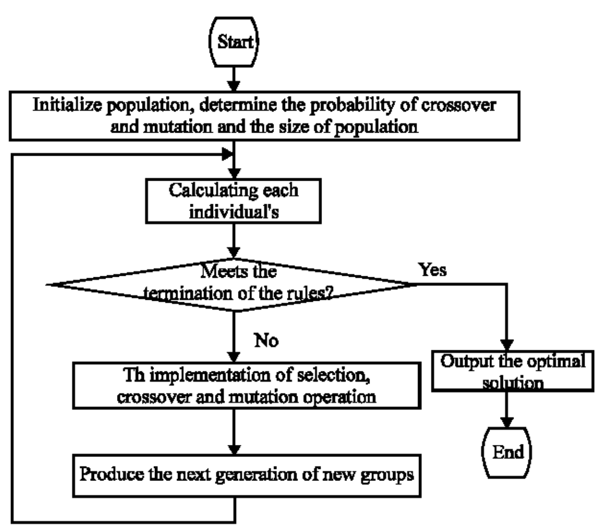

Fig. 2: Work flow of genetic algorithm

crossover and mutation, producing a new generation of population and running this again, eventually the genetic algorithm find the optimal solution of the problem. Work flow of genetic algorithm are shown in Fig. 2.

EXPERIMENTAL RESULTS AND ANALYSIS

In order to verify the optimize performance that genetic algorithm affect truck scheduling, in this study, using MATLAB genetic algorithm toolbox (Lei and Zhang, 2005), developed at the University of Sheffield in Britain, implements the specific experiments through given distance data that spade bit to the unloading point, time data and vehicle data (Huang and Qiao, 2006; Sun and Zhang, 2004). According to this reality, the time data regard as the price data, the vehicle data regard as trips data (Table 2-4). In Table 5, the data represents the cost of maintenance between spade bit and discharge point. The main parameters of genetic algorithm: population size is 50, due to the initial population is randomly generated, for example, the genetic algorithm may have the initial species as shown in Table 6; iterative number is 100, cross probability is 0.7, mutation probability is 0.001.

Applying the above parameters, the genetic algorithm carries out the global random search in initial population, after generations of successive operations, the changes in its fitness function as shown in Fig. 3.

In each generation, the dots, at the bottom of the Fig. 3 represent the best fitness value changes of the number of trucks, while the above dots indicate the average fitness changes of ones. The top of Fig. 3 is the best fitness and average fitness value.

As we see from the diagram that during early running, due to a the number of trucks' fitness value is far from ideal, the number of trucks' best fitness and average fitness is improved rapidly by the genetic algorithm. For example, when running about at the 9 and 11 iterations, the number of trucks' best fitness value has a cross and soon be improved. As the iteration proceeded, the number of trucks' best fitness value has been further improved at

Table 2: The distance between spade bit and various unloading point

	Spade bits									
Indicators	1	2	3	4	5	6	7	8	9	10
Ore leak	5.26	5.19	4.21	4.00	2.95	2.74	2.46	1.90	0.64	1.27
Flip-fiels 1	1.90	0.99	1.90	1.13	1.27	2.25	1.48	2.04	3.09	3.51
Rock field	5.89	5.61	5.61	4.65	3.51	3.65	2.46	2.46	1.06	0.57
Drain rock	0.64	1.76	1.27	1.83	2.74	2.60	4.21	3.72	5.05	6.10
Flip-fiels 2	4.42	3.89	3.72	3.16	2.25	2.81	0.78	1.62	1.27	0.50

Table 3: The cost of transport between spade bit and discharge point

	Spade bits									
Indicators	1	2	3	4	5	6	7	8	9	10
Ore leak	11.27	11.12	9.02	8.57	6.32	5.87	5.27	4.07	1.37	2.72
Flip-fiels 1	4.07	2.12	4.07	2.42	2.72	4.82	3.17	4.37	6.62	7.52
Rock field	12.62	12.02	12.02	9.77	7.52	7.82	5.27	5.27	2.27	1.22
Drain rock	1.37	3.77	2.72	3.92	5.87	5.57	9.02	7.97	10.82	13.07
Flip-fiels 2	9.47	8.27	7.97	6.77	4.82	6.02	1.67	3.47	2.72	1.07

Table 4: The vehicle trips between spade bit and discharge point

	Spade bits									
Indicators	1	2	3	4	5	6	7	8	9	10
Ore leak	6	6	5	5	4	3	3	3	2	2
Flip-fiels 1	3	2	3	2	2	3	2	3	4	4
Rock field	6	6	6	5	4	4	3	3	2	2
Drain rock	2	3	2	3	3	3	5	4	5	6
Flip-fiels 2	5	4	4	4	3	4	2	2	2	2

Table 5: The cost of maintenance between spade bit and discharge point

	Spade bits									
Indicators	1	2	3	4	5	6	7	8	9	10
Ore leak	0.96	1.05	0.26	0.85	0.26	0.49	0.37	0.27	1.26	1.61
Flip-fiels 1	0.80	0.76	1.56	0.11	0.52	0.92	0.39	0.22	0.44	0.51
Rock field	0.57	0.42	0.62	1.99	0.87	0.05	0.62	0.85	0.25	0.64
Drain rock	0.46	0.31	0.58	0.91	0.23	0.15	0.86	0.15	0.31	0.45
Flip-fiels 2	0.37	0.28	0.14	0.56	1.02	0.62	0.78	0.62	0.38	0.80

Table 6: The initial population

	Spade bit 1					Spade bit 2					Spade bit 3					...	Spade bit 10				
Nu of T	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{31}	X_{32}	X_{33}	X_{34}	X_{35}	...	X_{101}	X_{102}	X_{103}	X_{104}	X_{105}
$Chrom_1$	010	011	101	000	011	001	010	000	101	100	000	010	110	001	100	...	100	001	000	000	010
$Chrom_2$	100	010	001	001	101	100	001	000	000	001	001	100	000	101	110	...	000	000	001	101	011
$Chrom_3$	000	001	010	011	000	000	000	101	000	110	100	000	000	010	001	...	001	000	010	110	011
...						...					...					...	...				
$Chrom_{50}$	110	011	001	000	000	110	101	001	000	001	010	011	001	000	011	...	101	001	100	001	010

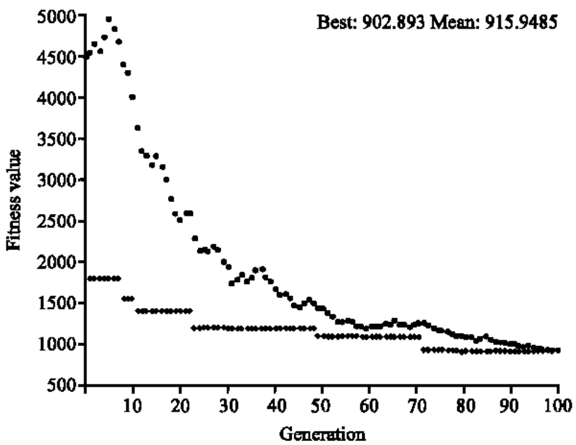

Fig. 3: Fitness variation

the 21, 50, 71 iterations, population move closer to the optimal solution. From the generation of 71 to 100, the number of trucks' best fitness value has basically been in a standstill state, improved slowly. Finally, the number of trucks' best fitness and average fitness value is basically the same about at the 100 generation, achieving the desired solution. At this point, the population's best fitness value is 902.893 and the average fitness value is 915.9485. That is, at this time the vehicle arrangements achieve the minimum cost which is 902.893.

CONCLUSION

In this study, the use of genetic algorithm improves the lack of truck transportation in open-pit mine and optimizes the number of trucks on the fixed-line under the premise of meeting the needs of the various unloading points, so that scheduling programs can be made quickly and the freight and maintenance costs achieve minimum which improves economic efficiency and make the vehicle scheduling more intelligent. Ultimately, the problem of economic and reasonable distribution of the vehicle, caused by lots of fixed-lines, has been resolved. In addition, through the typical experiment show that the use of genetic algorithms can improve the solving speed and obtain satisfactory scheduling results.

ACKNOWLEDGMENT

This study is supported by the National High Technology Research and Development Program of China (863 Program, No. 2009AA062704).

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