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The Aplication of Genetic Algorithms for the Scheduling of Electric Rolling Stock Maintenance

Kyaw Min Aung
Department of control and information security
Russian university of transport
Moscow, Russia
kyawminaung52@gmail.com

Sidorenko Valentina Gennadevna
Department of control and information security
Russian university of transport
Moscow, Russia
valenfalk@mail.ru

Safronov Anthon Igorevich
Department of control and information security
Russian university of transport
Moscow, Russia
flash_a@mail.ru

Buchirin Vladimir Grigorievich
Department of control and information security
Russian university of transport
Moscow, Russia
valenfalk@gmail.com

***Abstract*— This paper discusses the application of genetic algorithms for the scheduling of electric rolling stock maintenance. The main objective is to improve the automated train scheduling system of uniformity maintenance process with a variety of maintenance resources, including the limited resources. The methods of graph theory and Bellman principle allow us to get the entire set of suitable maintenance schedules and choose which maintenance corresponds to the train schedule, and the minimum differs from the optimal one according to the selected criteria. Traditionally, it takes a significant amount of time and the main problem is using the criterion of uniformity maintenance under limited resources. In this case, we used genetic algorithm for optimization. The results showed that the genetic algorithm is an effective tool for optimization of maintenance scheduling.**

***Keywords*— optimization scheduling, electric rolling stock maintenance, graph theory, genetic algorithms**

I. Introduction

Electric rolling stocks consist of various complex mechanical and electrical systems. To ensure reliability and safety of a railway service, the rolling stocks should be maintain in good working order and regular rolling stock inspection is an essential thing for the successful running of a railway system.

The scheduling of electric rolling stock maintenance is tightly linked with the planned train schedule. There are often occurs joint scheduling problems due to changes in source data. Many papers have been discussed for this joint scheduling problem by various methods [1][2]. The work of [3] described this problem as a classical assignment problem. In the work of [4] discussed a strict formalization of the maintenance scheduling of electric rolling stock of the subways by using the methods of graph theory and the Bellman principle.

The methods of graph theory and the Bellman principle can help to obtain all the sets of possible service assignments and choose manually from those all the sets of possible service assignments which one will correspond to the planned train schedule and differ minimally from the optimal according to the chosen criterion. It takes a significant amount of time and the problem occurs when we need to choose the criterion of uniformity maintenance under limited resources. Therefore, the main objective is to reduce the time consumption for the scheduling of electric rolling stock maintenance and to improve the automated train scheduling system. In this case, genetic algorithm is an effective tool to solve the scheduling optimization process.

II. Application of Genetic Algorithms

A. *Overview of genetic algorithms*

In the 1960s, genetic algorithms were introduced by John Holland based on the concept of Darwin's theory of evolution and were developed by Holland and his students and colleagues at the University of Michigan in the 1960s and the 1970. Holland's introduction of a genetic algorithm with crossover, selection, and mutation was a significant innovation for optimization and machine learning [5].

Today, genetic algorithms have been successfully applied to a wide range of real-world optimization problems like scheduling, adaptive control, cognitive modeling, optimal control problems, transportation problems, graph coloring problem, database query optimization, etc. [6][7]. In transportation, genetic algorithms have been widely used for optimization and various problems of transportation system such as:

- the railways scheduling problems [8][9];
- the urban passenger traffic system [10][11];
- the container transportation system [12];
- the estimating of transportation energy utilization [13];
- the generalized transportation problem [14];
- the transportation problem with discontinuous piecewise linear cost function [15];
- the multi-objective, multimodal transportation network design problem [16].

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B. Basic Concepts of genetic algorithms

Genetic algorithms are a branch of evolutionary algorithms which use mechanisms inspired by biological evolution. The main idea of genetic algorithms is the survival of the fittest, also known as natural selection which has been observed in nature.

Fig. 1 describes the principle of genetic algorithms.

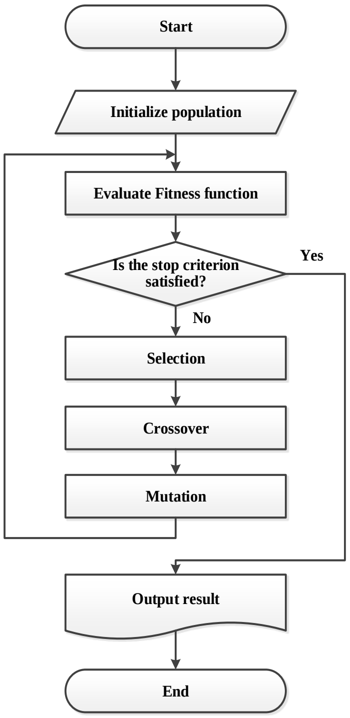

Fig. 1. Basic principle of genetic algorithms

The key parts of genetic algorithms are defining the population, defining the fitness function for the score of each chromosome and creation of a crossover method that takes into account with the specification of the task [17].

The basic terms of the genetic algorithm are explained in Table 1.

TABLE I. BASIC TERMS OF THE GENETIC ALGORITHMS

Genetics Terms	*Descriptions*
Chromosome	A variant of maintenance schedule in which each repair must be assigned to the corresponding candidate
Gens	Candidates that assigned to carry out repairs
Locus	One of the repairs that must be performed as one element of the maintenance schedule
Allele	Value of candidates (time and place for corresponding repairs)
Population	A subset of all possible maintenance schedules
Fitness function	Calculates fitness scores to each possible maintenance schedule and determine how fit to the desired maintenance schedule
Selection	Filter and select the better maintenance schedule for the next iteration or generation of algorithm
Mutation	Makes random small changes to the candidates
Crossover	Creates new maintenance schedule by combining the aspects of selected schedules

Pseudo-code for genetic algorithms

START

generate the initial population

evaluate fitness function

LOOP

  parent selection from population

  crossover and create new population

  mutation for new population

  evaluate fitness function

UNTIL termination criteria is reached

STOP

C. Genetic algorithms in maintenance scheduling

Firstly, genetic algorithms generate initial population of possible maintenance schedule. The population is randomly generated and the size of population is depending on the input parameter values. Fitness function classify how well the candidate fits with the desired requirement parameters. During the crossover create new maintenance schedule by combining the aspects of selected schedules. The algorithm will terminate the searching process if the solution is good enough for the desired maintenance schedule or there is no improvement in the population for the specified iterations.

III. RESULTS

A. Criteria for uniformity maintenance

There are two types of criteria for the uniformity maintenance of electric rolling stock scheduling:

- the sum of squares of deviation times for candidate maintenance start time from start time of planned maintenance schedule;
- the sum of squares of time intervals between maintenances.

The use of these two criteria implies that each candidate of the maintenance schedule must be satisfied with the requirements of the planned maintenance schedule. Otherwise, the value of criteria will assign to a function called as "penalty function". Fig. 2 illustrates the possible time for the candidates of maintenance schedule.

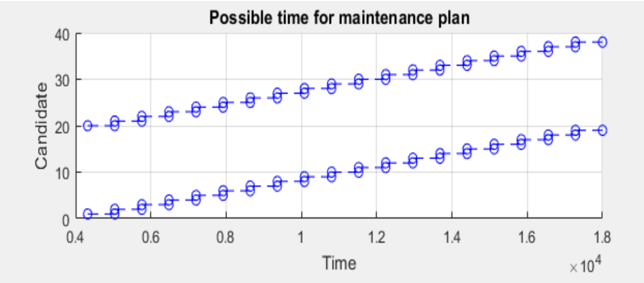

Fig. 2. Possible time for the candidates of planned maintanance schedule

Fig. 3 illustrates the desired time for each candidate of rolling stock maintenance schedule.

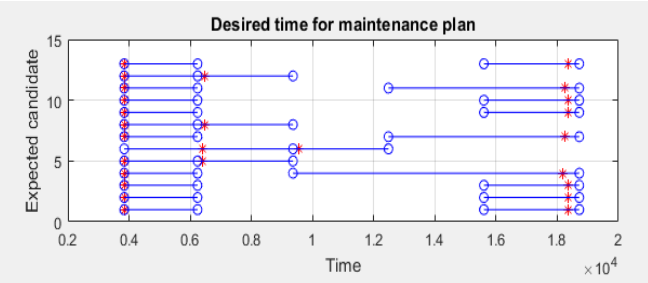

Fig. 3. Desired time for each candidate of maintenance schedule

B. *Defining the valid candidates*

In genetic algorithms, fitness function calculates the scores of each maintenance schedule. This scores indicate how close candidate solution is to the desired optimum solution.

If the fitness function score satisfied the resource requirements of the maintenance plan, the set of candidates perform as the valid repairs of maintenance schedule. Fig. 4 illustrates the result of maintenance schedule while the resources are enough for the necessary condition of maintenance scheduling.

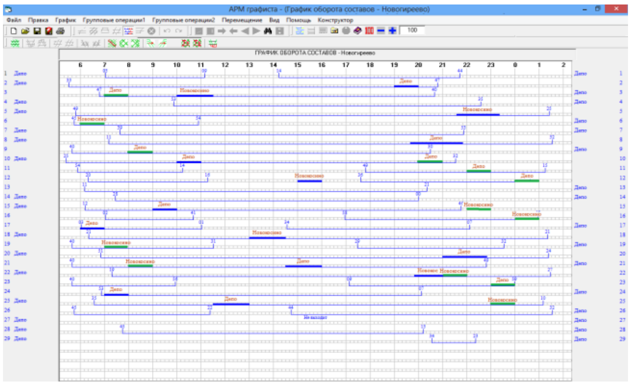

Fig. 4. the result of maintenance schedule while the resources are enough for the necessary condition of maintenance scheduling

If the score did not satisfy the requirements, fitness function will reflect the excess time over the limited interval time between two maintenances and then the set of candidates will expand to the total required maintenance of planned schedule by adding the set of imaginary maintenances. Fig. 5 illustrates the result of maintenance schedule while the resources are not enough for the necessary condition of maintenance scheduling.

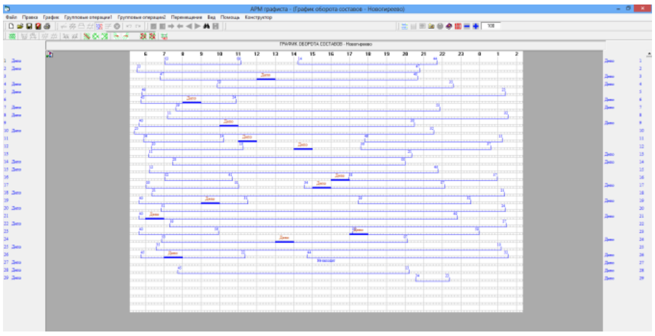

Fig. 5. the result of maintenance schedule while the resources are enough for the necessary condition of maintenance scheduling

As an experimental research, the authors developed a decision support system for the optimization of electric rolling stock maintenance scheduling. The decision support system fits to the features of the task:

- expanding the set of fitness functions that can be calculated based on the parameters of candidates;
- importing the chromosomes data from an external file;
- choosing the crossover type and numerical parameters of the genetic algorithms.

IV. Conclusion

In summary, we assumed that the total excess time over the limited interval time as an additional criterion to satisfy the uniformity maintenance under limited resources. Genetic algorithms provided optimal maintenance schedule for the situation of limited resources. The authors executed the adaption of crossover and mutation of the genetic algorithms. We analyzed the possibilities of joint scheduling process between the rolling stock maintenance schedule and the planned train schedule by using various crossover types, mutations and different input parameters (such as population size, number of iteration, accuracy, etc.) of genetic algorithms.

As a result, genetic algorithms provided optimal electric rolling stock maintenance schedule for the uniformity maintenance under limited resources.

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