Transportation Research Part C 44 (2014) 1–20

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Multi-objective optimization of train routing problem combined with train scheduling on a high-speed railway network

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ARTICLE INFO

Article history:
Received 9 August 2013
Received in revised form 23 January 2014
Accepted 27 February 2014

Keywords:
Train routing problem
Train scheduling problem
Multi-objective optimization model
Genetic algorithm

ABSTRACT

Based on train scheduling, this paper puts forward a multi-objective optimization model for train routing on high-speed railway network, which can offer an important reference for train plan to provide a better service. The model does not only consider the average travel time of trains, but also take the energy consumption and the user satisfaction into account. Based on this model, an improved GA is designed to solve the train routing problem. The simulation results demonstrate that the accurate algorithm is suitable for a small-scale network, while the improved genetic algorithm based on train control (GATC) applies to a large-scale network. Finally, a sensitivity analysis of the parameters is performed to obtain the ideal parameters; a perturbation analysis shows that the proposed method can quickly handle the train disturbance.

1. Introduction

With the rapid development of high-speed railway, more and more railway lines will be put into operation in china. The operation of new lines will lead to the adjustment of train route and timetable, while the train route and timetable should be also adjusted under the peak time. Besides, unpredictable events occur now and then which may cause some sections unavailable. To avoid larger loss of passengers and railway operational company, a timely adjustment of the timetable for the influenced trains in the network is necessary. In summary, we dedicate to finding an efficient method to select route and schedule the timetable for trains under these circumstances. Usually, the evaluation of train routing is mainly measured by the total travel time of trains. However, the total travel time of trains will be obtained by train schedules. To get a safe-based and efficient train schedule, we should primarily introduce a real-time train control process with constrains which will generate the schedules of trains. At last, a better solution is obtained after a series of process like data gathering, control process, data analysis, decision making and decision implementation. The train routing problem combined with train scheduling is a NP-hard problem in the perspective of optimization. The number of feasible solutions increases exponentially with problem size being larger due to the complexity of this problem. Meanwhile, the computing time of accurate algorithm may be too long to meet our demand. The heuristic techniques have been certified to be valid for solving the train scheduling problems, so we will prefer the heuristic technique to get a near optimal solution. The framework of approach to train routing and scheduling process is described as Fig. 1, where the information of railway network and trains is treated as input, and each of actual train movements is the output according to the train route selection and train control strategy, and at last a better train route schedule will be gained through the GA algorithm.

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http://dx.doi.org/10.1016/j.trc.2014.02.023
0968-090X/

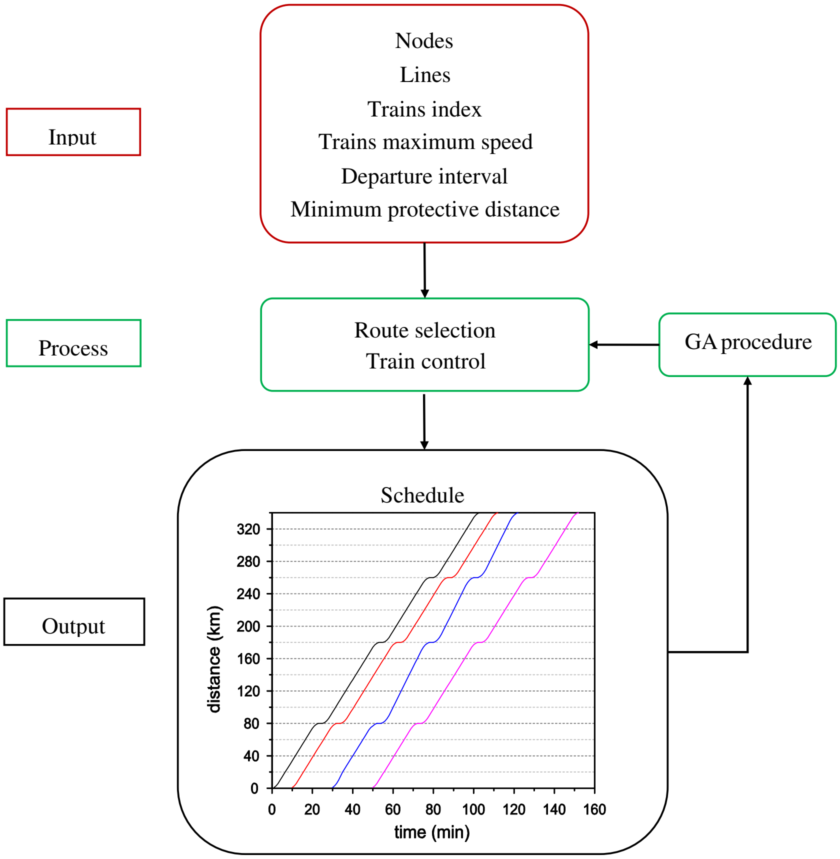

Fig. 1. The approach to train routing and scheduling process.

Train routing assigns trains to available tracks in the rail network and this problem has been studied by some researchers. Bodin et al. (1980) presented a nonlinear, mixed integer programming formulation of the routing problem, and a heuristic algorithm was designed to solve the problem. Assad (1983) proposed a dynamic programming method for a routing problem defined on a line network composed of *n* yards. Crainic (1984) proposed a nonlinear, mixed integer, multi-commodity flow problem that deals with the interactions between blocking, makeup, and train routing decisions. Haghani (1989) proposed a solution method for a combined train routing and makeup, and empty car distribution problem. Keaton (1992) considered strategy constraints for blocking and maximum transit times for each origin–destination pair. Martinelli and Teng (1996) used neural networks to solve the train routing problem. Gao et al. (2008) considered the influence of the random factors on the route choice of trains. Li et al. (2010) used random search strategy to solve the shortest problem on a rail network.

These routing models can produce a routing plan which describes the route of each train and the set of trains to be operated. Due to lack of train scheduling in these models, it becomes difficult to find a timetable which can accommodate all planned trains and satisfy line capacity. Besides, a good scheduling plan should consider the service level which includes the total delay, the energy consumption, the delayed times and so on. However, at the stage of line planning, the delay of trains and the energy consumption cannot be obtained because there is no train scheduling. Thus, compound routing and scheduling models is necessary to improve the service level.

The early train scheduling problem of developing timetables for passenger trains on a line was proposed by Nemhauser (1969) and Salzborn (1969). Recently, Ceder (1991) proposed an optimization model for minimizing total passenger waiting time in stations. Dorfman and Medanic (2004) proposed a new approach to solve the large-scale train scheduling problem. Li et al. (2008) improved the travel advance strategy (TAS) and presented an efficient strategy called efficient travel advance strategy (ETAS) to solve the train scheduling problem. Yang et al. (2010) proposed a simulation method to deal with the stochastic disturbance. Yang et al. (2011) proposed a control simulation method to deal with the irregular events on the railway network. Xu et al. (2012) presented the simulation of train scheduling based on cellular automaton (CA) model. Johanna (2012) designed an effective algorithm to solve the train scheduling during disturbances.

In summary, less researches centered on the compound models for the train routing and scheduling in the past decades. Morlok and Peterson (1970) initially integrated the routing problem and scheduling problem into an optimization model. Nachtigall (1995) proposed a compound method in strategic planning to help planners at CSX Transportation. Gorman (1998) addressed the weekly routing and scheduling problem, and constrains in his paper were given to guarantee trains