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Procedia Computer Science 37 (2014) 211 – 219

Procedia Computer Science

The 5th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN-2014)

DESIGN AND ANALYSIS OF OPTIMIZATION ALGORITHMS FOR MULTI-AGENT RAILWAY CONTROL SYSTEM

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Abstract

The paper is concerned with the schedule optimization problem in the railway control systems. The schedule optimization problem has been formulated as a problem of finding the global extreme of the fitness function. Authors propose 2 different methods for the problem solving using mathematical optimization technologies, namely stochastic optimization algorithm, and the genetic algorithm respectively.

Peer-review under responsibility of the Program Chairs of EUSPN-2014 and ICTH 2014.
Keywords: multi-agent systems, identification, railway control system, global extreme, optimization, job-shop scheduling

1. Introduction

In recent years creating and developing decision support systems is gaining importance, especially in intelligent transport systems. Construction of optimal schedules for traffic control is one of the most pressing problems that transport community faces. On its solution depends resource economy and overall performance of the exploited transport system. This problem is at the same time actual and time-consuming. Its complexity depends on the number of system parameters and limitations. The problem of finding optimal schedule may be approximated by the global optimization problem. Definition and solving of global extremum finding problem along with developing of search algorithms is common in different fields of technology. It is known a great variety of optimization algorithms for the real tasks of selection of the best decision that boil down to an optimization problem. However, there are many criteria to take into account while analyzing the efficiency of a particular method. In the field of the railway traffic management optimization problem has gained complication of phase space variables and its constraints that run out of the track infrastructure distinctive features and the railway transportation process. That's why the most of well-known optimization algorithms became not efficient as applied to complex control systems with large amount of constraints with non-clear structure[1]. This article explores optimal locomotive assignment problem as the global

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Peer-review under responsibility of the Program Chairs of EUSPN-2014 and ICTH 2014.
doi:10.1016/j.procs.2014.08.032

optimization problem and provides the efficiency analysis of proposed searching algorithms. The main attention was paid to construction of multi-agent model of the railway traffic management system as well as its future optimization by two different algorithms based on stochastic and genetic algorithm respectively.
For solving indicated problem the following steps had been accomplished:

- Developing of a mathematical model of the railway traffic management system based on multi-agent theory.
- Developing of searching algorithm for the most optimal scheduling and locomotive assignment.
- Comparison of the global optimization techniques with reference to indicated problem.
- Simulation developed freight management system on Far Eastern Railway and analysis of the efficiency of proposed searching algorithms.

2. Problem Description

An optimization problem can be formulated as follows: there is an initial data for locomotives and trains (or reserve locomotives) relocation plans with the specified slots. Initial data for locomotive contains its current status, attributes and location at the beginning of the period. Main goal is to assign locomotives to relocation plans for the base period providing the best fulfillment of the railway traffic management problem with required restrictions and technological normativity of locomotive exploitation. To qualify a variant of assignment the local utility function $u_i(x_i)$ is introduced for a pair "relocation train plan i (or relocation plan of reserve locomotive) — assigned to the plan locomotive x_i". Relocation plan contains information about train departure and arrival time, starting and arrival stations and unique train identifier, relocation plan of reserve locomotives — about corresponding reserve locomotive route. The local utility function $u_i(x_i)$ is as follows:

$$u_i(x_i) = C_1\frac{T_s(x_i)}{N_1} + C_2\frac{T(x_i)}{N_2} + C_3\frac{T_w(x_i)}{N_3} \quad (1)$$

- $C_1, C_2, C_3, N_1, N_2, N_3$ — specifying and normalization coefficients.
- $T_s(x_i)$ — time till the next locomotive servicing taking into account the journey time within the current plan's route and the time of the locomotive relocation from the arrival station to the nearest station, where the required service type is carried out.
- T — locomotive journey time within the current plan's route.
- $T_w(x_i)$ — lost time, during which locomotive was waiting departure with current plan.

For optimal locomotive assignment problem we define the total utility function by summing local utility functions $F(x) = \sum_i u_i(x_i)$. Total utility function can be concidered as multidimensional function of vector argument $X = [x_1, x_2, \ldots, x_m]^T$ where vector X is a solution of locomotive assignment problem (to train relocation plan or reserve locomotive relocation plan). We define X as $(loco_1, loco_2, \ldots, loco_m)^T$, where $loco_i$ is a unique locomotive number assigned to the i-th relocation plan, m – number of relocation plans in the the base period. Consequently we can approximate optimal locomotive assignment problem to the total objective function extremum seeking problem with corresponding constraints:

$$F(X) = \sum_i u_i(x_i) \rightarrow extr(max); \quad X^* = argextrF; \quad g_j(X^*) \leqslant b_j, \quad j = 1, \ldots, k \quad (2)$$

In the formula (2) X^* is a best solution; $g_j(X^*) \leqslant b_j$ — constraints of the problem; k - number of constraints. In general extremum seeking procedure can be represented as follows:

$$X^{n+1} = \|A\| X^n, \quad \|A\| < 1 \quad (3)$$

where A is an iterative operator. The algorithm carries out the extremum seeking on the constraint set related to technological normativity of locomotive exploitation in railway infrastructure. It is required to find the such form of iterative operator A by which the iteration process (3) converges to the best solution i.e. to the total extremum