The Fifth International Conference on Railway Technology
RAILWAYS 2022
22–25 August 2022
Montpellier, France

Proceedings of the Fifth International Conference on
Railway Technology:
Research, Development and Maintenance
Edited by J. Pombo
Civil-Comp Conferences, Volume 1, Paper 23.3
Civil-Comp Press, Edinburgh, United Kingdom, 2022, doi: 10.4203/ccc.1.23.3

AI FERODATA Application Enriched with Artificial Intelligence Models to Optimize Freight Transport

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Abstract

In freight transportation the planning methods and decision support systems are a crucial point to be considered, yielding interesting research opportunities for the development of optimization. The aim of our project was to research, develop and implement an artificial intelligence (AI) assistant module bringing new AI-based capabilities of optimization and simulation for enterprise-wide operational activities such as management of railway resources and constraints in an efficient and user-friendly manner. The main objective of the current paper concerned the best way to transport freight from given origins to given destinations within time constraints using the railway service provided by the network. This planning problem is faced in four steps (preprocessing, constraints definition, optimization phase and model's testing). The objective function considers the train operation costs, consumption and time duration. Machine learning algorithms are developed to optimize the objective function according to an enormous number of decision variables and complicated constraints. The platform is tested in a real-world Romania railway network. Future progress of the project will provide models' testing results and continuous improvement of the algorithms performance.

Keywords: artificial intelligence, machine learning, decision support systems, railway transportation orders, optimization, freight transport

1 Introduction

Railway freight is an important logistical system supporting both global and regional economies. Millions of railcars are continuously moving every day and night. In 2019, 58 808 000 ton-km of goods were transported on the Romanian railway network [1]. The demand for transportation is growing more rapidly than infrastructure investment and construction, thus motivating the optimization of current railway operations.

With the purpose of obtaining better management of logistical operations and enhace strategic positions on the market for the railway companies, our team developed a railway monitoring system aimed to integrate logistical activities and improve income management [2]. The system consists of three components: Ferodata BOX, Ferodata MOBILE, and Ferodata SYS, used to transmit to a web-server the status and operating information of the electric or diesel trains that operate within Romanian railway network. Train information includes data from locomotives, wagons, train driver, route, direction, fuel or electric consumption, speed, etc. All this information is processed in real-time and can be viewed in the web-server application. Additionally, the web-server application could manage and report details that are coming from the wagons, such as valuable information regarding the bogie wear, the identification of the wagons attached to a gasket, and identification the situations in which a wagon or group of wagons comes off the gasket configuration. All information about the status of trains is available online and at any moment the person responsible for management can use these data in their work.

Following the success of the implementation of our system within the Romanian railway network and in the context of growing demand for railway freight transportation, we are currently developing a novel module within our platform to meet the need for cost-optimized transportation orders.

In freight transportation, the planning methods are a crucial point to be considered, yielding interesting research opportunities. Several papers and review works concerning planning and optimization of logistic and freight transportation systems can be found in [3,4,5].

The aim of our project was to research, develop and implement an artificial intelligence (AI) assistant module bringing new AI-based capabilities of optimization and simulation for enterprise-wide operational activities such as management of railway resources and constraints in an efficient and user-friendly manner. Moreover, in contrast to the papers published so far, we propose an integrated solution which besides optimized management of order resources it also provides valuable real-time monitoring of entire rail park activities.

2 Methods

The problem faced in the present paper concerns the definition of the best path to be covered and the best transportation resources to be taken. We define an optimization procedure for deciding the best path on the network and the optimal assignment of trains to orders (these latter being characterized by an origin, a destination, a required delivery time window, a number of load units to be moved). The requester of the orders is able to choose between various cost-alternatives that prioritize either total cost or delivery time and date).

Many research works can be found about planning railway operations, in which the main objective is the optimal scheduling and routing of trains (see [6] for a review work on this field). For instance, in [7] a multiobjective programming model is defined in order to plan passenger trainservices; in [8] a model is proposed for scheduling loading and departure trains, as well as for optimally repositioning empty freight cars.

For developing our novel optimization AI-module, the railway network is represented by means of an oriented graph G = (N, L), where N is the set of nodes (railway terminals) and L is the set of links in the network.

The planning procedure we have devised is composed of four phases:

1. Preprocessing phase, aiming at loading the existing railway network representation with fixed operation costs in the form of a graph (G), pinpointing current available resources and defining the available optimization parameters.

2. Constraints definition.

3. Optimization phase, starting from data provided by the preprocessing phase and the list of order requests and consisting in the solution of a mathematical programming graph problem, such that each order requester is provided with various scheduling alternatives for their order that prioritize either total cost or delivery time and date.

4. Model testing consisting of three steps:

(a) Data preparation

This section tests the formulation and the proposed algorithm on a realistic railway network in Romania, as shown in Figure 1, using well-defined shipment demands between any two railway stations.

Figure 1: Web-server application to visualize current railway network and train circulation (screen capture).

(b) Determination of computational results and algorithm performance.

(c) Comparison with the current/traditional management of railway transport orders.

3 Results

We present the current stage of the implementation of the proposed module according to the planning procedure:

1. Preprocessing phase

The existing railway network representation with fixed operation costs is loaded in the form of a graph in our current platform. Current available resources in Romanian railway network are 1000 wagons and 450 locomotives.

We defined and identified the available optimization parameters for transportation orders in Table 1.

<u>Locomotive parameters</u>

<table>
<tr><td colspan="4">Number</td></tr>
<tr><td>Type</td><td colspan="3">Electric / Diesel-electric / Diesel-hydraulic</td></tr>
<tr><td>Construction type</td><td colspan="3"></td></tr>
<tr><td colspan="4">Power (KW)</td></tr>
<tr><td colspan="4">Regime of use</td></tr>
<tr><td rowspan="5">Functional status</td><td colspan="3">Functional</td></tr>
<tr><td rowspan="4">Defective</td><td rowspan="4">Possibility of displacement</td><td>Limited traction</td></tr>
<tr><td>Isolated</td></tr>
<tr><td>Immobilized</td></tr>
<tr><td>Trailed</td></tr>
</table>

Planned revisions / repairs	Date of delivery	
	Date of takeover	
Planning conservation periods	Date of entry into conservation	
	Date of exiting from the conservation period	
Activity planning	Mechanic	
	Start period	
	End period	
	Traction type	
	Train length	
	Gross tons	
	Net tons	
	Laden axles	
	Empty axles	
	Conduction system	Simplified / complete team
	Head of train	
Last location		

Station parameters

Name		
Region		
X end	Latitude	
	Longitude	
	Ray (meters)	
Y end	Latitude	
	Longitude	
	Ray (meters)	

Circulation segment parameters

From station	
To station	
Code	
Distance	
Class	A/B/C/D/E/R/I

Consumption norms parameters

Traction	Consumption norm section		
	Norm type		
	Available from		
	To		
	Construction type		
	Deviation accepted (+/-)		
	Example	Construction type	
		Train configuration	Holder locomotive
		Holder locomotive (specific consumption)	in kg/stb*km
Maneuver	Construction type		
	Consumption (kg/hour)		

Mechanics

Role	Mechanic/Mechanic assistant/Train leader
Workstation	

Planned activities	Activity type
	Start date
	End date
Service hours summary	Service on locomotive
	Conducting
	Service
	Rest

Table 1: Identified optimization parameters for transportation orders.

2. Constraints definition

Following field analysis, we defined several constraints: (a) the number of available mechanics at different time intervals in each workstation; (b) the number of available locomotives at a certain time and station area; (c) non-electrified railway network links only support Diesel electric locomotives; (d) single rails cannot lodge two trains going simultaneously in opposite directions but only one after the other; (e) the weight of the transport order load must not have a value greater than the capacity of the rail track from each itinerary segment.

3. Optimization phase

After the initial setup, several machine learning (ML) algorithms are fed with the input data previously defined and are employed to optimize either total cost or time to delivery (Figure 2).

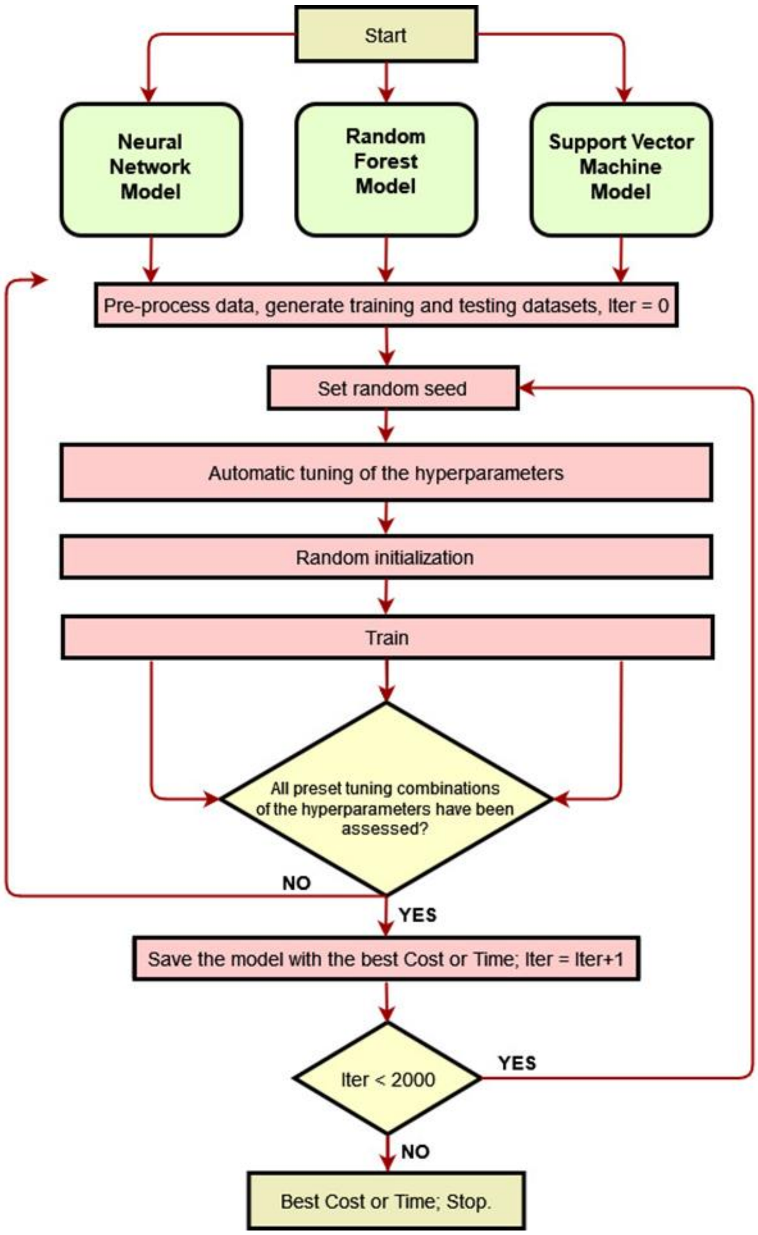

Figure 2: Implementation flow diagram of the machine learning algorithms.

4. Models' testing

Testing results will be available after the implementation finalization in 2022.

4 Conclusions and Contributions

The aim of our project was to propose an integrated solution which besides optimized management of the resources of railway transportation orders, it also provides valuable real-time monitoring of entire rail park activities. Such a multivalent platform is able to significantly improve the income and strategic positions on the market of the railway companies. The main objective of the current paper concerned the best way to transport freight from given origins to given destinations within time constraints using the railway service provided by the network. This planning problem is faced in four steps (preprocessing, constraints definition, optimization phase and model's testing). The objective function considers the train operation costs, consumption and time duration. Machine learning algorithms are developed to optimize the objective function according to an enormous number of decision variables and complicated constraints. The platform is tested in a real-world Romania railway network. Future progress of the project will provide models' testing results and continuous improvement of the algorithms performance.

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