ŽILINSKÁ UNIVERZITA v
Žiline, Slovensko
CETRA – Centre for
transportation research

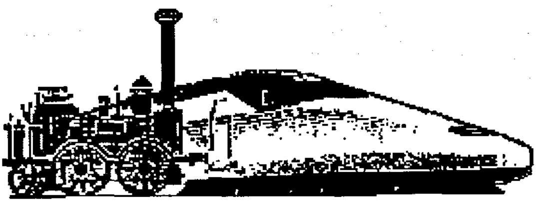
za podpory EURÓPSKEJ KOMISIE V BRUSELI

18. medzinárodné sympózium
18th International Symposium

„Oživenie ekonomiky - nová výzva pre železnice"

" Revitalisation of Economy - New Challenge for European Railways"

EURO - Žel 2010



Zborník prednášok
(1. diel)

26. - 27. máj 2010

Žilina
Slovenská republika, EÚ

GENETIC ALGORITHM FOR INTELLIGENT BRAKING CONTROLLER IN RAILWAY TRANSPORT SYSTEM

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Summary: The purpose of the research is to prevent railway accidents by reducing the human factor. Authors propose to use genetic algorithms for train's braking system controllers to be used for optimal routing and scheduling tasks on big railway stations. Mathematical models and target function of optimal braking controller with genetic algorithm are developed The results of computer modeling of proposed controllers in railway transport systems show the possibility to avoid crashes and detect dangerous conflict points on the way. As a result of research the experimental train emergency braking device is invented.

1. Introduction

Railway traffic flow is limited by safety criteria. Therefore, routing and scheduling task is actual for railway transport system. As well optimal braking control and safety of braking process is very important. The analysis of human behaviour [3] and simulation of train's braking [2] is investigated.

Nowadays human factor plays a considerable role in traffic system control as in railway as in city transport. But some conflict situations in transport systems need immediate reaction and decision, which is impossible to be made by human timely.

As a result railway crashes and accidents take place, as well as traffic jams in the cities are uncontrollable that follows increasing of additional costs of public electric transport, such as excessive energy consumption, idle time, schedule infringements and so on.

Intelligent transport control system give possibility to make traffic control safer and more cost-effective. It may find optimal solution of the conflict faster than human as a decision support system [7]. As well in case of emergency it may prevent crashes and accidents without human intervention.

In this paper authors propose the intelligent braking control device, which warns the driver about necessity of working braking start, taking in account signal of the traffic light. If working braking has not been started the controller activates emergency brakes with a purpose to stop before the beginning next block-section, if it is possible or to choose free way with enough free distance to stop without crash.

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The device receives the signal from the defined traffic light and defines its position using wireless communication network and has data storage with route control points as well.

Advantages of proposed device are following:

- The device is not using rail chains and works independently on automatic locomotive signalisation system.
- Proposed device is an alternative or auxiliary to existing safety systems [8].
- As opposed to existing systems new device uses wireless communication network and may work in a railway sections without automatic interlocking system.

Authors propose to use genetic algorithms [1] for optimal routing and scheduling tasks. Such kind of controllers may be integrated in working infrastructure for optimal speed control of railway traffic.

2. Mathematical Formulation of the Task

2.1. Railway objects and their interaction

Following objects may be defined in railway system: rail ways R; points P; stations ST; block-sections CP; signalisation, centralisation and interlocking system SCB; dispatching centre DC; traffic lights G; rolling stocks RS; locomotives L; wagons V.

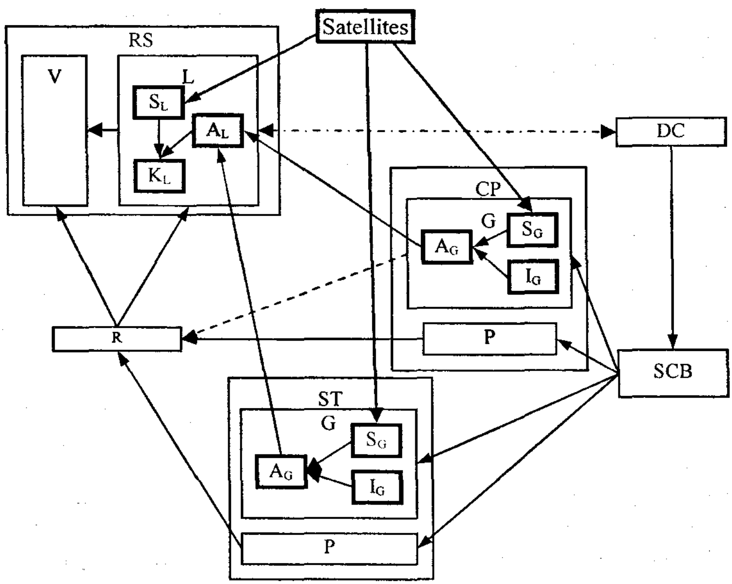


Fig.1. Proposed structure of interaction of railway objects

Fig.1. shows the functional connections between objects of railway system. Solid lines mean strong and permanent functional dependencies. Dashed lines mean usage of rail ways for signal transmitting from traffic light to the locomotive on the sections that are equipped with automatic interlocking. On the stations and on the sections with half-automatic interlocking automatic locomotive signalisation is not working.

Authors propose to add following objects to the existing system:

- Satelite navigation recievers of traffic lights S_G and locomotives S_L (GPS, GALILEO, ...);
- Wireless signal transmitting antennas of traffic lights A_G and locomotives A_L (GSM-R, ...);
- Device for signal generation of the traffic light I_G;
- Device of braking system control of the locomotive K_L.

2.2. Model of tracks and points

Rail ways may be represented as graph $R = \{C, S\}$, where rails are divided to sections S, and each section $s \in S$ connected with each other by two connectors $s =< c_i, c_j >$.

Each section $s \in S$ has constant length l_s, curve a_s, and speed limit v^*_s.

Each point $p \in C$ connecting set W of three or more sections and set of possible states of point D_p, where $d_p^n =< s_i, s_j >$ means opened both directions from s_i to s_j and from s_j to s_i is following for different point types:

single point: $D_p = \{< s_i, s_j >, < s_i, s_k >\}$;

dual point: $D_p = \{< s_i, s_j >, < s_i, s_k >, < s_i, s_m >\}$;

cross point: $D_p = \{< s_i, s_j >, < s_i, s_k >, < s_m, s_j >, < s_m, s_k >\}$.

Each state of point $d_p \in D_p$ has speed limit $v^*_{d_p}$; maximal each point‘s $d_p \in D_p$ switching time: t_{d_p}.

2.3. Model of railway signals

Railway signal G is an object with fixed coordinates x_0, y_0 connected to fixed position on the track.

Type of signal:

Each signal $g \in G$ has following states of signals $L_g \subseteq \{R, Y, YG, G, V, W\}$, where “R” – red, and rolling stock must stop before the signal; “Y” – yellow, can move and be ready to stop, next signal is red; "YG" – yellow and green, next two sections are free; "G" – green, "V" – violet, "W" – moonlight white.

Each signal set up speed limits for next block-section: v_{def} - maximal predefined speed on the section, v_0 - 0 kmh, stop; v_1 - < 50 kmh, movement on turnouts 1/9 and 1/11 types; v_2 - < 80 kmh for movement on turnout 1/18 type; v_3 - < 120kmh for movement on turnout 1/22 type.

2.4. Target function for optimal braking control task

Multi-criteria target function for braking:

$$\begin{cases} F^{br}(DL, CL, EL) \to \min \\ DL = \Delta s \to 0 \\ CL = a(t) \to a^* \\ EL = \dfrac{da}{dt} = const \end{cases}$$

where Δs - distance between closed section and rolling stock – danger level criteria (DL)

$a(t)$ - deceleration of rolling stock

a^* - optimal deceleration for passengers – comfort level criteria (CL)

da/dt - changes of deceleration and braking torque – optimal energy consumption criteria (EL)

F^{br} - function for braking process optimization

2.5. Target function for routing and scheduling task of the rolling stock

Routing task for accident prevention consists of generating of new route and schedule for rolling stocks V moving on points P.

Target function for scheduling and routing is to arrange points for each train to reach a destination and assigning of time moments t to each train and each point.

- Train's schedule: $\sigma_v : P \to \{t_{v1}, t_{v2}, \ldots, t_{vs}\} \subset \Re$
- Point's schedule: $\sigma_{p^i} : V \to \{t_{p1}, t_{p2}, \ldots, t_{pm}\} \subset \Re$

3. Generic Genetic Algorithm for Optimal Control of Braking Process of Rolling Stock

Genetic algorithm for task solution may be described with following steps.

1 step: Initialize random set of possible solutions: $S^{(0)} = \{s_1^{(0)}, s_2^{(0)}, \ldots, s_{s_{max}}^{(0)}\}$;

2 step: Evaluate each solution with a target function:

$$V^S = \{F(s_1), F(s_2), ..., F(s_p)\};$$

3 step: Arrange solutions by evaluation: $\overline{S} = \{\bar{s}_1, \bar{s}_2, ..., \bar{s}_p\}, \quad F(\bar{s}_1) = opt(V^S)$;

4 step: Duplicate best solutions in elite set: $S_E \subset \overline{S}$;

5 step: **Selection.** According to defined selection algorithm select from the set of solutions pairs: $S_C = \overline{S}$;

6 step: **Crossover:** According to defined crossover algorithm generate new population from the set of solution pairs:

$$\bar{s}_i \Pi \bar{s}_j \rightarrow s'_i = s_{ij}; s'_j = s_{ji}, \quad i, j = \overline{1, p};$$

7 step: **Mutation:** Random change of one of solution parameter that help to find global optimum of the function:

$$x_j^{s'_i} = x_j^{s'_i} + 1, \quad s'_i \in S', \quad j = rand(\overline{1, k}), \quad i = rand(\overline{1, p});$$

8 step: Evaluate new population using target function:

$$V^{S'} = \{F(s'_1), F(s'_2), ..., F(s'_p)\};$$

9 step: Arrange new population by the evaluation values:

$$\overline{S}' = \{\bar{s}'_1, \bar{s}'_2, ..., \bar{s}'_p\}, \quad F(\bar{s}'_1) = opt(V^{S'});$$

10 step: Add new population of solution to elite set: $S = (S_E + \overline{S}')$;

11 step: Delete last solutions from the population S if its size exceeds predefined population size p: $S = S / \{s_{p+1}, s_{p+2}, ...\}$;

12 step: Algorithm stops by time, generation, convergence or by another predefined criteria. If stop criteria is false then repeat the algorithm from step 4. If true then the result of algorithm is solution s_1.

4. Experimental Device

The result of this work is train emergency braking device [6]. Invented device is proposed to increase safety on railway transport. It gives possibility to stop rolling stock automatically before closed signal timely.

In difference of known devices that actuate brake only after the passing of closed signal, invented device provides a train emergency braking and stopping before a closed section, even if it is not equipped with automatic locomotive signaling. The device also provides distance control and the emergency braking way calculation.

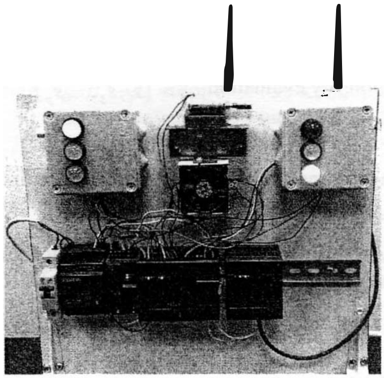


Fig.2. Fragment of functional prototype of train emergency braking device.

Train emergency braking device contains antenna installed at the beginning each block-section, the generator, a train-mounted antenna , data reception unit, a turning angle pickup meter, connected to a train wheel axle box, distance meter, wheel set tyre diameter meter, speed meter, acceleration meter , brake pressure meter, brake efficiency meter, data storage unit with the additional input for data base programming and train braking system and also contains data reception unit, which input is connected to the train-mounted satellite communication receiver, but output connected to the object distance detector, which is connected to the program braking unit, which is connected to a train braking system through the amplifier, but program braking unit has parallel inputs connected to the braking way detector and to data storage unit, but inputs of braking way detector are parallel connected to the outputs of brake efficiency meter, speed meter, distance meter and wheel set tyre diameter meter. The generator connected to each block-section satellite communication receiver, whose output connects to the antenna installed at the beginning each block-section which is in connection with the train-mounted antenna.

Train emergency braking device determines the starting location of block-section by satellite communication receiver installed at the beginning of each block-section and determines train location by the train-mounted satellite communication receiver. Object distance detector identifies a distance between the train and the beginning of block-section, but braking way detector determines braking way. Program braking unit evaluates braking way with the distance between the train and the beginning of block-section and actuates train braking system using amplifier.

Fig.2. presents the demonstrator of this device that, which can be installed on the train. There are two traffic lights; the electric motor; sensors and wireless communication equipment are installed on the demonstrator.

According to the traffic light signal controller selects the appropriate engine speed. When burning a red light, the control system automatically stops the engine. In response to the light sensor, the control unit in addition to the fan is turned on and switches to another mode of operation.

Remote monitoring and control of the processes is possible using of wireless communication. In real system, it could be dispatching control centres, from which it is possible to switch both signals and also take over control of the train speed.

5. Results of Experiments

For the experiments the program for programmable controller is realised. The controller performs all the calculations and controls electric drive and traffic lights on the functional prototype.

The computer model is created to show the results of controller's operations to perform emergency stop before the red signal of the traffic lights.

The specific environment is developed by authors for the modelling of railway system for safety improving algorithms (fig. 2).

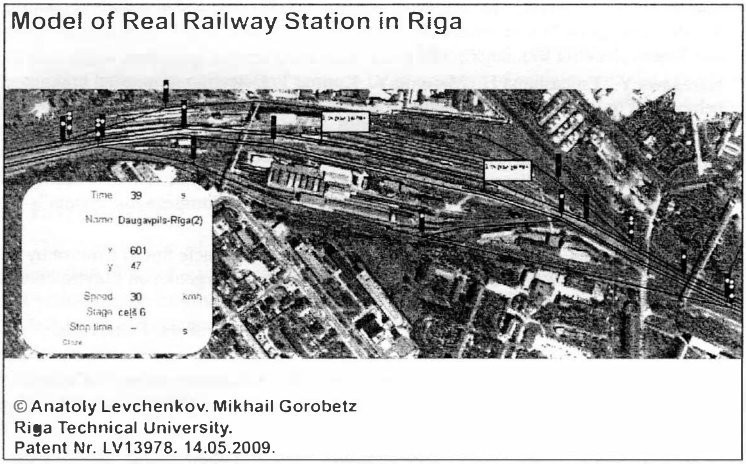
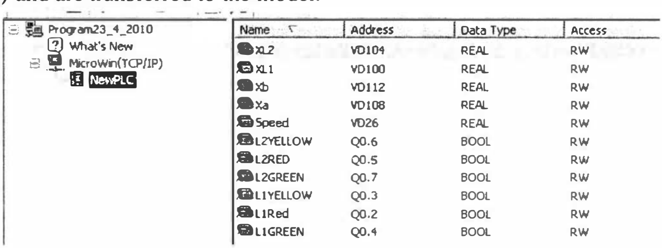


Fig. 2. Simulation environment

Data from the specific memory addresses of controller are read by the server (Fig. 3.) and are transferred to the model.



Name	Address	Data Type	Access
XL2	VD104	REAL	RW
XL1	VD100	REAL	RW
Xb	VD112	REAL	RW
Xa	VD108	REAL	RW
Speed	VD26	REAL	RW
L2YELLOW	Q0.6	BOOL	RW
L2RED	Q0.5	BOOL	RW
L2GREEN	Q0.7	BOOL	RW
L1YELLOW	Q0.3	BOOL	RW
L1Red	Q0.2	BOOL	RW
L1GREEN	Q0.4	BOOL	RW

Fig.3. Input data from PLC to computer model

6. Conclusions

Results of experiment show the possibility to use the proposed system as auxiliary safety device to prevent infringements of red signal crossing and crashes on the railway.

Technical efficiency of train emergency braking device is safety increasing of train movement on any railway section. Train emergency braking device allows stopping the train in time before the beginning of a closed block-section by automatic actuation of the emergency brake that prevents collision of trains.

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