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Visual Modeling of Power Processes Control in Mechatronics Systems

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Abstract

Article presents the mathematical problem formulation of intelligent agents in mechatronics problems for city transport optimal moving regimes control task solving. There are the methods of the problem solving, structure of problem solving algorithm is given in the article. There is experimental check of algorithm and main conclusions are given in the article. This work has been partly supported by European Social Fund within the National Programme "Support for carrying out doctoral study programme's and post-doctoral researches" project "Support for the development of doctoral studies at Riga Technical University" (grant No 2004/0002/VPD1/ESF/PIAA/04/NP/3.2.3.1/0002/0007).
KEY WORDS: *intelligent agents, modelling, intelligent transport systems, intelligent agent networks, electrical processes, mechatronics*

1. Introduction

By the present moment in a big city the number of personal cars and lorries is increasing but the general traffic capacity of the transport network is not changed, thus the possibility of the transport movement is decreasing, the quality of passenger service is lower than the private one, the time of the service is longer. In order to solve the task of the passenger service quality increasing it is necessary to consider the priority of the public transport in the traffic flow [1].

The main idea of this paper is to use intelligent agent networks and intelligent agent negotiation algorithms to create an algorithm and coordination mechanism for speed control of public electric transport to save electrical energy, in the case of rolling way and braking regime, when the energy is supplied into the network [2].

As the electric public transport is a cooperative system, motion control problem could not be solved autonomously, i.e. independently on other transport process participants. That is why coordination mechanism is needed. It is suggested to use intelligent superagent to cooperate work of all agent in transport system. The superagent's functions are to realize negotiation of intelligent agents and make a decision about changing in the system work according to the environment.

This paper provides the mathematical model and algorithm for optimal motion control of the electric vehicle. Algorithm is implemented in intelligent agent to get and process information of the current condition of electric transport unit [3].

2. Problem formulation

The purpose is to define the optimal speed for public electrical vehicle. There are two contrary criterions of optimality for public transport. On the one hand, electric transport uses electric energy, so the criterion is the minimization of energy consumption. On the other hand, public transport has the schedule and must follow it.

Possible problem solution is intelligent coordination mechanism – intelligent agent system with the superagent, which gives possibility to avoid these charges and can give economy of the electrical energy [4].

The following steps are taken for problem solving: to analyze the methods of interactive decisions evaluation, to apply the theory of lists, artificial intelligent [5] (intelligent agent networks), application efficiency for solving of the public transport problems taking into account passengers priority; to work out a searching procedure of and optimal route of public transport in the global network, taking into account the criteria of logistics; to formalize an interaction of the transport system, power system and consumer, using modelling of the system; to describe the essence of the theory of decision making and the special features in the solving of the transport problem; to investigate the efficiency of multiagent systems application for modelling of the transport system in the environment of global network.

3. Problem decision algorithm A

For the development and investigation of the software agents models of intellectual transport systems a complex (Fig. 1) of mutually coordinated models is investigated in the paper:

- a functional model of power supply system is Se;
- a functional model of city transport system is St;

- a functional model of set of consumers is *Sp*;
- functional model of information process in power supply system is E^m ;
- functional model of information process in city transport system is T^m;
- functional model of consumers' behaviour is P^m;
- model of software agents which interaction with the model of energy supply systems solves the task of optimal energy supply for transport system is A^e;
- model of software agents which interaction the model of city transport system solves the task of optimal transport units supply to set of consumers is A^t ;
- the model of software agents of the consumers which takes into account priority of the consumers in risky conditions, reaching the goals of the real expert groups is A^p.

Modelling of multicriterial consumers priority in risky conditions taking into account a complex task in the nearest future. The model of Supra software agent which provides the reaching of the goal nominated by the expert group with the help of software agents in the processes of transport logistics is also analyzed in the paper [6].

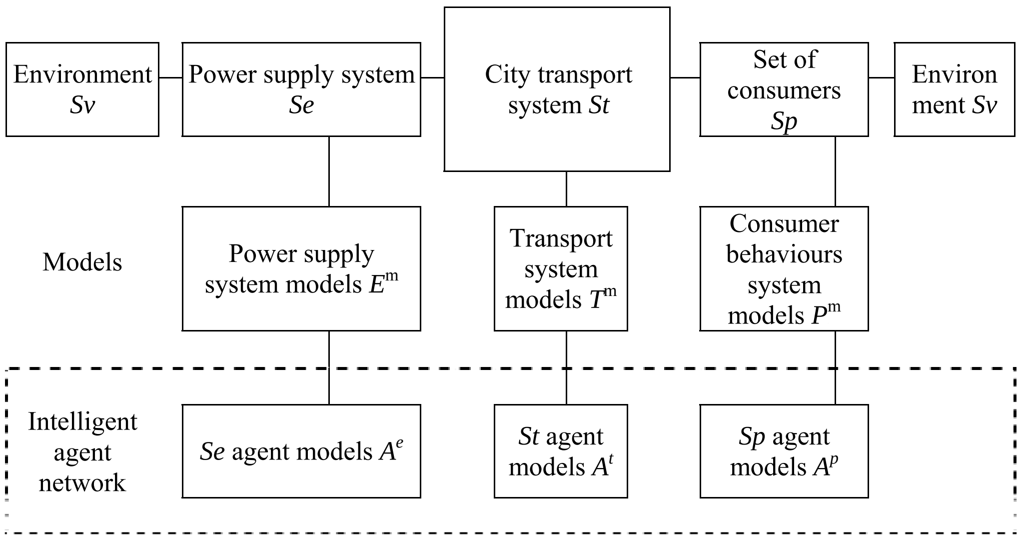


Fig. 1 Structure software agents models of electric power supply and transport logistics a complex

There will be the following designations used in this work:

Distributed data bases Dp, Distributed Web server (servers) Wd, Electric power systems Web servers Wr.

Given set of electro consumers *K* (*K*1, *K*2, …, *K*i); set of intellectual agents models A^i (i∈∅), $A^e \subset A^i$; $A^t \subset A^i$; $A^p \subset A^i$; set of consumers models P^m (P^m 1, P^m 2, …, P^m i).

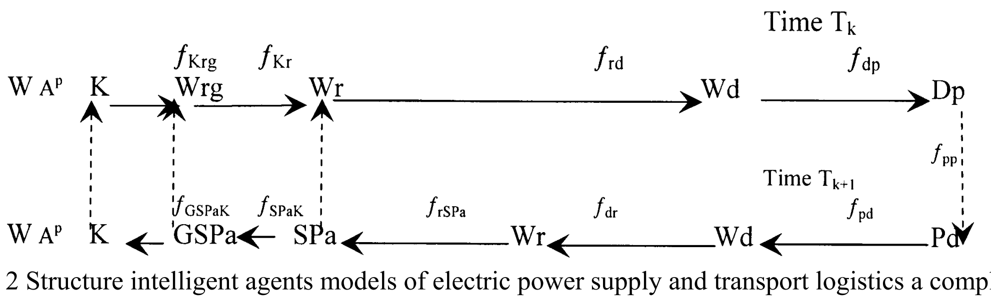


Fig. 2 Structure intelligent agents models of electric power supply and transport logistics a complex

1 step. Consumer (*Sp*), applying computer with connection (*Spr*) starts to develop an order for electric power, using information function (procedure) *f SpSpr*. If an answer is obtained from the server (proposal) the consumer can go to the following step. If the answer is not obtained then the solving of the task does not take place.

2 step. Server (*Srs*) starts to get answer from data base (*Srd*), using function (procedure) *f SrsSrd*.

3 step. Server (*Srs*) starts to send solutions of the clients tasks (proposals) to server (*Srp*), using function (procedure) *f SrpSrs*;

4 step. Server (*Srp*)starts to send solutions of the clients tasks to Supra software agent A^s, which analyses the results (*Z*) and suggests to the consumer the best solution, using function *f Srp* A^s.

5 step. If the decision is obtained to the Supra software agent A^s goals, then Supra software decision sent to all Hyper Supra program agent, which will make decision in all task decision management agent will check the condition (TxExP) →min (*t*); GA^p→min (*t*); (TxExP) →min (*t*) (Fig. 2).

GA^p is set of the passenger agents; T is the area of transport system; E is the area of power system; P is the set of passengers.

The passenger agent controls whether the operation of the transport system, power system [4] and passenger (consumers) systems is minimum according to the time criterion.

4. The mathematical model for task solution

The city transport (Fig. 3) network graph (Fig. 4) – $G(N,E)$, where.

1. Nodes: $N = \{n_1, n_2, ..., n_v\}$;
2. Edges – subset from Cartesian product of nodes: $E = \{e_1, e_2, ..., e_l\}$; $e_j = < n_a, n_b >, \quad j = \overline{1,l}, \quad a,b = \overline{1,v}, \quad a \neq b, \quad E \subseteq N \times N$

Fig. 3 Fragment of Riga city transport network

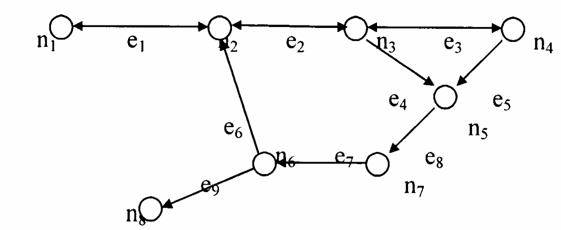


Fig. 4 An example of transport network

3. Routes for public transport – cyclic subgraph of G:

$$Routes = \{route_1, ..., route_y\}$$
$$route_k = \{< node_1, edge_1 >, ... < node_x, edge_z >, node_1\}$$
$$k = \overline{1,y} \quad x \in \overline{1,v}, \quad z \in \overline{1,l}$$
$$node_i \in N, \quad edge_j \in E$$

4. Each route stage – $route\_stage_r = < node, edge > \in route_k$ – has following parameters:
   a. $l \in \Re$ – length;
   b. $sp \in \Re$ - speed limit;
   c. $type \in \{"L", "X", "S", \ldots\}$ – type of stage – line, crossroad, stop, …;
   d. $cycle = <red\_cycle, green\_cycle>, red\_cycle, green\_cycle \in \Re$ additional parameter for crossroads only red light burning time, green light burning time.

The schedule

1. A set of processors P – stops and crossroads, where $P = \{P^1, P^2\}$, $P \in N$, where
   Stops: $P^1 = \{p_1^1, p_2^1, ..., p_s^1\} \subset P$
   Crossroads: $P^2 = \{p_1^2, p_2^2, ..., p_c^2\} \subset P$
2. A set of jobs U – vehicles, where $U = \{u_1, u_2, ..., u_m\}$
3. Each vehicle has the schedule: $\forall u \in U, \quad \sigma_u : P^1 \to \{t_{u1}, t_{u2}, ..., t_{us}\} \subset \Re$
4. Each stop has the schedule: $\forall p \in P^1, \quad \sigma_p : U \to \{t_{p1}, t_{p2}, ..., t_{pm}\} \subset \Re$

Vehicle electrical parameters:

Vehicle motion stages (Fig. 5) - $T_{ij} = \{< t_1^0, t_2^0 >, < t_1^1, t_2^1 >, ..., < t_1^k, t_2^k >\}, \quad i = \overline{1,m} \quad j = \overline{1,s}$

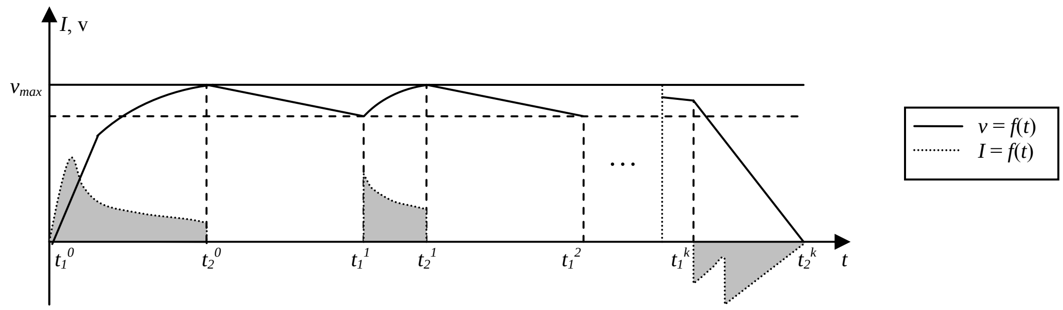


Fig. 5 Vehicle motion stages

net voltage - U; net current I_k; net resistance R_k

motor excitation current	I_e
motor armature current	I
magnetic flux	c_f
motor torque constant	$c_m = c_f/6.28$
rotation speed	n
motor voltage	U_m
duty ratio of pulse regulation	g
used net energy	E_a
used vagon energy	E_v
recuperation probability	a
recuperation energy	E_{rek}

Vehicle parameters [7]:
v - vehicle's speed
s - vehicle's distance from beginning of the route
$\forall u \in U, \quad v_{max}[u] \in \Re$ - vehicle maximal speed
$\forall u \in U, \quad route[u] \in Routes$ - vehicle's route

Route parameter:
$\forall u \in U, \quad v_{min} \in \Re$ - route's minimal speed to move without disturbing other participants.

Target function – minimization of energy consumption:

$$A = \int_{t_1^0}^{t_2^{k-1}} UI \ dt - \int_{t_1^k}^{t_2^k} UI \ dt \to min$$

at restriction:

$\forall t_2^k \in T_{ij}, \quad t_2^k \le t_{ij}, \quad t_{ij} \in \sigma_{u_i}(p_j^1), \quad i = \overline{1,m} \quad j = \overline{1,s}$ - following the schedule.

5. General algorithm for task solution II

This part presents the algorithm proposed for task solution. The flowchart in Fig. 4 describes the main cycle of motion control algorithm.

Fig. 6 describes speed control procedure, which optimizes the speed of a vehicle. The procedure has following steps.

1) First step is based on checkpoint *chp* definition – the stage of the route, where the change of speed is possible. Such places can be traffic light controlled crossroads, passenger stops or turnings, which have speed limit according to turning radius.
2) When checkpoint is detected the breaking point *brp* must be calculated. Breaking point is a point on the route, where a vehicle has to start breaking. At that point a vehicle speed must be minimal. With the breaking point the breaking time *brt* is calculated too.
3) The optimization is based on logic, that more energy is used for acceleration than returned by breaking. That's why acceleration must be stopped (*acceleration = false*) in a moment to reach breaking point by rolling (*brp = s + rw*) if it is possible, that's why rolling way *rw* from current speed to minimal is calculated every moment. Also rolling time *rt* is calculated.
4) If the next checkpoint is a crossroad ($type[chp] = "X"$), the vehicle agent starts negotiation with the traffic light agent to get the light for the arrival moment to the checkpoint.
5) If the checkpoint is a passenger stop ($type[chp] = "S"$), the schedule satisfaction is checked by negotiation with passenger stop agent. If it is impossible to reach the stop in directive time ($rt + brt \le t(chp)$), the acceleration is not switched off until the vehicle will follow the schedule again.

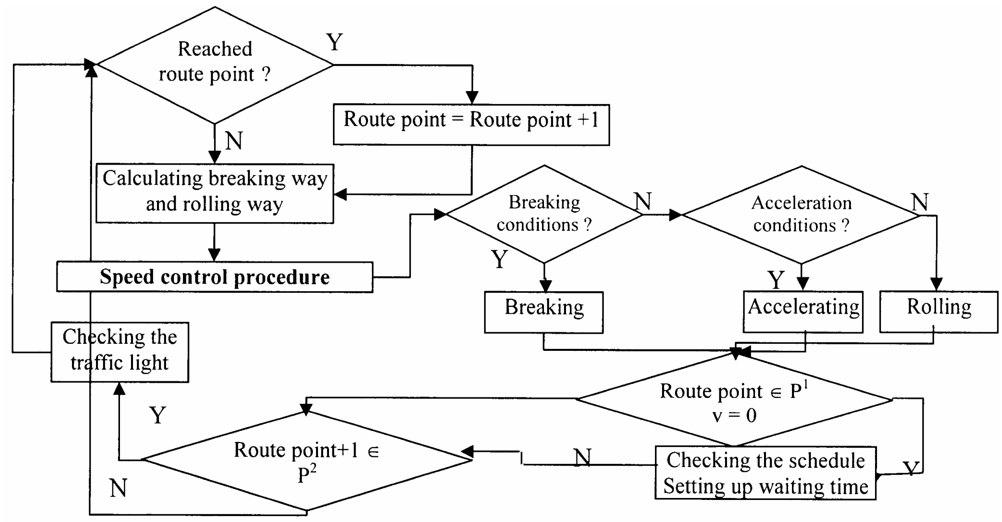


Fig. 6 Flowchart of main cycle

6. Approximation for breaking and rolling way calculation

The purpose of approximation is to define following functions:

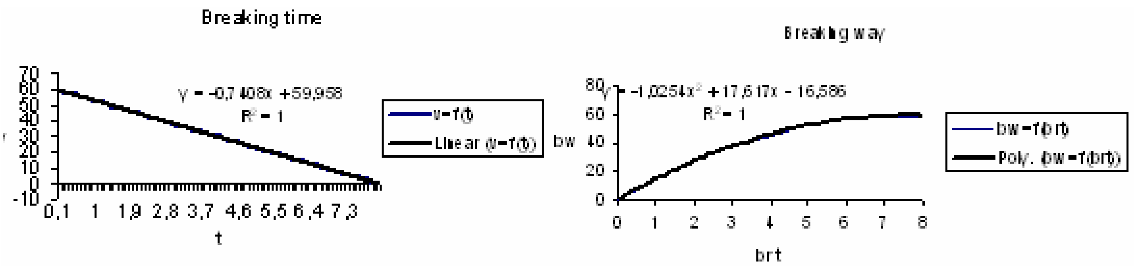
- $brt = f(v_0, v_1)$, $bw = f(brt)$ – breaking time and way from v_0 to v_1;

Discrete data were taken for analysis as a result of tram T3-A model simulation. Time steps for discrete data are following: $\Delta t = 1$ sec for rolling and $\Delta t = 0.1$ sec for breaking.

The approximation was made by trend line creation for dependencies of breaking and rolling by different speed v_0 values: $v_0 = 10$, $v_0 = 20$, $v_0 = 30$, $v_0 = 60$, $v_0 = 100$ and $v_1 = 0$ km/h.

An example of approximated formula's definition is shown on Fig. 6:

- breaking speed: $v = f(brt)$ (Fig. 7, a);
- breaking way: $bw = f(brt)$ (Fig. 7, b).



a b

Fig. 7 Approximation by $v_0 = 60$, $v_1 = 0$ km/h

In approximated formulas rotation speed is used: $n_0 = v_0*(1000*7.43)/(3600*3.14*0.655)$.

After approximation of parameters the following formulas are calculated:

breaking time: $brt = \dfrac{-(v_0 - v_1)}{-7.425}$;

breaking way: $bw = -1.02t^2 + 0.276 \cdot n_0 \cdot brt$.

The aproximated formulas are workable for speed between 0 and 100 km/h with time derivation ±2 sec and distance derivation ±4 m.

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7. Experiment with computer

The specific modelling environment is developed by the authors for computer experiment.

For the practical example object the tram system in Riga centre is taken. The part of the route selected for test is the way from the crossroad with "13. Janvara street" and to the stop "Valguma street" for one tram.

All simulation dynamics parameters of a tram are taken from the real tram T3-A.

Minimal speed set for tram is 20 km/h, but maximal 50 km/h.

Fig. 8 presents fragment of tram simulation with speed control. Time used in simulation is calculated in seconds and is relative to the beginning of simulation.

Simulation controls used energy calculation, tram moment speed, average speed, checkpoints, schedule and negotiation result with traffic light on the last crossroad.

Graphics in Fig. 8 present tram speed v and current I_k. Horizontal lines are speed limits v_{min} and v_{max}.

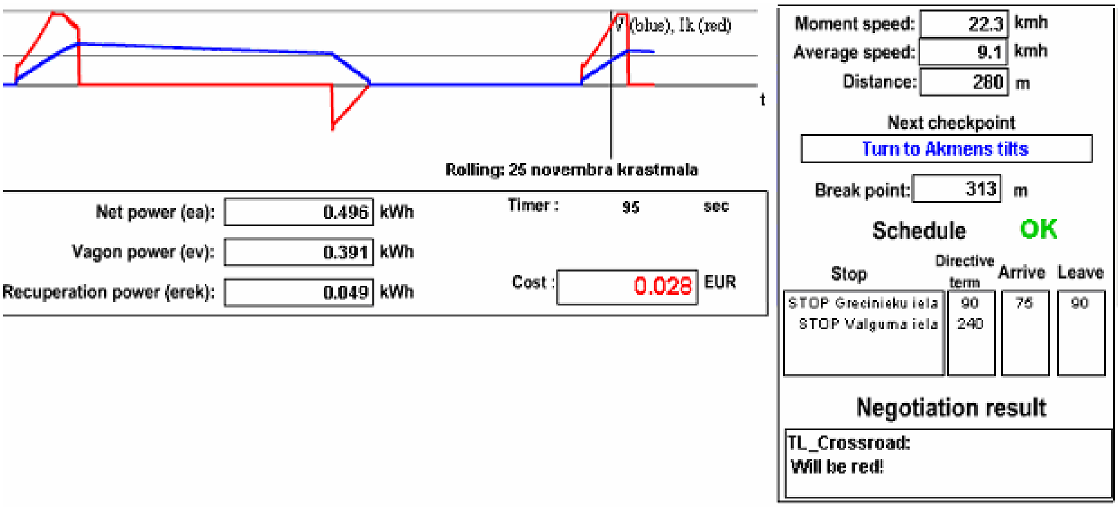

Fig. 8 Fragment of simulation

The results of simulation are presented in Table 1. The advantage of using speed control is obvious. It gives possibility to reduce the energy consumption at least by 25%. In both cases the directive time is satisfied (Tables 2 and 3).

Table 1

Energy consumption comparison (1 kWh = 0.064 €)

Mode	Energy used, kWh	Cost, €
Normal mode	1.427	0.091
Speed control mode	0.997	0.064

Table 2

Schedule in normal mode

Stop	Directive time	Arrival time	Leave time
Grecinieku str.	90	27	90
Valguma str.	240	160	240

Table 3

Schedule in speed control mode

Stop	Directive time	Arrival time	Leave time
Grecinieku str.	90	75	90
Valguma str.	240	177	240

8. Conclusions

The provided results prove, that the application of the proposed algorithm can be very useful for solving power and electrical technology problems in public electric transport systems.

The algorithm proposed on this stage of the authors work allows to reduce energy consumption by more than 25%. That means, the results of using intelligent agents for speed control in public electric transport motion control allow reducing running costs.

The developed simulation system is very flexible and gives great possibility for realization of new algorithms for public electric transport.

Authors' further plans are to continue the research of using intelligent agent systems in Computer Control of Electrical Technology.

The article descusses possibilities of multiagent systems development for the transports tasks solving in the Internet environment. A practical example for the diagnostics expert system with the using of abstract knowledge base is realised in the practical part. An expert system in WEB environment has been developed with the aim to solve a task of transport safety, one of the most important tasks, to define the reasons of devices failure which could be connected with the problems in the area of transport safety. The applied information technologies are PHP and MySQL for the testing of the algorihtm bt there are also plans to make a detail analisys of software. It is easier to apply the Internet for this aim as it is available anywhere 24 hours a day.

References

1. **Stepanova, Y., Baltskars, P., Shabarova, E.** The analysis of railway transit transport flows in Latvia. -Scientific Proc. of Riga Technical university. Transport and Engineering, Railway Transport.- Riga: RTU, v.6(12), 2003.
2. **Luger, G. F.** Artificial Intelligence. Structures and Strategies for Complex Problem Solving. -Williams, 2003. -863p.
3. **Rankis, I., Brazis, V., Simakof, A.** Simulation of tramcar's energy balance.-2nd Scientific Conf. Simulation, Gaming, Training and Business Process Reengineering in Operations, Riga, Latvia, 2000, p.160-163.
4. **Rankis, I., Gorobetz, M., Levchenkov, A.** Optimal electric vehicle speed control by intelligent devices**. –** Scientific Proc. of Riga Technical University. Power and Electrical Engineering.-Riga, RTU, v.4(15), 2006.-10.p. (in publication).
5. **Grundspenkis, J., Isajeva, L.** Qualitative Analysis of Port Organisational Structure Characteristics. -HMS 2003, Riga, 2003. -7p.
6. **Kunicina, N., Levchenkovs, A., Ribickis, L.** Logistic expert systems and artificial intelligent in electric power. – Proc. of 19th European Conf. on Modelling and Simulation ESM 2005, p. 211-215.
7. **Dirba, J., Ketners, K., Levins, N., Pugačevs, V.** Transporta elektriskās mašīnas. -Riga: Jumava, 2002. -342p. (in Latvian).