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Electronic Parking Control Systems

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Introduction

Near all big shopping and leisure centres big concentration of vehicles are allocated. These big vehicle concentrations can cause traffic jams in the parking area and in the areas near these objects. All this rising traffic flows can cause: rise exhaust gases in the parking area, bigger possibility of accidents such as fires, terror actions and others. In these areas usually not only cars but also peoples are constantly visiting, so if we have big vehicle concentration in one place (especially in the closed, or multi floor parking areas) we have to take care of area air ventilation, lighting, heating and others.

One of the ways to help to solve these problems is electronic control systems. To help solve these problems we can use many different electronic control subsystems:

- Parking guidance;
- Traffic jams detection;
- Traffic jam control;
- Parking area payment;
- Intelligent parking area administration and handling;
- Emergency situation control;
- Interface systems to city traffic control systems;
- Parking area ventilation and lighting control.

To create optimal and well running parking control system all subsystems have to be divided to the hierarchical levels, all functions and algorithms described and information flows have to be distributed. Adjusted parking control system hierarchy is shown in Fig. 1 [1,2]. Parking control system hierarchy consist of 3 layers: 1st layer is for parking coordination - where parking control strategy is described, 2nd layer is adaptation – where parking area control strategy is prepared for control layer parking area information is processed and 3rd layer is control – traffic flows are controlled and all data is collected.

Near recently opened big shopping and leisure centre “Akropolis” big multi floor parking lot with 2500 parking places was opened. To ensure best performance of this parking (as every day 4000-10000 cars are visiting this parking lot) – electronic control systems was implemented: parking guidance, traffic jams detection and control, intelligent administration and handling, data collection, emergency situation control and control of lighting and ventilation. All these systems was developed, installed, tuned, tested and experimental data collected for modelling of processes happening in the parking areas and in near locations of these parking-lots.

Parking guidance systems

Not only physical and architectural solutions (parking roads width, rise and down ramps structure, parking traffic structure and others) can optimize traffic flows in the parking areas, but parking guidance systems also can help on reaching these results.

For many tasks solution parking guidance system was developed and installed. Main tasks which parking guidance system solves is:

- Maximum decrease time of searching free parking space;
- Reduce possibility of traffic jams in the parking area;
- Reduce possibility of traffic jams in the roads and intersections near parking area;
- Gradually distribute incoming cars through the parking area;
- Give necessary information for traffic lights systems;
- Inform about too long parked vehicles;
- Collect statistical information about object attendance;
- Decrease quantity exhaust gas in the parking area;
- Locate possible fireplaces in the parking;
- Decrease possibility of car accidents;
- Central and distributed parking administration and handling;
- Control lighting and ventilation systems.

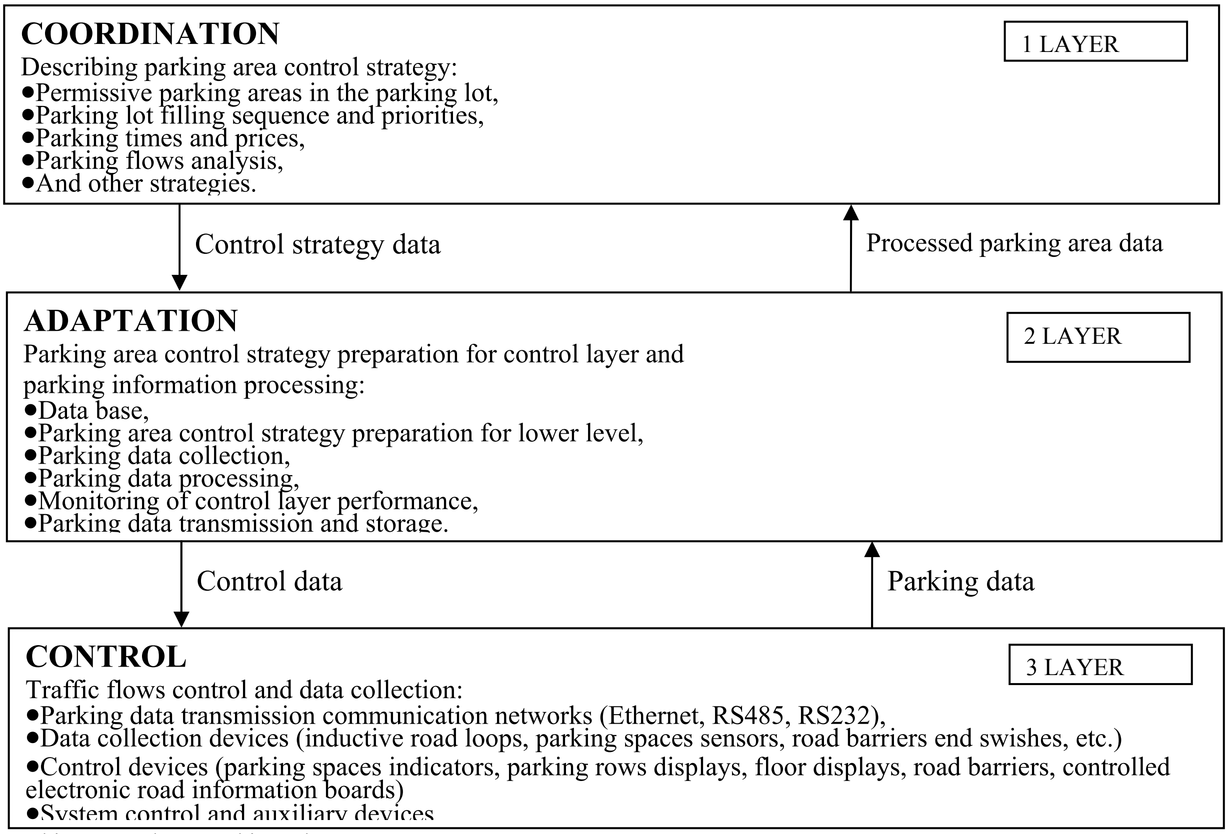

Fig. 1. Parking control system hierarchy

Implemented parking guidance system architecture with hierarchy layers is shown in Fig. 2. Lowest layer: parking space sensors and indicators, parking places displays and concentrators are communicating through RS485 bus. Middle layer equipment: parking concentrators, traffic controllers, servers with databases communicating to each other and to other layers through Ethernet network. Highest layer is management PC's with application software's .

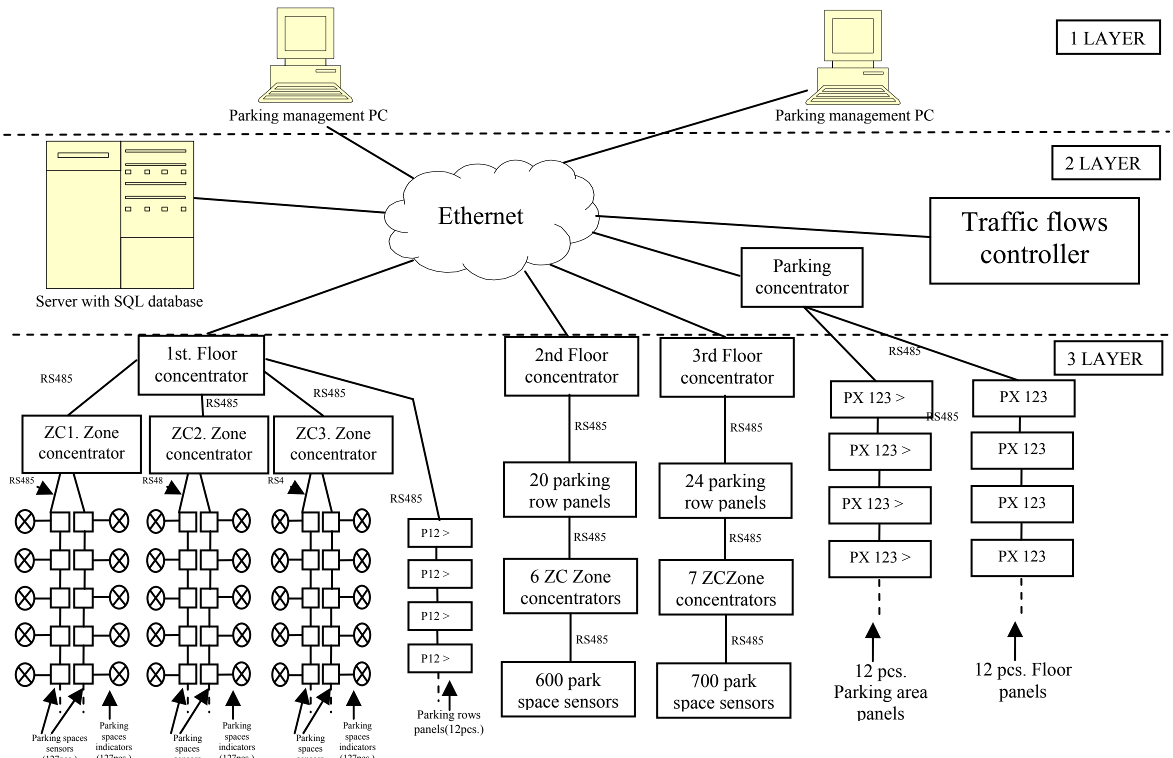

Fig. 2. Parking guidance system architecture

One of the main target for parking guidance system is to decrease vehicle time of searching free parking space and decrease traffic flows in the parking area. Principle of parking guidance system is: in each parking space ultrasonic vehicle detection sensor and LED indicators (green/red) are installed, on each parking row, entry roads and on raise and down ramps free parking places displays with direction arrows are installed also different counters, controllers and other equipment is integrated. So when vehicle arrives to the parking area driver by the parking spaces displays is leaded to the parking row where is enough free parking spaces and then he is directed to the free parking space by parking spaces indicators. In this way time of searching time and traffic flows are decreased as drivers do not going rounds through parking searching free parking space. An example of car cruising and searching free parking space with and without parking guidance is showed in Fig. 3–4.

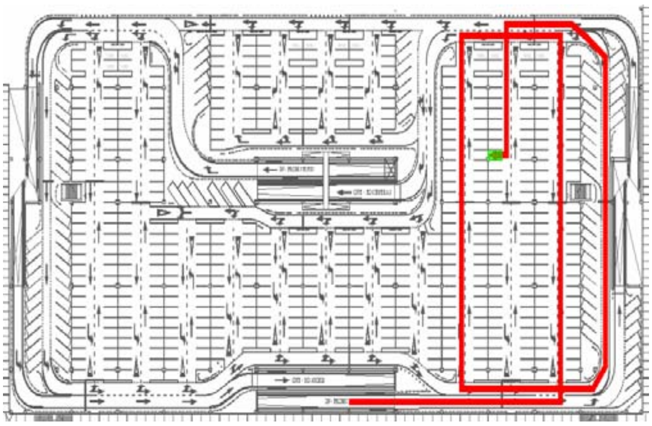

Fig. 3. Example of car cruising through parking without electronic guidance system

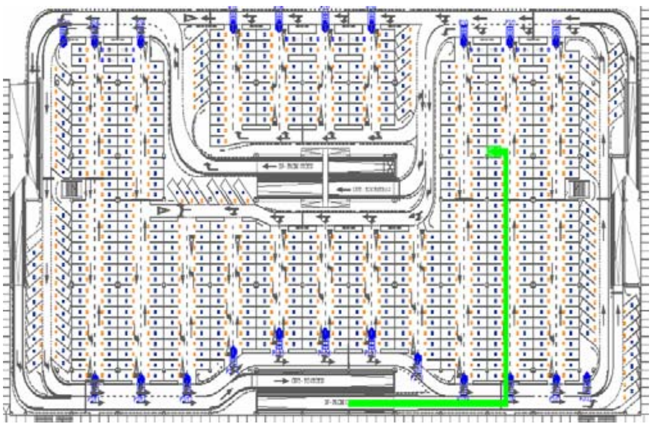

Fig. 4. Example of car cruising through parking with electronic guidance system

Before and after parking guidance system was implemented experiment was done and vehicle searching free parking space times was measured. During experiment 150 measurements was done and results are shown in Fig. 5. Results showed that average parking space searching time without electronic parking guidance system $t_{p.vid.o} = 84s$ and with electronic parking guidance $t_{p.vid.p} = 55s$, so we have time decrease of 65%.

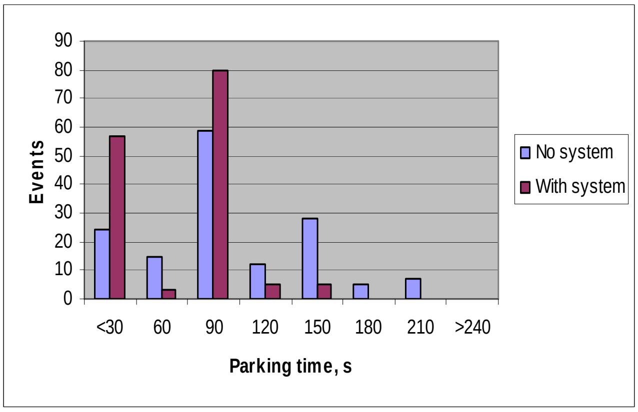

Fig. 5. Time histogram of searching free parking space with and without electronic parking guidance system

Traffic jams control system

Next no less important parking control system target is to detect and control possible traffic jams. Parking control systems part is traffic jams recognition and control systems. Few types of traffic jams in the parking-lots can be described: traffic jams on entry/exit roads, on raise and down ramps and on roads to parking lines. Best way to avoid such a jams is to detect not only traffic jam which is already formed, but to detect raised possibility of forming traffic jam. If we can detect the raised possibility of traffic jam formation we can take actions to avoid this traffic jam by: closing some entries exit roads, parking areas, inform drivers to avoid some suspicious places and in this way avoid traffic jams. So main target is to find phenomenon appearing before traffic jam is formed and inform drivers one step ahead.

To find such a phenomenon appearing before traffic jam is formed in the parking-lot 12 inductive road loops was installed. Inductive road loops are installed on the entry/exit roads and near each rise and down ramps. Automated measurements and registration system was created to collect traffic data, see this system structure in the Fig. 6. Over 500000 measurements were done during this experiment.

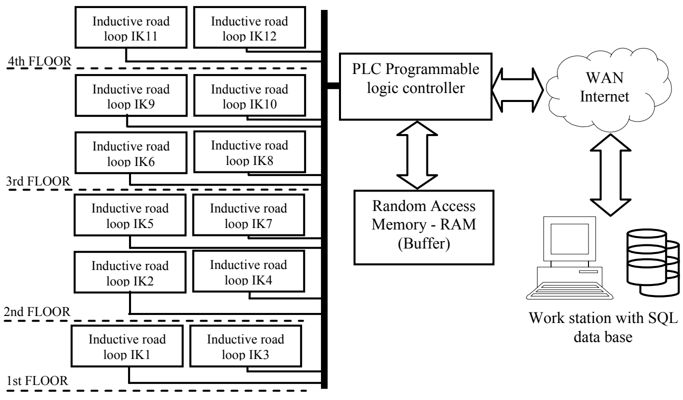

Fig. 6. Traffic jams detection and automated measurements and registration system structure

Two main parameters was registering during this experiment: time between cars passing inductive road loop and time of cars passing inductive road loop (cars speed). Two characteristic days was selected for analysis. One day is one of the shopping and leisure centre opening days (07.04.10) when parking lot had 10200 incoming cars per day also had formed traffic jams time to time and common working day (07.04.24) when parking lot had 4500 incoming cars and no traffic jams. These two days (opening day low attendance day) results histograms of two entry roads are shown in Fig. 7–10.

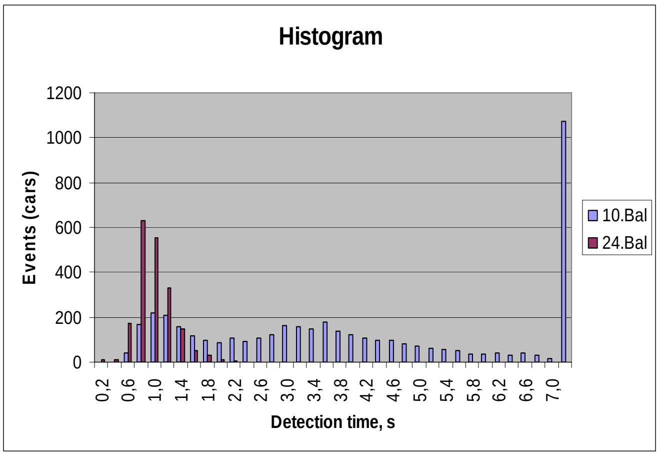

Fig. 7. Histogram of times cars passing inductive road loop incoming from 1st entrance

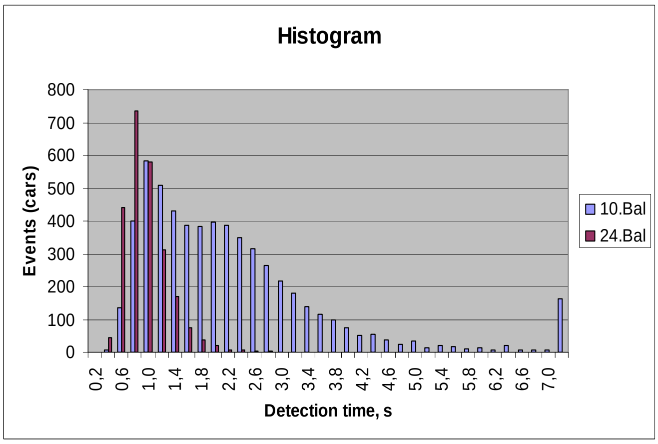

Fig. 8. Histogram of times cars passing inductive road loop incoming from 2nd entrance

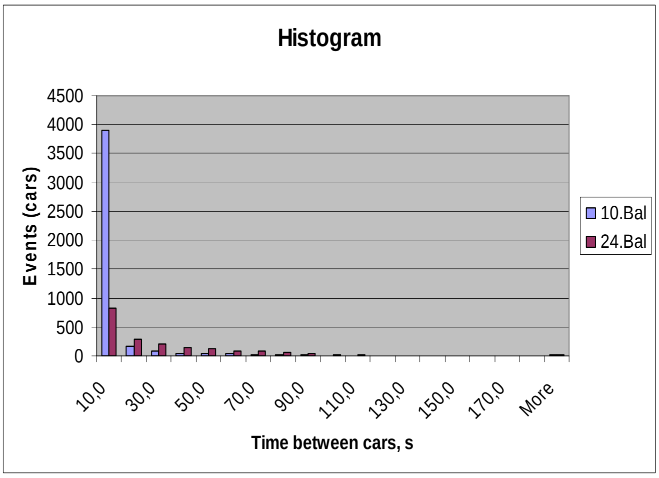

Fig. 9. Histogram of times between incoming cars from 1st entrance

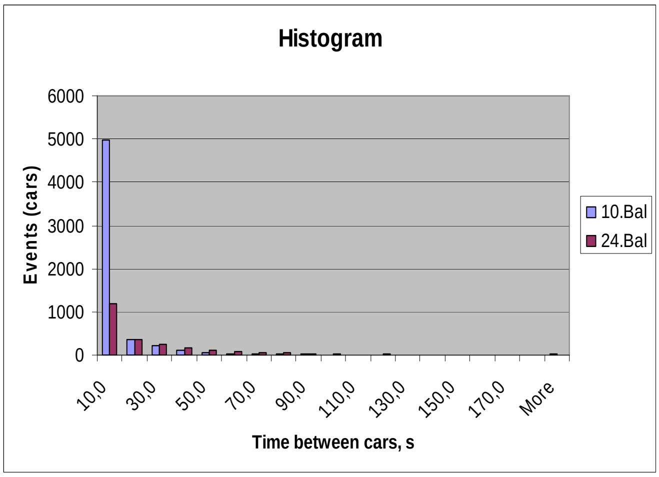

Fig. 10. Histogram of times between incoming cars from 2nd entrance

Analyzing two characteristic days collected data and histograms we see that times of incoming cars passing inductive road loop (speed) times is much bigger on the day when parking lot had big quantity of incoming cars and some traffic jams formed. So incoming cars speed when traffic jams occurring is much slower and histograms are showing it. Times between incoming cars are also different on these two characteristic days: on the day when jams was formed and big vehicle attendance was times between incoming cars was shorter comparing to the common working day, so the cars are going much closer to each other. Made an analysis we see that using this data we can forecast possibility of traffic jam formation.

Process simulation

To recognize and forecast traffic jams in the parking-lot model with neural network using Levenberg-Marquardt optimization was done. For the modelling Matlab nftool library was used. Structure of neural network is shown in the figure 11. For training and testing this neural model 510 data sets was prepared. Each data set includes events of times between incoming cars and times of car passing inductive road loop. Half of the data sets represent events which are occurring before traffic jam is formed and half data sets represent simple events when no traffic jam is formed. Output data set was also prepared.

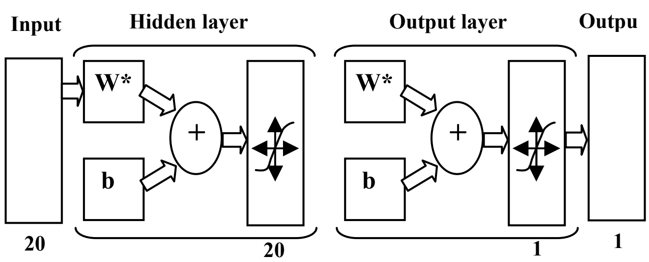

Fig. 11. Structure of neural network

During modelling was tested how many data sets neural network needs to recognize and forecast traffic jam. In 12th figure we can see mean square error pivot to the data sets quantity. And in the 13th figure regression (correlation) coefficient pivot to the data sets quantity we can see.

Fig. 12. Neural network mean square error pivot to the data sets quantity

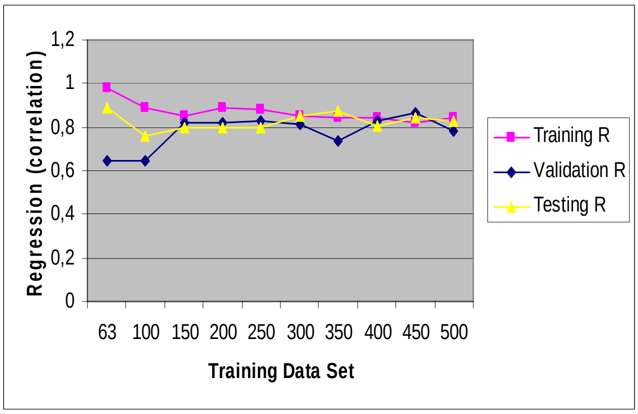

Fig. 13. Neural network regression (correlation) coefficient pivot to the data sets quantity

Mean square errors and regression (correlation) coefficient pivots to the number of events taken to recognize and forecast traffic jams. These pivots are shown in the Fig. 14–15.

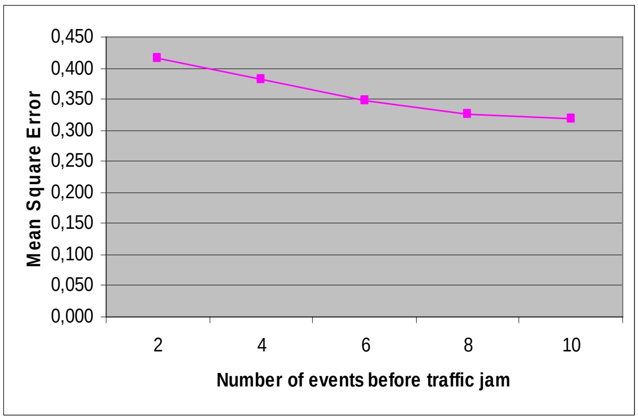

Fig. 14. Neural network mean square error pivot to the number of events

Analyzing the results we see that with neural network we have maximum reached successful traffic jam forecast with probability p=0.82. Also to reach forecasting probability p=0.82 we need minimum 8 events and it is enough 400 data sets to train this network. As it is very important to recognize traffic jam before it is formed so modeling showed that we can forecast it before approximately 5-10 seconds before it is formed.

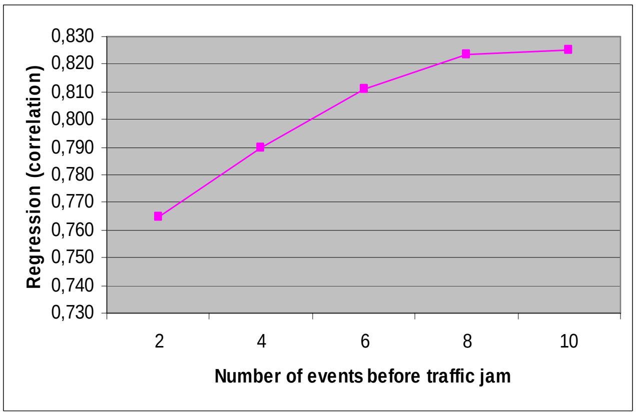

Fig. 15. Neural network regression (correlation) coefficient pivot to the number of events

Conclusions

1. Hierarchy structure of parking control systems was given.
2. Parking control system was developed and implemented to the real parking –lot.
3. Investigation of parking control system was done and experimental data was collected.
4. Experiment showed that Parking guidance and Traffic control systems decreased parking time up to 65%
5. Maximum reached traffic jam forecast with neural network probability p=0.82
6. Modelling with neural network showed that for traffic jam forecast (with probability p=0.82) we need at least 8 traffic events before it starts
7. Modelling with neural network showed that we can forecast traffic jam in approximately. 5-10sec. before it starts
8. Modelling with neural network showed that it is enough 400 data sets to train neural network for traffic jam forecasting with probability p=0.82

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Problems in the big parking lots near big people concentration places were researched. To control processes in parking lots electronic control systems are needed. These systems was analysed, systems architecture and their hierarchy structured. To ensure best performance in the multi floor parking lot with 2500 parking places electronic systems were implemented: parking guidance, traffic jams detection and control, intelligent administration and handling and emergency situation control. All these systems were developed, installed, tuned, tested and experimental data collected for modelling. To model these systems over 500000 measurements were done during experiment. To find a phenomenon appearing before traffic jam is formed in the parking-lot, recognize and forecast traffic jams in the parking-lot model with neural network using Levenberg-Marquardt optimization was done. Experimental and modelling results showed advantages of the Electronic Parking Control Systems. Ill. 15, bibl. 6 (in English; summaries in English, Russian and Lithuanian).

А. Марма, М. Жилис, Д. Эидукас, А. Валиневичюс. Электронные системы контроля автостоянок // Электроника и электротехника. – Каунас: Технология, 2007. – № 8(80). С. 57–62.

Исследованы проблемы в больших автостоянках, находящихся в близости к местам массового собрания людей. Для управления процессов в больших автостоянках нужны электронные системы контроля. Исследованы электронные системы контроля автостоянки, созданы структуры систем, разделены слои иерархии. Чтобы гарантировать хорошую роботу 2500-местной автостоянки были инсталлированы системы руководства по поискам свободного места, детектирования и контроля транспортных пробок, администрирования и система контроля экстремальных ситуаций. Все эти системы были разработаны, инсталлированы, настроены и попробованы, собраны результаты экспериментов. В эксперименте для моделирования системы контроли автостоянки, было собрано больше чем 500000 данных. Методом Левендбера-Маргуардта была создана модель с нейронными сетями для установления процессов, предшествующих транспортным пробкам, обнаружения транспортных пробок, их прогнозирования и контроля. Данные экспериментов и моделирования показали хорошие свойства электронных систем контроля автостоянок. Ил. 15, библ. 6 (на английском языке; рефераты на английском, русском и литовском яз.).

A. Marma, M. Žilys, D. Eidukas, A. Valinevičius. Elektroninės automobilių aikštelių valdymo sistemos // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 8(80). – P. 57–62.

Išnagrinėtos problemos, kylančios automobilių stovėjimo aikštelėse, esančiose prie masinio susibūrimo vietų. Didelėse aikštelėse vykstantiems procesams valdyti reikalingos elektroninės sistemos. Šios sistemos buvo išanalizuotos, sudarytos jų struktūros, suskirstyti hierarchiniai lygiai. Sklandžiam 2500 vietų aikštelės veikimui užtikrinti buvo sukurtos, įdiegtos, suderintos ir išbandytos automobilių statymo palydos, transporto spūsčių aptikimo ir valdymo, administravimo ir ekstremalių situacijų valdymo sistemos. Kontrolės sistemai sumodeliuoti surinkta daugiau nei 500000 eksperimentinių matavimų duomenų. Reiškiniams, vykstantiems prieš susidarant transporto spūsčiai aikštelės prieigose nustatyti ir transporto spūsčiai aptikti ir prognozuoti buvo atliktas modeliavimas neuroniniu tinklu, naudojant Levenbergo ir Marquardto metodą. Eksperimentų ir modeliavimo duomenys parodė elektroninių automobilių statymo aikštelių valdymo sistemų pranašumus. Il. 15, bibl. 6 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).