Research profile of the Faculty of Management Science and Informatics, University of Žilina (FMSI UNIZA)

The FMSI UNIZA is a technical faculty with a focus on information and communication technologies and wide range of their application in interdisciplinary oriented research projects. Our research strengths are focused in five strategic profile lines:

- Decision support systems for extensive service systems (e.g. transport systems)
- Modelling and simulation for biomedical applications
- Computer engineering – automation – IoT
- High performance computing
- Low energy computing

We would like to introduce to you our very successful research teams oriented to the following research topics:

- Agent-based simulation of transportation terminals
- Development of microfluidic devices for detection of circulating cancer cells
- Systems for railway corridors dispatching and basic railway transport planning
- Fuzzy logic with memristive circuits
- Mobile robots and their integration into the IoT world
- Fair optimal and reliable emergency system design

Agent-based simulation of transportation terminals

Head investigator Norbert Adamko

E-mail: norbert.adamko@fri.uniza.sk

Computer simulation is a research method offering a wide range of opportunities to explore systems. It can be applied in various spheres of human life (industry, transportation, crisis management, health service and others) where it helps to save money, optimize the system, improve its effectiveness and protect human lives. Using experiments with a computer model of the existing system, we are able to analyse its features and predict its behaviour in various conditions.

Long-term experience of staff at the Faculty of Management Science and Informatics in modelling and simulation presents a solid foundation for research and development of simulation architectures as well as for implementation of complex simulation tools. Our scientific and research activity is mostly concentrated to the agent-based simulation architecture. Our developed architecture ABAsim (Agent Based Architecture of simulation models) provides tools for creating flexible simulation models of complex service systems such as transportation and logistics systems. A lot of models, successfully applied in business environment as well, is based on this architecture.

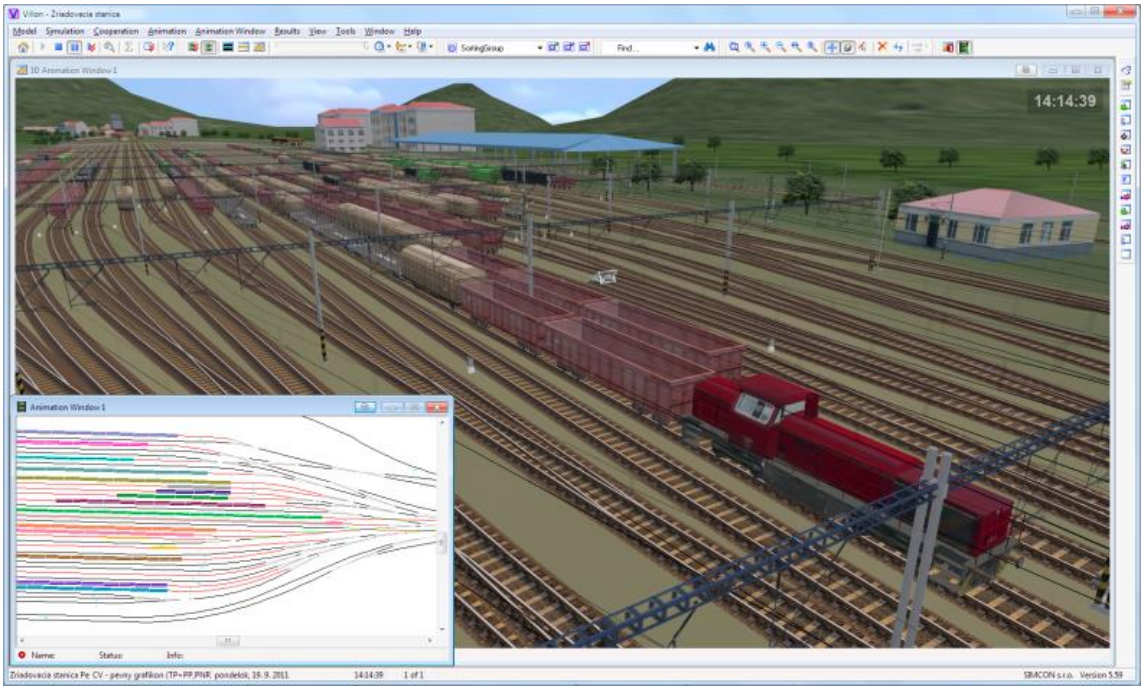

Figure 1: Simulation of marshalling yard operation in Villon simulation tool

An example of successful simulation models developed based-on the architecture ABAsim is the Villon simulation tool – a generic detailed microscopic simulation model of a transportation terminal (e.g. railway station, industrial sidings, container terminal, depot, production facility etc.). The simulation tool has been practically used to solve a large number of designing and optimization

problems of transport logistics terminals in many European and Asian countries (Germany, Austria, Switzerland, China, etc.). Villon helps in designing the infrastructure and verifying terminal operation, in changing transport organization, increasing the production in production facilities or in assessing the interaction of rail and road transport in terminals.

Furthermore, our research is also devoted to the development of a simulation tool for modelling movements and behaviour of pedestrians at the microscopic and macroscopic level called PedSim. Modelling pedestrian movement is used mainly in designing transportation hubs and in the field of crisis management, it contributes to a greater comfort and safety of passengers. Thanks to the employed ABAsim architecture, the pedestrian movement module is (besides the autonomous PedSim tool) also integrated in the Villon simulation tool. This provides a unique ability to create simulation models that include rail and road vehicles, manipulation equipment as well as pedestrians in a single simulation environment, allowing to model their mutual interactions in various types of transportation terminals.

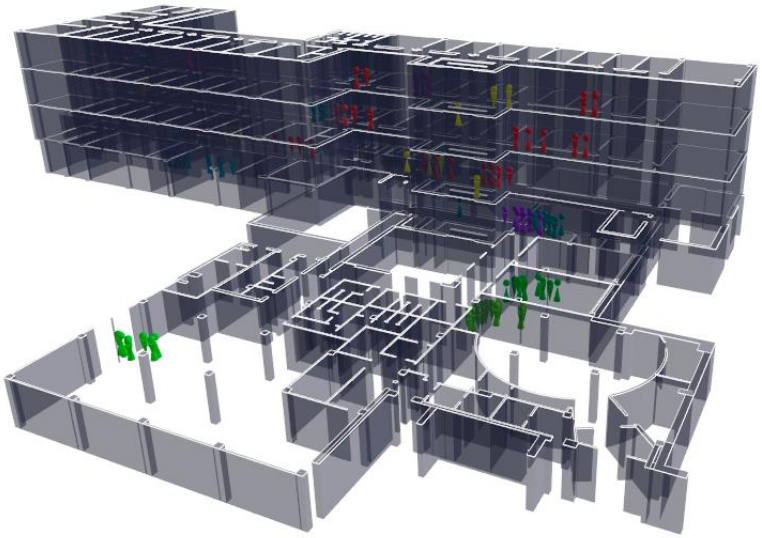

Figure 2: Simulation of pedestrian movement in PedSim simulation tool

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Development of microfluidic devices for detection of circulating cancer cells

Cell-in-fluid Research Group, Head investigator Ivan Cimrák

E-mail: ivan.cimrak@fri.uniza.sk

To design a microfluidic device with predefined purpose may be a hard task requiring a lot of knowledge and experience. Computational modelling belongs to strong and effective tools helping such process. We have developed a computational model which captures the bio-mechanical processes inside microfluidic devices including cell deformation, fluid flow, mutual cell-cell and cell-fluid interactions, cell adhesion. Using this model, we are able to model and simulate different devices such as periodic obstacle arrays, cell retention structures, different T- or Y-junctions, cell isolation channels, etc.

The model governs the fluid dynamics (Fig.1), as well as the elasticity of the cells immersed in the fluid (Fig. 2) During the simulation we have complete information about the cell membrane geometry and about the surrounding fluid. Therefore, we can compute a wide range of physical and mechanical quantities including local membrane stress, shear stress at the cell's boundary, cell velocity, its deformation index. We are able to see the cells' behavior by letting the cell pass various obstacles or retention structures (Fig. 3). With the latest developments of the model, we are able to simulate cell adhesion to functionalized surfaces, which enables modelling of devices for circulating tumor cells isolation.

Parallel implementation of the model allows us to simulate suspensions of thousands of cells which gives statistically significant information about global behavior of the suspension and thus we can model rheological properties of the suspension (Fig. 4). The model is implemented as Object-in-fluid module of open source scientific software package ESPResSo. The detailed documentation provides guidance for biologist with basic interest in modelling.

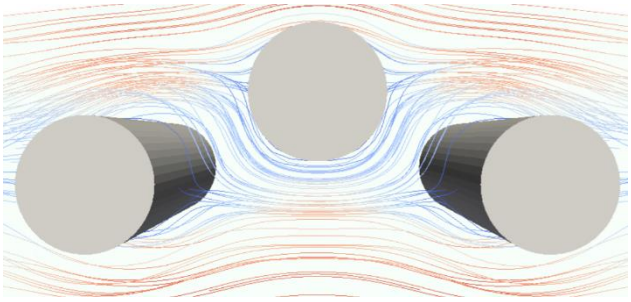

Figure 1: Lattice-Boltzmann method governs fluid dynamics

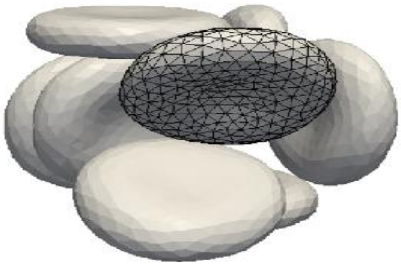

Figure 2: Immersed boundary method is based on the triangulation of the cell's membrane

With this model we have investigated the influence of cell suspension density on cell collision rates in periodic obstacle arrays (Fig. 5). Using simulations, we have discovered a hematocrit threshold, above which the cells do not enter the collision mode. Further, we have analyzed suspensions of red blood cells (Fig. 6) and rare cells in obstacle arrays and the capture rate of the rare cells.

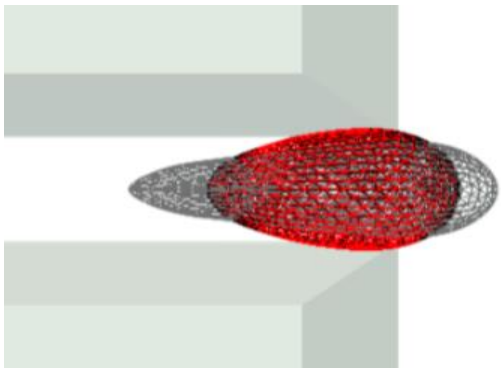

Figure 3: Deformation of elastic spherical objects with different membrane elasticity passing a narrow opening

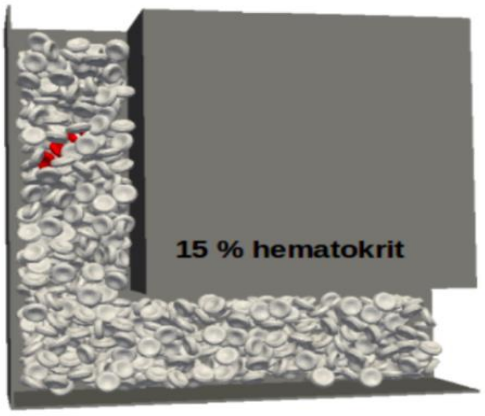

Figure 4: Simulation of red blood cell suspension with 15% hematocrit in a bent channel

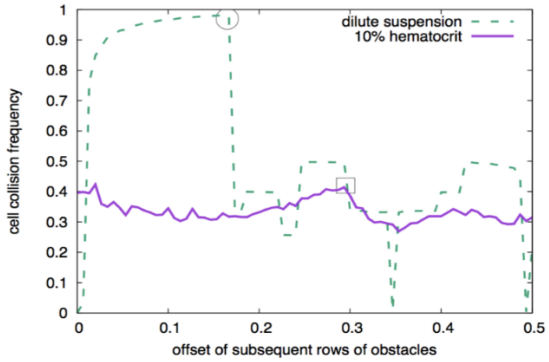

Figure 5: Cell collision frequency equal to 1 means that cell hits each row of obstacles. Lower values mean it passes some obstacles without touching. Maximal offset 0.5 means that the next obstacle is between the previous two, see Figure 6. Circle and square show different maxima for dilute and moderately dense suspensions.

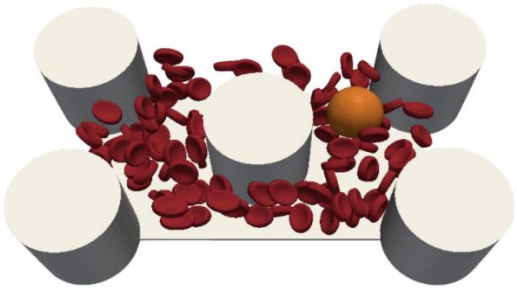

Figure 6: Simulation of a red blood cell suspension with a rare tumour cell giving information how red blood cells influence trajectory of the rare cell and its probability of capture on functionalized obstacles in periodic array

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Information systems for railway traffic planning, controlling and data management

Head investigator Hynek Bachratý

E-mail: hynek.bachraty@fri.uniza.sk

Research group designs, develops and maintenance several large information systems and software tools which serves in many branches of railway transport. All of them are in regular operation, but still under further development and improvement, connected to research and education activities of our department, faculty and university.

Main contractors are

- Railways of the Slovak Republic – infrastructure manager (ŽSR),
- Railway Infrastructure Administration – Czech Republic (SŽDC)
- Slovak railway company (ZSSK) – passenger transport operator Slovakia
- AŽD Praha Ltd (AŽD s.r.o) – Czech Republic,
- Scheidt&Bachmann A.G., Mönchengladbach, Germany

We briefly introduce our main activities and software tools. For more detailed information's you are welcome to contact us.

Expert - Infrastructure data collecting system

Graphic editor of railways infrastructure data developed in 1995-2000. Holds detailed proprietary database of Slovak and Czech railway infrastructure. Master source of infrastructure data for other railway information systems in Slovak Railways.

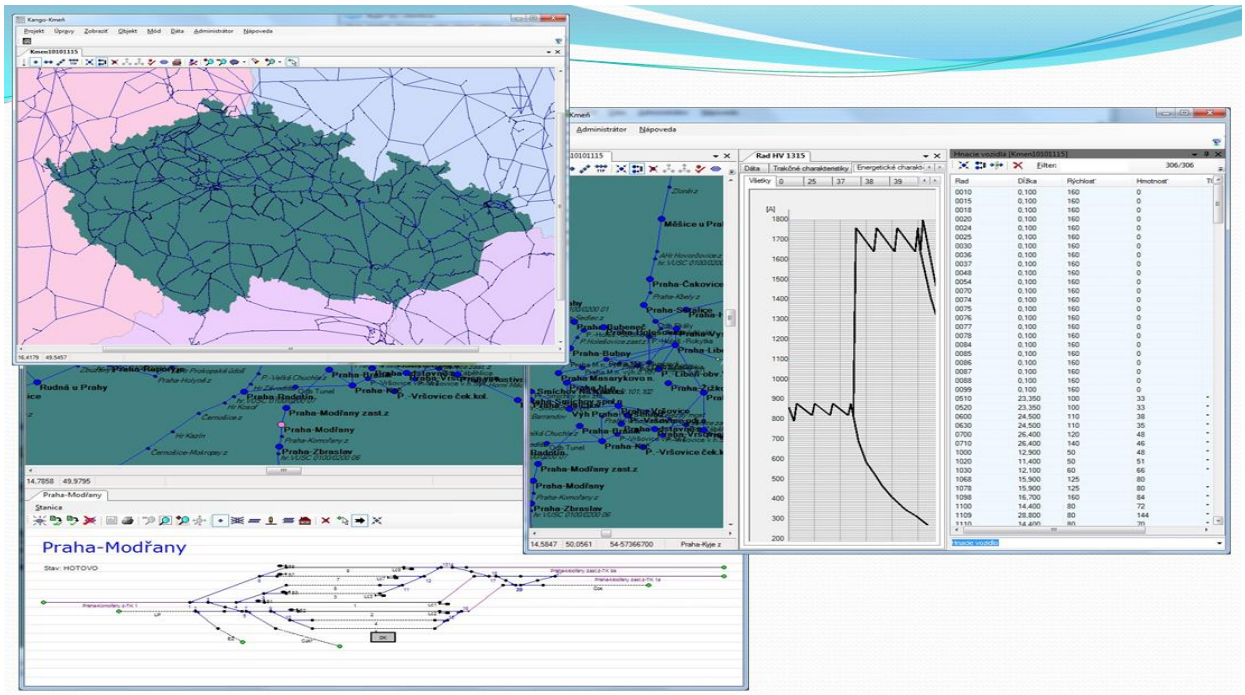

Figure 1 – Expert, KANGO Kmen: systems for railway infrastructure data management

KANGO Kmen – essentially improved infrastructure data collecting system for Czech Railway
Infrastructure Administration, developed 2008-2012. Detailed database based distributed system of Czech railway infrastructure. Master source and management tools of infrastructure data for other railway information systems in Czech Railways

ZONA and SENA railway schedule planning systems
First generation of time-table constructing systems for Czech and for Slovak railways Developed in 1990-1996 and used approximately until 2012-2014 as the main tool for long term railway traffic planning. Represents new approach and fundamental changes of the railway schedule planning process. Gives rise to quality increasing and further usage of obtained digital railroad transport plan.

MET – business train route editor
New generation graphical editor developed and used since 2009 in Slovak railways. Allows the basic input and editing train paths, assigning of train equipment essential attributes (driving vehicle, length, weight, assembly, ...), design of train time position. Strongly connected by two-way communication with the system ZONA.

KANGO-GVD – improved railway schedule planning systems for Czech railways
Based on new software and database architecture, allows centralized on-line timetable construction with new conception of data storage. Used from 2012.

EDYN – new generation of railway schedule planning systems for Slovak railways
New developed time-table construction system with new architecture, user interface and all algorithms and tools. In use since 2014.

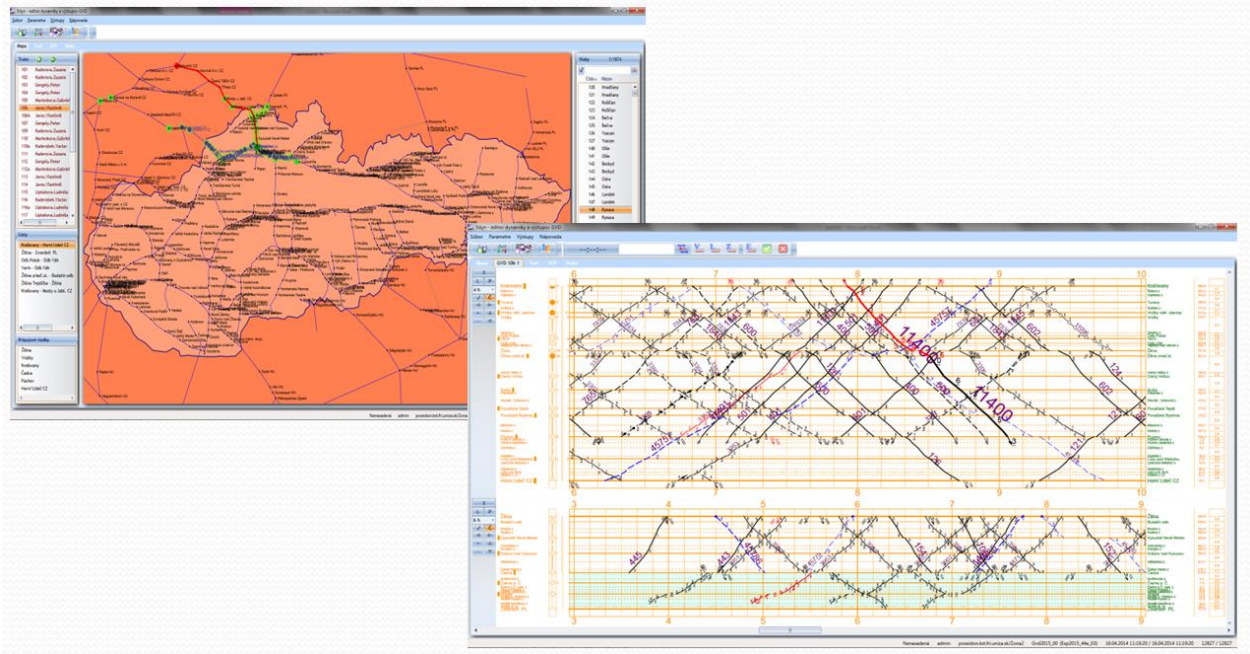

Figure 2 – Edyn - new generation of railway schedule planning systems for Slovak railways

GTN - Information System supporting the dispatcher and remote tracks control

Developed since 1996 in co-operation with AZD Prague Company. Contains a compact data, technology and software model of railway operation. Receiving information from the safety, interlocking and signalling equipment and from the other information and controlling railway systems serves as an supporting tool for dispatchers in the control centres. Performs saving, displaying and documenting of the traffic progression, trains movement and technological operations on them, displays the anticipated prognosis of the traffic situation and transmitting information about trains movement towards external IS, e. g. the passenger information systems at the stations etc. Currently 3rd generation of this system works on nearly 4000 km of Czech and Slovak railways.

Figure 3 – GTN system as a part o fcentral dispatching office

wVis - Train connection searching system

Used by Slovak railway company (ZSSK – passenger transport operator) for external and internal connection search. Developed since 2004 with cooperation of HP company.

EboEdit ERES – railways interlocking and signalling systems configuration Editor

In cooperation with Scheidt&Bachmann company developed and used since 2009 and used for Austrian, German and Poland interlocking systems design.

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Memristive Implementation of Fuzzy Logic for Cognitive Computing

Head investigator Martin Klimo

E-mail: martin.klimo@fri.uniza.sk

Today's digital computers are based on three cornerstones: von Neumann architecture, Boolean algebra, and transistor as the basic element. Approximately 70 year history of this concept has demonstrated a success for algorithmic computing. However, at present its disadvantages begin to appear in real time cognitive computing. Our aim is to elaborate the concept in which cognitive computing acts as a support for algorithmic computing, and the cognitive part is based on non-von Neumann architecture, Zadeh fuzzy logic, and resistive switch as the basic element [1].

We have found [2] that elementary circuits with resistive switches can give result for Min, Max, Avrg functions in voltage domain. This has the significant impact to the fuzzy computer architecture.

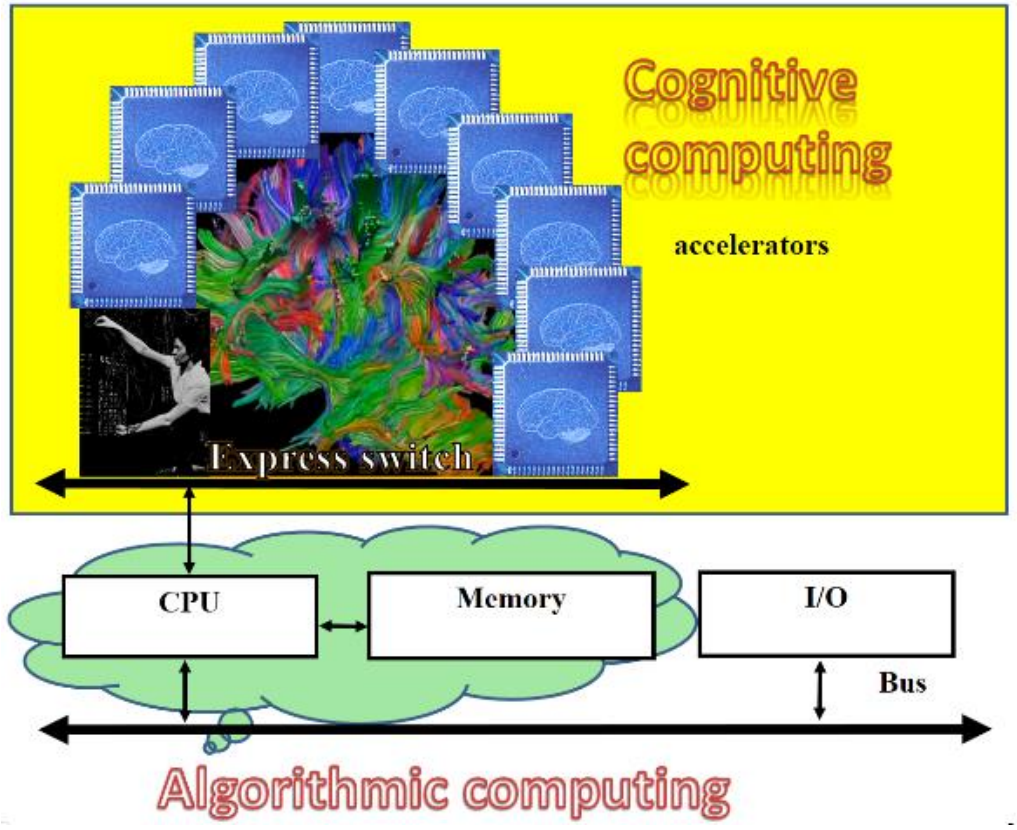

Figure 1 – von Neumann architecture accelerated by non-von Neumann architecture

Fig. 2 shows an example of the implementation of Y=Max(0,X) function using electrochemical metallization memory (ECM) resistive switches NEURO-BIT BT10001B14 [4]. To interpret this figure in terms of fuzzy logic, the input X after normalisation from <-1.5V, 1.5V> interval into <-1,1> interval represents the difference X=a-b in y=Max(a,b); a,b∈ <0, 1> function. Accuracy of mathematical function implementation depends mainly on switching threshold (approximately 0.2V for the measured resistive switches), and measurements repeatability. On the one hand, the non-volatility is useful, but on the other hand, the preservation of the switch state causes a memory-less in the input

– output relation in the Max circuit. More precisely, fuzzy logic circuits have to be assumed as state automata. Everything mentioned above for implementation of Max functions, is valid also for Min functions.

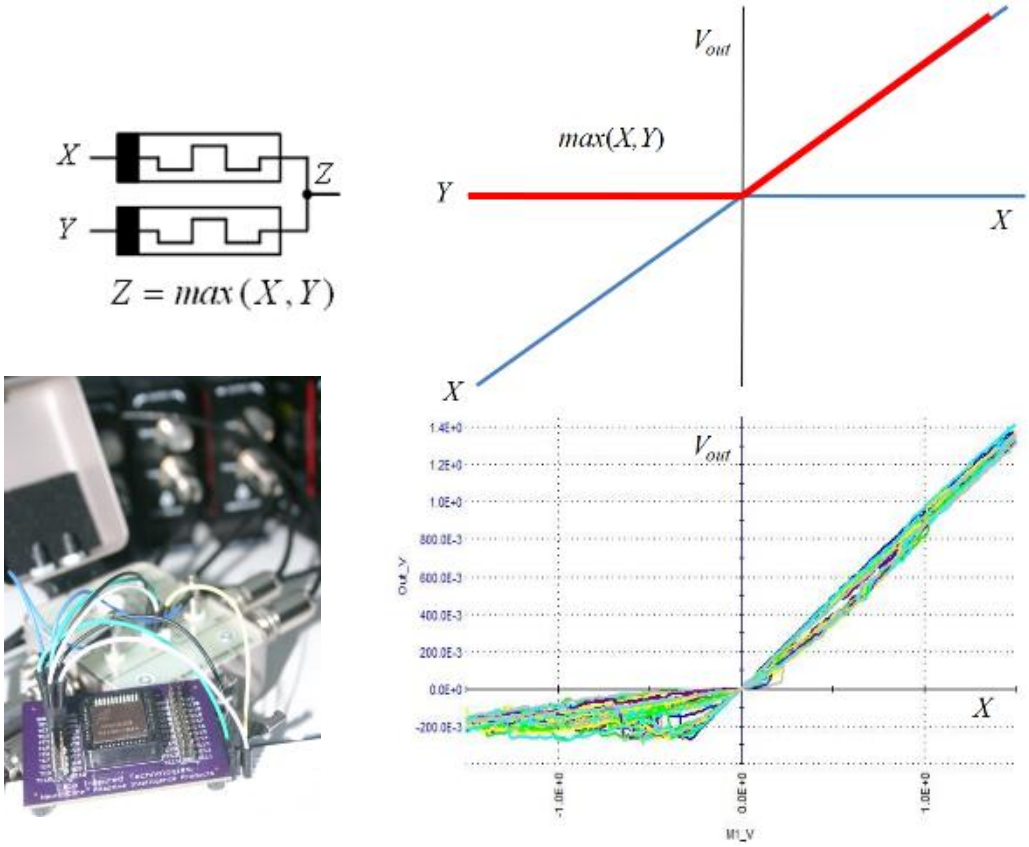

Figure 2 – The input/output characteristic of the Max circuit implemented by ECM memristors NEURO-BIT BT10001B14

Fig. 3 shows an example of the implementation of Y=Min(0, X1, X2) function. As the independent input is taken M1=X1, X1∈ <-1,1>, the second input is set into M2=1-0.7(1+X1), and the third one is a zero reference input. An impact of the switching threshold is visible even more than on Fig. 2.

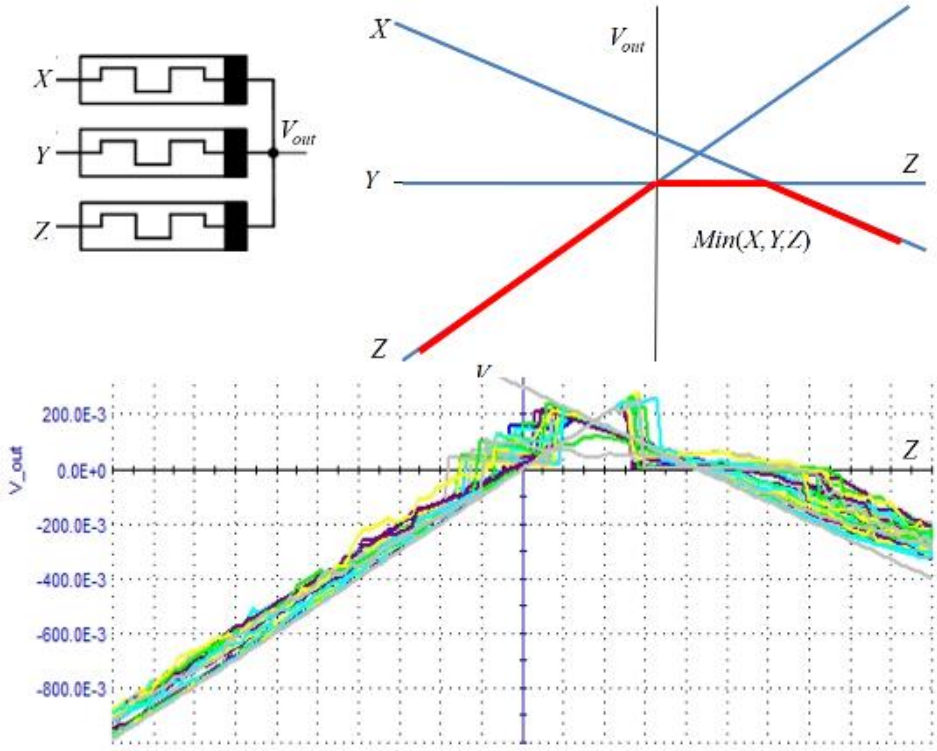

Figure 3 – The input/output characteristic of the 3 inputs Min circuit implemented by ECM memristors NEURO-BIT BT10001B14

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Mobile robots and their integration into the IoT world

Head investigator Juraj Miček

E-mail: peter.sevcik@fri.uniza.sk

Mobile robotics systems for educational purposes come still more and more to the foreground especially in terms of modern teaching. This progress goes hand-in-hand with OpenHW systems advancements, which enable a wide community of people to enter the world of computer engineering.

Yrobot high-school education kit was for the first time introduced at 2014 RAAD conference. From that time, already after 18 months, the robot was successfully integrated into the educational process in more than 20 high schools in Slovakia. During 2015, we decided to extend the kit with additional application modules to target an actual problematic of wireless communication and derived areas, such as Internet of Things; Collaborative Signal Processing; Distributed Signal Processing; etc. For that reason, Yrobot modules „Y-WiFi“, „Y-BlueTooth“ and „Y-ZigBee“ were introduced.

These modules can be easily installed within the platform, where provided functionalities, which can be easily translated into educational process. Especially in the popular fields such network administrator or network specialist.

To understand the concept of Yrobot, we have to mention an effort of Volkswagen Foundation, which was supporting the project continuously from 2013. The idea behind was to develop an educational kit that can be used for the purposes of IT education among the Slovak high schools. Original intent of authors was, by using of a simple technical device, to increase the motivation of secondary-school-students in the study of technical fields. Among the others, especially to arise their interests in information technology. The concepts of the system, its features and functions, as well as initial results from deployment in teaching were presented in international conferences on robotics.

As supporting activities, different workshops, where particular teachers got in first touch with the platform, were realized. To facilitate the work with Yrobot, the textbook where basic principles together with programming examples were described by the usage of simple, friendly and easy-to-understand way was published (Figure 1).

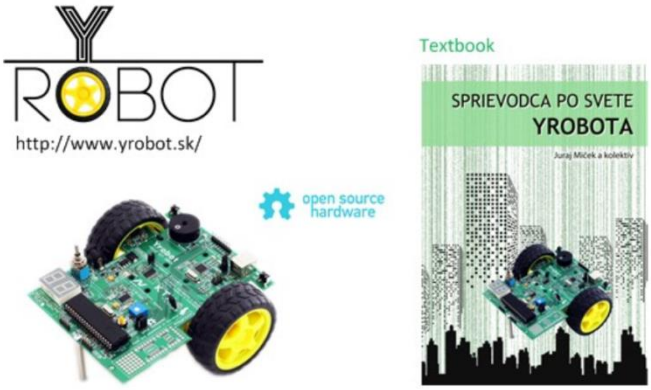

Figure 1 – Yrobot with textbook (Slovak Release)

RF Communication Expansion Modules

The Yrobot was originally developed as an autonomous Yrobot device capable to solve simple tasks by reading the status info of installed sensors (e.g. moving across the line, avoiding obstacles, discovering the space, ect.). Implementation of wireless communication allows transformation of Yrobot from single and autonomous functioning to robust multirobotic system able to solve the robust challenges and to bring the complex solutions. For an effective operation of the system it is possible to use various communication technologies, protocols and different network topologies. In our approach, we decided to implement three separate communication modules operating in the 2.4 GHz ISM band.

Figure 2 – Yrobot with Y-WiFi module

An extension of the Yrobot kit by the set of network modules significantly expands the variety of applications that can be implemented under it. The kit is since its inception conceived and designed for the needs of teaching of subjects in IT. In addition to this primary function, the kit serves also the popularization function. The kit should be used for an encouragement of the students for the study of the technical subjects/fields.

In the near future, the focus will be put on the development of interesting and original applications designed according to experiences with the communication modules usage. The delivery of supplementary textbook is in this case more than necessary. In the textbook, the basic capabilities of individual RF network technologies supplied with the simple examples, that will illustrate the benefits and limitations of wireless communication, will be described. Hopefully, other interesting applications, which could motivate the students to the own further development, will be part of the textbook too.

Further steps are, beside the textbook development, oriented in the development of additional modules in the field of RF communication. At the present time, RFID, NFC, Z-Wave modules, together with the chosen proprietary communication systems in the free ISM bands (e.g. RFM70), are being developed. It is expected that these extensions will expand the current status of the kit with other interesting ICT applications.

Fair optimal and reliable emergency system design

Head investigator Jaroslav Janáček

E-mail: jaroslav.janacek@fri.uniza.sk

Efficient and reliable emergency rescue systems, such as emergency ambulance system, police or fire brigades, are important for everyday life of concurrent societies. To ensure the reliable services, that an emergency rescue system has to provide, it is important to consider the reliability criterion, when the system is designed and not only while it is already in operation. The reliable system should have the ability to withstand consequences of failure events that may occur as the system is serving users. The probability of such events is relatively low but such events may have serious consequences and may significantly affect the quality of services that are provided by the system. In addition, very often when designing the emergency rescue systems, it is applied the criterion taking into account "the average user". As a consequence, the proposed system is incompatible with the requirements/expectations of users – taxpayers, who would like to have an equal (fair) access to the offered services. Here arises the need to apply fair approaches when placing service centres, which are able to consider for example the situation of the worst placed user. Emergency rescue systems can be considered as public service systems.

Our research team has long-term experiences in developing algorithms and decision support tools to solve large-scale public service systems based on modern information technologies which enable providing an effective decision support on how to use available resources efficiently to achieve various goals. Such decision support tools are necessary mainly if there are many feasible solutions available and it is not easy to choose the best ones or it is hard to find any solution which would meet the requirements at all. From the viewpoint of designing a solution for a defined decision problem, the first step consists of creating a model expressing the desired objective and a mathematical expression of the options how to achieve the objective. Using a suitable optimization algorithm integrated into a decision support tool, one or more feasible solutions can be found. The solutions are then provided to people responsible for decision-making in the particular field.

The field of designing the structure of emergency rescue systems has been one of our core research areas for a long time. Currently, we deal with the research projects that has the following objectives:

- To propose methods allowing considering various criteria of fairness in access to the provided service and propose efficient algorithms for designing reliable emergency systems
- To propose algorithms that will be able to solve tasks with quality criterion, which is more complex than commonly used min-sum criterion. We focus on criteria, where user interaction with multiple centers is taken into account and criteria, which reflect stochastic properties of the system such as reliability.
- To acquire new methods and techniques for solving public service system design problems with fair sharing criterion
- Based on real examples, to evaluate the relationship between the service system effectiveness and the fairness level in access to services that the system provides

Development of optimization methods

In the field of optimization methods, we are seeking new possibilities of applying general optimization tools such as Xpress-IVE. Here, we have proposed efficient methods of approximate solving of location problems by their transformation to a case of set-covering problem that is less time consuming. In the field of specialized algorithms, we have suggested and developed new exact algorithms that enable effective solving of large-scaled location problems. Furthermore, we focus on development of new heuristic and evolution algorithms.

We use experiences that we have collected while solving our research projects where we dealt with mixed integer problems and with the optimal design of public service systems. We built tools that are able to solve real-world instances of public service system design problems. Considering, that the application area of these projects were public service systems, the suitability of the resulting system design is typically evaluated using the sum of all costs that are proportional to the distance between users and facility locations. In addition to this, we have also modelled the demand of users using utility. Special case is the utility that takes into account individual users. This approach leads to the fair optimization and objective function that take into account equality. Considering the equality criterion, we have constructed the approximate algorithm that allows to find high quality solutions for real-world sized problems.

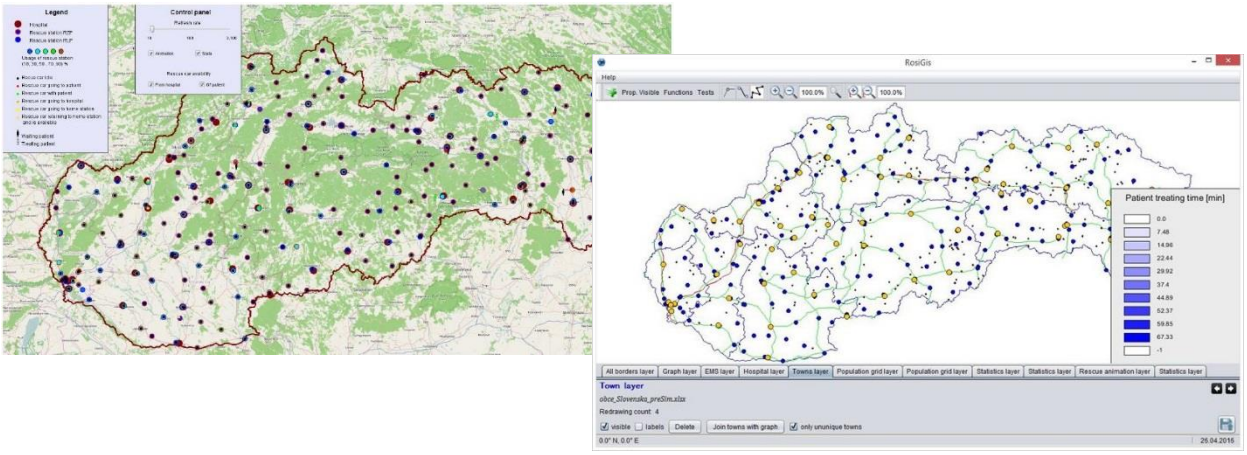

Figure 1 – Evaluation of emergency medical system proposal (location of ambulance stations)

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… in brief

Faculty of Management Science and Informatics, University of Žilina was founded on July 17th, 1990 by approval of University Senate. The main idea of foundation was integration of developing knowledge from ICT in the Faculty Programmes of study. That was above all students and staff from Department of Technical Cybernetics existing from 1972 on the University (in that time University of Transport and Communication, Faculty of Mechanical-Electrical Engineering). From this time University and Faculty were going through many changes and development connected by evolution, as well events, caused by society changes and corresponding legislative.

In previous academic year, we have celebrated the 25th anniversary of the Faculty of Management Science and Informatics.

Faculty of Management Science and Informatics is one of the seven Faculties at University of Žilina, where are:

- Faculty of Operation and Economy in Transport
- Faculty of Electrical Engineering
- Faculty of Mechanical Engineering
- Faculty of Civil Engineering
- Faculty of Security Engineering
- Faculty of Humanities

Activities of the Faculty are determined by new trends of information and communication technology development, where the high priority task is to insure the continual interconnection between research, education and acceptation of postgraduates in the praxis. The main education and professional activities lie with fields as design and realization of technical tools for information and control systems, analysis, synthesis and design of integrated information and control systems, management, marketing, logistics, entrepreneurship, activity of transportation and communication systems, control and optimization of goods and passenger transport, control and optimization of databases design and their transmission and data processing, problematic of multimedia information systems and graphic information systems, simulation mediums for communication networks and systems and mathematical modelling.

Faculty consists from seven departments:

- Department of Informatics
- Department of Information Networks
- Department of Management Theories
- Department of Mathematical Methods and Operations Research
- Department of Macro- and Microeconomics
- Department of Software Technologies
- Department of Technical Cybernetics