

# THE LABORATORY OF EVOLUTIONAL COMPUTING

*T. Ágh, M. Blaho, S. Bartoš, M. Foltin, M. Kollárčik, I. Sekaj*

Department of Automatic Control Systems, Faculty of Electrical Engineering  
and Information Technology,  
Slovak University of Technology, Ilkovičova 3, 812 19 Bratislava, Slovak Republic

## **Introduction:**

Modern methods to improve the system of education are used by many world universities. The global communication network - Internet - represents a great possibility for building virtual laboratories. The goal of our project is to build a virtual laboratory by joining the tools of numerical modelling, graphic displaying tools and network technologies. Interactive educational system based on virtual laboratory enables the student to make experiments and so to gain experiences by working independently. The experiments are made on virtual models which are characterised with minimal operation costs and the acquisition cost is a fraction of the real technological device's price. The point of this text is to briefly summarise our electronical learning knowledge, to explain the principle of functioning of virtual laboratories and to describe our virtual laboratory which is focused on evolutionary computing methods. The use of illustrating examples was logically followed on the nature of virtual solution. Many of the visualisations were made in virtual reality.

## **1. Analysis of the present state of virtual laboratories**

At present, one of the possibilities of improving the system of education is the use of the world-wide communication network - Internet - for building of virtual laboratories. The main advantage of such a solution is great accessibility for students – the access is possible anytime from any place in the world. All you need is just a computer with Internet access and web standard browser. Student can be familiarised with big amount of processes what could not be realised in classic laboratory. There is also the possibility of studying subjects on universities in a different city or country without the need to travel.

There are two basic components of interactive educational system which need to be differentiated. First of them – *eLearning* deals with the method how exactly study. Mostly are used web applications. These sophisticated programs consist of different modules which provide particular parts of studied problem. The virtual teacher can control the education process by making user profiles, controlling access rights and implementing the determined form of verifying adjusted knowledge of the students.

The second important component – the *virtual laboratory* deals with the interactivity with student. The object of these applications is to enable the student to make active experiments and so to gain experiences by working independently and to motivate him towards individual problem solutions. The experiments are being made on virtual models what significantly reduces the acquisition, operation and upkeep costs. Very important is also the question of safety – in case of using the virtual model with improper settings an injury or damage on the technological device can never occur. The user will be always warned in time or he will notice incorrect behaviour which will be of course not destructive.

In principle we can divide these interactive applications from the view of execution into the server and client applications. *Client-side* applications represent solutions mostly in *Java* language. This application burdens the processor of the client and has no significant influence on the server. The disadvantage is the need of finding universal and simple approaches so that most of the clients will be satisfied. The difficult aspects of this solution are system actualisation and also solving of individual problems. Virtual laboratories based on the *server-side* system are implemented with assistance of high-performance computing environments. Their kernel runs in background as a service and is used by every request from the client side. Well-known solution is Matlab with the MatlabWebServer module.

## **2. The project of virtual laboratory**

The project assumes developing of universal and extensible way of publication. We start from well-known conceptions of internet solutions. The navigation, publication and computing systems are implemented on the server side what respects the demand of minimal software requirement on the client side – everything that client needs is newer web browser (with virtual reality plug-in, which is not necessary).

The chosen operating system Windows 2003 Sever offers in case of insufficient computing performance the possibility of creating so-called computer cluster by connecting more servers into it. This set will be working as one server with performance representing sum of all connected servers computing performances. Because of this there is no need to develop algorithms for task distributing – such an algorithm is implemented directly in operating system. The virtual laboratory can be operated also on different platforms.

The essential part of the web application is operating of web server. In this project we have preferred web server Internet Information Server 6.0 (IIS 6.0) distributed with operating system windows 2003 Server to the well approved open-source product Apache. As an extension of the

web server (IIS 6.0) we have chosen the module of dynamic script language php ([www.php.net](http://www.php.net)) in combination with open-source sql database mySQL ([www.mysql.com](http://www.mysql.com)).

For programming of applications we decided to use the product Matlab version 7.0 from the company Mathworks Inc. This complex product offers lot of extra functions and minimises the need of classic programming. By using of the virtual reality toolbox is the idea of individual solution of such simulations (for example by using Java language) unacceptable, not flexible, not effective and it would exceed the time limit assigned to creating particular models.

### 3. Communication with client

The communication between server and client can be divided into computing communication and non-computing communication.

The non-computing communication occurs when the client uses our services just for purpose of studying the texts – *eLearning*. Just in this case we are using the extension of IIS – modules php and mysql. The publications are presented by system which belongs to the category of content management systems. It is a typical internet application which allows comfortable managing of documents, publishing the documents and modifying the pages, not like the documents with static content. Dynamic content is generated by open-source CMS MamboServer [5].



Fig. 1. The MamboServer in virtual laboratory

The computing communication occurs when the client works with application which uses Matlab functions. The communication on the client side consists of sending simulation parameters to the server. This task is first processed and analysed by IIS (typical web server) and after that sent to MatlabWebServer service, which connects Matlab with IIS. This is the way how we can transfer data from client to Matlab. The chosen application is started on the basis of received parameters. Outputs from this application are sent back to client. They can be in various forms: text, tables, images, graphs, sounds, videos or 3D animations.

#### **4. Study materials**

The virtual laboratory consists of two main components – study section and experiment section. We succeed in realising complete online electronic educational system which allows the user to study the evolutionary computing methods. The virtual laboratory also includes four dynamic applications: design of PID controller parameters by using of genetic algorithms [3], virtual model of robotic manipulator [1], controlling of traffic on the crossroad [2] and optimisation and visualisation of movement of two portal cranes by moving of containers.

##### **4.1. Textbook of evolutionary computing methods**

The new progressive and effective computing methods which are trying to imitate natural evolution are growing on popularity in last years. There are more methods which are in basis very similar and we call them evolutionary computing. They are very powerful tools for solving optimisation problems, searching problems and lot of other types of problems. Probably the most popular and useful among these methods are “genetic algorithms” and “genetic programming”. The object of this textbook is to explain the principles of their functionality, to point briefly to their particularities and to show possibilities of their application by solving different practical problems.

This virtual textbook is extended by interactive examples which are demonstrating particular methods and approaches of genetic algorithms. Theoretical text is enriched by interactive applications realised by Matlab program bundle with WebServer module. These applications give to the user the possibility of active participation on solving the optimisation examples.

##### **4.2. GAPID - design of PID controller parameters by using of genetic algorithms**

Genetic algorithms can be used with great advantage by design of control circuits. The main feature of this kind of problems is that before enumerating of the objective function’s value it is

necessary to simulate dynamic system by proper numeric tool which should copy the behaviour of the real dynamic system as good as it gets. Genetic algorithm should minimise the chosen objective function, which means to reach the chosen behaviour of the dynamic system. Typical example is design of PID controller in simple feedback control circuit [3]. The internet application implemented in virtual laboratory allows the user through simple HTML form to design PID regulator by using genetic algorithms.

### 4.3. Virtual model of robotic manipulator

Modelling of mechanical devices requires time-consuming and difficult method of description of its dynamic characteristics with help of mathematical model consisting of algebraic and differential equations. Many different program bundles are trying to make this modelling easier and faster. For purposes of designing the control and model of mechanical system and for its implementation into virtual laboratory SimMechanics appeared to us as the ideal solution. The result of our work is model of robotic arm and its use by controlling the position of the arm (Fig. 2).



Fig. 2. The virtual model of robotic arm

Visualisation of this process offers the user realistic animation of mechanical system. The user can step in the control program and define a set of wished positions. Movement of the robotic arm between chosen points is represented by 3D visualisation tools.

#### 4.4. Controlling of traffic on the crossroad

Fast development of computer technology, hardware and also software of computers caused that also complicated systems could be relatively fast and easy modelled. We can easily apply algorithms on these models and make different experiments with them. For constructing event driven systems we can with advantage use Stateflow which is a part of Matlab program bundle. Our event driven system is a crossroad (Fig. 3).

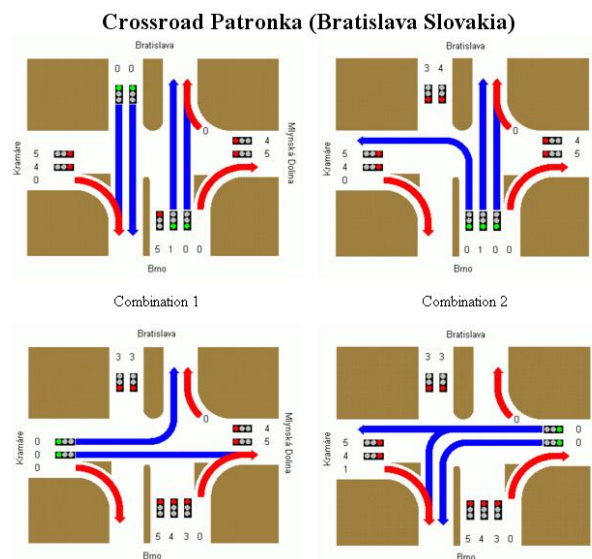


Fig. 3. The model of crossroad

The crossroad is relatively difficult and important task for control design. The time is very important in today's flustered world. The reason for accumulation of cars can be wrong designed control. It can cause traffic jams. It is the biggest problem in time of rush-hour traffic. The big corporations, which depend on traffic, can lose significant finances. It can have also bad influence on environment because of high level of air pollutants. Drivers are wasting fuel and time. Our object was to design model which should be closest to reality with the best possible control.

#### 4.5. Optimisation of movements of two portal cranes by moving the containers

This model should introduce to the user next concrete application of genetic algorithms in practice. It describes a possibility of optimisation of manipulating process, in which two portal cranes are moving containers (Fig. 4.).

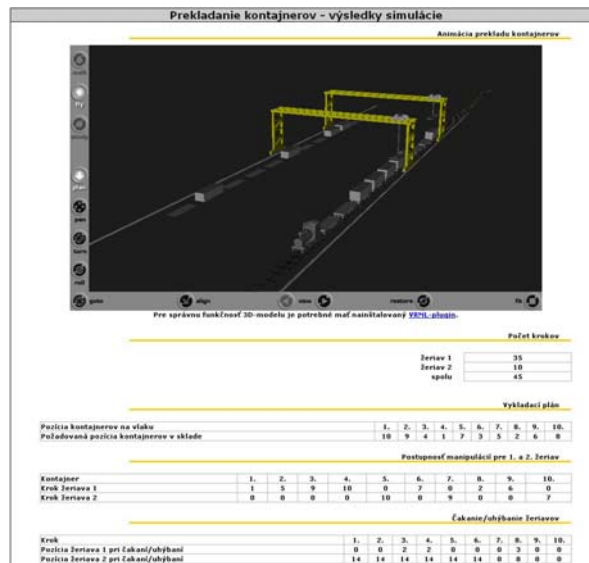


Fig. 4. The two portal cranes

Such devices are often used by freight but also somewhere else in practice. In our case there are two portal cranes moving on one axis. The optimisation task is to move containers from train on selected places in depot by minimising the trajectory of the cranes. The solution of this task should be sequence of partial movements of each crane. The minimal trajectory should be reached by executing these movements. Another possible task could be for example minimising the operation time or some compromise between minimising time and trajectory.

## 5. Conclusion

The massive spreading of Internet all over the world caused that also the area of education was affected by it. Classic methods of education are now complemented by alternative methods, the extern form of studying is improved and is getting more popular. The object of our work was to design and build virtual laboratory by using modern internet technologies. We have chosen server-side solution on the Windows 2003 Server platform. Particular applications were realised on the Matlab-Webserver basis. The user will definitely appreciate low requirements on his program accessories: all he needs is a web browser.

The *eLearning* is provided by editorial system MamboServer, where is to the users presented the textbook of evolutionary computing methods in form of text with interactive examples. The second part of the virtual laboratory is represented by four independent dynamic applications which are demonstrating usability and applicability of this product.

The portal of the virtual laboratory is still being developed and it will be constantly expanded by new models and hypertext materials. Currently we are working on adding some documents and interactive examples from the area of chemistry and energetics. This expansion is supported by the grant KEGA 3/3075/05.

The virtual laboratory can be found at address: <http://ural.elf.stuba.sk/teamp> or [www.vr-lab.info](http://www.vr-lab.info).

## 6. Reference

- [1] Foltin, M., Ágh, T., The Computer Model of Mechanical System Based on Matlab/SimMechanic, Matlab 2004, Praha – in slovak
- [2] Foltin, M., Blaho, M., The Computer Model of Cross-road Based on Matlab/Stateflow, Matlab 2004, Praha – in Slovak
- [3] Sekaj, I., Genetic Algorithm Based Controller Design, IFAC – Control System Design, Bratislava September 2003
- [4] Sekaj, I., Evolutionary Computing in Practice, IRIS, Bratislava 2005
- [5] [www.mamboserver.com](http://www.mamboserver.com)

## Contacts

[www.vr-lab.info](http://www.vr-lab.info)