

## NEW CONCEPT AND ICT BASED TOOLS FOR RAISING THE QUALIFICATION LEVEL IN MECHATRONICS AND RELATED FIELDS

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**Abstract:** The paper presents new concept based on ICT to raise the level of education in mechatronics in second and third educational schools and also in vocational education. Based on a modern set of e-learning tools (e.g. Distance Lab, Home Lab Kit and Center of Excellence) and concept, educational process can be made significantly more attractive for students and pupils and better accessible for continuing education.

**Key words:** automotive industry, e-learning, mechatronics, distance learning.

### I INTRODUCTION

The European industry is faced with Asian manufacturers' competition. Therefore concentrating on product development and improving are needed rather to large volume subcontracting to keep their worldwide esteem. The engineering studies have to be made more attractive for young people and feasible for practicing engineers. Serious problems exist on the continuous and vocational education with the practical study process. In continuous education the main problem is the lack of time of practicing engineers to participate in lectures or labs and the common problem is to exploit new Internet technology for practical studies in engineering field. The current paper describes the joint actions [1, 2] together with Estonian, German, French and Finnish universities to contribute to solve these issues.

The aim of the joint action is the contribution to raise the level of students and continuous education of engineers in the broad field of engineering domains by transferring the innovative study modules and hands-on tools supported by an e-platform of a consortium of European universities to mechatronics and new age automotive oriented schools. The new learning concept supported by theoretical and practical tools, is aimed to be applied in mechatronics and the automotive industry continuing education directly and in addition to system engineering related domains, i.e. integrated product development, industrial ICT, machine-building and apparatus industry.

According to the United States Distance Learning Association (USDLA), the term "Distance Learning System" stands for a "combination of technologies that facilitate teaching and learning among persons

not physically present in the same location." Here a Distance Learning System may include communications systems, presentation systems, and document sharing and also other extensions. The idea of Distance Education has been spread in the last years for an approach to raise the level of education. It is necessary to distinguish the different terms. "Distance Education" is a general term for the physical separation of teachers and learners and the application of information technologies for educational and student-related activities, linking teaching and students in different places. "Distance Learning" as distinguished from "Distance Education" puts the emphasis on the learning and is especially appropriate when students take on greater responsibility for their learning as it is frequently the case when doing so from a distance [3].

In this paper we are focusing on Distance Learning systems and methodological material, such as additional hardware, the so-called Home Lab Kit which will be described further below.

### II STATE-OF-ART

There are several systems and approaches existing and adopted on the market.

At the Technical University of Kaiserslautern (Germany) remotely controlled labs are established based on a commercial interface (e.g. Laybold Didactic) and special programmed web servers for controlling different parameters (e.g. laser on/off, motor control) during experimentation. Attempts to use low-cost alternatives collapsed due to a deficit in precision of electromechanical units and their limitation in data flow (I/O channels) handling. Open Source alternatives and accepted hardware standards (e.g. ATmega16) were applied for the base idea to enable teachers and students to build their own kits.

A distance lab has been built up at the University of Madrid to teach real time systems in course. The task of the students is to program the real time system RTEMS. The system can be reached by a web browser over the internet and can be directly programmed. It is possible for the teacher to control the students, as all occurrences and source codes are stored in a database. A remote correction by the supervisor is therefore possible [4].

The scientists from a laboratory at the Technical University of Catalonia have developed an educational platform around a robotic arm that allows emulating a practical laboratory in which engineering students can confirm their theoretical results comparing them with the real paths traced by the robot. All the project applications need a connection to MySQL database [5].

These solutions are pointing out an interesting way of application, which must be chased consequently in the next steps. The overall concept developed by the Interstudy consortium which is now being further developed in the project Autostudy based on a Distance Learning System which can be controlled by the Internet. In distinction to the systems mentioned above, the consortium has developed full learning concept where the hardware i.e. Home Lab and Distance Lab, are integrated with methodology, curricula and theoretical material as well as web based community support centre for teachers and the learners. Logically integrated study objects and tools are giving effective and methodical approach to study mechatronics and related fields despite problems regarding the time, the location and even the target group.

### III LEARNING CONCEPT

The mechatronic learning concept is a proposed methodology and set of supportive materials and hardware to carry out distance learning in mechatronics. The concept is relying on the curriculum which combines different mechatronics modules from different universities (see Fig. 1). However, the concept itself can be mostly applied without the whole curriculum and is successfully tested on the continuing education as well as on the high school pupils. The curriculum itself is in this case reduced and adapted to a specific sector or target group. Nevertheless the pedagogical learning path is important to ensure the logical order and efficiency of the studies. The curriculum (or study module) is supported by the different tools i.e.:

- Traditional textbook - "Integrated Systems and Design"
- Hands-On exercise book with examples
- Home Lab hardware packed into mobile suitcase
- Distance Lab environment and learning path management

- Mechatronics Home Lab Community website

These tools enables to study mechatronics and related fields efficiently and breaking the limits of location and time. The e-learning support is strongly built-in into all tools and strong integration offers the interesting learning process.

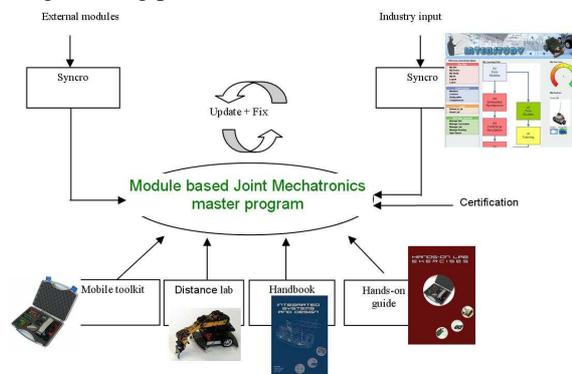


Figure 1: Advanced e-learning concept and tools

Main supportive tools for learning system are:

**Textbook - "Integrated Systems & Design"** presenting a selected overview of integrated system and design issues. The book has mainly descriptive orientation aiming to give a general overview for the reader through the practical university student involved projects. The book includes expert opinions from scientists and specialists of their specific areas, helping students to see perspectives and advances of the interdisciplinary studies. The book contains where possible also aid, practical tips and examples for students for solving different practical problems in research and future development of mechatronic systems.

**Hands-On exercise book** includes practical microcontroller oriented labs: microcontroller and digital i/o, sensors, actuators, navigation, communication, control, machine vision, etc. Exercises are fully compatible with Home Lab and Distance Lab hardware.

**E-environment** is a central web portal, enabling to manage the learning path, to get access to distance lab and to manage the home labs. Module based system has its main functionality as follows:

- Curriculum management,
- Learning path creation,
- Direct link to industry needs,
- Study process tracking,
- Home Lab check-out / check-in,
- Distance Lab management and access,
- Device programming and control.

**Distance Lab** is an interface to access different (e.g. mobile robotic) remote labs.

The multi-robot environment is developed as a pilot and is located in the university, consisting of a number of similar robots equipped with a short range wireless communication module. The site is fitted with web camera and server which communicate with the robots. The server has a master communication unit which can be contacted with any robot on the field and reprogram it at any time when needed. The site server is connected with the portal server passing and validating the communication between the robot and user input.

**Mechatronics Home Lab** is a mobile lab toolkit having a modular configuration for different levels and functions. Home Lab is built up for different kits i.e. Basic, Advanced, Add-Ons. Home Lab is a main practical set for personal studies in school, home or working place. Only ordinary computer is needed.

**Mechatronics Home Lab Community website** is a support site for Home Lab users and teachers. The site includes lots of materials in different languages. Website has forum for discussions and wiki pages for user contributions.

Although the whole concept can successfully be used as a personal study, it is mostly integrated into existing courses and robot building projects. The teaching process is based on practical exercises and is integrated into so called 'labs'. One lab can be passed like seen on the sequence described on the Fig. 2. The lab starts with introductory lecture where the theoretical part and practical hands-on tips are provided for the students. The lecture can be face-to-face or as a video conference. In both cases the lecture is expected to be duplicated in the video lecture which enables to listen to it again in case something is left unclear or the student hasn't been able to be in the lecture hall at the correct time. The next step is the practical lab work with Home Lab Kit which can be used in university computer classes, libraries or borrowed to home. The Home Lab kit has been developed in the way that the only thing the student needs is an ordinary computer (either with Windows or Linux op. system) and the rights to install the software. All other necessary components including software are included in the box. The practical work is supported by the Mechatronics Home Lab Community website providing lots of examples, problem solutions and projects. The website has also a multi-language forum enabling to ask the questions from other students or supervisors in a familiar environment. When the lab is finished, the student will upload the report with working solutions into e-learning system or simply sends it to supervisor (depending the internal rules and e-learning system in the organization). When the process is accomplished, the new lab will start in the same process again or ends in case of final lab. The process is visualized in Fig. 2.

The practical learning has an additional so-called Hands-On Learning Concept with integrates the Home Lab and Distance Lab functionality. The Distance Lab enables to program and control the small system built up from the same components included in the Home Lab Kit. When using the Home Lab in the traditional way, the user will study and test the single function e.g. reading the sensor output, controlling the motor, etc.

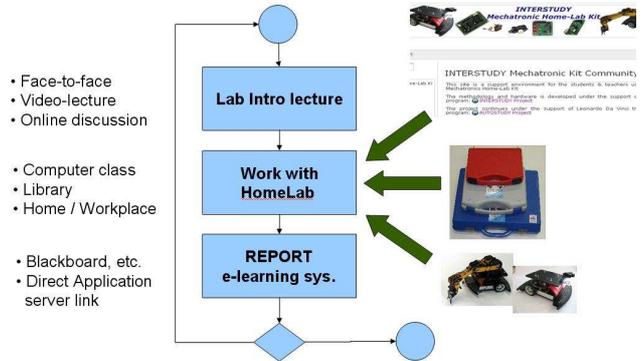


Figure 2: Practical lab learning process

In real life the single function alone is very rarely used in an application. Therefore when student has become familiar with different components of a mechatronic system, he needs to test his knowledge by using the different components on a single system. The Distance Lab has been developed for this purpose where students can get access to small systems through the Internet and try to program a system online.

#### IV HOME LAB HARDWARE

In general, the Home Lab Kit is a mobile, ready to use a small test stand, which can be connected to a PC and operated at home or at working place. The aim of the lab toolkit is to provide a practical and effective hands-on training. Students can combine various solutions on different levels of complexity and functionality, based on modules in the kit. The Home Lab Kit's main feature is mobility - toolboxes are small and compact and all modules with necessary tools are seated into box. The Toolkit has a USB connection to PC (for example student home computer). Software, which is simple and easy to install, is used to connect main controller to computer. This is particularly important because the student can start his/her experiment in school, and then continues at home or even in his/her workplace. The Home Lab toolkit includes all pedagogical materials, lab exercises and source code examples. In addition, practical questions and advanced exercises are given at the end of every lab. Solutions are also given as a HEX files (compiled format) on the disc.

All users will get special access to the Home Lab Support website for advanced examples. Only teachers get access to solutions and advanced exercises.

The Mechatronics Home Lab, which was developed jointly by European universities in 2008, is a microcontroller based modular kit consisting of the following modules:

- Main module - AVR 8bit microcontroller with motherboard,
- Digital I/O module,
- Sensor module (infrared and ultrasonic distance measure, temperature and light measures),
- Actuator module (dc motor, servo motor, stepper motor control and encoder input),
- Communication module (Bluetooth, SPI and Ethernet communication),
- RFID module,
- Machine vision module.

All modules are packed into a mobile suitcase and are provided together with software. Complete study methodology and an example handbook was composed and are included in the kit.



Figure 3: Mechatronic Home Lab Advanced Kit

## V AUTOMOTIVE MODULES

Due the fact that mechatronics and microcontroller based systems are rapidly growing part in a new age cars and automotive sector in general, the learning concept developed for mechatronics is easily transferable to the automotive sector. However, the needs of the automotive industry are slightly different from the origin (mechatronics sector). Therefore, new kits have been in the development progress for the automotive distance learning. The consortium has decided to engineer new modules for the Home Lab as well as for the Distance Lab. The CAN module prototype is shown in Fig. 4.



Figure 4: CAN module prototype

It can also be connected to a PC using USB connector. The aims for the modules are about teaching how the CAN bus works and how you can analyze the messages sent over CAN. For that reason a piece of software will be given to the students in addition to the hardware. By using the software the student will be able to "see" what really happens on the CAN bus system. It will be possible to connect multiple CAN nodes which can be set for different behaviour. Equipped with an external display, it is possible to simulate the manner of several automotive devices, like windscreen wipers or the window control. Of course, it is also possible to have real CAN bus participants like motor control, as the nodes behave like real ones. Since the nodes are very cheap, it will be possible to use many of them in a simulated CAN network. It is also planned to connect real hardware to our e-Environment. Students and apprentices can train on the cheap modules and start with using real automotive equipment after internalizing the basic knowledge.

## VI DISTANCE LAB

In recent years the remotely controlled and virtual labs have increased rapidly. The labs have different interfaces and technical realizations. Some have been integrated into the general study environment; some have just separated the web interface to program the device. Already now, one university may have several virtual labs controlled over the Internet. This has brought up the new issue - how to manage these Internet connected labs and devices on the particular lab. Different issues like booking the device, managing the rights, controlling and validating the user inputs etc. have to be solved. One possible solution for all these kinds of problems is the portal type remote lab management environment. With the support of the EU project, a complete distance lab management and programming environment have been developed [6, 7]. The functionality connected with remote lab is as following:

- User and group management,
  - Location, lab and device management,
  - Source code validation and version management,
  - Wireless device communication, including external reset and programming,
  - Device booking and booking rights.
- Having a broad view in mind, the system supports three levels of grouping:
- Location – this is the organizational level where different types of devices and labs can exist,
  - Lab – the virtual room where physically or virtually different devices can be located,
  - Device – a set of same type devices in one location.

Devices have additionally been grouped into several sub-groups according their type, e.g. mobile robots,

manipulators, frequency converters, etc. The Fig. 5 demonstrates the list of real devices in a particular distance lab.

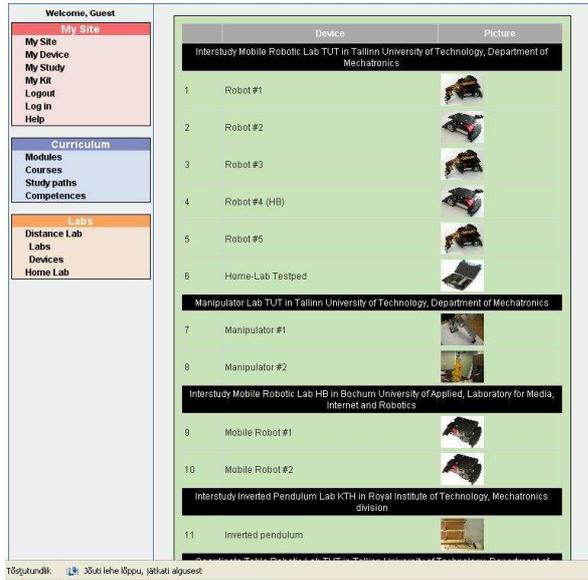


Figure 5: List of devices in physical locations

Managing different devices is a non trivial problem and needs several functional solutions. When creating a new device or enabling an existing one, the lab supervisor will have to provide the specific right and timetable for the user or user group (i.e. the legal participants of the particular course). When the user starts the booking procedure, the system will list available devices and information about the bookings by other users. The user has a choice to select the device and book it for the available time. When booking a device, the system will perform several validation checks procedures. Starting with the rights check and several timing conflict checks, all conditions have to be satisfied to get the positive result. In Fig. 6 the validation output in case of checking rights conflict results is shown.

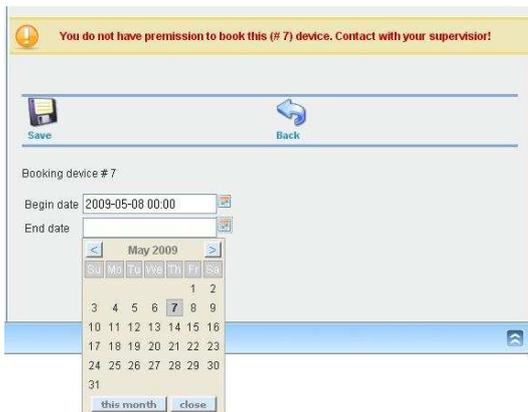


Figure 6: Booking result in case of conflict

The main concept of the e-environment is the user focused approach. It means that when the student/user logs in to the system, he or she has special

personalized content. The special menu *My site* is shown where the student can connect with the distance labs, study material, curriculum and other functions provided by the portal.

The remote lab management and study portal described above have an interface to access the mobile robotic distance lab. The multi robot environment has been developed as a pilot, but new labs can easily be added. The multi robot environment is located in the university and consists of a number of similar robots equipped with short range wireless communication module. The site is fitted with a web camera and a server which communicate with the robots.

The server has a master communication unit which can be contacted with any device on the Distance Lab; it can be reprogrammed at any time when needed. The site server is connected with the portal server passing and validating the communication between the robot and user input. The programming interface is shown on the Fig. 7 where a testped is opened for the public to test the system.

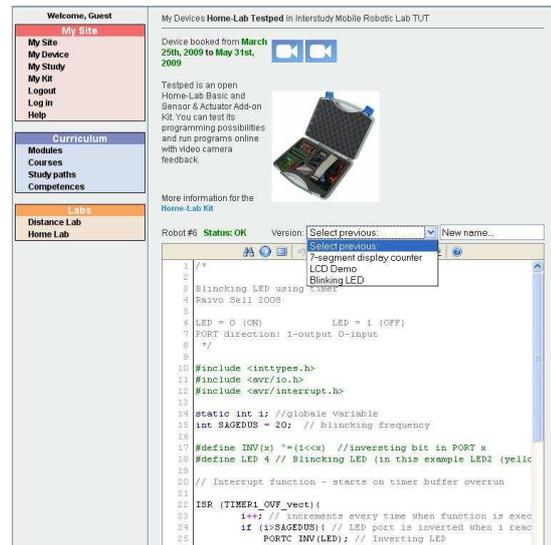


Figure 7: User interface of programming device

It is planned that the user will be able to insert a source code in C or C++ language and compile it online (no compiler is needed in the client computer). When the code is compiled and validated against rules, it can be downloaded to the device wirelessly. After the successful download, the user will be able to watch the video and see how the robot will perform in reality. If improvements are needed, the user can reprogram the device at any time by executing a new version of code.

## VII MECHATRONICS FOR FUTURE ENGINEERS

The engineering fields are unfortunately not popular among the young people, although the current situation in economical sector needs the innovation especially in the technology fields. It is critical to raise the popularity of integrated engineering fields like mechatronics and computer sciences and this can be done only when applying the new era Internet technology for the study process. The Internet plays very important role nowadays young's life and bringing the engineering studies into this environment we can be improve the engineering studies significant without losing the teaching quality. The key point in engineering studies is to make practical exercises.

The general concept and the ideas described above caught the attention of the Innovationszentrum Schule-Technik.Bochum.NRW (IST.NRW) [8], a project funded by North Rhine Westphalia parliament for cooperation of Hochschule Bochum with secondary educational schools from the environment of the city of Bochum.

The whole concept, described above, will be adopted for vocational schools in Germany by the support of EU project starting in autumn 2009.

With this project focus is on the vocational and secondary education sector. The approach of Distance Lab and Home Lab will be transferred from universities to vocational and secondary educational schools. This type of mobile, internet based learning environment can be shared between different schools. Only basic infrastructure (internet access, computer environment) must be available at most of the network partners sharing one Distance Lab. Therefore the sharing of resources between different schools or even between vocational schools and universities will be possible.

The modular Home Lab can also be shared and used as a class set in schools. As Distance Lab is in general based on the same hardware as Home Lab, pupils can train at home or in class and when they have internalized the basic principles they can move on to the more complex Distance Lab with additional (more expensive) hardware.

As we are in contact with several vocational schools and Berufskolleg am Haspel will participate as partner we directly obtain proposals about the actual issues concerning vocational and secondary education. Certainly it is conceivable to adapt the technologies for the professional skill development, as also engineers can use the system when they have free time, for their personal professional training. Hochschule Bochum and Tallinn University of Technology are strongly connected to the local industry.

Therefore we will elaborate the specific needs in industry from our partners in industry, their expectations from the vocational education and include these suggestions in the further development and im-

provement of the Home Lab and Distance Lab. In addition the Network of Excellence will further developed, which is a wiki based platform for collaborative working and helping each other. Therefore also Learners with special needs are addressed.

## VIII CONCLUSIONS

In summary, the new innovative study concept (Fig. 1) has been developed for the advanced mechatronics study and the concept will now be transferred to the automotive sector and by the project mentioned in VII also to the computer science sector, which both have very close relationships to mechatronics nowadays. The learning concept is opened in detail and the practical learning system components (i.e. Home Lab and Distance Lab) working principles are demonstrated. The concept is already applied into practice for different target groups. In Estonia, high school teachers are trained to apply the concept together with tools to local school engineering study process. The concept is successfully integrated into mechatronics curricula at consortium universities and is proven by the feedback from students as they have learned much more due to the support of the described learning concept. New component development of learning system is in progress and new target groups and sectors will be involved in near future.

## ACKNOWLEDGEMENT

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