Combined Robotic Platform for Research and Education

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Abstract. This paper describes an integrated solution for intelligent robotic and mechatronics subject study. The proposed concept provides the comprehensive set of tools and methodology by exploiting the most contemporary technology. However the traditional learning aids, like course textbook and lab guides are not excluded. The solution is fully developed and implemented in several educational institutions around Europe. In addition this paper gives an overview about the components of the overall concept and introduces briefly the learning process. Upcoming actions are pointed out in the last chapter.

Keywords: Robotic kit, remote lab, teaching and learning robotics, mechatronics

1 Introduction

Robotic education has got lot of attention in the last decade and its importance is still increasing. This seems to be a logical process as the robotics itself has entered into everyday life, where smart products are already widely used in many homes. Most contemporary devices at home and industry are mechatronic devices, which means that they consist of software in addition to mechanics and electronics, which controls the device behavior. Software part is growing on the nowadays products and programming the devices in relation to conventional computer programs are becoming more common. Due the fact, almost every nowadays machine is mechatronic device on its nature; there is need to educate more people to design, develop and maintenance these kind of devices.

The robot science is an ideal application of mechatronics, as it consists almost equally of all main mechatronics domains – mechanics, electronics and computer science, with a high level of attraction for young people. It is much easier to attract students to design the robot instead of designing washing machine; even both may have similar functional structure and design problems. Robotic education has grown very rapidly almost in every country. Previously, only being part of engineering

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curricula, it has now been integrated into primary and high schools programs or even to kindergarten. Lego Mindstorm NXT [1] kit is most known set of hardware used for the early stage robotic studies.

In this paper we introduce the *Robotic Teaching and Learning Concept* (RTLC) which consists of developed hardware solution with a full set of supporting learning aids, forming the logical concept of teaching and studying the robotics. Through the robotics also computer science, mechanics and integrated system design is taught. In the subsequent chapters the following terms of special solution has been assigned: *Robotic HomeLab Kit* – a set of hardware seated into mobile box and *Robotic DistanceLab* – a solution for remote access of hardware, consisting of web platform, servers, video cameras and hardware.

Mechatronics and its application robotics is a special subject, which is not easy to be taught and understand. Due its interdisciplinary nature, mechatronics demands the understanding and knowledge of its different underlying domains. This leads to the conclusion that the methods and learning aids needed for effective studying have to be non-traditional, where the focus is on practical training rather than studying, coaching rather than teaching, experimenting rather than reading and working together rather than alone [2].

2 Robotic Teaching and Learning Concept

In methodical works a similar concept is denoted as *Mechatronic Learning Concept* [3] or *Robotic Learning Concept*; however we would like to emphasize the teaching aspect in addition to learning, even when it is still primary key factor of getting new knowledge, especially in mechatronics. Pointing out the teaching aspects is quite important, as high level domains like robotic, needs innovative teaching approaches and methods. Relying on the conventional lecture-practice method is not applicable here and does not reach the young people. It is easy to lose first interests if the teaching methods are not modified according to young people needs, where the most important communication channel is Internet. About exploiting the possibilities of *Web 2.0* the robotic study is much more effective and the initial attractiveness of the field is not violated.

The mentioned *Robotic Teaching and Learning Concept* are built on a standard hardware system based on an *AT Mega 128* micro controller. The novel study aids, in form of a large set of material, exercises and tutorials to directly use the new hardware makes it different from known implementations, where at first stage a longer investment of time is needed in teaching the basics. The *RTLC* was applied and tested in Estonia, as well as in German vocational school and it turned out, the learning curve was much rapidly rising, then with conventional solutions on the market.

The important aspect of the concept is the collaboration and cooperation, especially the international one, in editing the practical examples, exercises and study material in one place, in the *Network of Excellence*, which is in fact accompanying wiki system to the *RTLC*. The importance of international collaboration is quite obvious – the global competence and being successful in multi-cultural team are the key factors of

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future career. The concept described in Fig. 1. below points out the teacher's and student tools supporting the learning process. However the tools are obviously overlapping, for example traditional textbooks and modern hardware kits are used by both parties. Although the web support environment is also intended for teachers and students, there is a special section which is available only for teachers. It is possible to create also closed groups in the project environment, if the material is not intended for the public view, like in most wiki systems. Nevertheless most of information and source is available for public and does not even require the registration.

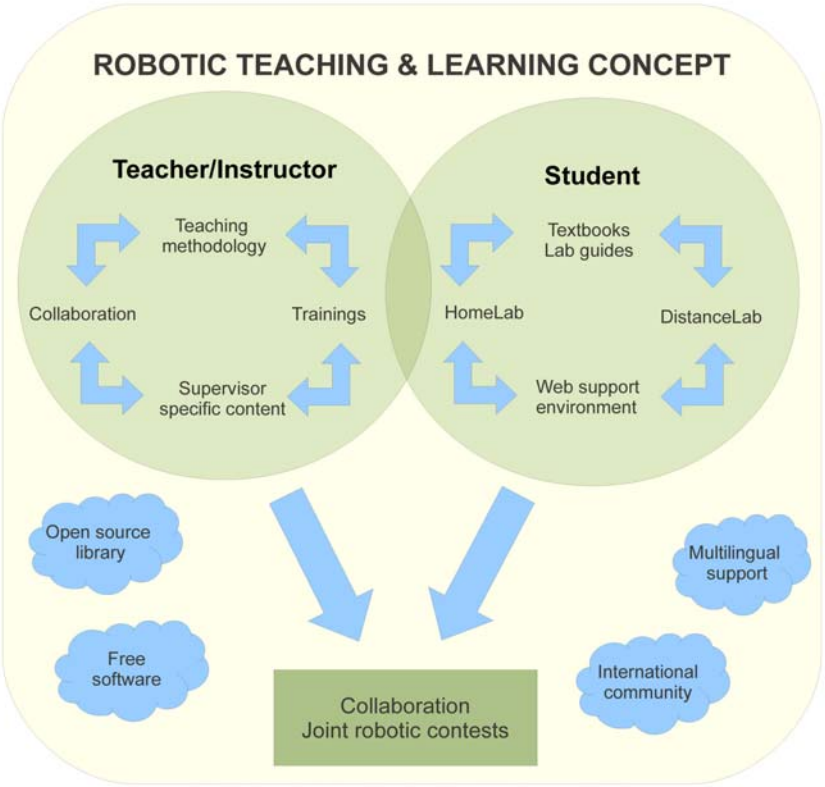

Fig. 1. Robotic Teaching and Learning Concept

3 The Study Process

Today's engineering studies cannot rely only on one specific teaching method, such as classical university lecture-practicum. Today's learner does not satisfy with fixed time

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lectures and labs. Most young people (and also grown-ups in continuous education) are living in information society era life, by spending much of the time on Internet or being *Digital Natives*. This means that classical study methods do not confirm the learner's way of studying any more. Based on this fact, the engineering studies need to be brought into Internet environment and made more attractive, but without losing the quality and practical hands-on experience.

The Robotic Teaching and Learning Concept incorporates the standard teaching methodologies with novel approaches involving the *Web 2.0* solutions and mobile hardware kits, which are all together integrated into one methodical unit. The following example helps to understand the proposed concept and on the same time to initiate the robotic studies or give an idea how to apply different studying concepts into practical learning in the technology field.

The concept includes the following teaching and learning aids:

- A hardware set - *Robotic HomeLab Kit*
- Remote access to lab equipment – *Robotic DistanceLab*
- A multi faced wiki environment - *The Network of Excellence of Robotic and Mechatronic Community*
- Traditional textbook & practical hands-on exercise book

In addition, the concept incorporates the support procedures and activities:

- Teacher training – 40 hours contact training and 40 hours independent work
- Example course outline for high schools, vocational schools and universities
- Teaching methodology

Theoretical study aids are traditional textbooks and exercise books which can be accessed in addition to paper version also electronically.

Practical part consists of *Robotic HomeLab Kit* and *DistanceLab* – a robot programming environment over the Internet. *Robotic HomeLab Kit*, combined with *DistanceLab* forms a solid solution, meaning that the learner can practice the single functions of robotics (i.e. sensor readings, motor control etc.) at home and on the same time apply his/her acquired knowledge on the robotic system. The robotic system can be accessed over the Internet – in the *DistanceLab*, which consists of real hardware equipment and test stands. The system is built up from the same components included in the *Robotic HomeLab* K*it* mobile case. At this way the user can test each single skill learned immediately on the robotic system. The feedback of the robotic system is provided over the real-time video stream. The sequence of one study process/lab-work is described on the Fig. 2.

Certain subjects are starting with an introduction which can be held as a classical lecture, distance online lecture or video lecture. The recorded video lecture is important to double conventional lecture as this enables to re-watch the lecture in case of something left unclear or the student wasn't able to participate on the lecture. The introduction lecture gives an overview of the subject and problem domain and along with the teacher the practical example can be gone through, supported by teachers comments. The theoretical part is supported by the textbook and hand-on exercise book.

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After the introduction lecture, the individual practical work is carried out. Practical work is about running the example code solution in the beginning and later modifying the example case, according to the first "Warm-up" exercise. This is followed by the more complex exercise which is assigned by the teacher for every person or team individually from "Exercise" pages of each topic. The practical work is carried out with the *HomeLab* or other robotic kit which is supported by the exercises and *DistanceLab*. An important role is played here by the *HomeLab Community* environment which supports individual studies, providing the communication environment and help for the learners and teachers.

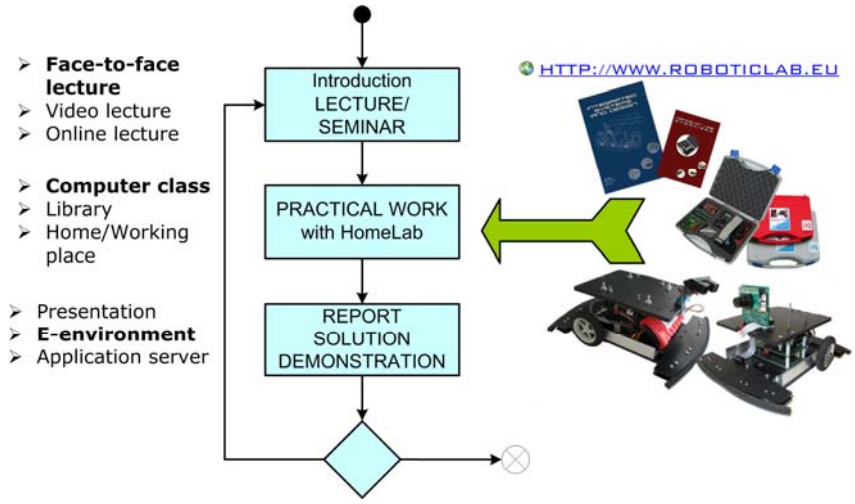

Fig. 2. Process example for one routine

The results of practical work are concluded in the report and this is sent to the supervisor. If the e-environment supports automatic report uploading, it can be used instead of sending e-mail. In addition to text report the working machine code HEX file is also required. The report includes typically the description of the work and full, clearly commented source code of the solution.

4 Components of the RTLC

The Robotic Teaching and Learning Concept incorporate several components as presented above. The following part is describing some of them which are most tangible and recognized. Several other components, like free software, teacher training etc. cannot be included into the paper due the limitation of a single paper. Certain processes are under the active development and will be completed on the next year. The most interesting new feature will be the *VirtualLab* component for the web environment. This enables to simulate the robot program before it will be uploaded to the real device. Another active process is the expansion of the languages. Currently

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the translations are going on for the German and Russian language, next year Turkish language translation will start. This chapter gives a short overview of the most tangible components of the concept like:

- *Robotic HomeLab Kit*
- *Robotic DistanceLab*
- *Robotic HomeLab Community*
- Textbooks
  ("*Integrated Systems & Design*" [5] and *Hands-On lab exercises book* [6], which are not presented in this paper)

4.1 Robotic HomeLab Kit – The Hardware

The *Robotic HomeLab Kit* (Fig. 3) was developed by consortium in the frame of European Leonardo projects, where both authors participated. It is a mobile, ready to use small test stand packed into the case, which can be connected to PC and operated in computer class, home or working place. The aim of the kit is to provide a practical and effective hands-on training. Student can combine various solutions on different levels of complexity and functionality, based on the modules inside the kit. The main feature of *HomeLab Kit* is the mobility – it is a small and compact and all modules with necessary tools are seated into the box. Taken the current development status into account, the *HomeLab Kit* offers for example hardware and exercises for 7-segment LED display, LCD (alphanumeric as well as graphical one), sensors (potensiometer, infrared, ultrasonic, etc.), different motors (DC, servo, stepper), as well as a networking module (for Bluetooth, Ethernet and ZigBee), a CAN module and USB for direct connection to PC (for example student home computer). Simple and easy to install software is used to connect main controller to computer. This is particularly important because the student can start practical experiments in school and then continue the work in home or even in his/her workplace. Experiences from authors' last European projects participating illustrate the quicker start-up while working with the *HomeLab Kit* then with other conventional solutions on the market.

Together with *DistanceLab* application and web environment the *HomeLab* forms integrated learning concept helping to make engineering studies more effective with practical hands-on experience [4].

An important part of *HomeLab Kit* is a specific developed software library which is Open Source for all users. The Library enables to access peripheral devices much easier and user does not have to bother himself with complicated register programming which is a part of usual microcontroller programming. One may argue that programming the registers is absolutely essential for understanding the nature of the microcontroller, but the real life situation limits quite often the time and other resources which can be consumed for the studies and by using the software library the student can pay more attention to the system behavior logic instead of trying have precise control over the controller by manipulating the registers. However the basic knowledge about the registers is definitely needed and therefore the first lab is usually done without using the library. In the example code below two different approaches are shown to do the same task. This example has similar volume of programming

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code by solving the task either with the help of library or not, but for example getting distance from ultrasonic sensor have only one line when using the library, but approximately 50 lines of code when doing the same functions without library.

Fig. 3. Robotic HomeLab Kits

Example of a LED manipulation program without library:

```
#include <avr/io.h>
int main(void)
{

  DDRB |= (1 << 7);
  PORTB &= ~(1 << 7);

}
```

Example of a LED manipulation program with HomeLab library:

```
#include <homelab/pin.h>
pin debug_led = PIN(B, 7);
int main(void)
{
  pin_setup_output(debug_led);
  pin_clear(debug_led);
}
```

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4.2 Robotic DistanceLab – the Web Access

The *Robotic DistanceLab* solution for the education and professional use is a web interface and a set of hardware, providing the access for microcontroller based system, which can, but most not base upon the *HomeLab Kit* hardware. The implemented lab comprises numbers of mobile robots which can be programmed over the Internet. The mobile robot specific interface enables to compile and execute the controller software written in C or C++ language and transfer it to the real robot acting in the specific field. When new program is compiled and sent out by program server, robot interrupts its current routine and acquires new algorithm. User can monitor the real actions over the two real-time cameras. The programming interfaces, together with the images of robot in different configurations are shown on Fig. 4. The didactically link between both the *DistanceLab* and the *HomeLab* kit is, that most test stands in the *DistanceLab* are using *HomeLab Kit* hardware components. The mobile robot solution, for example is completely realized by hardware from the kit. Therefore it is possible to train in home and have more expensive experiments (more motors and sensors in one test stand) with the distance aspect.

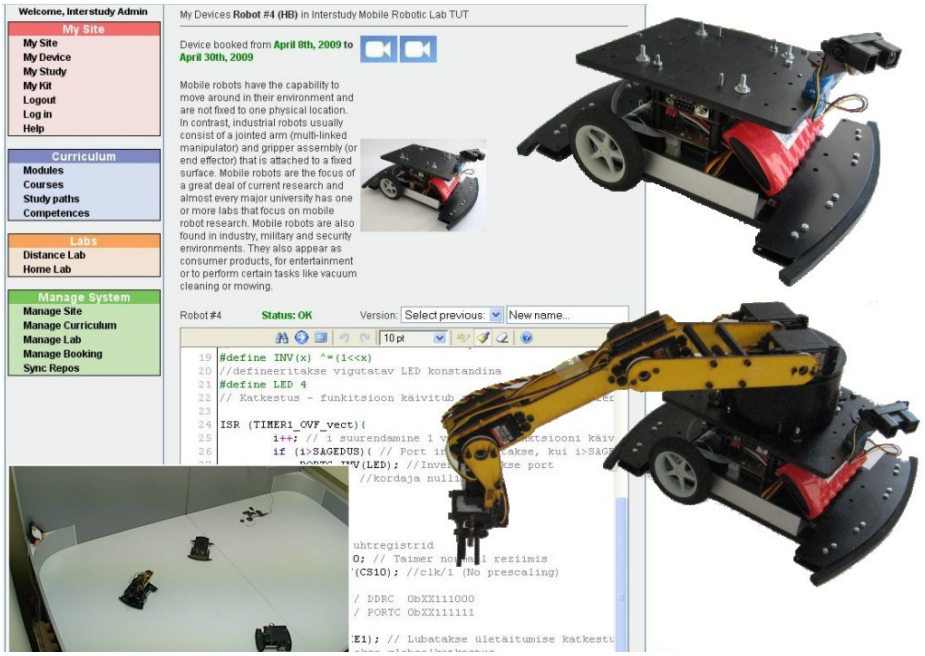

Fig. 4. *Robotic DistanceLab* programming interface and mobile robots

4.3 Robotic HomeLab Community

The *Robotic HomeLab Community* website is a supporting system for *HomeLab* users and teaching staff. The site includes lots of materials like examples, theory,

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overview of the hardware, overview of the software, etc. in different languages. The website has a forum for discussions and wiki pages for user contributions. The site has a special section for the teachers, which includes the teacher training material, and most important – the exercise solutions and answers of revision questions. In the *Robotic HomeLab Community* the consortium intends to have all learning material and also the teaching methodologies directly accessible for interested learners and teachers, as well as ready to implement curriculum for the vocational schools, to apply our solution directly in school, which is the main strength of our approach. The overall page is a multi-language system, with current translations to English, Estonian, German and French, where English is base language for all further translations. Next foreseen language is Turkish and Russian language. The strength of the this website is the amount of supporting teaching aids, administrated from teachers and developers from different European countries, and therefore the influence of various cultures, level of knowledge or styles of teaching, which leads to a full set of material. Currently during the frame of project *MoRobE* [7] a set of learning situation, with full methodology is developed and will also be available on the community website [8].

5 Collaboration and Joint Actions

The collaboration is absolutely essential in the robotic study process, especially international collaboration. On the presented concept the collaboration is built-in, and is supported by several tools, like discussion forums, joint project environment and running joint competition or scientific contests. The community website is trying to bring together the users of the *Robotic HomeLab* and initiate the joint actions. So far the collaboration has been in most active between German and Estonian supervisors and Estonian and Swedish robot building teams. However the many new joint initiatives are running and several other geographical areas in Europe are expected to join the community. By the support of Leonardo da Vinci projects Turkey and Finland are preparing the implementation of *Robotic Teaching and Learning Concept* in their homeland. The collaboration is supported by the *RTLC* component “Knowledgebase”, being a part of the web environment - *Network of Excellence* [8].

5 Conclusions

It has been proven [2] that mechatronics and robotics are special subjects in terms of teaching and learning it. A conventional method does not work but the need for the skilled professionals in this field increases drastically on the following years. The paper introduces the fully developed concept to overcome this gap and provide the versatile experience of learning the robotics and other disciplines related to it. The e-learning is trendy keyword currently in many educational institutions, but the hidden drawback is the quality drop of the studies. It may seem for the instructors that the e-

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learning does not require face-to-face contacts with learners and reduces the instructor's effort. To keep the quality of study outcome still high requires actually much more effort from the instructors and is therefore very often not favored. The proposed concept is offering the solution to raise the quality of the learning outcome and on the same time reducing the effort of the instructor or teacher. This is archived by combing the cutting-edge technology (like Web 2.0 and robotics) and methodologies for teaching. The solution is implemented on several educational institutions in Estonia and Germany and is proved the advantages over two years already. In the next steps, we are planning to enhance the developed hardware to fit the needs even for educating younger people (break-proof cable connections i.e.). One next step, to consequent using cutting edge technology could also be to try to totally virtualize the hardware solution in a software environment.

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