USER'S ACCESS TO THE ROBOTIC E-LEARNING SYSTEM SyRoTek

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Abstract: SyRoTek is an e-learning platform for mobile robotics, artificial inteligence, control and other related domains that provides access to mobile robots moving in the restricted area. The user is able not to only observe a gathered data using internet interface, but also control the robots in real-time. Unlike majority of existing e-learning robotic systems developed in the world in which the user can only tele-operate robots, behaviour of the robots in the SyRoTek system can be modified, as the system allows to run own algorithms developed by the user. The paper presents two interfaces providing access to the user: web pages and extension of IDE NetBeans. Furthermore, two courses based on SyRoTek taught at two universities are described and discussed.

1 INTRODUCTION

With a huge expansion of artificial intelligence and mobile robotics technologies into many industrial applications as well as day-to-day activities it is necessary to train students to understand and manage these technologies. Already young children get familiarize with the world of science and technology in kindergartens (Pekárová, 2008) (Stöckelmayr et al., 2011), where children (besides other activities) play with robotic toys like Bee-bot or the animatronic pet dinosaur Pleo. Older children at basic and secondary schools are introduced to toy building bricks Lego Mindstorms or Fischertechnik, which allow to design and build own robot models and program and control these models making use graphical software (Altin et al., 2010). Children thus understand main principles of robotics and problems needed to be solved to build an autonomous mobile robot. On the other hand, poor sensor equipment and fragile construction disqualify these tools for real-world problems and long-term experiments. Universities teaching robotics therefore use more powerful platforms like Videre Erratic or Pioneer or build their own robots. The main drawback of this approach is a price and a necessity of a continuous maintenance. This is more important when more than one robot is used.

The other stream focuses on building robotic laboratories accessible via Internet. These laboratories allow to share a robotic hardware among a large group of users from different places. One of the first robots controlled at distance and available to public was Telegarden (Telegarden, 2008). It has been running since 1995 with 9000 users registered to the system in the first month of operation. Bradford Robotic Telescope (Telescope, 2008) is a part of an e-learning course of which goal is to popularize astronomy. In addition to open up a unique equipment to a broad public, the many research programs use telescope for research of galaxies, supernovas, and black holes. The system thus combines a basic research with education by sharing limited sources. The project RHINO (Rhino, 2008) combines tele-operation with visualization as it offers a robotic guide in a museum. The robot Xavier (Simmons et al., 2000) is an autonomous robot operating in indoor environments of university hallways. The robot autonomy allows the users to enter high-level tasks (e.g. go to a specified position), which are performed by the robot autonomously. Robotoy (Robotoy, 2008) - a robotic arm with a gripper - allows the users to control it via a web interface. The user can choose between two cameras from which it can see robot's working environment. The robot is controlled in the command regime, i.e. the user enters a command which is immediately fulfilled. One of the most complex robotic e-learning laboratories was developed at Swiss Federal Institute of Technology in Lausanne (EPFL). The RobOnWeb project (Siegwart

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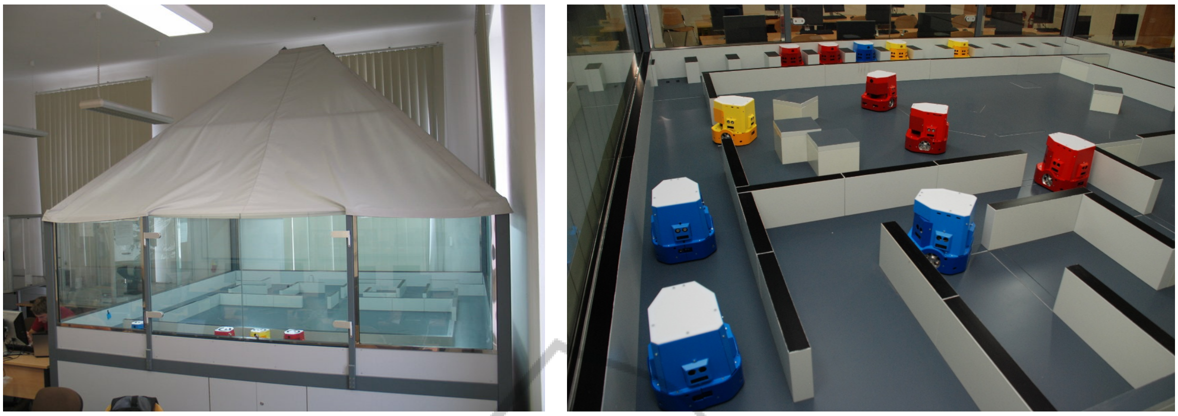


Figure 1: The Arena in the university computer lab (left) and robots operating in the Arena (right).

and Sauc, 1999) is focused on advanced robotic users. The authors define five fundamental services of web interface: chat, video, robot control, virtual robot representation, and logging. Several configurations are parts of the project varying mainly in the used robot platforms and sensors: TeleRoboLab, AliceOnWeb, Koala on the Web, and Pygmalion on the Web.

SyRoTek - a system for a robotic e-learning is similar to the above mentioned systems as it also provides remote access to robotic actuators and sensory data and a robot hardware has been integrated into e-learning framework. The users are able to develop own algorithms and monitor the behavior of these algorithms on-line during real experiments. In this paper we describe the system from user's point of view, i.e. user's access to the system is described by introduction of two main system interfaces: web pages and NetBeans integrated development environment (IDE).

The rest of the paper is organized as follows. The next section gives a short overview of the SyRoTek system as a whole. The sections 3 and 4 describe web interface to SyRoTek and SyRoTek plugins to NetBeans respectively. Courses taught with a support of the SyRoTek system is shortly presented in the section 5. Finally, remarks and future work are discussed in the conclusion.

2 SyRoTek OVERVIEW

An overview of the SyRoTek realization is depicted in Fig. 2 (see also (Kulich et al., 2009) for more details see).

SyRoTek mobile robots move inside an enclosed area (called Arena, see Fig. 1) consisting of necessary supporting subsystems, e.g. thirteen charging docks, lighting, visualization cameras, and localization subsystem. The Arena (sized $3.5 \times 3.8m$) was designed to be reconfigurable without need of human attendance. This feature was achieved by installing several moving obstacles, allowed to be retracted under the surface. The presence of moving obstacles allows to prepare more environment configurations in the arena before a user starts solving his/her task, as well to define tasks with dynamically changing environment. Moreover, the arena workspace may be divided into several mutually separated closed areas to create robot working spaces for several users without affecting each other.

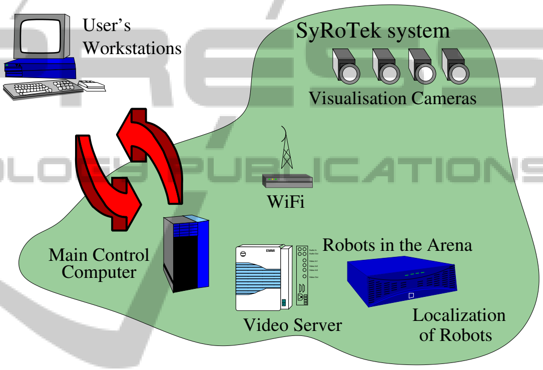


Figure 2: SyRoTek overview.

The SyRoTek system contains thirteen S1R robots developed especially for the system (Chudoba et al., 2011). The robots are equipped with standard sensors used in robotics (odometry, accelerometers, compass, infra-red range sensors, sonars, and optionally with a laser range-finder). The on-board computer with Gumstix Overo Fire processor at 600 MHz provides enough computational power for basic data processing and communication with other components of the system. Beside UART, SPI, I^{2}C, and USB communication interfaces, the computer provides an on-board 802.11g wireless network module.

The core of the SyRoTek system is the *Control computer* where main services of the system run and which mediates robotic hardware to the user. These services manage actual state of the robots, arena, prepare robots according to the actual reservations, provide views to the Arena from cameras placed around it, etc.

The Player/Stage framework (Gerkey et al., 2003) has been selected as the main programming interface. The Player is widely used in the robotic community as it supports a wide variety of mobile robots and sensors and contains huge library of state-of-the-art algorithms for obstacle avoidance, planning, localization, etc. The Stage is a simulator which can substitute a real hardware with the same interface. The user can therefore develop his/her code with the simulator and the same code with no or few modifications can be used for a real robot.

3 WEB INTERFACE

The web pages are the first and most visible access point to the SyRoTek system. They are designed to attach the attention of the randomly coming visitors, facilitate first steps with the system to the users, and help teachers to perform pedagogical tasks. At first glance visible part of the main page is the video showing example of the system usage. Unacquainted visitors can here find what the SyRoTek system is and how to use it. All the information about running courses, manuals, registration and contact persons are available even for non-registered users. On the other hand, interesting parts of the system are accessible for registered users only: they have access to the whole e-learning part of the system and can work with the robots.

All the users (both registered and non-registered) can read all the materials of all courses, but non-registered or non-enrolled users cannot access the quizzes and solve the tasks. The course materials are open for all to allow users take a informed decision if the courses are interesting for them and want to register into the SyRoTek system and enroll the courses.

The registration is the first step into the SyRoTek system. The registration form is accessible from the web page. The user, who wants tho use the SyRoTek system, provides the full name and affiliated organization, chooses the username and describes reasons, why he or she wants to use the system. The process of registration is not fully autonomous and every user is individually assessed by a system administrator. If the user is accepted, an e-mail is sent with the access information. From this moment, it can enroll into the offered courses. Some of the advanced courses can be opened only for the users with a selected level of knowledge. The level of new users is set to *novice* and it is increased as the user completes courses at a given level.

The reservation system is also accessible from the web. The current occupation of the arena and robots is visualized and registered user can reserve free time slots for enrolled tasks. Every user can reserve the robots and arena for a given total amount of time.

4 NETBEANS IDE INTEGRATION

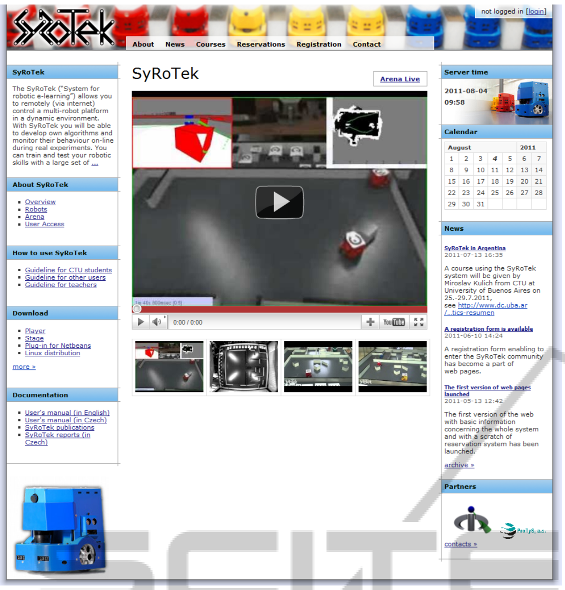
Solution of the task often requires algorithm design and development and its implementation in a certain programming language. A substantial part of student's work with the SyRoTek system is therefore related to writing, compiling and debugging of source codes.

There exists three interfaces of the SyRoTek: web, command line, and NetBeans IDE. The web interface is not suitable for development of the programs as quality of the Internet connection can vary and connection disturbances can easily cause lost of the significant part of student's work. Furthermore, functionality of editors on the web is very limited comparing to nowadays IDEs. The command line interface is well suitable for development of the programs and many Unix users are familiar with it. The SyRoTek system is fully equipped with tools for development in a command line environment. But many students, mainly beginners, appreciate the possibility to use an integrated development environment.

IDE is an environment, in which all the development is done and provides many features for authoring, modifying, compiling, deploying, version controlling and debugging software. Therefore, we introduce a set of plug-ins for NetBeans IDE, which allows to develop programs for the SyRoTek system within IDE. All the plug-ins integrate functionalities accessible from different places of the system.

The usage of the IDE with SyRoTek plug-ins brings the comfort of code completing, context help, visual debugging as well as the access to all the courses, tasks, reservation system and other components of the SyRoTek system.

The first step of the work in the NetBeans IDE is to login into SyRoTek system. After that the IDE is able to access all the data stored in the SyRoTek system related to the current user. It is necessary to mention that the active SyRoTek user account and Internet connection is required for almost all plug-ins to work. On the other hand, it is possible to work locally



The SyRoTek ("System for robotic e-learning") allows you to remotely (via internet) control a multi-robot platform in a dynamic environment. With SyRoTek you will be able to develop own algorithms and monitor their behaviour on-line during real experiments. You can train and test your robotic skills with a large set of ...

Server time

2011-08-04
09:58

August					2011	
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

SyRoTek in Argentina
2011-07-13 16:35

A course using the SyRoTek system will be given by Miroslav Kulich from CTU at University of Buenos Aires on 25.-29.7.2011, see http://www.dc.uba.ar/...tics-resumen

A registration form is available
2011-06-10 14:24

A registration form enabling to enter the SyRoTek community has become a part of web pages.

The first version of web pages launched
2011-05-13 12:42

The first version of the web with basic information concerning the whole system and with a scratch of reservation system has been launched.

archive »

Figure 3: The introductory web page http://syrotek.felk.cvut.cz.

(off-line) after few initial steps.

To start solving a given task, the NetBeans project is necessary to create. A special type of the project template - SyRoTek template - has been prepared and included into the NetBeans. The student chooses the course and task, which wants to solve, and all required steps are made automatically.

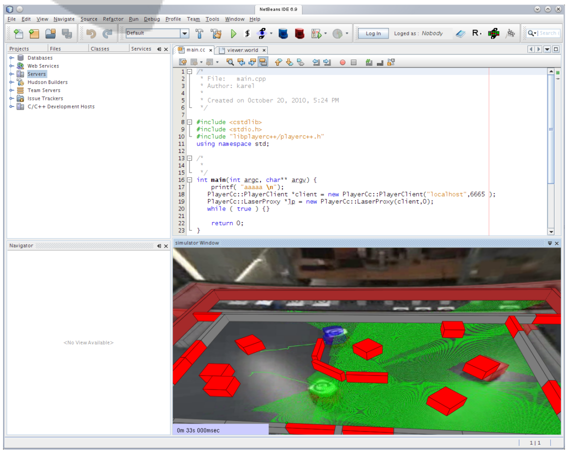
The result of the task is required to be placed in the version control system (Subversion) in student's repository in specified directory. The plug-in checks out the related repository and includes all the files (task related code skeletons) into the NetBeans project. NetBeans IDE is then able to natively work with the repository. As some of the tasks are designed to be solved by a group of students, the group repository allows to cooperate and share the code efficiently.

After the project is created, the student can work locally without a need of the Internet connection. The code can be tested in the simulator (Stage), which provides the same interfaces as a real hardware. This testing brings the advantage of possibility to manipulate the robot and the environment as well as the possibility to change the simulation speed. Of course, the student must keep in the mind, that the simulator does not model all the possible sensor noise and errors. When the student is satisfied with the performance of his/her algorithm in the simulator, then it is time to test the algorithm with real robots and sensors.

The reservation must be done to allow the student an access to the robots in a given time. The plug-in simplifies the reservation process, chooses the course and task according to the project which the student is currently working on. Appropriate robots with required sensors are chosen according to the task. The student just selects time and a required duration of the reservation. The reservation interface is the same as on the web, but it is accessible ”at one click” inside IDE. The Internet connection is necessary for reservation as well as for working with the real hardware.

Again, the SyRoTek plug-in provides the comfortable way of running student's program as well as the Player server from NetBeans IDE at one click. The plug-in provides two possible ways, how to connect student's program with the robot hardware. The first possibility is to run student's program locally on his/her computer and to connect to the control computer with the player server running. The second possibility is to run student's program also on the control computer in his/her user space. Outputs of student's program and the Player server are redirected into the IDE and they are accessible as usual.

The plug-in provides also the visualization (see Fig. 4) of the simulator or the real situation of the SyRoTek Arena. The visualization can show not only a video stream from cameras, but also sensors data, recent positions of the robots or other user graphical output. The student can dynamically change the camera, sensors and other visualization parameters.



```
/*
 * File:   main.cpp
 * Author: karel
 *
 * Created on October 20, 2010, 5:24 PM
 */

#include <cstdlib>
#include <stdio.h>
#include "libplayerc++/playerc++.h"
using namespace std;

/*
 *
 */
int main(int argc, char** argv) {
     printf( "aaaaa \n");
    PlayerCc::PlayerClient *client = new PlayerCc::PlayerClient("localhost",6665 );
    PlayerCc::LaserProxy *lp = new PlayerCc::LaserProxy(client,0);
    while ( true ) {}

     return 0;
}
```

Figure 4: Visualization SyRoTek plug-in.

As soon as the student considers the task to be solved, the resulting program should be submitted for the evaluation. There is also a possibility to submit the task for the test evaluation. The submission is done through the version control system. The current version of the program is tagged as final and the evaluation is done on this tagged version of the code.

At the first, the plug-in for submission asks the user whether the submission is final or testing only. After that, it takes the local copy of the source code, checks whether all the files are under version control and asks the user, what to do with those, which are not. It performs commit and sets the tag of the version according the requested type of submission finally.

The whole process of task solving from reading the specification, implementation, testing in simulator and with real robots, to the final submission can be done within the NetBeans IDE. On the other hand, a number of specific situations and advantageous tasks exists, which cannot be covered and managed in the IDE. We are expecting that as the users become more and more advanced, they start to use the command line tools to solve, if not the whole tasks, these more complex issues.

5 LABS

The SyRoTek system has been used in courses taught at Czech Technical University in Prague (CTU), Czech Republic and University of Buenos Aires (UBA), Argentina. The *Introduction to Mobile Robotics* course help as a part of School of Informatics at UBA in July 2011 was attended by 70 students and teachers from Argentina and Uruguay with different a-priory knowledge of robotics (from beginners to postgraduate students studying robotics). Its aim was to introduce main problems and solutions necessary to control an autonomous mobile robot. Besides eight lessons giving a theoretical overview of the field, the students solved a chosen practical exercise (wall following, obstacle avoidance or wandering) independently in teams by two or three under teacher's supervision. During the whole course they used the SyRoTek system: the started with registration and enrollment of the course. After that, they were requested to fill quizzes prepared by the teacher. Moreover, they were able to download and read learning material and SyRoTek manuals and documentation. The students also used forum on SyRoTek pages for asking questions and reporting bugs in the system, albeit this feature was not introduced to the students.

The work in the lab was scheduled at the end of the course. The students were split into two halves by cca 40 people, each half having one 180 minutes time slot for the experiments. The labs were performed in the university computer laboratory, where client software of the SyRoTek system (NetBeans with SyRoTek plugins, and extended version of Player/Stage) was installed in the form of virtual machine by the lab administrator before the course. Student's work consisted from the following steps:

- Login to a computer and launching a virtual machine with the SyRoTek software.
- Launching NetBeans and logging into SyRoTek system.
- Creation of a project from the template prepared by the teacher.
- Development of the application in the simulator.
- Running of the application with a real robots.

Although majority of students had no previous experience with development of a robotic application and some of them also a little programming experience, all the teams were able to control the robot in simulator in dedicated time. Of course, some applications were not perfect as the controlled robots were crashing to obstacles. Three of the teams tuned their applications so that they run real robots in Prague at distant. To attract the students, the teacher projected a live video showing an actual situation in the Arena on the wall, so the students were able to see behavior of the robots.

The final task for the students was to fill the questionnaire about their satisfaction with the system and suggestions for its further improvement. Although several bugs were detected by the students during the labs, the overall evaluation was very positive. They especially appreciated that they were able to develop a robotic application in a short time and run it on a real hardware. NetBeans IDE with the prepared code templates increased the speed of the development process as it provides all modern tools for writing, debugging, and running a code.

Students at CTU use the SyRoTek system in *Practical Robotics* course in the winter semester 2011/12. The course is designed as introductory and its aim is to create an interest in the ideas and possibilities of intelligent mobile robotics. Therefore, the emphasis is given to individual student's work under teacher's supervision in the laboratories. The course consist of six theoretical lectures lasting 90 minutes each at the beginning of the semester and fourteen lab sessions, where there is one session per week and lasts 135 minutes. The task to be solved in the labs is a modification of the exploration problem – the goal is to find mines randomly placed in the environment. The robot knows its position exactly and is equipped with a laser range-finder measuring the distance to obsacles, and mine-detector detecting mines close to the robot. On the other hand the map of the environment is not available, so the robot has to build it on its own. The course is attended by 18 students split into teams by two or three. The students were introduced to the SyRoTek system at first two sessions, when they solved obstacle avoidance task. After that, they began to solve the exploration task, working in the simulator at the first. From the middle of semester, the students have started experiments with real robots, initially in the lab with help of the teacher during time dedicated for sessions. After several attempts, they started to use the system individually either from the lab at the university or from home. At the end of the semester, all the groups presented their functioning code on real robots.

6 CONCLUSIONS

Two interfaces mediating user's access to the SyRoTek platform were introduced. Each of these interfaces has its own purpose and they are complementary to each other. While the web pages are an input gate to the system and serve as a source of information for incomers as well as for regular system users, the NetBeans environment extended by a set of plugins facilitates particularly a whole process of user's control application development.

Experience from the courses taught with the support of SyRoTek shows that both interfaces are inseparable parts of the system and widely used by the users. Especially the NetBeans IDE is appreciated by the users in general as they have previous experience with it or a similar IDE so they do not need to change their programming habits. IDE is also suitable for beginners, because it provides many functionalities by one click only and thus familiarization with it is fast.

As mentioned, the current programming interface is based on Player/Stage system, which is simple to use and widely expanded in the robotic community. On the other hand, this system is being substituted by the Robot Operating System (ROS) (Robot Operating System, 2011), popularity of which is rapidly increasing. Interfacing SyRoTek into ROS together with related changes in IDE is therefore one of the main activities for the future. Moreover, more courses will be offered by the system and these will be advertised to other universities.

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