Remotely-Accessible Robotics Laboratory

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Robotické laboratórium so vzdialeným prístupom.

ABSTRAKT

Robotnačka je autonómny mobilný kresliaci robot, ktorý sa používa pri výuke základov programovania v jazyku Logo. Dá sa však využiť aj ako experimentálna platforma, v našom prípade v robotickom laboratóriu s možnosťou riadenia robotov cez Internet. V laboratóriu môžu byť umiestnené až tri roboty, okrem základnej verzie aj model doplnený chápadlom a model s bezdrôtovou kamerou. Laboratórium je prístupné nepretržite 24 hodín 7 dní v týždni a umožňuje začleniť jednoduchým spôsobom problematiku robotiky do vyučovania matematiky, programovania a iných predmetov.

INTRODUCTION

The importance and impact of robotics and automation systems as part of the evolution of mankind is obvious and inevitable. In order to achieve sustainable and steady progress of the technology, supply of the qualified workers is essential. In a democratic society with the freedom of choice, this can be achieved only through promoting the interest of young people in technology, and maximizing their possibilities for hands-on experiences and small scientific and technological projects. At the same time, researchers and teachers at the universities and other higher education institutions need suitable platforms and "microworlds", which will allow them to easily setup student projects as well as develop and test their research contributions.

Very popular approaches to achieve both of these goals are robotics competitions. An example is the robot football, which contributes significantly to the research in the areas of multiagent systems, sensor technologies, navigation, coordination, localization, vision, and other fields. There are many other robotics contests, see for instance [1] for an overview article. One of the advantages, but also disadvantages of the robotics contests is that the same artificial problem gets solved again and again by various groups, often reaching only a moderate level of already existing systems and thus limiting the positive outcome to the learning experience of the participating team. The contests have a particular engineering goal set by the rules. This restricts the researcher or teacher in the free experimentation. A good alternative to the contests poses the robotics construction sets. Construction sets typically contain multitudes of tuned and well-fitting parts, sensors and actuators, which put a flexible and open tool for experimentation right on the desk of a student or a researcher. An example of such set is the popular LEGO Mindstorms Robotics Invention System [6, 3], or Fischertechnik [5] at the level of a toy, or Parallax Robotics [8], or Microbric [7] at the level of a hobbyist or student, or Khepera robots and accessories at the level of the researcher.

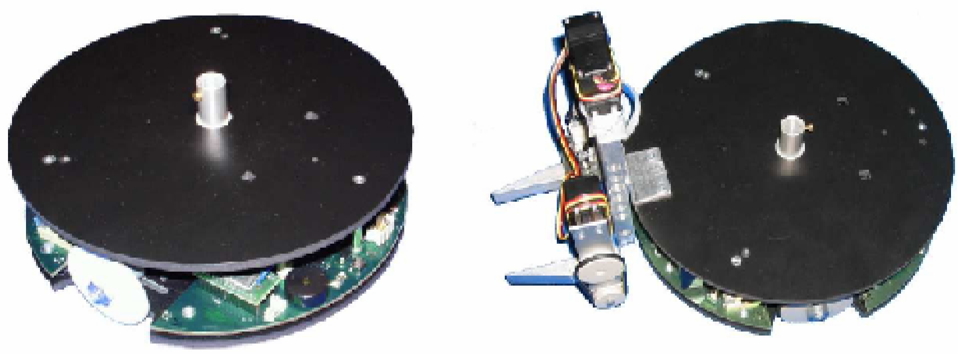

Figure 1: Robotnacka robot (left), with an attached gripper (right).

Our approach is to provide yet another alternative, an open educational and research toolkit based on an extensible and modular drawing robot Robotnacka [4]. Several instances of Robotnacka are exposed for free use by educators, hobbyists, and researchers in the robotics laboratory accessible through the Internet. The robots in the robotics laboratory [9] are running 24 hours, 7 days a week. They are autonomous, powered from a rechargeable battery, and controlled remotely using built-in BlueTooth modem. The robots are performing in the maintenance-free operation. In the following sections, we review the functionality, implementation, and use of the remotely-controlled robotics laboratory, the maintenance-free operation, and describe the future projects in the laboratory.

The Department of Automation and Control at the Slovak Technical University is educating tens of engineering students per year in the field of robotics. Annually, it organizes a robotics contest Istrobot with several categories. The Department of Informatics Education at Comenius University is for more than a decade involved in developing and working with professional Logo educational programming environment for schools [2]. Finally, the company MicroStep-MIS has many years of experience in developing sensor and automation systems. Students and workers from all three institutions met together their efforts in developing a mobile drawing robot compatible with the Imagine Logo [2] (as part of a joint laboratory [9]). Further development resulted in more general use of this robot platform, and additional modular extensions. The robots were installed for perpetual operation in a remotely accessible robotics laboratory.

HARDWARE

The mobile autonomous robot Robotnacka is shown in figure 1 left. It is a very accurate mobile two-wheel differential driven robot controlled by a simple 8-bit microcontroller. It can be remotely controlled over BlueTooth radio connection from a workstation. It is propelled by two stepper motors. The distance traveled per 1 step is less than 0.2 mm. The robot is equipped with six IR sensors mounted on the bottom, allowing the robots to recognize guiding marks on the floor surface. It can also be equipped with a gripper, see figure 1 right, which allows pick and place operations. A wireless network camera can be mounted on top. The environment for operation in the laboratory consists of a whiteboard ceramic surface, which can be decorated with guiding marks. A top-view camera with a wide zoom overlooking the whole arena is mounted over the whiteboard, see figure 2. In addition, a second camera is mounted on the side of the whiteboard providing a side-view image.

The robots are exposed freely on the Internet. Users can control the robots remotely using Internet browser with Java technology enabled. Their movements can be viewed with three cameras (top-view, side-view, and from camera mounted on the robot) in the browser with ActiveX plugin installed, see figure 3. In addition, Internet users can control the robots and view the camera image from the laboratory directly from Imagine Logo programming environment, Java applications, or any application higher-level programming language utilizing the provided DLL or ActiveX software components. The server software allows an easy control of the camera image and bandwidth settings, as well as a calibrated image compensating the distortion by camera lenses.

Figure 2: Remotely-controlled robotics laboratory.

OPERATION

Robots in the laboratory are automatically recognized and connected by the server, which monitors their operation, and provides extensive functionality for both user control and protected administrator maintenance. Night operation of the laboratory is possible by means of a network-controlled light source that can be turned on and off on demand. The power source of the robot is a 6V/2.3Ah lead acid maintenance-free battery and lasts for about 2-3 hours of continuous operation. The battery is recharged automatically.

With its open architecture, the laboratory has unlimited possibilities to be used both in research educational projects [4] for primary and secondary schools, as well as research and project platform for both undergraduate and graduate students. It can be employed in distance learning. The laboratory is used for several undergraduate semester and diploma projects, e.g. analysis of the power sources for mobile robots, platform for development of multi-agent architectures, as well as for experiments of graduate students with evolutionary and behavior-based robotics. In the educational projects, the robots in the laboratory can be attached to the turtle objects in the Logo programming language of a student sitting anywhere around the world. In combination with the top-view camera, the laboratory can be used as an educational tool in lessons

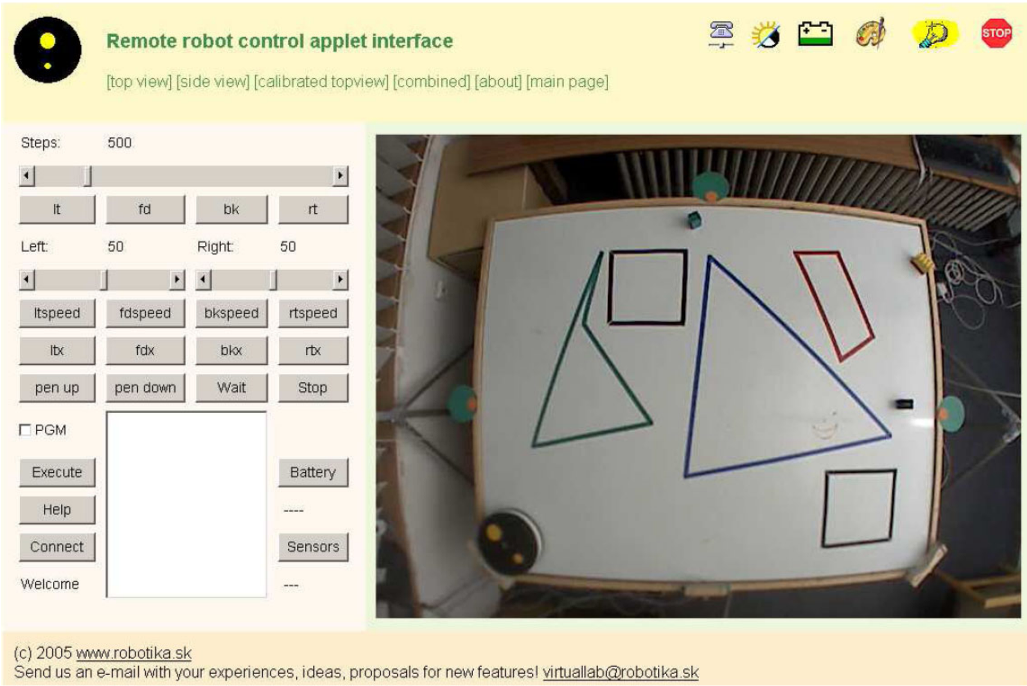

Figure 3: Remotely-controlled robotics laboratory www interface.

of mathematics, physics, and programming. For instance, the software is able to detect polygon shapes, and provides a creative environment for solving constructive geometry tasks in a novel and exciting way. With the ability to move objects in the arena, the robots are a perfect platform for experiments with computer vision and artificial intelligence. The robots can work as a physical instantiation and testing platform for instance for planning and reasoning algorithms. The exploitation of robots is also planned for the Robotics introductory course at the Faculty of Electrical Engineering and Information Technology STU.

Another important use is the promotion of robotics technology on public through numerous presentations and shows. To name one, the robots and the laboratory were presented at the Eurobot 2005 contest in Prague, see figure 4.

The programming of the robots is designed to be easy to understand and learn. For instance, the following portion of a C++ program makes the remote robot draw a star (if the pen is inserted). Other example projects allow to control the robots with joystick, or computer mouse and even with user head using a camera and image recognition software.

Figure 4: Robots on display at Eurobot'2005 in Prague attracted all ages.

```
int r = robot_init(1);                        // create robot object
robot_user(r, "john", "turtle");              // provide user/ passwd
if (! robot_connect(r, "147.175.125.30"))     // connect the lab
{
  printf (" Could not connect \n");
  return 1;
}
robot_alwayswait(r, "on");                    // set synchronous mode
for (int i = 0; i < 5; i++)
{
  robot_fd (r, 500);                          // move forward 500 steps
  robot_rt (r, 1152);                         // turn 144 degrees right (144*8=1152)
}                                             // (the precision is 8 steps/ degree )
robot_close(r);                               // close the connection
```
.

IMPLEMENTATION

The latest version of the robot consists of standard accessible parts and can be produced serially. The robot mainboard equipped with the Atmel AT89S8252 CPU allows easy re-programming using ISP (in-system programming) interface. Connecting of an extra sensor, actuator, or interface boards is possible using serial peripheral interface (SPI). An example of such periphery is an intelligent gripper controlled by its own microcontroller. The communication with the workstation can be established through a cable serial port, or Bluetooth wireless connection. The robot has a built-in battery recharging circuitry, which operates autonomously and indicates the recharging status with two LEDs.

The robots are connected (through Bluetooth) to the laboratory server - a low-profile PC workstation running GNU/Linux with our own open-source robotics server software that provides control over the Internet, camera image calibration, access for users in registered timeslots with an automatic on-line registration system. The system is implemented in C++, and the web-scripts are running on PHP/mysql platform with Apache webserver. The communication with the robots over the Internet uses standard TCP/IP protocol on dedicated ports. Image processing functionality is implemented with the help of an OpenCV library. The server-side software supports both simultaneous operation for multiple users as well as an exclusive access for the connected user on request.

During its normal operation, the robot monitors the battery power level. When the voltage falls below an indication threshold, it notifies the server. The server chooses to wait until the user finishes the current operations, or possibly interrupts the current user and using the calibrated image navigates the robot towards determined recharging station. If there are any robots on the way, they are automatically moved away, or avoided, if they do not respond. The parking software automatically turns on illumination light and adjusts the camera settings. After the robot is docked, the parking software monitors the power level, and in the cases of a missing contact, attempts to remedy the situation by turning and redocking. If all attempts fail, the administrator is notified by an e-mail so that a possible manual docking could be performed.

The locations of the robots are determined according the yellow marks placed on tops of the robots. The parking software detects the yellow components in the image that are placed inside of black components, while it attempts to filter-out irrelevant information (the administrator can adjust various sensitivity settings so that an accurate operation is reached at various daylight conditions as well as with artificial illumination at night). Since the camera is not permanently attached to the drawing surface, but rather mounted on an independent stand, the software automatically detects the position, and zooming aspect of the camera relative to the surface in order to calculate proper locations and thus the distances and angles in the position commands given to the robots when approaching the recharging station.

All parts of the server side software are open-source and publicly available at the project website [9]. Interested developers are encouraged to contact us and join the development team.

FUTURE WORK

The development of the robots running in the robotics laboratory during the past years brought us a lot of ideas and inspirations for the future work. First of all, we are perpetually working on improving its current state. At the time of writing of this article, already the third version of gripper is being tested, some power issues of the camera robot are being resolved, and educational projects are being worked on. A diploma thesis that should combine behavior-based architecture with vision input has been started. We are preparing an online contest, and entertainment activities and software packages. We also consider additional extensions for the robots, which will allow better interaction with the environment - for example collecting or moving multiple objects.

At the same time, we are working on new robot bases (non-drawing), which will enjoy higher autonomy and CPU power, and thus combined allow to create an extensive environment for AI and computer vision experimentation, as well as use of robots in primary and secondary school curricula.

CONCLUSIONS

Drawing robots Robotnacka are installed in the robotics laboratory and available through the Internet for public use. Teachers at various levels might consider using our laboratory in their lessons - from mathematics, physics and programming at the levels of primary and secondary schools, to the programming, control, hardware, computer vision, artificial intelligence courses at the undergraduate or graduate level. Without previous advertisement of the laboratory that is still under development, there already were hundreds of visitors who logged into the laboratory.

This article focuses on the technical challenge of maintenance-free operation of the robots in the laboratory, which is achieved through a combination of hardware (built-in recharger, mechanical setup of recharging stations) and software solutions (Linux server with robot daemon and parking software).

As far as we are concerned, there are very few other perpetual robot installations in the World. Our goal is to continue and improve the operation of the remotely-controlled laboratory and serve with our best efforts to the teachers and students communities at various educational levels, where the use of robotics might be useful in educational process. We encourage the developers to join our development team.

ACKNOWLEDGEMENT

Project of the remote accessible laboratory was supported by the grant KEGA 3/2399/04. Publication and presentation of this article is supported by the Project KEGA 3/3121/05 “Network of virtual laboratories for real process control”

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