Robotics Education at Innsbruck Medical University

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***Abstract*—Robotics is having an increasing impact on life sciences, but is still not included in the curriculum of medical universities. In surgery, robots are used like complex instruments to enhance a surgeon's technical possibilities. To give our students the opportunity to learn about the abilities and limits of robots we run a "hands-on robotics workshop" at Innsbruck Medical University. Our aim is not to teach surgical procedures, but to construct robots. To our knowledge, this is the first robotics workshop held at a medical university. LEGO Mindstorms NXT was selected as the workshop platform for easy construction and programming. This paper presents the different goals and the replies received to a feedback questionnaire.**

***Keywords*— robotics, construction, workshop, surgery**

I. Background

One of the probably most cited robotics articles in 2007 was the one by Bill Gates that appeared in Scientific American with the title "A robot in every home"[1]. Today, the robotics industry is booming just like the personal computer business was 30 years ago. Consequently, the next question is, when will we have a robot in every operating room, in every lab, at every patient's bedside? Robots are already present in many places in a hospital: lab[2], transportation[3], operating room (general surgery[4], thoracic surgery[5], cardiac surgery[6], gynaecology[7], paediatric surgery[8], urology[9], orthopaedics[10], neurosurgery[11], radiosurgery[12]), telerounding[13] and telementoring[14]). They are also becoming involved in nursing[15] and rehabilitation[16].

From the standpoint of a surgeon, robots are complex instruments that enhance their technical possibilities, but are no substitute for good surgical knowledge and skills. For efficient and safe handling it is important to know their abilities and limits, especially when they are used on patients. At the moment, robotics is not a standard part of a medical school curriculum like e.g. pathology is. However, hospitals continue to introduce more and more applications for robots. Robotic surgical site training[17] includes surgical procedures and system handling, but not basic robotics like kinematics and path planning.

For this reason Innsbruck Medical University launched the elective course "Theoretical Surgery," which includes a hands-on workshop for medical robotics giving the theoretical background for today's robotics applications and future aspects. At this workshop students are given several challenges to solve by planning, building and programming their own robots.

II. Material and Methods

In 1980 MIT (Massachussetts Institute of Technology) Professor Seymour Papert was the first to devise a robotics kit for education[18]. Through a partnership between the LEGO Group and MIT, Mindstorms was born in 1984 and in 2006 the third generation of Mindstorms NXT was put on the market. Primarily intended for school kids aged about 12, it was happily adopted by universities for research and education purposes[19].
Several commercial robotics kits are available. We decided to use the third generation of LEGO Mindstorms, the NXT set, because we found it to be the most flexible for our purposes.

The NXT kit consists of a programmable brick holding a 32-bit ARM processor at 48MHz, an 8-bit Atmel AVR coprocessor at 8MHz, an LCD matrix display with 100*64 pixels, a Bluetooth and a USB2 interface, three motor driver ports with encoders and four sensor inputs: light, ultrasonic, sound and touch. Third-party companies are building enhanced sensors for the NXT system including GPS (Global Positioning System), compass, acceleration, pressure, color, temperature, pH and many more. There is a good open source IDE (integrated development environment) named brixcc[20] (see bricxcc.sourceforge.net) that permits robot programming with several programming languages like LASM (assembly-like), MindScript and NBC (script-like), NQC and NXC[21] (both c-like), c/c++, Pascal, Java[22] and Forth. For medical students without any programming skills the graphical languages NXT-G[23] and LabVIEW are available[24]. Robots are made with the LEGO Technic system, enabling a wide range of possibilities.

For the first robotics workshop (two units of 5 hours each) we invited our medical students and also biomedical informatics students from The Health & Life Sciences University UMIT[25]. Following a short (30 minutes) oral presentation about the NXT kit, the IDE software and organisation issues, we proceeded directly to the challenges.

Challenges:

Subjects from the operating room were selected as standard tasks on day 1 (line following to get into constructing and programming) and special medical issues on day 2. In every challenge students could receive up to four points by solving the challenge, with an additional point going to the fastest team (start to finish).

1.) In the first challenge we used a 10mm black marker to draw a floor plan showing two operating rooms, a corridor and the central sterilisation room (size: two tables). The challenge was to go from OR 13 to the sterilisation room without crossing wall lines and without using a sensor. The aim was to take used instruments to the sterilisation room following an operation.

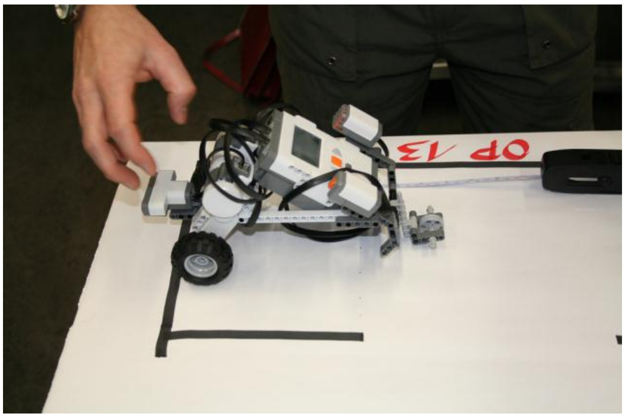

Fig. 1 Floor plan

2.) Same situation as in 1.), but this time a light sensor was used to follow the line drawn down the center of the corridor leading from the operating room to the sterilisation room.

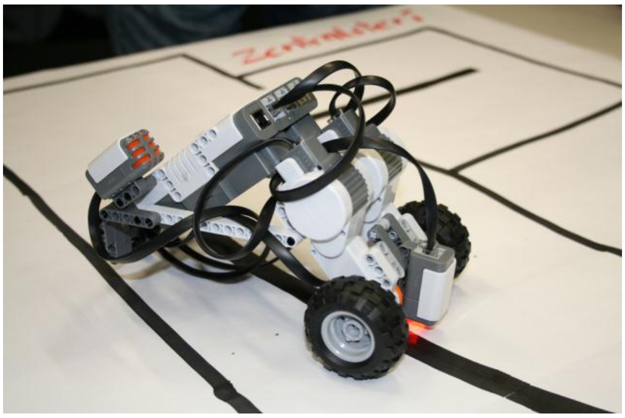

Fig. 2 Follow the line

3.) In this challenge a table represented the operating room: in the middle stood the operating table made of bricks. On the floor were small bricks representing dirty items which had to be cleaned (thrown from the table) without hitting the operating table and, of course, without the robot falling off the table.

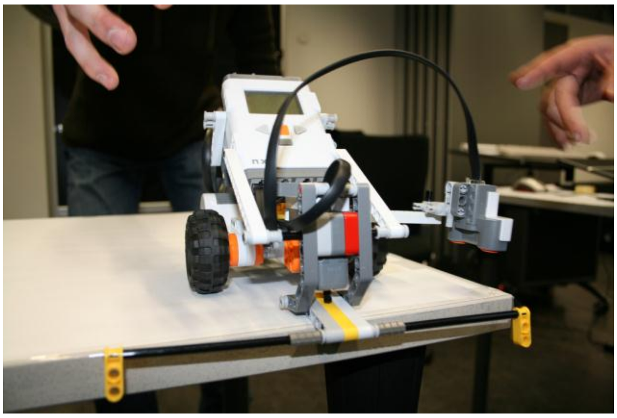

Fig. 3 Cleaning the operating room

4.) Final challenge: Design a robot for intravenous medication administration. Find the artificial forearm (white), artery (red) and the vein (blue). Identify the vein and place the yellow/medication brick on it.

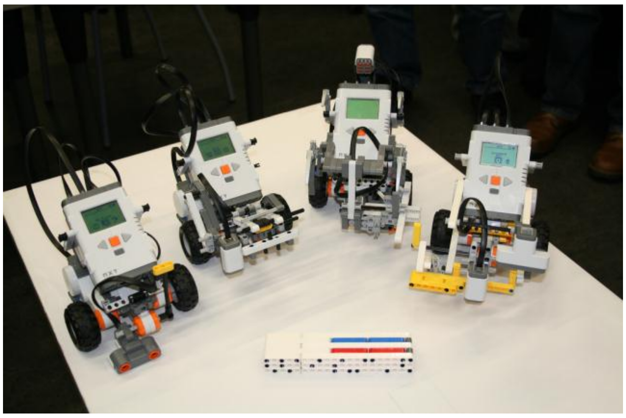

Fig. 4 i.v. Medication robots

The students elaborated on the LEGO Tribot (see mindstorms.lego.com/en-us/support/buildinginstructions/8527-/Tribot.aspx) to construct their robots. More photos and two videos from the workshop can be found at www.TiRoLab.at/imedrws/ .

To evaluate the workshop we distributed a questionnaire asking 27 questions divided into four groups: pre- and post-workshop robotics experience, support during the workshop, preferred programming language, and design of the challenges.

III. Results

All challenges were solved, even when the robots often did something unexpected (see Table 1) in the final rounds (contest) and failed to complete the task.

A maximum of 4 points was awarded for solving the challenge on time, less for a partial solution. The fastest team earned a bonus point, for a grand total of 5 points. Points were deducted for crossing a wall in challenge 1 or 2, touching the operating table or putting the medication in the wrong place. A robot that fell off the table meant immediate disqualification (zero points).

The interdisciplinary team (NOS) including informatics and medical students showed the best results. Another exciting fact was that all robots were made from the same LEGO NXT kit, but no two mechanical solutions to a challenge were even similar.

Team	**Challenge**			
	1	2	3	4
	Training / Contest	Training / Contest	Training / Contest	Training / Contest
Elkdestroyer	2 / 0	4 / 4	3 / 0	3 / 0
Bruteforce	2 / 0	4 / 4	3 / 0	4 / 0
NOS	4 / 5	4 / 5	3 / 0	4 / 0
DontFallFrom TheTable	1 / 0	3 / 1	3 / 0	4 / 0

Table 1 Challenge results

Questionnaire results:
All 11 participating students completed the questionnaire.

Figure 5 compares pre- and post-workshop robotics experience reported by the students themselves on a scale from 1 (excellent) to 5 (poor). Count shows the number of students. It shows that the students gained robotics experience during the workshop.

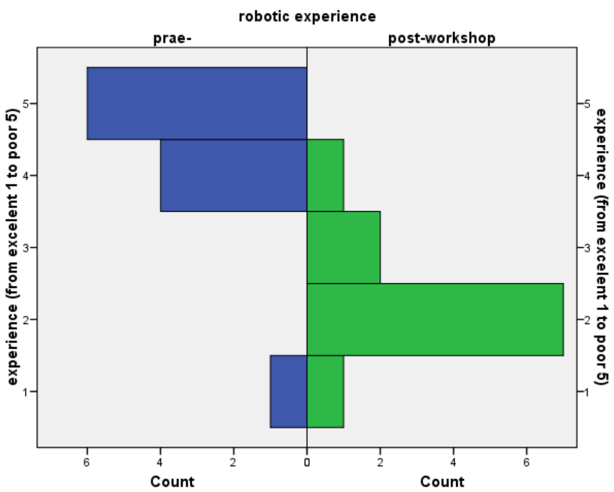

Fig. 5 Robotics experience

Figure 6 shows the replies to the items “Were the challenges didactically useful (learning progress)?” and “Did the workshop meet your expectations?” Grading and count are the same as in Fig. 5. The students rated the workshop as useful, and reported that it highly met their expectations.

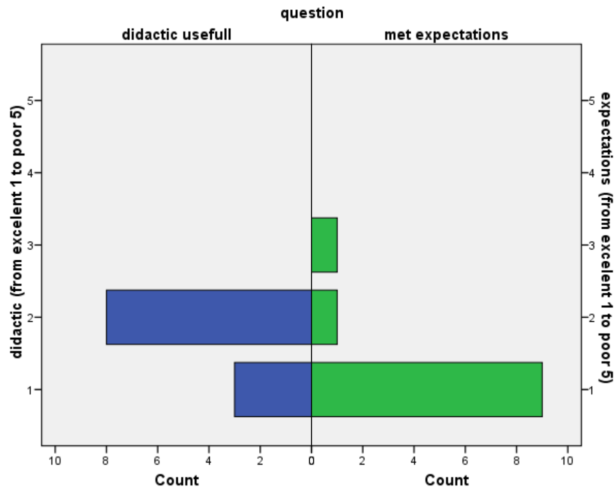

Fig. 6 Didactics and expectations

Further results are that the informatics students were quite happy with the NXC (Not eXactly C), but some would have preferred Java, which has more powerful libraries. The medical students wanted to program graphically, because they had poor know-how of syntax in textural languages.

IV. Conclusions

The LEGO Mindstorms NXT kit is a relatively inexpensive and powerful tool for running hands-on robotics workshops. The LEGO Technic bricks enable very flexible possibilities for constructing robotic models. A wide range of available programming languages ensures quick results and potent applications by running the robots with a graphical approach for novices and the possibility to code programs in C or Java for experts.

We found that interdisciplinary teams have a big advantage due to the transverse knowledge shift on the team and should be given priority. Thus, if you get the chance to cooperate with a technical university - take it! Fascinating team working processes started during the workshop and will hopefully continue. The first challenges showed us that the next to the last program was usually the best solution. The conclusion for the future is that teams need more time to solve individual tasks and team size will be enlarged to four members to ensure enough manpower for constructing and programming in parallel.

The workshop is an opportunity for medical students to make mistakes and learn from them. In hospitals they have to work with the state of the art. Software engineers have a much more intuitive access: they look inside the debugger to see what's wrong and fix it. When errors are allowed, they can help overcome borders to create new things, new approaches and optimize tools for a special task. Despite all the theory, robotics is great fun. If your robot never fell off the table, you weren't trying hard enough.

Today, robotics is widely used in medicine. Even if we don't yet have a robot in every operating room or at every patient's bedside, they are already in every automated lab. Early adopters show us where the way could go, and if we are to believe robotics associations, robots will be standard equipment in the next 20 years, like television and mobile phones are now. Robotics education at medical universities or during hospital residency can help turn users into knowing operators, who understand a little more of the underlying technical stuff. In this way, error handling derives from error understanding and hopefully leads to safer applications for our patients.

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