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RoboKing - Bringing Robotics closer to Pupils

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***Abstract*— In this paper, we introduce RoboKing, a national contest of mobile autonomous robots, dedicated to teams of high school students. RoboKing differs from similar contests by supporting the participating teams with a 250 Euro voucher and by not restricting the kind of materials the robots can be build with. Its task is manageable for students without previous knowledge in robotics but offers enough complexity to be challenging for advanced participants. The first RoboKing contest with 12 participating teams from different parts of Germany took place at the Hannover Messe in 2004. Because of its great success, RoboKing will be held annually. RoboKing 2005 has been extended to 20 teams of pupils and offers a new challenging task. More pictures and video files can be found under www.roboking.de .**

***Index Terms*— robotics contest, competition, pupils, students**

I. Introduction

During the past few years, mobile robotics has increasingly attracted public attention. Many TV documentations about the DARPA Grand Challenge, about new developments in robotics in general, several reports about RoboCup and of course the latest movie "I, Robot" demonstrate this development. Nonetheless, many universities report stagnating or even declining numbers of students in engineering subjects while at the same time, the economy experiences a massive lack of skilled engineers. Therefore, universities and private enterprises make big efforts to increase the number of young students in engineering subjects.
The best way to encourage pupils to study engineering sciences is to increase their interest in technical issues. This, on the other hand, is best done by giving them the opportunity to gain some practical, hands-on experience, combining fun and learning. As mobile robotics combines electrical and mechanical engineering as well as computer science, a contest of mobile autonomous robots provides an excellent opportunity to bring pupils of different interests together in one team and raise or increase their interest in engineering and technology.

II. Why yet another robot competition?

Today, there already exist a number of international and national robotics contests. The most famous international robotics contest is the annual RoboCup. There is a german RoboCup competition every year, which acts as a qualification round for the international finals [1]. Although the Junior-League, Sony-League or even the Small-Size-League could be suitable for teams of encouraged pupils, several problems occur. The Junior-League is well suited for young pupils, but pupils with some advanced knowledge feel very limited by the few opportunities the mandatory LEGO Mindstorms environment offers. They also feel subchallenged by the relatively simple tasks the robots have to do. On the other hand, the Sony- and Small-Size Leagues are too complex for pupils because the tasks always require multi-robot interaction and advanced image processing. Furthermore, both the AIBO-Robots and the parts for the small-size-robots are very expensive, thus taking part in these competitions requires a lot of financial support, which in most cases neither schools nor parents can provide.
Another international contest is Eurobot [2], which has been annually held in France and is now going to take place in different countries every year. But because the tasks are very complex, Eurobot is more appealing to teams of university students than to pupils.
Besides these international contests, there are several national robotics competitions in Germany. The universities from Dresden and Rostock organize two events which are explicitly dedicated to pupils. The SPURT contest from the University of Rostock concentrates on LEGO Mindstorms robots that have to follow a line [3]. The robotics event at Dresden University focuses on older pupils [4]. The participants are provided with a kit that contains a microcontroller board and several other parts. The task combines line-following and finding a ball which has to be kicked into a goal.
Besides these contests, there are two more events that are organized by private persons from the public robotics community in Germany [5]. These competitions act as meeting points for robotics-hobbyists from the whole country but are not focused on pupils or educational issues.

In this situation, we felt there was a gap to fill and thus we created the idea of RoboKing. This new robotics contest should have the following characteristics:

- A task suitable for teams of up to 5 pupils of 9th grade and above. The task should be simple enough for committed pupils without previous knowledge in robotics, but should also offer enough potential and complexity to be challenging for advanced pupils.

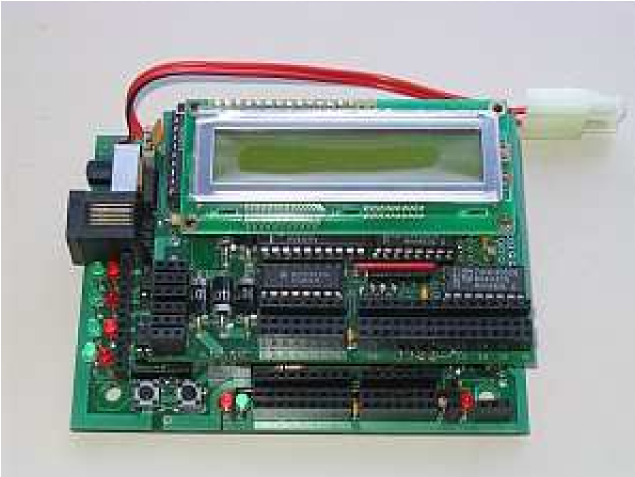

Fig. 1. The Handyboard was used as the only mandatory part in RoboKing 2004.

- Financial support for the teams. Each team should be supported with a voucher they can use to pay for all the materials that are needed to build the robot.
- Unexperienced teams should be supported with a detailed documentation about sensors and other robotics specific issues. There should be a forum where the participants can ask questions about whatever problem they might face.
- No restrictions regarding the materials or sensors used. The pupils should be able to build the robot just the way they want to.
- Presentation on a fair to get as much public attention as possible.
- The teams should be able to keep their robot after the contest.
- Attractive prizes as additional incentives. The first prize at RoboKing 2004 was a Sony AIBO.

III. RoboKing 2004 - The Task

As mentioned above, the task should be simple enough for beginners in robotics but should also offer challenging aspects to advanced pupils.

Simply said, the robots had to navigate through an unknown maze, find some infrared emitting beacons and switch them into one of two possible states. At the same time, the opponent robot tried to switch the beacons in the opposite state. So there were always two robots playing against each other. The field was a flat blue surface with dimensions of 2.40 by 2.40 meters. Black lines divided it into 64 quadratic fields of 30 cm length each. The robots could use these lines for orientation. A simple CNY70 reflex-coupler was able to distinguish between the blue surface and the black lines.

The corridors and dead ends of the maze the robots had to move through, were formed by white walls of 15 cm height. These walls could be put together in a very flexible way which enabled us to create many different mazes. The only limitation was that the walls always had to form rectangular corners. The robots started in two opposing corners of the table. The maze was always designed symmetrically, so that it looked the same for both robots. See Fig. 2 an example of a maze.

The beacons (Fig. 4) hung down from the walls into the corridors and emitted a infrared signal that was modulated with 38 kHz. The robots could sense that signal with a TSOP38 sensor. To switch the states of the beacons between ”red” and ”green” the robots simply pushed against a trigger at the bottom of the beacons. The beacon’s current state was signaled by two LEDs on top of them. To make the states ”visible” to the robots, the emitted infrared signal changed as well. The ”red” and ”green” signal had different on-off ratios. One robot had to switch all beacons to red, the opponent had to switch everything to green.

All beacons started in a neutral state. After being triggered for the first time, they switched into red or green randomly. After that, each trigger pulse switched the state from red to green alternately. After a beacon had been switched to green, the ”red” robot was of course able to switch it back to red and vice versa.

Each game lasted 10 minutes. After that, each team got points for each beacon switched to their respective color. If the teams had to touch the robots during the match, maybe because they got stuck, the referees subtracted penalty points for each interference.

This task met our requirements in terms of complexity. The very basic behaviors the robots needed to have were detecting the beacons, sensing walls and being able to drive straight ahead in the corridors and turn at junctions. A team of beginners without previous knowledge should be able to construct and program such a basic robot in the given time. More sophisticated robots could include algorithms for mapping of the maze, path planning or even strategies that took the movements of the opponent robot into account.

IV. RoboKing 2004 - General Issues

After we settled the task and rules of the game, we introduced RoboKing to the pubic through our homepage, several media reports and a presentation at the Hannover Messe in April 2003.

Interested teams of pupils could apply for participation from April to July 2003. We asked them to write about their previous knowledge in the fields of electronics, mechanics, and programming. They also should describe what motivated them to take part. At the end of the application period, there were 48 applications from all over the country. Of course, 48 teams were much more than we could handle. So we decided to choose 12 teams for participation. Making the decision, which teams were given the chance to take part and which were not, was not always easy. We tried to select those teams who were able to solve the task well. But a motivated team and a

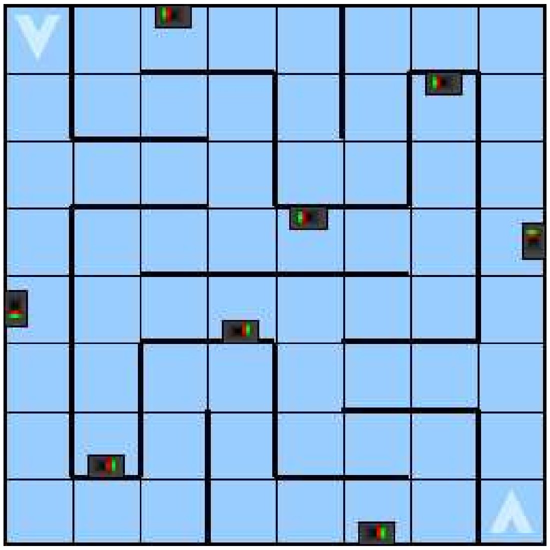

Fig. 2. Example of a maze. Notice the symmetric layout of the walls and the beacons. The starting positions of the two opposing robots are marked in two of the corners.

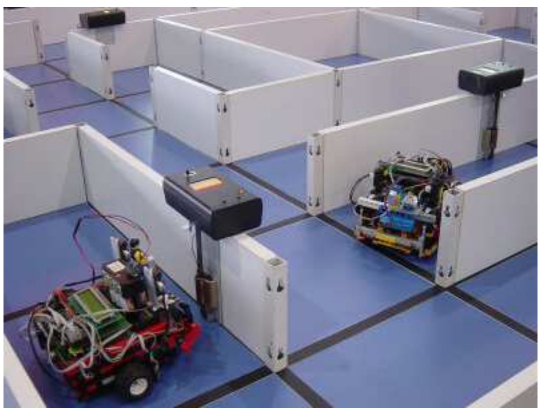

Fig. 3. Two LEGO-Robots in the maze. Notice the black beacons and how the black lines divide the table into quadratic sections

Fig. 4. A beacon. Notice the big red and green LED on top of it. They show the actual state the beacon is in. The infrared-LED is just beneath the white body. The switch is at the bottom, so that the robots can simply drive against it.

capable adult teamleader was more important to us than lots of previous knowledge.

So the average participant was about 16 years old, has always had interests in electronics or programming, but did not realize any robotics projects before the RoboKing. As we expected, the team members were almost exclusively boys; we only had two girls within the 56 participating pupils. The youngest team was a group of 10 to 12 year old children, who were members in a computer club in their hometown. Under the guidance of the father of two of them, they had already successfully taken part in two local robotics contests.

After the participating teams were informed, the pupils started constructing their robots in late July or after the summer holidays. Each team got a starter kit, containing a Handyboard and its software, a beacon and the documentation. The documentation described the rules of the contest but also gave a detailed overview about lots of different sensors available on the market. It also contained information about motors and provided other useful hints that made life much easier for the beginners.

As common sensors like the Sharp GP2D12 or the SRF04 are quite expensive, each team got a 250 Euro voucher in addition. The teams were able to spend the 250 Euro at every shop they wanted. To control the kind of materials the pupils bought and to be able to give them some advice where they could buy certain things cheaper, they had to tell us what they intended to buy. We set up a kind of webshop on our homepage, where the teams could enter the parts so that we could confirm or refuse their order. After we confirmed it, the pupils bought their materials in the normal way and payed for it in the first place. Then they sent us the bill from the shop and we transfered the spent money to the account of the adult team leader. It turned out that the 250 Euro voucher was quite appropriate. In average, each team spent about 200 Euro for their robot. The funding to support the teams came from many sponsors, big and smaller companies as well as engineering organizations as listed at the end of the paper .

Since we did not want to limit the teams' creativity and did not want to end up with almost identical robots, the teams were allowed to build their robots from every

Fig. 5. The game field during the finals, surrounded by spectators, participants, and referees.

Fig. 6. The winning team from Limbach with their robot and the first prize, a Sony AIBO.

material they wanted, using every sensor or actor available on the market. The only restriction was that they had to use the Handyboard microcontroller board. Due to our experiences with the board, we knew it was the best solution for beginners. No need for external circuits or extra soldering to get the robot running, an extensive library, an integrated development environment and last but not least, our experience with the system that enabled us to help quickly when questions or problems arose, made it the best choice. Another advantage was, that if every team had to use the same microcontroller system, nobody was able to dominate the other teams only by using a very sophisticated controller system.
In January we invited the teams for one weekend to a preliminary contest in a local youth hostel. The robots simply had to follow a path in the maze, the fastest robot was the winner. That preliminary contest was meant to motivate the teams to start building their robots early so that they did not let time go by until shortly before the finals in April. As it turned out, actually not all robots were able to solve the simple task well because they started too late working on the problems. However, the preliminary contest was a very successful event. The pupils had the chance to test their robots on the original game field, they met the other participants and were able to exchange ideas. In the evening, each team introduced itself so that everyone got to know the others.

V. RoboKing 2004 - The Finals

The final round of RoboKing 2004 took place at Hannover Messe from April 22nd to April 24th. We accommodated the pupils and most of the adults in a nearby youth hostel. The Deutsche Messe AG provided us a $160m^2$ stand and equipment on the fair. (We also used that stand for the german Eurobot-Qualifications two days before RoboKing started.) The stand was located in the so called "Go-For-Hightech"-hall, an area dedicated to young visitors like pupils and students and was thus perfectly suitable for our event. The participants arrived on Thursday and could use the day to test their robots and to adapt them to the local conditions. Unfortunately, three of the twelve teams had to give up shortly before the final round in Hannover. But the remaining nine teams were highly enthusiastic. We had two game fields, one was used for the contest, the other one could be used for testing all three days long. On Friday morning, we started the play-offs. The play-offs were designed in a way that each team played at least 5 matches and eight teams stayed in the contest until Saturday. This was an important issue, as we wanted to prevent that many teams departed after the first day because they had dropped out of the contest. The semi-finals and finals were held on Saturday early afternoon. Despite the competitive character of RoboKing, all teams behaved very fair and helped each other. Everyone really enjoyed the three days and we all had a lot of fun.
Our stand attracted many visitors throughout all three days. We projected a top-view of the field on a big screen and had two moderators who commented the matches and ongoing events. Four of our students and two pupils from supported the moderators as referees or general staff. We received very positive feedback, not only from the spectators but also from the fair management and from our sponsors.

VI. Review

It is remarkable, how well many of the robots accomplished the task. Most teams used the Sharp GP2D120 sensors to detect the walls of the maze. Some teams used these sensors to align to walls and thus were able to drive through the maze relatively straight. Others used wheel encoders to drive straight or they used the black lines on the ground to orientate which they sensed with reflex-couplers like CNY70.
Some robots were advanced enough to map the maze. The

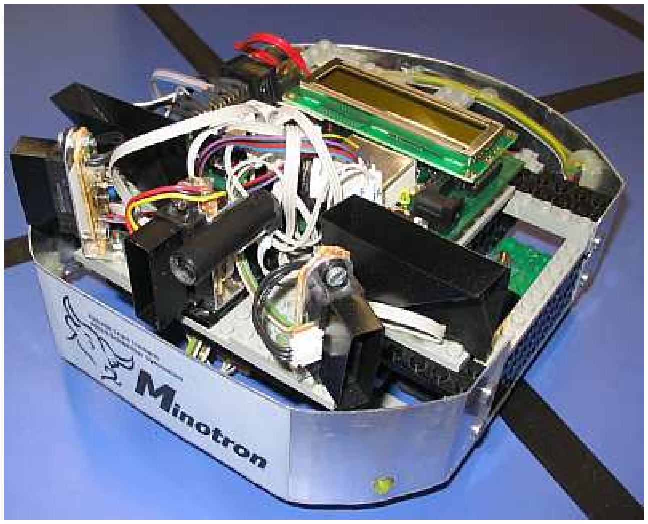

Fig. 7. A close-up of the winning robot, Minotron. It was based on LEGO bricks, but used a lot of non-LEGO sensors like GP2D120. The runner-up was made from LEGO bricks as well.

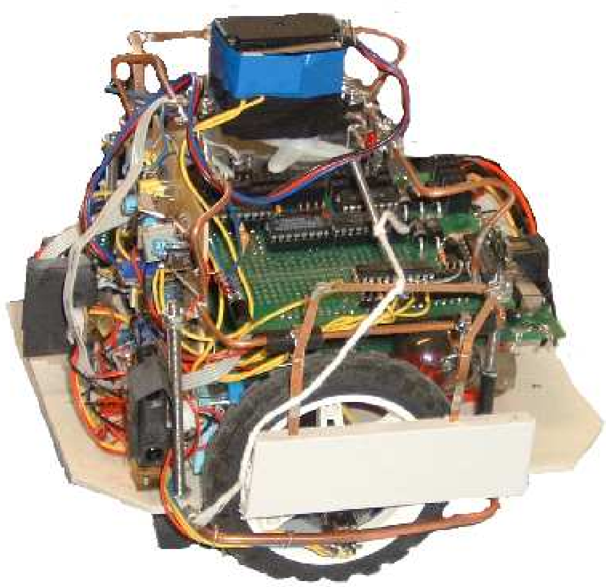

Fig. 8. This robot has a wing (the bright plate covering the wheel) on each side that could be flipped up to touch the trigger of the beacons. It was built by the pupils from Aschaffenburg and reached the 4th place in the final rankings.

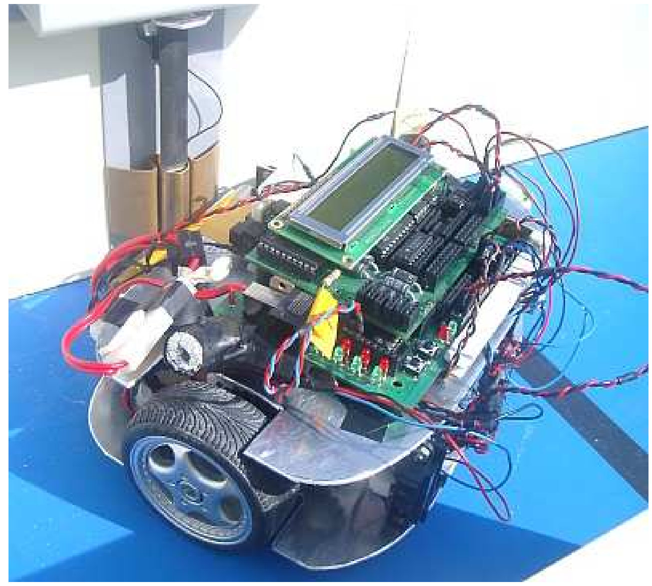

Fig. 9. Another robot constructed by participants. Notice the Handyboard on top of it.

common solution to store the map was a 8x8 array, as the black lines on the ground divided the environment into 64 quadratic tiles. Most teams used bit-patterns to store the information for each of the tiles. These information could be the position of bounding walls or whether a beacon was present or not. The robots usually tried to explore all of the maze and then searched for the closest beacon. The programmers were able to make use of the symmetrical structure of the maze, so the robot did not have to explore the environment completely, but only half of it.

All robots used a differential drive. This was the most practical solution because it enabled the robots to turn in place, which comes in handy at dead ends or junctions. The winning robot was the only one who could drive real smooth curves around the corners of the maze. All the others stopped at junctions, turned 90 degrees in place and went further straight ahead.

The pupils used very different materials as the basis for their robots. We could see robots made of LEGO bricks, aluminum, perspex, wood or plastic. It may be remarkable that both the winning robot and the runner-up were made of LEGO bricks. Both teams concentrated less on mechanical perfection but more on robust programming.

If we analyze the team structure, we notice how different the teams were. In some groups, there were pupils of different age, sometimes 3 years apart. Other teams consisted of classmates that had been together before. According to our experience, the pupils are able to learn very quickly new issues in programming or electronics, when they can immediately see the results as it is the case in robotics. Even students without previous knowledge are able to master the given task well. The adult teamleader plays an important role, especially in motivating and organizing the team and giving advice, but only rarely has to intervene in the actual construction or programming. The level of difficulty of the task was appropriate. The teamleader of the youngest participants (10 to 12 years old, 5th place in the final ranking) said that it was just on the edge of being manageable for the children. All others were very satisfied with the task.

One important point we learned is that the teams need some incentive to start building the robots early. A preliminary qualification contest at half-time, where some teams have to leave the contest seems to be suitable. Demanding a technical documentation about the way the robot is being build, which sensors are being used etc., is also appropriate if it has to be finished one or two months before the preliminary qualifications.

VII. RoboKing 2005 - To be continued ...

All the experience we have gained with the first RoboKing competition in 2004 influences the way we organize the RoboKing 2005. Again, we started the application period in April. We informed the accepted teams in July. The finals are going to take place at the Hannover Messe again. In this year, we have got a different task and made some changes to the rules. First of all we have increased the number of participating teams from 12 to 20. As mentioned in the last chapter, we also increased the competitive aspect. The teams have to deliver a documentation by the end of November. This documentation is a prerequisite for taking part in the qualification round in January. Only the best 16 teams will qualify for the finals in April. This way, we hope to prevent the teams from giving up shortly before the finals, like three of them did in 2004.

The new task is more dynamic than the old one. So watching the robots play against each other will be even more interesting for the spectators and more attractive to the media.

In 2005, the robots have to find and gather tennis balls which are laying around on the field and bring them back to their home base. To make the task more challenging and more dynamic, there are two hidden switches on the field. If a robot activates that switch, the home base of the enemy is being lifted up, so all collected balls will roll out back into the field. Of course, these switches are not easy to find. The robots have to find a way through some obstacles before they can reach the switch.

For RoboKing 2005, we did not oblige the teams to use the Handyboard anymore, but extended the voucher to 350 Euro. Although we still encourage beginners to use the Handyboard, the participants are free to use any 8 bit microcontroller they want. This way, the robots will be more different, while still all allowed microcontroller systems have similar capabilities.

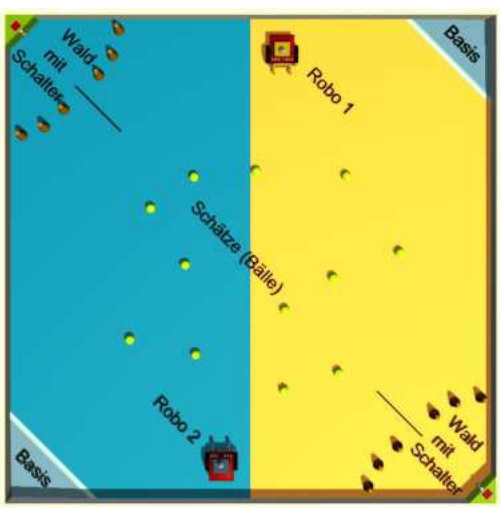

Fig. 10. Layout of the game field for RoboKing 2005. It is divided into two parts: A blue and an orange one. There are up to 12 tennis balls on the table that have to be found by the robots and brought back into their home base in the corner of the table. In the other two corners, behind the obstacles are switches, which empty the opponent's base.

VIII. Conclusions

Robotics contests are excellent events to increase the interest of pupils and young students for technical issues and engineering. Not only the participating students are influenced in that way, but also the spectators of the event or even those reading about the contest on a homepage. There are many pupils out there who would like to gain practical experience and apply their knowledge and talents. Too often, they lack the opportunity to do so, or they cannot find classmates or friends with the same interests. Technical contests in general, not only those related to robotics, can help to bring those interested pupils together. Very often, once the first step is taken, a permanent study group is established in the school under the supervision of a teacher. This way, even after the contest, more pupils in that school can share their interests and continue working on technical projects.

We can think of extending RoboKing to an international contest. There could be national competitions in each participating country. The best pupils are qualified to participate in the international finals, which could take place in varying countries every year. This way, we would create an all-european contest, comparable to Eurobot, but explicitly dedicated to pupils with all the advantages RoboKing already offers today.

Acknowledgments

An event like RoboKing can only be organized by a team of very committed people. We therefore want to thank all those who made RoboKing possible. Primarily Andreas Aurich, Jens Kreher, Annika Neidhardt and Manuela Wolf as well as Matthias Arzt and Fabian Heusel, Günther Benedikt, Klaus Korb and Elke Herfter. Andre Heller and Jan Schiller did an excellent job in designing all the layouts for posters, flyers and the homepage. Last but not least, the RoboKing was made possible by our sponsors. We would like to thank our sponsors VDE, Siemens, Bosch, BMW, Sick, Roboter-Teile, Embedit, Micromaus, Reichelt, Robo-Store, Krause-Robotics and E-Lab.

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