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Bringing Robotics Closer to Students - A Threefold Approach

Niko Sünderhauf, Thomas Krause, Peter Protzel
Department of Computer Science and Department of Electrical Engineering and Information Technology
Chemnitz University of Technology
09126 Chemnitz, Germany
niko.suenderhauf@informatik.tu-chemnitz.de
{thomas.krause, peter.protzel}@etit.tu-chemnitz.de

***Abstract*— In this paper, we present our threefold concept of "bringing robotics closer to students". Our efforts begin with motivating high-school students to study engineering sciences by increasing their interest in technical issues. This is achieved by a national robotics contest.**
Besides our work with high-school students, we also focus on projects for undergraduate university students. Several robotics projects and competitions are included into the curriculum of electrical and mechanical engineering and computer science. These projects offer chances to do special assignments and student research projects. It may be important to point out that most of the work described in this paper, including inventing and specifying the projects and organizing the events, has been done by undergraduate and graduate students.

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

I. Introduction

Robotics, seen from an educational point of view, is a mixture of electrical and mechanical engineering and computer science. Hardly any other topic is better suited to address students interested in either topic and bring them together with other students with other fields of interest. Teamwork with other students and interdisciplinary communication skills are important soft-skills that can only be developed and improved by practical experiences and projects. During the past years, our group has initiated several projects with two main goals: The first is to motivate high-school students to study engineering sciences by increasing their interest in technical issues. This is achieved by a unique national robotics contest, called RoboKing. Up to 25 teams of high-school students can participate in this contest every year. We will present and explain the idea and concept of RoboKing in the first part of this paper. Our second goal is to address young university students which study electrical or mechanical engineering or computer science. We want to raise their interest in mobile robotics and help them develop the necessary hard- and soft-skills. Following the successful RoboKing-concept, we organize several robotics projects and robotics competitions at our university.

It may be important to point out, that most of the work described in this paper, including inventing, specifying, and organizing the projects, has been done by undergraduate and graduate students.

II. RoboKing - A contest for high-school students

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, and several reports about RoboCup 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 high-school students 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 students of different interests together in one team and raise or increase their interest in engineering and technology.

A. 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 [1] [2] [3]. Although the Junior-League, Sony-League or even the Small-Size-League could be suitable for teams of encouraged young students, several problems occur. The Junior-League is well suited for younger kids, but students 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 students 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

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lot of financial support, which in most cases neither schools nor parents can provide.
The First Lego League (FLL) [4] [5] is an international contest especially aimed at students. It offers challenging and complex tasks which are changing every year. Although the tasks are quite complex, they consist of easier subtasks which can also be mastered by younger students. The main drawbacks of FLL are the mandatory use of LEGO and a relatively high fee the teams have to pay for participation.
Another international contest is Eurobot [6], which has been annually held in France and is now going to take place in different countries every year. Due to its very complex tasks, Eurobot is more appealing to teams of university students than to high-school students.
Besides these international contests, there are several national robotics competitions in Germany. Most of these competitions act as meeting points for robotics-hobbyists from the whole country but are not focused on students or educational issues.
In this situation, we felt there was a gap to fill and thus we created the idea of RoboKing [7] [8]. This new robotics contest should have the following characteristics:

- A task suitable for teams of up to 5 students of age 14 and above. The task should be simple enough for committed students without previous knowledge in robotics, but should also offer enough potential and complexity to be challenging for advanced pupils.
- Financial support for the teams. Each team should be supported with a voucher of approximately 300 Euro they can use to pay for all the materials that are needed to build the robot. These vouchers are completely financed by our sponsors.
- 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 students 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, this year's price will be a Robonova humanoid robot.)

After we developed the ideas and a detailed concept, we began looking for sponsors and supporters. We were able to organize the first RoboKing finals on the Hannover Messe, the biggest industrial fair worldwide, in April 2004. All RoboKing finals have been held on the fair since then. After the great success, we continued and extended RoboKing to more teams. And of course, there is a new task every year. The following sections describe the tasks of the three contests that took place so far.

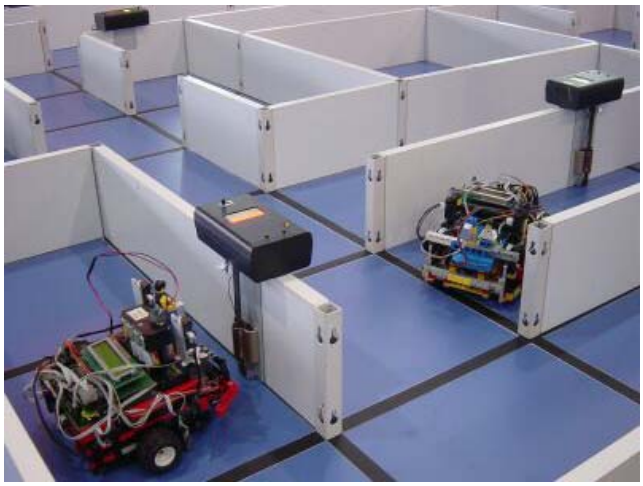

Fig. 1. Two LEGO-Robots in the maze of RoboKing 2004. Notice the black beacons and how the black lines divide the table into quadratic sections.

B. The Tasks

As mentioned above, the tasks should be a challenge to advanced students without asking too much of the beginners. So the tasks have to be designed in a way that they can be solved by several differently complex (regarding programming as well as mechanics) strategies and solutions. The more complex these solutions are, the more advantages should the robot have, but the harder it is to implement them.

C. The Task 2004

In the first contest in 2004, 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.
The beacons (Fig. 2) 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

Fig. 2. 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.

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. Teams of beginners without previous knowledge were able to construct and program such a basic robot in the given time. More sophisticated robots included algorithms for mapping of the maze, path planning or even strategies that took the movements of the opponent robot into account.

Fig. 3. The arena of RoboKing 2005 during the finals in April 2005 at Hannover Messe, the biggest industrial fair worldwide. Notice the homebases (red triangles), the tennisballs, and the hidden switches in the corners behind the trees which emptied the opponent’s base.

D. The Task 2005

The task for the second national RoboKing contest was entitled ”Treasure Hunt”. The robots had to collect 10 tennis balls that laid on the field and bring them into their own base. To make the task more challenging and more dynamic, there were two hidden switches on the field. If a robot activated that switch, the home base of the enemy was lifted up, so all collected balls rolled out back into the field. Of course, these switches were not easy to find. The robots had to find a way through some stylized ”trees” which served as obstacles before they could reach the switch. Although a black line could be used to navigate *into* the forest (see figure 3 for a layout of the arena), finding out was very difficult for the robots. So only the best teams were able to use this strategic possibility. The switches could be used only twice per game and were deactivated during the last 90 seconds of the match. Each match lasted 5 minutes.
20 Teams participated in this second national RoboKing contest. Again, the teams tried several strategies of different difficulty levels to solve the task. Some tried to find the balls and homebases by using a small camera, the CMUcam. Others searched the table systematically and used the walls to localize themselves on the arena. The matches themselves were very dynamic, due to the many balls that were rolling and moving across the table. The possibility to empty the opponents base added an extra amount of thrill and challenge so both teams and spectators got very excited watching the matches.

E. The Task 2006

The motto of the current contest is ”Building the Castle”. The robots have to collect wooden building blocks and transport them through a series of obstacles to a predefined construction site on the opposite side of the table. Obstacles include a narrow bridge over a trench, a canyon and a stylized forest. The robots can score bonus points by

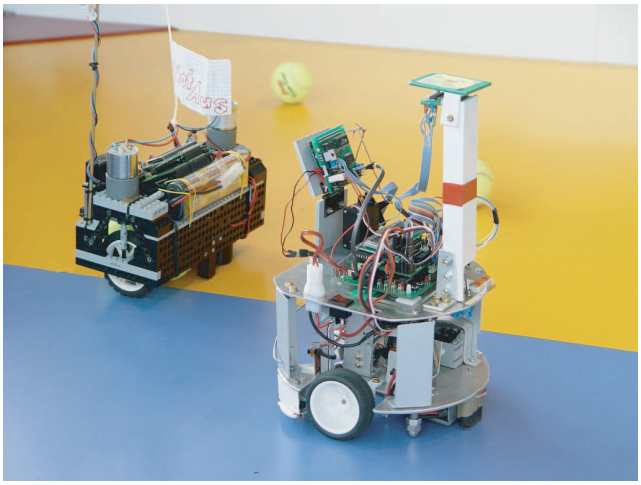

Fig. 4. Two of the robots built by high-school students during RoboKing 2005.

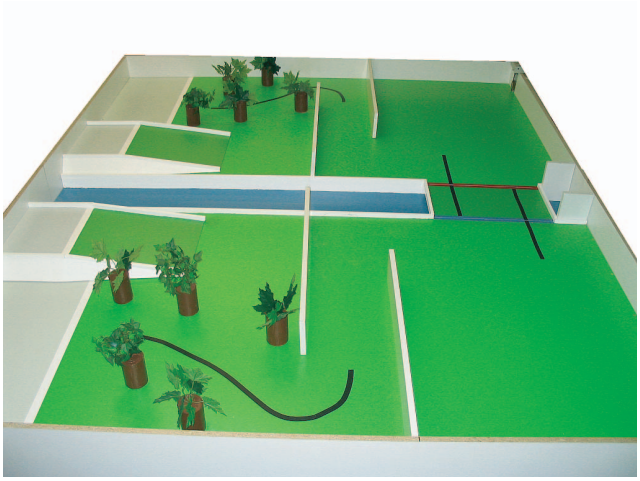

Fig. 5. The arena for RoboKing 2006. Notice the three main obstacles: The bridge, the canyon, and the forest.

delivering the wooden blocks on a small elevated platform which can be reached by a hidden slope. To our surprise, hardly any team used the slope to actually drive up that platform. Instead, they constructed a mechanical device to lift the stones up from the side and let them slip onto the platform.
Although this task is more statically than the previous one, it requires several different abilities, such as wall following, line following, precise navigation by wheel encoders and re-orientation on several landmarks. Due to increasing support from our sponsors we were able to extend the number of participating teams to 25.

F. RoboKing - A successful concept

The public presentation of the RoboKing contest on the Hannover Messe, the world's biggest industrial fair, caused a lot of positive feedback and reactions by media, sponsors and spectators. Several newspapers and magazines reported, as well as one of the best known TV science program in Germany and Austria. Since the first RoboKing in 2004, over 280 high-school students participated in the contest. Many teachers who served as team leaders started to use robots in their lessons, especially during computer science courses. We further support those teachers by organizing workshops and tutorials, sharing our experience with educational robotics and thus giving them a good start. In addition, many students and teachers continue to work in robotics or electronics projects in their spare time after school.

G. Evaluation

Of course we are interested in the team's opinion about the contest itself, but also in how they addressed the task, how and what they learned, what their main interests are and what they are going to study after finishing school. These answers are gained by questionnaires for the team as a whole and for individual students. This section presents some of the most interesting results from this year's evaluation.

Asked "What are your main interests?", the majority (25 from 40) mentioned "programming", and 17 answered "electronics". An interesting effect is that being asked "In which fields did you learn most during the contest?" 26 from 40 answered "electronics" and only 18 said "programming". So it seems the students learned most in the fields they were not interested most in the beginning. Figure 6 shows these results. Another proof which stresses the fact that RoboKing is a team-experience can be found in the answers to the question "How did you learn?" 48% answered "from other team members", 36% claimed "I learned by myself from books, internet etc.". Only 15% learned from the teacher or adult tutor (fig. 7). The student's main interests also influence what they want to study after finishing school. Only one of the 40 asked students does not want to study at an university. As can be seen in figure 8, the students clearly favor computer science as their planned main subject at university (26%), followed by electrical engineering, information technology and automation (13% together), and physics (13%). Mechanical engineering ranked 4th with 11%. These ratings did not change significantly during the participation, although a few students changed their plans signigicantly (e.g. from becoming a police officer to studying electrical engineering).

III. RoboKing - A contest for university students

RoboKing is not only a contest for high-school students. A similar concept (and the same name) has been used for 5 years for an internal contest for university students of automation technology and computer science. Accompanied by lessons in control theory, automation technology and a basic course in artificial intelligence, they have to solve the "Robots-In-A-Maze"-task described in section II-C during a one year mandatory course. The students can use a fleet of six little robots which are equipped with two turnable range sensors mounted on servos, wheel encoders, reflex couplers and bumpers (figure 9). The robot's controller, an ATmega32, is programmed in C.

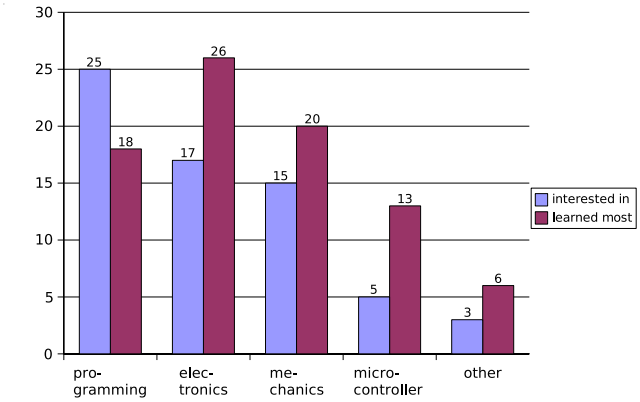

Fig. 6. What are RoboKing students interested in and what did they learn most during the contest?

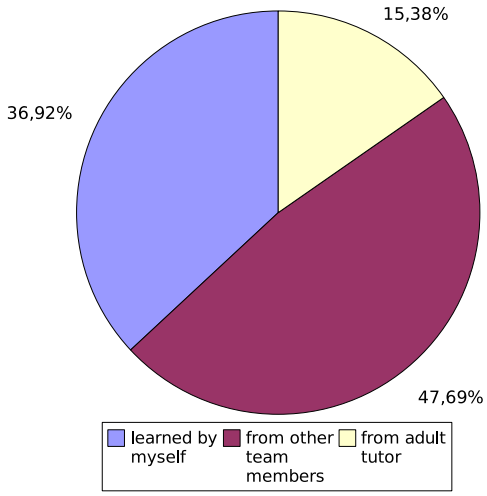

Fig. 7. How did RoboKing students learn during the contest?

During the course, the students can apply several topics they learned in the theoretical lessons, for instance the various types of controllers, or software architecture approaches like the well-known subsumption architecture or simple neural networks.
Students work together in small groups of 2 or 3 students. We usually form mixed groups consisting of one student of electrical engineering and one of computer science. This helps students to improve their interdisciplinary communication skills, and makes them learn from each other. This concept has profen to be very effective.

Over the year, we hold several preliminary contests, where the robots have to solve simple tasks that are part of the overall task of navigating through the maze. These sub-tasks involve wall-following or driving straight ahead without orienting on walls but using wheel encoders only. The preliminary contests serve as milestones and help students to develop the robot's abilities in a logical order. The contest ends with the big finals which attract many spectators, students as well as professors. If possible, we hold the finals on public events at the university, for instance the open day. The best teams are awarded with certificates and prices.

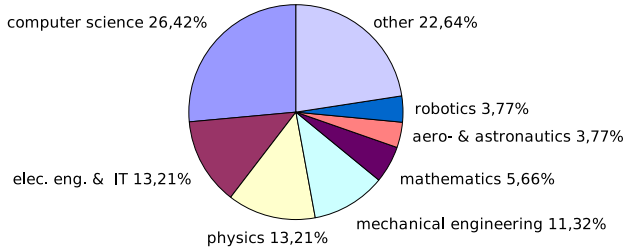

Fig. 8. What do RoboKing students want to study after finishing school?

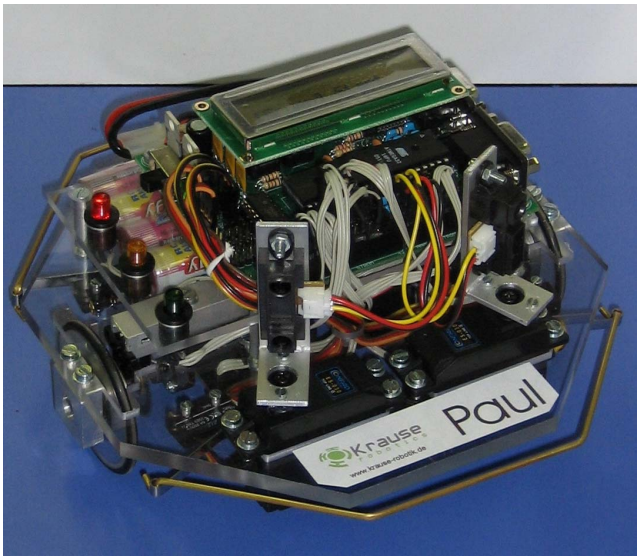

Fig. 9. One of the robots used by undergraduate students during their contest.

IV. Eurobot - An international challenge for our best robot builders

Eurobot [6] is an international robotics contest which is especially aimed at university students but is also open to amateur robotics groups. It evolved from the French Coupe de France de Robotique to an international event open to teams from all over the world. Eurobot is held annually in different European countries, for instance France, Switzerland or Italy. The first international Eurobot competition was held in 1998. Since that time the contest grew constantly and thus over 50 teams participated in the latest Eurobot in 2005.

The rules are changed every year, although some key features, e.g. the match time of 90 seconds, remain the same. The competition area is usually a 2 x 3 meter wide surface. During the last years, the robots had to play Rugby, Bowling, Billiard or Basketball. Besides the exciting robot competitions, Eurobot also includes demonstrations, talks and conferences and social events. Eurobot is promoted throughout Europe by television stations, like the French M6 channel.

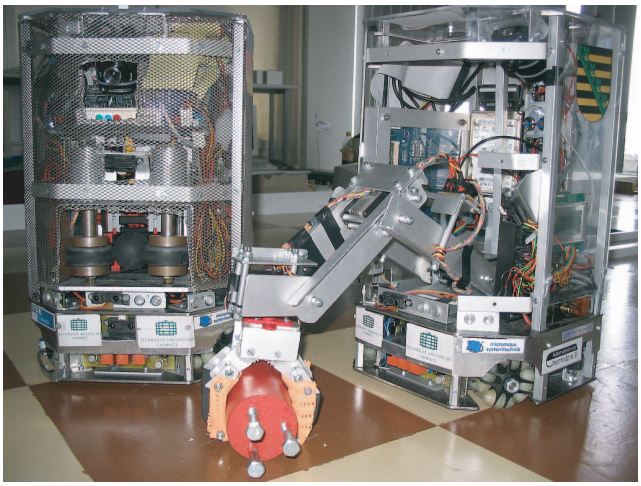

Fig. 10. The two robots our team built for Eurobot 2005. The left robot is the attacker, it can shoot squash-balls at the enemy skittles to make them fall down. The robot on the right is the defender, it can use its gripper to re-erect the own skittles that were shot by the opponent.

At our university, our robotics group participated three times in this unique competition. Every year, a team of approximately 20 students is formed. The challenging tasks requires the team to consist of students of different engineering sciences. Our team usually unites students from the electronics, mechanics and computer science department. Students can not only use the Eurobot competition as a perfect chance to apply the knowledge they gained during their studies in a practical project. Even more important is the teamwork, the collaboration of students from so many different backgrounds and subjects. So participating in Eurobot does not only require and advance technical knowledge, but also a lot of soft-skills. Besides that, to finance the costs for the robots (which are usually more than 1000 Euro each), the students have to look for sponsors and support.

The many hours of work the students invest into the Eurobot project are credited by a special certificate. Participating students also use the Eurobot project to gain their mandatory project assignments, seminar papers or student research projects. In this way, Eurobot is integrated into the normal curriculum.

Eurobot's rules are always published in late September. The international finals are held in May, but the rules require national qualification contests if there are more than three teams from one country. We organized the last two national contests in conjunction with the RoboKing contest for high-school students on the Hannover Messe in April. So besides building, programming and testing our robots, our group also has to deal with the organizational issues of organizing a booth on a fair.

V. Conclusions

We presented our threefold approach to increase the interest of high-school students and young university students in robotics and in technical issues and engineering in general. Our first goal is to motivate high-school students to study engineering sciences. Robotics contests offer excellent possibilities to achieve this goal. Not only the participating students are influenced in a positive way, but also the spectators of the event or even those reading about the contest on a website. There are many high-school students 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 students together. Very often, once the first step is taken, a permanent interest 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.

The second goal of our efforts, motivating young university students to specialize in robotics or related disciplines, can also be supported by the contests we presented in this paper. Many Students entered our robotics group during their first years at the university and later took part in RoboKing or Eurobot competition or even both. During the end of their studies, these students are more and more involved into the current robotics related research going on at our institute. [9] [10] [11].

Most of the work described in our paper has been done and organized by undergraduate and graduate students, including the authors. These very committed students spend many hours of their spare time to help bringing robotics closer to other students and therefore help to foster and educate future researchers in the field of robotics.

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