A review of eight years of CEABOT contest: a National wide Mini Humanoids Competition

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Abstract. This paper presents a review of CEABOT, the unique humanoids competition for university students at Spain wide level. This annual competition started in 2006 and it has been celebrated during the last eight editions. Aimed at initiate graduate and master's students in humanoid robotics, they have to program the sensor and motor skills of little humanoids built by themselves, or tune up a commercial kit. The challenge is to obtain the best platform able to complete a set of trials that are reviewed and renewed each year. In this paper, a review of similar contests, objectives and results will be discussed. A brief review of platforms and trials evolution will also allow presenting some key ideas for the promotion and future assurance of this initiative. Furthermore, a brief review of some didactic approaches experienced, and some insights about the future of this and similar contests that use robotic platforms to face similar goals will be presented.

Keywords: Humanoids contest, robot competitions, didactic approaches, teaching with robotics

1 Introduction

During the last decades, many initiatives related with robotics' contests have appeared, and many of them still are alive. Mainly, there are three types of motivation for the use of robotic devices in contests and therefore three types of contest flavours. The first are "open to all" contests and fairs, e.g. any amateur and robotics hobbyist, like RoboGames ™ [1] or COMBOTS©[2] among many others, where the show and fun are the main goal. The second type of competitions is formed by these designed for students in any of their courses, from undergraduate to high school and University.

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[1] RoboGames (formerly RoboOlympics) is ™ of non-profit The Robotics Society of America, Inc. http://robogames.net/

[2] COMBOTS is © of ComBots, LLC. http://combots.net/

adfa, p. 1, 2011.

Contest like RoboCup Junior [1] , VEX Robotics World Champioship [2] or FIRST LEGO LEAGE (FLL) [3] fit in this category, where didactic approaches and goals are clearly claimed. And the last type are scientific challenges, promoted by research institutions or research programs at international level, such as DARPA Robochallenge[3] or ICRA Robot Challenges[4], where fostering the current state of the art is the main motivation. In this paper, the focus will be placed in the second type of contests, although along the following review, many of these flavours can be found mixed in the same event with many trials.

A general problem is the increasing disinterests of young people, in particular girls in science and technology studies. To cope with this, some initiatives like ROBOCUP, the international scientific initiative [4] have grown in the last decades. RoboCup Junior (RCJ) focuses on educational aspects encouraging young students to deal with science and technology [1]. RCJ uses robots as technical tool to educate, motivate and inspire pupils and undergraduate students up to the age of 19. The work of Papert [5], with his pioneer LEGO/LOGO project, is considered a precursor of several works involving Robotics in Education. Various papers have been published on this topic, a good review can be found in [6] . The authors of [7] provide an evaluation of the FIRST Robotics Competition (FRC)[5]. FRC, which was founded in 1989, is a high school robotics initiative located in New Hampshire (United States). The program aims to get young people interested in science and technology. A detailed, but not exhaustive, list of robot competitions around the world can be found online[6] sorted by Date, instead of category.

The competitions of mini-humanoid robotics offer engineering students the chance to get some actively initiated a field of humanoid robotics. These contests are an easy way to get into the development of control systems for robot kinematics and recognition of the work environment, as well as the challenge of a small robot to provide the skills needed to complete certain tests. In addition, they are a way to compare the development of their own systems regarding to the other systems developed for the participants of these competitions. Furthermore, these competitions allow students from around the world and from different fields of work to be related to them so that they can start friendships or sharing knowledge.

To this end, this paper will review the Spanish annual championship of mini-humanoid robotics organized by the Spanish Committee of Automatics, named CEABOT, which has been celebrated for the last eight years. The aim of the competition is to show the skills of each humanoid robot by developing several tests to be performed autonomously. A review of existing robot competitions, their motivations and brief comparison among the robotics platform employed will be highlighted. A

[3] DRC is a prize competition funded by the US Defense Advanced Research Projects Agency. http://www.theroboticschallenge.org/

[4] ICRA conference starts to host Robot Challenge at 2008 and continues, each year with several challenges like Virtual manufacturing, Mobile Manipulation, etc. http://www.ieee-ras.org/conferences-workshops/icra

[5] FIRST, a not-for-profit public charity, was founded in 1989 to inspire young people's interest and participation in science and technology. http://www.usfirst.org/

[6] URL: http://robot.net/rcfaq.html

detailed description of CEABOT contest, trials and procedures will be reviewed. To conclude, some considerations about CEABOT experience of the last eight years and a future view and expectations will be presented.

2 Humanoid platform based competitions

As mentioned above, the well kwon international competitions as FIRST (FRC), LEGO®MINDSTORM®, VEX ROBOTICS or EUROBOT[7] [8] are not focused on humanoids. At Spanish level, the traditional ALCABOT-HISPABOT (based on wheeled robots)[8], AESSBot[9] in Barcelona, and many other younger initiatives like ARDERO (Abierto de Robótica ARDE[10]) promoted also by student associations, lack in the special interest for humanoids.

RobotChallenge, is maybe the biggest and may be most popular active competition in Europe. In March 2013 has celebrated its 10th anniversary. There were 470 robot designers from 23 different nations, which competed with their 399 self-made, autonomous robots in 15 different competitions. In addition to the traditional competitions - Robot Sumo, Line Follower, Puck Collect, Humanoid Sprint and Freestyle - flying robots took part in the “Air Race” for the second time. “LEGO Line Follower”, a new category for robots built out of LEGO bricks, which is aimed primarily at beginners, was introduced.

The first RobotChallenge took place in March 2004 in Vienna, Austria. What started as a small event with only a few participants and three different competitions soon became one of the biggest robotic championships worldwide. Throughout the years, RobotChallenge adapted itself to the rapid changes in the international field of robotics: More and more competitions were added to the event, and each year participants were encouraged to experiment in the area of informatics, electronics, mechanics and artificial intelligence. Since 2006, the Robot Sumo competition was gradually divided into various weight categories. With the first Freestyle exhibition in 2007, RobotChallenge opened the competition for extra-ordinary robots with special abilities. They started the Humanoids sumo contest in the 2009 edition, and some of the authors were invited to participate and get involved in the rule definition for this novel contest. This year an UC3M team participated in the VI RobotChallenge 2009 European Robotics Championship, in Vienna, Austria, being the unique Spanish representative in the event. This event consisted in two independent contests: running and sumo fighting. The Spanish team obtained the first position among the five teams. After that experience, in 2009, the CEABOT organization opened the Free-style trial inspired by the RoboChallenge event, with the only limitation in the type of robot platform that must be humanoid like, but without weight and height limitations.

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[7] Created in 1998, EUROBOT is an international amateur robotics contest open to teams of young people, organized either in student projects or in independent clubs.

[8] ALCABOT web site: http://asimov.depeca.uah.es/robotica/

[9] Concursos de pruebas clásicas organizado por la UPC. http://aess.upc.es/aessbot/

[10] Concursos de pruebas clásicas organizado por la Asociación de Robótica y Domótica de España. http://www.webdearde.com/

A special mention is required for the RoboCup Humanoid League. In the Humanoid League, autonomous robots with a human-like body and human-like senses plan and play soccer against each other. Unlike humanoid robots outside the Humanoid League, the task of perception and world modeling is not simplified by using non-human like range sensors. In addition to soccer competitions, technical challenges take place. Dynamic walking, running, and kicking the ball while maintaining balance, visual perception of the ball, other players, and the field, self-localization, and team play are among the many research issues investigated in the Humanoid League. Also to mention, the Robot Soccer Competitions in Kid Size category (30-60 cm height), that uses DARwIn-OP[11], and the ICRA 2012 DARwIn-OP Humanoid Application Challenge[12]. DARwIn is medium size open platform humanoid robot, from the ROBOTIS company, with advanced computational power, sophisticated sensors, high payload capacity, and dynamic motion ability to enable many exciting research and education activities.

As presented before, there are many growing initiatives of educational courses in robotics, workshops, and other less formal initiatives [9], [10]. All of these activities have in common that they are frequently used to generate interest in engineering careers, and develop teamwork and communication skills. However, frequently they teach very little in the way of robotics specific pedagogy. Except for those mentioned above, the majority of courses tend to focus on designing and programming mobile robots, and rely less on advanced treatment of legged or serial chain articulated robots, such as humanoids. CEABOT was originally targeted at senior level undergraduates or first year master's students, to overcome this deficiency [11].

3 Description of the CEABOT championship

In 2006 the CEABOT contest was born as a national competition of small humanoid's robots as an initiative of Prof. Carlos Balaguer. Although the first years there were few participants, CEABOT has been growing in importance, acquiring international status, and becoming one of the most important robotic contests in our country, with an average of 10 teams and 20 robots participating each year.

The tasks the participating robots must accomplish are stated in the CEABOT contest rules [12]. The robots must have an anthropomorphic constitution, and the mode of locomotion should be walking or running on two legs. Wheels, skids or similar devices are forbidden. Another specific characteristic of the CEABOT championship is that each robot must be completely autonomous. Autonomy must be achieved at locomotion, sensing, and processing level, and by being battery powered. Actuators, sensors, and processing power must be incorporated into the robot; it must make its own decisions. This issue makes CEABOT quiet different to other humanoid compe-

[11] DARwIn's official webpage: http://robotsource.org/
[12] http://www.icra2012.org/program/robotChallenge.php

tition around the world like ROBO-ONE[13] [13] or KONDO BATTLE [14] and similar, really popular in Japan and USA, where the robots are tele-operated by a human controllers using a custom RC controller, and where the objective is pure entertainment.

3.1 Main features of mini-humanoid robots

The robot maximum weight is 3 kg and the maximum height is 50 cm. Furthermore, the robot foot length should be lower than 11 cm in any maximum measure. The most common platforms used in the CEABOT Spanish competition are shown in Fig 1. They are based on commercially available kits. These kit's prices are normally between 500 and 1000€, and must be completed with additional sensors and wiring. Sometimes some other teams have removed the original on-board processor and replaced it by PIC or Arduino based processors boards. These must rebuild the locomotion capabilities of the humanoid from low level, programming all the servo commands signal to achieve the desired motion. Others teams choose to exploit the original kit board's hardware resources and manufactures' programming tools at maximum level.

Fig. 1. Kondo KHR-2HV [15], ROBONOVA-1 (center) [16], BIOLOID (right) [17].

Other popular low size platforms like DARwIn-OP or NAO[14] are excluded intentionally by weight and size (note that other contests such as the RoboCup Standard Platform League, SPL, do allow the NAO platform), due non-affordable prices, in comparison with smaller and simplest commercially available humanoids robot kits.

3.2 Description of tests

The contest has a set of test to determine the capabilities of the mini-humanoid robots participating. Each one of these test is associated to a different scenario. All the sensorial processing, algorithms execution and showed behaviour must be performed

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[13] ROBO-ONE is biped robot entertainment contest promoted by a robot Japanese retailer. http://www.robots-dreams.com/

[14] NAO is medium size humanoid platform. http://www.aldebaran-robotics.com/en/

autonomously by the robot. Obviously to embed enough processing power on board is a challenge due the platforms limitations in power and payload autonomy. In the following, some details concerning the trials and scenarios are described.

- Obstacle race: This test is based on navigating in a partially known environment with obstacles, having to cross this area from one line to another, and returning. The measurements of the race scenario are shown in Fig 2. In this scenario, up to six rectangular blocks painted in white could be placed. The number of obstacles used can depend on configuration of the test during the competition, and its location is not previously known by teams. The score will depend on how long the robot lasts to finish the testing space and the imposed penalties. The penalties will be imposed if the robot needs help from the judges due to a fall or a clear mismatch in the obstacle avoidance behaviour that makes the robot to fall into a loop.

Fig. 2. Obstacle race measures. The ground will be painted in green (Pantone Code: 16C606 (R:22:G:198:B:6)).

At the beginning of the race, rectangular shaped obstacles (20x20 cm width and 50 cm height, Fig. 3) are placed inside the field. The robots may not move them.

Fig. 3. The robot finds a gap between the obstacles and the wall. If the robot moves or throws an obstacle, the team will get a penalty. All the robots are place in the Committee's table until its turn arrives.

Finally, scores are given by formula (1).

$$P = \frac{(T_{MAX}(s) - T(s)) \cdot k_T}{T_{MAX}(s)} + \frac{d(cm)}{d_{MAX}(cm)} \cdot k_D - (2 \cdot pen)^{kp} \tag{1}$$

Where:

- T_{MAX} [s] is the maximum time (300 s).
- T [s] is the completion time in seconds. If the robot does not finish the race, this value will the maximum time (300s).
- d [cm] is the walked distance, measured from the white line to the feet.
- d_{MAX} [cm] is the maximum obstacle area distance (150 cm).
- pen [#] is number of penalties.
- k_T, k_D and k_P are time, distance and penalty constants, used to scalar the punctuations.

- Stairs: This test demonstrates the ability of the robot to climb stairs. All the steps are 3 cm high but there are three different lengths: 15, 25 and 50 cm, respectively (see Fig. 4).

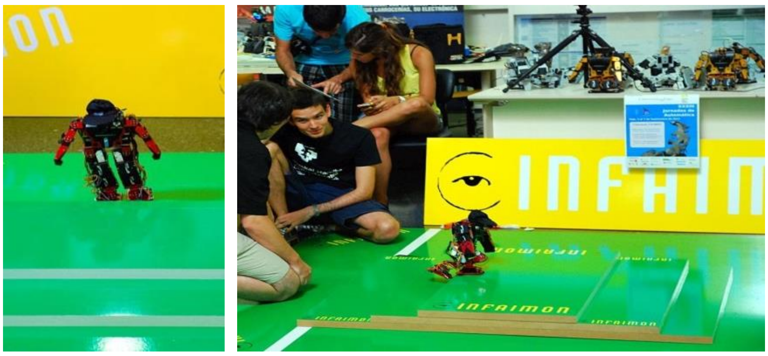

Fig. 4. A humanoid robot is climbing the stairs autonomously.

There is a time limit of 5 minutes. The team will get a penalty if the robot touches the ground with the arm/hand or if the robot falls down and cannot stand up by itself (only the referee will stand it up). For score calculation, teams will be organized by the number of penalties (less is better) and the time needed by the robot (less time is better). Depending on this ranking, the robots will get more points depending on the number of climbed steps.

- Sumo: In this trial, a battle by sumo is performed between two opponent's robots. The robots will try to locate the opponent robot and will try to knock him down.

The sumo battle is performed in a circular ring, sized 1.5 m and painted in green, using the same Pantone colour as the others scenarios, as seen in Fig 5.

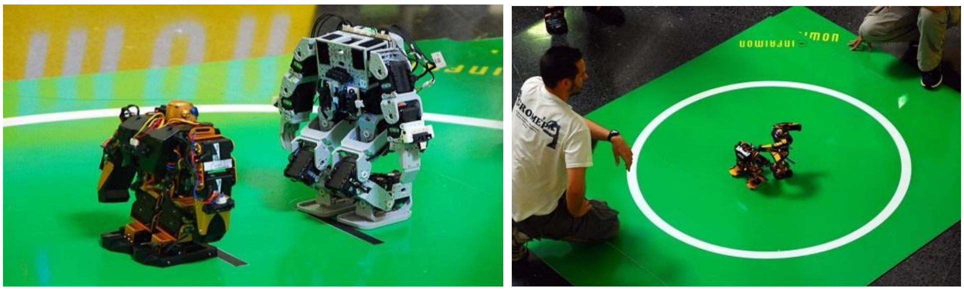

Fig. 5. Two robots fighting sumo in the circular ring.

This trial is organized as a league, where all the robots should fight among all of them. Each combat has three rounds (2 minutes per round). The team (e.g. the robot) with highest score will win the round. The team's score will increase if the robot opponent: a) goes out the ring, b) touches the ground with the hand or knee, or c) is knocked down. Any non-competitive behaviour is sanctioned, e.g. erratic movements or a passive behaviour.

The teams and jury panel

The members of a team should be students of any of the standard categories belonging to a University, Company or Research centre (e.g. undergraduate, graduate, MSc, or PhD student). Each team may consist of a maximum of five members.

The maximum number of robots per team is three. Obviously, it depends on each team to use only one robot per trial, or to use the same robot for all trials, etc. The registration is performed by mail through organizers. Each team should fill a form with all the relevant information: name, email, university, etc. about participants.

The judging panel performs the scheduling of the trials along the three days of the hosting event. The judging panel will be the responsible for scoring during the three aforementioned trials. With this aim, three members are designated: one referee, and two assistants. The referee will be the chair to take the main decisions during trials, with the help of the assistants.

4 Some reflexions about CEABOT and its future

It is clear that designing this competition was not an easy task. Different types of goals were proposed, depending on the targeted audience. CEABOT, while attempting to be interesting and non-boring, was born in a scientific context, held by the CEA Robotics group, and focused on University researchers and students. Its aim is to foster the introduction to research, allow exchange of low cost approaches for exploring new scientific ideas and algorithms, but must maintain its appeal to students.

How to keep easy access to novel participants, while improving the difficulty of the tasks to perform in each test is not trivial. Adding or replacing trials or modifying rules in established tests implies changes that can bring failure (or success) to the event. How to measure this is also a relevant topic in the scientific community [18].

According to the initial CEABOT goal, "attract the student to the amazing world of the humanoid robotics", a complementary initiative has been adopted from the past five years by some of the co-authors (which are also co-founders and members), called ASROB[15]. They are currently combining efforts to create a new paradigm of education, where students, initially supervised by teachers, can develop new capabilities. This includes contributing with new ideas and experiences, working as a team with other students, and becoming more independent. The ultimate goal is to improve the student's abilities to face the challenges and difficulties in his/her professional life. The vision of our learning methodology was published in [19]. The CEABOT initiative and ASROB has allowed creating the proper environment to set up an interesting experiment in peer-to-peer learning. Members of the class collectively set up a complex robotic system that is continuously evolving and that needs to be documented. Therefore, they have to maintain a community Wiki and a source code repository. They are also motivated to co-author and contribute to papers with their experiences (e.g., this one). From a curricular perspective, at most Universities, entering the first course is typically selective. However, Robotics Lab and ASROB are open to teach and introduce any student of any year and specialty (if any specialty). Another interesting approach has born from the ASROB incubator, like Robot Devastation: a new-generation shooter with augmented reality and real robots[16]. You can play online with other users with your PC or smartphone, moving robots in championships and campaigns.

4.1 Actual difficulties of CEABOT contest

Past editions have demonstrated that there are no negligible access barriers for students that are attracted to CEABOT contest: while humanoids robot kits have medium and low prices, the conference's accommodation and registration costs are expensive and obstruct their effective registration in the event. While the registration fee has been lower or also free for students participating at CEABOT, the travelling and accommodation costs are high due the itinerancy of CEABOT venue, that changes every year according to the University that hosts each year CEA's conference and the fact that the contest lasts the three days of the hosting conference.

It is important to also remark the personal effort of both students and teachers. Teams need many hours of tuning up, testing and programming in order to get a reliable platform minimally ready to achieve each one of the three trials. Although each year the difficulty of trials is modulated, each year the competition level trends to increase, and the help of past year veterans is a high value resource. Additionally, the dates for the conference are hosting the event every year in early September, forcing

[15] ASROB: Robotics Society of the Universidad Carlos III de Madrid. http://asrob.uc3m.es

[16] A demo video is available at: http://www.youtube.com/watch?v=2RJayuBKR6Q

many participants to extend their work in labs in August (vacation in many Spanish institutions) to complete their preparations in time.

Tests and contest evolution

In section 3.2, the current set of tests has been described in detail. Originally, there were only three trials: robot sprint, stairs and sumo challenges. The sprint test was replaced after two editions, by the obstacle race, because stable gait skills at relative high speeds become a standard in almost teams. However, from 2010, the Free-style test was added with the intention of attracting more participants. As robot platforms become more capable, it is the intention of the organizers committee to evolve the current rules to present greater challenges. The current CEABOT scientific objectives are focused on postural path planning and control, and walking and climbing trials, where navigation in structured environments may only be successfully achieved by means of a proper interpretation of simple sensorial data, like IR proximity sensors, inclinometers, and sometimes a gyro-compass. The quick evolution of robot platforms and decreasing prices of processors and complex sensors, like cameras, FRS etc., in conjunction with new open-source boards and source code, can drastically improve any off-the-shelf robot kit allowing achieve more sophisticated challenges. The issue of how newly available hardware or software can facilitate the inclusion of these topics, traditionally assumed to be too difficult, is also relevant. This is our own personal experience with the adoption of Arduino based Boards or x86 CPU boards.

With this in mind, the authors argue that the future of the competition is to maintain itself attractive enough to continue gaining popularity, especially among students, and increase the interest of these to participate and therefore initiate or strengthen their hobby in robotics. A possible critical point is the need of training programs for teachers who are often not confident with humanoids robotics, e.g. best practices by mentors, in order to reinforce their educational competences that help them improve their way to teach robotics.

4.2 Exporting the contest: The iCOMIHU proposal

The iCOMIHU competition is the CEA-GTRob initiative to become an international championship of mini-humanoid robots aimed at participation of European universities interested in this field. The first edition is scheduled for November of 2014, hosted the by IEEE-RAS HUMANOIDS 2014 conference. The underlying idea is to extend the CEABOT contest throughout all Europe. The first difficulty that appears is how to make the classification stage in order to get only a reduced group with the best of the teams. A deep review in the contest design, rules and scoring procedures is definitely needed.

5 Conclusions

The different successful robot competitions reviewed in Section 1, that have been organized in the last years, have shown a successfully way to let the student learners actively carry on experiments. Students are involved in physically assembling and programming a robot and using the on-board sensors, focusing on both the results and the abilities acquired of comparing the performance of the competing systems. This has been possible by means of very well defined rules, trials, procedures and metrics for scoring. As well as these scientific competitions have proved a quick way to attract substantial research efforts, rapidly produce high-quality working solutions, and additionally obtain a significant success in obtaining sponsors and popularity (e.g. media dissemination), CEABOT and other research initiation contests have proved to be a good tool for feeding students' curiosity and exploring new educational approaches [20], [21]. Along the past years, the authors' experiences show a very prolific collection of supervised works, ranging from Master Thesis to Final Degree Project works. Although a long-term evaluation is still not available to prove it formally, past years' results indicate a strong relation between robotic research and their educational and personal development among participants in this type of educationally oriented contest. Due to this fact, it is mandatory to introduce some metrics for measuring the goals achievement obtained, as only score calculation in each trial could be no enough. Another question to keep in mind is related to the design of this Europe -wide competition of mini-humanoids. Does it be designed for easy measurement or adapt the competitions rules and procedures for easier benchmarking? How to manage the classification or scoring procedures, before the contest itself, for many teams of each nation subscribed is still an open question.

The experience gained in previous editions of CEABOT suggests that this kind of robotics competitions has a huge potential in exploring new educational approaches peer to peer and self-motivation of students. It is necessary take advantage of the learning experience that based on the effort of students, which learn to carry out technical projects with an initial supervision, investigate new resources and ideas, collaborate in teams, and develop new capabilities and personal attitudes.

The next editions of CEABOT must facilitate the student's hands-on exploration of legged locomotion, also at the undergraduate level. The setup of new hardware has been discovered as new challenge by itself and it could help in the expansion of CEABOT's scientific goals. The evolution of rules and contest procedures must be designed to facilitate the exchange of experiences, methodologies and materials to motivate students about science and technology, while keeping a balance of show, appeal and popularity that attract sponsors and assure the longevity of the contest.

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