UnBeatables Team Description

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Abstract. This paper describes the UnBeatables team, from the University of Brasilia, and hopes to illustrate the current and past work that is being done with the NAO platform.

Keywords: humanoid robotics, computer vision, robot soccer

1 INTRODUCTION

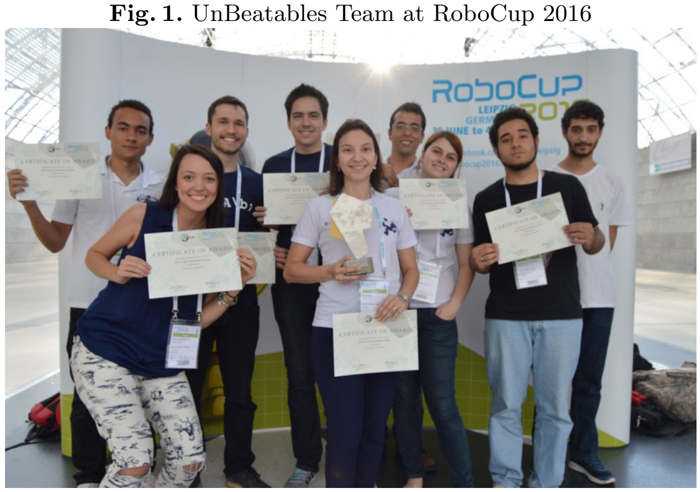
UnBeatables is a technology and social project from the University of Brasilia. It is affiliated to the Automation and Robotics Laboratory (LARA), where research on localization and mapping, computer vision, locomotion, robots cooperation and human-robot interaction have been conducted. The more recent usage of NAO from Aldebran Robotics appeared as a platform that encompasses the main fields of study performed within LARA.

In this scenario, the opportunity for participating on competitions Humanoid Robots Soccer was presented with the RoboCup 2014, that occurred in Joo Pessoa (PB). Seeing that the objectives of the RoboCups SPL league had a great affinity with the current work developed at LARA and the university, UnBeatables team was created with the goal of enrolling on the RoboCup SPL Drop-In category. This team description paper provides brief description of the past and current situation of the team, as well as its main achievements.

2 THE TEAM

The team believes that taking part in competitions and events is an opportunity to apply and test the ongoing researches and inspire the development of new projects. The team formation for 2018 consists of 8 undergraduate students of Electrical and Mechatronics Engineering and 1 gradute student under the tutoring of Dr. Mariana Costa Bernardes and Dr. Antonio Padilha Lanari Bo.

Fig. 1. UnBeatables Team at RoboCup 2016



A Team Data

Team: UnBeatables.
Leader: Felipe Dalosto and Débora Ferreira.
Members: 8 Undergraduate Students, 1 Graduate Student and 2 Ph.D professors
Affiliation: UnB Universidade de Brasilia
Currently Have 2 H25 NAO v4 Competition
Video: https://www.youtube.com/watch?v=oPoPOf_SRsU
Email: unbeatables.unb@gmail.com
Facebook: https://www.facebook.com/unbeatablesbr

B Participation and Perfomance

Since its creation in 2014, the team has engaged in national and international competitions and has achieved the following titles:

- RoboCup Soccer Robot Standard Plataform League Drop-in Competition MVP (Drop-in Only) First Place RoboCup - Joao Pessoa Brazil - 2014
- RoboCup Humanoid Kid Size Drop-in challenge Champion LARC - Sao Carlos Brazil - 2014
- Standard Plataform League Drop-in Competition MVP First Place - RoboCup - Hefei China - 2015
- RoboCup Humanoid Standard Plataform League Champion LARC - Uberlndia Brazil - 2015
- Standard Plataform League Drop-in Competition MVP First Place - RoboCup - Leipzig Germany - 2016

– RoboCup Soccer Humanoid League / Standard Platform League (SPL) Champion - Recife Brazil - 2016
– Robocup Humanoid Standart Plataform League Second Place LARC - Curitiba Brazil - 2017

3 MIXED TEAMS

Considering the lack of competition and research when compared to other regions, UnBetables team is willing to develop Robotics and the Latin American SPL league by applying to the mixed team league at RoboCup 2018.

Better results at international championships may encourage other teams and universities. Investing their time and resources into improving the teams or even creating newer ones.

Since the extinction of the Drop In category, most Brazilian teams would become unable to compete. The solution found is to team up with other Brazilians teams that share the same will.

As the reigning champion RinoBot accepted to work with us as one team, participating under the name of AstroNAOtas and using yellow jerseys as a way to represent our country at Robocup 2018. Since both teams are composed of mainly undergraduate students the opportunity to work together and share more within a now bigger team may help us compete against the more traditional teams.

Brazil with its continental size makes most teams reside far from another, but instead of affecting the teamwork, with project management tools as GitHub, Slack and several communications channels as Google Hangouts, we can work together several kilometers away. The distance actually brings one more benefit, since we intend to assemble resources for the competition, so being afar gives the opportunity to find more partners and sponsors. The support from two big universities also helps a lot our new team.

4 CODE DESCRIPTION

In the past, the UnBeatables team has used many different approaches in the code development for the RoboCup. At first, the team has built its system with modules written on C++ and Python, and relied heavily on the ROS framework, which took control of the internal communication and task management [12]. That approach, though robust, proved to take a lot from the robot processing capabilities, making its response time slow and very ineffective in a real game.

Therefore, aiming to achieve great improvement, a thorough study on the past RoboCup code releases and papers concerning the subject was made, leading the team on an attempt of building a new application based on the B-Human 2014 release [17].

Still, even though our results with the implementation based on the B-Human were great, from the second half of 2015 and onwards the developing strategy has changed; we built a new architecture from scratch, mostly developed by the current team. In fact, the only external module that is incorporated to the new system is the motion module released by RunSwift on 2014 [14]. Also, sensor access is based on previous implementations by B-Human, RunSwift as well as the NAOqi API [1]. The state machine, perception and localization modules are developed in C++, and thread management is done with the boost library [2]. In the following sections there should be a more detailed explanation of the main areas we have been developing and the mainly changes from past years.

A Architecture
Currently, we are using our new improved architecture which our system is based. Taking foundation on the paradigms for object-oriented programing and thread management, and by using the boost library in order to make a clean and effective code, our structure is based on a shared memory in which all threads can publish and access data. This approach is based on the Blackboard implementation of the Runswift team and is currently functional, effective and robust.

B Locomotion
At first, most of the previous work done by the team on relation to locomotion used the software Choregraphe, where we saved some movement sequences, and, through the snapshots taken, acquired the data for the angles and global coordinates from the robots joints. This process, though very simple and effective, was based on a series of trials and errors.
In order to overcome the lack of theory and control of the Choregraphe method, as a first measure, we used the movement libraries provided by BHuman, taking full advantage of the faster march and a football-oriented tool for developing movements such as kicks. Adopting this arrangement, we observed many occurrences of slips and falls during matches. Also we faced many difficulties when trying to fully incorporate BHumans motion code to our own code.
Having in mind the benefits of a motion module pivoted on other code able to achieve good movements, we decided to include the RunSwift motion in our new architecture. Since it is developed in the same language as our framework, we could achieve a better integrability when compared to BHumans code. Our autonomous behaviour is responsible for ascribing the action type based on the information of sensors and information provided by image processing performed in the perception thread, as described in the subsequent section. Then, the desired action is performed as the motors are activated following the RunSwift parameters.
In spite of the fact that the current approach rested on RunSwift has shown good action performance, we have a long term plan for developing our own movement library that could enable the walk on artificial grass.

C Perception
The area that requires the most use of our computer vision knowledge, with the objective to filter sensor data, detect and classify features and objects, mapping and localization. Since computer vision algorithms are well developed, we chose the OpenCV [5] library for such detections, as goal posts,

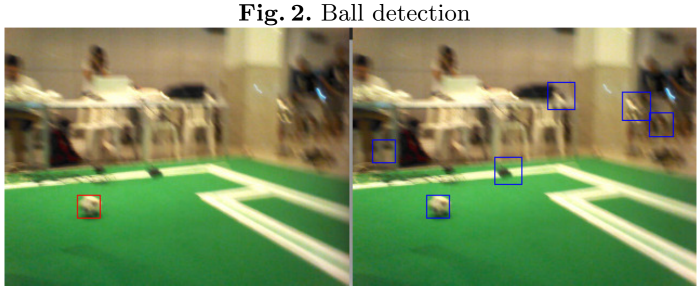
field lines, ball and other robots. Bearing in mind image processing requires a lot of computing time and instructions, the team is working on the usage of more efficient programming languages or libraries, creating them ourselves or using new tools, in order to outperform the OpenCV library.

The perception uses a number of detector classes, each one responsible to detect something specific (field, field lines, etc.). The segmentation starts by separating the soccer field from the surroundings. This is done finding the green pixels in the bottom camera and using this definition of green in the top camera. Then it is possible to look for features that are in some ways connected to the field, such as the field lines and the ball. Goal posts and other robots that appear above the field line can be found outside that segmentation.

For every feature the same protocol is followed: first find candidates with resembling characteristics, then a classifier is used to differentiate the real ones. The classifiers are made taking in account how the features are expected to appear: the field lines are either parallel or perpendicular to each other, the goal posts are vertical and above the field. All these feature data is used to provide input to a global map for the robots localization in the field.

The soccer ball is the most important object to be detected, by searching for high contrast regions on the green field, the ball regions and white pattern can be detected, generating ball candidates over the image. This method is admissible when detecting balls from afar, however if the ball is near the robot and over a white line the method wont perform very well. So there is a second method only used to detect up close ball candidates. After the candidates are detected, a classifier choose the best one to be labeled as ball. The figure 2 shows in red the output of the classifier and the candidates for features are shown in blue.

Fig. 2. Ball detection



In order to have a good classifier, two factors were chosen, speed and accuracy. Several machine learning models were tested such as Support Vector Machine, Neural Networks, Convolutional Neural Networks, QLearning and others. Since the OpenCV library is still used, we started by implementing the methods already programed in its functions. To classify the ball, the best method was the Neural Networks, which was later optimized to extract its best performance. Others features have less priority such as the goal posts, field lines and robots. For the goal, the white posts above the field are detected and a classifier that evaluates distance and height to compare with the real goal to choose the goal position.

The robot also detects robots jerseys in order to find teammates positions and the adversary team. Field lines and the points where they intersect (corners) are very important features for localization within the field, as well as the midfield circle (seen as an ellipse).

To find the lines, first it is used the Hough Line Transform, and then a classifier filters the ones which are most probably the real ones. With the filtered lines, for each pair of lines it is found the point (corner) in the image where those two lines intersect (points outside the image are ignored). The corners are strong features in the field that help to find out to where in the field the robot is looking at.

Besides the corners and the goal posts, another very strong field feature is the midfield circle. Since the robot is not looking exactly above it, the circle appears deformed as an ellipse. So, to detect an ellipse, first we use the findContours OpenCV function in the field region, then, with the returned sets of points, we choose the contours that are ellipses with fitEllipse. In the end, it is used a classifier to filter the ellipses that are within the expected dimensions of the deformed midfield circle.

As for the integration of other sensors of the NAO robot, we currently rely on the raw data they provide, mostly working with the inertial sensor and sonar. Mainly, those sensors are used to provide extra data for obstacle avoidance and for the implementation of localization and mapping algorithms.

D Autonomous Behaviour

Currently the team has put a lot of effort on developing robust and efficient strategies for our game-play. In the context of Internationl RoboCup Drop-In games, robots are evaluated for their performance, therefore we focused on a conservative and more defensive strategy, where collision avoidance takes high priority. The state machine developed by our team consists on a few different stages: we start the game by turning around and searching for the ball at a close proximity, we then start looking for it in further away positions and finally we randomly walk around to a different position if the ball is still not detected.

Once the ball is found, we make sure our robot is aligned with the right goal as well as the ball itself and then call for the kicking routine. We are currently developing methods to determine the goal distance and calculate the force required to reach the goal. The behavior should also recognize when it is not possible to kick the ball directly into the goal and plan a new play. If an obstacle, (i.e. another robot) presents itself, our module for obstacle avoidance activates, giving priority to avoiding it. Another feature of our behavior control routine is the implementation of different actions when different game states are called by the game controller.

In addition, we developed a different behaviour for the goalkeeper. This is based on a simple state machine in which the robot will always be trying to spot the ball and align itself to it, so once close enough it can make the defense. Also, from time to time, the robot checks for the goal posts to make sure it is aligned to it and, if needed be, make any necessary corrections. Our strategy, even though with room for improvement, has proven to be effective in the many times it was put to test, either in a controlled environment or in actual games.

E Communication

One important feature of our current implementation is the use of communication routines. We observed in RoboCup Drop-In games it is very important to be able to communicate with other robots in order to create a full localization and mapping. Presently the robots are able to communicate with the Game Controller by sending and receiving messages. In this context, the development of reliable and meaningful messages has been one of our main focus.

By using UDP protocols, we broadcast some important data from our robot sensors, as well as gather game state variables from the game controller. We plan on keep developing this area in order to get relevant information from other teammates, as well as creating algorithms to determine the reliability of another robot based on our own information, which we know to be true.

5 PAST HISTORY

A Locomotion and Mapping

For a long time, at LARA, the projects on mobile robots had been developed on wheeled platforms, such as the Pioneer from Adept, and on quadrupeds developed in the Lab with the purpose of studying gait control and stabilization algorithms. With an increasing interest on the subject, the research moved to humanoid robotics: a small platform, which consisted on a Robotis Bioloid robot, along with supplemental pressure sensors installed in the feet, an Inertial Measurement Unit in the robots center of gravity, and a Gumstix Verdex PXA27 0 ARM processor. All of the software was custom-made for the platform, focusing on realtime control and data acquisition [6]. Within this platform, first experiments on posture control using inertial sensors were performed using both traditional PID controllers [5] and fuzzy controllers [7]. Concerning humanoid motion control, in particular controlling different modes of locomotion, our work has concentrated in improving gait speed and robustness, and also smoothing transitions between different gait modes. Recently, we have used a Central Pattern Generator (CPG) to generate gait commands to a simulated humanoid robot [8]. Different nonlinear models were used to represent the CPG: Matsuoka oscillators and truncated Fourier series. Due to the difficulty to obtain the parameters of the oscillators in order to obtain a suitable gait, different optimization methods, such as Particle

Swarm Optimization (PSO) and Genetic Algorithm (GA), have been used to provide the parameters of the coupled oscillators. The oscillators provide the trajectories of each joint, and also independent parameters that enable setting gait speed and locomotion mode.
Raphael Resende, a former team member, proposed an algorithm based on extended Kalman Filter to locate a humanoid robot inside a soccer field.[16] The robot distance to field structures can be estimated using the data from inertial sensors as gyroscope and accelerometer as well as features observed by the camera facing the ambiguity of a symmetrical field.

B Robot interaction

With respect to robot interaction with environment and humans, team members, based on LIRMM, France, use a Fujitsu Hoap3 robot that was programmed to perform collaborative tasks with a person, such as pouring water. The methodology, mainly described in [3], is based in applying a novel mathematical framework to define, in an uncomplicated fashion, new kinematic tasks based on the relative pose between the person and the humanoid. The experiments involved pose representation and computation using dual quaternions and robot teleoperation based on human motion.
Concerning the Aldebarans NAO platform, a former member, in France, had conducted a work on computer vision and odometry based on inertial sensors that were integrated to provide localization estimates. More specifically, the SURF algorithm (Speeded Up Robust Features) was used to detect landmarks in the environment and guide the robot navigation throughout a pre-defined set of landmarks[9]. That same member has also developed an interface for teleoperation control, in which she used the Microsoft Kinetic to capture some movements to be mimicked by NAO [10]. Extending this work and using NAO, Henrique Balbino developed a solution for teleoperation by human body movements. The visualization of the environment was implemented with virtual reality, simulating the physical presence of user in the environment where the robot is located [4].
Other team members, when based in Korea, had used the platform to manipulate objects in an industrial environment [15]. Cristiana Miranda and Yuri Rocha worked on the challenge proposed in 2016 RoboCup and created a framework for the communication between two robots without the use of wireless network. They also studied control techniques in order to develop a cooperative control between humanoids robots[13].
The members have also worked on a paper that revises and extends the problem of robust singularity and joint limits avoidance to the cooperative task-space using unit dual quaternion frameworkensuring singularity-free coupled representation of the cooperative space[11].

6 IMPACT AND COMMITMENT

In the past, projects over NAO platform conducted at LARA relied mainly on simulations and virtual demonstrations of codes and models. The establishment of the team allowed the acquisition of two NAO robots, creating a suitable research environment and inspiring students to take researches in robotics fields.

Aiming to put together innovation, education and technology, the team has implemented projects beyond academia, reaching the local community. Team members visit schools and hospitals presenting the NAO robot and related technological topics as well as teaching programming to high school students. This project has a great social impact that has been acknowledged by our institution and outsider institutions as well.

This extension of our usual projects has also proved to be an area for future research on ways to actively use the NAO[9] platform to social causes and to make positive marks on society. Other research works of interest, naturally, comes from the competition environment. The competitions yield challenges that must be solved as well as encourage the team to have a continuous improvement creating the solid foundation for future research on robotics.

7 CONCLUSION

In this paper, we have presented the UnBeatables humanoid soccer team. The team consists on researchers and students with experience on humanoid motion control, computer vision and other fields of robotics. Our main mission is fomenting the robotics field in Latin America by both making an active contribution to the engineering community and promoting science and technology to society.

Participating in competitions is an inducement to enhance our knowledge; hence, we are always trying to keep on participating on competitions and scientific events, both national and international. In this context, we hope that this summary is enough to demonstrate the eligibility of our team for the Robocup 2018.

We also would like to thank the organizing committee for the attention and express our gratitude for the chance to participate in such an important event. We believe the challenges we face when competing and the knowledge we gain through the exchange of information with all the other researchers and competitors at the site, are extremely beneficial, as well as rewarding for both the team and each individual member.

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