CAMBADA@Home'2012: Team Description Paper

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Abstract. This paper presents the CAMBADA@Home team for the purpose of qualification to the RoboCup@Home competition in RoboCup 2012. The CAMBADA@Home team was created in 2011 and builds on the success of the CAMBADA robotic soccer team which competes in the Middle Size League. Based on the lessons learned from the last participation, the team focused this year on integrating the ROS framework that allows faster development and reuse of mature and time-tested components. Furthermore, the team expects to present a new platform in time for this edition of RoboCup@Home.

1 Introduction

The CAMBADA@Home[1] is the University of Aveiro RoboCup@Home team. The project was created in January 2011 following the team past experience in the CAMBADA [1] robotic soccer team. The development of the CAMBADA soccer team started in 2003 and a steady progress was observed since then.

CAMBADA has participated in several national and international competitions, including RoboCup world championships (5^{th} place in 2007, 1^{st} in 2008 and 3^{rd} in 2009, 2010 and 2011), the European RoboLudens, German Open (2^{nd} in 2010) and the annual Portuguese Open Robotics Festival (3^{rd} place in 2006, 1^{st} in 2007, 2008, 2009, 2010 and 2011). Moreover, the CAMBADA team achieved excellent results in the mandatory technical challenge of the RoboCup MSL: 2^{nd} place in 2008 and 1^{st} place in 2009 along with the 1^{st} place in the free challenge in 2011.

The CAMBADA@Home team is comprised of students from the Department of Electronics, Telecommunications and Informatics and researchers from the Institute of Electronics and Telematics Engineering of Aveiro. The team participated in the last RoboCup@Home edition, where, unfortunately, it performed below the expectations. However this initial experience provided a valuable insight into future research directions. With the lessons learned from last year's

[1] CAMBADA is an acronym of Cooperative Autonomous Mobile roBots with Advanced Distributed Architecture.

errors, the team is motivated to achieve the level of performance of other teams in the competition.

In the following section we present the new robotic platform under construction where we plan to carry out future research as well as future participations in the Robocup@Home. Section 3 describes the architecture of the robots, currently based on the Robot Operating System framework [2, 3]. Section 4 presents the current solutions used for navigation, from map building to localization approaches and safe navigation. Section 5 discusses the new developments in human detection, identification and tracking for tasks such as "Follow me" and "Who is Who". In section 6 we describe our solutions used in voice-based human-robot interaction with the novelty of the application of a microphone array. Finally, in section 7 we present the conclusions are future work.

2 New Robot Platform

The new CAMBADA@Home platform is designed as a three layer platform which can accommodate in an effective way the number of sensors and actuators needed to perform the RoboCup@Home tasks.

Bottom layer adopts a four motor system which drives a symmetrical set of omni-wheels ensuring a stable and versatile motion solution. This layer, which encompasses a sandwich like mechanical structure also includes three Li-Po batteries, all the low level control hardware (adopting a distributed approach over a CAN network), a SICK LMS100 and the support for a linear actuator. The top part of the sandwich allows a standard laptop to be located in the back side and has room for other needed equipment such as a switch for a robot local network. This approach lowers the centre of the gravity of the robot increasing the overall stability.

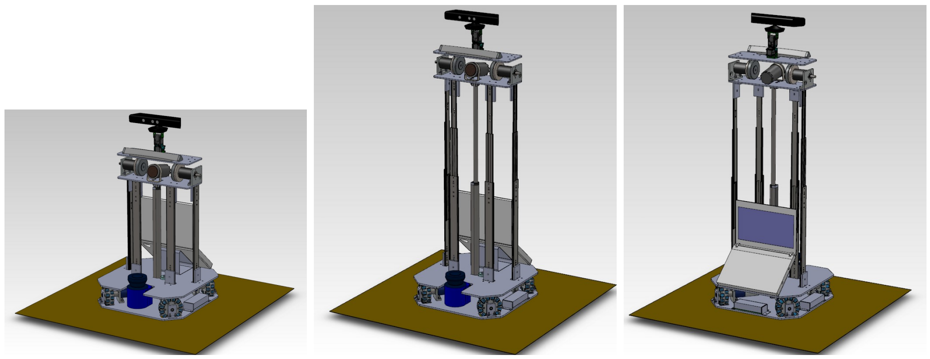
The second layer, which can be moved up and down by means of the linear actuator, represents the torso of the robot. The linear actuator allows a 450mm movement at 50mm/s. At the lowest point the robot is 0.95m high while at the maximum position the robot is 1.40m high. This layer includes a set of powerful BLDC motors that will support two anthropomorphic robotic arms (still under design), a speaker, and a Voice Tracker II multidirectional microphone array.

On top of the torso, a third layer is developed upon a pan and tilt structure that holds a Kinect vision system. This layer symbolically represents the head of the robot.

The current state of design is shown in Figure 1.

3 Software Architecture

Initially the CAMBADA@Home software followed the general architecture of the CAMBADA robotic soccer team. While the adaptation from the soccer field to the @Home arena was successful, the architecture did not generalize well to the variety of tasks to be performed. Therefore this year the CAMBADA@Home



a) **b)** **c)**

Fig. 1. The new CAMBADA@Home platform: **a)** Front view with linear actuator at lowest position. **b)** Front view with linear actuator at highest position. **c)** Rear view of the robot with easily accessible laptop.

team adopted ROS as its main middleware and framework. ROS is becoming a standard in the field of Robotics and provides a modular component-driven framework based on the producer/consumer paradigm. ROS also eases the integration of third-party code fostering the reuse of well-established solutions. Finally, ROS also presents a careful software engineering design providing a variety of tools that allow faster development.

In the initial phases of transitioning to ROS, the CAMBADA@Home team adopted existing ROS nodes. Nonetheless, the team is now actively developing their own solutions to compete at the same level as other RoboCup@Home teams. Our research interests cover robot localization and navigation techniques, human-aware robotics, multimodal human-robot interaction and robot learning. We expect in the future, to follow the example of other teams and release our solution in open-source in our own ROS repository.

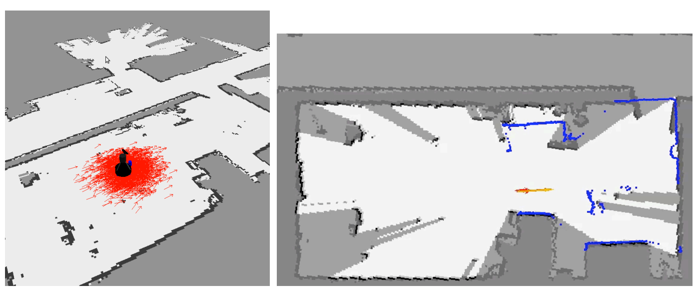
4 Localization and Navigation

With the transition to ROS, one of the first nodes adopted was the Gmapping [4, 5] node. This node uses laser scans and odometry information to build a map of the environment using SLAM. Opposed to our previous solution where we had to hand measure the environment, this presents a clear advantage as the robot builds its map autonomously. However the team is developing methodologies that allow a map to be provided beforehand based, for example, on a blueprint. This way a robot can navigate in an environment that has never visited before, not requiring to do SLAM in an initial phase. An example of a map built by the described solution is presented in Figure 2.

Using the map built with Gmapping we can apply localization techniques to allow the robot to know its position in the environment. A well established solution is the Adaptive Monte-Carlo Localization algorithm [6], also available as

Fig. 2. The resulting map of our lab floor, at the University of Aveiro, with the Gmapping algorithm. The main corridor measures more than 40m.

a ROS node. While this algorithm is very robust and easily available, the CAMBADA@Home team is testing an alternative based on the localization method presented in the last competition. This localization method is adapted directly from the robotic soccer localization method [7] used in the Middle Size League. It basically performs a gradient descent matching between the observed laser scan and the known map of the environment. Figure 3 presents a visual representation of both approaches.



a) **b)**

Fig. 3. The localization algorithms used in the CAMBADA@Home team: **a)** The Adaptive Monte Carlo Localization algorithm, available in ROS. **b)** The scan matching algorithm based on robotic soccer localization method.

Finally, as many RoboCup@Home challenges require autonomous exploration, such as "Go Get It", the CAMBADA@Home team is actively researching exploration methodologies.

5 Human Detection and Tracking

An important part of RoboCup@Home deals with sharing the environment with robots. Therefore a crucial ability for an @Home robot is to be able to perceive and track humans. This year the team is developing a modular architecture that fuses the information of a Microsoft Kinect sensor and an LMS laser range finder to detect, identify and track multiple persons in the environment. The architecture is generic and can be applied in the different @Home challenges that require human interaction. Figure 4 presents the aforementioned architecture.

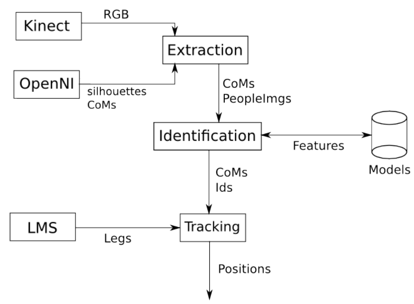


Fig. 4. The modular architecture for identifying and tracking people. Each box represents a ROS node.

The architecture is implemented as a set of ROS nodes that exchange data. There are two main sensors used: the Microsoft Kinect and a SICK LMS100. From the Kinect Sensor we use both the color and depth images. From the depth image, using OpenNI tracker available in ROS, we developed a node that extracts the Centers of Mass (CoMs) and the silhouette (a mask of the corresponding pixels) of every person detected in the image.

Then a node fuses the produced masks with the color image, resulting in an image composed only of the detected people, with the background extracted. For every detected person there will be an image with only that corresponding person. In this way we can, in a later phase, extract features with little noise produced by the pixels of the scene surrounding a person.

These features are then used to build models that are able to identify known persons. With the people in the image identified we can instantiate separate filters that are able to track each person independently. In order to complement the Microsoft Kinect narrow field of view, we integrate in the tracking filters the legs extracted from the laser scans [8]. This allows the robot to keep track of a person even if it is not seen by the Kinect.

Figure 5 presents a resulting image that combines all extracted people in the scene using the methods described above.

6 Human-Robot Interaction

Spoken language is a natural way – possibly the most natural - to control and process human-robot interaction. It has some important advantages: eyes and

Fig. 5. The result of people extraction phase, fusing both the depth and color image of the Kinect. This is a debug image with all detected people. There will also be an image for every person detected.

hands free; communication from a distance, even without being in line of sight; no need for additional learning for humans.

Therefore, we integrated in our mobile service robot some interaction facilities by means of three spoken and natural language processing components: an Automatic Speech Recognition (ASR) component to process the human requests (in form of command-like small sentences), a Text-to-Speech (TTS) component to generate more natural responses from the robot side, and a semantic framework (dialog manager) to control how these two components work together.

The requirements for this spoken and natural language interaction system result from the rulebook of the RoboCup@Home competition. An example of an use-case is the *Follow Me* task where the robot is asked to follow the user. In this use-case two command-like sentences are needed: "[Robot's Name] follow me" and"[Robot's Name] stop follow me".

According to the use-cases the following requirements for our speech-based interaction system are defined:

- The speech recognition component should be speaker independent, have a small vocabulary, and be context dependent and robust against stationary and non-stationary environmental noise.
- The speech output should be intelligible and sound natural.
- The dialog manager system should be mixed-initiative allowing both robot and user to start the action, provide or ask for help if no input is received or incorrect action is recognized, and ask for confirmation in case of irreversible actions.

In terms of hardware, two types of input systems are being tested: a robot mounted microphone and a microphone array framework with noise reduction and echo cancellation. To deal with the high amount of non-stationary background noises and background speech usually present in these interaction environments, a close speech detection framework is applied in parallel to noise robust speech recognition techniques.

Speech recognition is accomplished through the use of CMUSphinx, an Open Source Toolkit for Speech Recognition project by Carnegie Mellon University. Additionally, we are testing speech recognition results obtained by using the Microsoft Speech SDK. For this purpose both speaker dependent and speaker independent profiles are being trained, and a specific grammar for command interaction defined, with each command-like sentence preceded by a predefined prefix (robot's name).

For robot speak-back interaction and user feedback, external speech output devices (external speakers) will be used. The speech synthesis component will be implemented by means of a concatenative system for speech output. For that purpose, we are testing the Microsoft Speech SDK and the FESTIVAL Speech Synthesis system developed at the Edinburgh University. We are trying to implement some adaptation features like using the information on distance from robot to user to dynamically change the output volume, and changing the TTS rate from normal to slower according to user's age.

These tools are integrated in the Olympus framework [9] (Figure 6), developed at Carnegie Mellon University, which provides a domain independent voice based interaction system. This framework provides the Ravenclaw dialog manager [10], which interacts with an application back-end, in this case the robot software architecture, to perform predefined tasks such as the "Follow me" example.

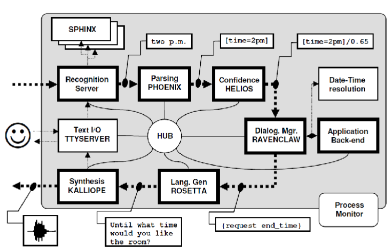


Fig. 6. The Olympus framework, adapted from [9].

7 Conclusion

This paper presents an overview of the current stage of development of the CAMBADA@home team. For this year the team focused on a series of new developments. The team is designing a new robotic platform for future RoboCup@Home participations. Additionally the team adopted ROS as main framework and middleware. The team has also developed new localization methodologies, based on robotic soccer localization as well as techniques to better perceive humans in the environments, a crucial ability for RoboCup@Home robots.

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