Birmingham Autonomous Robot Club (BARC) - Team Description Paper

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Abstract—**Robotic competitions provide an excellent opportunity for students to use their knowledge and skills from formal lectures and research to real world challenging scenarios. Moreover, they can influence and promote robotics to the public. Experience and knowledge gained from these events pushes research into progressing faster and benefits the robotics community.**

Birmingham Autonomous Robot Club (BARC) aims in connecting the students from the School of Computer Science, University of Birmingham, with strong motivation in robotic applications and competitions. This paper is part of our application for participating in the RoCKIn 2014 competition. It provides an overview of our team, including team members, description of their research interests and previous experiences. Also, it provides information on the team's robot and the hardware that will be used. Lastly, it is described in detail how the competition's tasks will be tackled by the team and the software implementation/architecture that is currently used.

I. Introduction

BARC team was established five years ago in the School of Computer Science at the University of Birmingham. The main purpose was to provide an extra opportunity for students to get more knowledge about robotics and to work on real robotic platforms and projects. Students were familiarising themselves with the Robot Operating System (ROS), by using a variety of ROS libraries and packages.

Several students involved in the team were solving more complicated projects, mainly useful to promote robotics during school's Open day. Such an example was a robot Waitress, that was accepting orders for drinks and was bringing them to a person, who made the order. This robot had no manipulation, drinks were placed on the robot by a person. Another example can be a project with a Nao robot repeating gestures of kids. An extra Kinect sensor was used to recognize children's gestures in this project. In spite of these interesting projects a lot of students involved in previous years in the club had no real goal and no real deadlines, thus they did not produced any comprehensive work.

This year, BARC structure was changed in order to incorporate the lessons learned and to allow the team to take part in a robotic competition. We would like to join RoCKIn@home 2014 competition because it provides an interesting challenge and will help progressing domestic and industrial robots research and applications. Moreover, the cooperation between students is necessary. As a result, students can learn how to work in a team, but still work on some challenging part alone and gain valuable knowledge while learning how to be responsible for their work.

The team has the support of the Intelligent Robotics Lab [1] in the school of Computer Science. The lab conducts research and has expertise in a variety of fields such as but not limited to computer vision, manipulation, planning, architectures, reasoning and mobile robots. Furthermore the lab has strong links with the industry.

II. Our focus and plan

We summarise in this section three different challenges provided in the RoCKIN@home 2014 competition and it is explained, what we intend to perform with our robot this year. Our intention is to prepare a complete robotic platform, which will integrate the state of the art of areas, in which we do not have too much experiences, with our own research. Therefore, we would like to aim for high reusability of our robotic system.

A. Catering for Granny Annies Comfort

A robot will receive requirements from Granny Annie. These requirements may contain a cooperation with an intelligent flat or bringing to her a specific object. We would like to prepare our robot, that it can perform the first part - cooperation with intelligent flat. This subtask still contain interesting challenges to us, such as robust speech recognition and robot navigation in the way that it is comfortable and natural for a human. Of course, the communication with a flat's server must be working, but we do not expect too much difficulties in that.

A problem of speech recognition is often discussed within robotic community. It is definitely helpful for future robot's cooperation with human, but it also brings a lot of difficulties during competition. If we assume a robot working at Granny's flat, the robot can learn her specific voice and increases its performance over time. Moreover, Granny is living alone, thus, it can be assumed that a level of background noise is minimal. In contrast, the background noise is really high during competition because of audience watching a match. Moreover, the person playing Granny Annie changes, thus a robot cannot improve its behaviour. We do not assume to develop our system from scratch, rather we think to use CMU Sphinx - Open Source Toolkit For Speech Recognition [2]. Moreover, we might cooperate with a group for Natural Language Processing within our school to improve behaviour of our system.

In human approaching challenge, we expect to use the state-of-the-art systems again. However, we haven't yet done a proper search for approaches, which will suit us. We might

Month	May				June					July				August				September					October				November			
Week	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24
Lenka																														
Marco																														
Manolis																														
Sean																														
New																														
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Fig. 1. Timetable

use opportunity of closer cooperation with project STRANDS [3], as our robotic group within our school leads this project. Especially, a cooperation with Christian Dondrup, the PhD student at the University of Lincoln, might be beneficial in this stage, as he is working on Human Robot Interaction.

The second part of this task - bringing a specific object - is even more challenging as it includes two large robotics domain - computer vision and manipulation. As our robot has no manipulator this year (see Section IV), we might be able to perform only search for an object. Here, we might take benefit of experiences from previous project in our robotic group - CogX [4], where one of robot's performance was searching for known object, where it took into account different probabilities of object's presence in different rooms. However, this will still require a lot of effort for us, as the robot was not using ROS before and we will need to understand and integrate bits to our system. As a result, we are not sure if we will perform this part this year, as we have limited numbers of members in our team.

B. Welcoming visitors

In this task, a robot should welcome visitors, recognized them and accompany them to a specific place in Granny's flat. Several areas are needed in this task : computer vision for face recognition (in case of known person Dr. Kimbley) and for an uniform detection (in case of Deli-man). Moreover, machine learning techniques are needed to be able to learn these two patterns before in order to recognize them. A robot can also benefit from speech recognition, if face/uniform recognition does not provide certain decision. Finally, a robot must have robust navigation in an environment in order to accompany person to specific place.

In our team, we agreed to start with this task, because of our expertise. We have already prepared a robotic system, which is able to recognize faces based on OpenCV (for details see Section V-H) and robustly navigate in a known environment (see Section V-E). As a next step, we will work on an uniform detection. Again, we might take a benefit from expertise within STRANDS project, where a robot also must recognize different types of uniforms. If we found more team members, we would like to improve robot's behaviour. For example, it will recognize if a person follows it and perform actions to ensure this.

C. Getting to know my home

A robot should recognize changes in a flat in this scenario, which can be done autonomously or by cooperation with a human. We assume that our robot will be able to recognize a state of doors autonomously. It will combine measurements taken by a laser scanner and a Kinect. We have experiences with such a problem, thus we will only integrate the solution to our robotic system.

In order to automatically recognize changes in position of furniture or objects, we might take benefit of cooperation with STRANDS project again, as this is one of challenges being solved there. However, we also might combine it with cooperation with a human, where he/she will guide a robot to the object, which position has changed. We have already prepared a system to be able to follow a person. Moreover, a former team member was working on a project, where a robot should recognize, where a human is pointing by his/her finger. We might take benefit of work, which has be done and enlarge it to fit our needs.

D. Timetable

An expected plan of our activities can be seen in Fig. 1.

III. Team members

Currently, team has four active members - one bachelor student and three PhD students in first year of their studies. All team members are students in the School of Computer Science, University of Birmingham. The overview of team members follows along with a description of their background and research interests. The final team line-up is likely to change until the competition as more members will contribute.

A. Lenka Mudrova

She is a PhD student with research interest at AI planning and scheduling. In the team, she has two roles. First, she is the team leader, which includes mainly representation of the team, when formal communication outside of the team is necessary. Also, she takes care that every member of the team knows what is happening, how their modules will be used within the system and what is required from them. The second role is that she is working also on robot's subsystem. Her research interest in AI planning will be useful for creating an overall robot's behaviour. Moreover, she is interested in computer vision and speech recognition.

Scientific background: She did her bachelor and master studies at the Czech Technical University in Prague with focus on Robotics. This study branch give her wide range of knowledges from fields of mechatronics and artificial intelligence. She was involved as a team leader of the student robotic team FELaaCZech that took part in the international competition Eurobot for four years. Moreover, she was a member of team participating in robotic outdoor challenge RoboTour and Sick Robotic day.

Nowadays, she is a PhD student with focus on AI planning and scheduling, which are important techniques for a robot to make a decisions when, how and what needs to be performed. Such decisions are necessary in service robotics, when a robot should fulfil tasks assigned by a human. The robot needs to have a control framework that makes decisions concerning which particular task should be executed. The quality of the decisions influence the overall performance of the robot and of course, the robot's goal must be to satisfy as many of the requirements assigned by people as possible. Requirements for the robot's control framework are deadline awareness, handling uncertainty about task duration and resources, creating plans on how to complete general tasks and awareness of changes in the environment where the robot operates.

The assigned task might have some time constraints, for example release and due dates. Therefore, scheduling techniques are important to handle this. Each task has also defined goal or activity, which needs to be achieved or performed, respectively. This performance can be represented by state machine for well defined tasks. However, planning techniques are needed for more general tasks, for example finding of an object, which position varies in a robot's environment.

Her research is influenced by the EU STRANDS project. "STRANDS aims to enable a robot to achieve robust and intelligent behaviour in human environments through adaptation to, and the exploitation of, long-term experience (at least 120 days by the end of the project)." [3] Therefore, the robot's control framework will exploit long-term experiences and observations of the robot's world.

B. Marco Antonio Becerra Pedraza

He obtained his B.Eng. degree in Mechatronics from the Instituto Politcnico Nacional in Mexico and the M.Eng. degree in Computer Science from the Universidad Nacional Autnoma de Mxico. He is a former member of the PUMAS RoboCup@Home team. Nowadays, he is PhD student with research interests including 3D perception, human sensing, knowledge representation and reasoning for robotics.

Research Interests: He started his PhD studies five months ago, thus he has not yet specified his research topic. However, he is interested in two fields, semantic mapping and activity recognition.

Semantic mapping can be conceived as an extension of a mapping problem in robotics [5]. Traditional maps take in consideration a spatial shape of an environment for motion planning purposes (e.g. navigation, localization). But generally, the environment has a more complex structure. Therefore, the role of semantic maps is to add concrete descriptions of components of the environment, their structure and relations. The robot can reason about the scene (e.g. planning, prediction, explanation, interpretation) using this descriptions in semantic map.

Activity recognition can be useful in service robotics, where robots should share scenarios with other agents (e.g. humans, animals, other robots) and an interaction between them is expected. A robot need to be aware of another agent's actions, i.e. the capacity to recognize the ongoing actions in the environment. The goal of activity recognition is to be able to build representations of an activity from observations; specially interesting are qualitative spatio-temporal representations of an activity, because they are more human alike and they can be used in general cases.

C. Manolis Chiou

He is a PhD student in the Intelligent robotics lab of School of Computer Science, University of Birmingham. He has a multidisciplinary background with hands on work on robots and AI. His work on BARC involves but is not limited to navigation, localization and in the future Human-Robot-Interaction (HRI) and different controllers.

Scientific background: His first degree is in Control Engineering from the Technological Institute of Piraeus, in which he got involved in many robotic projects including demonstrating these projects to the public and exhibitions. His undergraduate thesis was on implementing control algorithms to robots (e.g. Model Predictive Control for stability/balance on moving platforms). He has a MSc in Computational Intelligence with his master thesis be on formation and transportation of objects with a swarm of robots.

The title of his PhD thesis is "Flexible robotic control via co-operation between an Operator and an AI based control system". It addresses the problem of variable autonomy in teleoperated mobile robots. Variable autonomy refers to the different levels of autonomous capabilities that are implemented on a robot. Robots used on demanding and safety critical tasks (e.g. search and rescue, hazardous environments inspection, bomb disposal), which are currently teleoperated, could soon start to benefit from autonomous capabilities, such as algorithms for automatic robot navigation or algorithms for SLAM. Robots could usefully use AI control algorithms to autonomously take control of certain functions when the human operator is suffering a high workload, high cognitive load, anxiety, or other distractions and stresses. In contrast, some circumstances may still necessitate direct human control of the robot.

The research will tackle the problem by designing a mixed-initiative control algorithm for switching between the different autonomy levels in an optimal way. Mixed-initiative refers to the peer-to-peer relationship between the robot and the operator in terms of the authority to initiate actions and changes in the autonomy level. Research will be conducted and evaluated in a principled way by designing experiments with methods drawn from human factors, psychology, Human-Robot-Interaction and robotics. Lastly, State of the art AI algorithms (e.g. SLAM, navigation etc.) will be implemented on ROS and tested for improving the performance of this variable autonomy - mixed initiative framework.

D. Sean Bastable

He is an bachelor student in his final year. It is expected that he will continue in his studies at master degree. He was also BARC member the previous year, so he has solid experience with ROS and different robotic platforms. He also attended RoCKIn camp 2014 in Rome.

Scientific background: His final year project was about investigating and implementing a visual localization system for a mobile robot. This allowed the robot to continue localising in environments where laser based localisation cannot be used. A good example of this, are domestic environments where the presence of people moving around the robot may obstruct the laser scan and provide false readings.

The project used a ceiling facing omnidirectional camera on the top of a robot in order to take pictures of its surroundings. The robot was trained by taking many pictures of the environment, along with location data provided through laser based localisation under ideal conditions. When localising, it can then take additional pictures and compare them to the training images in order to find an estimate of its location. Principal Components Analysis (PCA) was used to match images in the localisation phase to those in the test phase.

Another potential use of this project is to provide an initial location estimate to a laser based localisation system in order to allow the robot to quickly localise from any position without any human input.

This project follows on his Summer project working on a drinks serving robot for a launch event for the 2014 British Science Festival. As a robot was moving in the crowd, one of the key failure points was if the robot became de-localised. Visual localisation developed in his final year project overcomes this issue.

IV. Hardware

The robot Dora (a pioneer robot) was kindly given for the team's needs, see Fig.2. She is constructed from a Pioneer 3D-X robotic platform with a Hokuyo laser scanner in the front. Moreover, a pan-tilt unit carrying a Kinect depth camera and one RGB camera is mounted on the higher platform in order to get snapshot from cameras from better views than just place it on the Pioneer robot. Dora has also a travel luggage kit, thus it is possible to take her to the competition.

Furthermore, team members have access to different sensors such as laser scanners, depth and RGB cameras. At the moment, Dora has no manipulator arm installed. In the future, it is planned to mount one small manipulator arm in order to extent Dora's capabilities.

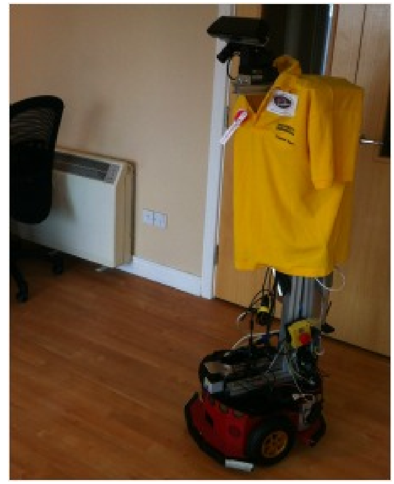

Fig. 2. Dora robot

V. Software architecture

The system is composed of several independent programs/nodes and thus reusable parts of code with different functionality. The different nodes communicate between them by exchanging ROS messages and ROS actions 3. The core element of our framework that binds the rest of the node/processes together is a state machine node. (needs heavy editing this part)

A. Middleware-Robot Operating System

Robot Operating System (ROS) (cite here) will be used as the middleware. ROS open source philosophy is powerful and allows code re-usability by different programmers. It allows us to use robust, state of the art or our own AI algorithms without worrying about how to write code for low level motor commands or sensor drivers. Even more important is the fact that can save valuable time that otherwise would be spend in merging different architectures or worrying of how different pieces of software would communicate with each other. Lastly, ROS was also chosen as it has become almost a standard choice for researchers and thus our lab has extensive hands on experience.

B. State machine

The core element of our framework that binds the rest of the node/processes together is a state machine node. It is responsible for monitoring the state of the robot and the world. Also it is responsible for deciding what is going to be the next robot action. It was developed with ROS SMACH framework and it works by....

C. Building the map with SLAM

Since the map is it assumed to be known there is a need to build it before further tests can be done. For initially building a map we made use of the OpenSlam's GMapping algorithm [6] through the ROS wrapper package called slam gmapping. This approach uses a Rao-Blackwellized particle filter in which

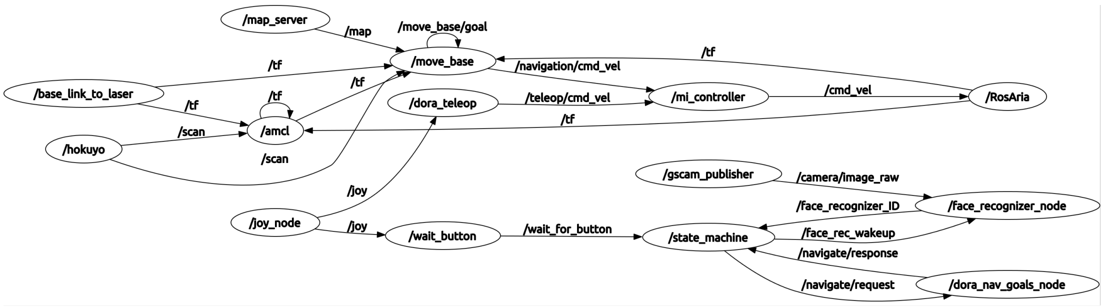

Fig. 3. An overview of the software architecture and how the nodes are connected interact with each other

each particle carries an individual map of the environment. The particles are updated by taking into account both odometry and the latests observations from a laser range finder.

D. Localising in a known map with adaptive Monte Carlo localisation

After the map is known and saved, an Adaptive Monte Carlo Localisation (AMCL) [7] algorithm (is part of the ROS navigation stack - see navigation section) is used to localise the robot inside the known environment. It uses laser range finder readings to update a particle filter. Every particle is representing a specific discrete state and stores the uncertainty of robot being in that state/position within the known map. Also every time the robot moves uses the motor information to shift the particles to the corresponding direction. The robot's pose estimate is then been published through a ROS topic for use with other nodes.

E. Navigation

For navigation and obstacle avoidance, ROS navigation stack is used. It is a proven robust solution for domestic environments (citation here of marathon). More specifically navigation stack reads the odometry, the pose estimate and laser range finder scans from the relevant topics and drives safety the robot inside the environment to some goal. The goal is represented by some given coordinates. For example it drives the robot to the door coordinates, where the robot should perform its face recognition to the person ringing the bell. For achiving this it make use of a global and a local planer. The global planner creates an optimal global path based on robot's pose and a global costmap. Then a local planner, making use of the Dynamic Window Approach algorithm (citation here), is responsible for following that global path and reactively avoiding obstacles.

F. Mixed initiative controller and teleoperation

These nodes were made as part of another project involving mixed initiative HRI in emergency response robots. Thus, the name is not representative of their exact functionality in this case. The controller it is used to decide which velocity commands to give to the motors whenever some coupling of commands is needed. On one hand are the motor commands coming from robot's AI (e.g. AI navigation) and on the other hand are motor commands coming from a teleoperation node and a human through a joystick. Although the robot is autonomous, the latter is necessary as the user needs to place the robot in the initial state, move it around during testing just by pausing AI commands, or stop the robot in the case of an emergency (e.g. robot repeatedly hitting a wall, so the user has to stop it and drive it away). This is another example of code which can be reused in many different applications.

G. Dora navigation goals node

H. Face detection and recognition

In order to improve the HRI skills of the robot we have implemented in our system face detection and face recognition capabilities (see FIG.4). The first one is used to find candidate face patterns inside an image, while the latter tries to find the best match of a new face with a known dataset.

Face detection is performed using the Viola-Jones algorithm [8]. The algorithm uses a supervised machine learning approach, where a cascade function is trained with many positive and negative images. Then, it is used to detect faces in other images. The algorithm uses many simple Haar feature classifiers which are applied incrementally in different regions of the image in order to discriminate candidate face regions. One of these feature classifiers won't identify a face just by itself, but the combined and supplementary use of all the simple Haar classifiers succeeds.

Face recognition is performed by applying a Local Binary Pattern Histogram (LBPH) algorithm [9]. The principle is to build local binary patterns (LBP) for each pixel depending on a variable neighbourhood scheme. Then, divide the formed LBP image into m local regions and extract the histogram from each. Finally, classification is performed by comparing the resulting histograms with the ones of the classes in the dataset.

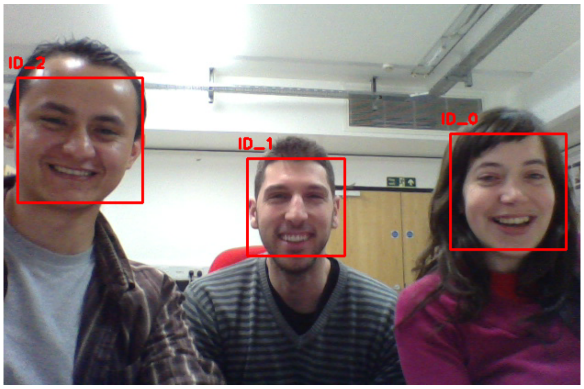

Fig. 4. An example of the face detection and face recognition algorithms. The red bounding boxes surround the successfully detected faces, while each of them is given a corresponding identification code.

I. Transformations

VI. Future work

VII. Conclusion

All team members have a strong motivation in participating in the robotic competitions. We think that the RoCKIn@Home will provide interesting challenge for us and it will address the problematic of the real robots in our homes. As a result, we are expecting to obtain more knowledge in the ongoing research in many fields in robotic.

If three our members will be accepted to participate in the RoCKIn camp, we assumed this will help us to get into the demanding robotic topics more faster and produce better and more interesting solution of the overall system.

References

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