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 it 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. Also, they had the chance to work with different robotics platforms.

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 the person. 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 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, the BARC structure was changed in order to incorporate the lessons learned and to allow the team to take part in a robotics 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 gaining valuable knowledge while learning how to be responsible for their work.

The team has the support of the Intelligent Robotic Lab (cite site here) 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

(I think we should mainly focus on re-usability and the chance to produce a complete robotic platform by on state of the art and proven AI for real world applications.) The team would like to join RoCKIn@Home competition, but the exact rules are not provided yet. Thus, we took a rules of the Robocup@Home challenge and we agree that we will focus on *Follow me* and *Cocktail party* tasks first. We discus the architecture of your system using the Dora robot, see Section **??**.

III. Team members

Currently 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

Her role in the team is mainly team leader. She is doing the organization work, such as reports from regular meetings, website presentation and communication with the school about support. She is also a technical manager, this means that she is meeting with single groups solving a particular robot module and try to understand briefly all the system. As a result, she is creating a bridge between the groups and she takes care that everyone knows what is happening and how the modules will communicate and so on. Instead of this, she is working on the robot controller.

Scientific background: Her previous background is also in the robotics, mainly focus on localization of robots. She was involved as a team leader of student robotic team before in the Czech Republic, as you can see from her CV sent as a separate file.

Nowadays, she is a PhD student with the focus on robotics. Her PhD thesis topic is "Cognitive control framework for long-term autonomy". Broadly speaking, the goal her thesis is to create a collection of functions to schedule and plan tasks for a robot that will exploit long-term experiences and observations. Her work is influenced by the EU STRANDS project (http://strands-project.eu/). Citating from the projects abstract: "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)."

Currently, she is working on a scheduling system that will be used in the first year of the project. This system will be based on state-of-the-art schedulers. Each input task is defined by a time window when it needs to be executed, expected duration and where in the environment the task should be performed. The scheduler will then output an ordering for the list of input tasks. It also will handle "on-demand" tasks, thus it will also include a rescheduling procedure for when a new task arrives.

Afterwards, she will extend this approach so that the scheduler can tackle other common issues that arise in the robotics domain e.g., uncertainty about time duration of task, errors occurring during the execution of the task and so on. Also, she will add a planning approach and integrate it with the scheduler, so that more efficient scheduling of tasks can be achieved. In particular, she will investigate how different tasks can be mixed or executed in parallel, instead of the sequential execution usually present in state-of-the-art schedulers.

B. Sean Bastable

He is an undergraduate student in the Computer Science but with focus on robotics. As he was also a BARC member the previous year, he has experience with ROS and different robotic platforms. ((******He is one of the two people working on a visual tracking system, using the skeleton body recognition and colour information. He is also interested in computer vision, thus the RoCKin camp will be beneficial for him.****)) ¡- plz update this part.

Scientific background: His final year project is about investigating and implementing a visual localization system for a mobile robot. This will allow 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 will involve mounting a ceiling facing omnidirectional camera on the top of a robot in order to take pictures of its surroundings. The robot will be 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. He will primarily be using Principal Components Analysis (PCA) to match images in the localisation phase to those in the test phase. The planing of his project also involves investigating other techniques and methods to improve the robustness of the system.

Another potential use of this 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. One of the key failure points was if the robot became de-localised. It needs to know exactly where it is in order to effectively navigate through gaps in between crowds of people, but the crowds make this much more difficult. Visual localisation was considered as a potential solution but would have taken too long to implement.

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.

IV. HARDWARE

The robot Dora (a pioneer robot) was kindly given for the team's needs. Furthermore, team members have access to different sensors such as laser scanners and depth 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 and allow for participation in more challenging scenarios in future competitions.

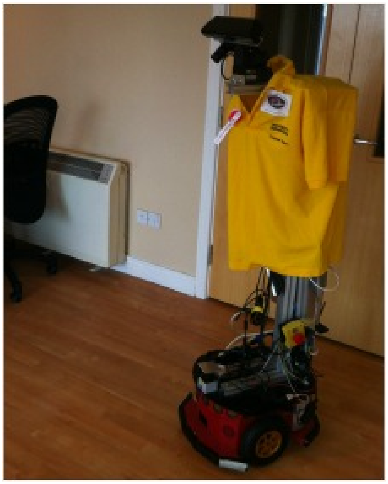

Fig. 1. Dora robot

Dora robot (see Fig.1) is a Pioneer 3D-X robotic platform with a Hokuyo laser scanner in the front and a Kinect depth camera mounted on a pan-tilt unit. It is placed on the stick to get snapshot from better heigh 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.

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. 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 (citation) through the ROS wrapper package slam gmapping. It uses bla bla...

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

After the map is known and saved, Adaptive Monte Carlo Localisation (AMCL) algorithm (is part of the ROS navigation stack - see next section) is used to localise the robot inside the environment. It uses robot odometry and laser range finder readings to update a particle filter that is representing the uncertainty of robot's position within the known map. The robot's pose estimate is then published through a ROS topic...

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 Human-Robot Interaction (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 recognition*

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.