

Birmingham Autonomous Robot Club (BARC)

Motto: *Learning by doing*

Members: Lenka Mudrova, Manolis Chiou, Marco Becerra,
Sean Bastable, Joshua Smith, Edoardo Bacci, Tanya Daskova and Anya Hristova

Email: robot-club@cs.bham.ac.uk

Affiliation: School of Computer Science, University of Birmingham, UK

Website: <http://lenka-robotics.eu/index.php/robotic-club>

Abstract—Birmingham Autonomous Robot Club (BARC) connects students from the University of Birmingham, with a strong interest in robotic applications and competitions. This paper is part of our qualification for the RoCKIn@Home 2015 competition. Therefore, it overviews our robot Dora and developed software structure based on ROS middleware.

It overviews how this challenge relates to our interests and experiences and how we can achieve high reusability of our system by integrating different subsystems from other projects. Moreover, team members, their experiences and research interests are described in detail.

Finally, the conclusion summarises our motivation and relevance for this competition.

I. INTRODUCTION

Our interest in robotics is expressed through learning by doing. Therefore we are actively engaging or organising different workshops, projects and public engagement events. Our main focus is our participation in the EU funded RoCKIN@Home robotics competition.

Birmingham Autonomous Robot Club (BARC) was established in 2011 in the School of Computer Science at the University of Birmingham. The main purpose was to provide an extra opportunity for students to gain additional knowledge about robotics and to work on real robotic platforms and projects. Several students involved in the team contributed to projects, which were mainly used to promote robotics during the school's open days, for example a robot waitress, which accepted orders for drinks and brought them to the person.

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 the RoCKIn@home 2014 competition because it provides an interesting challenge and will help with progressing research and developing applications for domestic and industrial robots. Moreover, the cooperation between students in the team is necessary. As a result, students can learn how to work in a team, but still work on some challenging parts alone and gain valuable knowledge while learning how to be responsible for their work.

The team has the support of the Intelligent Robotics Lab [?] in the School of Computer Science. The lab conducts research and has expertise in a variety of fields including but not limited to computer vision, manipulation, planning,

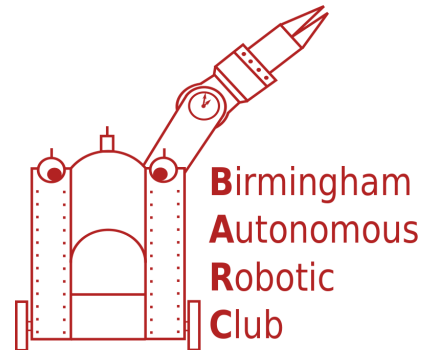


Fig. 1. Our logo represents our university campus with famous clock tower Old Joe.

architectures, reasoning and mobile robots. Furthermore, the lab has strong links with the industry.

II. OUR FOCUS AND PLAN

This section summarises three different RoCKIN@home 2014 competition challenges and it describes what is intended to be performed with our robot this year. Our intention is to prepare a complete robotic platform, which will integrate the state of the art in different Artificial Intelligent (AI) areas. The team does not have explicit expertise in any of those fields. Therefore, we would like to aim for high reusability of code in our robotic system and to demonstrate that the current state of the art in AI algorithms can be successfully used to produce a robust, effective and complete robotic system with domestic applications.

A. Catering for Granny Annie's Comfort

A robot will receive requirements from Granny Annie, which may contain interaction with an intelligent flat or bringing to her a specific object. We would like to prepare our robot so that it can perform the first part - cooperation/interaction with an intelligent flat. This subtask still contains interesting challenges, such as robust speech recognition and robot navigation in a way, which is comfortable and natural for a human.

The problem of speech recognition is often discussed within the robotic community. It is something, which is necessary for future robots to cooperate with humans. Assuming a robot is working at Granny's flat, the robot can learn and adapt

to her voice, which will increase its performance over time. Moreover, Granny is living alone, thus, it can be assumed that the level of background noise is minimal. In contrast, during the competition, speech recognition provides a lot of challenges. The background noise is really high during competition because of the spectators. Furthermore, the person playing Granny Annie changes, hence a robot cannot improve its behaviour. We do not plan to develop our system from scratch, rather we plan to use CMU Sphinx - Open Source Toolkit For Speech Recognition [?]. Moreover, we might cooperate with a Natural Language Processing group within our school to improve the system's behaviour.

For a challenge, where the robot approaches humans, we will use the opportunity for closer cooperation with the STRANDS [?] project, as our robotics group within our school leads this project. Especially, a cooperation with Christian Dondrup, a 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 someone a specific object - is even more challenging as it includes two large robotics domains, computer vision and manipulation. As our robot has no manipulator this year (see Section IV), we might be able to perform only object search. We might benefit from experiences from a previous project in our robotic group - CogX [?]. In this project, one of the robot's abilities was to search for known objects by taking into account common sense knowledge (i.e. prior knowledge) in the form of probabilities of objects' presence in different rooms. However, this will still require a lot of effort from us, as the robot was not using ROS before and we will need to understand and integrate bits into our system. We assume to work on this part next year.

B. Welcoming visitors

In this task, a robot should welcome visitors, recognize them and accompany them to a specific location in Granny's flat. Several areas are needed in this task: computer vision for face recognition (in the known person case, Dr. Kimbley) and for uniform detection (in the case of the delivery-man). Moreover, machine learning techniques are needed to be able to learn these two patterns in order to recognise them. A robot can also benefit from speech recognition if face/uniform recognition does not provide a certain decision. Finally, a robot must have robust navigation in an environment in order to accompany a person to a 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 recognise faces based on OpenCV (for details see Section V-D0d) and robustly navigate in a known environment (see Section ??). As a next step, we will work on uniform detection. Again, we will use the expertise within the STRANDS project, where a robot also must recognise different types of uniforms. We also plan to improve the robot's behaviour and we are currently recruiting members towards this goal. For example, it will recognise if a person is following it and will perform actions to ensure this.

C. Getting to know my home

A robot should recognise changes in a flat in this scenario, which can be done autonomously or by cooperation with a human. It is assumed that our robot will be able to recognise the state of doors autonomously. It will combine measurements taken by a laser scanner and a Kinect. The team has experience with such a problem, thus the already found solution will be integrated into our robotic system.

In order to automatically recognise changes in the position of furniture or objects, we might take benefit of cooperation with the STRANDS project again, as this is one of the challenges being solved there. However, we plan to combine it with cooperation with a human, where he/she will guide the robot to the object, which has changed position. The algorithms for the robot to be able to follow a person are already prepared. Furthermore, a former team member was working on a project where a robot can recognise where a human finger is pointing. We will use this work and extend it to fit our needs.

D. Timetable

Our plan is to perform complete *Welcoming visitor* (referred as MW) task during competition. Moreover, we will work on *Getting to know my home* (referred as MG) task, where we assume to be able to recognise state of doors. In order to achieve these goals, we set up our milestones:

- MW1 - training of a face, recognising a known person based on the face, mapping, localisation, robust navigation in a known map. Deadline: 7.5.2014
- MW2 - Increase robustness of face recognition, detection if a person is following the robot, speech recognition. Deadline: 27.7.2014
- MW3 - Integration and test, producing new video. Deadline: 31.7.2014
- MW4 - Cloth recognition, robot behaviour to restrict person to follow it. Deadline 31.8.2014
- MW5 - Integration and test. Deadline: 5.9.2014
- MW6 - **Perform complete Welcoming visitor task during British science festival 6.9.-11.9.2014**
- MW7 - Perform more test. Deadline 30.9.2014
- MG1 - Work on autonomous recognition of state of doors, cooperation with human in detection of other changes. Deadline 31.10.2014
- Test of overall system. Deadline 23.11.2014

The expected timetable of our milestones can be seen in Fig. ??.

III. TEAM MEMBERS

Currently, the team has four active members - one bachelor's student and three PhD students in the 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 before the competition as more members will contribute.

A. Lenka Mudrova

She is a PhD student with research interests in AI planning and scheduling. In the team, she has two roles. First, she is the team leader, which mainly includes representation of the team when formal communication outside of the team is necessary. Also, she makes sure 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 the robot's subsystem. Her research interest in Artificial Intelligence (AI) planning will be useful for creating the robot's overall behaviour next year. Moreover, she is interested in computer vision and speech recognition.

Scientific background: She did her bachelor's and master's studies at the Czech Technical University in Prague with a focus on Robotics. This study branch gave her a wide range of knowledge in the fields of mechatronics and artificial intelligence. She was involved as a team leader of the student robotics team FELaaCZech that took part in the international competition Eurobot for four years.

Currently, she is a PhD student with a focus on AI planning and scheduling, which are important techniques for a robot to make decisions on when, how and what needs to be performed. Such decisions are necessary in service robotics when a robot needs to complete 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 satisfy as many of the requirements assigned by the humans 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.

Her research is part of 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)". Therefore, the robot's control framework will exploit long-term experiences and observations of the robot's world.

B. Marco Antonio Becerra Pedraza

He is a PhD student in the School of Computer Science, University of Birmingham. His research interests are 3D perception, human sensing, knowledge representation and reasoning. Inside the team he has worked with the human sensing capabilities of the robot.

Scientific background: He obtained his bachelor degree in Mechatronics Engineering from the Instituto Politécnico Nacional in Mexico and a master degree in Computer Science from the Universidad Nacional Autónoma de México. He is a former member of the PUMAS RoboCup@Home team.

During his PhD, he will be doing research about semantic mapping of human events. The topic has two main components:

Semantic mapping can be conceived as an extension of the mapping problem [?]. Traditionally maps were used in robotics mostly for navigation purposes. But the environment has additional spatial information that needs to be handled. Semantic maps extend the concept of maps to handle more features from the environment (e.g. structure, functionalities, events). The goal is to reason about the scene (e.g. planning, prediction, explanation, interpretation).

Activity recognition is about using observations from the world to build representations of the ongoing actions. Later, these representations can be used to find associated structures.

C. Manolis Chiou

He is a PhD student with a multidisciplinary background in control engineering, robotics and AI. His work on BARC involves but is not limited to control, navigation, localisation and in the future Human-Robot-Interaction (HRI).

Scientific background: His first degree is in Control Engineering from the Technological Institute of Piraeus, in which he got involved in a variety of 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). He has an MSc in Computational Intelligence with his master thesis on formation control and transportation of objects with a swarm of robots.

The working 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 capabilities include algorithms for automatic robot navigation, algorithms for Simultaneous Localisation And Mapping (SLAM) and etc. 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 control algorithms for switching between the different autonomy levels in an optimal way.

D. Sean Bastable

He is a Computer Science bachelor's student in his final year. It is expected that he will continue to further his studies with a master's degree in Robotics. As the oldest BARC member, he has solid experience with ROS and different robotic platforms. He is also one of the team members who attended RoCKIn camp 2014 in Rome.



Fig. 2. Dora is an extended Pioneer 3D-X robot with sensors such as a laser range finder, depth camera and a laptop mounted on top.

Scientific background: His final year project was about investigating and implementing a visual localisation 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 is in 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 take additional pictures and compare them to the training images in order to find an estimate of its location. Principal Component 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 previous summer project of a drinks serving robot used in a launch event for the 2014 British Science Festival. As the robot was moving in a crowd, one of the key failure points was that it could become de-localised. The robot had the need to know exactly where it is in order to effectively navigate through gaps in-between crowds. Visual localisation was considered as a potential solution but due to time constraints was not implemented.

IV. HARDWARE

Our robot Dora is created using the differential platform Pioneer 3D-X and central supporting construction for sensors and a laptop, see Fig. ???. In last year, Dora was equipped with 2 laser rangefinders and 1 depth camera, see overview

sensor	parameters	usage
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TABLE I

in Tab. I, which were used to ensure safe navigation and people detection. This year, we are going to do significant improvements of her hardware, see Tab. ??, providing more support for:

- *human robot interaction* - Dora's speech understanding and speech reproduction were strongly limited to the used laptop last year. We are going to extend Dora by mounting a microphone and a speaker on her. Additionally, we are going to improve her appearance to be more user-friendly.
- *safe and robust navigation* - We are investigating usage of Pioneer's sonar to detect objects shorter than height when laser rangefinders are mounted. Moreover, Pioneer's bumpers will be used to stop the robot when an object is hit.
- *object recognition* - another depth camera with short range is added to allow detection of small household objects.

V. SOFTWARE ARCHITECTURE

As our goal is to achieve high re-usability, modularity and openness, we built our software architecture on the Robot Operating System (ROS) middleware, using version Indigo [?] running on Ubuntu Trusty Tahr. Additionally, our system this year uses some of the publicly released packages from the STRANDS project [?]. This allows us not only integrate the cutting edge research to our robot, but also contribute to the evaluation of this research. Moreover, we integrate our own research where our interest overlaps with the focus of the competition. Our system architecture can be seen on Fig. ?? containing six modules which are explained below.

A. State machine

Even though, AI planning is in our expertise, we use *finite state machines* to control and monitor robot's states and actions. We have two main reasons for this decision. First, the competition defines all *task benchmarks* as short scripts, so a robot does not have too much freedom in order to decide how to fulfil a task. Second, a state machine provides us with *repeatability* during testing.

For each of the benchmarks, we develop the state machine using ROS's SMACH package, that is "a task-level architecture for rapidly creating complex robot behaviour" [?]. All of the task's state machines are linked with the central state machine which communicates with the referee box.

B. Navigation

a) *Mapping:* - we used *OpenSlam's GMapping* algorithm [?] through the ROS wrapper package called *slam_gmapping*. This approach uses a Rao-Blackwellized particle filter in which each particle carries an individual map of the environment. The particles are updated by taking into account both odometry and the latest observations from a laser range finder.

b) *Localising*: in a known map with Adaptive Monte Carlo Localisation. After the map is known and saved, an *Adaptive Monte Carlo Localisation* (AMCL) [?] algorithm is used to localise the robot inside the known environment. This node is part of the ROS navigation stack package. For details, see the section below. It uses laser range finder readings to update a particle filter. Every particle represents a specific discrete state and stores the uncertainty of the robot being in that state/position within the known map. Also, every time the robot moves it uses the motor information to shift the particles to the corresponding direction.

c) *Move-base*: For navigation and obstacle avoidance, ROS's navigation stack is used. It is a proven robust solution for domestic environments [?]. More specifically this node reads the odometry, the current pose estimate and the laser range finder scans from the relevant topics and safely drives the robot in the environment to a predefined goal. In order to navigate smoothly, it uses a combination of a global and a local planner. The global planner creates an optimal global path based on the robot's pose and a global cost-map. Then the local planner, which uses the *Dynamic Window Approach* algorithm [?], is responsible for following the global path and reactively avoiding obstacles.

C. Object detection and recognition

D. Human detection and interaction

d) *Face detection and recognition*: In order to be able to recognise a person standing in front of the entrance, the system implements face detection, which is used to find candidate face patterns inside an image, and face recognition, which finds the best match of a detected face with a known dataset, see Fig. ??.

Face detection is performed using the *Viola-Jones* algorithm [?]. The algorithm looks for faces by applying incrementally many simple Haar classifiers. The composition is performed by a cascade function, which needs to be trained *a priori* with many positive and negative images. The resulting classifier can find faces efficiently with independence of the size of the faces and light conditions.

Face recognition is performed by applying a *Local Binary Pattern Histogram* (LBPH) algorithm [?]. The principle of the algorithm is to build local binary patterns (LBP) for each pixel depending on a variable neighbourhood scheme. Then, it divides the formed LBP image into m local regions and computes the LBP distribution histogram from each region. Finally, classification is performed by comparison between the LBP histograms of a new face with the ones from the dataset.

E. Speech recognition

F. Semantic mapping

VI. CONCLUSION

Our team has strong relevance to the domestic service robotics, as Lenka's, Marco's and Manolis's research interests involved cooperation with humans. We would like to use our expertises to combine the state of the art in AI techniques with

our own contributions. As a result, a robotic system will be created with high reusability, as we use ROS middleware.

We would like to achieve high robustness of our robotic system that it can perform tasks repeatedly. In order of this our goal, we would like to put attention to verification and evaluation of our system. Therefore, we decided to focus only on a part of the RoCKIn@Home challenge this year. We expect that our robot Dora will be able to perform completely the *Welcoming visitors* task and recognise the doors' state in the *Getting to know my home* task. In order of fulfil these tasks, we plan to merge techniques for face and an uniform detection, speech recognition and synthesis, navigation, people detection, HRI behaviour that will ensure that a person is following the robot, door detection, following a person and gesture recognition.

Moreover, we plan to cooperate more with first year bachelor's students in order to introduce them to robotics and provide them with some interesting challenges, which can be used during competition. We believe that participating in the RoCKIn@Home challenge will bring a lot of experience not only to the young students, but also to us. As a result, we are expecting to obtain more knowledge in the ongoing research in many fields of robotics.