ROSolution
Team Description Paper

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***Abstract* — This paper describes the team and the robot that will participate at the RoCKIn@Home 2015 competition, representing Piraeus University of Applied Science. ROSolution Team consists of five undergraduate students and a member of faculty, with a common strong incentive in robotics and automation engineering. The robot is specifically customised to meet the specifications and targets of various RoCKIn@Home challenges.**

I. INTRODUCTION

ROSolution Team is a robotics team from Piraeus University of Applied Science and more specifically from the Department of Automation. It was established as part of the Digital Control Systems Lab Robotics team at the beginning of 2015 and now it counts five undergraduate students, advised and coordinated by the Lab's head, a Lecturer of the same Department. The team was formed aiming to inspire and give the incentive to undergraduate students to get involved in robotics, more than the standard curriculum does. This is accomplished by working on projects solving real life robotic applications problems and by participating in student competitions.

Student projects as final year theses or as extra curricula activities focus on subjects concerning state of the art industrial or assistive robotic applications, combining artificial intelligence, autonomous system theory, hardware and/or software design, using robotic platforms like ROS.

In the past the robotics team of the lab has taken part in Greek national competitions like I2Fest (Information Technology Festival), World Robot Olympiad Hellas and Athens Digital Week with great distinctions like Best Robot award on I2Fest and 1st and 2nd places on the others. This year it was decided to form a team to compete on international student robotic competitions level. RoCKIn@home's aims for the promotion of robotics through collaboration and competition perfectly coincide with ROSolution's team purposes so it became the obvious choice for the team's first international challenge.

II. FOCUS AND PLAN

This section overviews all three tasks from RoCKIn@Home 2015 contest and describes the way our robot is going to face them.

A. Getting to know my home

Our robot, using its sensors, should look around the whole flat and recognise any changes, made by the operators, which deviate from the primary scenario.

Specifically, it will combine measurements taken by a Kinect sensor in order to specify the state of the doors as well as furniture's position and, in general, to create a 3D map of the whole flat. Moreover, machine intelligence will be used in favour of tracking and recognising different-shaped objects like glasses, knives etc. Finally, the robot will be able to track the quickest route to every target and reach it without hitting any object.

B. Welcoming Visitors

In this section, the robot has to recognise visitors and depending on who is or what their job is, will accompany them to a specific location in granny's flat.

In this task, it is necessary to use tools from several engineering fields such as Machine Learning, Computer Vision, Speech Recognition and Path Planning. More specifically, the robot, in cooperation with the Ethernet camera, in order to recognise the visitor has to use machine intelligence and computer vision and in favour of ensuring the correctness of the visual recognition has to use speech recognition as well. Path planning is used by the robot to accompany the visitor to the correct place of granny's flat. Lastly, our robot has to achieve intercommunication between itself and the Ethernet camera for the purpose of receiving mpeg4 images, published by the camera.

C. Catering for granny Annie's Comfort

The most significant challenge in this task is listening to granny's requests; hence, speech recognition is on focus. One of the difficulties that we have to cope with is background noises during the contest. The approach of our team is to make use of ready packages made by Michael Ferguson (CMU Sphinx) and “Jenkins jobs” (sound play) and try to customize them in our needs.

Additionally, in this section of the contest, the robot has to integrate with granny’s intelligent flat and that will be achieved by communicating with the home automation controller. Last but not least, the robot has to wander around the house easily and quickly in order to cater for granny Annie’s needs, thus optimised path planning and navigation actions are as essential as the speech recognition.

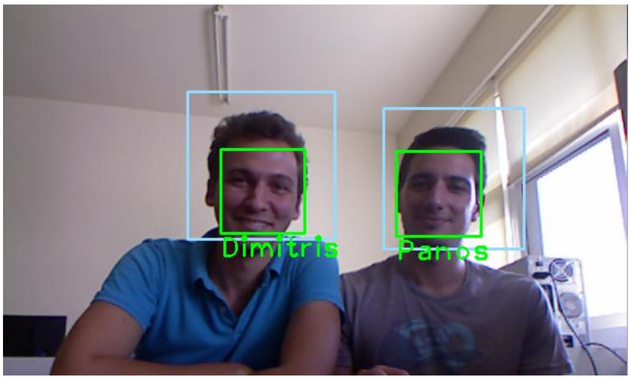

Figure 1. Example of face detection, recognition and identification

III. SOFTWARE ARCHITECTURE

The platform of choice for ROSolution’s Team software development is Robot Operating System, ROS, middleware using Hydro version. This, allowed us to take advantage of its open source philosophy and avoid, by using state-of-the-art packages, difficulties beyond our experience levels. Our team, has focused on object / face detection and recognition, voice recognition and navigation with a view to accomplish main tasks with optimal results.

1. Object, Face and Voice Detection and Recognition

Face Recognition

The cob_people_detection package is used for face detection and recognition. It works with nearly any sensor providing depth and color images. At the moment of writing, the chosen sensor is a Microsoft Kinect.

The Viola-Jones classifier is used to detect heads and faces. It works by feeding it with both positive and negative examples of faces and applies the Haar classifier to find them. Fast and robust methods, 2- Dimensional Linear Discriminant Analysis(LDA2D) and 2-Dimensional Principal Component Analysis(PCA2D), are available. The drawback is that they need the images of at least two people in the training data. It was decided to utilize the LDA2D method, as it outputs more reliable results, even if the training data contains images of the faces with noise due to illumination, non-frontal poses or face cropping during the capture procedure. Moreover, if one manages to filter the noise, the reliability is even higher on both methods, but LDA2D still outperforms the PCA2D.

The Head Detector node detects heads in the depth images taken and the face detector finds the faces within these regions. Then, the Face Recognizer node identifies all visible faces and finally, the Detection Tracker collects all recognition results, publishing it to a topic useful for continuous detection.

Object Recognition

OpenCV and Object Recognition Kitchen (ORK) will be used for solving these tasks. These packages have been chosen for their high adaptability and reliability.

OpenCV is an open-source library that includes several hundreds of computer vision algorithms, thus being a top-notch tool for this kind of applications. In addition, it has a large user community that supports it, documenting and coping with any bugs or errors that may occur.

ORK consists of several pipelines, each designed to use in different types of objects (rigid, transparent, textured etc.) For our purposes the most useful pipeline is Tabletop. Tabletop detects the dominant plane and points above it are considered to belong to objects. Then, clustering implementation determines which points belong to which object and thus the detection is completed. Clusters and tables (dominant planes) are published to topics. To recognize the objects, an iterative technique similar to ICP (Iterative Closest Point) is used. Tabletop uses CouchDB to collect and manage the objects' characteristics that will return to the respective cluster, during the recognition process.

2. Simulation

The gazebo simulation tool is one of the most commonly used packages for the purpose of building realistic scenarios. It provides user friendly building tools and interface in order to create and design custom worlds and also it gives the ability to create custom plugins for an even more real to life schemes like the differential plugin or the Kinect plugin.

Figure 2 Granny Annie's home in Gazebo

The first step for building our simulation was to create a well-designed world. Next, packages like turtlebot_gazebo and gazebo_ros were adopted so as to create the launch file which integrates our custom grannys_flat.world with the Turtlebot robot. The three files that implement these functions are grannys_flat.world, grannys_flat.launch and turtlebot_grannys_world.launch. Grannys_flat.world, contains the scripting code for the world creation and the second file, grannys_flat.launch, connects the .world file from the gazebo_resource_path with the gazebo application. Moreover, it imports arguments like physics or debugging and starts gazebo clients like gzclient. The third file, which is the most important, combines grannys_flat.world and grannys_flat.launch with a simulated Turtlebot with its physics, states and poses.

3. Voice Recognition

Pocketsphinx, written by Michael Ferguson is the package used for voice recognition. The main tool it uses is GStreamer, a pipeline-based multimedia framework written in C, while the type system is based on GObject. GStreamer gives pocketsphinx input from the robot's microphone, so it can analyze and convert it from sound waves into electric signals and from electric signals into strings, the way that computer programs understand our text. The package uses the CMU Pocket Sphinx speech recognizer and with the help of the Online Sphinx Knowledge Base Tool, the dictionary and language model files are created. The recognizer node achieves all of the above and publishes the output string in the std_msgs/String topic.

Sound play, written by Blaise Gassend (Maintainer: Austin Hendrix), has the exact opposite function of pocketsphinx. The sound commands are issued to the sound_play node through a sound_play/SoundRequest message and then are published into the. With the help of GStreamer and the festival speech synthesis system the package gives the audio output of the string or an audio file through the speakers.

The combination of these two packages makes the robot understand voice commands and talk back to the user. This is illustrated in the flowchart below by an example concerning a voice request given to the robot. The robot using the pocketsphinx package understands the voice of the user as text and via the sound_play package repeats the order that the user gave and asks for verification. Then the user replies "Yes", or "No". Again, via the recognizer node the system converts user's voice command into a string. If the answer is "yes" the robot performs the action asked by the user. If the answer is "no" the robot politely asks again the user to repeat his command.

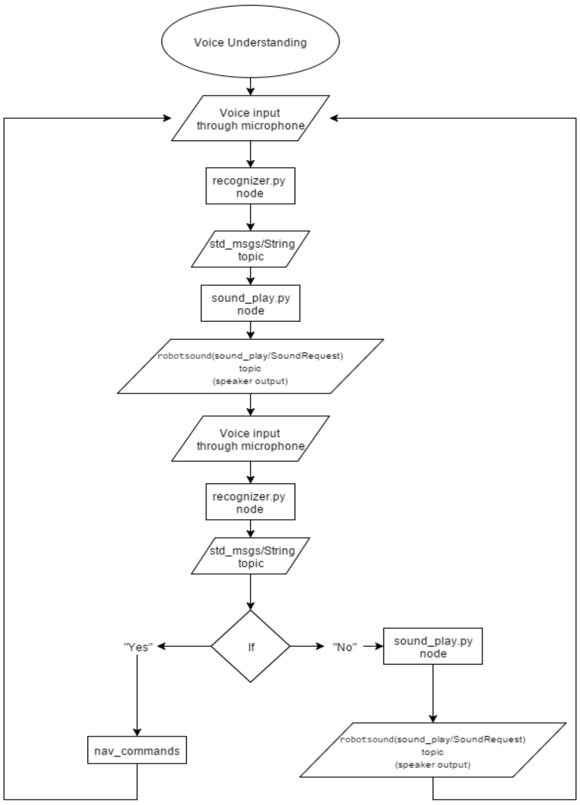

Figure 3 Flowchart of voice understanding

4. Odometry, Mapping and Navigation

The purpose of autonomous navigation is to allow the robot to reach a desired position without coming in contact with objects or people in the environment and without human intervention.

To achieve autonomous navigation we make use of three ROS packages:

gmapping: This package provides a SLAM (Simultaneous Localization and Mapping) algorithm. The purpose of the algorithm is the creation of a map while localizing the robot by utilizing the robot's internal position measurements along with external observations.

The package is used to make a 2D map from point cloud data by navigating the robot around the desired area.

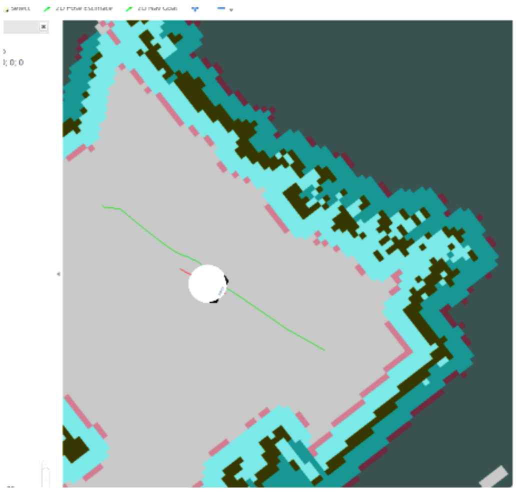

Figure 4 Turtlebot path planning after the use of SLAM algorithm

amcl: When the map is ready then the amcl package is used to recover the position of the robot in space at each time.

This package makes use of Particle Filter algorithms to compare the sensor readings with the existing map and return the most probable position.

For best results a laser scanner should be used but sensors such as Microsoft's Kinect can produce pseudo laser scans to calculate the position.

move_base: This package is the heart of autonomous movement. Given the goal position, the current base position, the previously built map and current sensor readings it is using a global and a local planner to compute the best route for the robot to use and returns velocity commands which can be used directly by the robot base.

Our goal is to fine tune the parameters of each component properly to accomplish efficient robot motion while avoiding collisions.

IV. HARDWARE

At the moment of writing this Team Description Paper the robot platform of choice is the Turtlebot. Turtlebot is a low cost, open source robotic platform with plenty sensors fitted in and well-established ROS support. Our approach makes use of the Kinect sensor in order to accomplish Odometry, Navigation and Face/Object Detection tasks. So far, project development is based on ROS simulation using visual packages like Gazebo and rviz.

Sensors:

Kinect sensor. It combines An infrared (IR) emitter and an IR depth sensor, an VGA camera and a multi-array microphone. We use it on navigation for sensing the position of the objects in the environment. Also the RGB camera is used in object detection and face recognition. The microphone is used for speech recognition in rooms with low ambient noise.

Logitech HD Webcam C270. This webcam is used in addition to wheel encoders and the Inertial Measurement Unit of the base to calculate the position of the base. Navigation through vision is achieved through an Optical Flow algorithm.

HC - SR04 Ultrasound Proximity sensor. Provides 2cm - 400cm non-contact distance measurement. These sensors are put around the robot to accommodate for the inability of the RGB-D camera to detect objects closer than 50cm and also for objects that are outside of the Kinect's field of view.

V. TEAM MEMBERS

At present, this team consists of five active members. They are all undergraduate students at the department of Automation Engineering and three of them are bound to graduate this year. A brief presentation of each member follows along with a small background description and research interests.

A. Panos Tsilivis

He is an undergraduate student in his final year. His thesis is on Autonomous Navigation for Flying Drones and next year he will pursuit a master's degree in Control Theory. Also, he has a good command on ROS and operating Matlab.

As member of the team for this contest, he is responsible for the simulation part on ROS and partly for navigation and robot positioning.

Scientific Background: His final thesis concerns Unmanned Aerial Vehicles and specifically autonomous navigating in indoor environment. He has won a 3rd place award as the leader of his team on World Robot Olympiad Hellas high school challenge. Last but not least, he has been involved on projects like autonomous vehicles or makeshift zeppelins.

B. Dimitris Koikas

As an undergraduate student in his final year, he has focused his research towards Machine learning, AI, and Microcontrollers. His thesis is on Machine Learning Applications in Robotics and he is eager to extend his studies with a master degree.

As for his role in the team, the object manipulation related tasks are assigned to him. Specifically, object detection and recognition techniques will be used via ROS.

C. Vangelis Kaloterakis

He is an undergraduate student in his final year. He is interested in the fields of AI mainly regarding autonomous vehicle navigation. His thesis is on Autonomous Robot Swarms dealing with the reaction of a low cost robotic platform and the corresponding swarm control algorithms for usage in the execution of various tasks.

His responsibility in the team regards the robot localization and navigation in cooperation with Panos Tsilivis.

D. Angelos Antikatzidis

Angelo is a third year undergraduate automation engineering student who loves to make, and fix things. Since his fourth and final year of study is yet to come he has not chosen his final year thesis. He is interested in autonomous robots and artificial intelligence and his vision is to see things in our everyday life running AI programs. His task in the competition is voice perception and control. This is his first participation in a competition.

E. Luke Katsamagos

Luke is also a third year undergraduate automation engineering student. His passion is coding, developing software and solving real problems with his knowledge, while always trying to find the most efficient ways to do it.

It is his first time that he is participating in a contest like this. Right now he is dedicated to the voice recognition part of the competition, in which he and his partner Angelo are cooperating.

F. Grigoris Nikolaou

Grigoris received his M.Sc. in Control Systems from the Department of Automatic Control of the University of Sheffield in 1998 and his PhD from the same Department in 2002. He is an Applications Professor at the Department of Automation since 2012, while he was a research associate at the same department since 2002.

His role at in the team is to provide guidance, advice and coordination to the members of the team.

VI. CONCLUSION

RoCKIn@Home competition brings together robotic teams from all over the world aiming for the collaboration of the research community and to raise the awareness of the general public on robotic innovation. On the other hand ROSolution Team was created to inspire and motivate undergraduate students to participate on international robotics student challenges. While the team lacks the experience on a postgraduate research level has a lot of passion and has devoted many man hours on studying, experimenting and preparing to face the challenges offered by RoCKIn@Home.

Every team member has focused on a specific task of the competition and complements each other depending on their specific personal expertise and interest. Angelo is focused in artificial intelligence that can improve our daily routine, similar to Dimitris with a general tendency on AI and machine learning in Robotics. Luke on the other hand, is passionate with programming that makes our life easier with innovative solutions. Panos’ research on autonomous navigation with an extend view on precise position control and path planning. Finally, Vangelis is also highly interested in autonomous vehicle navigation with a tendency to combine swarm theory.

The combined team effort aims to a competitive robot that meets the scope and standards of RoCKIn@Home competition. This experience will be of great benefit to the members of the current team and great inspiration for the rest of the undergraduate students of our department.

VII. REFERENCES

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