RoboCup@Home 2022 - RoboFEI@Home Team Description Paper

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Abstract. This paper describes the robot Hera and the activities developed by the team RoboFEI@Home for the participation at the LARC 2022 competition in São Paulo, Brazil. The robot Hera is fully developed by ourselves at the FEI university center. Heading to our researches, in our last competition the manipulator was our main problem and we were able to solve it by implementing the Octomap technique and by using a new setup with a camera on the top of the gripper. In this camera we use an image segmentation system, so we can be able to differ the color of the object and make manipulation more accurate. Even with the limitations of the pandemic we kept developing our physical robot, by doing so we could complete our research of Dynamic Power Management on our robot. Last year (2021) we had good results in this league and this year, in July, we were champions of the RoboCup world competition, keeping our status as a team of relevance since we started competing in 2015. This document details all the research, developments and what we are working to improve on our robotic platform HERA.

1 Introduction

The RoboFEI@HOME team was created in 2015 at the FEI university center as a research team for the Human-Robot Interaction area. To accomplish all the tasks that a domestic environment demands, we developed the service robot Hera, consisting of the combination of software and hardware systems that allow the robot to navigate safely, detect objects, humans and other robots, recognize human commands and manipulate objects.

The RoboFEI @HOME team seeks to be in a constant evolution to always develop new technologies in the domestic assistant area. The main researchers

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developed by our team in the last year are focused to make our robot Hera even more autonomous. The human-robot communication is the key point in the assistant robot area. Looking into that, we focussed on creating new ways for the robot to communicate even with people with disabilities. With the Sign Language Recognition System[1] a hearing impaired person is able to talk with our robot, allowing our robot to understand what was ordered and execute the task, making a hard situation easier to the user. Moving on to our Social Navigation system, when our robot is navigating and finds itself in an environment with people interacting with each other, the robot is capable to identify a human-human interaction and, through the Social Navigation, create a new route that doesn't pass between the people that are talking even if the new route is not the fastest, to avoid a uncomfortable situation to people around it. Lastly, a domestic robot demands a lot of energy to work properly, so we developed a system that analyze the quantity of energy it takes, in real time, when the robot is performing a task and when it is in stand-by mode, allowing the robot to make a Dynamic Power Management [2]., improving the batteries lifespan.

To accomplish our goals in our researches, some softwares modifications were needed. Our operation system was updated to Ubuntu 20.04 and to ROS Noetic.

In this paper developments related to perception, object manipulation and hardware updates are presented and for each one of them the researcher, results and improvements are given.

2 Focus and interests

The main focus of the researches conducted by the RoboFEI@Home is the interaction between humans and machines. The research in the field of human-machine interaction is highly influential to the development of service robots. The RoboFEI@Home also contributes to the development of methodologies, techniques, models, and algorithms in the following topics: adaptive interfaces, brain-computer interfaces; planning; intelligent home and building automation; autonomous systems, and the internet of things (IoT).

2.1 Team Achievements, Participations and Collaborations

The first participation of the RoboFEI@Home in an @Home competition was during the Brazilian Robotics Competition 2015, and ranked in third place. In 2016, the team managed to reach its first international competition and also conquer the first place in the CBR@Home 2016. After that, the RoboFEI@Home has ranked in first place in the 2017, 2018, 2019 and 2020 edition. In 2021 the team participated in the RoboCup@HOME Competition, ranking in seventh place and also had good results conquering the third place in our local league.This year, the team won the RoboCup Competition, in first place.

To publicize the league locally, and demonstrating to people the importance and potential of social robotics The team participated in various scientific events, demonstrations, workshops, and interviews for local television channels as CNN, Globo, Record and many others.

3 Description of the approach used to solve RoboCup@Home challenges

3.1 Robot Vision

The vision system consists of efficientdet-d0 [3], using TensorFlow 2.0 for object detection. For the creation of the dataset of the objects, we used the generation of synthetic [4] data with the salient model [5] to save time in the markup of images and to create a larger amount of data. We integrate a vision and manipulation system for specific objects, with image segmentation techniques to perform fine-tuning in object manipulation, not needing to train a model from scratch to recognize a single object, reducing the time spent on training.

The robot has people recognition, capable of names and faces memories, allowing us to guarantee a wide variety of tasks, in addition, we implemented the Octomap [6] which would be an Occupation Grid Mapping, in which it recognizes surfaces and obstacles and avoids colliding, performing tasks more fluidly and efficiently.

3.2 Voice Recognition

The team decided to use the Google Speech Recognition API. For this, a ROS package was developed which operates by a set of APIs. These are online tools that works directly in Ubuntu. In addition, a comparison with generic phrases is made through the Hamming distance for the recognition of phrases variations.

Our team developed a usage of this API by researching methods to make the code easier to adapt to a certain environment, creating a new use of words choices in the speech.

In this year competition the team is using MATRIX Creator™ [7], a board with sensors, wireless communications and a FPGA. The main goal of using this board is to make a directional voice recognition, this way being able to recognize from where the operator is talking with the robot.

Raspberry Pi connected to the MATRIX is used for communicating with the core of our robot. The Raspberry is responsible for reading the information of the many sensors in the board, then send this information for the main system.

3.3 Robot Navigation

An autonomous robot, to be able to navigate alone,needs the ability to map the place where it is, to define its position in space and decide which is the best possible route. To make this possible, sensors that capture external environments are used, and this information is transformed into interpretable data for the robot to choose the best route. When the robot is in an unknown location, it must do the environment, where it is located, mapping and at the same time define its position in space. This technique is known as Simultaneous Localization and Mapping (SLAM). In the navigation, the robot has the capacity to choose the best possible route and avoid possible obstacles using parameters where the slightest path error is corrected instantly.

3.4 Manipulator

This year´s manipulator, shown on figure 1, still has the same number of degrees of freedom (DOF) contained in a human arm, with the purpose of obtaining a great similarity to real movements using the anthropomorphic principle. Based on that, an anatomy and human kinesiology study was initiated, more specifically on the skeleton of the free portion of the upper limbs, which are: arm, forearm, carpus, metacarpus. It was noticed that the main movements are extension and flexion.

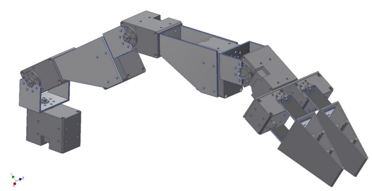

Fig. 1: Manipulator developed for robot HERA.

In the simulated competitions that we had during the pandemic, our manipulator was changed. We developed a new revolute joint at the base of the manipulator to reach objects on the floor, as shown on figure 2 and now we are working to implement it in our physical robot HERA. Another change in the manipulator is the new materials that we are using, for the parts with more complex shapes we use 3D print and, for plain shape parts we are using carbon fiber, which results in a great resistance with less weight and a smaller dimension.

The gripper was also changed substantially from the physical robot's current form. The physical gripper relies on applying enough pressure to the object to keep it in its grasp. Although, this method would not work in a simulated environment, since the virtual objects' hitbox could collide with the gripper's, causing a flick, that sends the item flying away from the manipulator. Therefore, the virtual robot was using a gripper that hugs the object and locks it into place like a human hand would, with sensors on the inner part of each finger. These sensors measure the amount of force that is being applied to the object, thus, making it easier to manipulate different kinds of items. We have learned a lot using this new gripper and now that we are back to pyshical competitions, the team has been reasearching how to upgrade our current gripper with these new learnings.

Kinematics and control For the manipulator mobility some distinctive algorithms, which describe the freedom that it has in the space where it is located, are used. Manipulator extenders and junctions analysis methods that use direct and inverse kinematic were implemented, this way allowing to describe the behavior and state in the space. Together with an control algorithm, we can

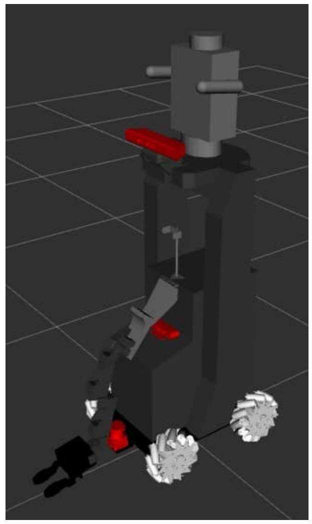

Fig. 2: Improved setting to reach objects on the floor.

accomplish simple and even complex tasks, as the space information can be captured through the sensors and comprehended, so it can make decisions for new tasks and interactions using the manipulator. Using the Octomap technique, it is possible to pick up more complex objects and in places that are more difficult to reach. Using all the above, we have a much more advanced manipulation.

4 RoboFEI@Home Projects and Researches

4.1 Sign Language Recognition

According to the World Report on Hearing there are 1,5 billion people in the world with some degree of deafness. It is possible to observe that hearing impaired people have a great difficulty in communicating, due to the lack of incentives.

It is very important to create inclusive projects that can change and impact the life of hearing impaired people. The key to accomplish these tasks, like making an order at a restaurant, was to develop a system that uses computational vision to recognize the gestures[1], normally utilized in a restaurant. After recognizing the gesture, the semantic interpretation step starts, on this step the system uses the existing dataset to promote a fine and accurate translation of the gesture to the robot and consequently the intention or needs of the hearing impaired person. The last step is to transmit the message of the user to the correct plane, for example the order to the waitress.

To reach this goal it was necessary to create a new dataset, our dataset was created recording videos, using the logitech c920, of a great number of people realizing the gestures equivalent to the 5 groups of foods chosen by the team.

After recording the videos it was utilized the computer vision package CVzone to process the videos and generate face mesh detection and hand tracking of the pearson on the video, doing that our team applied a treatment on the video to substitute the background by a black screen and it was printed only the results of the CVZone, reducing the noise and instability of the dataset, resulting in a smaller training.

The videos treated on the Cvzone were divided in frames dividing the gesture in three different stages, after that we used an EfficientNet B3 to run the frames using a 300 x 300 px images as input, then our team trained the network using ImageNet weights and Transferlearn to make the recognition more accurate. To obtain success on the task while performing the gesture, the robot must recognize 3 parts of every gesture, since the beginning of some gestures are the same, we used redundancy to elevate the accuracy of the reading, obtaining more success in our tests.

4.2 Social navigation

The main focus of this research is on the people's comfort in spatial interactions with a social robot. It verified the influence of a social and non social robot behavior and also the physical and emotional safety of the people, as well the spatial and temporal efficiency of the robot in environments shared with people.

This research had as motivation the difficulty found when dealing with the social robot´s navigation in a safe, natural and social way, making the robot´s presence comfortable for the people interacting around it. In each situation, it was observed that navigation that doesn't follow social rules causes more discomfort to the people and the main reason of people´s discomfort is the robot´s noise when navigating.

In an environment shared with a robot, the ideal scenario is that the person doesn't notice the robot's presence unless it actively draws attention. Lookin into that, any action that unnecessarily draws attention, as an unexpected movement, is a potential discomfort for humans.

On Social Navigation the robot respected the human to human interactions and clearly was more accepted, not causing much discomfort to the people in the environment. Using these research results we could develop improvements on our robotic platform HERA to maximize the comfort of the people around it.

This research is currently being revised to be published in a Scientific magazine of the area.

4.3 Dynamic Power Management

The constant development of our robotic platform substantially increased its power consumption. As a consequence, our first solution was to increase the number of battery cells but soon enough we reached the maximum payload of our robot. After that, the next step was to migrate to higher energetic density batteries, which solved our problem but wasn't a good solution due it´s prices so we started research into Dynamic Power Management[2]..

The Dynamic Power Management (DPM) is a method developed with the purpose of optimizing available energy sources. DPM proposes to optimize energy use through the control of the energy used by the system's modules, made by the idleness exploitation: If a device (or components of a device) is idle, its energy consumption should be reduced as much as possible to save for when it will be needed.

There are several ways to implement the DPM, but the first step is to detect with accuracy the idleness in the system´s module to quickly deactivate and force it into an energetic dissipation state in which the wasted energy is as low as possible.

To develop the research and implement the most suitable DPM[2]. in our system, it was necessary to conduct a lot of tests, which consisted into analyse the operating current of each module as a function of time, while the robot performs a task.The current was acquired using a ACS712 sensor and the data was sent to a computer through an Arduino. Then the operating current of each module was multiplied by its operating voltage to obtain the energy consumption of each module, generating the graph shown on figure 3 .

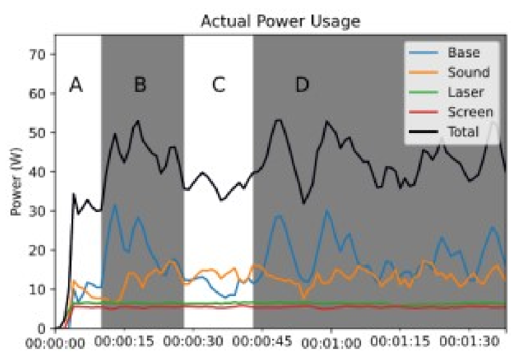

Fig. 3: Consumption of each module and total consumption.

Analysing the graph, the Average Consumption per Second (Cps), Execution Time (Texec) and the Total Consumption (Ct) were calculated. From the data obtained, simulations were made considering different DPM methods, and the one closest to the ideal was the predictive method with pre wake up, saving more than 35% of wasted energy, increasing the running time substantially and by consequence the batteries lifespan[2]..

Our team implemented this DPM module on HERA utilizing an electronic relay module to deactivate the module that is in idleness and is conducting a new research into implementing a battery bank to supply energy to the entire robot and make the management even more efficient.

5 Conclusion

Since 2015, when RoboFEI@Home started competing, the team's research on service robots has improved substantially. Both the software and hardware has been evolving since then. At CBR@Home 2021 we learned from our mistakes and focused even more to develop our robot and we changed a lot with the new inclusive human-robot interaction, the new vision system and an even better social navigation to have a better performance than the last years. This made possible for us to win the RoboCup@Home world competition. The research being conducted by the team shows development in areas of interest for home assistance robotics, with some of the projects already showing positive results in competitions. All the research mentioned in this paper is available for anyone on our GitHub and website. As future works, it is intended to improve the performance in structures that require the manipulation of objects on the ground, using new technologies, in addition to implementing simultaneous mapping to create a 3D map using a camera, as well as the development of a modular camera, to facilitate the transport and maintenance of the robot.

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Robot Technical Specifications

Hardware Description:

- Base: Mecanum Wheel Robot platform.
  - Sensors:
    - Hokuyo UTM-30LX-EW.
  - Actuators:
    - Omnidirectional wheels.
- Chest: PeopleBot extension.
  - Sensors:
    - Emergency switch.
    - Asus Xtion
  - Actuators:
    - 6 DOF manipulator + 1 DOF gripper.
- Head: Apple Ipad 2.
  - Sensors:
    - Microsoft Kinect 1;
    - Logitech c920 webcam;
    - 2 RODE VideoMic GO directional microphones;
- Control: Intel® NUC Mini-PC i5.

Software Description:

- OS: Ubuntu 20.04;
- Middleware: ROS Noetic;
- Localization/Navigation/Mapping: SLAM;
- People detection and tracking: OpenPose
- Object recognition: MobileNet v2 + SSD on Synthetic Data;
- Object manipulation: Moveit!;
- Speech recognition: DeepSpeech (offline) or a package based on the Speech Recognition library (online);
- Speech synthesis: Flite (offline) or GTTs (online).
- Simulation environment: Gazebo

Fig. 4: Phisycal and simulated HERA