Warthog Robotics @Home 2024 Team Description Paper

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***Abstract*—This paper aims to describe the Antares system, Warthogs Robotics @Home robot, focusing on innovations from the last year. The robot and its auxiliary software and tools are developed inside the Robotics Center (CRob) of the University of São Paulo. It has been used in presentations and fairs apart from competing in the Latin American RoboCup@Home Competition (LARC/CBR) for the past seven years. This paper shows Antares' software and hardware features, emphasizing the improvements made in the past year. These innovations include a software architecture overhaul, a vision and human-interaction modules update, a power supply distribution, and a new manipulator. It states that the improvements made in the robot allow it to test new technologies and hold more research on them.**

***Index Terms*—RoboCup@Home Brazil, ROS2, Software Architecture Overhaul.**

I. Overview

Warthog Robotics is a traditional research and extension robotics group from the University of São Paulo (USP). Since its creation in 2007, through the merger of the GEAR and USPDroids groups, the group has aimed to research and develop technologies associated with robotics and their application in complex competition robotics environments. The processes, methodologies adopted, and the technical-scientific improvement of members offer a teamwork environment and the learning of different skills, enabling them to work in other areas of knowledge with excellence.

Nowadays, Warthog Robotics works with teams of soccer robots, competing in the RoboCup Small Size League (SSL) and IEEE Very Small Size Soccer (VSSS) leagues, assistance and service robots, competing in the RoboCup@Home league, and combat robots, competing in the Beetle Weight and Feather Weight leagues. The group has achieved over 30 prizes and published above 60 papers.

Warthog Robotics launched its assistance and service robot program in 2017. The Antares robot was designed to explore and advance human-robot interaction and develop practical robot household skills. Desiring to contribute to the scientific and robotics community by formulating a machine that can assist people in household activities. The Warthog Robotics @Home team has been effortlessly researching areas like machine learning, path planning, and control. From the start of the project to the present date, more than 50 undergraduate and graduate students of the University of São Paulo have worked on the robot and participated in related competitions.

Since the beginning of the robot development, Antares have been participating in the RoboCup@Home league in Latin American Robotics Competition and RoboCup Brazil Open Competition (LARC/CBR). We have achieved gold and silver prizes in the past years and contributed to scientific community with studies in navigation systems, control, emotions simulations, docker architecture, object detection, face detection with mask, gesture recognition and semantic mapping.

Figure 1 show the Antares robot. It's structure is composed by a Pioneer 3-DX as its main support, locomotion and power supply. It has a LIDAR and a camera sensor, a LCD screen, external speakers, a microphone and a computer to process and integrate the equipment's functions and environment interactions. The mechanical structure is metalon and plastic based and designed and manufactured for Antares. An overview of the Antares modules is presented in Figure 2.

At the current iteration, the robot's development is divided in two main areas: Software and Hardware. The Software team is responsible to perform an overhaul in the previous software system and plan tasks aiming to use the implemented robot's resources to fulfil the competition tasks requirements. On the other hand, the Hardware team goal is to provide maintenance to the robot's hardware (such as the Pioneer locomotion base) as to develop new versions of the current actuators (such as a new robotic manipulator).

In this paper, the shortcomings and innovation in development to the 2024 LARC/CBR competition will be discussed. The paper is organized as follows. The section *II. Software Improvements* discusses the changes in the software made

Fig. 1. Real robot (left) and CAD model (right).

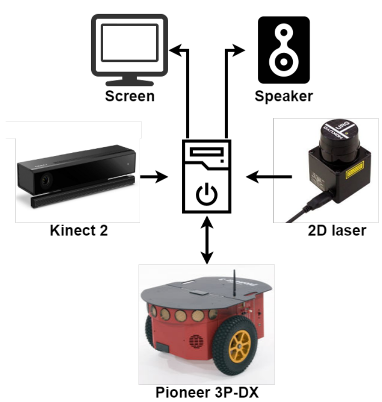

Fig. 2. Overview of the Antares robots sensors and actuators.

after six years. The main purpose on it was to update the old software to the new technologies, bringing a new perspective in architecture. The section *III. Hardware Improvements* shows the changes in the robot's hardware, from minor projects to the conclusion of a years-long project.

II. Software Improvements

The software library of Antares is composed by modules that implement behaviors in order to allow natural human-robot interaction, as well as performing tasks related to activities of daily living.

Therefore, the software infrastructure is responsible for the sensor reading (such as LIDAR and camera), actuator drive (locomotion base) and, most importantly, the communication in between all the modules. Additionally, the software architecture must allow customisation in order to provide the team the tools needed to develop scripts to perform complex tasks.

This Section will describe the under development software improvements to the Antares software system.

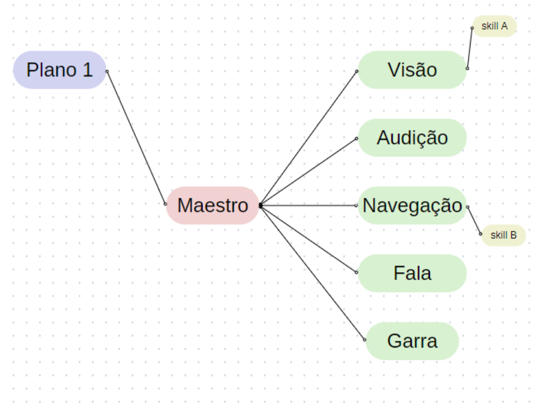

Fig. 3. Overview of the components of the new software architecture.

A. Software Architecture Overhaul

After 2021, the Warthog @Home had a major update of members, in which the members who developed the majority of the Antares software base left the team. With a legacy system, without well documented code and with a lot of depreciated or outdated packages, it was decided that the best for the team was a major software infrastructure overhaul.

The old software infrastructure was a collection of Robotics Operating System (ROS) nodes that follow the publisher/subscriber protocol and enable easy integration and communication in between different modules. With the overhaul in mind, the old nodes written in ROS1 (Robotics Operating System) are being updated to ROS2. In addition, to improve software modularity and compatibility (for future updates), the nodes are being implemented as Docker containers, which will be stored on the group's cloud servers.

In relation to the actual software internals, we replaced the older architecture based on state machines controlled by a central ROS node by a new architecture. This new architecture can still be used with state-machines but its more flexible than the previous one. Figure 3 shows an overview of the components of the new planning architecture.

The components present in the Figure will be described as follows:

- **Skills:** correspond to the low-level actions, such as 'go to ...', 'listen to ...', 'find the object ...', etc.
- **Managers (Vision, Navigation, Speak, Listener and Arm):** managers customise the skills behaviours with custom arguments and queue the requests from the conductors.
- **Conductor:** is the component that communicates with the managers and the plans, forwarding messages in between the two components. Conductors redirect the requests from the plans to the suitable managers (vision, navigation, etc).
- **Plans:** implement the high-level planning for complex tasks. The plans coordinate skills to perform the competition tasks.

The information and requests flows from the plans to skills (and vice-versa) similar to a client-server model. Plans act as clients and the managers and conductors act as servers.

B. ROSAria

In the update from ROS1 to ROS2, mainly motivated by recent support and the new features of packages such as navigation2[1], a problem was encountered. ROSAria, the application used for communication between the computer and the Pioneer 3DX locomotion base (used by Antares), had not been ported to ROS2.

As this is the main component of the robot's locomotion hardware, it is necessary to develop a solution for the transmission of data between the interfaces provided by ROS2 and the serial communication of the locomotion base. For the best of the knowledge of the Warthog @Home group, there is no public solution available at the moment.

Therefore, it was decided to create a new ROS package, zodiac_rosaria2, which plays the role of updating the ROSAria package in order to use ROS2.

C. Vision, Speech-to-text and Text-to-speech Update

To develop functionalities required to perform the daily life tasks, @Home robots usually require computer vision, speech-to-text and text-speech modules. Note that mostly of the challenges of the mentioned areas are solved using deep learning models. During the planning of the team software overhaul, it was observed that the majority of the deep learning models (or Python packages), used in the cited modules, was outdated or deprecated.

Thus, in order to update the modules, the team members allocated to vision and human-interaction areas were given the task of research the current state-of-the-art of the related fields. Additionally, several tests are being done using the Antares built in computer, to evaluate if the chosen models are compatible with the computational resources available.

In relation to computer vision, one of the main tasks is object detection or recognition. Recognize objects is necessary, in order to perform tasks such as informing its location or grabbing them to deliver to the user. In this context, the previous used YOLOv4 was updated to the YOLOv8[2] to improve the object detection pipeline.

Such methods are trained in supervised fashion. Therefore, the addition of new labels is a complex task. Labeling enough images to train a object detection model, in order to recognize labels not present in training, is a challenge an active field of research in computer vision. For this reason, the team is exploring different approaches to avoid the amount of manual labor required to train these model in addition to the model selection.

In addition to object detection, the team is studying methodologies used for face recognition. Since following an human operator is an basic assist robot task, face (or person) identification is a must. The team is currently evaluating state-of-the-art models from OpenVINO[3] toolkit for this tasks.

At last, the members are still researching and testing models used for human interaction (speech-to-text and speech-to-text). In addition to the model's performance, the trade-off between local and cloud based methods is being investigated. The team is also studying language model based strategies to process the transcribed text in order to perform question answering [1], [2], aiming to replace the current approach (based in text similarity) to a more robust approach.

III. Hardware Improvements

As the robot has been developed and maintained over several years, major adjustments were not necessary in the past years. However, some enhancements were implemented in both the mechanical and electrical systems to ensure optimal performance.

Mechanically, there was a need to balance the robot's weight and adjust its center of mass due to the new robotic manipulator, which is significantly heavier than the previous one. To address this, in addition to adjusting certain components, a decision was made to add a caster wheel to the front of the robot, resulting in a configuration with two main wheels and two caster wheels arranged in a cross pattern. This adjustment improved the robot's stability and maneuverability.

On the electrical side, a redistribution of the robot's power supply was carried out to reduce the load on the lead-acid batteries. An additional LiPo power supply was introduced specifically for the manipulator's operation. This change led to better task performance and increased the durability and conservation of the batteries.

Also, the manipulator project completion was a significant achievement, representing the culmination of years of research, design, and iteration. The challenges posed by the COVID-19 pandemic and the transition to a new team added complexity to the project; however, these obstacles were overcome through collaborative efforts and a shared commitment to innovation. Figure 4 shows Antares with it's new manipulator.

A. Manipulator

The final phase of the manipulator's development focused on refining and validating the control system [3]. Utilizing MATLAB and Simulink, the team conducted extensive simulations to model the manipulator's dynamics and optimize its control algorithms. Additionally, Unity was employed for virtual simulations, providing a realistic testing environment to predict the manipulator's behavior in various scenarios. This thorough testing and validation process ensured the manipulator's performance and reliability. Figure 5 shows the new manipulator simulation.

The development of the firmware was a pivotal step in bringing the manipulator to life. The selected integrated circuit for the project was the Microchip PIC32MX1024MCF100[4]

[1]https://github.com/ros-navigation/navigation2

[2]https://github.com/ultralytics/ultralytics

[3]https://docs.openvino.ai/2024/index.html

[4]https://www.microchip.com/en-us/product/PIC32MK1024MCF100

Fig. 4. Antares with new manipulator.

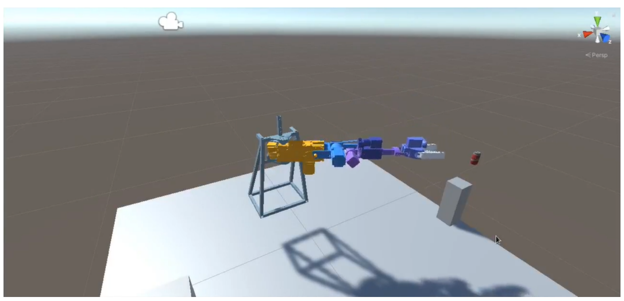

Fig. 5. New manipulator simulation on Unity.

microprocessor, chosen for its processing power and reliability. This firmware was responsible for several key functions, including environmental analysis, motor control, and system diagnostics. Environmental analysis involved processing data from sensors (camera and laser sensor) to understand the manipulator's surroundings, while motor control and movement verification (using encoders) ensured precise movements and responses to commands.

One of the critical achievements of this phase was the successful integration of high-level and low-level systems. The high-level software, which interprets visual data and makes decisions, was seamlessly linked with the low-level code that directly controls the motors and other hardware. This integration enabled the manipulator to perform complex and accurate tasks, responding appropriately to its environment and user commands. The firmware infrastructure development laid the foundation for future enhancements and applications, setting the stage for further innovations in robotic manipulation.

The project's completion also opens the door for future research and development, as the team can now focus on refining the system and exploring new functionalities and applications.

IV. Conclusion

In this paper, we presented Antares, the Warthog Robotics @Home robot, showing its structure, architecture, and innovations. The software and hardware improvements state a new moment of the transformation on the team, which is willing to keep on its development. Therefore, the software architecture overhaul allows the test of the latest technologies and research to be held on the development of the robot, as it is accurate to the new technologies in the area. Furthermore, all the projects settled permit new studies for the robotics environment, which enriches the scientific community. For future work, we look to validate our architecture scheme and improve its multi-system integration, as in activities like follow me. Also, more studies on how to ensure precision on the manipulator are needed.

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