# Pumas Team Description Paper 2025

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**Abstract.** This paper describes the development made for the robots Festinos of team Pumas. It is intended to participate in the 2025 Mexican Tournament of Robotics and the 2025 RoboCup Logistics League. The work done with the robots includes Navigation Planning, Image Processing, Use of the Point Cloud, Pattern Recognition, Environment Representations, and Action Planning, among others. We expect to transfer the VIrtual and Real roBOT system (VIRBOT) to do the Action Planning, combined with the Analysis of the Environment to obtain a composed behavior of the robot that completes the tasks required in the Logistics League.

**Keywords:** Image Processing, RGB-D camera, Grasping, Navigation, Object Detection, RoboCup, Logistics League, Action Planning, Virtual Environments, Object Manipulation.

## 1 Introduction

The Main Track of the RoboCup Logistics League aims to simulate a production process in an industrial environment. The goal is for the participant teams to implement strategies that include basic robotics skills such as navigation, action planning, object manipulation, among others, to complete an order with a finished product that satisfies certain conditions.

Additionally, the implementation needs to include collaborative working between a maximum of three robots (per team) and to operate in a shared space with the opponent team, both working simultaneously. The environment mentioned includes different types of Modular Production Systems (MPS), each one of which does a specific task in the production process, accepting and delivering intermediate pieces. This setting explores the connection with a common server that manages and monitors the game, informs the competing teams of the products orders and acts as an interface with the MPSs, publishing each MPS's status information. This server is called Referee Box (RefBox).

In addition, the League has a subcategory in which it is possible to participate evaluating not the full implementation, but the isolated basic skills needed, these are the Challenge Tracks and evaluate progressively the navigation, manipulation, action planning and production success of the teams. It is scored separately from the Main Track and its an effort to integrate new teams into the competition and help them evaluate their performance.

The team has its origin in the RoboCup competition in the OPL and DSPL categories of the @Home League with the robots Justina (a custom-made domestic service robot) and Takeshi (HSRB by Toyota), respectively, being able to be in the Top 3 winners of this competitions on several occasions. Pumas team is part of the Bio-Robotics Laboratory of the School of Engineering of the

National Autonomous University of Mexico. For the Logistics League, team Pumas has decided to name its robots as **Festinos** similar to its predecessor Justina.

## 2 RoboCup Logistics League

The accelerated advance of the industry leads to giving robots the ability to sense their environment and plan the most efficient way to complete a task, as well as including new and more powerful equipment to follow the rhythm of the industry. The Logistics League aims to simulate an industrial-like environment, in which teams can demonstrate the development made for such tasks.

In this specific setting, the robot is supposed to take initial pieces and move them to different stations where they are going to be processed to obtain a final-composed piece. Each one of these stations (MPS) does a different part of the simulated production line and the robot must help with this task moving sequentially the pieces from one station to another to complete the process.

To be capable of such activities the robot must move around the workspace and interact with each MPS. It must be able to avoid mobile and static obstacles in its way and localize itself in the space. Once the navigation part is assured, the next task would be to integrate an algorithm that makes the robot navigate freely, explore its environment, and find representative marks to identify the objects around it.

On the top level of these activities, a central system must know the state of the production process and the robot, as well as the sequence of actions that compose the whole line. For this, it is necessary to have an element that generates a plan and then integrates the new information to it to be able to react to changes on the conditions of the environment.

Reactive behaviors to different mistakes are important, such as not positioning the pieces correctly in the conveyor belt and them falling off of it. The robot should notice this situation, stop the process, and then re-plan the strategy to restart or discard the process the order.

For all of these tasks it is imperative to listen to instructions given by a central system. The software that does this management is called *Referee Box (RefBox)*, it is in charge of evaluating, monitoring and controlling the game, it is also the communication bridge between the referees and the participating teams. The RefBox gives to the teams the information of the state of the competition, the MPS, deliveries of the orders, among other important information. To communicate with the teams it uses User Datagram Protocol (UDP) and each team must be constantly receiving the information, given the conditions of the competition, where the network connection is not always available or it is not always stable, the messages are published continuously to avoid information loss [4].

In previous editions of the competition some teams have a central system that reunites the information of the robots, stations and then assign the tasks according to a determined plan to optimize the time and number of steps that need to be done to accomplish the goal in time [1].

## 3 Team Summary

Team Pumas competed in the Logistics League of the RoboCup 2023, and integrated parts of the development made for the @Home League into the tasks asked for in the @Work setting. That participation helped to set a base frame from which to continue to build the infrastructure for the development of the Team. A strong part of the implementation is the navigation algorithm, developed by colleagues of the Bio-Robotics laboratory. It has been tested on several occasions, in different categories and environments, proving to be a robust navigation system. Team Pumas expects to integrate several modifications to both the mechanical infrastructure and software development of two Robotino-based robots in order to participate in the 2025 RoboCup. It is integrated by electrical-electronic, mechatronic, and computer engineers and students, as well as computer scientists, they are working to obtain their bachelor's, master or Ph.D. degrees. Some of them have experience working on Justina or Takeshi as well as other categories of the RoboCup, and some others are completely new to the competition but have experience in robotic-related topics. The team is under the guidance of Dr. Jesus Savage and Dr. Marco Negrete who are in charge of the Bio-Robotics laboratory. Both of them are familiar with the RoboCup and other international competitions and are experienced engineers and researchers.


Fig. 1: RoboCup 2024

Additionally, in 2023 team Pumas received the support and help of team GRIPS, who have participated in the League for several years and as a result have many experience in the different aspects that need to be addressed in order to participate successfully. During this year, an exchange of stays was organized. Two members of team GRIPS arrived in Mexico to advise team Pumas and a member of team Pumas went to Germany to observe and get familiar to the competition and its requirements.

During the 2023 Robotics Mexican Torunament, team Pumas won the first place participating in the @Home League, competing against eight other National Teams, this being the first time the team participated as such in a competition using the Robotino FESTO platform and as a preparation for the RoboCup. Furthermore, in the RoboCup 2023 and RoboCup 2024, the team obtained the *Exceeding Performance in Challenge Track* award in the Logistics League.

After the competition, the team decided to update the Robotino 3 operating system, which they successfully achieved, so now the team has two Robotino platform with Ubuntu 20.04.

# 4 Hardware

As in the previous year, we will use the 3-degree-of-freedom Cartesian manipulator designed by the team. It consists of an aluminum structure with 3 links that move with 4 NEMA 17 stepper motors; the end effector uses a Dynamixel AX12A servo motor. This year, the manipulator has been resized to increase its reach, enabling it to perform a broader range of tasks. Additionally, the control system has been upgraded to an ESP32 microcontroller mounted on a custom PCB (see Figure 2.), which aims to streamline the control system, improve its efficiency, and reduce energy consumption. Furthermore, we plan to integrate an additional camera to enhance object detection and localization.

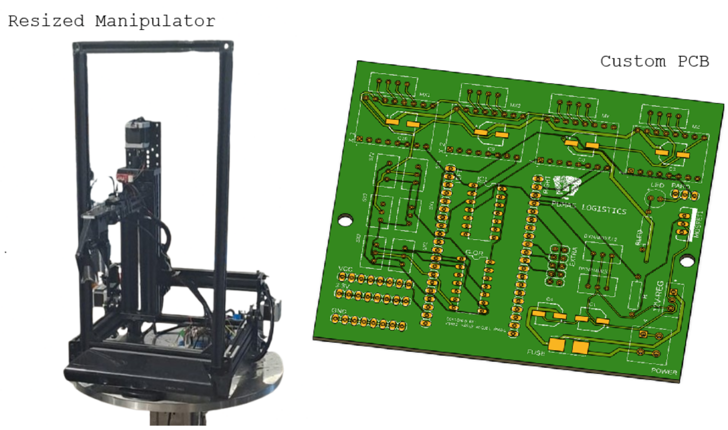



Fig. 2: Manipulator and Custom PCB

# 5 Software

## 5.1 Connection with RefBox

The team communication is made using protocol buffers (by Google) to obtain the information and then send these messages to the planning stage, which is going to translate this information into commands to be used in our ROS system to control the robot [2].

Team Pumas is integrating some of the advice received from team GRIPS into the communication structure to manage the collaborative work between two robots, with which also the planning scheme will need to be updated to integrate these changes and implement a system that administrates the pending activities and allow the two robots to work simultaneously.

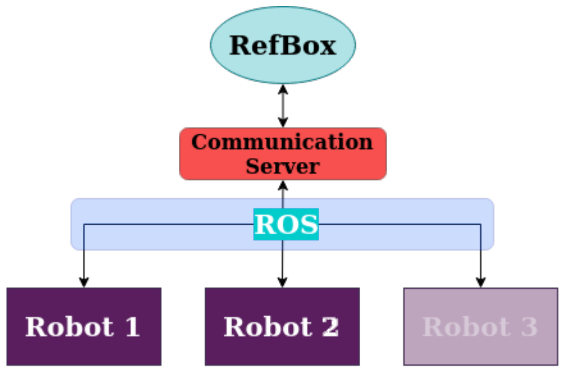



Fig. 3: Communication System

### 5.2 Planning

The software configuration regarding Action Planning is made with Finite State Machines, it is very simple, and the actions are predefined with a GoThere-DoThat scheme. The team is currently working on implementing an architecture with the VIRBOT [3] structure.

The VIRBOT architecture is separated into four different layers, the **INPUT** that the robot receives from the environment, the **PLANNING** that is made with CLIPS, and the **EXECUTION** that we make with ROS. In this system, ROS is used to communicate the low-level parts of the system, the actuators, cameras, and different sensors that compose the robot, all of them are communicated using ROS nodes.

– **Input**
  This stage is composed of the information that the robot receives from the sensors and they define the robot's perception of the environment and his own internal state. Some of the sensors are the RGB-D camera and the LiDAR laser scanner, with the information that the robot gets from the sensors it forms the environment description and is able to interact with its surroundings.
– **Planning**
  The assumptions that are being made by the perception module are validated here, using Knowledge Management and creating a situation recognition that activates a set of goals that ideally are going to find a solution, establishing a set of tasks for the robot to finish a task.
– **Knowledge Management**
  In this stage, an expert system is implemented, in which a set of maps are created using a combination of SLAM techniques and a localization system that uses a Kalman filter to generate an environment description that is going to be processed by CLIPS to generate a set of rules to give the robot the definition of its knowledge.
– **Execution**
  This is the stage where the plans and the different tasks that compose them are executed by

the robot, this specific tasks translated to actions could be FindObject, GotoPlace, AlignMPS, AlignObject, etc. Defined as individual actions that give the robot the capacity to complete complex instructions.

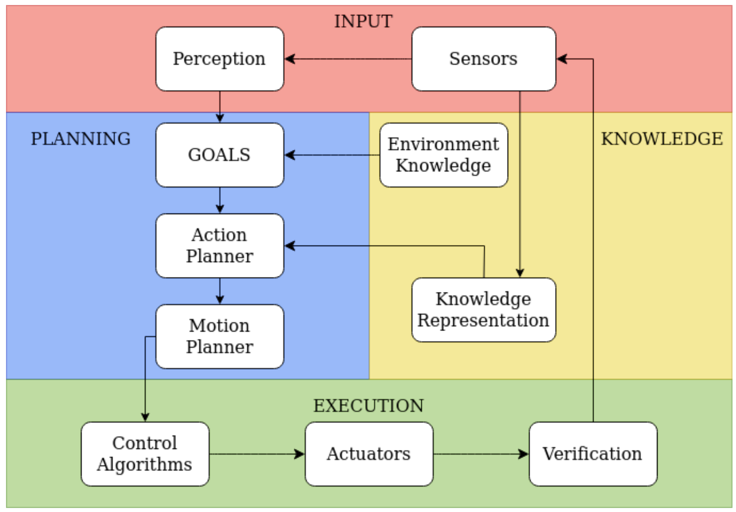



Fig. 4: VIRBOT structure

### 5.3 Navigation

We use a navigation system developed at the Biorobotics Laboratory. This system has been tested before in robot Justina in @Home league and has showed a better performance than ROS navigation stack. It uses A* algorithm for path planning, AMCL and odometry for localization, and a combination of Point Cloud-processing with the measurements of the LiDAR for obstacle avoidance. This system has been used in previous competitions for robots Justina and Takeshi. It is programmed using mostly C++ and executed by the middleware ROS.

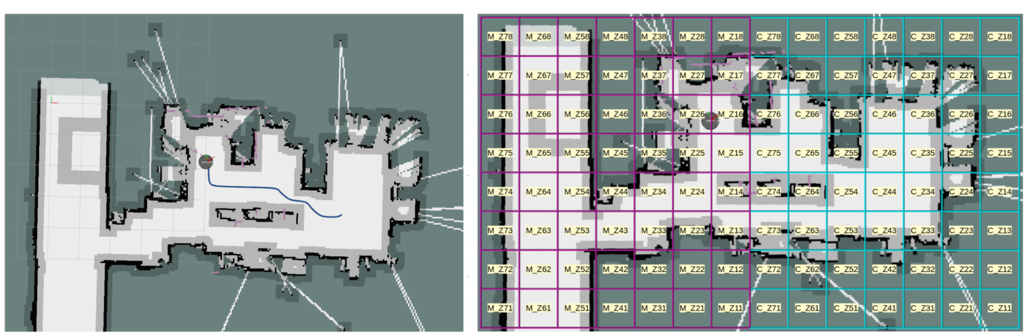


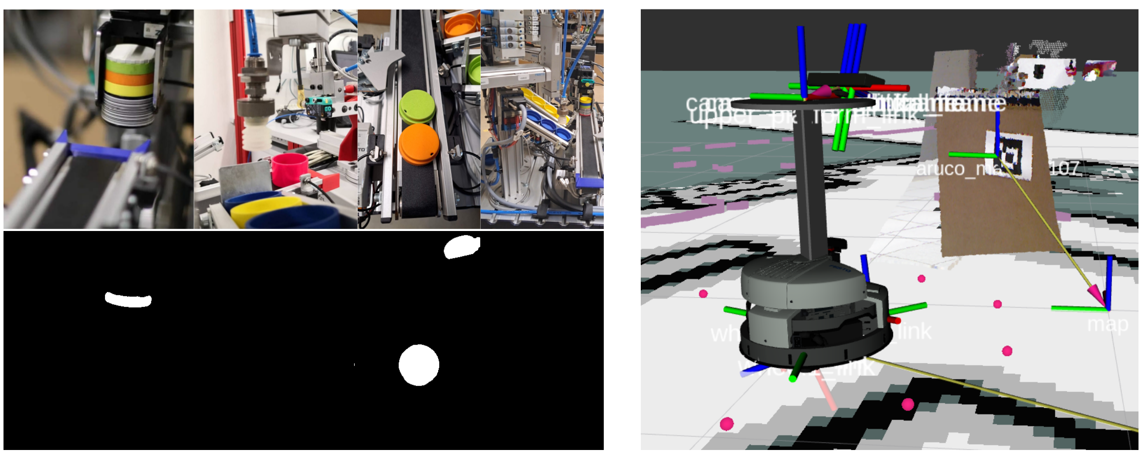
Fig. 5: Navigation Path

To make tests in the space available on the Laboratory, a Layout with the Lab's map and the League map was made. This, aiming to navigate using the most similar posible nomenclature to the one used in the competition, this has been helpful to test and evaluate the performance of the algorithms.

### 5.4 Image Processing

We use Image Processing algorithms with the RGB-D to find the MPS and find the piece to grasp them, the team has been working with color segmentation using OpenCV packages and combining algorithms to localize the geometrical centroid of the pieces. The Point Cloud is used to associate a coordinate to the MPS and pieces and its place in the map, it is used as well to exclude some of the noise generated in the segmentation. Those elements were programmed in a combination of C++ and Python and the communication is done through ROS topics. in figure 6a is an example of the color segmentation applied to the OrangeRing in different settings of the Machines.

For the exploration phase, the robot first finds the ARUCO tag in each MPS and gets close to one particular station and using the Point Cloud delivered by the Kinect sensor, we made the homogeneous transformation to assign a static mark in the map, using as references the robot position(Figure 6b).




(a) Color segmentation

(b) ARUCO Tag position

Fig. 6: Image Processing

**MPS and Gripper alignment** To align with the stations, a combination of filters and algorithms is used to find planes and lines that show us the inclination of the station referring to the robot and minimizing that angle with base movements.

Once the robot's base is aligned with the station, it needs to align its gripper with the input of the conveyor belt, using Image-Processing and Point Cloud-Processing in an Active-Vision process.

Fig. 7: Grasping

## 6 Conclusion

For 2025 Team Pumas is upgrading both software and hardware that were used to participate in 2024 edition for both of our robots. As well as integrating a new Cartesian manipulator, simplifying the trajectory calculations for grasping and reducing the complexity of the system. Additionally, a MPS was introduced in the laboratory equipment and it will be used to test the development beforehand.

## References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