LyonTech, Team Description Paper RoboCup@Home 2024 Open Platform League

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https://robocup-lyontech.github.io/,
Qualification video : https://www.youtube.com/watch?v=P_qb1CmQl90

Abstract. LyonTech consortium is ready and motivated for RoboCup @Home thematics [1]. Strong of 3 successful participation in SSPL (Montréal 2018, Sydney 2019, Simulation 2021), we decided to continue our effort into the Open Plateform (Leipzig 2016, Virtual Competition 2021, Bordeaux 2023). Our team gather : i) highly qualified researchers in several areas of robotics (robot navigation, robot control, computer vision); ii) a fruitful collaboration between researchers and engineers; iii) past participation in the competition; iv) the integration of a large number of highly qualified students from different engineering schools (eq. Universities); v) expertise on ROS frameworks; vi) software contributions on github.

1 Introduction

The LyonTech team members belong to two teaching entities, two research laboratories :

- CPE Lyon, Engineering school[1], former RoboCup team in 2013 and 2016
- INSA Lyon, Engineering school[1], candidate for RoboCup 2016 organization
- Chroma research team from CITI Lab., Centre of Innovation in Telecommunications and Integration of Service (INRIA)

This paper is organized as follows:

- Research and engineering interests
- Previous results and contributions to RoboCup and RoboCup@Home
- Our solutions for the OPL
- Conclusion and references

[1] eq. University

2 Research and engineering competences

The LyonTech consortium consists of highly qualified teachers-researchers in computer science (AI, vision, navigation, multi-agents) working with students. one main laboratory is involved in the LyonTech team.

CITI is an academic laboratory associated with INSA Lyon and INRIA. The members involved in the LyonTech project are part of the "human-aware navigation and multi-robot systems" Chroma team led by Olivier Simonin.

The RoboCup@Home challenge is an opportunity for team members to work on their specialties (image analysis, navigation, robot fleet management). It helps them to define use cases to drive research focus. For example the cases of robot waiter and tour guide robot are directly considered in our study benchmarks for navigation.

3 Previous results and contributions to RoboCup and RoboCup@Home

We have participated to the RoboCup competitions since 2013:

- "Lyon CPE" team : **3rd place at RoboCup@Work**, Joao Pessoa, Brazil, **2013**
- "CPE Robot Forum" team : **15th place at RoboCup@Home OPL**, Leipzig, Germany, **2016**
- "LyonTech" team : **5th place at RoboCup@Home SSPL**, Montreal, CANADA, **2018**
- "LyonTech" team : **3rd place at RoboCup@Home SSPL**, Sydney, AUSTRALIA, **2019**
- "LyonTech" team : **2nd place, Best Clean Up Award at RoboCup@Home SSPL**, Virtual Competion, **2021**
- "LyonTech" team : **6th place at RoboCup@Home OPL**, Virtual Competion, **2021**
- "LyonTech" team : **12th place at RoboCup@Home OPL**, Bordeaux, FRANCE, **2023**

Contributions at the robocup Symposium :

- Human Presence Probability Map (HPP): a Probability propagation based on Human Flow Grid [2], **2023**
- People management framework using a 2D camera for human-robot social interactions, **Best scientific paper** [3], **2019**
- Towards S-NAMO: Socially-aware Navigation Among Movable Obstacles [4], **2019**
- Context Aware Robot Architecture, Application to the RoboCup@Home Challenge [5], **2018**

Additional contributions have been made to help the RoboCup organization and promotion:

- Lyon city and INSA was candidate for the organization of the RoboCup, in 2016 (co-led by O. Simonin from Chroma/CITI team).
- Fabrice Jumel (CPE Lyon/CITI) is a RoboCup@Home evangelist for France, linked with the application of Bordeaux for RoboCup 2023. He was OC chair and co-chair in 2018-2021 and TC of RoboCup@Home in 2017-2018 and OC member of RoboCup@Home since 2017.

4 Our solutions for the OPL

4.1 Overview

Our Open Platform named **Palbator** (Figure 5 and Figure 1) is made from a PMB-2 PAL mobile base, enhanced by several hardware and software features. Its body supports a Universal Robot UR5e industrial arm modified for on-board use, offering a payload of 5kg and repeatability of 0.03mm under load.

Our software architecture is distributed on several hardware platforms as shown in Figure 6. As we use ROS and independent software modules, we can easily (un)scale our hardware .

The architecture of LyonTech's software is shown in Figure 7. It contains modules which have been developed in the different research groups of the consortium, completed by off-the shelf modules which tackle standard tasks, as well as engineering bricks interconnecting these modules.

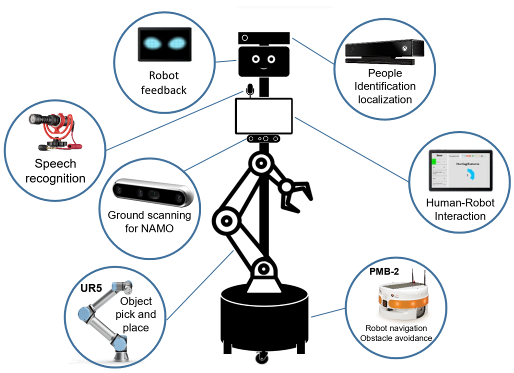

Fig. 1. Robot main hardware features

Code reusability, applicability and status: Our code is a branch of our SSPL code which fits on the OPL robot. It's a proof of the re-usability of our code offered to the community [6]. However, the Human-Robot interaction (independent module) has to be modified because of SSPL Naoqi dependencies. Other packages are rather tuned than modified. The gripper module using MoveIt! is in the process of being improved and shared, as is the rest of the code, to offer stable control of our industrial arm. All our codes are tested in robocup scenarios performed in several robocup-like apartment (living lab).

Perception: Our computer vision experts bring knowledge in gesture recognition [7], activity recognition [8] articulated pose estimation [9] and object recognition [10],see Fig. 4 . A large part of these methods are capable of running on real time and have been integrated in our platforms of mobile robots. Our combined work allows us to be aware of the objects present in a room, their locations, as well as the ongoing activities in this room.

Motion planning and Decision making: Our work focuses on autonomous navigation in crowded environments (human-aware navigation) and in urban traffic (autonomous vehicles) for human assistance [11,12]. We also explore robot fleet cooperation for human scene observation [13], 3D environment mapping, service delivery [14] and Namo thematics [15].

Human-Robot Interaction: Human-Robot Interaction is managed with a classical combination of natural language communication and use of a tablet.

For Natural Language Understanding (NLU), we are using our custom solution based on Whisper.cpp, a C++ local re-implementation of the OpenAI ASR (Automatic Speech Recognition).

For tablet interaction, we reused a web application (based on ReactJS) developed for pepper robot and successfully used during SSPL robocup@home competition in Sydney.

Integration: The Ros Middleware is used to integrate components (customized packages and LyonTech packages). The set of functional blocks (Figure 7) are orchestrated through a General manager [5]. The section 4.2 detailed the set of tools and software used.

At the same time, we are working on migrating our architecture to ROS2, while simplifying the reuse of software building blocks. Our aim is to use and share this new architecture at the 2024 robocup.

4.2 Contributions and 3^{rd} party dependencies

Our solution is composed of a mix of existing and customized solutions, as well as full contributions. We share a GitHub repository [6] pointing to every other repository as submodule.

Contributions

- **General Manager*** [5] [16]: we developed a general orchestrator allowing the robot to coordinate its capacities (navigation, perception, interaction) and make decision on defined scenario.
- **Navigation Manager*** [5] [17]: this functionality provide a set of navigation strategies depending on the observed context. Regarding to the context (lots of people, complex environment, large free space zone), the robot changes it way of navigation.
- **People Manager*** [3]: we developed a framework that allows the extraction of high-level person features from a 2D camera in addition to tracking people over time. The proposed people management framework aggregates body and person features including an original pose estimation using only a 2D camera. At this time, people pose and posture, clothing colors, face recognition are combined with tracking and re-identification abilities, as shown in Figure 2. These people features detection form also individual contributions:
  - **Face recognition*** [18]: a solution (based on python detection module) was developed to automatically catch face and learn it for future detection.
  - **Color detection*** [19]: we extract main colors of a given picture (e.g t-shirt, trousers) based on HSV format and K-mean clustering helping us to track people. Another tools was then built to distinguish color of different body parts [20]
  - **Pose detection*** [21]: based on the OpenPose data, we build a pose extractor giving us the estimated pose (stand, sit, lying down, left or right arm up,...) and even people distance.

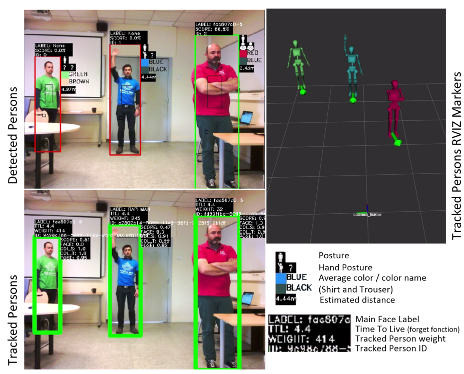

Fig. 2. People Management features extraction

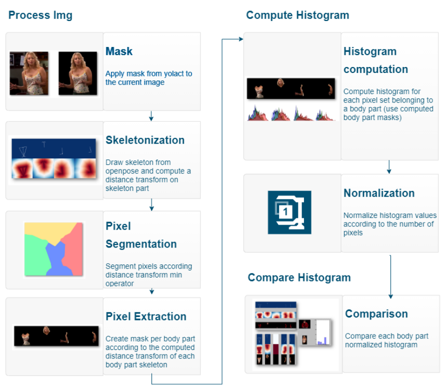

Fig. 3. Body part color extraction workflow

3^{rd} party dependencies

- Palbator navigation: PAL Navigation Stack
- Palbator Perception:
  - ∗ Darknet Yolo TensorFlow : we use the deep neural network framework YOLO
  - ∗ OpenPose MediaPipe : this solution are used to detect human and estimate their position
- OpenVoiceOS are used for natural language communication

5 Conclusion

We gave an overview of the approach which will be used by the LyonTech team to target the OPL RoboCup@Home competition, including the different AI modules developed in the different research groups of the consortium. Fig. 4 and the video submitted with this paper present a scenario illustrating our ongoing work.

We have implemented substantial hardware upgrades for the competition in Bordeaux, and these improvements are set to be fully leveraged in the upcoming cup. Our goal for the Eindhoven event is to attain a strong position in the OPL, aiming to mirror the success of our SSPL team in Sydney (2019), where we achieved the 3rd place.

We believe in the following strengths of the LyonTech consortium: i) highly qualified researchers in several areas of robotics which are vital for this competition (robot navigation, robot control, computer vision); ii) a fruitful collaboration between researchers and engineers; iii) past participation's in the competition which allowed us to gain valuable experiences in real situation; iv) the integration of a large number of highly qualified students from different engineering schools (eq. Universities).

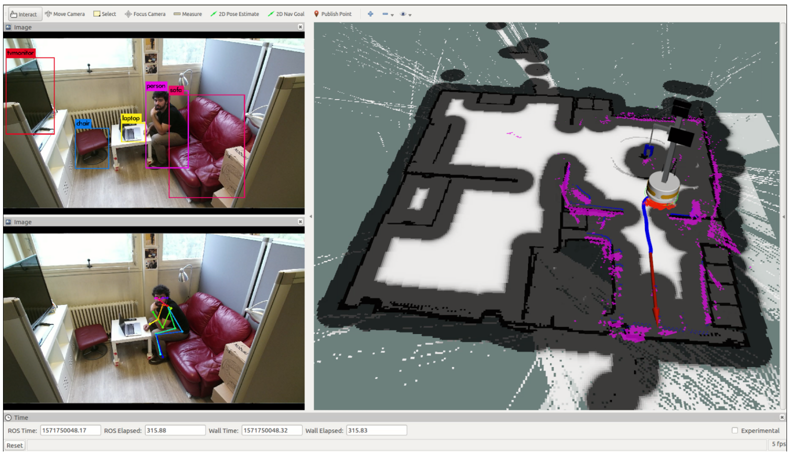

Fig. 4. LyonTech robot capabilities including navigation, people detection (Yolo), object detect (customized Yolo), pose detection (openPose) in living lab apartment

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Fig. 5. PALbator

Appendix

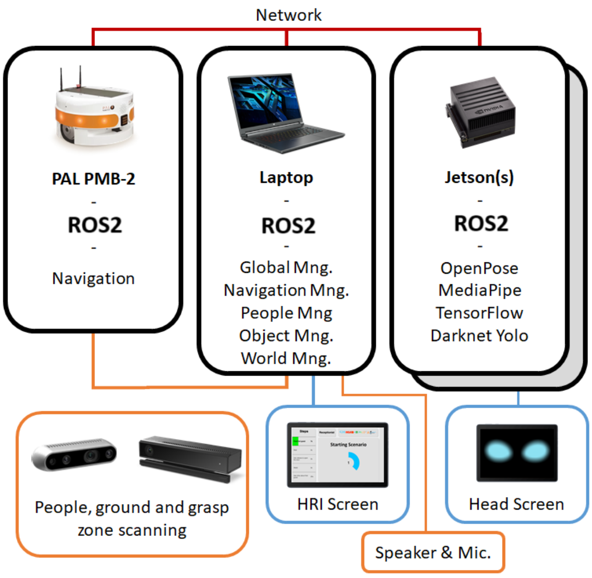

Fig. 6. PALbator Hardware/Software Architecture Overview

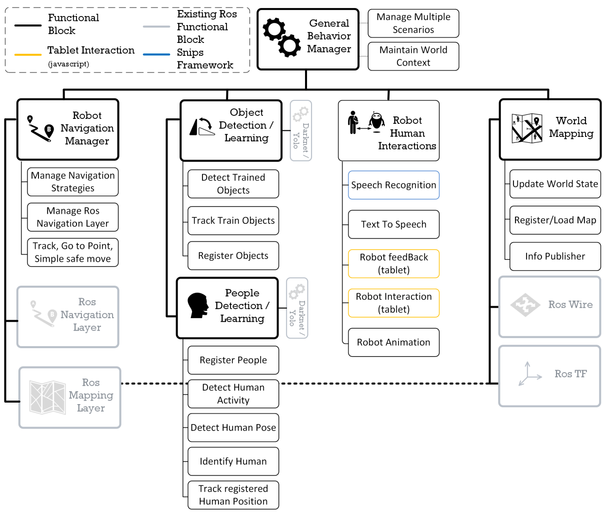

Fig. 7. LyonTech Software Architecture Overview