NUTNAPPERS*
robocup@work
Team Description Paper

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Abstract. This 2020 year is the first opportunity for the NUTNAPPERS team to participate at the robocup@work challenge. Through innovative pedagogical actions, the project aims to bring together two groups of students from two engineering schools of the south west of France and their teachers to work together on areas of excellence in robotics, but also to the development of excellence in robotics teaching and research. In addition, it is expected to give rise to professional vocations of the students in order to direct them towards promising professions in a rapidly emerging sector. The participation at the @Work challenge is a unique opportunity for our group of students to create an inter-institutional community on the theme of robotics, they will be able to share their experiences and learn from each other.
NUTNAPPERS, we kidnap nuts.... BEWARE!

Keywords: Mecanum robot · inverted kinematics · Yolo · Computer vision · parallel gripper · 6 DOF arm · Deep Learning · AI · Cobot · Industry.

1 Focus of research

Our approach consists in a modular and low-cost architecture that combines independent modules using state-of-the-art methods in computer vision, gripping technologies and artificial intelligence (decision-making) in order to deal with

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uncertain environments and real-time computation constrained to embedded systems. One of the advantages of our approach is that the independent methods allow a simplicity of handling and possibility of several improvements resulted from several ongoing research projects of our engineering schools (ESTIA and Enseirb-Matmeca) and associated laboratories (ESTIA-Research and IMS CNRS 5218), that we briefly describe in paragraphs below.

ESTIA-Research was funded in 2009, by merging two research units: LIPSI (Laboratory in Engineering and Industrial Processes) and a part of the GRAPHOS (Pluridisciplinary Applied Research Group on Hospital, Health and Social Organizations and their networks). ESTIA-Research brings together Engineering Sciences and Management Sciences to contribute to the evolution towards the factory of the future and take into account the energy and digital transitions. ESTIA-Research is the unique research lab of the ESTIA INSTITUTE OF TECHNOLOGY and is associated to the University of Bordeaux. ESTIA-Research total staff is around 80: 28 senior researchers, 30 post-doctoral researchers and PhD candidates, 16 engineers and business staff. Over the last five years, ESTIA researchers published 82 journal papers, 199 conference papers and applied for 3 patents. ESTIA-Research offers a unique point of view on complex systems by the combination of human factors and technologies, especially for industry. Re-searchers study, design and implement Smart and Empowering Interfaces for Human-Human, Human-System and System-System interactions.

IMS CNRS 5218 (Integration: from Material to Systems) laboratory was funded in 2007, by merging three research units: IXL, PIOM and LAPS. IMS brings together fundamental research, engineering and technology, emphasizing an integrative systems approach in the disciplines of Information Technologies. IMS is a joint research unit for the French National Center for Scientic Research (CNRS), University of Bordeaux and Bordeaux INP. In CNRS, IMS is affiliated to the Institute for Engineering and Systems Sciences (INSIS) and to the Institute for Information Sciences and Technologies (INS2I). IMS total staff is around 350: 135 senior researchers, 150 post-doctoral researchers and PhD candidates, 65 engineers and technical staff. Over the last five years, IMS researchers published 800 journal papers, 1200 conference papers and applied for 50 patents. IMS offers a unique scientific positioning in systems engineering: the integration of hardware, intelligence and knowledge in communicating and human centered systems.

IMS, as well as ESTIA-Research supports fundamental research as well as project-based interdisciplinary research. More than one hundred research grants are currently runnning in the laboratories, targeting domains such as manufacturing, transportation, telecommunications, health, environment and energy.

Past few years, significant results was done especially in signal processing, image processing, robotics, automatic control: localization, data fusion, path planning [10] [12], path tracking [8] [17] [18], dynamic modelling, autonomous vehicule [9], control [19]. Large research effort was focused on human-robots interaction. First we defined a gestural language [3] to interact jointly with a swam of drones, a swarm of Metabot and a group of perforating musicians. We also described issues of indoor control of a swarm of drones [2, 1]. Based on actuated shape-changing interfaces, we proposed robotic systems [4, 5], first one to notify of renewable energy availability and second, applied to for eyes-free interaction in cockpit. With an industrial approach we improved accuracy in robotized fiber applied to material composites [11, 16, 6].

Through the specific issues of the @Work league, the platform enables us the implementation of approaches developed in labs, the development of new approaches and know-how. Finally, the proposed modular architecture, see sections 2 and 3, allows significant potential for innovations in different industrial applications and academic research.

2 Description of the hardware

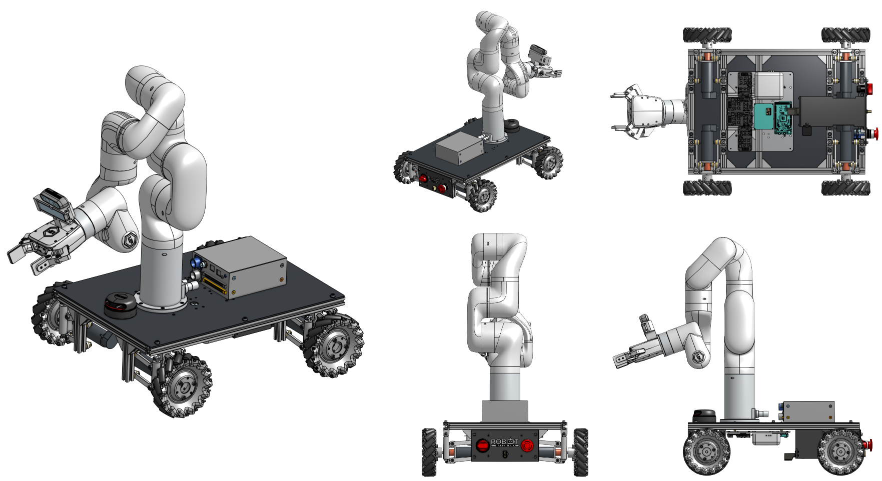

Fig. 1. The Hardware robot overview: mecanum wheelbase for omnidirectional displacement, the arm and the gripper.

The robot is an assembly of four independent modules, see figure 1.

1. The wheelbase is a mecanum wheelbase for omnidirectional displacement, equipped with four 35W 24V dc motors equipped with encoders. Each motor is mounted on independent spring suspensions and an Inertial measurement unit IMUMPU9250 and a 360-degree Lidar sensor RPLIDAR A2 are completing this wheelbase. The brain of the base is an Arduino due board. It controls the motors' speed with a PID control loop, reads the different sensors and perform inboard relative position estimation and obstacle avoidance

allowing a safe collaboration with humans. The Arduino Due board read commands and send data such as velocity, positions, and obstacle points using a UART Serial protocol.

2. The arm and gripper module are an XArm 6 with an XArm parallel gripper from Ufactory. This arm is a precise 6 DoF arm, with a payload of 5 kg, repeatability of +/- 0.1mm and a length of 691 mm. The XArm 6 is equipped with a great collision detection thanks to the current feedback combined with the dynamics compensation to sense the force precisely. If any collision happened, xArm would detect it and stop moving within 0.5s allowing a safe collaboration with humans. The XArm parallel gripper has a 12-bit absolute encoder as well as an integrated force sensor.

3. The AI module is a computer board, currently an "NVIDIA Jetson Nano", that we could upgrade later if more computational power is needed, plus vision sensors including intel depth sensor D435 and tracking sensor T265. The AI module can detect and locate obstacles, targets or visual landmarks and it communicates with the other modules to receive data or send commands. The AI module also handles all the task planification, robot and arm trajectories, path planning, localization and mapping.

4. The power supply module integrates a 6S 12Ah Li-po battery and security systems like on/off switch, emergency buttons and fuses. The emergency button cuts the power supply for all modules except the AI module.

In order to meet the growing demands, Industrials should produce more, faster and cheaper. In order to do so, buildings are getting bigger and bigger, a lot of proccesses are fully automated and there are more and more robots in industries. Industry 4.0 aims at improving factory productivity with the use of new technologies including robots and nowadays all big companies work with robots in order to increase their production rate and productivity. Thus, this work seems relevant to industry. Indeed, smart picking robot allowing to precisely pick small parts can be useful in an assembly line for processes like part customizations or bring parts to another assembly line. By using robots, workers can be relieved of painful and low added value tasks and manufacturing processes can become more efficient. By being able to handle repetitive tasks autonomously, our robot meets the industry 4.0 requirements. A moving robot could seamlessly be integrated into a production environment, taking part in production line supply, moving parts from one point of the line to another or getting the finished product to the warehouse, ready for delivery. For such kind of scenarios, versatile and adaptable robots are a real must-have. Workers would no longer need to handle tedious tasks like lifting and carrying parts or walk long repetitive distances in buildings. The chosen mobile base and robotic arm are perfoming polyvalent and low cost.

3 Description of the software, esp. the functional and software architectures

In our software architecture, three different tasks are considered: sensor task, action task and brain task. Sensor task: use the information provided by the sensors to construct a 3D map of the environment, the robot localization and the objects of interest. Action task: control the displacement of the robot and the actions needed to recover, transport and position the object of interest. Brain task: receive the information provided by the sensor task and decide the actions required to achieve the different objectives (recover objects, navigation and position objects). Each task consists of the following modules that run in parallel and communicate each other via message passing (see 2). In every module, there is an interface to receive data (input) and to send data (output).

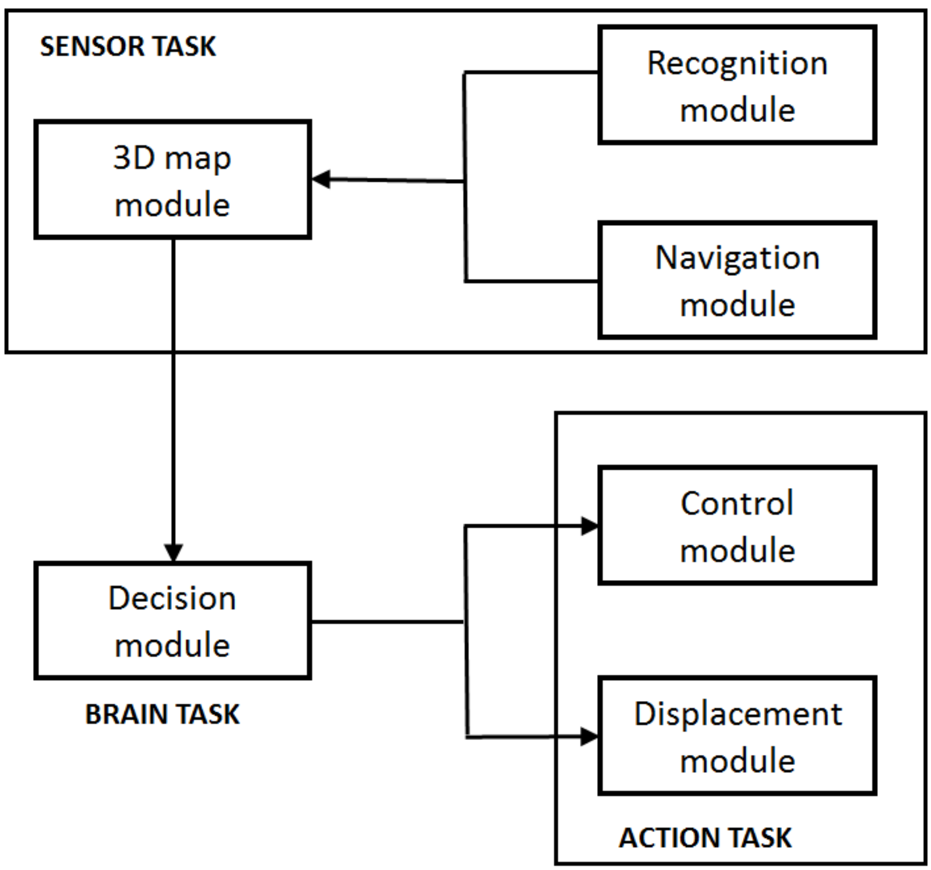

Fig. 2. Diagram of the software architecture

Recognition module implements computer vision (OpenCV library [7]) and deep learning algorithms (YOLO framework [13]). to detect and recognize the objects of interest in real-time. The output data correspond to the 3D position (X, Y, Z coordinates) of each object of interest.

Navigation module detects the obstacles and the path of the environment where the robot must navigate. While grid based mapping has become the standard for representing a robot environment, we have chosen a different approach based on a vectorial representation of objects. Being computationally much less taxing, we see it as a great solution for typically cheaper robots.

3D map module constructs and updates a map of the environment while simultaneously keeping track of the robot location within it. This map also includes the localization of the objects of interest.

Control module determines the robot arm's joint parameters that provide the desired 3D position where the object of interest is located. Real-time inverse kinematics methods are used to solve the joint angles [15].

Displacement module controls the displacement of the steer motors by changing the speed and direction of the wheels. The robot will move with the target speed according to translation (X, Y) and rotation parameters.

Decision module allows to manage and control the workflow of actions based on the information provided by the 3D map module. Decision-making strategies are implemented modeling the uncertainty in unknown environments in order to accomplish the given tasks [14].

4 Re-usability of the system or parts thereof

Thanks to the fact that the robot is composed of independent modules, it is easy to reuse any of these modules in other robots or with different configuration. We can easily replace or add modules for another task. i.e. We can imagine change for a more powerful IA module to have more computational power, use cheaper robot arm to be more cost-effective, or implement different specific tooling for specific tasks... This offer a high versatility that can be used in various situations and allow to provide cost-effective solutions with only what is needed to perform the requested task.

5 Applicability and relevance to industrial tasks

The student team developments are made in the frame of their studies (engineers in mechanic, software, mechatronics...) and they are driven by their teachers and an external robotic engineer (former student). Both teachers and an external robotic engineer are involved in advanced industrial robotic tasks where they daily face the needs of the industry thanks to R&D collaboration (funded project like European Project, but also classical R&D contracts) with SME but also big industrial companies.

The developments made in the frame of our RoboCup participation will deal with perception and manipulation using a moving platform. Mobility in robotics is something that is needed when you want to work on big structure for machining (drilling but not only). And of course, manipulation requires accuracy in mobility, or at least perception system to improve this accuracy and to guide the operation. Also, mobility gives the opportunity to work in collaboration with humans, but it implies also to deal with the human factors. An example could be a robot in charge of cleaning a workshop and storing tools at the end of the day. In this case, the robot needs to know its environment, where it is located, where the tools are, how to grip them, how to access the right place to store them...

If there is a gap between large part machining (or manufacturing using additive process) and cleaning a workshop, many developments are common to both scenarios (precise localization, vision algorithms, grasping operation, tasks learning...). And these developments are recurring demands from industrials dealing with process robotization. Thus, there is no doubt that developments will be made with applicability and relevance to industrial tasks as objective.

6 Performance in previous competitions

Although this is first participation of ESTIA and ENSEIRB-MATMECA in the RoboCup, we already have had the opportunity to participate in various robotics competitions. Students from the Student Union "ESTIA-SYSTEM ", have participating in the "Coupe de France de Robotique", an autonomous robot competition that must perform various tasks without colliding with the opposing robot. For example, last year, they designed a robot mounted with a 4-axis arm capable of detecting and catching various game elements, see Figure 3. Their first participation was in 2006, since this date they have been participating annually since 2013: Happy Birthday (2013), Préhistobot (2014), Robomovies (2015), BeachBots (2016), Moon Village (2017), Robot Cities (2018), Atom Factory (2019), Sail the World (2020). Enseirb-Matmeca Robot Club has participating also to the "Coupe de France de Robotique" past years. ESTIA has participating in the "Dassault UAV Challenge", which consists in the implementation of an autonomous UAV capable of performing image (and shape) recognition in order to orientate itself properly. Enseirb-Matmeca students have participating to an interdisciplinary challenge: "Concept Drone AETOS"[3] and they has participating with Rhoban team to the Robocup humanoïde kid-size[4] (champion 2016, 2017, 2018, 2019), and with Namec team to SSL league since 2018.

[3] https://sciences-ingenieur.u-bordeaux.fr/Actualites/Un-nouveau-challenge-pour-Aetos-ConceptDrone)
[4] https://enseirb-matmeca.bordeaux-inp.fr/fr/robocup-2019

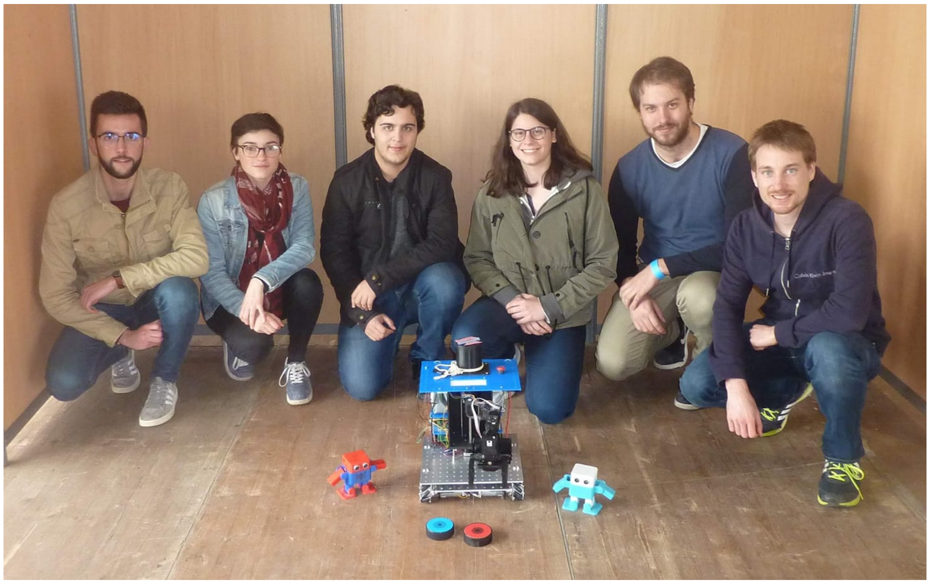

Fig. 3. The Team at the "Coupe de France de Robotique", French Robotics Cup

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