2nd YEAR INTERNSHIP REPORT

11/01/23 to 08/31/24
(10 Months during Year Off)

Haptics Technology Enhancement for Avatar Robot Teleoperation

(Researcher assistant subject)

Software Integration and System Testing for Mall Waste Management Robot

(Intern subject)

Ocean NOEL
FISE 24 – ROB

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Abstract (ENGLISH)

In this report, I present my work at CNRS-AIST JRL, where I served both as an Intern and a Research Assistant (RA). During this internship, I had the opportunity to work on two distinct subjects. The first, as an intern, involved integrating the complete software for an omnidirectional robot equipped with a mounted arm, designed to collect cardboards and trash bags in shopping malls. This work encompassed low-level algorithms for sensor data acquisition and actuator control, as well as high-level perception, mapping, and navigation features. My main contribution is a novel approach for efficient 2D navigation using a multimodal sensor fusion technique, implemented as a ROS2 package. This work resulted in a paper submission to the robotic conference SII 2025. As a Researcher Assistant, my project centered on conducting research and development related to Avatar robot technology, aimed at transporting human presence and senses to a remote location in real time. A critical aspect of this technology is the implementation of a proper haptics system, enabling the operator to feel pressure, texture, and temperature at a remote location through the avatar robot. My research in this area led to the development of a novel concept for an omnidirectional robot on a soft spheric roller and the creation of a Coaxial Multi-Channel Rotary Transmission System. We are currently in the process of applying for a patent with CNRS-AIST JRL for this system.

Abstract (FRENCH)

Dans ce rapport, je présente mon travail au CNRS-AIST JRL, où j'ai servi à la fois en tant que stagiaire et assistant de recherche (RA). Pendant ce stage, j'ai eu l'opportunité de travailler sur deux sujets distincts. Le premier, en tant que stagiaire, consistait à intégrer le logiciel complet d’un robot omnidirectionnel équipé d'un bras, conçu pour collecter des cartons et des sacs poubelles dans les centres commerciaux. Ce travail englobait des algorithmes de bas niveau pour l'acquisition de données de capteurs et le contrôle des actionneurs, ainsi que des fonctionnalités de perception, de cartographie et de navigation de haut niveau. Ma principale contribution est une nouvelle approche pour une navigation 2D efficace utilisant une technique de fusion de capteurs multimodale, implémentée en tant que package ROS2. Ce travail a abouti à la soumission d'un article à la conférence robotique SII 2025. En tant qu'assistant de recherche, mon projet s'est concentré sur la conduite de recherches et de développements liés à la technologie des robots avatars, visant à transporter la présence et les sens humains en temps réel vers un emplacement distant. Un aspect critique de cette technologie est la mise en œuvre d'un système haptique approprié, permettant à l'opérateur de ressentir la pression, la texture et la température à un emplacement distant via le robot avatar. Mes recherches dans ce domaine ont conduit au développement d'un nouveau concept pour un robot omnidirectionnel sur « roller » sphérique souple et à la création d'un Système de Transmission Rotatif Coaxial Multi-Canal, pour lequel nous somme en cours de dépôt de brevet avec le CNRS-AIST JRL pour ce système.

1. Introduction

The CNRS-AIST Joint Robotics Laboratory (JRL) [**1**], recognized as an International Research Laboratory (IRL) by both the French CNRS (National Center for Scientific Research) [**2**] and the Japanese AIST (National Institute of Advanced Industrial Science and Technology) [**3**], is situated within the Department of Information Technology and Human Factors at AIST in Tsukuba, Japan. This laboratory brings together researchers from France and Japan, to work on key research areas including task and motion planning, control, multimodal interaction with humans and the environment through sensory perception, and cognitive robotics. Active international collaborations are maintained with various CNRS laboratories in France and other research institutions through joint projects, including those funded by the European Union. The laboratory consistently hosts several international researchers, currently, 3 directors, 9 permanent researchers, 4 Post doctors, 13 PhD students and 16 Master students creating a diverse and global research atmosphere. Also, the CNRS-AIST JRL follows AIST's vision described in **Fig.1**. AIST is a prominent public research organization in Japan, that aims to develop and implement technologies beneficial to Japanese industry and society, bridging the gap between innovation and commercialization. Organized into five departments, two centers and with approximately 2,300 researchers working at 12 research bases nationwide, AIST aligns its efforts with national innovation strategies. Finally, AIST actively builds a global network through partnerships and memorandums of understanding with major research institutes worldwide [**3**]. In this report, I describe the context, challenges and results of my work at CNRS-AIST JRL.

Designing and co-creating the future with society.
Encouraging mutual respect and endeavors.

We promote diverse activities beyond the conventional AIST roles through:
- achieving excellence in research
- discovering social issues and implementing solutions
- underpinning intellectual infrastructure and assisting with policy advocacy

We respect creating diverse values through individual strengths and organizational power.

We foster a culture that attracts diverse people with high aspirations and encourages mutual respect and endeavors.

Fig.1: AIST Japan's vision

2. Context and challenges

2.1. As an Intern

Shopping centers and malls generate approximately 10 kg of waste per square meter, with a typical composition of over 40% cardboard, 35% paper, 8% plastic, 1% metal, 5% glass, and 10% miscellaneous waste [**4**]. Managing this volume of waste, especially considering increasing recycling regulations, requires a well-organized and consistent approach. Thus, automating this process can significantly enhance waste management and recycling efficiency. However, deploying autonomous robots for trash collection in shopping centers presents several critical challenges, including navigating through complex and dynamic environments.

Effective navigation relies on accurate mapping and localization, which are essential for autonomous agents to understand their surroundings and make informed decisions. Simultaneous Localization and Mapping (SLAM) has emerged as a popular solution for these challenges [**5**]. However, 3D SLAM methods and most current navigation features that consider 3D obstacles often demand substantial computational resources, which can be a limiting factor for resource-constrained autonomous systems. Additionally, processing real-time data from multiple sensors can be challenging, leading to delays and reduced performance [**6**].

To address these issues, during my internship, I developed a lightweight software solution for consistent 2D navigation that accounts for 3D dynamic obstacles and several different sensors while keeping a low computation load. The Ikeuchi Gate [**7**] shopping center in Sapporo has expressed interest in purchasing the robot I worked on during my internship.

2.2. As a Researcher Assistant

Avatar robot technology, designed to transport human presence and senses to remote locations in real time, is at the forefront of innovative research and development [**8**]. A crucial component of this technology is the implementation of an advanced haptics system, which allows operators to experience pressure, texture, and temperature through the avatar robot. This haptic feedback is essential for creating an immersive and realistic user experience [**9**] that allows the user to perform complex tasks using a teleoperated robot that could go in inaccessible areas for example.

However, developing such sophisticated haptic systems comes with several significant challenges. These include the need for high-precision sensors capable of capturing detailed tactile data, as well as robust actuators that can accurately replicate these sensations for the operator. Integrating these components can be mechanically challenging, as for the user experience they should be as small as possible. Current systems seems to be limited to skin stretch [**10**], vibrations feedback [**11**], thermal feedback [**11**] and touch/pressure feedback [**10**], [**12**].

During my internship, I focused on developing a novel actuator designed to provide tangential speed feedback within a haptic glove. To the best of our knowledge, this type of continuous speed feedback has not been previously explored in the literature. Initially, my work resulted in a concept that was not easy to miniaturize and thus unsuitable for haptic devices. However, I redirected my efforts to create a novel mechanism capable of generating omnidirectional speeds at a macroscopic scale. This innovation proved particularly applicable to mobile robotics, allowing us to develop a prototype to validate the concept.

3. Work and results

3.1. Software integration for Mall Robot (Intern)

As an intern, I had the opportunity to develop the navigation software for an omnidirectional robot named CALL-M. This robot is designed to collect cardboards and trash bags in a shopping mall, necessitating navigation through an environment with complex-shaped objects and dynamic obstacles. This section of the report details the navigation software I implemented in ROS2 during my 10-month internship.

3.1.1. Hardware and simulated environment

As illustrated in **Fig.2**, CALL-M is equipped with two 2D RpLidars SLAMTEC A1 [**13**], two Zed-Mini [**14**] cameras, and four Ultrasonic sensors Maxbotic MB1403 [**15**]. Additionally, the two cameras are mounted on servomotors, enabling them to sweep up and down. The ultrasonic sensors were added later and are not yet integrated into the ROS2 navigation system; therefore, they are not utilized in the navigation system described in this report. The Universal Robots [**16**] mounted on top is also not currently considered, and the navigation system treats the robot as having a fixed height without an arm. Consequently, the arm and the ultrasonic sensors are not represented in the simulated robot model shown in **Fig.2.**

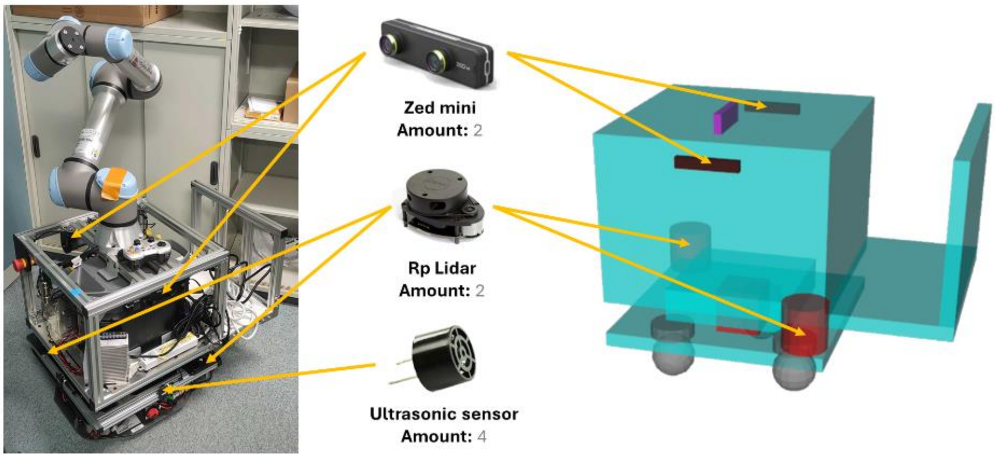


Fig.2 CALL-M Hardware (left) and simulated model (right)

As the robot employs the holonomic[1] solution developed by Triorb [**17**], we were unable to precisely simulate the system in Gazebo. Triorb utilizes spherical wheels driven by friction for movement, but creating actuated spherical joints in Gazebo[2] is not feasible, and replicating the complex friction system used by Triorb could result in unrealistic motions, as accurately simulating friction remains a challenge in existing simulators. Consequently, we opted to simulate the omnidirectional motion using three cartwheels. Simulating cartwheels is more straightforward, as they only require two cylindrical actuated joints. We can replicate omnidirectional holonomic motion by instantly rotating the wheel in the desired direction and setting the desired speed. The concept is illustrated in **Fig.3**, which shows three spherical wheels, each mounted with a cylindrical actuated joint (horizontal axis) beneath a small disk, connected to the body with another cylindrical joint (vertical axis). This configuration allows us to control the direction and speed of each wheel.

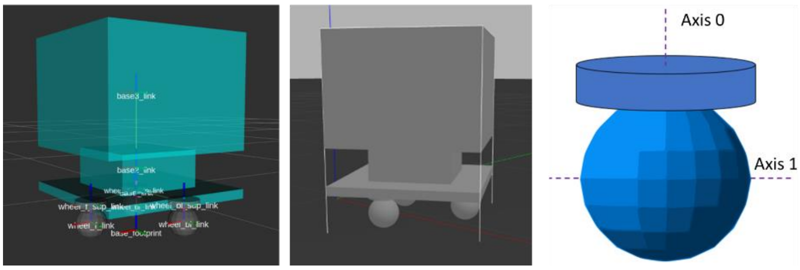
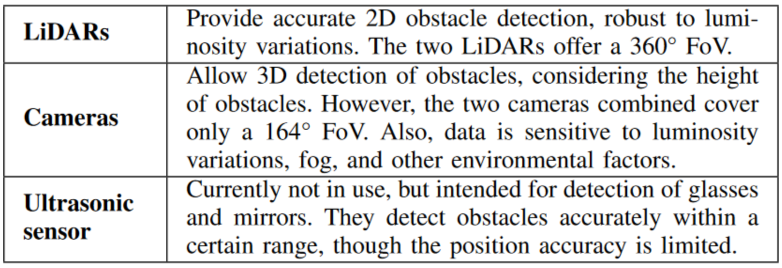


Fig.3 Omnidirectional spheric wheel simulation with cartwheel

3.1.2. Perception System (Paper submission)

Then, as previously mentioned, to navigate the complex and dynamic environment of a shopping mall, the robot requires accurate localization and mapping capabilities. Several existing methods and ROS2 packages can achieve this using 2D Lidars and cameras. For the CALL-M robot, we are specifically interested in integrating the 3D depth point clouds from the cameras, the 2D Lidar scans (referred to as 'Laser-Scan'), and the range data from the ultrasonic sensors. Therefore, we need to merge 3D and 2D data from various sensors, each with its own advantages and drawbacks, as detailed in **Fig.4**.



LiDARs	Provide accurate 2D obstacle detection, robust to luminosity variations. The two LiDARs offer a 360° FoV.
Cameras	Allow 3D detection of obstacles, considering the height of obstacles. However, the two cameras combined cover only a 164° FoV. Also, data is sensitive to luminosity variations, fog, and other environmental factors.
Ultrasonic sensor	Currently not in use, but intended for detection of glasses and mirrors. They detect obstacles accurately within a certain range, though the position accuracy is limited.

Fig.4 Advantages and drawbacks of LiDARs, Cameras and Ultrasonic sensors

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[1] Holonomic robot: Robot that can move in any direction, regardless of its orientation.

[2] Gazebo: 3D, kinematic, dynamic and multi-robot simulator allowing you to simulate articulated robots in complex environments.

Processing data from multiple sensors in real-time can be challenging, potentially leading to delays and reduced performance. Even today, multimodal sensor fusion remains a complex issue without a standardized solution, often requiring the use, customization, or creation of methods specific to the robot in use. During my internship, I developed a lightweight and modular ROS2 solution for fusing sensor data at the Laser-Scan level from an unrestricted number of sensors. This solution, named "multi-laserscan-toolbox-ros2," is available on GitHub at [**18**]. This package facilitates efficient and accurate 2D navigation or mapping while considering 3D obstacles. The method involves converting data from various sensors into a standardized Laser-Scan format and performing fusion to create a rich Laser-Scan for mapping or any Laser-Scan-based navigation system. It does not aim to replace existing methods for 2D mapping and navigation but rather seeks to enhance them by reducing their computational load and integrating data from multiple 3D and 2D sensors. The process is briefly illustrated in **Fig.5**. For more detailed information, the paper submitted to SII25 related to this package can be found attached to this report: "A Lightweight Approach to Efficient Multimodal 2D Navigation and Mapping Unified LaserScans as an Alternative to 3D Methods.pdf."

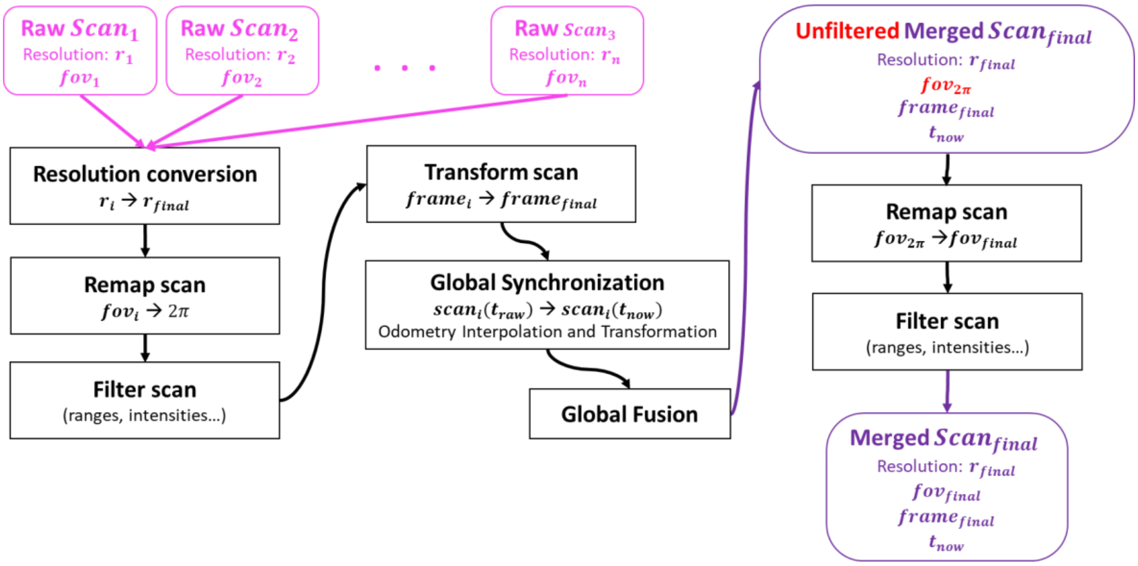
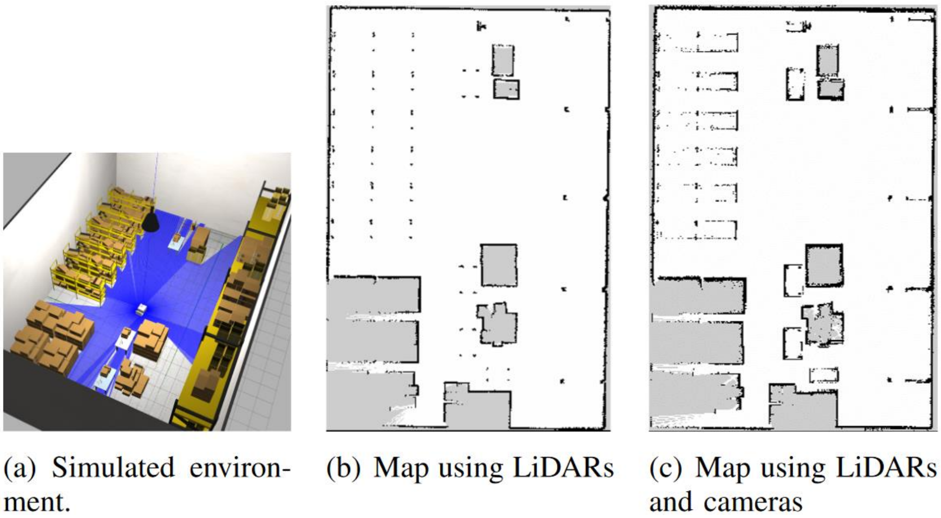


Fig.5: Code schematic of package 'multi-laserscan-toolbox-ros2'

Finally, **Fig.6** demonstrates that we can successfully fuse the 3D data from the cameras and the 2D data from the LiDARs into a rich, unified Laser-Scan. This Laser-Scan can then be used to generate a comprehensive map that includes information about 3D obstacles through a classic 2D SLAM approach. In our case, the 'slam-toolbox' [**19**] package has been used. **Fig.6.a** shows the 3D scene used for mapping. **Fig.6.b** displays the map before integrating the camera data, where only the footprints of tables and shelves are visible. However, considering the robot's height and the mounted arm, it is crucial to avoid the robot passing beneath these objects. Therefore, we needed to incorporate the 3D camera data. **Fig.6.c** shows the map resulting from this integration. We can see that this map contains the appropriate obstacles that should be considered according to our robot's height, improving the environment knowledge and proving that we could correctly enhance the classical 2D SLAM using our package. The mapping of the shelves in the top left corner is incomplete because the robot did not navigate between each shelf to perform a thorough mapping during this experiment.


(a) Simulated environment.

(b) Map using LiDARs

(c) Map using LiDARs and cameras

Fig.6 Mapping using LiDARs Only and with Depth Cameras' data integration

Furthermore, when using the merged Laser-Scan for navigation in the scenario described **Fig.7**, the package demonstrates a reduction in computational load compared to the use of classical method, while maintaining good navigation quality. **Fig.8** illustrates those results. The orange line represents the computer's load when using the two LiDARs and the two cameras directly with the default perception system of the Navigation2 (NAV2) plugin (NAV2) [**20**]. The green line represents the load when the sensors are first fused into one unified Laser-Scan using our package, and then this rich Laser-Scan is utilized by NAV2.

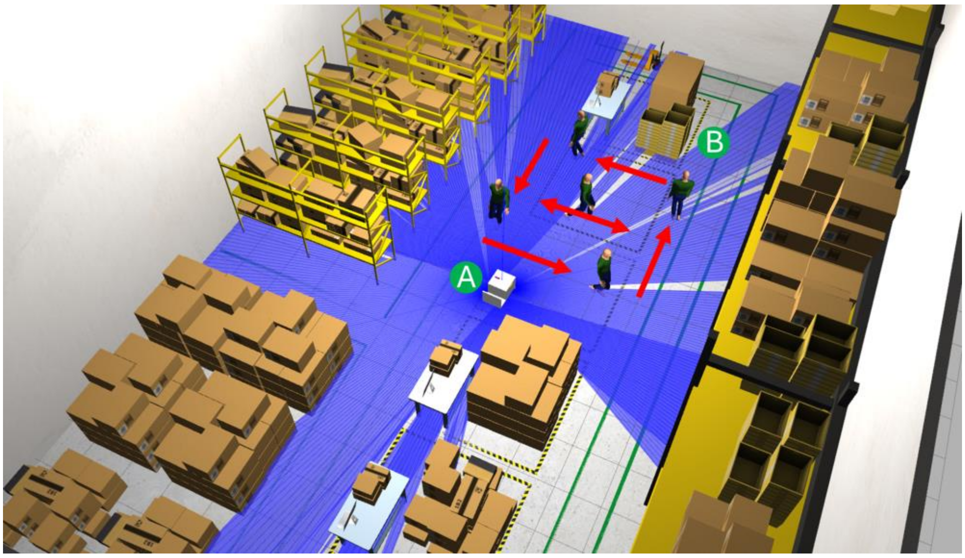


Fig.7 Navigation scenario, the robot navigates from Point A to Point B while avoiding walking humans and static obstacles

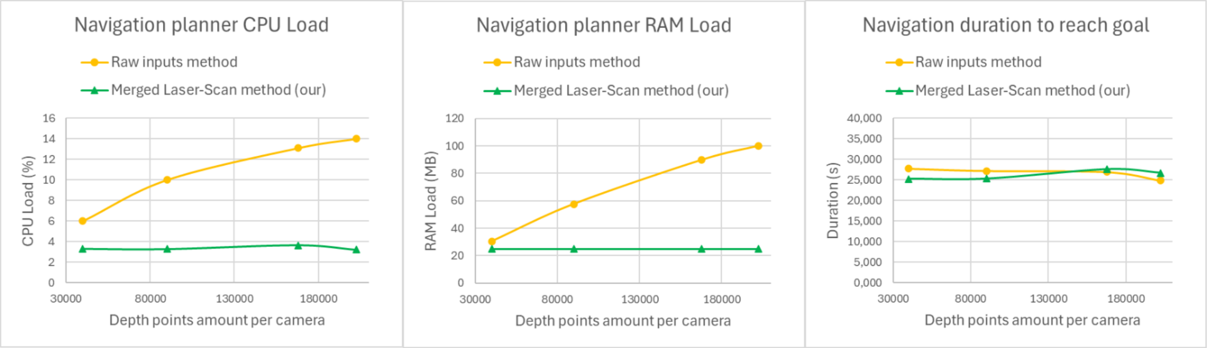


Fig.8 Navigation system load for different cameras' amount of points and for each method

First, we observe that the navigation duration remains unaffected regardless of the method used, indicating that our method maintains good navigation quality. Additionally, we notice that as the number of depth points increases, the NAV2 default navigation system consumes more CPU and RAM. In contrast, the CPU and RAM load remains constant when using our algorithm.

The details and complete conclusions of the experiments are not included in this report but can be found in the submitted paper attached to this report or on the GitHub repository [**18**].

3.1.3 Navigation System

One of the features wanted on CALL-M was the possibility for an operator to teleoperate it while having the robot still avoiding collision with detected obstacles. However, the default 'Navigation2' plugin, previously introduced, only supports autonomous navigation to a point, to several checkpoints, or through different positions. Fortunately, this plugin is based on behavior trees [**21**] making it modular and easy to customize. By modifying the default behavior tree, we could add an assisted teleoperation feature where the robot follows speed commands sent by the user but still computes obstacles to avoid and plans ways to avoid them. Specifically, we wanted the robot to 'smartly' avoid obstacles by sliding around them while trying to follow the user's speed commands, rather than simply stopping its motion.

To achieve this, another package I developed during my internship was a ROS2 vector field controller, available on GitHub as "ros2-vector-field-controller" [**22**]. This package computes obstacles around the robot as repulsive areas based on a Laser-Scan (using the rich one presented earlier in the perception section) and then follows an attractive point or a speed command by generating the corresponding attractive vector field and combining it with the repulsive one. **Fig.9** illustrates an example: on the left, the vector field is configured to prevent the robot from passing through two obstacles (acting like a wall), while on the right, the parameters allow the robot to pass through and reach the attractive point while avoiding obstacles.

Due to time constraints, we could not complete the integration of this controller into the NAV2 plugin. However, **Fig.10** shows how it was intended to be integrated, and **Fig.11** shows the current implementation.

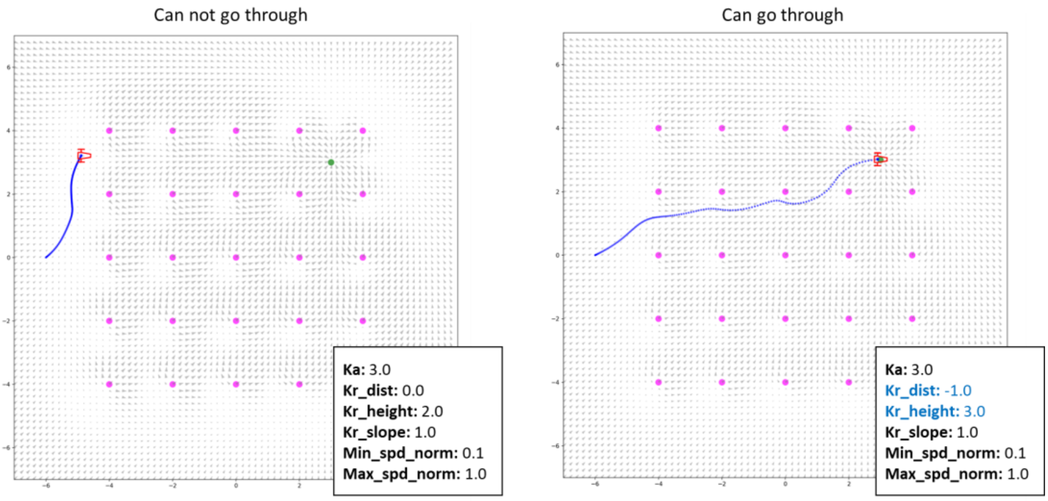


Fig.9: Example of point following using "ros2-vector-field-controller"

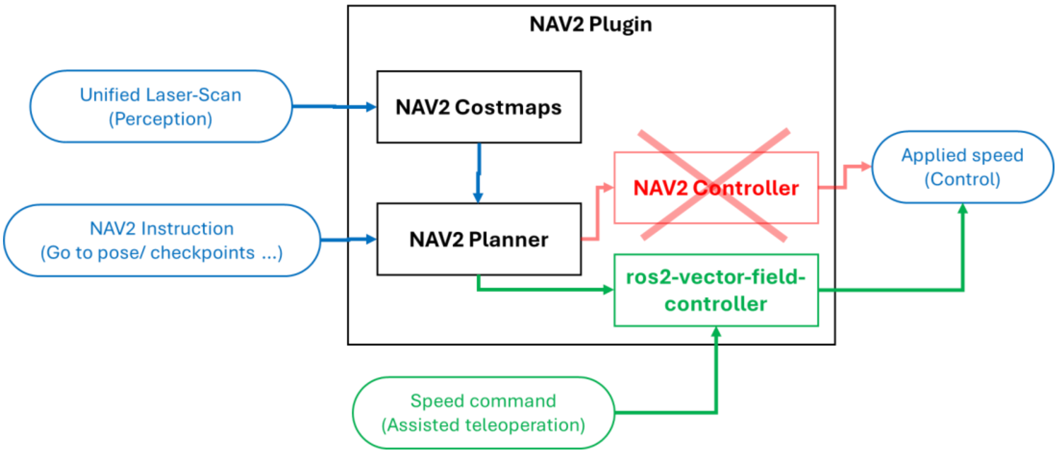


Fig.10: Planned ROS2 Structure using "ros2-vector-field-controller"

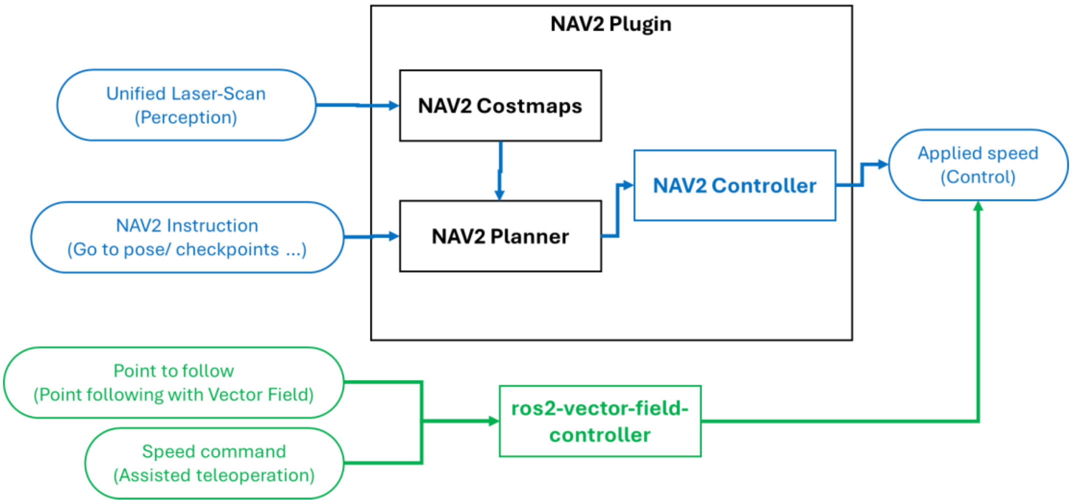


Fig.11: Implemented ROS2 Structure using "ros2-vector-field-controller"

Again, **Fig.12** provides a simple illustration of how our package works. But for more details and the underlying theory, please refer to our repository [**22**]. Currently, the package can run on CALL-M but is not yet fully integrated with the NAV2 planning system as shown **Fig.11**. Nonetheless, we have obtained some results regarding assisted teleoperation and point following while avoiding obstacles. **Fig.13** shows an example of the computed vector field around the robot when it attempts to follow an attractive point. The speeds that the robot will follow are represented by the purple arrows. We can observe how those arrows are repulsive near obstacles. This controller has proven to be efficient for assisted teleoperation and point following. Videos demonstrating these capabilities are available on our GitHub repository [**22**].

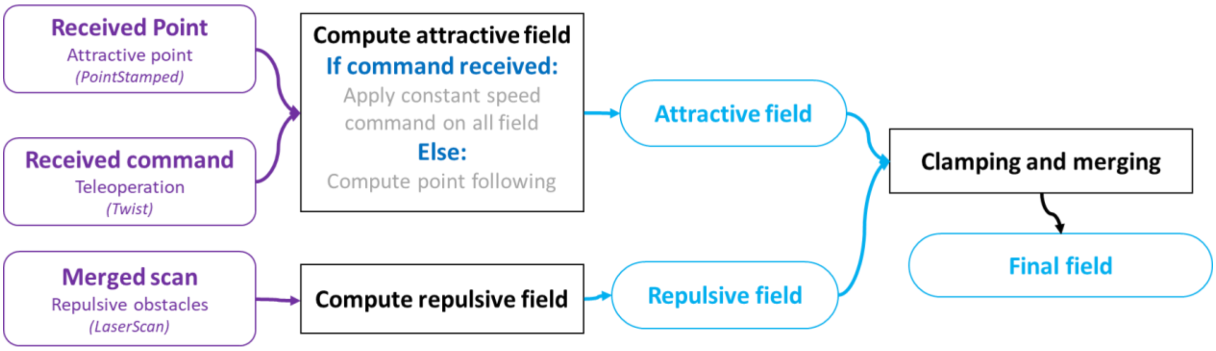
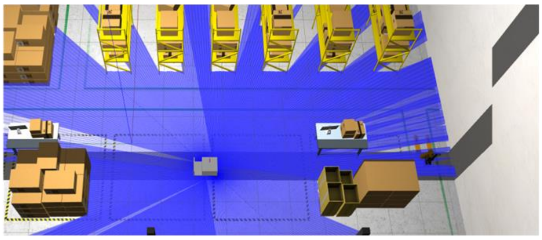
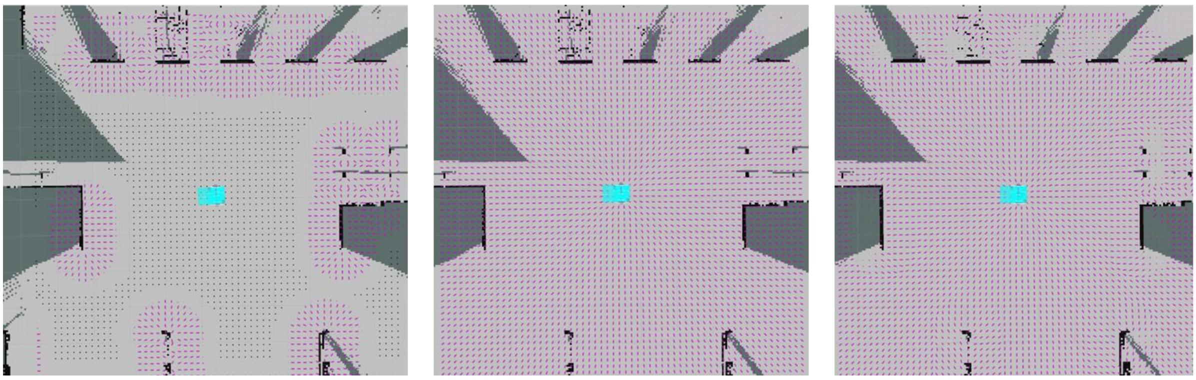


Fig.12: Simple code schematic for "ros2-vector-field-controller"



(a) Simulated environement



(b) Repulsive Field (c) Repulsive Field (d) Final Vector Field

Fig.13: Example of computed Vector Field with the simulated CALL-M robot

3.2. Omnidirectional actuator (Research Assistant)

As a Research Assistant, I initially focused on developing a system to enhance haptic feedback, specifically a device that generates a sensation of tangential speeds on the fingers when the avatar robot slides its finger over a surface. My research and conclusions on this topic are detailed in section 3.2.1. However, as introduced in section 2.2, my findings led to the development of an omnidirectional actuator more suited for mobile robotics. Section 3.2.2 explains this omnidirectional actuator and its potential applications in mobile robotics.

3.2.1. Haptic applied research and limitations

Haptic technologies can be divided into two primary categories: cutaneous feedback, which stimulates the skin's surface using vibrations, pressure, or temperature changes, and kinetic feedback, which applies forces to the user's body through actuators and motors, simulating physical resistance and movement. Both types of haptic feedback enhance user interaction by providing tactile cues that complement visual and auditory information, making experiences more immersive and realistic.

The CNRS-AIST JRL laboratory, where I worked for 10 months, is actively researching technologies to improve these feedback mechanisms. Currently, there is no performant, easy-to-wear feedback device that allows a user to teleoperate a robot effectively from a distance and perform complex tasks without extensive training. My research focused on improving haptic feedback through gloves. The laboratory already has an avatar teleoperated robot and a trained user capable of performing tasks such as opening a door, pushing a button, or grabbing objects. The gloves used can generate kinetic feedback to add resistance to the fingers once an object is grabbed, but the cutaneous feedback is limited to vibrations.

Therefore, I initially concentrated my research on enhancing this cutaneous feedback. Specifically, as shown in **Fig.14**, I was interested in adding the sensation of tangential speeds. This feature, which is not present in any existing device, would allow a user to precisely place their fingers on objects or surfaces. Knowing how fast the robot's fingers are moving on a surface enables better control of the robot's behavior compared to relying solely on visual feedback from a camera. Latency and errors from the user's estimated speed through the camera often lead to the user moving too fast or too slow, necessitating more training to understand the robot's sensitivity.

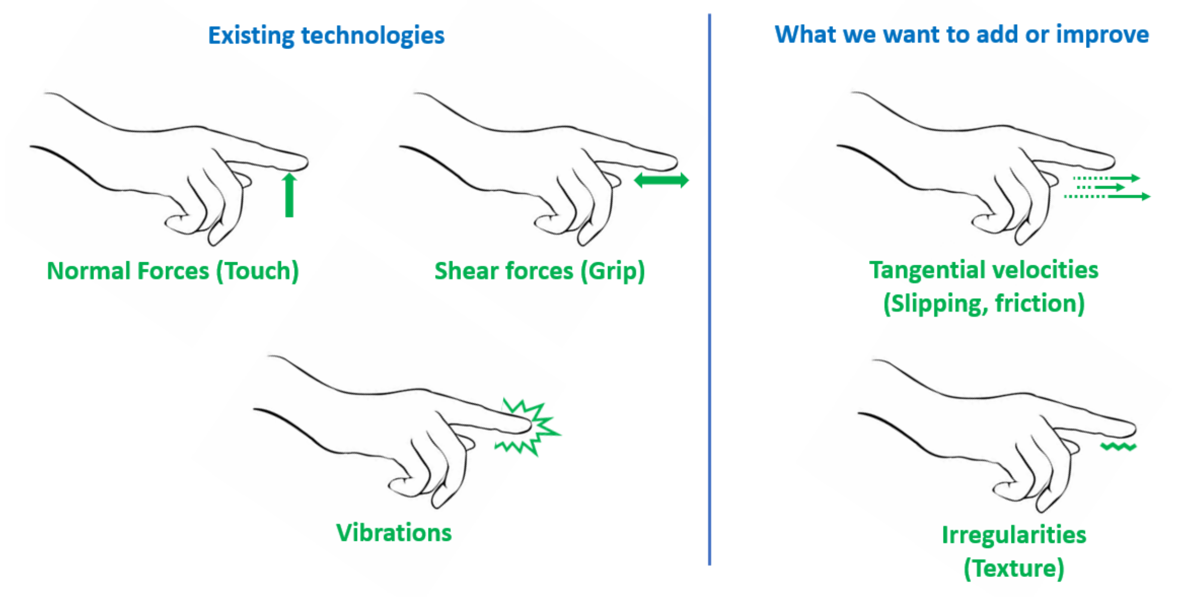


Fig.14: Cutaneous Haptic Feedback, State of the Art

To generate the sensation of tangential speeds on the skin, several technologies could be considered, such as pressurized air or electro-tactile stimulation. However, the chosen solution needed to be compact enough to be implemented on gloves (using pressurized air would require an external compressor) and operate at low voltage. Therefore, the initial concept was to develop an electrically actuated haptic pad using tiny motors that could generate tangential speeds in any direction. We can refer to this as an omnidirectional pixel, as multiple such pixels would be required to generate speeds around the fingers in the desired areas of the skin.

Fig.15 illustrates this concept, showing a schematic view of the omnidirectional pixel on the left and the theoretical way it would be used to create a flexible pad that wraps around each finger on the right. The main challenge with this actuator is making it small enough for practical use.

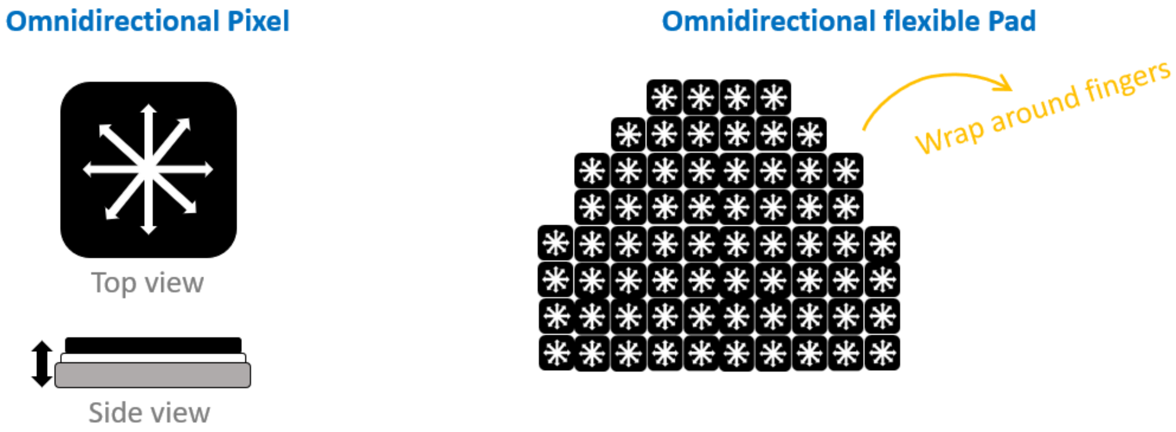


Fig.15: Tangential speed feedback actuator concept

The first concept developed for the omnidirectional pixel is illustrated in **Fig.16**. On the left, the theoretical 3D schematic shows a motor rotating on clutches, each of which can be controlled to determine how much they are engaged using a linear actuator. This allows us to control the amount of power transmitted through each clutch by friction. By manipulating these clutches and maintaining a constant motor speed, the system can drive the upper sphere by friction in any direction using just one motor and two linear actuators.

This design was chosen to minimize the number of motors required, as motors with sufficient torque are difficult to miniaturize with current technologies. In contrast, linear actuators, such as those using piezoelectric actuators, can already generate micro translations with high loads [**23**]. The right part of **Fig.16** shows the corresponding realistic CAD (Computer-aided design) model used to validate this transmission concept using existing technologies constraints.

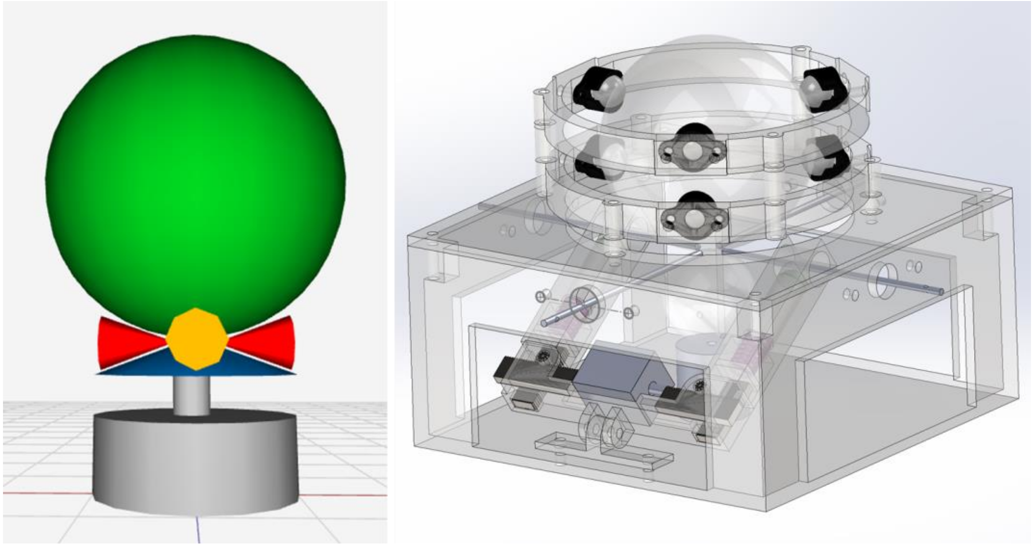


Fig.16: 3D theorical concept & 3D CAD for omnidirectional Pixel (120mm length)

Using SolidWorks, we simulated the speed transmission from the motor to the sphere using the clutches, which could be engaged to varying degrees. However, we could not prove that the sphere could be driven correctly in the desired direction. This system heavily relies on friction forces competitions, which are not yet fully understood, making it impossible to control with an open-loop system. A controller with sphere speed feedback would be necessary, but this would require adding more sensors, further complicating miniaturization.

Considering these difficulties, I had to explore other, simpler designs that could generate omnidirectional speeds. The most suitable actuator found is presented in **Fig.17**. As shown in the figure, this actuator can drive the sphere by friction using only two motors. The simulations as proven that this design is able to generate speeds in any direction.

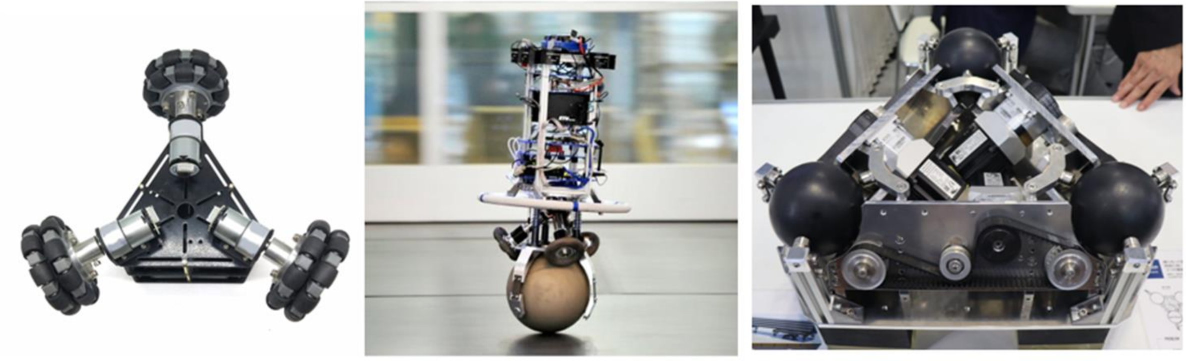
However, this design still presents the same drawbacks as my previous attempts: it is currently difficult to miniaturize.

Fig.17: Last Omnidirectional Pixel prototype (55 mm diameter)

Thus, although we ultimately decided that this design was not suitable for integration into haptic devices, we found potential in exploring its use in other applications, such as industrial rollers or mobile robotics. And we decided to focus on how this type of omnidirectional transmission could contribute to omnidirectional robot technologies. The next section describes my work and results in this area.

3.2.2. Omnidirectional robot on soft spheric roller (patent application)

Existing omnidirectional robots are extensively used in resource storage for large warehouses, such as those operated by Amazon. Several structures exist for such robots, some of which are presented in **Fig.18**.



(a) Omnidirectional robot using 3 omni wheels

(b) Omnidirectional robot using 3 servomotors and 1 spheric roller

(b) Omnidirectional robot using 3 servomotors and 3 spheric rollers

Fig.18: Omnidirectional robot examples

During my internship, I focused on improving the design illustrated **Fig.18.b**, After meeting with the French team from Enchanted Tools [**24**], who develop a similar robot, I learned that the main drawback of this design is its lack of adaptability to uneven terrain. The rigid roller only allows for limited navigation on flat surfaces without irregularities. To address this, we aimed to extend the capabilities of such a robot by using a soft roller instead of a rigid one. This would enable the robot to absorb any irregularities on the floor and achieve more stable navigation on uneven terrain.

However, considering a soft, flexible skin inflated with air for the roller, we could no longer use the design in **Fig.18.b**, which requires the servomotors to be mounted tightly on the roller. Therefore, we designed a new transmission system adapted to drive a soft skin, with a support inside to allow for correct power transmission. We don't have any materials to represent the soft roller and its inner support yet, but the transmission system, called the "Coaxial Multi-Channel Rotary Transmission System," is presented in **Fig.19**. A patent with AIST-CNRS JRL is pending for this design.

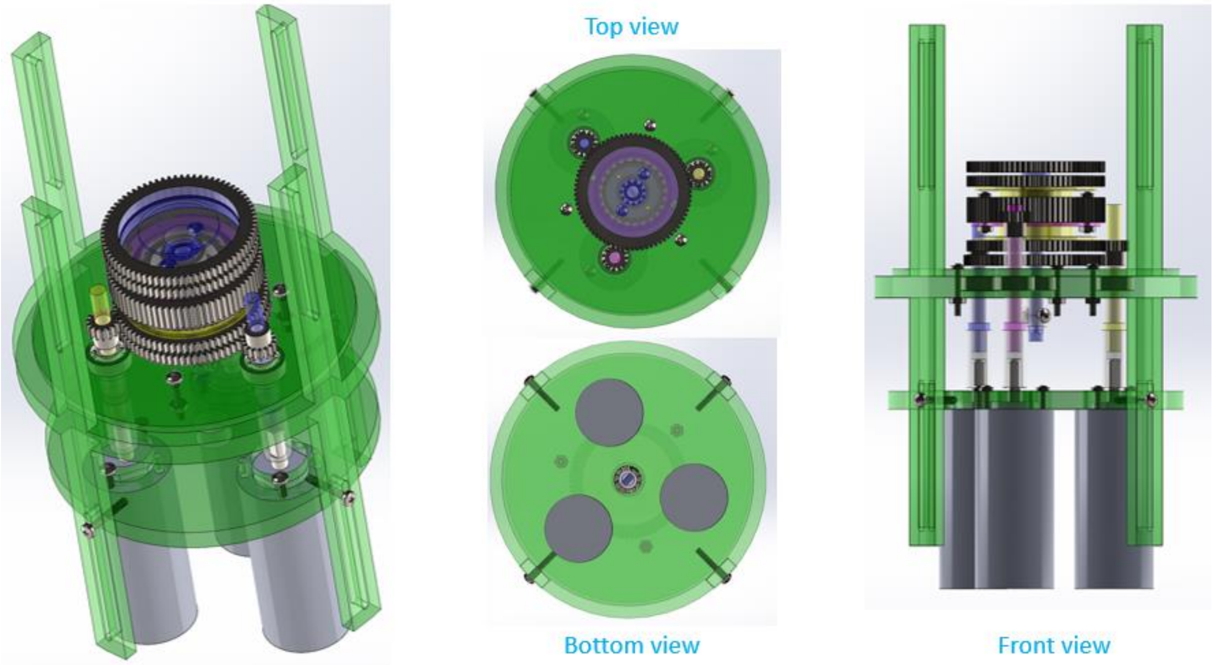


Fig.19: Coaxial Multi-Channel Rotary Transmission System CAD

This transmission system allows for power transmission on three independent coaxial axes. Any head can be attached to it, converting these rotary transmissions into the desired motion. In our case, this transmission system will be used to drive a soft spherical ball. The head chosen for this purpose is illustrated in **Fig.20**. It has been designed to maximize contact points that drive the ball, thus avoiding shearing of the soft skin and fitting the future support that will be inside the roller. This head converts two of the rotary motions to drive the Omni wheels (which will be used to drive the spherical roller in the future) so that the ones in the same plane will rotate in the same direction. The last rotary motion is used to allow the head to spin. Thus, this design allows for the transmission of linear speeds in any direction and a rotational speed.

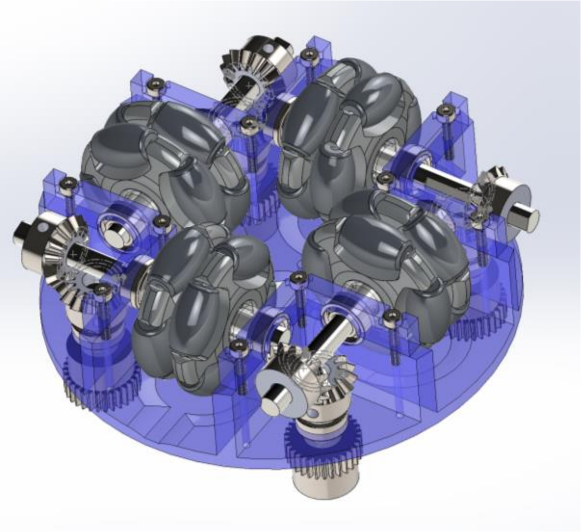


Fig.20: Header for power transmission to a soft spheric roller

We were able to 3D print most of the parts and create a prototype to test this transmission system before further developing the soft spherical roller. As shown in **Fig.21**, we successfully assembled the prototype and performed some tests.

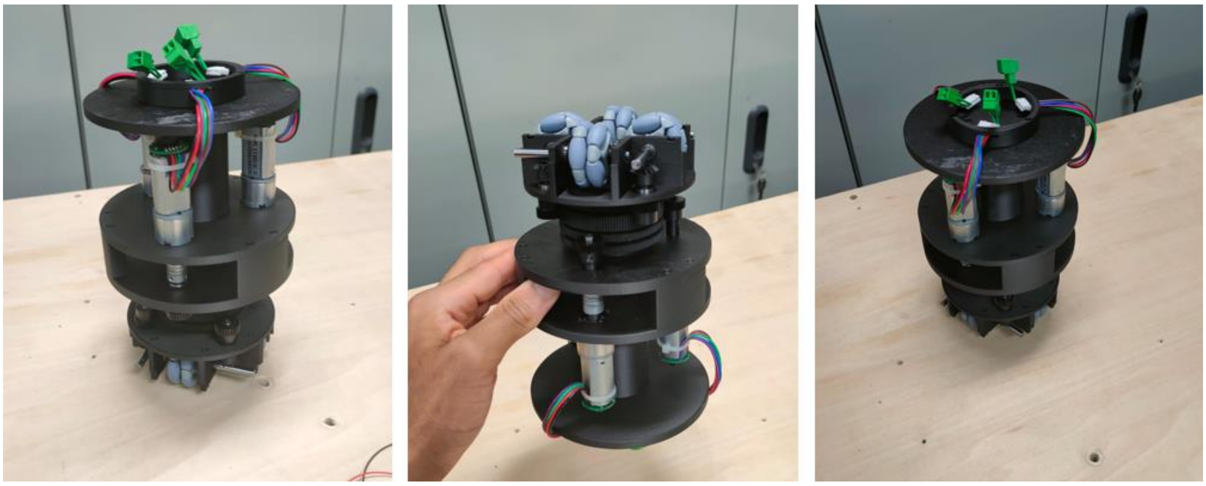


Fig.21: Soft spheric roller transmission system

For the control, the design makes it a bit more complex as the rotation speed influences the linear speeds. A controller to manage this has been theorized. **Fig.22** illustrates this open-loop controller structure without the detailed coefficients. However, due to time constraints, this controller could not be implemented, and simple tests were performed using potentiometers to manually control each motor. **Fig.23** shows the wiring used for this simple control.

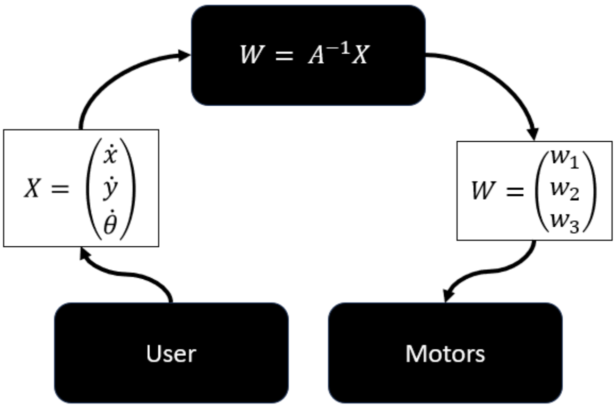


Fig.22: Open Loop controller used to control the prototype

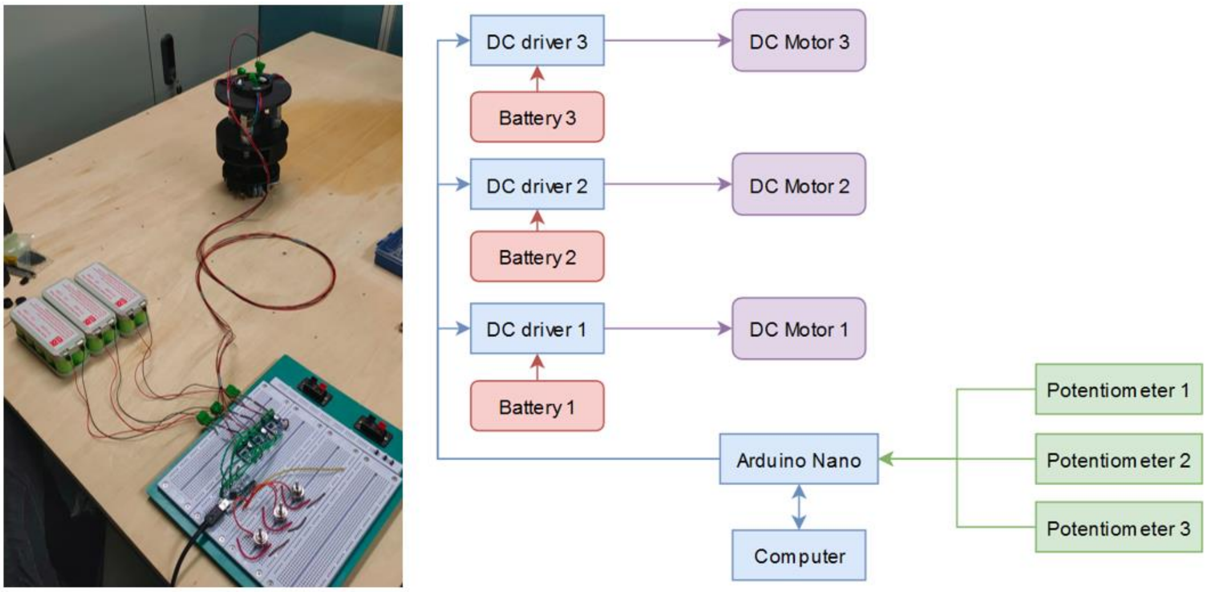


Fig.23: Wiring to manually control each motor with potentiometers

Finally, the performed tests were aimed at verifying whether such a transmission system could generate omnidirectional speeds and spin on itself without affecting linear speeds. All these motions could be performed, and the JRL laboratory decided to apply for a patent. The robot is now ready to be integrated with a soft spherical roller, which still needs to be developed. I am currently gathering a team at my school, ENSTA Bretagne, to work on this further development.

4. Conclusion

To conclude, my work as a research assistant initially focused on developing an haptic cutaneous feedback system to generate the sensation of tangential speeds on fingers. After several simulations, it became apparent that the solution, called the "omnidirectional pixel," was not feasible with current technologies. However, the system I designed seemed more suitable for mobile robotics applications. I was able to investigate and design a new model aimed at driving a soft spherical roller, which would enable stable navigation on uneven terrain while maintaining holonomic capabilities. Although I could only print and assemble the transmission part of this robot at CNRS-AIST JRL, for which a patent is waiting, I am motivated to continue further developments with the robotic club at ENSTA Bretagne.

My work as an intern provided me with an intensive engineering experience. I developed an entire ROS2 workspace from scratch, including sensor and driver-level algorithms up to high-level navigation and mapping algorithms. I created a novel lightweight approach for 2D navigation that considers 3D obstacles by fusing all sensor data into a Laser-Scan message. This solution proved to reduce computational load while maintaining good navigation quality through dynamic obstacles, and I was able to submit a paper to the SII25 conference. Additionally, I developed an omnidirectional navigation controller based on repulsive and attractive vector fields, aiming to enhance the NAV2 plugin's controller. This controller demonstrated smooth behavior when navigating to a point or following user speed commands. Unfortunately, I did not have time to submit this contribution to the NAV2 maintainers.

This internship was incredibly enriching, as it allowed me to experience working both as a researcher and as an engineer. I also gained valuable knowledge about applying for patents and submitting papers to conferences. This experience has greatly helped me decide whether to pursue a PhD or work in a company. However, since I have only done laboratory internships so far, I feel I still need to experience the work rhythm within a company.

5. Acknowledgements

I would like to express my gratitude to my supervisor, Rafael Cisneros, at CNRS-AIST JRL, for his unwavering support and guidance throughout my developments and decision-making processes.

Additionally, I extend my thanks to all the members of the JRL for the incredible experiences I had both within the laboratory and outside of it in Japan. The weekly seminars allowed me to learn a lot about my domain, as well as other domains that I was not previously familiar with.

Finally, I would like to thank Luc Jaulin, my supervisor from France, for allowing me to pursue this internship abroad during my year off.

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ENSTA
Bretagne

RAPPORT D'EVALUATION
ASSESSMENT REPORT

Merci de retourner ce rapport par courrier ou par voie électronique en fin du stage à :
At the end of the internship, please return this report via mail or email to:

ENSTA Bretagne – *Bureau des stages - 2 rue François Verny - 29806 BREST cedex 9 – FRANCE*
☎ 00.33 (0) 2.98.34.87.70 / stages@ensta-bretagne.fr

I - ORGANISME / *HOST ORGANISATION*

NOM / *Name* National Institute of Advanced Industrial Science and Technology (AIST)

Adresse / *Address* 1-1-1 Umezono, Tsukuba, Ibaraki, 305-8560 JAPAN

Tél / *Phone (including country and area code)* +81-80-2204-2363

Nom du superviseur / *Name of internship supervisor* Rafael Cisneros Limon

Fonction / *Function* Researcher

Adresse e-mail / *E-mail address* rafael.cisneros@aist.go.jp

Nom du stagiaire accueilli / *Name of intern* Ocean Noel

II - EVALUATION / *ASSESSMENT*

Veuillez attribuer une note, en encerclant la lettre appropriée, pour chacune des caractéristiques suivantes. Cette note devra se situer entre **A (très bien)** et **F (très faible)**
Please attribute a mark from ***A (excellent)*** *to* ***F (very weak).***

MISSION / *TASK*

- La mission de départ a-t-elle été remplie ? [✓ A] B C D E F
  Was the initial contract carried out to your satisfaction?

- Manquait-il au stagiaire des connaissances ? ☐ oui/*yes* ☒ non/*no*
  Was the intern lacking skills?

  Si oui, lesquelles ? / *If so, which skills?*

ESPRIT D'EQUIPE / *TEAM SPIRIT*

- Le stagiaire s'est-il bien intégré dans l'organisme d'accueil (disponible, sérieux, s'est adapté au travail en groupe) / *Did the intern easily integrate the host organisation? (flexible, conscientious, adapted to team work)*

  [✓ A] B C D E F

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here* Ocean had no problem adapting to team work. He was always participating actively in the team discussions.

COMPORTEMENT AU TRAVAIL / *BEHAVIOUR TOWARDS WORK*

Le comportement du stagiaire était-il conforme à vos attentes (Ponctuel, ordonné, respectueux, soucieux de participer et d'acquérir de nouvelles connaissances) ?

Did the intern live up to expectations? (Punctual, methodical, responsive to management instructions, attentive to quality, concerned with acquiring new skills)?

[✓ A] B C D E F

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here* Ocean was responsible and extremely methodical and hard-working. He usually outperformed any given task. I would say that he surpassed the initial expectations of his internship.

INITIATIVE – AUTONOMIE / *INITIATIVE – AUTONOMY*

Le stagiaire s'est –il rapidement adapté à de nouvelles situations ? [✓ A] B C D E F
(Proposition de solutions aux problèmes rencontrés, autonomie dans le travail, etc.)

Did the intern adapt well to new situations? [✓ A] B C D E F
(eg. suggested solutions to problems encountered, demonstrated autonomy in his/her job, etc.)

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here* Ocean usually worked autonomously, solving by himself most of the problems that he encountered.

CULTUREL – COMMUNICATION / *CULTURAL – COMMUNICATION*

Le stagiaire était-il ouvert, d'une manière générale, à la communication ? [✓ A] B C D E F
Was the intern open to listening and expressing himself /herself?

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here* Ocean was always open to listen and hear recommendations, as well as to express his points of view.

OPINION GLOBALE / *OVERALL ASSESSMENT*

❖ La valeur technique du stagiaire était : [✓ A] B C D E F
Please evaluate the technical skills of the intern:

III - PARTENARIAT FUTUR / *FUTURE PARTNERSHIP*

❖ Etes-vous prêt à accueillir un autre stagiaire l'an prochain ?

Would you be willing to host another intern next year? ☒ oui/*yes* ☐ non/*no*

Fait à ____________________, le ____________________
In Tsukuba, Ibaraki, Japan , on October 1st, 2024

CNRS-AIST JRL
(Joint Robotics Laboratory),
UMI3218/RL
AIST Central 1, 1-1-1 Umezono,
Tsukuba, Ibaraki 305-8560 Japan
Tel: +81-298-61-3443

Signature Entreprise ____________________ Signature stagiaire
Company stamp ____________________ *Intern's signature*

Merci pour votre coopération
We thank you very much for your cooperation