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Report

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Robotics for Automated Inspection using a Multimodal Sensor Gimbal

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Abstract

Railway inspection is essential to ensuring the safe and efficient operation of rail networks. Regular inspections help detect structural faults around railway lines, preventing accidents that could lead to severe damage. As part of the European IAM4RAILS project, a collaboration between NORCE and SNCF is developing a robot to automate this process. The robot uses various sensors, including cameras and LIDARs, to inspect cables, electric pillars, rails, and tunnels. Innovative techniques, such as cable reflection detection to estimate wear, and 2D LIDAR for rail and cable positioning, are being explored. A tunnel scanning system is also being developed to identify structural issues. To validate these solutions, a field test was conducted, recording data from the sensors. The control of these sensors by a user is an integral part of the project, with different options explored such as using a basic gamepad, or a SteamDeck.

Résumé

L'inspection des chemins de fer est essentielle pour garantir le fonctionnement sûr et efficace des réseaux ferroviaires. Des inspections régulières permettent de détecter les défauts structurels autour des lignes ferroviaires, évitant ainsi des accidents qui pourraient entraîner de graves dommages. Dans le cadre du projet européen IAM4RAILS, une collaboration entre NORCE et la SNCF développe un robot pour automatiser ce processus. Le robot utilise divers capteurs, notamment des caméras et des LIDARs, pour inspecter les câbles, les poteaux électriques, les rails et les tunnels. Des techniques innovantes, telles que la détection du reflet d'un câble pour estimer l'usure, et l'utilisation d'un LIDAR 2D pour déterminer la position des rails et des câbles, sont utilisées. Un système de scan des tunnels est également en cours de développement pour identifier d'éventuels problèmes dans sa structure. Pour valider ces solutions, un test sur le terrain a été réalisé et a permis d'enregistrer des données des capteurs. Le contrôle de ces capteurs par un utilisateur fait partie intégrante du projet. Différentes options ont été explorées, tel que l'utilisation d'une manette de jeu ou d'un SteamDeck.

Acknowledgements

First of all, I'd like to thank my tutor Atle Aalerud, who trusted me throughout my internship and answered my questions at all times, before, during and after the internship. I would also like to thank all the members of the NORCE office in Grimstad who were very kind to me and helped me when I arrived.

Special thanks also go to the other trainees with whom I worked during the insternship: Julien, Thomas, Yasmine, Siwon, Mathieu, Valentin and Léa.

Glossary

cantiveler A cantiveler is a horizontal rigid structure unsupported at one end. 5, 10

catenary system Overhead lines system transporting power and providing it to the train, through the pantograph. 5, 8, 10

Contact wire An overhead line providing power from the catenary line to the pantograph of an electric train. 5–11, 18, 23

LIDAR Laser Imaging Detection and Danging, a lidar is a device using is a method for determining ranges by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver. 2, 5–7, 11–13, 17–20, 22–24

pantograph A mechanical device mounted on the roof of an electric train to collect power through an overhead line. 7, 8, 10

ROS Robotical Operating System. 18–20, 23

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Introduction

Presentation of NORCE and the DARWIN team

NORCE is an independant research institute which works on many fields such as energy, health care, technology, etc... The NORCE group is divided in 3 sections (Climate & environment, Energy & Technology, and Health & Social Sciences) plus a commercialisation department. The internship was inside the **Energy & Technology** section, in the DARWIN team.
Indeed, there are several NORCE research teams all around Norway working on different topics. The DARWIN team is manly focused on the conception of machines with non-conventional sensing in order to fully embrace the capacities of sensors in automation. The DARWIN team works on societal problems such as transports, infrastructure maintenance or industrial automation.

Context of the internship

The internship was supervised by Atle Aalerud, senior researcher part of the DARWIN team specialised in sensor technology. The internship will be part of a large European project named IAM4RAIL. IAM4RAIL aims to link and automatize the European railway network by working on different automatised devices, better traffic management and share of data between national European railway networks. This European project includes more than 90 partners and dozens of use cases [3]. The sub-project led by NORCE in this context, in collaboration with SNCF, is to provide an automatized system for railways infrastructures monitoring, using different types of sensor and actuators.
Before the beginning of the internship, a lot had already happened. The choice of the sensors and actuators was already done, and most of the sensors were already bought. Thanks to the work of the previous interns the use case of each sensor was precisely documented[1].

Objectives

In this context, the goal of the internship was the hardware and software integration of several sensors, in order to perform a test on field to record data. This includes the implementation of a zoom camera, spotlight, thermal camera, pan-tilt unit, RTK GNSS/INS, machine vision camera, barlight, 2D and 3D LIDAR, joystick, SteamDeck for tele-operation, and an industrial PC. The test was done using a locomotive, however the sensors will then be put on a mobile platform designed by the french company SNCF.
This document will first explain the application for the different sensors, then the software and hardware implementation will be presented. And finally, the data recorded during the on-field test will be presented.

1 Infrastructures monitoring

This chapter contains mainly background, relevant to understand the internship. It will summarize the work of the previous student regarding the use of the sensors in this project.
First, it is important to understand how a train works, and which are the infrastructures more exposed to wear.

1.1 Catenary system monitoring

1.1.1 Cable wear monitoring

The Contact wires are use to provide power to the train. In Norway, a single overhead cable is used for the electricity supply, as the return path is through the railways. The contact between the train and the Contact wire is made through a pantograph as it is shown in figure 1. It is important that the pantograph keeps a constant pressure on the Contact wire in order to avoid electrical irregularities. To do so, a pneumatic pressure is used, it enables a constant pressure, but also to decrease the risk of damage on the Contact wire and on the pantograph. Indeed, too low pressure leads to the apparition of electric arcs, and too much pressure leads to increased wear on both the Contact wire and the pantograph.

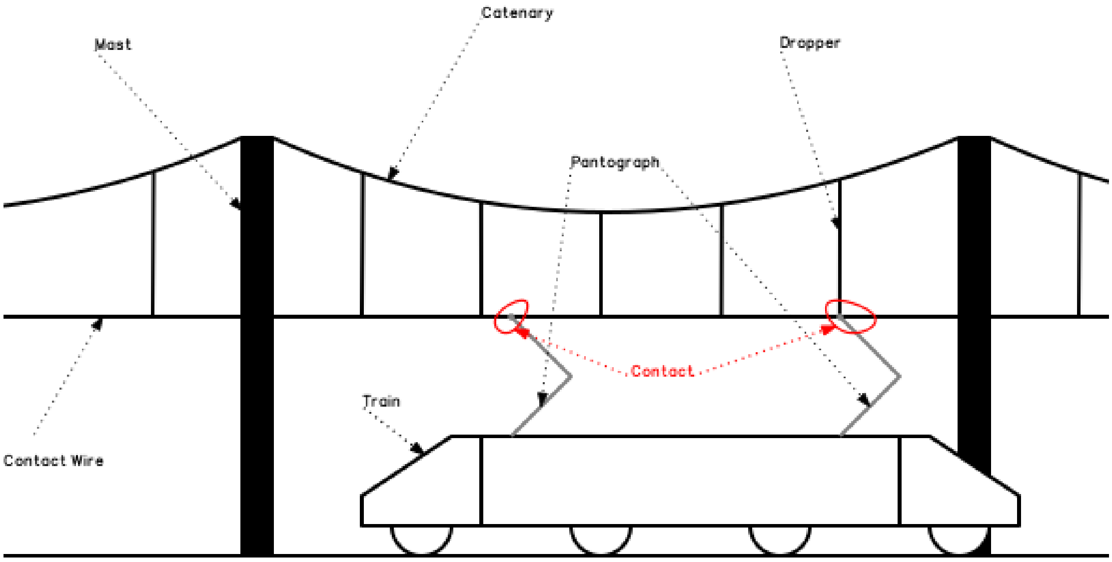
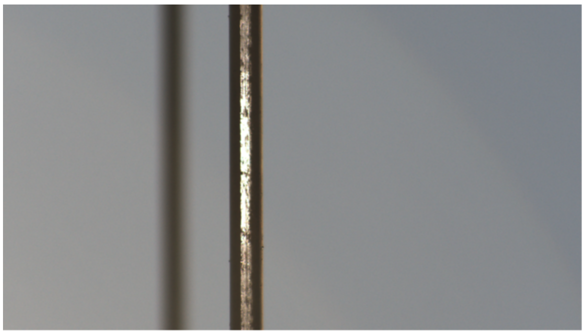


Figure 1: Scheme representing a simplified side view of a catenary system

However, even so the risk of damage is reduced with the right constant pressure, with time, wear appears on the Contact wire which can lead to its breakdown. A regular observation of the Contact wire is thus necessary to anticipate better its wear and possible breakdown. However currently, the observation process is very slow and costly since it has to be done manually.
In order to reduce the costs, an innovative way of determining the wear of the Contact wire by using reflection of light. Indeed, the more the Contact wire is damaged, the more part of the cable which is in contact with the pantograph will be flattened and thus the reflection of the light will be wider.



(a) Light source

(b) No light source

Figure 2: Difference between a cable lighten and a cable with no light source [1]

Using a camera and image processing, the width of the wear can be determined since the reflection is highly visible on the camera as it is shown on figure 2 [1]. The figure 2a is a picture of a copper cable lighten meanwhile figure 2b has no light source. The reflection of light where the cable is flat due to the wear is highly visible on figure 2a. This principle is therefore very useful for the objectives since it enables to estimate automatically the wear of Contact wire.
Then, in order to detect clearly the wear, the cable has to be illuminated by a powerful light so the wear appears very strongly on the picture. Furthermore, the camera needs to be placed around 1m

above the ground because of the size of the mobile platform, then, the light has to be strong enough to illuminate the Contact wire which is from 5m to 5.6m above the ground.

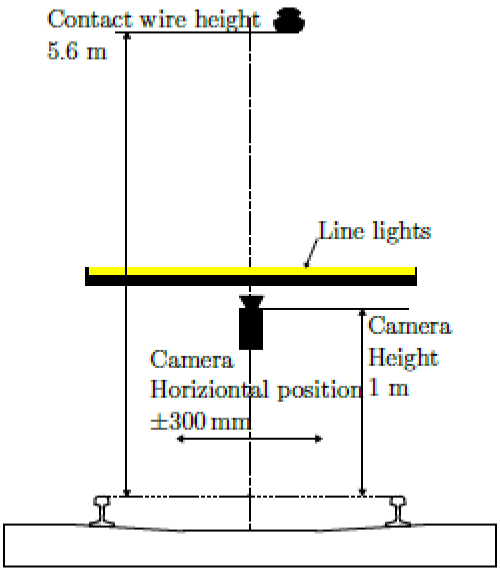


Figure 3: Scheme showing the solution imagined to light the Contact wire [1]

Figure 3 shows a solution imagined by the former interns to light the Contact wire. The idea is to fix a camera to a powerful line of lights in the direction of the cables. This structure enables to have the best possible reflection on camera, and to have light below the Contact wire in any situation. Indeed, the catenary system is built following a lateral zig-zag pattern of max 400mm width (in Norway) [4]. Therefore the bar light needs to be large enough to illuminate the Contact wire in every possible position (max ±400mm from the center of the rails). Then, using an image processing program, the wear can be automatically estimated as it is shown in figure 4.

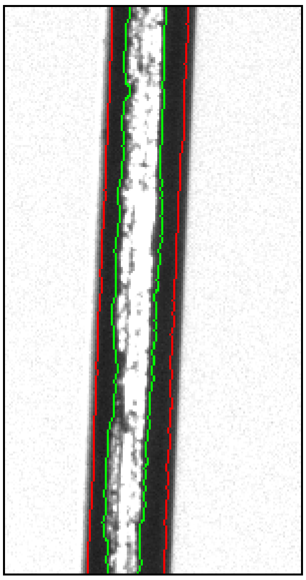


Figure 4: Estimation of wear on a cable using the reflection and image processing [1]

1.1.2 Mast and cantiveler monitoring

The previous point was focusing on analyzing the wear of the Contact wires using the reflection of a light. However, the wear of the cables due to the direct contact with the pantograph is not the only potential source of breakdown for the cables. Indeed, another critical zone is the junction between the mast and the cables. In railways, this part is called the cantiveler due to its shape.

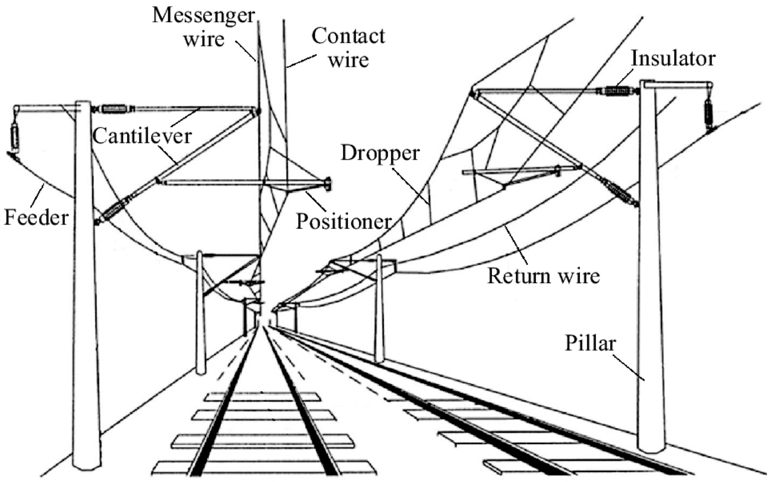


Figure 5: Scheme representing a front view of a catenary system [2]

The cantivelers support the catenary and the Contact wire as it is shown on figure 5. In each end of the wires, pulleys and counterweights ensures a constant tension in both catenary and contact wire [1]. Thus, it is important to regulary verify that the cantivelers are not damaged to unsure the stability of the whole catenary system. A simple solution that has been found for inspecting the cantiveler, is to use a camera with a big zoom which could be controlled by a user first, and then automatically. The targeting can be controlled using an external actuator.

Figure 6: Picture of a cantiveler along railway in Norway

1.2 Rails and cables positioning

To answer the requirements of the project, the Contact wires and rails position must be measured [1]. In order to accomplish this task, a 2D LIDAR can be used. It must be placed strategically on the robot, since it needs to detect the rails and the cables at the same time.

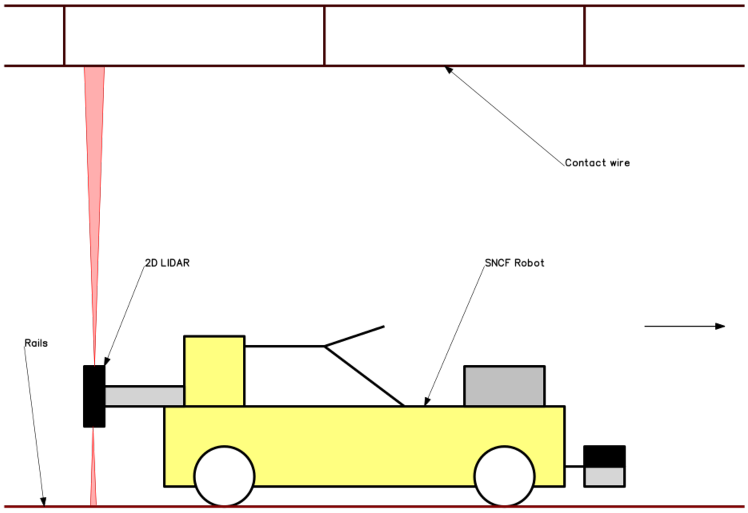


Figure 7: Scheme representing the 2D LIDAR "seeing" both the cables and the rails

In order to detect both the rails and the cables, the LIDAR must be placed in the front or in the back of the robot. Indeed, the robot must not block its vision as it is represented in figure 7. Also, the 2D LIDAR must be placed the higher possible in order to maximize the probability that a laser beam touches the Contact wire. Also a higher position will minimize the angle of reflection. Indeed, if the angle of reflection of the laser is too big, the 2D LIDAR will not detect its reflection and thus the laser beam will be lost. If the position of the 2D LIDAR is right, the Contact wire can be detected as it is shown in figure 8.

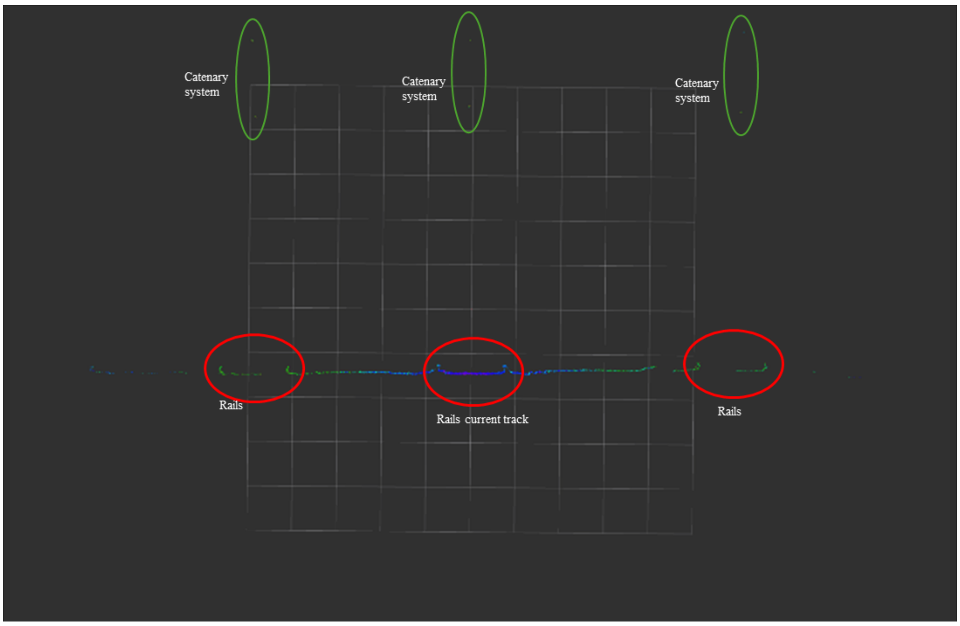


Figure 8: 2D LIDAR cloud point build from data taken on a railway, visualised using Rviz2. Size of squares: 1m side

Several tracks and cables can be seen in figure 8, however only the actual track where the robot is, needs to be analyzed. The rails appears clearly on the image inside the red circle, whilst the cables are less visible since they are thinner but they still appear inside the green ellipse. Once the data can be used, the next step is to get their position automatically. To do this, some assumptions needs to be made:

- The cables are always in the same zone: 5m±1 above the ground, max ±400mm from the center of the tracks;
- The rails width is the standard gauge: 1,435mm

These 2 assumptions are useful to apply a filter to the data, in order to reduce the search area of cables and rails. Also, reducing this zone, it prevents from confusing a cable or rails with anything else. Another parameter to implement is the height where the 2D LIDAR is placed. Figure 9 illustrate which are the zone to study in order to be sure to detect the rails and cables, without having the risk to detect another object.

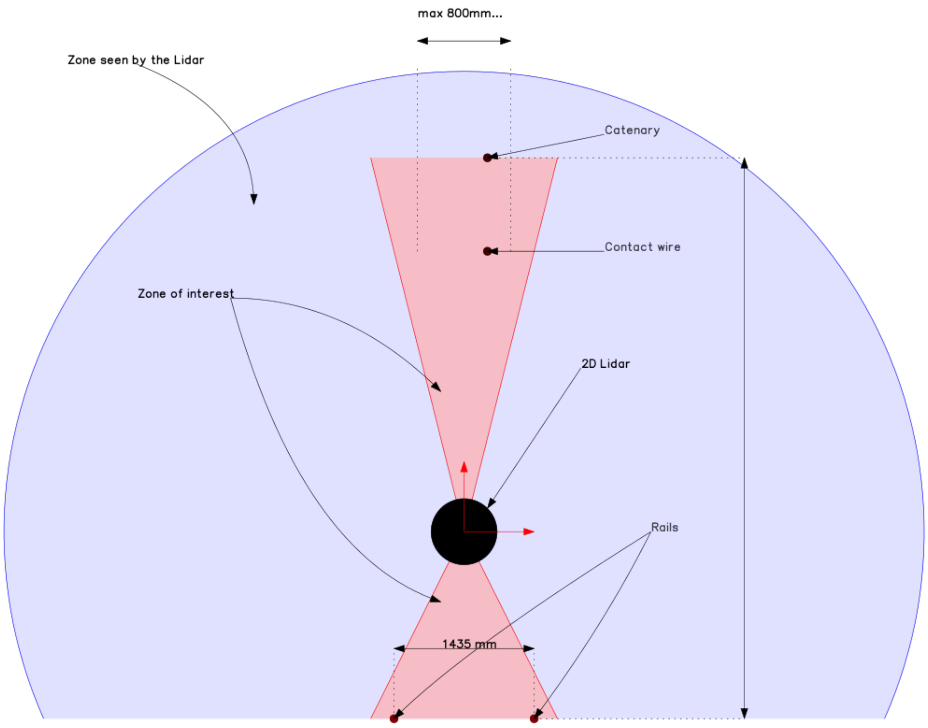


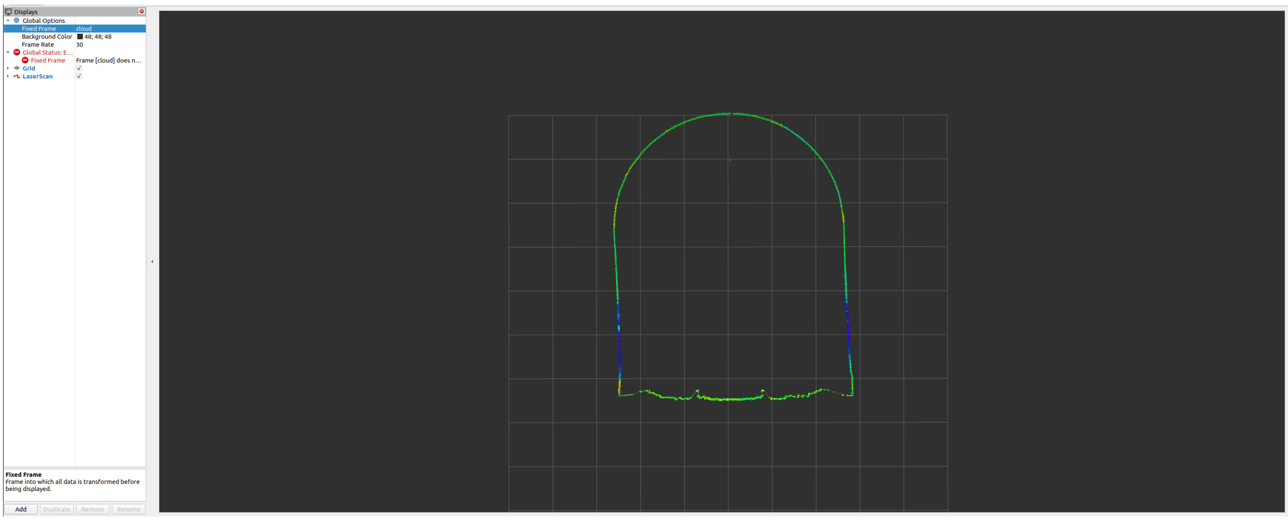
Figure 9: Scheme showing the zone to study in order to get only the cables and rails

Using this technique, it is possible to automatically detect the laser beams reflection, corresponding to the cables and the rails ranges. Then, the relative position between the rails and the cable can be computed and studied. This technique is quite rudimentary since if for any reason the cable or the rails are not inside the zone of interest, there will be no possibility to detect them. However, it is sufficient for now since if the objects are not inside the zone of interest, that means that there is significant damage to the structure and it will be visible by the user.

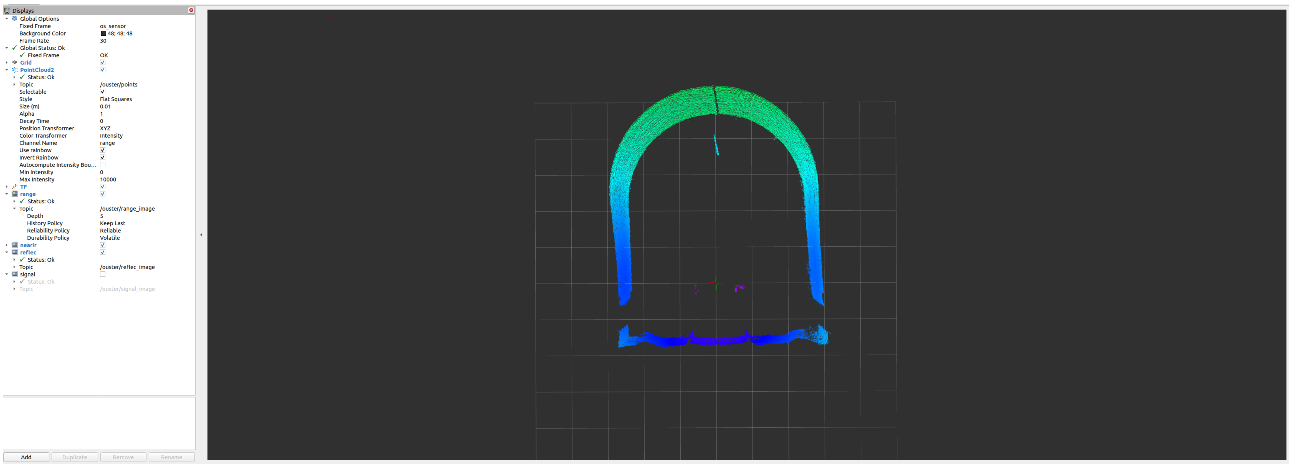
1.3 Tunnel scanning

Scanning the profile tunnel can be useful to detect damages to the structure and prevent from serious accident. For scanning the tunnel, a 3D LIDAR in translation is used with a scanning pattern radial to the tracks.
There's a significant difference between 2D and 3D LIDARs for this task. A 2D LIDAR only scans a single line across the railway, which can leave gaps in the data because objects along the track might

block parts of the tunnel wall, creating shadows. On the other hand, a 3D LIDAR, with its broader field of view, can capture multiple angles as it moves along, helping to fill in those gaps as it is shown in figure 10 (The gaps on the 3D LIDAR's data are due to its position on the structure when the data was taken).



(a) Scan 2D



(b) Scan 3D

Figure 10: Scanning the profile tunnel with 2 different LIDARs: one 2D and one 3D. Visualized using Rviz2

Another advantage of 3D LIDARs is that, as long as the scan rate matches the speed of the platform, the scans will overlap. This overlap makes it easier to stick the scans together into one complete image using software. With 2D LIDARs, very precise measurements would be necessary to accurately piece together the scans [1].

1.4 Manual control and automation

1.4.1 Manual control

For the first version of this project, the goal would be to have a user controlling the sensors. The user would also have access to the images sent by the different cameras, and the other data in real time. There are many thing to control, such as the switch on/off of the bar-lights, the zoom of the "zoom camera", and the actuators enabling to move the "zoom-camera". In order to achieve this goal, two options were developed. One is temporary meanwhile the other is more permanent.

Controlling through a basic joystick controller

This temporary solution is to control the sensors and actuators using a simple gamepad. The joystick controller would be plugged directly to an embedded pc connected to the sensors. As for the visualization of the images and the data, a simple screen can be used. Despite not being very practical, this solution is quite easy to set up and can work effectively. Additionally, gamepads are very common in daily life, making it easy to use for any user. The downgrades of such a solution are the organisation of the space, since a screen must be connected to the embedded pc without falling. Also it is absolutely not waterproof. This solution can be used for first tests, but will not be suited for the final robot.

Controlling through a Steam Deck

The Steam Deck is a handheld gaming console designed by Valve for playing PC games anywhere. It runs on a customized version of Linux called SteamOS. It features a touchscreen, built-in controls, and the ability to connect to an external display making it very interesting for this project. It has everything the user could need for controlling the sensors and actuators. However, it is not as easy as a joystick controller to implement. Indeed, in order to control the sensors, and display the data and images it must be connected to the embedded computer.

1.4.2 Automatic control

A more distant objective is to automatize some of the sensors and actuators such as the "zoom camera" for instance. Using GNSS position of the robot, and GNSS position of the targets, it is possible to automatically control the actuators linked to the "zoom camera", and the zoom of the camera.

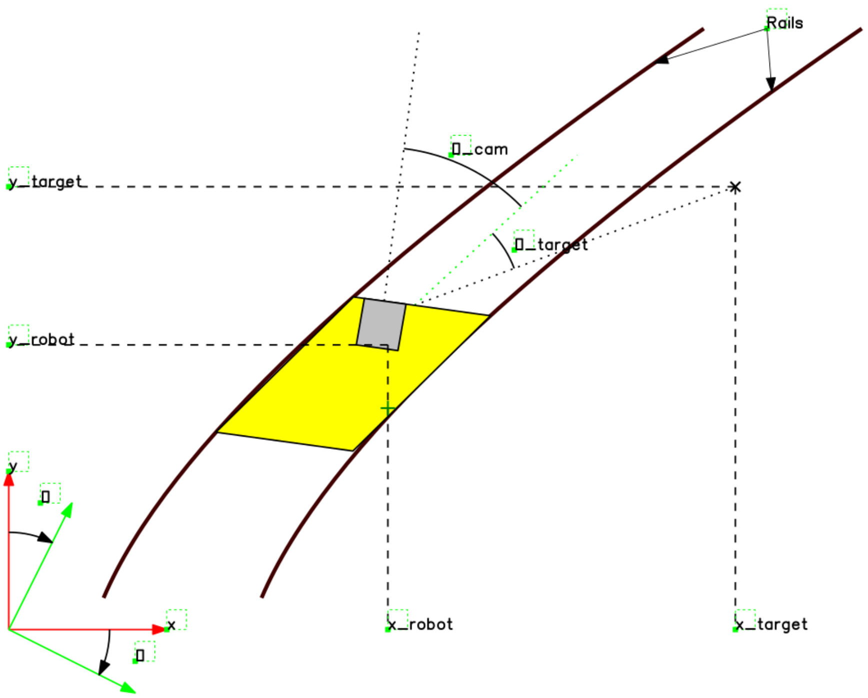


Figure 11: Scheme representing the angles to take in account for the target locking

In order to control automatically the actuators on the "zoom camera", some information described in figure 11 is needed:

- (x_{robot}, y_{robot}): GNSS coordinates of the robot in a local reference;
- (x_{target}, y_{target}): GNSS coordinates of the target in a local reference;

- θ: the heading of the robot;
- θ_{cam}: the orientation of the camera relatively to the heading;
- θ_{target}: the angle between the heading and the target;
- h_{target}: the height of the mast

Using a GNSS antenna and an IMU, it is possible to get the heading of the robot as well as its position. The angle θ_{cam}, and the GNSS localization of the targets can also be considered as known. However, in order to be able to compute the angle θ_{target}, the coordinates of the robot and of the target must be projected in the same local reference. For this projection, the library PROJ can be used [5], from GNSS coordinate WGS84 to UTM zone 32N corresponding to south Norway.
Once the coordinates are projected in a local reference, they can be used for computing the angle between the robot's heading and the target with this formula:

$$\theta_{target} = \arctan_2(y_{target} - y_{robot}, x_{target} - x_{robot})$$

Then, as a first approach the actuator can be controlled using a proportional controller. The error for this controller would be:

$$err = \theta_{target} - \theta - \theta_{cam}$$

. Using the "sawtooth" function, the controller would be:

$$pan_{cmd} = k_2 * sawtooth(err)$$

Since the mast are higher than the robot, a control command must be implemented so the camera can point at the right altitude. First, the distance between the target and the robot must be computed using pythagore. Since it is in 3D we get :

$$distance = sqrt(pow(dx, 2) + pow(dy, 2) + pow(dz, 2))$$

with dx, dy, and dz the distances between the target and the robot on each axis. Then, to get the height error, we compute:

$$height_{err} = asin(dx/distance)$$

Finally, the command can then be computed:

$$tilt_{cmd} = k1 * sawtooth(height_{err})$$

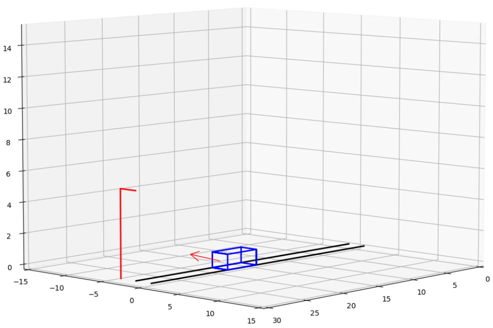


Figure 12: Simulation of the target locking

2 Implementation of sensors

The previous part was about presenting the systems to be implemented during the internship. Most of them were already imagined before the beginning of the internship (such as the use of reflection, or cable and rails positioning), however they were not yet designed. Most of the sensors were bought, and tested. The goal of this internship was to implement all the sensors to make them work together, and enabling a user to control them easily. This part will focus on which sensors were used, and how were they implemented.

2.1 Hardware integration

2.1.1 List of sensors

The table 1 is a list of all sensors that were implemented during the internship, and how they were used.
Components already chosen before the beginning of the internship:

Sensor	Use in the project
	The Ace2 Basler camera will be used to film the contact wire as represented in figure 3. A lens must be added and the camera must be calibrated to get an image as sharp as possible of the cables.
	A sick LIDAR LRS4581R was used in the configuration represented in figure 7.
	The Imagingsource Z20 camera was used as a "zoom camera", indeed it has a strong zoom and can be controlled by a user thanks to its c++ open source library **tiscamera**.
	An Ouster LIDAR OS1 was used for the tunnel scanning. It was already used in previous projects so it was easier to configure it.
	A Xsens MTI80 IMU was chosen for this project, it includes a GNSS antenna with RTK.
	This Pan-Tilt Unit (PTU) from Flir was used to be able to move the "zoom camera". It uses serial communication and thus, can be controlled through a computer. However, it can not be controlled using its speed which makes it not practical for automated control.
	Five LXE300 light bars form Smart Vision Light were used as explained in figure 3. Several bars can be easily connected thanks to its integrated connectors which makes it very adapted for the project.

Table 1: List of the sensors and their use in the project.

Component chosen during the internship:

If every sensors where already chosen, the embedded computer still had to be chosen and configured. The computer K804 from the company OnLogic was selected for its price, strong physical resistance, and its variety of possible configuration. The most important components to select in the configuration were the CPU, GPU and storage. Indeed, the computer had to have robust performance to handle the ROS2 workspace, and to store the data which can be heavy as it will be explained in this report. Also, in prevention for the future, the computer had to be able to process live data. This is why a strong GPU had to be selected.
Thus, a Intel Core i9-12900E 16 cores CPU, and a Nvidia RTX A4000 GPU-16 GB were chosen. For the storage, a 1 TB SSD disk was added which should be enough for the missions the robot is supposed to complete.
As for the power, an Ecoflow battery of 1000Wh power capacity was chosen.

2.1.2 Architecture

The electric architecture is divided in two parts, linked by an embedded industrial computer. The two parts are physically separated. All components of the first part will be on the same mechanical piece meanwhile the components of the second part will be on another mechanical piece.

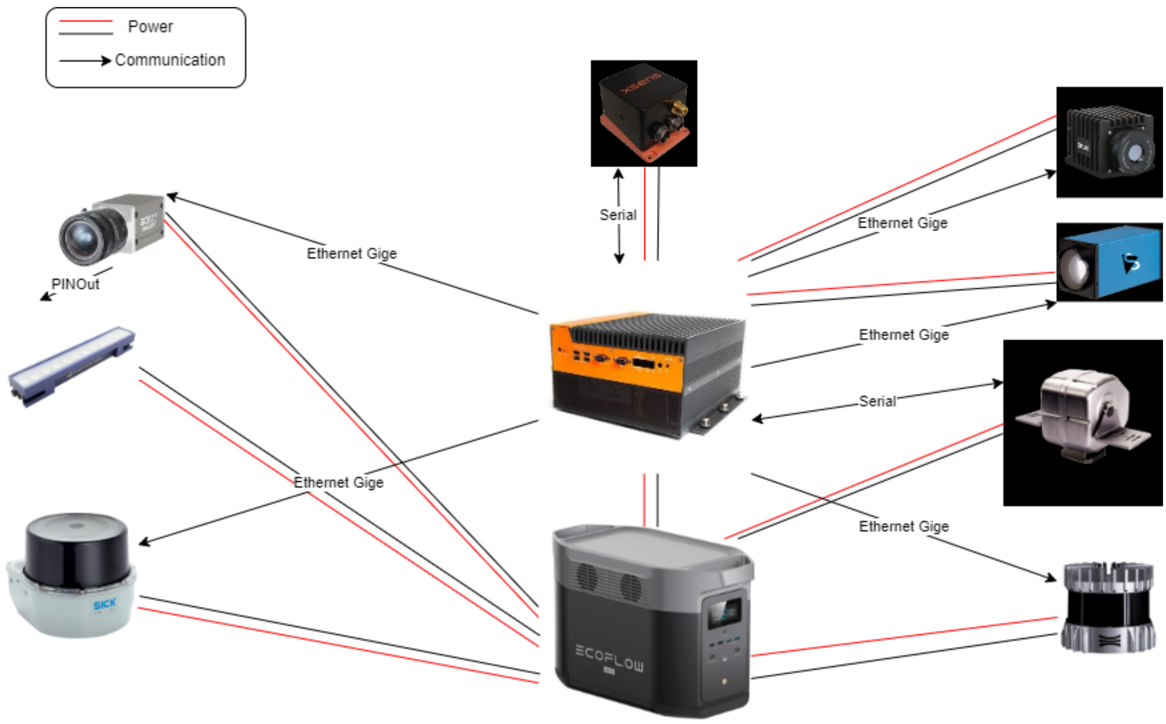
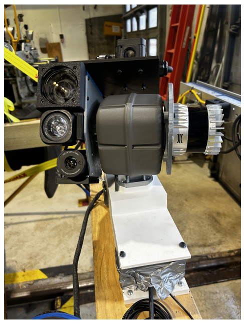


Figure 13: Scheme of the electric architecture of the robot

The first part is composed of the Basler camera, the bar lights and the sick LIDAR. This part will be use to determine the position of the cables and of the rails, and to estimate the wear of Contact wires. In the future, it will be mentioned as the **rear part**. The second part is composed of the zoom camera, a thermal camera, and a 3D lidar. All these components will be fixed on the PTU which can be controlled by a user. Then, the second part will be useful for tunnel scanning, and to analyze the structures with the zoom camera, and with the thermal camera. In the future it will be mentioned as the **front part**.

(a) Rear part



(b) Front part

Figure 14: Front part and rear part pictures

2.2 Software integration

2.2.1 ROS2

ROS2 (Robot Operating System 2) is an open-source framework for developing robotic software. It provides standardized services for device management, inter-process communication, and package management. The software architecture is based on a system of interconnected nodes, each responsible for a specific task. These nodes communicate with each other through messages, services, and actions, enabling efficient coordination between the various components of the robot.
It is widely used, and its open-source nature makes it highly practical. In this case, official ROS2 drivers can be found for some sensors making them easy to integrate. However, for some other, the driver must be written or modified such as for the Pan-Tilt Unit.

2.2.2 Principal nodes

The principal nodes of the software architecture are:

- **gscam2**: This node brings video streams from GStreamer-supported devices into the ROS2 ecosystem, turning them into image messages that other ROS2 nodes can use. The GStreamer pipeline can be easily modified in order to optimize the video before turning it into a ROS2 message

- **Ouster-ros**: This node integrates Ouster LIDARs sensors into the ROS2 ecosystem. Data from Ouster LIDAR is captured and converted into ROS2 messages, such as point clouds or laser scans, which can then be used by other ROS2 nodes. It can be configured to get a live image, by using the 3D laser scans. It also publishes lighter data that can be recorded in bags without taking too much space, and then be transformed again into lidar scans.

- **xsens-mti-ros2-driver**: This node is the driver of the MTI 80 IMU. It pusblishes the IMU data and GNSS data (if activated) so it can be used by other ROS2 nodes.

- **hal-flir**: The hal-flir node is used to communicate with the Pan-Tilt Unit. It gets the current position of the PTU through serial communication, and transforms it into ROS2 messages. It can also send position commands to the PTU, using the serial communication.

- **pylon-ros2-camera-component**: Similarly to the gscam2 node, this node gets video stream from Pylon-supported (usually Basler components) devices into the ROS2 ecosystem. It also enables to control the camera through services (such as the Region Of Interest, or the activation of pins).

- **sick-scan-xd**: Similarly to the Ouster-ros node, this node integrates Sick LIDARs sensors into the ROS2 ecosystem. Data from Sick LIDAR is captured and converted into ROS2 messages, such as point clouds or laser scans, which can then be used by other ROS2 nodes.
- **spinnaker-camera-driver**: This node enables to get video stream from Flir thermal cameras, and transforms it into ROS2 image messages. It also interacts with the camera to eventually change its settings such as the view (thermal or visual).
- **teleop-twist-joy**: Teleop-Twist-Joy enables to transform gamepad or joysticks inputs into ROS2 messages that can be used by other nodes. It enables to control the sensors, like the position of the PTU, the bar lights, the zoom of the "zoom-camera" or the view of the thermal camera.

All nodes are written in c++.

2.3 Network organisation

The Ethernet communication is widely used in this project. It offers a wide transfer data which is necessary for sensors like LIDARs or cameras. Furthermore, some cameras use POE (Power Over Ethernet) connection making the cable management easier (one cable for data and power).

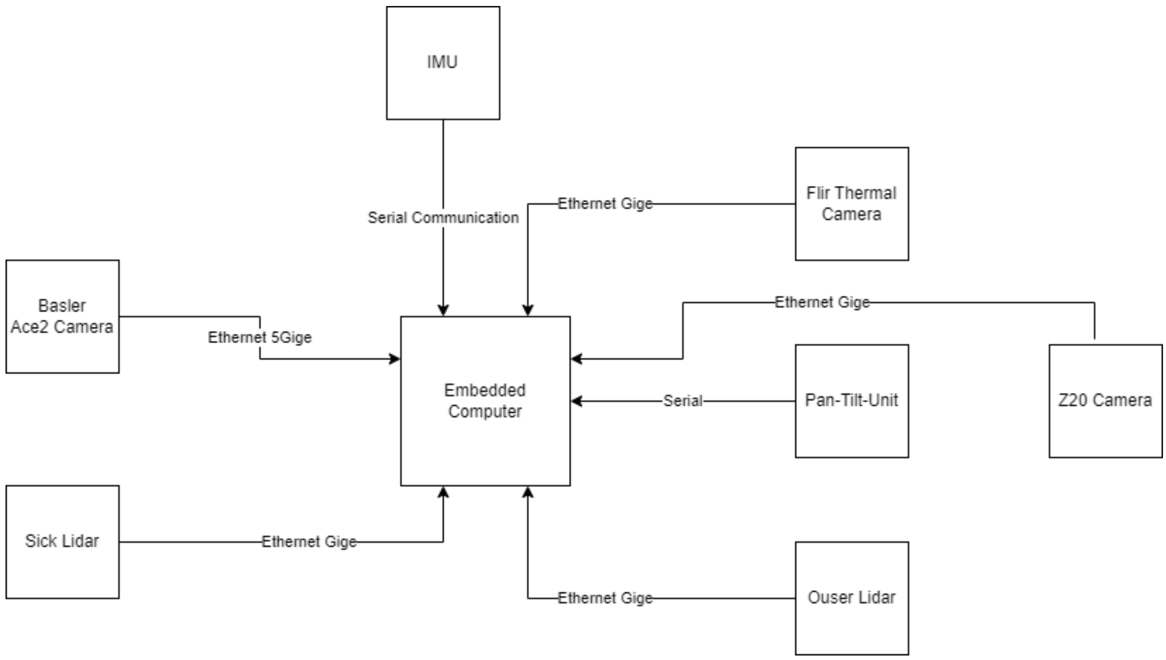


Figure 15: Scheme of the network organization of the robot

Since the cameras and LIDARs use large bandwidth, each sensor must be configured on different subnets. Otherwise, it will create problems in the connection.

3 Final test and results

3.1 Test organization

In order to test our sensors and to get some data that can be used to train the methods described in first part, a "on-field" test needed to be planned. Since the actual structure of the robot was not available (still being designed by SNCF in France), the sensors had to be fixed on a train. A first meeting with the local railway company was planned to see what could be used to fix the equipment.

(a) Picture of a wagon potentially useful to fix our sensors

(b) Picture of the locomotive that would be used the day of the test

Figure 16: Picture of a locomotive and a wagon that were presented to us to see if they could be useful for the test

After this visit, the locomotive seemed the more appropriate to the test. It has a cabin inside where a small desk could be organised. The locomotives buffers could be used to fix a simple wooden structure shown in figure 17.

Figure 17: Image of the structure that was made for this test

The main constraint to build this structure was to try to avoid vibrations. Indeed, any vibration will have an impact on the data collected, and especially on the zoom camera. Since it has a very powerful zoom, a slight vibration will be felt strongly on the video stream. Then, in order to prevent from the vibration, straps were added.

3.2 Mission

The data recording was made in railways around the repair Station of the company BANE NOR in the city of Kristiansand. The goal of the test was to record all the data needed to develop/test the

software programs described in the first part of this report.
These are the principal data needed:

- **Tunnel scanning**: For the tunnel scanning, the data needed are the 3D LIDAR's data and the IMU data;
- **Estimating the wear of the cables**: Image of the cables from the Basler Camera;
- **Analyzing the masts**: Image of the zoom-camera, and image of the thermal camera;
- **Automatic control**: GNSS data, position of the PTU, heading from the IMU;
- **Rails and cables positioning**: 2D LIDAR's data.

During the test

The test started around 9 A.M and ended around 3 P.M, 5 people in total were inside the locomotive. 2 people were from BANE NOR, one to pilot the locomotive, and the other to supervise the mission for safety reasons. 3 people from NORCE, 2 interns and the internship tutor. One intern was charged of the mechanical part, and the other of the sensors part. To launch the sensors, the "control centre" was in the small cabin, next to the pilot. Also, this position enables to have a great view on the structure to be sure that nothing goes wrong.

(a) Picture of the control centre inside the cabin in the locomotive

(b) View from the control center on the structure

Figure 18: Picture of a locomotive and a wagon that were presented to us to see if they could be useful for the test

There was different situation that were needed for the test:

- One static measurement outside;
- One static measurement inside a tunnel;
- One measurement session in slow movement (5km/h) inside a tunnel;
- One measurement session in slow movement (5km/h) outside;

The static measurement sessions were important to collect data that we can use for sure for the development of the software's program. Indeed, these data will not be disturbed by any external event (something breaking because of the movement for example). Then, the measurement in movement enables to see if the rates of the sensors are fast enough to get usable data. This is crucial to understand

what are the points to improve, and to test if the calibrations are optimal.
During the test, the command to activate the bar lights failed to work. These lights are crucial for accurately estimating cable wear. To address the issue, a workaround was implemented by bypassing the command and connecting the bar lights directly to a power source. Although all the necessary data was collected, some of the data did not meet the expected quality.

3.3 Results

The test was done at the very end of the internship, therefore, there was no time to precisely analyze the data recorded after the test. However some rapid conclusions can still be done. As it was said previously, most of the data was recorded without any problem, but some are not as good as expected.

3.3.1 The Basler Camera

This is the camera used to film the Contact wires, in theory it can provide a maximum 34 frame rate. However, during the test, a 5fps rate was barely achieved which is way to slow to have an efficient live wear estimation. There are several things to verify in order to understand where does the problem comes from. Indeed, it could be due to the ROS2 driver that is not optimised for high frame rates. I could also comes from the internet connection, however this is unlikely since the Basler camera was connected using an 5Gige ethernet card, and no other sensor was using this card. Another solution to this problem could be to set a small region of interest in order to rise up the frame rate.
Also, as it can be seen in figure 19a, when the sky is very bright, it can be very difficult to distinguish the cable wear from the sky (the cable is the one on the left of the picture). In this picture, the wear can steel be seen, but an idea to not confuse the wear reflection with the sky could be to use a very precise Region Of Interest to only look where the cable is. This could be done using the estimated cable position with the 2D LIDAR, or using image processing.

(a) View of the reflection outside

(b) View of the reflection inside a tunnel

Figure 19: Picture of Contact wires for the wear estimation during the test

3.3.2 The Ouster Lidar

The Ouster LIDAR's raw data is too heavy to save it, thus another way to record it is by using "metadata", "lidar packets" and "imu packets". This is a lighter version, that can then be transformed into point cloud using a "metadata reader" as shown in figure 20. Even if this enables to store the LIDAR's data, it can also bring some data loss in the process.

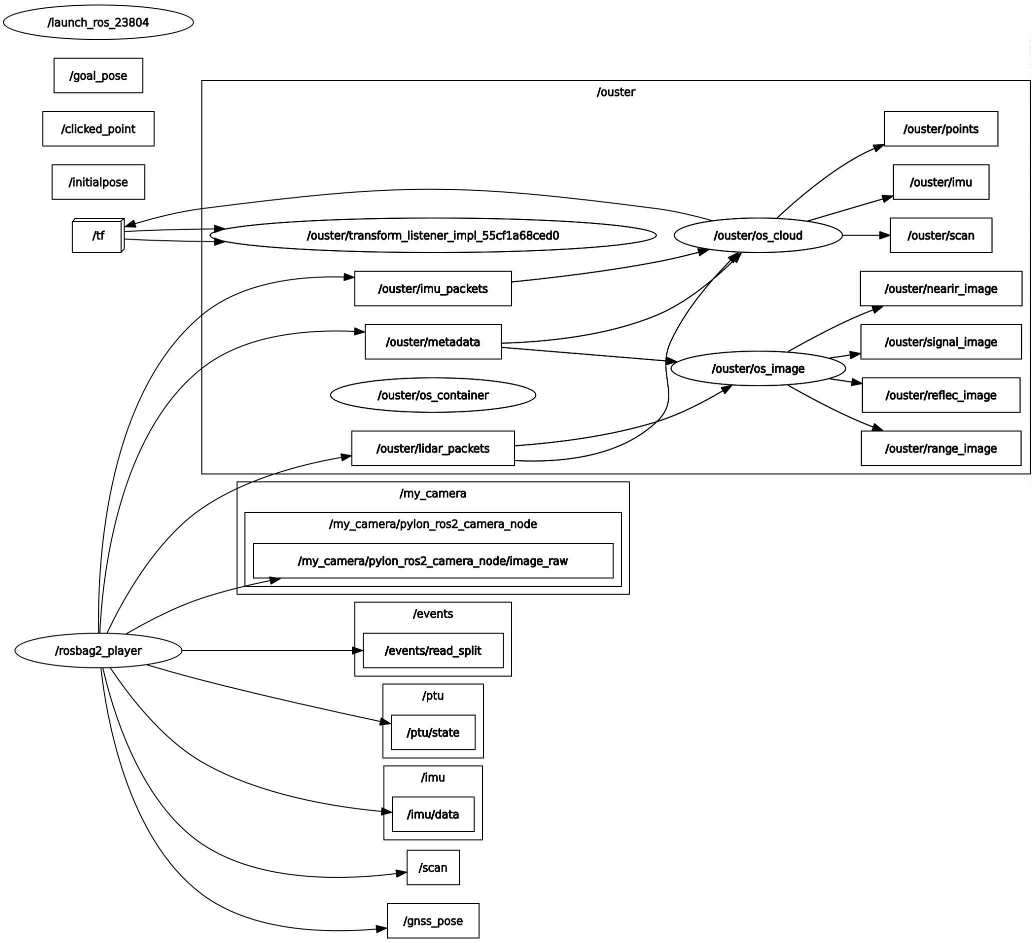
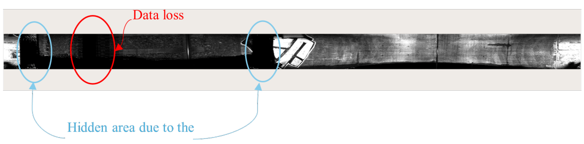
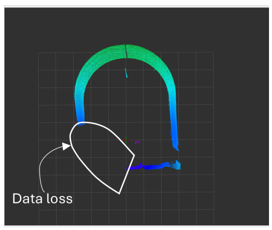


Figure 20: Node graph of the bags of the test being played, and the metadata reader transforming the metadata into a point cloud

The figure 21 shows the repercussions on the visualization of the data loss. This loss can be due to several problems, including the rosbags that cannot keep-up with the rate when there are several topics to record.



(a) View of the data loss on the image generated by the 3D LIDAR scan



(b) View of the data loss on the point cloud generated by the 3D LIDAR scan

Figure 21: Illustration of the data loss on the ouster LIDAR

3.3.3 Other sensors

The 2D LIDAR data were recorded precisely, and can be used to determine the position of the cables automatically as it is shown in figure 10a.

If the other sensors data was recorded as expected, some problems were encountered with the Pan-Tilt Unit. Indeed, the weight it had to support and the cables made it difficult to control precisely. In the future, a change for the actuator might be a good idea.

Conclusion

This project aimed to automatize the inspection of railways infrastructure using different innovative techniques. In this project, the goal of this internship was to do the hardware and software implementation of the sensors, and to develop some software application such as rail and cable positioning or target locking. This work would lead to an "on-field" test at the end of the internship in order to record data. Although some limitations were encountered, a lot of data could be saved and the main objectives were achieved.
The test showed that some sensors will have to be calibrated more precisely (such as the Region of Interest of the Basler camera), and some changed (the Pan-Tilt Unit automated control is too imprecise do to the incapacity to use speed control), but is globally a good step forward in the project.

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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* NORCE Norwegian Research Centre

Adresse / *Address* Jon Lilletuns vei 9H, 4879 Grimstad, Norway

Tél / *Phone (including country and area code)* +47 56 10 79 02

Nom du superviseur / *Name of internship supervisor*
ATLE AALERUD

Fonction / *Function* Senior Researcher

Adresse e-mail / *E-mail address* ataa@norceresearch.no

Nom du stagiaire accueilli / *Name of intern* Gaétan Pérez

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* ____________

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* ______________________________

____

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* ______________________________

____

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* ______________________________

____

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 ____________ ? ____________, on ______ ? ______

Alle Aaboud

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

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