RAPPORT DE STAGE SEMESTRE 8

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« Titre du stage»

Rapport présenté et soutenu à « Lieu », le « date»

Composition du Jury :

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Entreprise :	Upteko ApS
Établissement :	École Nationale d'Ingénieurs de Brest (ENIB)
Dates :	du 06 Mars 2023 au 04 Aôut 2023

Acknowledgement

Je tiens à remercier

I would like to thank. my parents..

J’adresse également toute ma reconnaissance à ....

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Chapter 1

Company presentation

1.1 Field of activity

1.1.1 Wind energy

Upteko has been manually inspecting wind-turbines since 2018. Today, they are using this data and knowledge to build a system to automatically inspect wind turbines Upteko's autonomous drone system will provide high-quality aerial data for all inspections and maintenance requirements, in a safer, more efficient manner, without causing operational downtime. Their drones are pre-programmed with geo-referenced 3D trajectories for the inspection of wind turbines. While flying the planned routes, several images are acquired. The actual number depends on the camera specification, flight altitude and post-processing performance (overlap between images). All images are georeferenced using the UAV position at the acquisition time and these images are afterwards stitched together and in one picture on which the locations of the damages are shown. They deliver these data as per the clients' requirements in raw files or provide a damage report that explains the severity of damages from type 1 to type 5.

1.1.2 Oil and Gas

Upteko is working on a solution for detecting oil spills on the surface of the water. They are developing payloads for their drone system that can help detect the signature of oil floating on water surfaces. This payload can be installed on Lärke and can be used to automatically or manually detect oil spills. Upteko have developed an application to detect pirate attacks on off-shore oil rigs and large commercial ships. Pirates use small ships to attack these oil rigs and large commercial ships at night. They take the crew and contents hostage. There are no mobile long-range detection tools with aerial insight to give the crew information about nearby pirates. This results not only in huge loss to the oil industry but also endangers the crew at huge life risks. The total cost of piracy to the shipping industry, from insurance and time lost, is estimated at over €6B/year. Upteko's multipurpose drone system has a feature called perimeter control. This feature allows any member of the crew to investigate surrounding vessels approaching the premises. A built-in feature within the drone system is added to allow a crew member to operate and control the aerial camera in any direction with no prior drone experience. The geothermic cameras and the infrared sensors help to detect the approach of any pirates faster even during night-time.

1.1.3 Offshore and Maritime

Upteko has been consistently involved with the maritime industry since its inception. They are developing a drone system solution to live on the ship, to connect port operations on the ground and at the sea, with insight from the sky. This system includes a drone and a charging station for the drone that will be installed on the ship. The drone can autonomously perform a variety of tasks and then fly back and charge its batteries while staying protected against the weather. With an in-depth understanding of the challenges that the maritime industries face in attempting long and expensive inspections and other operational tasks, Upteko's software and hardware drone system allows a 100% automatic inspection of a ship in less than 2 hours. Having a permanent drone on a ship will be extremely helpful in a number of cases that can range from Search and Rescue (SAR) operations, vessel docking, dry dock inspections, fire hazard detection and situational awareness among other functionalities.

1.2 History

Upteko™ was founded in 2018 by Mads Joergensen, Benjamin Mejnertz, and Sebastian Duus to pursue the opportunity of developing drone applications for the maritime sector. For Benjamin and Sebastian, it started as a hobby, competing in RC Helicopter competitions around the world and later became a business worth pursuing. Mads came onboard, and together they created Upteko and built a great team of experienced drone pilots, software- and hardware engineers, and business developers. Today Upteko has offices located in Copenhagen, Odense, and Skanderborg. Upteko is about using their creativity and initiative to become leaders in the drone industry. To develop fitting solutions to your needs, they value collaboration and co-creation highly among external parties. Through several years of collaborating with their customers, complementary assets providers, and even competitors, they have achieved priceless partnership within the maritime and other sectors. They are continuously on the hunt for new collaborations.

1.3 Legal and social model

In Denmark, most companies operate under a legal structure of a private limited company (Anpartsselskab, ApS) as Upteko. The country has strong social welfare systems and labor laws, which mandate fair treatment and protection of employees. Danish companies usually have a strong focus on maintaining a healthy work-life balance and uphold high ethical standards, both socially and environmentally.

1.4 Economic model

Denmark follows a mixed-market capitalist system, combining free market principles with a strong regulatory oversight. Upteko operates under a model of sustainable growth, focusing on long-term stability rather than short-term profits. This includes social responsibility, ethical business practices, and environmental sustainability.

1.5 Type of work organization

Denmark has a distinctive workplace culture, often characterized by a flat organizational structure. This implies low power distance, high levels of trust, and extensive collaboration between different levels of the organization. Danish companies typically have strong communication and decision-making practices, promoting employee empowerment and autonomy. Upteko is organised in three main sectors : `Technical Development`, `Finance` and `Product management`. Here is the actual organization chart of the company :

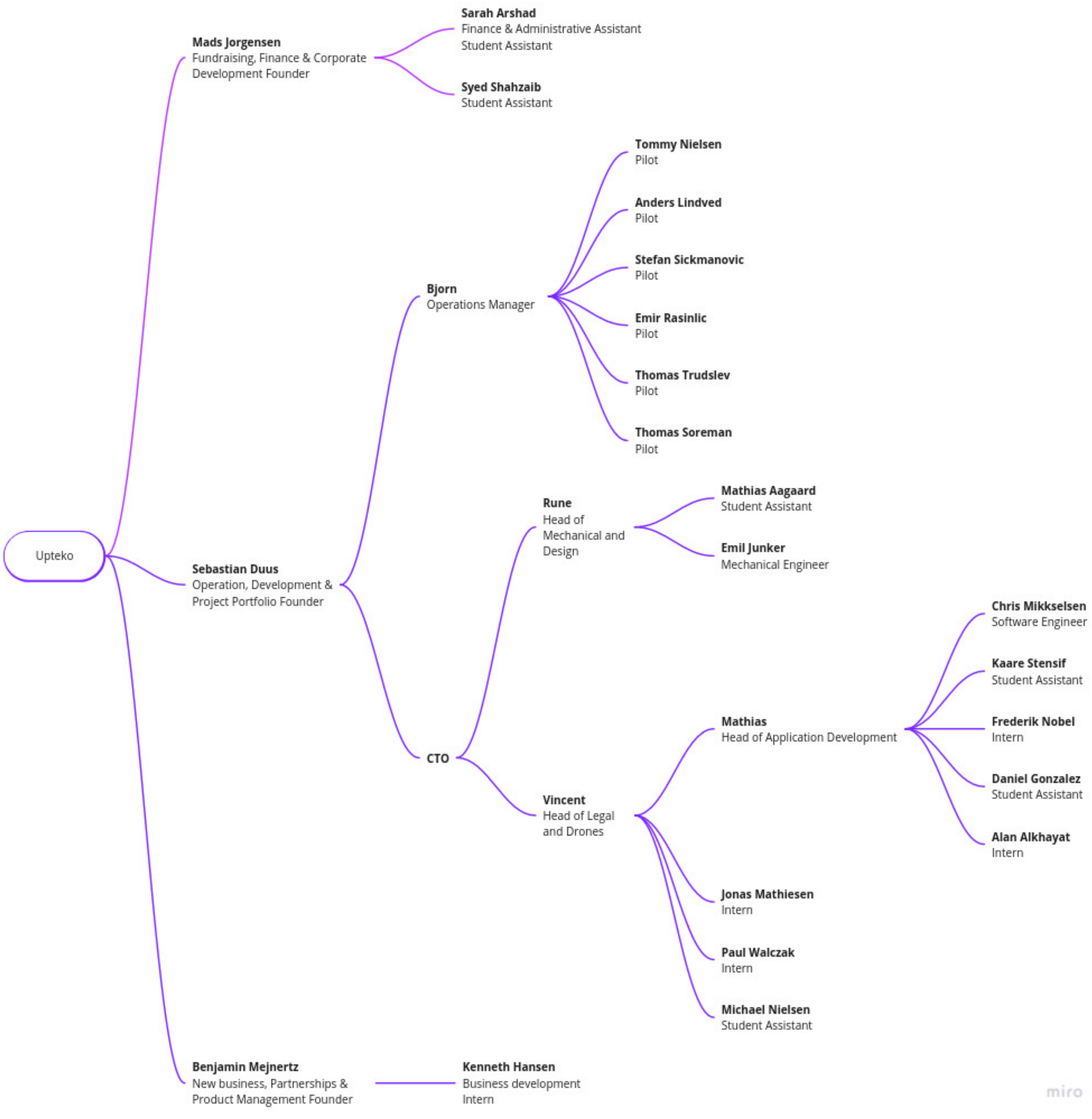


Figure 1.1 – Upteko company organization chart

Chapter 2

Projects

2.1 STM32 IMU

2.1.1 PModNav

The purpose is to get the `roll`, `pitch` and `yaw` from the PModNav to plot a 3D visualization of the IMU. The final purpose of it is to create log files from the orientation and attitude of the drone in real-time. By combining data from accelerometers, gyroscopes and magnetometers, an IMU can provide information about the object's position, orientation and angular velocity. This is crucial for tasks such as safety deployement or drone tracking. The STM32-L4796ZG recovers the value of the sensors from the `PModNav` via `SPI Bus` and transmits them to the HMI via `UART` connection.

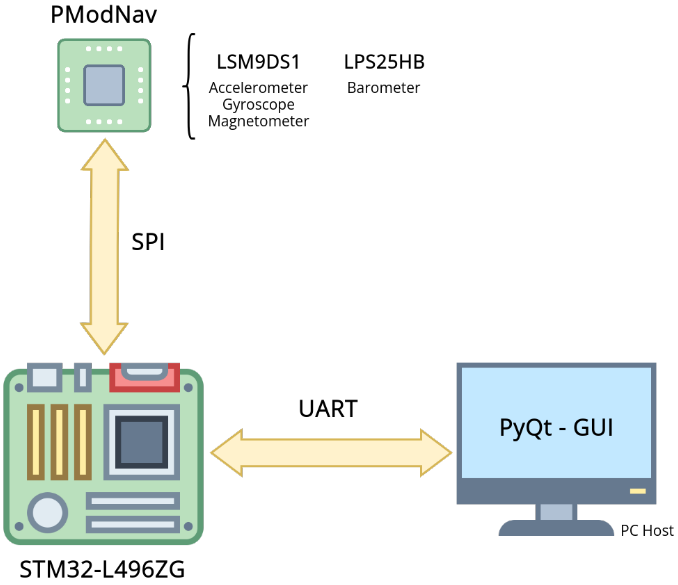


Figure 2.1 – Project communication overview

2.1.1.1 Hardware

The PModNav module is equipped with the `LSM9DS1` [1] sensor, offering 10-degrees-of-freedom (10-DOF) functionality. It integrates a 3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer, and an LPS25HB digital barometer. This comprehensive sensor suite allows users to obtain orientation-related data and determine the precise position and heading of the module. The module supports various full-scale options for linear acceleration, angular rate, and magnetic field measurements. It follows the Digilent Interface Specification Type 2A and utilizes a 12-pin Pmod connector with an SPI interface.

2.1.1.2 Software and Development Environment

The development environment for the PModNav project is STM32 CubeIDE. The documentation references project sources, including code snippets and libraries, such as the PModNav driver and Madgwick's filter implementation.

2.1.1.3 Data Processing

The project outlines two approaches for deriving object attitudes: Euler angles and quaternions. Euler angles are obtained through the integration of angular velocity and provide information about the roll, pitch, and yaw of an object. However, a challenge known as `Gimbal Lock` [2] arises when using Euler angles directly, resulting in a loss of a degree of freedom when two axes of rotation overlap. To overcome this, quaternions are introduced as a mathematical representation of displacement and rotation. They effectively resolve the Gimbal Lock issue and provide a more robust solution for determining attitudes.

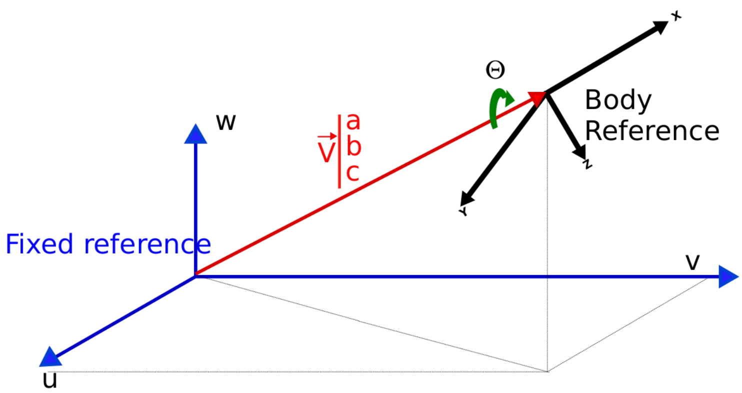


Figure 2.2 – Quaternion representation

$$Q = [q_0, q_1, q_2, q_3]$$

$$Q = \left[cos(\frac{\theta}{2}), a.sin(\frac{\theta}{2}), b.sin(\frac{\theta}{2}), c.sin(\frac{\theta}{2})\right]$$

At each `Te`, we can calculate the new value of the quaternion vector from the velocity :

$$Q_{k+1} = Q_k + \frac{1}{2}.T_e.\omega_k.Q_k$$

For cheap IMUs, it is unavoidable to perform a data fusion to make the accelerometer compensate for the gyroscope defect. If using a Kalmann filter is possible, there are other (faster) algorithms like Madgwick's. The idea is to compensate for the gyroscope measurement error by modulating its values by the result of a comparison between an estimate of the gravity field and the measured gravity field (with the accelerometer).

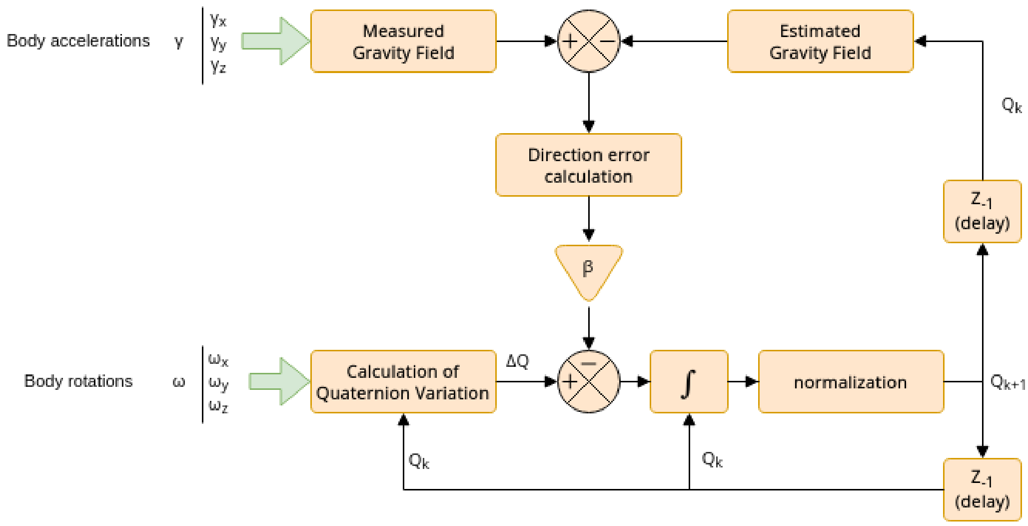


Figure 2.3 – Madgwick filter schematic

I decided to use the most popular open source algorithm to compute rotations, the `Madgwick's algorithm` [3]. This calculation updates the quaternion, from which the attitudes (Euler angles) can be calculated.

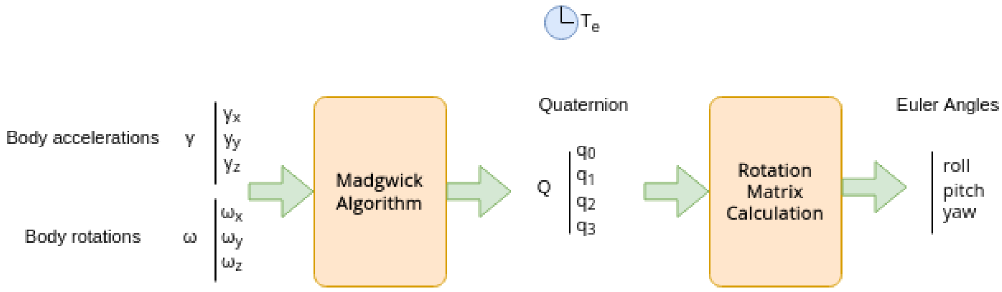


Figure 2.4 – Data transform schematic

$$R_{12} = 2.(q_1.q_2 + q_0.q_3)$$

$$R_{22} = q_0^2 + q_1^2 - q_2^2 - q_3^2$$

$$R_{31} = 2.(q_0.q_1 + q_2.q_3)$$

$$R_{32} = 2.(q_1.q_3 - q_0.q_2)$$

$$R_{33} = q_0^2 - q_1^2 - q_2^2 + q_3^2$$

Calculation of the Euler Angles from the rotation matrix :

$$roll = atan2(R_{12}, R_{22})$$

$$pitch = atan2(R_{31}, R_{33})$$

$$yaw = asin(R_{32})$$

2.1.2 Graphical User Interface

Additionally, a graphical user interface (GUI) is provided, leveraging PyQt5 and PyOpenGL modules. The GUI manages the main window and handles OpenGL object management. It offers features like port selection and serial communication. The received data is displayed in a textbox within the GUI, facilitating real-time monitoring and analysis. Here is how the GUI is threaded :

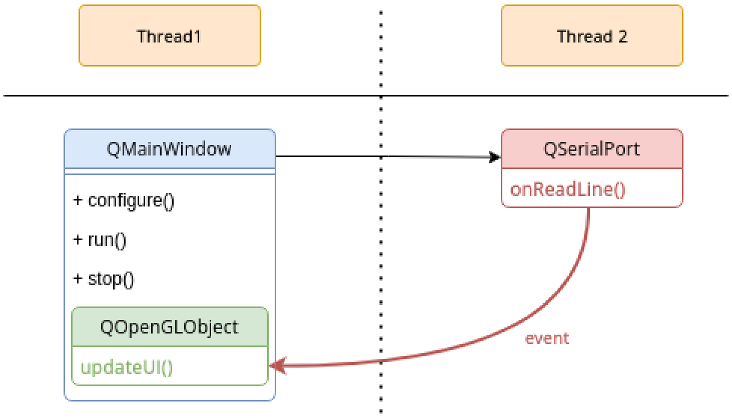


Figure 2.5 – Python GUI threads schematic

The use is rather simple for the communication configuration (cyan box) :

- the port
- the baud rate
- the number of bits per frame
- the number of stop bits
- the parity
- the flow control

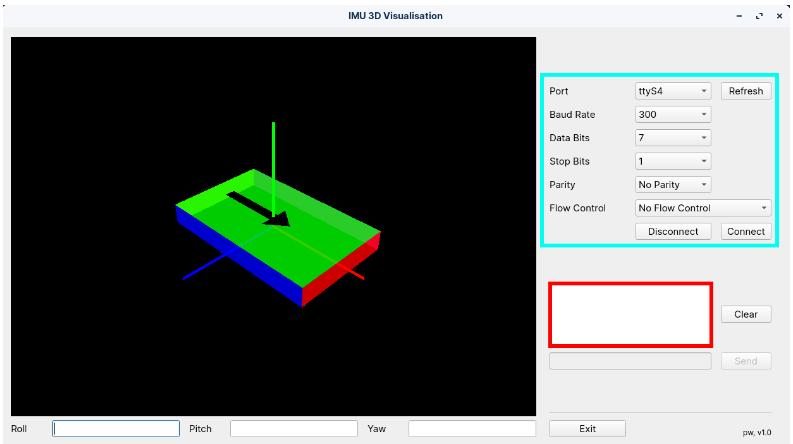


Figure 2.6 – Python GUI window screenshot

Then click on `Connect` to start the serial communication. Every received line appeared in the textBox (red box).

2.1.2.1 Final result

2.1.3 Telemetry data

2.2 LogViewer

2.2.1 Sensors tests

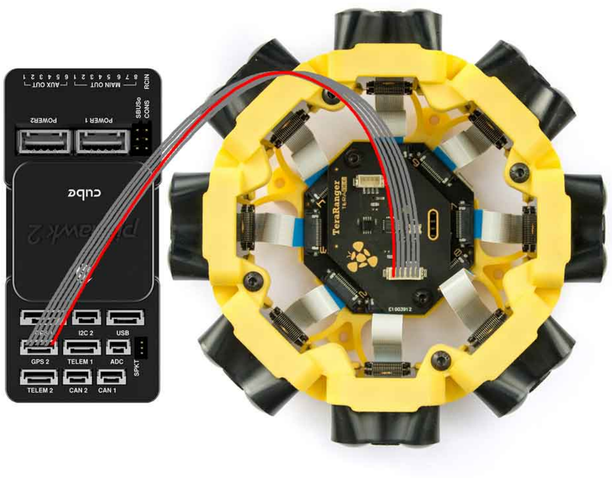


Figure 2.7 – Terabee TowerEvo sensors and Pixhawk FlightController

	TowerEvo	Description
PRX_ORIENT	0	Default
PRX_TYPE	6	TeraRangerTowerEvo
SERIAL_BAUD	921600	serial baud
SERIAL_PROTOCOLE	11	Lidar 360 deg
AVOID_ANGLE	1300	max lean angle
AVOID_BEHAVE	1	Stop when obstacle detected
AVOID_DIST_MAX	5	max distance avoidance
AVOID_ENABLE	3	Enable drone reaction
AVOID_MARGIN	3	min distance avoidance

Table 2.1 – Ardupilot flight controller configuration

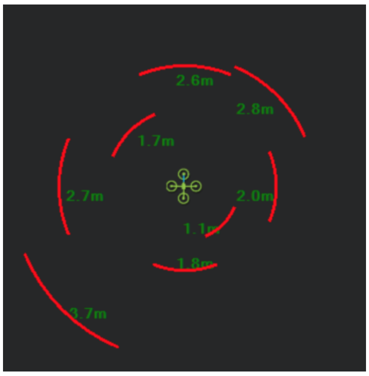


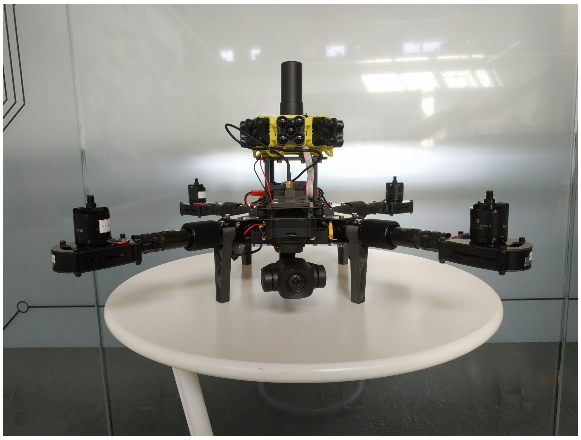
Figure 2.8 – Data acquisition acknowledgement

2.2.2 Drone Integration

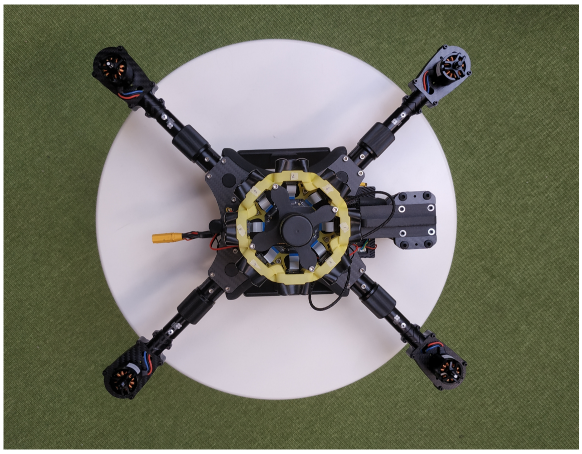
Drone integration

(a) Front left view

(b) Left view



(c) Front view



(d) Top view

Figure 2.9 – Larke Mini drone pictures with 360° degrees LIDAR mounted

2.2.3 Drone Flight

2.2.4 Python Plotly Visualizer

2.3 Collision avoidance SITL

2.3.1 Environement description

2.3.1.1 Robot Operating System

`ROS2` is an open-source framework for building robotic systems. It supports distributed systems, allowing communication between different components and nodes running on separate devices. It provides a communication infrastructure for exchanging messages and supports various protocols. ROS 2 introduces a quality of service system for controlling communication behavior. It includes real-time capabilities for time-critical applications. It supports multiple programming languages and emphasizes modularity and extensibility. ROS 2 comes with development tools and has an active community and ecosystem. Overall, ROS 2 provides a powerful and versatile platform for developing robotic systems. Its distributed architecture, flexible communication infrastructure, real-time capabilities, language support, and extensibility make it a valuable tool for building complex and advanced robots.

2.3.1.2 Gazebo

`Gazebo` is an open-source 3D simulation environment for robotics. It allows developers to create virtual worlds where they can simulate and test robots. Gazebo provides realistic physics-based simulations, visualizes the environment in 3D, and simulates sensors like cameras and lidars. Users can model robots and their surroundings, integrate with the Robot Operating System (ROS), and extend its functionality using plugins. Gazebo has a supportive community and offers a wide range of resources for developers. In summary, Gazebo is a valuable tool for simulating and evaluating robotic systems before deploying them in real-world environments.

2.3.1.3 Ardupilot

`Ardupilot` is open-source software used for controlling autonomous vehicles like drones. It includes firmware that runs on the vehicle's autopilot hardware, as well as ground control station software for mission planning and monitoring. Ardupilot supports different flight modes, navigation based on waypoints, and telemetry for communication with the vehicle. It is compatible with various hardware platforms and can be customized and extended. Ardupilot is widely used in drones and other vehicles, and it has a supportive community and extensive documentation. In summary, Ardupilot is a versatile and customizable software suite for autonomous vehicle control.

2.3.2 Built-In Ardupilot collision avoidance

2.3.3 Collision Avoidance ROS2 Migration

Chapter 3

Temporal organization of tasks - Gantt

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Annexes

bla bla bla

Stagiaire: Paul WALCZAK
Semestre: Semestre 8
Entreprise: Upteko ApS
Tuteur Entreprise:Vincent KLYVERTS TOFTERUP
Tuteur ENIB: Alexis MICHEL

Sujet : «Mon Sujet»

Mot clés : «de 3 à 6 mots clefs»

Entreprise : Eius populus ab incunabulis primis ad usque pueritiae tempus extremum, quod annis circumcluditur fere trecentis, circummurana pertulit bella, deinde aetatem ingressus adultam post multiplices bellorum aerumnas Alpes transcendit et fretum, in iuvenem erectus et virum ex omni plaga quam orbis ambit inmensus, reportavit laureas et triumphos, iamque vergens in senium et nomine solo aliquotiens vincens ad tranquilliora vitae discessit. Hoc inmaturo interitu ipse quoque sui pertaesus excessit e vita aetatis nono anno atque vicensimo cum quadriennio imperasset. natus apud Tuscos in Massa Veternensi, patre Constantio Constantini fratre imperatoris, matreque Galla. Thalassius vero ea tempestate praefectus praetorio praesens ipse quoque adrogantis ingenii.

Travaux Réalisés : Eius populus ab incunabulis primis ad usque pueritiae tempus extremum, quod annis circumcluditur fere trecentis, circummurana pertulit bella, deinde aetatem ingressus adultam post multiplices bellorum aerumnas Alpes transcendit et fretum, in iuvenem erectus et virum ex omni plaga quam orbis ambit inmensus, reportavit laureas et triumphos, iamque vergens in senium et nomine solo aliquotiens vincens ad tranquilliora vitae discessit. Hoc inmaturo interitu ipse quoque sui pertaesus excessit e vita aetatis nono anno atque vicensimo cum quadriennio imperasset. natus apud Tuscos in Massa Veternensi, patre Constantio Constantini fratre imperatoris, matreque Galla. Thalassius vero ea tempestate praefectus praetorio praesens ipse quoque adrogantis ingenii, considerans incitationem eius ad multorum augeri discrimina, non maturitate vel consiliis mitigabat, ut aliquotiens celsae potestates iras principum molliverunt, sed adversando iurgandoque cum parum congrueret, eum ad rabiem potius evibrabat, Augustum actus eius exaggerando creberrime docens, idque, incertum qua mente, ne lateret adfectans. quibus mox Caesar acrius efferatus, velut contumaciae quoddam vexillum altius erigens, sine respectu salutis alienae vel suae ad vertenda opposita instar rapidi fluminis irrevocabili impetu ferebatur. Hae duae provinciae bello quondam piratico catervis mixtae praedonum.

Conclusion : Eius populus ab incunabulis primis ad usque pueritiae tempus extremum, quod annis circumcluditur fere trecentis, circummurana pertulit bella, deinde aetatem ingressus adultam post multiplices bellorum aerumnas Alpes transcendit et fretum, in iuvenem erectus et virum ex omni plaga quam orbis ambit inmensus, reportavit laureas et triumphos, iamque vergens in senium et nomine solo aliquotiens vincens ad tranquilliora vitae discessit. Hoc inmaturo interitu ipse quoque sui pertaesus excessit e vita aetatis nono anno atque vicensimo cum quadriennio imperasset. natus apud Tuscos in Massa Veternensi, patre Constantio Constantini fratre imperatoris, matreque Galla.