***Localization and mapping with autonomous robot, based on LIDAR sensor***

Keyword – SLAM; localization; mapping; obstacle detection; LIDAR-SLAM; autonomous mobile robots; real-world autonomous navigation; local map; global map; odometry.

Localization methods - <https://blog.cometlabs.io/teaching-robots-presence-what-you-need-to-know-about-slam-9bf0ca037553>

SLAM - <http://ais.informatik.uni-freiburg.de/teaching/ss12/robotics/slides/12-slam.pdf>

<https://ceit.aut.ac.ir/~shiry/lecture/robotics/Robot%20Navigation/Introduction%20to%20SLAM.pdf>

**Mapping and localization**

Robotic mapping is a discipline related to computer vision and cartography. Mapping robots can now be found in several areas like industry, military, home appliances, exploration and self-driving cars [1]. In most of the cases, these robots are used where humans cannot reach or is very hard for a human to reach those areas.

The goal of this robot is to be able to construct and use a map (indoor or outdoor) and to localize its position in this map. [2]

“*Robotic mapping is that branch which deals with the study and application of ability to localize itself in a map/plan and sometimes to construct the map or floor plan by the autonomous robot*”. [2]

The problem of robot mapping is to acquire information about the robot environment based on a set of data received from a set of sensors. To acquire a map, robots must use a set of multiple sensors, which will allow them to perceive the outside world. Most of the sensors used in this task are cameras, distance sensors (using sonar, laser, and infrared technology), radar, compasses, and GPS. However, all these sensors are subject to errors, like measurement errors or noises, but also some limitations (range limitation, sensor position limitation). [3]

When creating a map, it is very important, the robot localization on the map. “Localization is the problem of using sensor measurements to estimate the robot’s pose relative to some map”. [4] Localization is essential to decide on future actions, to avoid dangerous situations (collisions or unsafe conditions – temperature, radiation, exposure to weather).

“Robot navigation means the robot’s ability to determine its position in its frame of reference and then plan a path toward some goal location”. [5]

The problem with localization and mapping is that each process is based on having data and information from the robot sensor and actuators. The sensor information isn’t 100% accurate, so in order to avoid measurement errors, it will be needed complex algorithms and calculations.

To create an accurate map of the environment, we need information about the robot pose; this means that in order to create the mapping, we need the localization. But to determine the robot pose, we need to have information about the environment, like a map. This problem is known as the “chicken and egg” problem. [6]

There exists a technique which overcomes this problem, which is called: Simultaneous Localization and Mapping (SLAM). [6]

The main principle of SLAM is to detect the outside environment using sensors on the robot and construct the map of the environment while estimating the pose – localization, and orientation – of the robot.

SLAM application can be found in automatic car piloting or unrehearsed off-road terrains, rescue tasks for high-risk or difficult-navigation environment, planetary, aerial, terrestrial and oceanic exploration, medicine and many more.

Lidar technology, also known as ‘Light Detection and Ranging’ technology, uses light technology to detect the distance to an object. The basic principle of the a lidar sensor is based on a laser light and measures the reflection of it. “Lidar, which stands for Light Detection and Ranging, is a [remote sensing](https://oceanservice.noaa.gov/facts/remotesensing.html) method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.” [7]

The main goal of a lidar sensor is supporting an autonomous car to navigate in a environment, but the sensors have also many additional application, acrous various industries and fieds.

According to [8], which found “100 Uses for lidar 3D sensing techonoly” , the most used application can be found in: digital elevation models, agriculture, astronomy, biology and conservation, image recognition and so on.

Further will be present some examples of usage of lidar sensor in different areas.

1. Autonomous vehicle

In this case, Lidar is popular as guidance systems for autonomous vehicles and has some particular usage like: collision avoidance, thanks to its speed and accuracy, autonomous cruise control and obstacle detection. “Lidar enables a self-driving car” .

1. Digital elevation models(DEMs)

These models are used to creat 3D models or representation of a surface. In this case, Lidar made a huge progress in this domain, based on its speed and easability to use; before lidar, the map was created using a photogrammetry or ground surveys.

1. Agriculture

In agriculture, lidar sensors are used to take preciss measurements, which can be used for topographic analysis and prediction of soil properties. Also, with lidar technology, it is reasier to categorise crops based their characterics. “A crop may thrive in one area of the farm, but may not do well in another area”.

1. Image recognition

The lidar sensor used in the project is a low cost unidirectional ranging lidar sensor, especially created for Arduino boards, colled “Benewake TF Mini micro lidar”. The sensor range varies from 30 centimeters to 12 meters, with long range and high-precision of 1 cm and a very low power consumption.

This sensor principale is based on TOF, namely, Time of Flight principle. [9] This principle is a method for measuring the distance between an object and a sensor, based on the time difference between the emission of a signal and its return to the signal, after being reflected by an object. [10], as shown in the following picture.

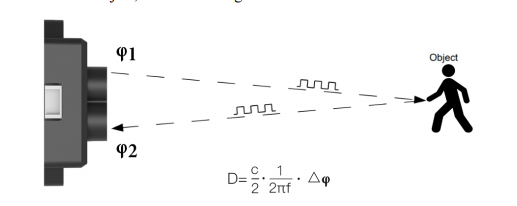
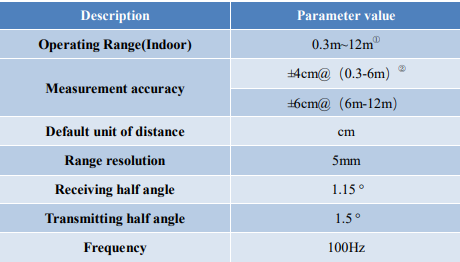


Fig. TOF principle [9]

Characteristic parameters:



Measurement range of the sensor is affected by the environment illumination intensity and the reflectivity of detection object. [9]. Accordint to TF mini product manual, there are 5 areas of measurement ranges, as follow: [9]

1. The first area is the blind area of the sensor, between 0 cm and 30 cm, in which the data read by the sensor are unreliable.
2. The second range is represented by the extreme condition, which is between 0.3 m and 3m. Extreme condition relate to the outdoor open field, where illumination intensity is aroung 100klux, and detection of black target, where reflectivity is 10%.
3. The third range represent the range for white target under normal sunshine condition, with approximatively 70klux illumination intensity, which includes also the seconde range and is between 0.3 m and 7 m.
4. The forth range is represented by indoor environment, or the range where the ambient light is very low, and consist between 0.3 m to 12m.
5. The last range represent the “minimum side length of effective detection for TFmini at a different distances” [9]. In order for the data to be reliable, the side length of the detection object must be equal or more than the minimum side length. This minimum side length depends on FOV of sensor – FOV refers to the smaller value between the receiving angle and the transmitting angle, and has the following formula:

d = 2\*D\*tan(beta), where d is the minimum side length of effective detection, D is detection range and beta is the half of the value of the receiving angle of the sensor, 1.15°.

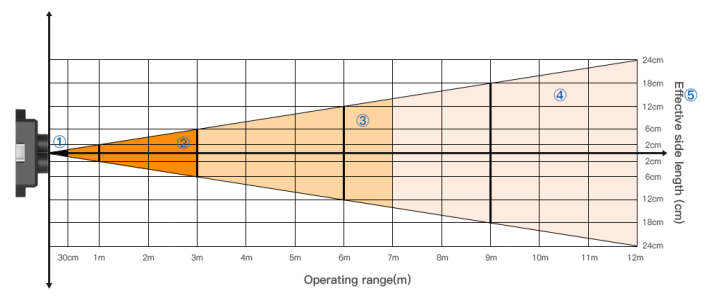
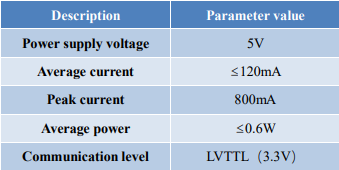


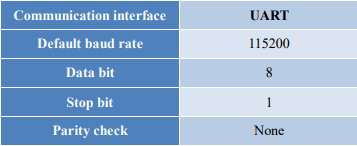
Fig. Schematic of range of distance measurement

Electrical characteristic:



Data communication protocol

The sensor used the serial port communication protocol, as shown in the following picture:



The sensor output came in two format: the standar data output format and Pixhawk data format.

The first one has each data package in 9 byte, which include the header of the package, distance information, signal strength information, distance mode and data check byte (CRC). The format of this data is hexadecimal, and is detailed in the following picture:



Fig. Data format

Data code exmplation:

* Byte 0: 0x59 represent the frame header, same for each frame
* Byte 1: 0x59 represent the frame header, same for each frame
* Byte 2: Dist\_L represent the lower value of the distance – 8 bits
* Byte 3: Dist\_H represent the higher value of the distance – 8 bits
* Byte 4: Strength\_L represent the lower value of the strength – 8 bits
* Byte 5: Strength\_H represent the higher value of the strength – 8 bits
* Byte 6: Mode represent the distance mode and can be 02 for short distances and 07 for long distances, which is automatically switchable by default.
* Byte 7: Not used, 00 by default
* Byte 8: Checksum represent the cumulative sum of the numbers of the first 8 bytes – 8 bits.

Pixhawk data format is the format of character string and its unit in meters. For example, if the measured distance is 2.74m, the ouput string will be 2.74, followed by the escape character.

[1] - LIDAR Application for Mapping and Robot Navigation on Closed Environment – PDF

[2] - <https://en.wikipedia.org/wiki/Robotic_mapping>

[3] - <http://robots.stanford.edu/papers/thrun.mapping-tr.pdf>

[4] - <https://ri.cmu.edu/pub_files/2009/1/thesis_revision_2009_02_13.pdf>

[5] - <https://en.wikipedia.org/wiki/Robot_navigation>

[6] - master\_thesis\_benjamin\_mader%20(3).pdf

[7] - <https://oceanservice.noaa.gov/facts/lidar.html>

[8] - <https://levelfivesupplies.com/100-real-world-applications-of-lidar-technology/>

[9] - <https://cdn-shop.adafruit.com/product-files/3978/3978_manual_SJ-PM-TFmini-T-01_A03ProductManual_EN.pdf>

[10] - <https://www.terabee.com/time-of-flight-principle/#:~:text=Time%2Dof%2DFlight%20Principle,being%20reflected%20by%20an%20object.>

<https://learn.sparkfun.com/tutorials/tfmini---micro-lidar-module-hookup-guide/all>