ADOPTICUM

Livox Mid-40 and Mid-70 Evaluation

This document gives our evaluation of the Livox Mid-40 and Mid-70. It is based on evaluation of the sensor performed by Stiftelsen Adopticum in a project financed by Kempestiftelserna. For more information about the sensor, please feel free to contact Adopticum.

Introduction

This is a document summarizing properties of the Livox Mid-40 and Mid-70 LIDAR sensor. The manual for the sensor includes technical data and information (see Software below).

This document, however, focuses on information acquired from our testing with a sensor available and analysing properties of interest. The goal is to make it clearer what kind of measurement cases this sensor would be useful for.

Equipment

The equipment used during testing was:

- Livox Mid-40 and Mid-70 LIDAR sensors.
- I/O-cables for the sensor, from the developer Livoxtech.
- Separate Voltage adapter, 12 V DC.
- Laptop with USB-LAN-port-cable.

Figure 1 The Livox Mid-40

Software

We have not yet developed code for communication with the sensors. Instead, the Livox viewer can be used for communication with the sensor and then illustrating the point clouds. You can also write the point clouds to file, .csv or .lvs format. The .lvs files can be loaded again into the Livox viewer. We have developed .NET (C#) code for reading .lvs files programmatically.

Startup steps (Windows 10):

Configure the network

- Go to Control Panel -> Network and Sharing Center
- Click on the desired network connection.
- Go to Properties.
- Choose Internet Protocol Version 4 (TCP/IPv4) and click on Properties.
- Choose the option *Use the following IP address*.
- Set the following:
    - IP Address: 192.168.1.5
    - Subnet Mask: 255.255.255.0
- Click OK.

Start the sensor

- Download the Livox viewer from livoxtech. https://www.livoxtech.com/downloads
- Run the Livox Viewer.exe.
- Connect the livox sensor to the power supply. It should be shown in the viewer.
- Select the sensor and make sure that the IP-address and the network you've configured are on the same network. Configure the network otherwise.
- Click on the sensor of choice and it should connect.

Sensor settings

The sensor is operating as it starts with mainly the settings in the viewer available to allow for choosing how to handle the data in the viewer. This includes the following parameters:

- The number of seconds, between 0.1 - 3 seconds, of data to show in the viewer (and that can be written to a file).
- Choose point size to display.
- Writing the current cloud points to the file.
- Displaying points coloured by reflectivity, point distance, Lidar ID, solid Colour, Elevation.

Sensor properties of note

Range

The sensor can measure points from about a 5 cm to as far away as 260 m under the right circumstances (clear sight, no fog/rain/snow, >= 80 % reflectivity of the surface). The sensor is suitable for measuring big areas or objects even at larger distances, where the accuracy and resolution will change with the distance though. As close as 5 cm the accuracy of the sensor is not reliable, and the scene should be farther away when using this sensor. At least a meter minimum is recommended.

Accuracy

The accuracy and resolution of the sensor can be found in data sheets and have not been analysed extensively. However, the observations made seem to indicate that the accuracy described in the data sheets are comparable to the real-life measurements that we have performed using the sensor.

When using the sensor for measuring piles of snow of with a volume from 9 to 54 m^3 the estimated volume differed with about 6-7 % from the expected value (see Figure 2 below).

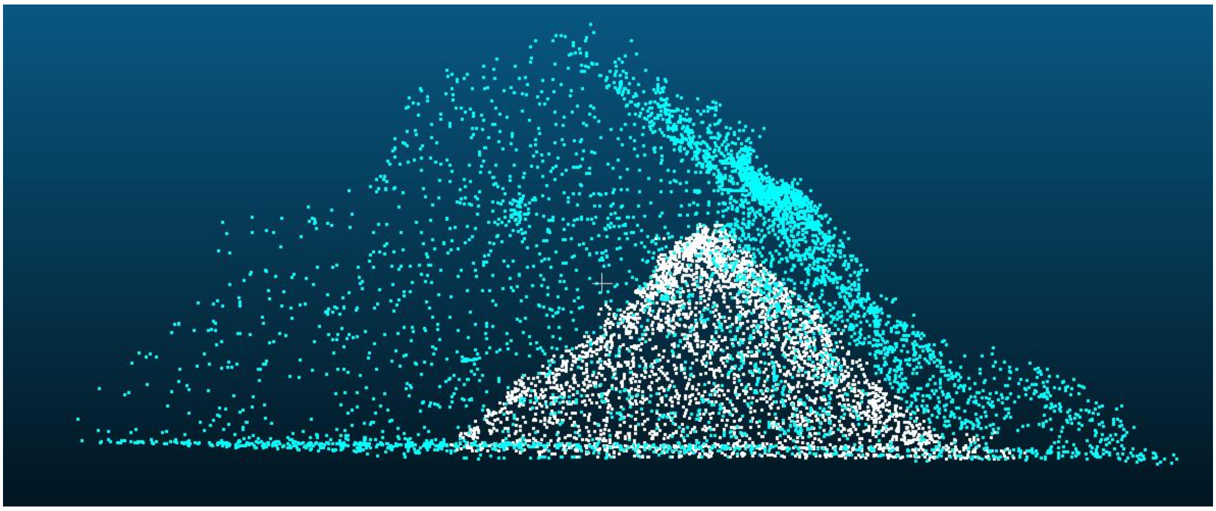


Figure 2: Point clouds of measurements of two piles, using both Livox Mid-40 and Mid-70 sensors. The white points represent a pile of volume 9 m³ and the turquoise points a pile of volume 54 m³.

High reflectivity targets, such as reflective material, can affect the accuracy of the measurements. The measurement points can move closer to the sensor than they actually are. This can possibly be corrected by using the reflectivity as a measure of how much you have to adjust the distance value.

When developing a solution based on this sensor this should be taken to account and be tested further, where reflective objects are measured at different distances. This test should be performed multiple times to make sure that the error is comparable every time, dependant on the distance from the sensor, and not a random error.

Figure 3: Tripod (black points) with reflective band at the top (white/gray points), measured with the Livox Mid-70 sensor. The reflective band is tightly attached to the cylinder, but the data points are farther away from the tripod axis, due to the highly reflective surface. The distance is about 60 mm from where it should be.

Data format:

The data in the .lvs-files contain the data from the sensor, where the files contain every 3D-point with attributes. The attributes of interest for us have been:

- X-, Y- and Z-coordinates for every point.
- Reflectivity of the current point.
- Tag (unused as of now)

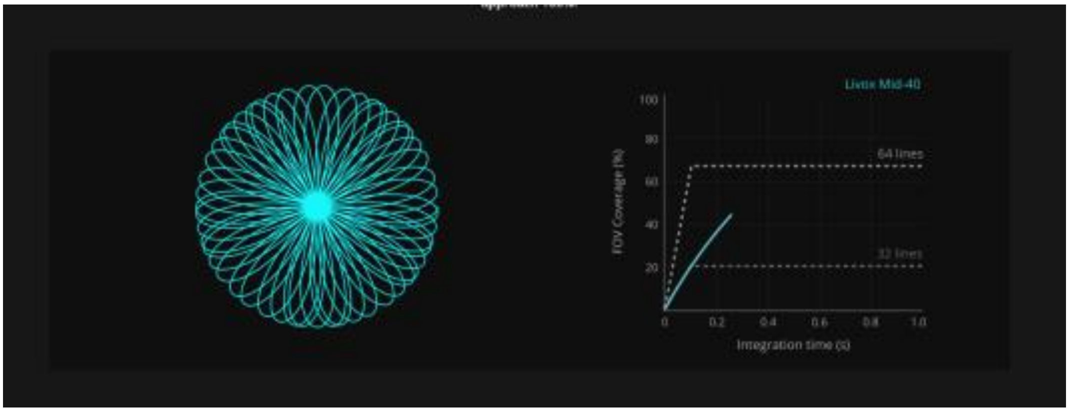
It is also possible to get timestamps and status codes. We developed .NET(C#)-code (in Volymscan) for reading .lvs-files and convert them to .csv-files with the format shown in Table 1 below.

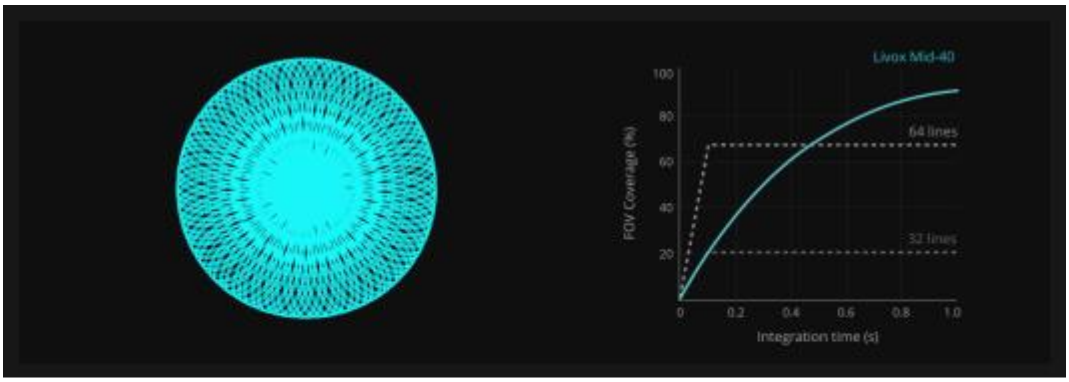
X	Y	Z	Reflectivity	Tag
51939	-35571	8498	19	16
52069	-35679	8448	19	16
51953	-35616	8360	17	16
57353	-39344	9067	20	16
54224	-37207	8495	20	16
54313	-37273	8434	22	16
54376	-37318	8364	18	16

Table 1: The X-, Y-, and Z-coordinates along with the Reflectivity and a Tag value is written for every 3D point from the sensor in the .csv-files we use for storing the livox sensor data.

Sensor speed:

The sensor measures the distance from the sensor to the points in 3D-space in non-repetitive scanning patterns, where more and more points of the scenery is measured the longer the sensor is allowed to measure. 100 000 points/second. This can be seen in the Livox viewer as more and more points are visible. The same point (or a point close enough to it that the accuracy of the sensor might not yield a notable difference) in the scenery will eventually be measured again, but giving the sensor a couple of seconds to measure the scene and more points will be included in the point cloud. This means that the sensor is suitable for measuring objects and scenes that are still. It is also aimed at automotive applications, but it is not suitable for cases where really fast measurements are required (where laser triangulation might be a good choice). Since not all of the scene is measured right away, this should be taken into account when using this sensor to measure/detecting moving objects. By storing the coordinates of the points with the time they were measured and the position of the sensor at that time the sensor could still be used for mapping a bigger area, measured little by little.





Temperature range:

The operating temperature is between $-20℃$ to $+65℃$, allowing for use in a wider span of outdoor climates.

Sunlight:

The LIDAR sensors can perform measurements even outdoor in direct sunlight, which other technologies (laser triangulation, structured light and Time-of-flight cameras) typically struggle with.

Prices

The price range for livox Mid-40-sensors is about 6 300 SEK. The Mid-70 has a price about 11 500 SEK. Which means relatively low price for a LIDAR sensor, but also an affordable measurement system in general.

Challenges

While the sensors started without a problem in sub-zero temperature, the network connection to the laptops gave up during testing. Only a few seconds of data each time could be acquired before the laptop would lose the connection with the sensor. What is the cause of this has not been determined. A potential problem is that it is the cold that caused problem on the laptop side and not the sensor, but this has not been thoroughly evaluated.

When evaluating point clouds acquired using the Mid-40 sensor we have often noticed how there seems to be a double cloud, as in objects are clearly shown twice in the cloud but with a slight shift in position. In Figure 4 below this can be seen. Why this is the case we do not know as of now. Is the sensor slightly dislocated from its original position? Or is it a known problem with the sensor model? Or is it a problem for the specific unit we have? This is something that could be discussed with the developer/manufacturer of the sensors.

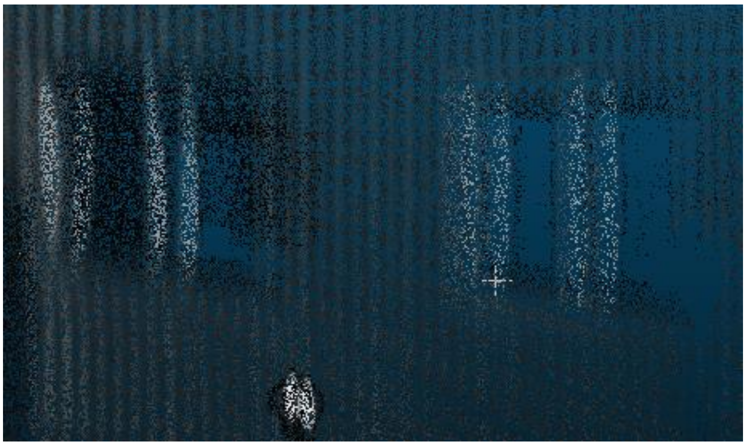


Figure 4: Double point cloud where the same objects can be seen twice, close to each other. This is most easily seen the brighter points in the image.

User cases

While the sensor could still be used for automotive applications, the user cases we found very fitting for the sensor include measurement applications where:

- Large distances (1 - 200 m) to the scene to measure.
- Outdoor measuring applications (in colder climates, direct sunlight, etc.).
- Measuring big stationary objects.
- Measuring stationary objects from multiple angles to get a full map of bigger surroundings.
- When price is a factor.

Summary

With the relatively low-price range, 6 300 SEK for Mid-40 and 11 500 SEK for Mid-70, and no calibration necessary, these sensors are a relatively easy and cost-effective way to get up and running for performing non-invasive measurements on many different scenes, not the least for scenes containing larger objects at a longer distance from the sensor. The Livox viewer simplifies getting the sensor started and getting measurement data from the sensor for analysis later. Works well for initial test measurements. As with any sensor, when a measurement application is required to work at all times, programming is necessary.

The operating temperature span between $-20°C$ to $+65°C$ and with the range of the sensors of up to (in good conditions) 260 m they can be well suited for measuring scenes/objects in outdoor environments.

With the use of non-repetitive scanning patterns the sensors can acquire many data points of measurement at stationary scenes by allowing the sensor to scan the area for a couple of seconds.

The sensors yield intensity values as well as 3D-coordinate data, which can be used for visual feedback as well as identifying objects in the scene.

Even though the sensors can acquire up to 100 000 points/second the non-repetitive pattern can make it hard to quickly measure specific areas of the scenes fully. This means that for automotive applications where a sensor is used for recognizing objects in real-time, these sensors can prove difficult to use. Their field-of-view is limited so one sensor can't see in all directions around the vehicle at once, meaning that on more expensive sensor may mean a simpler and more elegant and possibly cheaper and more robust solution for that kind of application than using several of Mid-40 or Mid-70 sensors, aligning and correlating them to use for the same purpose.

When using the sensors for outdoor applications in colder climates, the problems that were experienced with the network connection needs some consideration. The sensor could still be partially capsuled with a heating system to prevent similar problems. If the problem lies with the PC network-port and not the sensor this might not be a problem if the PC is kept at higher temperatures above $0°C$ while still connected to the sensor positioned outdoors with the correct setup.

The double clouds seen when measuring using the Mid-40 sensor does of course affect the result of a measurement, but we have been able to use the sensor for our applications without the accuracy being affected too much. Make note that we work in the cm to dm range with these sensors. The effect is still a source of error and is something that could be discussed with the developer/manufacturer of the sensors to find out if the effect can be removed.