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Autonomous Vehicle Mapping With VLP-16 Lidar Using Lidar Odometry and Mapping Algorithm

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Abstract:

Mapping is one of the important aspects in Simultaneous Localization and Mapping (SLAM) methods. It is imperative for an autonomous vehicle (AV) to be able to map its surrounding environment in an accurate manner so that it can be used by the other systems in the AV. This led to the issue thatfaced by many SLAM researches that asks for the possibility for an AV to simultaneously build a consistent map of the surrounding unknown environment and verify its location within the said map. One of the obstacles in mapping the AV is localization estimation. Scattered GPS signal problem is a known factor held by the earlier AVs and to counter this issue Light Detection and Ranging (LiDAR) sensor was utilised due to its ability to collect large amount of data in a short amount of time. This research aims to provide the AV mapping by using LIDAR focusing on the optimization-based method. Data was collected using a 3D LiDAR sensor, Velodyne Puck in the selected area around UniversitiTeknologi MARA. This project was experimented with Robotic Operating System (ROS) and visualized through the RViz tool in ROS. This research employed Lidar Odometry and Mapping (LOAM) algorithm in building the map and has produced a viable result with less than 5% percent error rate. It demonstrates the benefits of the LOAM algorithm on the real-world data. With the high accuracy achieved shows this algorithm can help in the development of autonomous vehicle for the mapping process. Future works can be done to ensure the performance of the system is in excellent condition and increase its accuracy.

Keywords: *Autonomous Vehicle, LIDAR, LOAM, Mapping, SLAM*

1. INTRODUCTION

Autonomous vehicles (AV) are designed to be able to manoeuvre on its own without human driver. However, before starting the journey, an AV need to know its surrounding environment or in other words build a map surrounding it. This will help the AV to locate itself and learn of the direction that it should take to arrive to its destination. This problem often referred to as the simultaneous localization and mapping (SLAM) willasks for the possibility for an AV to build a consistent map of the environment surroundings while simultaneously verifying its location within the said map (Bailey &

Durrant-Whyte, 2015). One of the obstaclesin AV mapping is its localization accuracy. Early AV uses a global positioning system (GPS) to locate its position but the signal obtained is highly sporadic thus making the position located is less accurate than its real position. To counter this problem LiDARwas introduced where theAV relies on cameras and LiDAR sensors to take advantage of the visual as well as spatial features obtained from the surrounding environment (Kim, et al., 2017).Thus, it is important for an AV to have a mapping functionality in its system to function properly.As stated before, AV utilizes LiDAR sensors to solve the GPS signal problem. The data obtains from LiDAR can get large at times and LiDAR data is considered big data with its high volume and velocity (Kitchin&Gavin 2016). A reliable algorithm must be identified and utilized to handle the data. With a functioning map available, the AV ability need to be tested prior to its utilization. One of the popularly used method to build the map is by using Lidar Odometry and Mapping (LOAM) (Zhang & Singh 2014). Therefore, this research proposes the utilization of LOAM to build the map using LiDAR.

2. MATERIALS AND METHODS

This section discusses the literature of the previous studies or researches being conducted that is related to this paper. This section provides further description on the domain, technique and other related topics to its domain area.

2.1 LIDAR

LiDAR is aremote sensing method that utilizes light in a pulsed laser form to measure the distance between two objects (National Oceanic and Atmospheric Administration, 2012). LiDAR functions by firing lasers rapidly at a specified target or destination. There are two types of LiDAR available; airborne and terrestrial.Airborne LiDAR is often installed in aerial vehicles such as drones or helicopters.It is often used to measure water depths and shoreline elevations (NIBT, 2018). Terrestrial LiDAR is available in two types which are static and mobile which collects point clouds data that are dense and highly accurate to have a precise identification of objects. In mobile LiDAR, the LiDAR system is mounted on a moving vehicle meanwhile static LiDAR is typically mounted on a stationary device or a tripod. Mobile LiDAR is a collection of LiDAR point clouds obtained from a dynamic platform. Mobile LiDAR data can be used to analyse road infrastructure and locate objects like overhead wires, light poles, or traffic signs near roads or railways. Static LiDAR is the collection of LiDAR point clouds from a fixed location. These systems collect LiDAR point clouds inside and outside of a building and is commonly used in mining and archaeology (NIBT, 2018).LiDAR sensors can be categorized by 2D and 3D LiDAR. Blind area obtained by the 2D LiDAR can be reduces through the usage of a tilted 3D LiDAR configuration. However, a larger data packet is required (Kim, et al.,2017).This paper used Velodyne Puck or VLP-16, a mobile terrestrial 3D LiDAR sensor, as its main sensor.VLP-16 also known as Velodyne Puck is one of the latest models of 3D LIDAR sensor that able toscan real-time 360 degrees in a 100-metre range. The VLP-16 outputs two separate broadcast UDP packets. By using a network monitoring tool such as Wireshark packets can be captured and observed as they are generated by the unit. The data packet from the Ethernet port need to be analysed to extract the metadata of the packet including the azimuth, elevation angle, distance to the object, and time stamp. The VLP-16 obtained coordinates in spherical coordinates (r, ω, α). Therefore, a transformation is necessary to convert the coordinates to XYZ coordinates. The distance (r) is calculated by multiplying the speed of light with the time taken for the laser to bounce back and divided by two. The vertical angle (ω) is fixed and given by the Laser ID. The horizontal angle/azimuth (α) is reported at the beginning of each firing sequence. Using this information, the XYZ coordinates can be calculated and stored or displayed on a computer as a series of point clouds data (Velodyne, 2016).

2.2 Lidar Odometry and Mapping

Lidar Odometry and Mapping (LOAM) is a real-time method for state estimation and mapping using a 3D lidar. It consists of two major threads running in parallel. An "odometry" thread calculates the motion of the LiDAR between two sweeps, at a higher frame rate while removing the distortion in the point cloud caused by motion of the LiDAR. Meanwhile, a "mapping" thread takes the undistorted point cloud and incrementally builds a map simultaneously computes pose of the LiDAR on the map at a lower frame rate. The LiDAR state estimation is combination of the outputs from the two threads. To handle the information, the structure is shown in Figure 1.

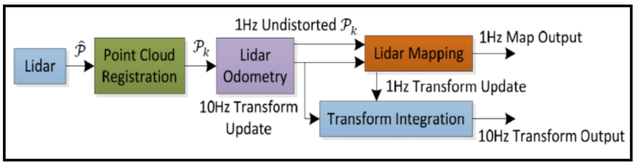


Figure 1.LOAM Algorithm Process (Zhang, 2015)

3. METHODOLOGY

This chapter discusses the processes of conducting the research. It consists of two main phases; data processing and model development.

3.1 Data Processing

The LiDAR data is collected using Velodyne LiDAR sensor, VLP-16 or Velodyne Puck. LiDAR sensor captured raw point cloud data from the surrounding environment around the sensor. Data is collected in three different places around the Faculty of Computer Science and Mathematics area in UiTM Shah Alam as shown in Figure2.

(a)

(b)

Label	Color	Description (Location data collected)
data2	Red	CS2 →CS2 Parking Lot → CS1 → CS2
data3	Green	CS2 →DataranCendekia→ CS2
data8	Blue	Around Engineering Complex

Figure 2. (a) Map of Data Collection Area and (b) Description of each dataset

The LiDAR sensor needs to be set up first by turn onthe 8-watts power of VLP-16 sensor. The sensor is then connected to a power converter in the car and the sensor is ready to be connected to the computer using standard RJ45 Ethernet cable. The IP address for VLP-16 is set at default but can be changed by the Webserver GUI. For MAC address, each of the VLP-16 produced by Velodyne LiDAR Company has a unique MAC address.Once the connection from VLP-16 to computer is established, it is ready to scan the environment. VeloView installed to monitor the data collection process. Using VeloView, the data collected can be observed through the computer monitor connected to the LiDAR sensor. The sensor is mounted at the top of the vehicle before data collection. The sensor collects data by rotating 360 degrees and emitting laser to obtain data of the targeted environment in the packets data form. Thus, all the packets that contain valuable information are stored. Before starting the journey, the VeloView will start recording the data collected by pressing the record function. Point cloud data of the environment is captured by the sensor are recorded when the car moving. After the collection process ended, VeloView will stop recording data and save the raw point cloud data. Data that collected is in .PCAP data form which is a standard network packet capturefile format provided by the VLP-16. There are two data formats used during data pre-processing. The.CSV format helps in analyse the data inside the raw data in a more readable format. The .BAG formats used during model development process. In the data analysis phase, the data is analysed to study its structure. The features that contain in each data packet is important to be used in the next phase. Table 2 shows the description of each attribute of the data packets.

Table 2. Description of each attribute in .CSV

Attributes	Description	Attributes	Description
Points_m_XYZ:0 & X	The X coordinate of each point cloud	laser_id&vertical_angle	The vertical angle ID
Points_m_XYZ:1 & Y	The Y coordinate of each point cloud	Azimuth	The horizontal angle ID
Points_m_XYZ:2 & Z	The Z coordina	Distance	The distance

	te of each point cloud		of each point cloud to the sensor (m)
Intensity	The return strength of the laser pulse	adjustedtime& timestamp	The time of each point cloud is obtained in milliseconds (μs)

3.2 Model Development

Two basic software is needed which is Robot Operating System (ROS) and RViz. ROS Kinetic Kame used due to it is most stable and latest ROS with simulation capability. ROS visualization is a 3D visualizer (RViz) for displaying sensor data and state information from ROS. Using RViz, a virtual model of the robot can be visualized and live representations of sensor values coming from ROS is displayed.The model development phase begins by installing using Ubuntu OS. The computer was then dual-booted with Ubuntu 16.04 Xenial alongside Windows 10 that was pre-installed in the computer. Then, ROS was installed along site with RVizsoftware obtained alongside the ROS package that was installed earlier. Velodyne ROS package was installed in ROS where it support the 3D LIDARs produced by Velodyne. Then, LOAM algorithmwas implemented following the work done by (Laboshin, 2015) which was a modified copy of the original LOAM algorithm from Ji Zhang (Zhang, 2015).This algorithm is then modified to be able to read the data collected earlier and be able to display the full map instead of submaps.

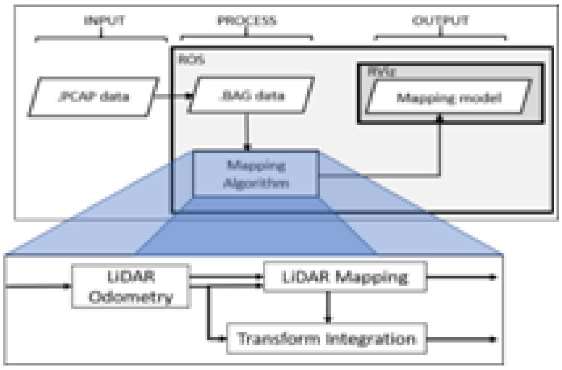


Figure 3. Architecture Design

Figure 3 shows the architecture design of the project.The point cloud data that was collected was used to begin the mapping simulation by implementing the LOAM algorithm. During the process, the .BAG file, which is the data collected earlier were linked to the algorithm as inputs for the mapping process to occurred. Output was visualized through RViz for the simulation and the map created will be tested for accuracy in the next phase.

3.3 LOAM EVALUATION

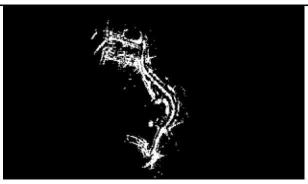
The evaluation on the LOAM algorithm towards the collected LiDAR data is done by using percent errorfocusing on the distance measurements. Two types of distance measurements were presented using measurements mobile application and RViS-LOAM. The percent error is automatically calculated by Rvis software based on the difference between a measured value and an exact value. The exact and measured values are referring to the distance on each location. The purpose of a percent error calculation is to report the difference between a measured or experimental value and a true or exact value (Helmenstine, 2018). The measurements in the same location is also done in the LOAM mapping results through the Measure tool available in RViz. Both measurements were recorded and then compared to calculate the accuracy of LOAM measurements. The calculation is done by following (1). Let P be the real live measurements and Q be the LOAM mapping measurements.

$$Percent\ Error = \ | P - Q | / P \times 100\% \quad (1)$$

4. RESULTS AND FINDINGS

Table 3shows the mapping results obtained from LOAM algorithm throughRViz. Nine measurements were taken from each dataset in different locations of the map totalling to twenty-six measurements. Figure 4 shows the location in which the measurement is taken and marked with the red coloured arrows.It shows that LOAM algorithm successful generatesmapssame as real world in the environment. The results were shows in Table 4.

Table 3.LOAM map results of each dataset

Google Maps (Aerial view)		
		
LOAM		
		

The average percent errors were valued at 4.64%, 2.73% and 0.89% for data2, data3 and data8 respectively.Some measurements obtained a high percent error value might be caused by the lack of buildings surrounding the environment. LOAM environment works well with surroundings with geometrical shapes around and not work very well at spacious environment such as parking lots. This can be clearly seen at loc1g, loc1h, loc1i and loc2f (Figure 4) that has a high percent error rate with 4.84%, 5.34%, 8.62% and 13.68%. These error rates obtained from the CS2 parking lot contribute to the high average percent error of data2. Contrary to data8 which the environment is closely packed with buildings at the Engineering Complex. Most of the measurements obtain has a low percent error rate.

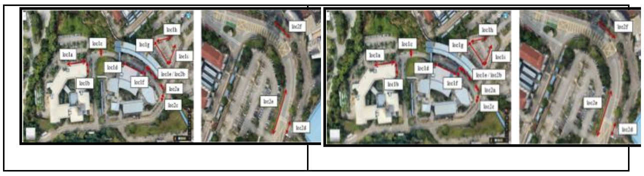


Figure 4. Locations of Measurement

Table 4. Percent Error of each dataset

Percent		*Location (loc1 / loc2 / loc3)*									*Average*
Error(%)		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	*(%)*
Data	**data2**	1.90	8.64	4.07	3.87	0.69	3.83	4.84	5.34	8.62	**4.64**
	data3	0.43	1.12	0.59	1.18	0.57	13.68	5.22	0.87	0.93	**2.73**
	data8	0.94	1.72	0.14	0.04	2.56	0.31	0.84	0.51	0.94	**0.89**

5. CONCLUSIONAND FUTURE WORK

This research paper presented an algorithm called LOAM, as a solution to the mapping problem. This algorithm utilizes two major processes that run simultaneously; LiDAR Odometry and LiDAR Mapping. Using data collected inside the UiTM premises, the mapping process is done using ROS and visualizes through RViz with the resulting to a satisfactory map. With a high accuracy in the result, this algorithm can help in the development of autonomous vehicle in mapping process. In the future, more studies are needed to be done to ensure a higher accuracy either using another algorithm or a revised version that can handle data obtained from Velodyne LiDAR.

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