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NavX: Harris Robotic Path Planning - Problem A

LiDAR Detection: Underlying Technology and Path Planning Applications

Collecting spatial data of manmade and natural environments with accuracy, precision, and flexibility is a common need for scientists and engineers. From surveying land for geological applications to detecting the environment for autonomous cars, LiDAR sensors bring these capabilities to the table: high-resolution and quickly-acquired data for various applications of aerial mapping [2].

General Commercial Applications:

In the 1960s, the United States, Canada, and Australia military conceived LiDAR to detect submarines from overhead aircrafts – a modernization of SONAR (Sound Navigation and Ranging) [4]. Since its inception, LiDAR succeeded past its purely military intentions and has become a prime tool for developing comprehensive topological data and providing immediate situational awareness [3]. LiDAR applications currently include creating terrain contour maps (archeology, geology, surveying), calculating depth-fields (autonomous vehicles, military, transportation), and many more [4].

Tools for compiling LiDAR data range by purpose (geological contour maps, city building elevations, non-aerial image processing), interface (ground computer, onboard iPad, remote server), and features (cross-sectional viewing, file compression efficiency, point cloud classification) [6, 7, 8]. There are three popular LiDAR Geographic Information Systems (GIS) applications among scientists and engineers used to acquire appropriate three-dimensional maps.

Global Mapper LiDAR Module is the flagship software for LiDAR data compilation: a \$998 Mapping software which translates images, IMU, and GPS data from a drone to develop and illustrate point-cloud models of a three-dimensional surface [6]. RIEGL Laser Measurement Systems is a very similar tool but is marketed primarily for its cross-platform compatibility – specifically with regard to going between a computer and tablet (iPad) [7]. LizardTech's LiDAR Compressor, unlike the previous two applications, is a LiDAR data compression software rather than a LiDAR data compilation/illustration software - since LiDAR is known for its very high resolution, this LiDAR Compressor application is used to filter through multiple terabytes of information to more usable quantities [8].

How does LiDAR work

LiDAR sensors (Light Detection and Ranging) uses pulses of laser light to create a three-dimensional map of a target area. Multiplying elapsed time between sent and received laser-pulses with the

velocity of the laser beam equates the distance between the LiDAR sensor and the nearest object in its path [1]. Stringing these individual data points into a matrix and accounting for additional GPS/IMU information creates a distance scalar field useful for illustrating spatial data. The advantages of LiDAR sensors primarily stem from lasers being both precise and fast: resultant three-dimensional maps have high resolutions (lasers have low beam dispersion) which can be updated quickly (speed of light $c = 2.99 \times 10^8$) [5]. Furthermore, LiDAR data can be acquired day/night, is less susceptible to geometric distortions, and can even measure surface terrain through a forest canopy [2]. However, LiDAR has its fair share of disadvantages: environmental conditions may render the sensor inoperable (high sun angles, altitude cap of 2000m, bodies of water), and data analytic challenges can prevent proper data capture (high data resolution requires advanced data analysis and interpretation) [11].

Implementation of LiDAR

LiDAR mapping requires the sensor itself (consisting of a laser emitter, a laser detector, a GPS, and an IMU), data storage acting as a pool of distance readings and GPS/IMU data, data compression to translate the terabytes of distance data to a more manageable file size that can be processed in near-real-time speeds, and translation/illustration software displaying the data received by the sensor in the form of a three-dimensional map[14].

As defined by J.J. Leonard, there are three questions involved in robotic path planning: “Where I am, Where I am going, and How I get to the destination” [15]. Implementing LiDAR as a tool for Robotic planning requires answering these three questions with data calculated via LiDAR mapping. After collecting altitudes of a given terrain and defining start and start points, barriers, steep elevation dips (ditches), and other obstacles; a global “path of least resistance” is calculated – taking into account a short path that is still manageable by a vehicle or robot. There are many algorithms with translate raw LiDAR data to a specific path, the most common of which is establishing an environmental model with a set global path consisting of different potential local paths. Using real-time data, a navigating robot would choose “path of least resistance” data to choose local paths which culminate to a final successful global path [12, 13].

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