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Autonomous mapping 2D - 3D Lidar scanning

RESERCH REPORT

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1. Abstract

Our world is moving towards a time of automation were driving yourself will eventually become a thing of the past. The idea of this project is not unlike what you may already know about self-driving cars and the big players in this field of technology, Tesla and Google to name the biggest. However, they have different ideas on how automation will continue to evolve, Tesla using advanced camera technology and Google using LiDAR.

This project is about building an application around a scanner called a LiDAR, it can map objects in 2D and 3D along with mapping the environment in which it is in. Utilizing this in an application will prove valuable in terms of object avoidance and route planning, as the idea is to develop a mobile unit that will avail of this and drive itself via a plotted route and avoid obstacles to get there.

2. Introduction

This document will outline the research that was carried out for this project. This project aims to create a functional mapping interface with the LiDAR to potentially map the environment, to then later introduce some machine learning to have an autonomous drone.

The document will review technologies already in the industry and compare the features that they have. This will also include a little bit about some of the big players in autonomous machines and mapping today.

The final portion of this document will look at the technologies to be considered for the development of the project.

3. Background

LiDAR, which stands for light detection and ranging, and is a technology that uses safe, invisible laser beams to detect objects both in motion. Each beam travels through its environment, bouncing off each object and then returns to the sensor to create a digital 3D point cloud of its environment [1].

Then awareness software understands this point cloud so that you can see objects in 3D and determine exact distance, height, volume, speed, direction and even reflectivity of objects within the field of view. LiDAR scanners come in many shapes and sizes, with some projecting many beams that sweep a 360° circle while others produce multiple vibrating beams in a pixel density rich cone. The quick advances in both LiDAR scanners and awareness software have been incredibly exciting to research and yet there is still so much more to learn.

So, some of the features of the application I want to build are:

- Distance detection
- Mapping of objects in either 2D or 3D
- Object detection with avoidance
- Route plotting
- GUI to display all the relevant information

There is a multitude of use cases for this type of application, one of which is drones that can be programmed to scout out potential weak points in collapsed buildings in an emergency. Using something like this in rescue operations could help the responders significantly reduce the risk of getting trapped themselves and help determine other potential risks to all who are involved.

Autonomous driving and mapping are the main ideas here, once the application features these options and functions I have outlined above, we could potentially build a drone to operate under these parameters.

4. Existing Technologies

One of the biggest tech companies in self driving and autonomous vehicles Tesla had an event this year in which Elon Musk said and I quote "LiDAR is a fool's errand," and then continued "anyone relying on LIDAR is doomed. Doomed. Expensive sensors that are unnecessary. It's like having a whole bunch of redundant appendices." [2]. He was potentially hinting to the automotive industry's use of LiDAR for advanced driver assistance systems in autonomous vehicles. However, his remarks merely showed that LiDAR has awareness problems, and it needs more attention to get to where it needs to be.

Not many people quite understand or seem to fully appreciate what LiDAR as a technology is capable of. The way this is implemented today doesn't portray well enough the advantages that LiDAR can bring to the world, and the opportunities that developers can capitalize on to produce efficient and secure applications. Evolving beyond its current sector of autonomous vehicles and other more traditional applications in the farming and geology sectors, we see LiDAR quickly moving to serve an array of applications.

4.1 Environmental pollutants

LiDAR's short wavelength allows scientists to detect air pollutants such as carbon dioxide, sulphur dioxide, and methane and can-do important mass mapping in this age of climate change. Additionally, engineers as well as interior designers are using LiDAR to exactly measure and restructure the building spaces they're working on. The Notre Dame cathedral was so accurately mapped using LiDAR that despite the disaster of this spring's fire, architects and civil engineers are confident that they can accurately rebuild Notre Dame's roof and spire, thanks to LiDAR.

4.2 Airport efficiency

Airports such as the Los Angeles International Airport have seen yearly passenger counts grow by up to 60% since 2009 [4]. There for it leads to the conclusion that LAX will need to manage approximately 90 million passengers in the year of 2019 [5], in comparison to 56 million in 2009. Dealing with 34 million extra passengers within the same structure requires far better equipment for this massive undertaking of passengers and to organize their staff to deal with the issues that may arise. A variety of airports spanning the continent of the USA have, as a solution, installed LiDAR scanner technologies

for interior motion analytics to better manage the security and improve upon passenger flow throughout their busy airports.
Integration of accurate passenger foot traffic statistics produced by the LiDAR scanner technologies and in conjunction with smart motion analytics, airports can now keep all their passengers updated via email or app on their expected queue-times. This will allow passengers to plan their departure from home or office. Airports working in conjunction with the TSA can apply this same set of data analytics to bring increasingly efficient procedures, predict bottlenecks and reallocate resources to more efficiently process a growing number of passengers.

Studies have shown that smarter airports can provide a better travel experience for passengers [6] and that more satisfied passengers spend more in airports overall. With the help of technology like LiDAR and by providing a better sense of passenger flow within terminals and surrounding areas, airports could boost their airport revenue by positioning shops in better locations and displaying adverts in prime traffic locations.

4.3 Summary

Having found this information and, of course, pushing this type of technology into work and public environments like an airport, it may raise the issue of security and the protection of personal identification if not done correctly. But this is where LiDAR stands out from the crowd and other solutions specifically like cameras. Instead of capturing a pixelated passenger image, like the ones a stereoscopic camera renders on a television screen, LiDAR scanners can translate positional data into anonymous point cloud data in a 3D spectrum, allowing airports to fully protect their passenger's identities and comply with GDPR regulations.

A common problem I found researching was the wealth of information on all the different applications I could have chosen to write about. I could have potentially written infinitely about the subject, so I needed to figure out what ones to focus and write about. So, I chose the most uncommon topics that not many people would potentially know about, as autonomous driving is the most common. To understand what the extent of the LiDAR scanner can do I had to look elsewhere, finding the two topics I have discussed above I found it all very interesting and the level of thought put into using the scanner in this way was incredibly smart and creative.

5. 2D - 3D LiDAR

Many people think that AI-powered cameras will evolve to the point where they make LiDAR obsolete and that LiDAR is now being simply used as a crutch of sorts. However, there will always be a need for LiDAR because it's purely more discreet than a camera and it works great in multiple scenarios.

Unlike the stereoscopic cameras that Tesla use, which require good lighting conditions, they can potentially have a narrow field of view and they might not perform great in some high-ceiling surroundings. LiDAR scanners on the other hand can operate in more challenging lighting situations, and perform well across all ceiling heights, their precision is not affected by other light sources through windows or by subpar lighting conditions. If we also examine, big data and cloud computing they both will advance just as quick as AI-powered cameras so LiDAR scanners will become much more sophisticated and feature rich as their counterparts.

With the growing popularity of LiDAR scanners, and with some thanks to the notoriety gained from Google and their autonomous car projects. More developers offer other solutions, and the constantly evolving scanners, and eventually the technology that is being produced, will simply get better, faster and more secure. Ultimately there will be smarter, more responsive, awareness software that will apply similar AI capabilities of image analysis, but without violating people’s privacy.

According to venture capital analyst firm CB Insights, start-ups working with LiDAR have raised USD 1.2 billion in the past five years [7]. Most of the money that has been raised won’t be going into the development of autonomous cars specifically. But it will go into making more accurate measurements from the hardware and software side of things, allowing developers to make use of it in a multitude of different applications, i.e. security, archaeology and even video games.

So, with that, I believe that the LiDAR scanner will be a great jumping-on point to develop my application to deal with the problem I have been given for this project as it has a wealth of knowledge and support from various sources in many different sectors.

6. Technologies

In this section of the document, I will explore the possible technologies and development environments that could be used to develop this application. This research aims to find out what the big tech companies are using and find what would be best suited to meet the requirements of this project.

The application will be running on a desktop or phone, with an interface to the LiDAR scanner and a visualisation of the environment scanned and saved for visualisation and or route planning. The LiDAR scanner can then be attached to a mobile unit of some sort that will navigate an area using real-time input from the application.

6.1 Languages

There are many languages in which could be used for this type of application, I will give some overview as to why I believe these will work.

6.1.1 Python

Due to my research I believe Python could be of great benefit to this project as it has numerous libraries to support the development of AI learning and the ability to control drones effectively due to the vast amount of support from developers in this field of study.

“Python is a multi-paradigm programming language. Object-oriented programming and structured programming are fully supported, and many of its features support functional programming and aspect-oriented programming (including by metaprogramming and metaobjects (magic methods)). Many other paradigms are supported via extensions, including design by contract and logic programming.

Python uses dynamic typing, and a combination of reference counting and a cycle-detecting garbage collector for memory management. It also features dynamic name resolution (late binding), which binds method and variable names during program execution.” [10]

6.1.2 C++

In my research and knowledge of C++ from the past year of studies, utilizing C++ 's speed and efficiency would be a huge benefit to this project. I believe, if coded correctly, an API that you can push and pull data from via Python could be the most optimal way to maximise speed and process time.

"C++ is a cross-platformed language that can be used to create sophisticated high-performance applications. It was developed by Bjarne Stroustrup at Bell labs in 1979, as an extension to the C language. The language gives programmers a high level of control over system resources and memory." [11]

6.1.3 SQL

Due to the addons and extensions of SQL I believe working with SQL and C++ will be of great benefit as they work very well together. This can then lend itself to the speed of which I need to process the data in Python, hopefully producing a fast and responsive application.

SQL (Structured Query Language) is used for storing, changing and retrieving data in databases. "SQL commands allow you to create a host of components such as tables, schemas, stored procedures, indexes, domains, character sets, or even new databases altogether." [8].

6.2 Additional Technologies

6.2.1 Doxygen

Utilizing the tools that Doxygen provide will be of great use in the coming development of this project as it can allow you to generate reports for your documentation, as it can do it in much more detail with greater readability.

"Doxygen is a documentation generator, a tool for writing software reference documentation. The documentation is written within code and is thus relatively easy to keep up to date. Doxygen can cross reference documentation and code, so that the reader of a document can easily refer to the actual code." [12]

6.2.2 GitHub

In every project, it is critical to have some form of version control. Version control will allow developers to save and backup their work, allowing them the ability to collaborate with a team depending on the project. Managing the source code of a project is critical to the health of the code and version control will allow a developer to view previous versions of their code, even rollback to a previous version if a problem pops up within the current version.

Git can be used locally on a system for version control but to store a git repository online a web-based host is required. GitHub, as the name suggests,

is a hub or hosting service for git repositories. If your local system crashes it could mean you lose personal files as well as your code. For this reason, it is important to use a web-based host such as GitHub. [14]

6.3 Development Environments

This section will give an overview of the numerous different environments in which developers have access to today, and to try and identify the best ones to use for this project.

6.3.1 Visual Studio Code

"Visual Studio Code (VSCode) is a source code editor developed by Microsoft that can be run on Windows, macOS, and Linux." [9]. It is customisable and offers themes in which can be beneficial to a developer for viewing syntax highlighting in different colours, even more so when using multiple languages like Python, C++ and all the common web development languages. It is also free to use and provides the ability to debug and use version control through a multitude of extensions.

There is an incredible support for the hybrid IDE/Text Editor from the community that uses it all many different and it is personally my favourite editor all Linux and Windows 10 due to its multiple terminals that are built in, and if you don't like them, there is bound to be an extension for that.

6.3.2 Visual Studio 2017

Using Visual Studio 2017 in this project will ensure compatibility with some of the SDKs I have found for the LiDAR scanner. This means that coding the LiDAR to take data from and be given data via a Python application will ensure the best possible compatibility in this project.

"Use Visual Studio 2017 to develop apps for Android, iOS, Windows, web, and cloud. Code fast, debug and diagnose with ease, test often, and release with confidence. You can also extend and customize Visual Studio by building your own extensions. Use version control, be agile, and collaborate efficiently with this new release." [13]

6.4 Technology Summary

For this project it is intended that most if not all the technologies will be a part of the final application. From this, I have concluded that the main code editor will be Visual Studio Code as it has a great range of extensions that can help produce solid code on either Windows or Linux environments.

Most of the research carried out has led me to believe that the main language will be Python as it can support the needs of this project with its vast array of libraries. Because of the support for many different databases, SQL being the one we have looked at, we will be using SQL with C++ and Python to produce the application.

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