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VL53L0X

Introduction

The VL53L0X is a new generation Time-of-Flight (ToF) laser-ranging module housed in the smallest package on the market today, providing accurate distance measurement whatever the target reflectance, unlike conventional technologies. Time of Flight sensors like the VL53L0X measure the time taken by an emitted laser pulse to reflect off a target and return to the sensor, calculating the distance based on the speed of light. This makes them highly effective in various applications such as robotics, drones, smartphones, and industrial automation where accurate distance measurement is critical. The VL53L0X stands out due to its ability to measure distances up to 2 meters with millimeter-level accuracy, making it particularly suitable for short-range applications.

Despite its advantages, the sensor's performance can be affected by environmental factors such as lighting conditions, target reflectivity, and angles of incidence, which may limit its usage in some scenarios. These limitations have motivated ongoing research into improving sensor algorithms and hardware design.

Literature Review

In recent years, advancements in Time-of-Flight technology have drastically impacted fields ranging from independent navigation to object detection. The VL53L0X represents a step forward in miniaturized ToF sensors by combining the entire laser-ranging module into a single package. Studies by (Komarizadehasl et al., 2022) and Another (Jegadeeshwaran et al., 2023) have highlighted the sensor's ability to achieve reliable distance measurements across various environments. Research has focused on improving the accuracy and range of ToF sensors through innovations in optics, signal processing, and power efficiency. (Khoa et al, 2022) demonstrated the application of enhanced algorithms to reduce noise involvement in real-world scenarios, significantly extending the sensor's effective range. Additionally, (Khoa et al, 2022) explored the integration of multi-sensor arrays to improve structural awareness in robotic systems using VL53L0X sensors. Although the VL53L0X is widely used in diverse applications, several studies, such as (Jegadeeshwaran al., 2023), have pointed out limitations in performance, particularly when dealing with highly reflective or transparent surfaces. The precision of distance measurements is also reduced in environments with direct sunlight or high ambient light conditions. Additionally, the maximum detection range decreases significantly when measuring small or irregularly shaped objects. Despite improvements in ToF sensor technology, challenges related to environmental factors, target reflectivity, and angle sensitivity remain prevalent, limiting the VL53L0X's is relevant in some scenarios. Therefore, how can the VL53L0X sensors accuracy be improved for consistent performance across different environmental conditions and object surfaces?

Operating Systems

Operating systems are a vital part of all computing systems. They allow users to take advantage of any computational resource to the best of its ability. Operating systems enable computers to be used by all people even if they have never interacted with one before. Since

Raspberry Pis are a type of computational device, Operating systems determine how accessible the device will be to users and dictate the complexity of it. There are numerous different operating systems that can be installed onto Raspberry Pis, each of which having its own set of pros and cons. The different choices available are all valid under different circumstances and it’s very important to choose the correct one depending on what the device will be used for. For example, Raspberry Pis that run very lightweight, simple applications may only need a command line interface (CLI) operating system to get up and running. If the device will be running a more complex app that interacts with other devices or even the internet, a full installation of Windows or Linux may be justified.

The two main types of operating systems that concern Raspberry Pi are graphical user interface (GUI) operating systems and CLI operating systems. A GUI operating system allows users to interact with the computer by clicking on icons and seeing visual representations of computer programs. CLI operating systems provide no visual aid to the user. The only way to use the computer in this case is to type commands into the command terminal. While there are many of each type that can be installed and used on a Raspberry Pi, this section will focus only on Raspberry Pi OS, which has options for GUI and CLI, and Ubuntu Desktop, which only has a GUI option.

The Raspberry Pi Operating System is an OS that has specifically been optimized to run on Raspberry Pis. The offical website explains “Raspberry Pi OS is a free, Debian-based operating system optimized for the Raspberry Pi hardware,” (Raspberry Pi, 2023). Because it has been tailored to Raspberry Pis, it is generally the top choice for most projects involving Raspberry Pis. It provides an intuitive GUI with an option for a CLI based OS that makes managing the device simple and efficient.

Ubuntu is a Linux based operating system that is a very common choice for desktop computers. Because of its widespread popularity and light weight architecture, it is also a common choice for Raspberry Pi projects. It is known to be an extremely user-friendly OS that is capable of running simple programs to complex server frameworks. Because Ubuntu is already being used extensively on many kinds of devices, there is documentation and resources available for nearly any type of use case.

As far as comparisons go, there are clear pros and cons to each. Ubuntu being a full-scale desktop operating system, it will be a much better choice for intense applications that require complex architectures to run properly. When doing complicated tasks, Ubuntu makes organizing the project structure much easier and allows for any actions to take place. This is simply because it has been refined by so many users for many years. Raspberry Pi OS on the other hand will serve as an efficient lightweight operating system that simplifies the process of creating a small-scale program. Because it is specifically tailored for Raspberry Pis, integration with the device will be extremely easy, and there should be no compatibility issues. If the CLI is the main concern, both OS will be usable as they both have options for command line interfaces.

Since we are planning to make a lightweight application using only one sensor and some light programming, Raspberry Pi is the clear choice for us. It will minimize the overhead and operating costs associated with getting up and running. Also, its GUI features will make our project easy to build and intuitively guide us in the right direction when building. While Ubuntu does offer more extensive features and documentation, we most likely will not take advantage of them since our project is quite small.

Installing Raspberry Pi OS is made extremely easy by the Raspberry Pi team. There are two methods, one that requires another computer and another that only requires the Raspberry Pi itself. We’ll go with the latter of the two. To install the operating system, we'll first need to plug a keyboard, monitor, and connect a storage device into the Raspberry Pi. After making all of the connections to the device, we’ll need to instantiate a wired internet connection as well. Next, powering the device on while holding the shift key will prompt us with a network installation of the operating system. From there, we just follow the given steps (Getting Started - Raspberry Pi Documentation, 2024).

Memory

Rasperry Pi computers can use a few different methods of memory.The most common one used in most cases would be have RAM. Most models coming in 2, 4, and 8 GB of RAM. They also have 1 GB models, and even some in betweener models like 3 GB for example. Computer Scientists tested how well each of the different RAM levels performed on a Raspberry Pi 4, at 2, 4, and 8 GB of ram on a desktop computer since its a more powerful model. They found that the 2 GB of ram will be good enough for most desktop usage such as browsing the internet and even using certain applications. The benchmark programs used in all 3 levels of RAM were a startup into Raspbian, Entire LibreOffice suite loaded (Writer, Calc, etc) without opening anything more than what was prompted: 567MB, Minecraft Pi (creating new world): 610MB, and Blender: 725MB (Cook, 2020). The 2 GB of RAM. That being said it struggled in certain circumtances, and thats where the 4 GB comes in. There is a noticable performance boost when switching to 4 GB of RAM. However it’s only useful if you require many programs open at once which would give the 4 GB of RAM the edge, but for most things it doesn’t make a huge difference. The 8 GB was found to be rather unecessary in most cases as the 4 GB performed well and RAM didn’t seem to be a serious bottle neck problem, but rather it was the CPU(Cook, 2020).

Another form of Memory is SD or microSD card. All Raspberry Pis have a slot for a microSD or SD card on their board (Kingston Technology, 2021). This is incase you want to use onboard memory. Some Rasperry Pi units require an SD card such as the original Rasperry Pi Model A and Model B. Model B+(2014) Onwards a microSD card is used instead. Minimum SD card capacity comes in at 8GB or 32GB (Kingston Technology, 2021). The last form of memory that some models do or don’t have would be USB. Booting your Raspberry Pi from a USB can improve the devices speed, storage capacity, and improve life span (Kingston Technology, 2021).

Communication

Rasperry Pis can use a variety of ways to communicate. In other words to send or receive data. Protocols such as Bluetooth, WiFi, Zigbee, LoRa, MQTT, and NFC. An ethernet cable can also be used to connect a Raspberry Pi to a laptop.

Another way it can communicate is Secure Shell (SSH). SSH is a secure network protocol that can be used to remotely operate a Raspberry Pi via command-line. SSH can be used to copy files and text to the Pi's command line, type commands, and use the Raspberry Pi without a dedicated display.

Another very useful way to communicate would be real time communication (RTC). A Raspberry Pi can use a client like a browser to access a server on a computer to establish voice communication.

Conclusion

This paper outlines the major aspects of the VL53L0X sensor and the Raspberry Pi. It also makes sure to introduce various operating systems associated with Raspberry Pi, its memory related information, and necessary background details of the time-of-flight sensor. We also lay foundational knowledge of communication and how the Raspberry Pi transfers data. It will serve as the foundation of our project that we intend to build using these devices. We will reference this document, retrieving necessary information related to our sensor, technical details of the Raspberry Pi, and installation guidance of the operating system.

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