LOW COST DATA ACQUISITION FOR AUTONOMOUS VEHICLE

by

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Dedicated to my family, my father SeungBok Lee, my mother KapIm Jun, my brother DongHan Lee, sister-in-law BoRam Kim, my niece CheaMin Lee, my nephew JunWoo Lee for their support and always believing in me.

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LIST OF ABBREVIATIONS

FEA – Finite element Analysis
LAN – Local Area Network
GPS – Global Positioning System

GLOSSARY

3D printing – 3D printing is printing that print physical product that is designed by 3D CAD software. 3D CAD digital file is a blueprint of the actual printing result. The process of 3D printing is a method of additive processes. Each layer of printing lays down on the previous top layer to make shape horizontally. (What is 3D printing? How does a 3D printer work? Learn 3D printing, 2019)

Finite Element Analysis – Finite element analysis (FEA) is a simulator that computers predict the reaction of products about heat, vibration, and other mechanical effects. Finite element analysis presents material breaking points such as yield point to maximize the strength of the product. (Finite Element Analysis Software, 2019)

myRIO – myRIO is an evaluation board or microprocessor that is a real-time embedded to operate applications. (myRIO, 2019)

LabVIEW – Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is engineering workbench software for academic application and manufacturing application about measurement, control, and test. (LabVIEW, 2019)

Ultrasonic sensor – Ultrasonic sensor is a sensor that measures the distance between sensor and object by emitting ultrasonic waves. The sensor converts ultrasonic waves into an electrical signal to present as a numeral distance unit. (MB7363 HRXL-MaxSonar-WRLS, 2020)

LiDAR – Lidar is a distance measuring hardware. Lidar uses laser light to measure the distance to target by illuminating with laser light. Lidar uses wavelengths to show measured distance on display. (Garmin & subsidiaries, 2019)

Stepper motor – Stepper motor is known as a brushless DC motor. The motor uses an open-loop controller system due to position feedback. This type of motor is used for robotics, remote controller vehicle, and other electronic devices. (Polifka, M, 2020)

ABSTRACT

The study of this research has a challenge of learning data gathering sensor programming and design of electronic sensor circuit. The cost of autonomous vehicle development is expensive compared to purchasing an economy vehicle such as the Hyundai Elantra. Keeping the development cost down is critical to maintaining a competitive edge on vehicle pricing with newer technologies. Autonomous vehicle sensor integration was designed and then tested for the driving vision data-gathering system that requires the system to gather driving vision data utilizing area scan sensors, Lidar, ultrasonic sensor, and camera on real road scenarios. The project utilized sensors such as cheap cost LIDAR, which is that drone is used for on the road testing; other sensors include myRIO (myRIO Hardware), LabVIEW (LabVIEW software), LIDAR-Lite v3 (Garmin, 2019), Ultrasonic sensor, and Wantai stepper motor (Polifka, 2020). This research helps to reduce the price of usage of autonomous vehicle driving systems in the city. Due to resolution and Lidar detecting distance, the test environment is limited to within city areas. Lidar is the most expensive equipment on autonomous vehicle driving data gathering systems. This study focuses on replacing expensive Lidar, ultrasonic sensor, and camera to drone scale low-cost Lidar to real size vehicle. With this study, economic expense autonomous vehicle driving data acquisition is possible. Lowering the price of autonomous vehicle driving data acquisition increases involving new companies on the autonomous vehicle market. Multiple testing with multiple cars is possible. Since multiple testing at the same time is possible, collecting time reduces.

CHAPTER 1. INTRODUCTION

The mechanical assembly is designed to mount onto a standard size vehicle hood to gather data at a low cost. The purpose of this project is to build on that prior work by connecting sensors, designing a power supply, programming the device correctly and demonstrating a collection of sensor data on a flash drive. This data can then be analyzed while testing suitable data analysis methodologies.

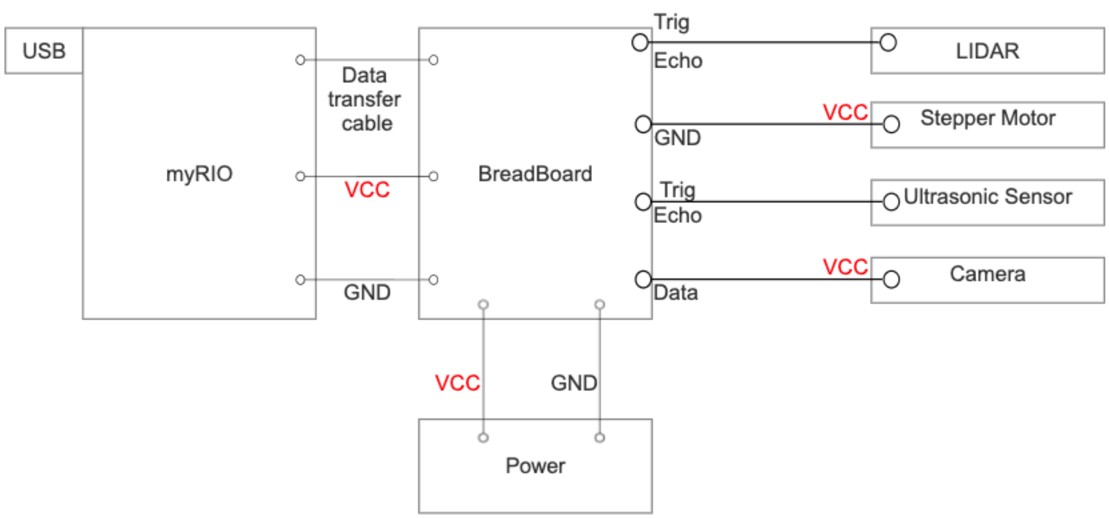


Figure 1.1: Demo Circuit Block Diagram for Data Acquisition

The assembly housing is designed to fit all the sensors in the system. In the previous work (Chapin, 2018), the housing was designed to be 3D printed. The 3D body assembly design was analyzed by Finite Element Analysis (FEA). Analyzing the 3D design estimates the mechanical dynamics of the actual system, such as the center of mass and strength of the body. All sensors need to connect each other inside of the mechanical assembly. Besides, previous work did not include the code to operate the data acquisition. The customized code with

LabVIEW (LabVIEW, 2019) requires intending to gather driving data. The purpose of this project is to connect sensors, designing a power supply, and programming the device correctly and demonstrating a collection of sensor data on a flash drive. This data, distance of between object and a vehicle on the road, can then be analyzed while testing suitable data analysis methodologies for this system.

The mechanical assembly needs a re-adjustment for sensor location to operate the data acquisition and connect all sensors with jumper wires. Jumper wires for input power and output do not connect each sensor. Between the camera and Wantai stepper motor (Polifka, 2020), the wire space was not enough due to the thickness of the power cable. As soon as assembly parts were listed, all the accessories such as wires, LAN cable adapter, stepper motor drive were fully listed. All sensors manuals have been researched to find out the specification of each part and parts that need to be purchased to make a circuit. The first purchasing part list was only a cable and wire list for testing myRIO (myRIO, 2019). The second accessory list was the final list that includes camera data cable, power cable, stepper motor drive, and LAN cable adapter. The final list was ordered and arrived the last week of staying at Kettering University.

While the final list was on the way to the school, miscellaneous studies and tests were made about LabVIEW (LabVIEW, 2019) and sensor connection. LabVIEW (LabVIEW, 2019) was an appropriate software to gather data with myRIO (myRIO, 2019). Three LabVIEW (LabVIEW, 2019) instruction books such as Learning with LabVIEW (Bishop, R. H., 2015), LabVIEW Graphical Programming (Jennings, R., & Cueva, F. D. L., 2020), and Hands-on Introduction to LabVIEW for Scientists and Engineers (Essick, 2019) have been read to create new code and find an solution for an error in the code. After all the LabVIEW (LabVIEW, 2019) books were read, a demo system circuit was created to connect all sensors. Before the physical circuit was made, the demo system circuit was discussed with Dr. Peters. After that, each sensor demo circuit was made for each trial to avoid the failure of the total circuit system. Each part, such as power, data, input, and output cable connector, was recorded to figure out the size of battery and resistance from each sensor manual. As soon as the performance listed up and accessories have arrived, the physical circuit was tested.

The first test was a Wantai stepper motor (Polifka, 2020). The purpose of a Wantai stepper motor (Polifka, 2020) is to turn the angle of LIDAR to scan at most 180 degrees while a vehicle is moving. The motor power test was made. After that, many different stepper motor codes were tested on the myRIO (myRIO, 2019). However, it did not work. Customized code was also tested to figure out the error on the code. However, the error code was not found. There is no time to stick on a single test. The test was moved to next. The second test was an Ultrasonic sensor. The Ultrasonic senor test process was the same as the physical circuit, and then the coding test was made. The ultrasonic sensor also did not work for the first time. At the second test, the sensor worked for a few seconds. However, it was the last time that the Ultrasonic sensor worked. The code was all green on the dashboard, but the sensor and circuit were did not worked.

The reason for failure was not found even though the Ultrasonic sensor did not work. While the Ultrasonic sensor was testing, LAN cable and LAN cable hub arrived. The physical LAN cable and HUB tested. However, the coding test was not made due to time. The LAN cable and HUB has arrived at the end of last week of staying at the Kettering University. In result, knowledge was acquired that have learned how LabVIEW (LabVIEW, 2019) control physical sensors and circuit. The graphical program language is required to control LabVIEW (LabVIEW, 2019). The block diagram function was used to run mechanical assembly. The result could not make a significant step on the project. However, there is learning from failure. The failure taught how the whole system should be connected and error codes on customized code. The customized code is not fit to the ultrasonic sensor that is used in the project. The possible reason is that the customized code input signal is different from the open-source code input signal in a physical graphic icon. It is hard to match and replace two different icons to run the system.

Assumptions

This research study is anchored on the assumption that expensive sensors and economical sensors help to move and drive an autonomous vehicle in the city area and driving track. Collaborating with economical cost sensors has a driving performance as collaborating of expensive sensors that typically, many vehicle brands use now to sell their cars.

Delimitations

The research defines and helps reduce the price of development about an autonomous vehicle system by gathering autonomous vehicle driving data with a fair price to test algorithms, and it affects the price of selling an autonomous vehicle. Therefore, the scope of the topic is limited. The research is conducted on a sensor and driving data study. The mechanical assembly of this study applies to specific vehicle types such as sedan, SUV, and coupe because the main body assembly must be attached to the hood of a car to get driving data. The delimitations that this study relates are the study of autonomous parts. The depth of sensors coding algorithms is not going to be discussed in this paper. The process of the project is not done yet and not studied to have its own coding algorithms for an autonomous vehicle module. The depth of sensors coding algorithms will be discussed in the next step of the study. Until now, a mainly physical module of an autonomous vehicle and electronic circuit are discussed. This study will only have in the city area and driving test track due to the measurement of the distance sensors such as an ultrasonic sensor that is HRLX-MaxSonar-WRLS (MaxSonar-WRLS, 2019), and LIDAR-Lite v3 (Garmin, 2019). HRLX-MaxSonar-WRLS (MaxSonar-WRLS, 2019), and LIDAR-Lite v3 (Garmin, 2019) detect objects on the road in a short distance. Therefore, driving data from this project targets to city-based driving.

Limitations

One of the limitations of the previous design was the stationary mounting for sensors. By utilizing adjustability and the ability to remove sensors, the system becomes much more flexible and allows for a clear line of sight for drivers of any height. A vehicle will have limitations in driving speed. The lack of stationary of a mechanical assembly on the hood of a vehicle affects a limitation in driving speed. In the past work, a mechanical assembly made a result that it can hold it as a mechanical structure until the speed of 20m/s (44 mph).

The mechanical assembly needs to be modified from the one done in the previous project. Previous projects did not account for the thickness of the cables used for each sensor. There are two cables per sensor, one for data transmission and the other for power. If sensors are unplugged, the mechanical assembly power cable outline is acceptable because it does not have useless space inside. Most of the sensors work well at the current location.

Figure 1.2: Space between Area Scan Camera and Stepper Motor

An area scan camera needs to move location to forward to make space to plug cables. Camera data and power cables are thicker than other cables. Areas scan camera and the Wantai stepper motor (Polifka, 2020) are too close to each other. It is hard to plug cable to an area scan camera. The center camera was moved to forward a little bit. Therefore, data and power cables are easily plugged to the center camera and Wantai stepper motor (Polifka, 2020).

COVID-19 Pandemic Effect on Finalization of Research stopped the final test of the project. The final customized code is created even though the COVID-19 Pandemic effect is going on. The stepper motor code is based on open source that is Mark, & Mark. (2019, June 12). All the information to customize stepper motor is from Learning with LabVIEW (Bishop, R. H., 2015), LabVIEW Graphical Programming (Jennings, R., & Cueva, F. D. L., 2020), and Hands-on Introduction to LabVIEW for Scientists and Engineers (Essick, 2019). After customized ultrasonic, and stepper motor code was created, the final data transferring code was created to work as one system with two HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019), Basler Ace U ac A1300-75gc (Basler ace acA1300-75gc - Area Scan Camera, 2019), and LIDAR-Lite v3 (Garmin, 2019).

CHAPTER 2. REVIEW OF LITERATURE

Collecting massive driving data for an autonomous vehicle is essential to determine the driving path and on-road safety. Amount of autonomous vehicle driving data collected differently in each different autonomous vehicle driving level, such as Level 0 to 5. From Dmitriev, S., 2019, a lower level of autonomous driving such as Level 0 to 2 collects and generates around 25 Gigabytes of data per hour. The importance of data analysis in autonomous vehicle development, the article discussed the type of sensors that use in an autonomous vehicle such as radar, Lidar, computer vision, sonar, GPS, and ultrasonic. The article also mentioned that the method of managing massive driving data is essential. Managing driving data helps to speed up decision-making when an autonomous vehicle is driving on the road.

The safety of autonomous driving depends on the method and speed of managing driving data. For autonomous driving data, it does not have to be collected by experiment. Public autonomous driving data is easily found on the Internet. Researchers can use the public an autonomous vehicle driving data for their simulation. (TempletonGraham, G., & Graham, 2019) However, researchers are careful about using public data. Using public autonomous vehicle driving data depends on the depth of their study. Waymo, Uber, General Motors, and other vehicle companies start to release an autonomous vehicle-driven data to the public. As soon as many autonomous vehicle companies share their driving data, shared driving data becomes open-source code such as programmer use in their work. (Hawkins, A. J., 2019) Even if researchers use public data, they should add more own driving data to improve and prove their study.

Adding more own driving data to public data could be risky to have code error and slow data transferring due to accumulated neural networks with multiple algorithms. Using a combination of a public data set and additional data set causes overfitting in machine learning and autonomous vehicle system. Autonomous vehicle system with a high resolution of the camera, ultrasonic sensors, and LIDAR collect a massive data set that most data set is similar. Overfitting causes reducing predictive power on an autonomous vehicle system.

Prediction is a main portion of autonomous vehicle driving. That is why training with examples and changing the complexity of the network and algorithm are essential in autonomous vehicle driving. According to You're Doing Machine Learning Wrong (2020), the overfitting is not the only issues in the machine learning and an autonomous vehicle but also lacking quality data, having algorithms become obsolete as soon as data grows, and getting wrong predictions to come together with biases, and making the wrong assumptions. Quantity of data collecting cause overfitting, lacking quality data, having algorithms become obsolete as soon as data grows, and getting wrong predictions to come together with biases, and making the wrong assumptions due to requiring tremendous sample or test data set. An autonomous vehicle driving data collecting system from this project uses a drone size sensor and gathers driving data that can use for an autonomous vehicle. Reducing the size of sensors and the cost of data acquisition increases the proportion of data piling up.

This project is developed with the intent to follow and build upon what was completed by another student in an earlier project. (Chapin, 2018) The requirements of this project are provided in Table 2.1.

Table 2.1: Essential Criteria for the Sensor Data Collection Assembly

1	The data collection system must mount on a vehicle without damaging it in any way. Thus, allowing for the data collection assembly to be mounted at different heights on the hood and onto vehicles with varying heights.
2	The system must not impair a driver's vision or present any type of hazard while the vehicles are in motion.
3	The data collection assembly must comply with traffic laws and regulations.
4	The system must not violate any applicable laws regarding what can be mounted on vehicles on public roads to allow for testing on public roads.
5	The system must a commercially available battery power or by the car itself.
6	At a minimum, three forms of sensors should be used. These forms are camera images, LIDAR-Lite v3 (Garmin, 2019) images, and ultrasonic data.

The mechanical assembly is flexible and may be moved to different places on the hood of a vehicle and can be used at any location on the vehicle. The mechanical assembly can fit any type of vehicle such as a sedan, coupe, or SUV, and any type of personal vehicle brands such as Hyundai, Tesla, Kia, BMW, Audi, and other automobile companies. On top of that, this project can help to produce crowd-sourced for the acquisition of data for autonomous vehicle driving. The mechanical assembly uses a one-inch wide quick-tight nylon strap with S-hooks to give a combination of the adjustability and removability on the vehicle hood. The height of the mechanical assembly is designed with a low profile to eliminate obstruction of the driver's field of vision. Even though a mechanical assembly has low height, the range of driver's height is not fixed and may vary a great deal. Therefore, using adjustable and removable sensors is critical to future work.

From the FEA result of the earlier project (Chapin, 2018), two-failure scenarios ware found for the design of a mechanical assembly. To conclude the failure scenario, the Finite Element analysis used to yield stress. The previous work has two estimate numbers of maximum stress achieved, such as 16.65 MPa and 0.171 MPa. However, it is not an exact number because 3-D printing makes the body structure. The material of 3-D printing is impossible to represent the stresses and strains with an exact number by simulation.

Limitations of past physical design

One of the limitations of the previous design was the stationary mounting for sensors. By utilizing adjustability and the ability to remove sensors, the system becomes much more flexible and allows for a clear line of sight for drivers of any height.

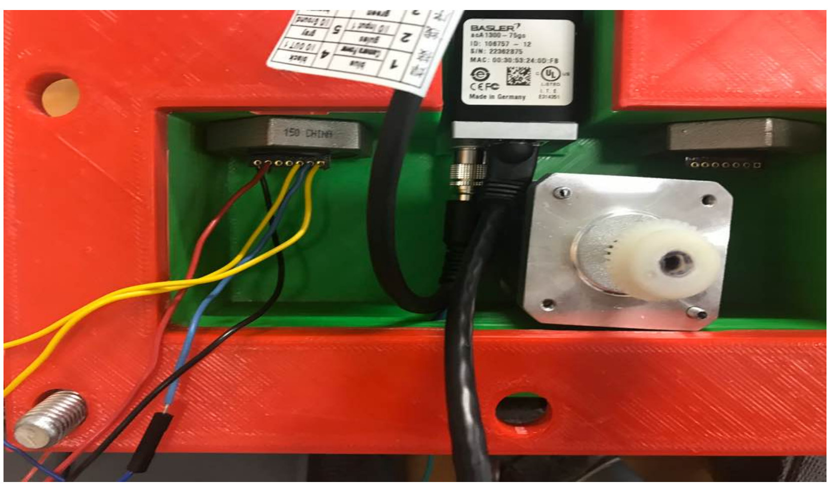


Figure 2.1: Mechanical Module Assembly Cables are plugged (Donghun Lee. May 20, 2019)

The mechanical assembly needs to be modified from the one done in the previous project. Previous projects did not account for the thickness of the cables used for each sensor. There are two cables per sensor, one for data transmission and the other for power. If sensors are unplugged, the mechanical assembly is well adjusted to working correctly because it does not have useless space inside. Most of the sensors work well at the current location. An area scan camera needs to move location to forward to make space to plug cables. Camera data and power cables are thicker than other cables. The area scan camera and Wantai stepper motor (Polifka, 2020) are too close to each other. It is hard to plug cable to an area scan camera. The center camera was moved to forward a little bit. Therefore, data and power cables are easily plugged to the center camera and Wantai stepper motor (Polifka, 2020).

Background

The current data gathering methods utilize area scan cameras, low-quality LIDAR-Lite v3 (Garmin, 2019), and ultrasonic sensors used at the mechanical assembly. This project utilizes a National Instruments myRIO (myRIO, 2019), power supply to the myRIO (myRIO, 2019), and the sensors while programming the myRIO (myRIO, 2019) to correctly receive sensor data and save it to a flash drive. The myRIO (myRIO, 2019) and LabVIEW (LabVIEW, 2019) were paired with data sharing. LabVIEW (LabVIEW, 2019) can order action to a mechanical assembly through myRIO (myRIO, 2019), where the mechanical assembly needs its code to gather data by using LabVIEW (LabVIEW, 2019). The equipment utilized in this project is described in the following Table 2.2.

Table 2.2: Hardware, Sensors, Software List

Hardware

- National Instruments myRIO (myRIO, 2019)
  - A processor of a data-gathering system
  - Power supply with a power cable or 5V battery
- Basler Ace U ac A1300-75gc (Basler ace acA1300-75gc – Area Scan Camera, 2019)
  - Area Scan Camera with data LAN cable

Sensors

- LIDAR-Lite v3 (Garmin, 2019)
  - Driving mapping sensor
- HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019)
  - Driving distancing sensor

Software

- LabVIEW (LabVIEW, 2019)
  - Graphical program language

Hardware

The mechanical assembly includes LIDAR-Lite v3 (Garmin, 2019), camera, Ultrasonic sensor, Wantai stepper motor (Polifka, 2020), and myRIO (myRIO, 2019). All the sensors and hardware are in one system to scan and detect the area while a vehicle is moving. The previous assembly was designed for only physical design and did not hook up each other. The project includes the process that ties all sensors in one system with myRIO (myRIO, 2019). The equipment used in the previously designed system is described in the following Table 2.3.

Table 2.3: Hardware Specification

Basler Ace U ac A1300-75gc (Basler ace acA1300-75gc-Area Scan Camera, 2019)

- Camera
  - Basler Ace U ac A1300-75gc
  - Scan area while a car is moving
  - Actual area image data transfer to LabVIEW (LabVIEW, 2019)
  - 6Pin power cable
  - LAN cable data transfer requires X-hub to use with myRIO (myRIO, 2019)
  - 88 frames
  - PYTHON 1300 sensor
  - 1280 px * 1024 px Resolution (H*V), 1.3MP

Table 2.4: Hardware Specification (continued)

LIDAR-LITE V3 (Garmin, 2019)

- Low-Quality LiDAR
  - LIDAR-LITE V3
  - Optical distant measuring distance between obstacles and a vehicle
  - Communication via 12C and PW<
  - Power: 5V
  - Range: 5cm-40m
  - 1cm resolution

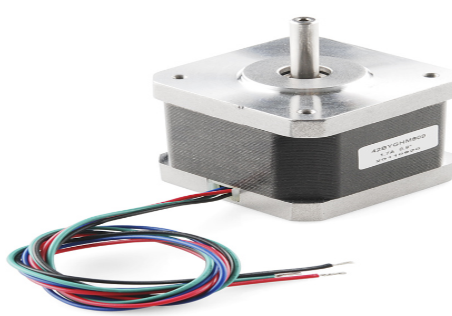
HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019)

- Ultrasonic Sensors
  - HRXL-MaxSonar-WRLS
  - Using pulse-width, and analog voltage to measure the distance
  - Power; 2.7-5.5V
  - 1mm resolution
  - Max range: 10m

Table 2.5: Hardware Specification (continued)

National Instruments myRIO (myRIO, 2019)

- National Instruments myRIO (myRIO, 2019)
  - Xilinx Z-7000 Processor 667 MHz
  - A real-time embedded evaluation board
  - FPGA type
  - Three-axis accelerometer
  - Breakout Board support



Wantai Stepper Motor (Polifka, 2020)

- Wantai stepper motor (Polifka, 2020)
  - Bipolar motor
  - Step angle (0.9 degrees)
  - 2-Phase; 1.7A/Phase (Current), 3V (Voltage)
  - Diameter Drive Shaft (5mm)
  - Torque (48N.cm)

Software

The previous design required software to operate. LabVIEW (LabVIEW, 2019) was chosen as the preferred choice to control the myRIO (myRIO, 2019). National Instruments manufactures both, and LabVIEW (LabVIEW, 2019) is versatile in that it can accommodate two different programming modes such as dataflow and graphical. Dataflow in LabVIEW (LabVIEW, 2019) does not use sequential lines of text. The data moving through the nodes determines the execution order of the functions on the block diagram. The Graphical in LabVIEW (LabVIEW, 2019) is that design program language with icons on a diagram. Icons on a diagram represent graphically instead of with text. In terms of gathering data, the vehicle needs to gather dataflow and graphical type simultaneously. LabVIEW (LabVIEW, 2019) can control multiple processing and multi-threading hardware with the built-in code. LabVIEW (LabVIEW, 2019) can read and operate itself without connecting to a different computer while an autonomous vehicle is driving data transferring from the mechanical assembly. The user interface is required to run a system through LabVIEW (LabVIEW, 2019) and to control a data-gathering system. LabVIEW (LabVIEW, 2019) uses a block diagram to construct the code for visual interpretation purposes. The block code is easier to understand clearly. LabVIEW (LabVIEW, 2019) is a system-design platform and utilizes visual programming language, utilizing data acquisition and controlling instrumentation.

Table 2.6: Software Work

Code working with LabVIEW
• Communication among sensors • Gathering data into myRIO from sensors • Displaying status of data acquisition system.

These systems, along with those developed in this work, are utilized to reduce vehicle accidents. The research data can be used to upgrade an advanced driver assistance system, such as ADAS. Also, the research data can help to improve the lane-keeping assistance system. Both systems use Lidar, mapping, and objective detection algorithms to run autonomous driving. They are intended to make driving safer by reducing human error, avoiding unexpected situations on the road. Both are discussed at length, considering many of the current issues, and those things that this system may make driving safer.

Avoiding Unexpected Situations on the Road

Avoiding unexpected situations, an autonomous vehicle collects driving data as quickly as possible and updates traffic data as soon as possible. Collecting Road Situation Data, Autonomous vehicles got into an accident due to errors in the prediction of self-driving. According to Murdock, J. (2018), Google self-driving car caused a freeway crash on the forbidden route. The Google engineer reported that Google's software was not ready for this accident scenario that traffic is merging the situation between high speeding vehicles. Collecting massive driving data, autonomous vehicles can predict the avoidance of accidents. The autonomous vehicle can save multiple scenarios of different accidents. An autonomous vehicle can practice a diversity of accident scenarios with experienced and saved driving data. Therefore, the autonomous vehicle can have knowledge that it can warn drivers, or it can make a decision itself when it detects the pre-condition of an accident, such as slowing down, turning on hazard light, and using a high beam. As a result, the autonomous vehicle, using accumulated driving data, could reduce self-driving accident.

Technologies that Assist Autonomous Vehicles

According to Avoiding Crashes with Self-Driving Cars (2014), a variety of technologies assist an autonomous vehicle to predict possible scenarios of car accidents and next path, including pedestrian crash avoidance mitigation, adaptive advanced cruise control, pre-collision avoidance, lane departure warning system, blind spots, 5G networking system, and automatic lane centering. For the advanced autonomous vehicle driving in the city, autonomous vehicle companies focus on detecting traffic light as a real-time system. To get real-time traffic data, an autonomous vehicle requires a 5G networking system due to the speed of data transferring speed. According to Will (2018), 5G networking is the fastest networking that data cloud system uses, and 5G data transferring speed is 1.056 Gbit/s. The speed of 5G data transferring is adequate to take care of real-time traffic data transferring.

CHAPTER 3. RESEARCH METHODOLOGY

Approach to Work

At the beginning of the research project, manuals of each part, such as stepper motor, ultrasonic sensor, camera, and Lidar, were reviewed. Finding and collecting each part manuals were important. All of the circuit connection information such as input, output, power, and wire was recorded on manuals. Part manuals helped to prepare to make an accessory list to put all sensors and parts used in the mechanical module. Two HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019), areas Basler Ace U ac A1300-75gc (Basler ace acA1300-75gc - Area Scan Camera, 2019), Wantai stepper motor (Polifka, 2020) and LIDAR-Lite v3 (Garmin, 2019) were parts and sensors that are in the mechanical assembly module. The primary purpose of a mechanical part was to connect all of the sensors in one system. After that, the mechanical assembly needed its code to work itself while the vehicle was moving. Before every sensor and parts were put in one system, all of the steps were recorded, and the research work was step by step. Working one by one helps to fix errors even if collecting driving data had trouble in real-time operation.

Project Development

The project has taken several steps that include hardware and software development. First, Wantai stepper motor (Polifka, 2020) with motor drive and myRIO (myRIO, 2019) was tested. All example codes and papers related to the Wantai stepper motor (Polifka, 2020) and DC motor with myRIO (myRIO, 2019) were downloaded. Second, the official example of working Wantai stepper motor (Polifka, 2020) with myRIO (myRIO, 2019), such as open sources, was not found. Bountiful example codes from the website about Wantai stepper motor (Polifka, 2020) and DC motor was collected to customize to the data integration machine.

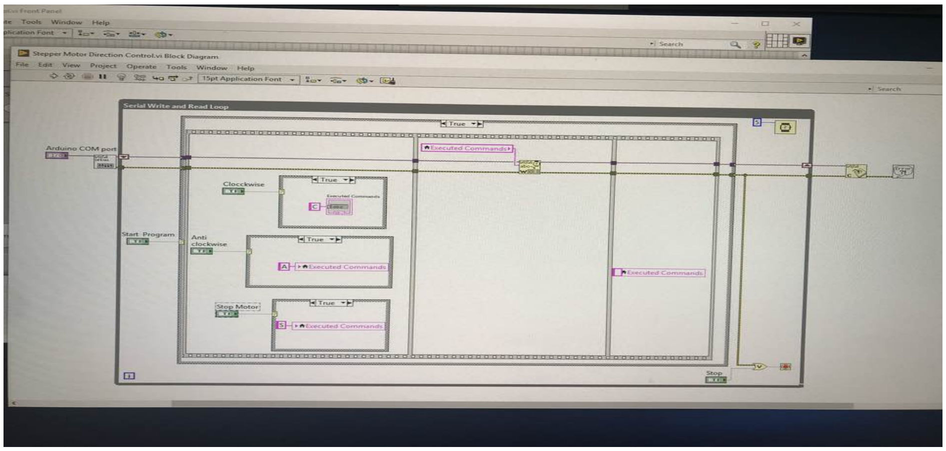


Figure 3.1: Stepper Motor Code, Donghun Lee. May 20, 2019

Third, three different books about LabVIEW (LabVIEW, 2019) were reviewed to know how to use and connect LabVIEW to myRIO (myRIO, 2019) to customize code for a stepper motor. Necessary tools and coding language of LabVIEW (LabVIEW, 2019) were studied, and tutorials of myRIO (myRIO, 2019) were watched on online tutorials. Forth, the specification of all sensors and other parts was summarized, and demo circuits of complete assembly on paper were created to make an overall view of the total circuit. Multiple demo circuits in case of not working were tested and made. Fifth, ss soon as many demo codes and circuits were built, a list of all parts that need to use to hook up all sensors was made. Cables for all sensors, motor drive, and data cable adapter on myRIO (myRIO, 2019) were not purchased. All the accessories for sensors were searched. X-hub to use LAN cable to transfer data from an area scan camera was purchased due to area camera requires using LAN cable. While the parts are on the way to the school, customized code for the stepper code was tested several times.

Table 3.1: Accessories for Sensors

Purchased accessories

- X-Hub Adapter for myRIO
  - Storing data to a USB or Hard drive
  - Gathering image data from a picture capturing device
  - Link between network and Ethernet
  - transmission over Ethernet-based communication protocols
- Jumper cable
  - Connecting each sensor through breadboard
- Power cable
  - Camera power
- LAN cable
  - Camera data transfer to myRIO

The customized code was edited at each testimonial. However, customized code did not work. Sixth, the research step was moved to the ultrasonic sensor to avoid wasting time from failure. Two HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019) were ready to use for the research. However, one HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019) was used. The reason is that recoding a single HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019) code helps to find and fix code error when two HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019) run together in one system. Ultrasonic code samples were gathered, and codes for a mechanical assembly were customized. IPWM code was created to use into HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019) code because the ultrasonic sensor can use PWM to measure the distance between obstacles and sensor. After that, the main ultrasonic sensor code was created.

However, HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019), the customized code, did not work.

Last, delivery of accessories of sensors was not made. Therefore, errors in code were studied to fix customized code for stepper motor, and HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019). The first code error was found. The first code error was a myRIO (myRIO, 2019) access denied error. The error was about using a different version of LabVIEW (LabVIEW, 2019) between myRIO (myRIO, 2019), and the University computer. Access denied error was the main issue for code error. It was hard to fix this error because a university computer was used to use LabVIEW (LabVIEW, 2019), and the university computer was locked to update or install software without the university permission.

Previous Work In This Area

Multiple types of classification method were used in this field to increase safety of an autonomous driving. The edge detection method can figure out most of the traffic signs because every traffic sign has different shapes. According to Vishwanathan, Peters, and Zhang (2017), edge detection is one method that increases avoidance of autonomous vehicle accidents by detecting the edge of traffic signs. A stop sign has an identical shape so that edge detection can recognize a STOP sign, and an autonomous vehicle can prepare to stop on the line of a stop sign. Many people can ignore a stop sign while they are driving or rush in driving. Sometimes, a stop sign is small and hard to catch by human eyes. Human errors can occur. However, in an autonomous vehicle, as soon as the sensors detect the shape of a stop sign, autonomous vehicles will be stopped on the line of a stop sign.

They can have better performance on autonomous vehicle driving if they can get an accurate road data and traffic information for autonomous driving. With the given information, lane detection system training with the unstructured road, regular road, lane marked road, and non-lane marking road is essential for an autonomous vehicle driving. In other words, they focused on a lane detecting system to make safer driving.

The edge detection can help more on the unprepared environments, such as off-road and rural areas. Edge detection can determine the moving obstacles as well, such as wild animals. In the United States, many wild animals jump into the road without notice. In other words, many drivers have experience with roadkill. Therefore, edge detection can reduce roadkill and ignoring traffic signs at the same time. It means that edge detection can improve safer autonomous vehicle driving while driving on an urban and rural side.

Work Procedures

The assembly housing is calibrated to fit all the sensors in the system. Each sensor has a different size to fit in a physical system that is designed by 3D printing. To print the body structure of the mechanical assembly with a 3D printer, Finite Element Analysis (FEA) applied to the body of the mechanical assembly. This process helps estimate and evaluate the strength and weight of the mechanical assembly when the mechanical assembly is attached to the hood of a vehicle. Finite Element Analysis (FEA) can provide evidence to create a 3D printing housing design of a mechanical assembly. There is additional work on the mechanical assembly to connecting multiple sensors in one system. The previous mechanical assembly needs to be re-organized a little bit to make space for connecting cables and attaching processors such as myRIO (myRIO, 2019). The mechanical assembly does not have its code to gather driving data on the road. It requires making its code with LabVIEW (LabVIEW, 2019).

After checking the physical assembly, it required improvement as it is installed on the actual vehicle. The camera location was adjusted connected to operate because the camera power cable was thicker than expected.

All sensor and motor manuals have been read. The final list includes camera data cable, power cable, and LAN cable hub. The needed items were then ordered, and the best way to connect sensors was investigated and tested. The primary study was about LabVIEW (LabVIEW, 2019). LabVIEW (LabVIEW, 2019) was a leading software to operate the whole system to gather data. The multiple LabVIEW (LabVIEW, 2019) instruction books have been read to understand open-source code and to create the customized code. The demonstration was discussed with Dr. Peters to avoid the failure of connecting jump cables between sensors. The power supply, input, and output cable connectors were recorded to figure out the size of the battery and the user manual's resistance.

The Wantai stepper motor (Polifka, 2020) was the first tested hardware. The Wantai stepper motor (Polifka, 2020) operates the angle of LIDAR-Lite v3 (Garmin, 2019) to scan driving vision that is 180 degrees at the center of the vehicle hood. Multiple open-source codes from National Instruments Community were tested for Wantai stepper motor (Polifka, 2020). However, customized codes did not work. The error code was not found for the customized code. Every sensors manual must be read, and multiple open sources need to be found. The next procedure was an ultrasonic sensor test. The ultrasonic sensor worked a few seconds and did not work for other trials. The simulation of code does not have errors on the LabVIEW (LabVIEW, 2019). However, the ultrasonic sensor did not work with the code.

The Last test was camera LAN cable and myRIO LAN cable adapter, X-Hub, test. LAN cable was connected between camera and X-Hub, and the customized code was tested. The power was on, but the camera did not transfer data to myRIO (myRIO, 2019). To finalize the result, the customized code equipped into the mechanical assembly, and inside of the mechanical assembly were adjusted space for connection cables.

CHAPTER 4. RESULTS

Study Result

An autonomous vehicle driving data was not collected. However, accomplishments help future work. The actual autonomous driving test was not made during the research. The numeric data could not be gathered as the research data result. The research was reviewed existing design of LabVIEW (LabVIEW, 2019) software coding, Wantai stepper motor (Polifka, 2020) control with myRIO (myRIO, 2019), and operating process of LIDAR-Lite v3 (Garmin, 2019), HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019), and Wantai stepper motor (Polifka, 2020) in one system such as myRIO with LabVIEW (LabVIEW, 2019). This study evaluated how to run each sensor cables and connectors and found that the thickness of cables can affect the location of each sensor in the assembly machine for this study. The routing of cables was planned out by this study for the assembly machine. Before planning out the routing of cable for the assembly machine, the research was identified all sensors that would be required, such as output power, input power, and weight, and came up with a full list of accessory purchasing.

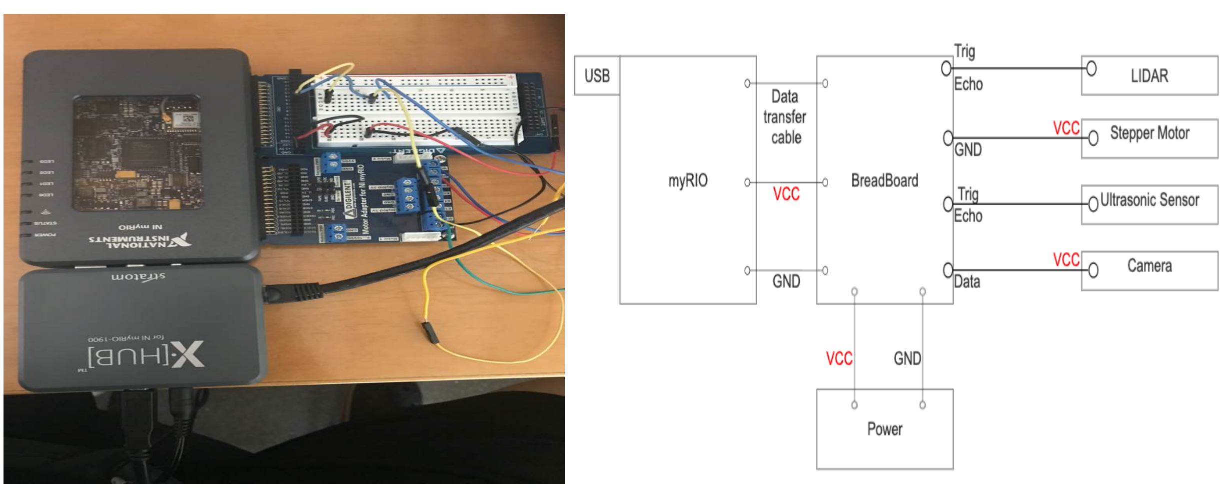


Figure 4.1: Data Transfer Hardware Wiring (Donghun Lee, May 20, 2019)

The research was gathered and investigated information about using data for the future work of this study. The researcher has two different methods to use autonomous vehicle driving data, once it is acquired. The first method to use driving data is by comparing data accuracy with expensive Lidar sensor-equipped driving data. The latter method is comparing data transfer speed with expensive Lidar sensor-equipped driving data.

Final Result

The customized program coding was not tested in a car. This project used public data that used sensors and cameras with a similar specification of equipment used by this project due to the pandemic situation. Publicly data from the Ford Autonomous Vehicle Dataset. (Ford real dataset, 2020) was used in the finalization of this work. This data set has data points from testing (Ford real dataset, 2020) tested on an average route of 66 km in the Detroit area. The driving area includes the DTW airport, the University of Michigan Dearborn campus, and residential communities. For the equipment, Four HDL-32E Velodyne 3-D Lidars, 6 Point Grey 1.3MP Cameras, 1point Grey 5 MP Dash Camera, and Applanix POS – LV IMU are used for Ford Autonomous Vehicle Dataset. (Ford real dataset, 2020) Besides, 3D Ground Reflectivity Maps, 3D Point Cloud Maps, 6 DoF Ground-truth Pose, 3 DoF Localized Pose, and Sensor Transforms and Calibration are included. Seven cameras are installed on a vehicle. There are two front cameras, two rear cameras, two side cameras, and a front dashboard camera. The result that this project wants to use from Ford Autonomous Vehicle Dataset (Ford real dataset, 2020) is pictures from the front dashboard camera. The dashboard camera has similar performance as Basler Ace U ac A1300-75gc (Basler ace acA1300-75gc - Area Scan Camera, 2019) has. The camera resolution of Basler Ace U ac A1300-75gc (Basler ace acA1300-75gc - Area Scan Camera,

2019) and a camera that Ford Autonomous Vehicle Dataset (Ford real dataset, 2020) use is same that is 1.3MP.

Figure 4.2: Front Dashboard Camera Picture (Ford real dataset, 2020)

Figure 4.2 shows that the dashboard camera detects all the traffic environment on the road such as construction fences, traffic signal light, road signs, and trees. The dashboard camera is not a high-end camera that uses in the real size autonomous vehicle driving. However, it is still catching objects for an autonomous vehicle driving. Figure 4.2 shows that the dashboard camera and Basler Ace U ac A1300-75gc (Basler ace acA1300-75gc - Area Scan Camera, 2019) can be used as object recognizers because objects that an autonomous vehicle should warn for driving are clearly in the picture from the dashboard cam.

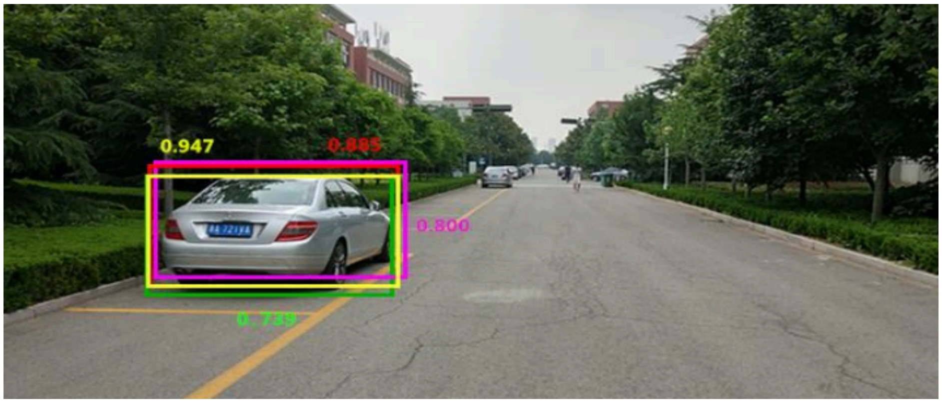


Figure 4.3: Performance Comparision of BB2 Model Under 4 kinds of Traning Steps. (Han, Liao, Zhang, Wang, & Li, 2018)

Figure 4.3 is made by Lidar sensor and camera. YOLO system is applied to the figure 4.3 to decontaminate other objects to help autonomous driving. This study uses the same system, such as the Lidar sensor and camera. In this way, the dashboard camera takes a picture of real-time traffic scenes. Lidar uses laser light with target detection to find the distance to the target is located with the YOLO system, and You only look once (YOLO) is a target real-time detection model based on convolutional neural network, and You only look once (YOLO) is a convolutional neural network algorithm that uses a real-time target detection. For the data process, the YOLO algorithm use method that extracts the point-to-point of pixel frame and real-time recognition for target detection. (Han, Liao, Zhang, Wang, & Li, 2018). This research has similar method, but different performance. Equipment that this research use such as Lidar, camera, and ultrasonic is lower performance than equipment that figure 4.3 use.

CHAPTER 5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The physical design was developed with a data-gathering module by using 3D CAD and Finite Element Analysis (FEA) software. The physical design of a data-gathering module holds Wantai stepper motor (Polifka, 2020), LIDAR-Lite v3 (Garmin, 2019), and HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019). Flexibility and hardness of the physical design were simulated by Finite Element Analysis (FEA) about holding on a hood of a vehicle. The goal of this study was to gather driving data of real-size vehicles by using a data gathering module, wire jump cable to run the mechanical assembly with all sensors, and create running code with LabVIEW (LabVIEW, 2019). The beginning of the research was collecting specification of myRIO (myRIO, 2019), Wantai stepper motor (Polifka, 2020), LIDAR-Lite v3 (Garmin, 2019), and HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019) to connect and run them in the one system.

Figure 5.1: The Mechanical Assembly and Data Transfer System are connected (Donghun Lee, May 20, 2019)

Continuing work need to finish connecting myRIO (myRIO, 2019), Wantai stepper motor (Polifka, 2020), LIDAR-Lite v3 (Garmin, 2019), HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019), listing sensor accessories such as cables, a data hub, and LabVIEW (LabVIEW, 2019) data gathering coding.

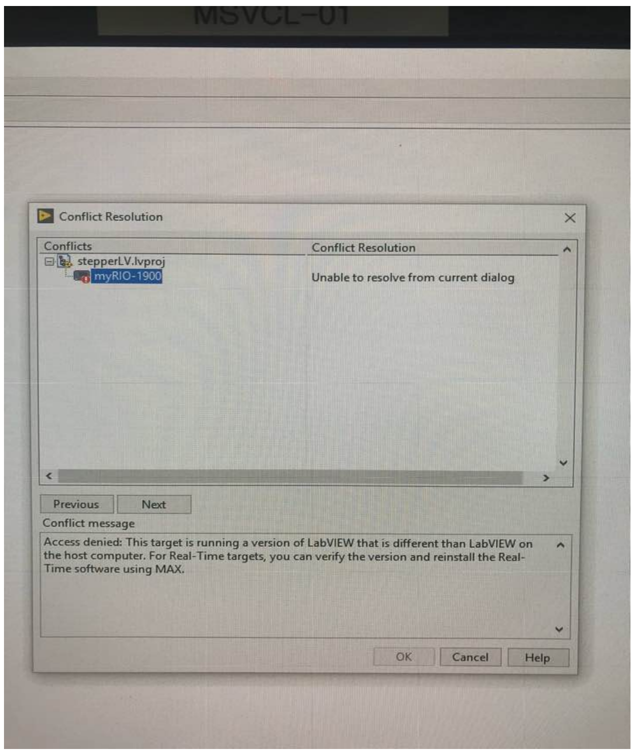


Figure 5.2: The Customized Code Error (Donghun Lee, May 20, 2019)

The customized code needs to be tested and to fix errors that occurred at 2019 summer. At the end of the project, it became evident that it is possible to utilize economical hardware to collect autonomous vehicle driving data.

Conclusions

This research provides assurance that utilizes a Wantai stepper Motor (Polifka, 2020) and HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019). Many different open source codes from the National Instruments community were tested to run Wantai stepper motor (Polifka, 2020) and HRXL-MaxSonar-WRLS (MaxSonar-WRLS, 2019).

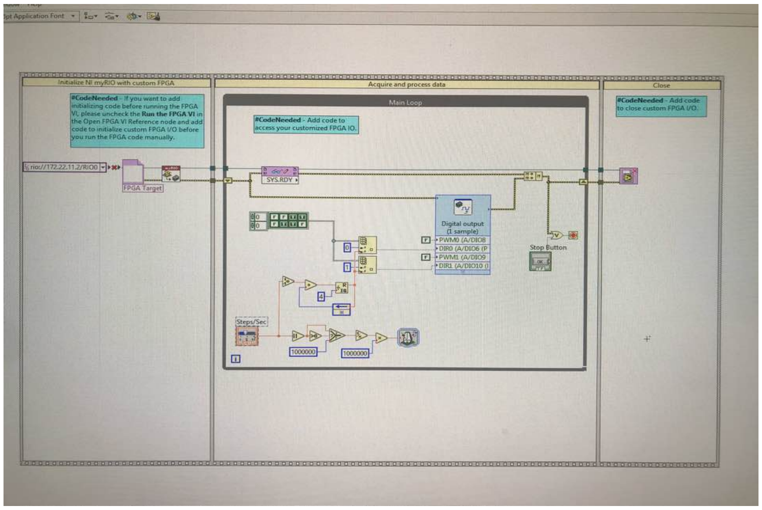


Figure 5.3: The Customized Code for Stepper Motor and Ultrasonic Sensor (Donghun Lee, May 20, 2019)

The method and coding of running all sensors in the one myRIO (myRIO, 2019) was found. In the physical process, this study improved the research that shows the routing of cables and the new location of a Wantai stepper motor (Polifka, 2020) in the data-gathering module. Each sensor block diagram was built to avoid an electrical short.

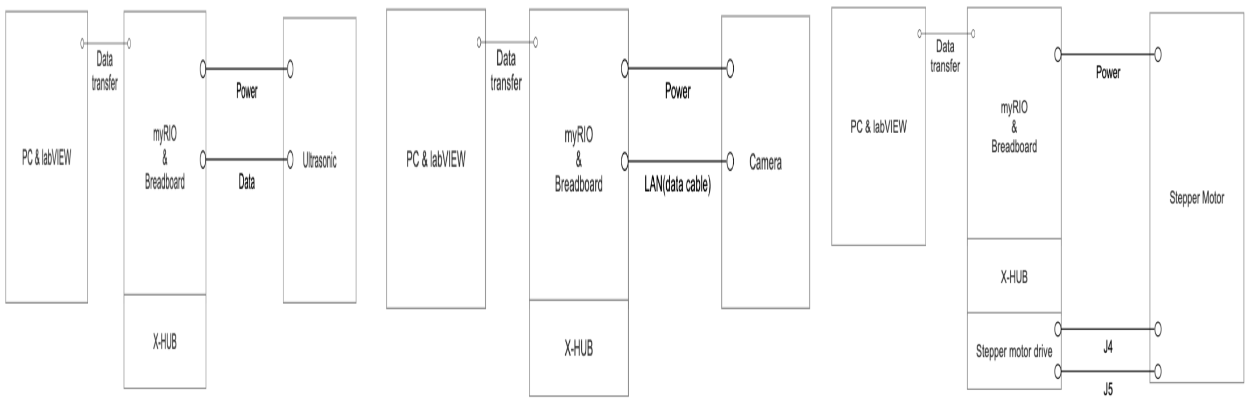


Figure 5.4: The Collection of Each Sensor Block Diagram (Donghun Lee, May 20, 2019)

Each sensor is connected with jump cable through a breadboard. Stepper motor and camera has an additional adapter to operate, such as motor drive and X-HUB. Stepper motor was combined with a motor drive that is from National Instruments to run a stepper motor. A camera requires to use LAN cable to transfer picture data. MyRIO (myRIO, 2019) needs an X-Hub adapter for plugging LAN cable to transfer picture data from a camera. After electric power goes on the circuit, the circuit does not have an electrical shot with all sensors and hardware was connected with a jumper cable.

After checking the circuit and hardware that works well with the planned block diagram, multiple open-source codes from the National Instruments community were tested to find the right base of the customized code. The customized code was tested with each sensor and the whole system, but it does not fully work.

As a result, the tangible result was not gathered in this study. However, from this research, a similar study found Ford Autonomous Vehicle Dataset (Ford real dataset, 2020). Ford Autonomous Vehicle Dataset (Ford real dataset, 2020) shows that economic quality hardware such as ultrasonic sensor, camera, and LIDAR can collect an autonomous vehicle driving data that can be used to improve autonomous vehicle driving algorithm as the purpose of this study.

Recommendations

This project figured out that the quality of the camera is good enough to test an autonomous vehicle by a public driving dataset. Furthermore, a future project can test the customized coding with the mechanical assembly on the road to get another sensor dataset. Using open-source code requires a different version of LabVIEW (LabVIEW, 2019) to test with the hardware. Theoretically, opens source code does not have an error, but a different version of LabVIEW (LabVIEW, 2019) updates the graphical icon in the code. A future project should check the version of LabVIEW (LabVIEW, 2019) before creating a code to use on the hardware.

Future work

The LabVIEW (LabVIEW, 2019) study is needed to figure out the exact code error and better-customized code. Further study, better control display can be made. The myRIO (myRIO, 2019) version difference should be fixed before testing the assembly machine. The best goal is getting real data from the assembly machine as soon as customized code errors are solved. After the mechanical assembly gets driving data, the driving data can be used in the YOLO algorithm. YOLO algorithm is a detection system that detects the 20 objects classes. The YOLO algorithm uses a solo neural network to the full-size image. The network predicts objects based on bounding boxes in the image that gets through the camera or another image collecting machine. From the 20 object classifications, pedestrian, bird, dog, cat, bicycle, bus, vehicle, motorcycle, train, chair, table, potted plant, and a yacht can be detected in real-time object detection. An autonomous vehicle driving system needs to detect most of the 20 object classes to run an autonomous vehicle system in the city area. The 20 object classes are lived, equipped, and placed in city and suburban areas. The YOLO algorithm works a similar detection method that edge detection uses, such as using a frame of picture to define objects classes. According to Redmon, Divvala, Girshick, & Farhadi (2016), the YOLO algorithm declared object classes base on the size of the picture frame from camera data, and it defines object classes. For the future work, this study can use YOLO algorithm to figure out the object classes during an autonomous vehicle is moving. After data acquisition system gets all picture data with YOLO algorithm, training system must be operated over and over to help that data acquisition system make accurate decision. MATLAB has options to use machine learning training such as regression, classification, CNN, or RNN. From the MATLAB toolbox, classification MATLAB algorithm reduces unstable decision. Training with MATLAB classification algorithm calls the Classification Learner. The Classification Learner practice a system to filter data. Using the Classification Learner requires set up that this study must have object classification such as what the YOLO use. With the set-up, a data acquisition system will not increase percentage of error in decision making even though new traffic data is collected.

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VITA

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Work Experience

- **Samsung Electronics**
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  - Design industrial robot body and actuator brake body by using NX software.
  - Test robot by using ROS.
  - Test robot body with ANSYS.
  - Personal project about new brake system for industrial robot.
- **DucWon Industry**
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  - Organized documents, presentations and research data for meetings.
  - Quality check after CNC machining with measurement machine.

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