A DEVELOPMENT OF AN INTERNET OF THINGS EQUIPPED UNMANNED GROUND VEHICLE FOR SURVEILANCE PURPOSE

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A DEVELOPMENT OF AN INTERNET OF THINGS EQUIPPED UNMANNED GROUND VEHICLE FOR SURVEILANCE PURPOSE

by

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ENDORSEMENT

I, Anis Natasha Azizan hereby declare that I have checked and revised the whole draft of dissertation as required by my supervisor

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A DEVELOPMENT OF AN INTERNET OF THINGS EQUIPPED UNMANNED GROUND VEHICLE FOR SURVEILANCE PURPOSE

ABSTRACT

An Unmanned Ground Vehicle (UGV) is a ground vehicle that operates remotely, without having human on-board. UGVs are widely used for mission-based applications that are often hazardous or inconvenient for humankind. Practically, depending on its purposes, UGVs often equipped with sensors and on-board camera to enable self-navigation in order to achieve the desired mission requisite. the number of devices involved in machine-to-machine communications is expected to steadily grow, thus realizing the envisioned revolution called the Internet of Things (IoT), in which one of the main proclaimed goal is to connect everything and everyone everywhere to everything and everyone else. In this project, the UGV combines two main elements, which are collision avoidance system (CAS), path planning system (PPS) and implementation of (IoT) for data analysing in developing an IoT equipped UGV for surveillance purpose. Costing is highly concerned for this project, therefore a low-cost ultrasonic sensor (HC-SR04) is used as a distance sensor for obstacle detection and avoidance purpose. Meanwhile, an *Arduino Mega 2560* (Controller) is used as microcontroller for obstacle avoidance and path optimization purpose respectively. The maneuver is assisted with ultrasonic sensors (front and rear) sense and avoid the obstacles within 1 to 2 meters range. The ultrasonic sensors are programmed in such a way that it sweeps the sensors that the field of view of 180° angle both front and rear of the vehicle. Path planning is the key element for unmanned vehicle. Therefore,

controller is used for navigation before and after approaching obstacles. Path planning algorithm in this project provides the best path to avoid the obstacle and create temporary new waypoints within split seconds. This practice makes the UGV more authentic and proximately imitable with human sensors and its responses. The second element, implementation of IoT is with the purpose of collecting surveillance data. The data will be sent into the cloud with the assist of Wi-Fi module NodeMCU so it can be connected to the internet. The data stored in the cloud can be retrieved and processed using ThingSpeak software as this software allow user to aggregate, visualize, and analyze live data streams in the cloud. These implementations possibly makes the UGV more authentic and widen its application in mission-based operation or even in simple commercial operation.

KENDERAAN DARAT TANPA PEMANDU YANG DILENGKAPI INTERNET PELBAGAI BENDA BAGI TUJUAN PEMANTAUAN

ABSTRAK

Kenderaan Tanpa Pemandu (KTP) adalah kenderaan darat yang bertujuan untuk beroperasi secara autonomi dengan campur tangan manusia yang minimum. Pada masa ini, teknologi KTP telah menunjukkan keupayaan untuk bergerak dan menavigasi sendiri dengan menggunakan sensor termasuk kompas dan Sistem Penentududukan Sejagat (SPS) dilengkapi bersama. Oleh itu, dengan keupayaan autonomi, KTP kini boleh digunakan untuk pelbagai aplikasi seperti SAR (mencari dan menyelamat) dan koleksi data. Sebelum ini dapat menyediakan pelbagai aplikasi selagi data langsung boleh dikumpul oleh sistem dan menghantar ke terminal yang dikehendaki dari jauh. Protokol penghantaran konvensional seperti telemetri dan XBee mengehadkan kadar penghantaran data terutama melibatkan data besar. Jadi, kemajuan dalam teknologi digital membolehkan data dipindahkan ke awan melalui WIFI di bawah istilah Internet Pelbagai Benda (IPB), di mana salah satu tujuan utama yang diisytiharkan adalah untuk menghubungkan segala-galanya dan semua orang di mana-mana ke segala-galanya dan orang lain. Dalam projek ini, KTP menggabungkan dua elemen utama iaitu sistem mengelak perlanggaran (CAS), sistem perancangan jalan (PPS) dan pelaksanaan (IPB) untuk menganalisis data dalam membangun KTP dilengkapi IPB untuk tujuan pengawasan. Kos adalah sangat prihatin untuk projek ini, jadi sensor ultrasonik kos rendah (HC-SR04) digunakan sebagai sensor jarak untuk pengesanan halangan dan tujuan pencegahan. Sementara itu, Arduino Mega 2560 (AM) digunakan sebagai

mikrokontroler untuk tujuan penghindaran halangan dan tujuan pengoptimuman jalur. Manuver dibantu dengan sensor ultrasonik (depan dan belakang) dan mengelakkan rintangan dalam julat 1 hingga 2 meter. Sensor ultrasonik diprogram sedemikian rupa sehingga ia berpusing sensor yang bidang pandangan 180 ° sudut kedua-dua depan dan belakang kenderaan. Perancangan jalan adalah unsur utama untuk kenderaan tanpa pemandu. Oleh itu, AM digunakan untuk navigasi sebelum dan selepas menghampiri halangan. Algoritma perancangan jalan dalam projek ini memberikan laluan yang terbaik untuk mengelakkan halangan dan membuat titik arah sementara sementara dalam masa perpisahan. Amalan ini menjadikan KTP lebih tulen dan kurang tepat dengan sensor manusia dan jawapannya. Unsur kedua, pelaksanaan IPB adalah dengan tujuan mengumpulkan data pengawasan. Data akan dihantar ke awan dengan bantuan modul Wi-Fi NodeMCU supaya ia boleh disambungkan ke internet. Data yang disimpan di awan boleh diambil dan diproses menggunakan perisian ThingSpeak kerana perisian ini membenarkan pengguna mengagregat, memvisualisasikan, dan menganalisis aliran data langsung dalam awan. Pelaksanaan ini mungkin menjadikan KTP lebih tulen dan meluaskan aplikasinya dalam operasi berasaskan misi atau bahkan dalam operasi komersial yang mudah.

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Last but not least, my final year project would have been impossible without the support of my family. I would like to thank my parents and to my sister for supporting me spiritually throughout the project and my life in general.

DECLARATION

This thesis is the result of my own investigation, except where otherwise stated and has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any other degree.

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(Signature of Student)

Date :

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LIST OF ABBREVIATIONS

UGV	:	UNMANNED GROUND VEHICLE
CAS	:	COLLISION AVOIDANCE SYSTEM
PPS	:	PATH PLANNING SYSTEM
IOT	:	INTERNET OF THINGS
NODEMCU	:	NODE MICROCONTROLLER UNIT
WIFI	:	WIRELESS FIDELITY
M2M	:	MACHINE TO MACHINE
AEB	:	AUTONOMOUS EMERGENCY BRAKE
RFID	:	RADIO FREQUENCY IDENTIFICATION
LORA	:	LONG RANGE RADIO
LIDAR	:	LIGHT DETECTION AND RANGING

CHAPTER 1

INTRODUCTION

This chapter provides general introduction on research background, problem statement, research objectives and thesis outline.

1.1 Background

UGV is a vehicle that operates without human on-board. It is commonly used for application that is hazardous and inconvenient for humans. Generally, UGVs are equipped with sensors and camera to perceive surrounding and make decisions about its localization and heading. Another purpose for the equipped sensor is for data acquisition purposes. For the UGV to operate autonomously, an ultrasonic sensor is utilized as a mean to sense and avoids obstacle. It is widely used for non-contact distance measurement from a point to any obstacles using the principle of sound wave propagation. The ultrasound sensors uses echo adapted by is bio-inspired bats, which use ultrasonic waves to navigate in the dark (Szlachetko and Lower, 2014).

Having the vehicle to move autonomously, obstacle avoidance is a vital feature for UGVs. The accuracy of obstacle sensing is significantly important to estimate the geometry of the obstacle. This provides a clear picture and position of the incoming objects. To achieve that, a special algorithm/decision table that works with ultrasonic sensor is needed. This helps in acquiring geometry of the approaching obstacle and the response of the vehicle to avoid obstacle. There are many types of low-cost ultrasonic sensors are available in the market today with a typical field of view of 30° and the maximum measuring distance is 280cm to 300cm (Szlachetko and Lower, 2014). The detecting distance for this project is set at 100cm, therefore ultrasonic sensors with a minimum measuring distance below than 100cm will be the requirement.

Historically, the IoT is a concept where objects are uniquely identified by barcodes, RFID, tags, etc. During the physical object lifecycle, readings are made using (RFID, GPS, Wi-Fi, etc) collected and recorded in databases for private use or in the cloud. All these records are further aggregated, merged or consolidated with other information that are already handled in computer systems for traceability, logistics, management or sales issues. Now, this concept has been implemented on the devices which are commercially available and it is developing at a fast pace. This idea now is complying to military specifications and standards to ensure that a reliable and quality assurance can be provided in battlefield environment (Pradhan et al., 2016).

IoT is based on the idea: "Anytime, anyplace connectivity for anything, ubiquitous network with ubiquitous computing". The capability of nodes of a Wireless Sensor Network i.e. these nodes have the ability to sense events using sensors, store and process data using the on-board micro-computers / micro-controllers and communicate this data over network links is provided by the independent IoT devices communicating wirelessly. Therefore, IoT devices can be used for military, unmanned warfare, and surveillance purpose.

1.2 Problem Statement

Many researches have been carried out in making autonomous platform more robust. But most of the research involve small vehicles (mobile robots) and skid steer type steering (Mandow et al., 2007). This approach is not practical since it does not replicate the conventional on-road vehicles. Furthermore, previous projects and research on mobile robots are not suitable on off-road terrain due to absence of suspension system. These implementations possibly makes the UGV more authentic widen its application in mission-based operation or even in simple commercial operation.

To improve the intention of widening the UGV application, the implementation of IoT element is considered. Both IoT-based and robotics applications have been successfully applied in several scenarios. Nevertheless, little work has been carried out on the interaction between the two fields, which deserves more in depth investigation. Most of modern robots require the element of sensing, computing and communication capabilities, which make them able to execute complex and coordinated operations. Indeed, these features would be significantly magnified by IoT technology, toward the fulfilment of requirements posed by advanced applications in pervasive and distributed environments, especially those characterized by a high level of criticality. In our vision, several entities should complement the robot works, such as smart objects, field sensors, servers, and network devices of any kind, connected through a complex and heterogeneous network infrastructure. These challenging goals can be achieved by exploiting a dense IoT network, whose devices continuously interact with humans, robots, and the environment.

Vehicles and equipment that operate with little or no operator intervention are desirable partly because they remove the operator from harm’s way in dangerous applications and because they offer direct labour costs savings in commercial applications. In many instances, this limited intervention is exemplified by an operator removed from the confines of the vehicle itself and placed in a location with a remote control device that interfaces with and controls the vehicle.

Nowadays technologies play an important role in our life. Since few decades, robotics has developed drastically solution for various controlling purpose. The current surveillance systems present in the market are very expensive and have limited capabilities. A large base station is required in order to communicate with the robot and have unnecessary features.

This paper proposes an autonomous vehicle platform that is equipped with IoT feature to enable the data to be transferred to the cloud and can be access anywhere. This system provides data collection at the locations along the path of the UGV.

1.3 Objectives

1. To propose a path planning and collision avoidance using ultrasonic sensor and GPS installed.
2. To develop an IoT system that can upload data to cloud to be able accessible anywhere, any platform.

1.4 Thesis Outline

The thesis consists of five chapters. Chapter 1 consists of sub-topics e.g. background, problem statement, objectives, etc. Chapter 2 describes the previous and current researches within this area. In addition, this chapter includes the outcome of other research work as well. Chapter 3 explains the method used to carry out the project work and relates them with a simple set of experiments. Chapter 4 contains all the results of the experiments based on the test run done on the UGV. Finally, chapter 5 summarizes the entire research work and suggested plans for future improvement.

CHAPTER 2

LITERATURE REVIEW

With the advent of automobile technology in the early 80s, humankind could also easily travel from one place to another. Based on the report, the accident rate has increased significantly due to road accidents (Mane[1] et al., 2018). Although there are numerous reasons to blame according to (Rolison et al., 2018), the major contributor of road accidents is due to human error. Therefore, it seems that vehicles with autonomous and intelligent would help to reduce the human error, hence minimize accident. With this advantage, many car manufacturers work hard towards applying collision avoidance system (CAS) to their cars which could reduce the number of road accidents (Shaout et al., 2011) . A CAS mainly consists of three phase: 1) *object detection* 2) *decision-making* 3) *actuation* (Llorca et al., 2011). The first autonomous collision avoidance was introduced for unmanned aerial vehicles (UAVs) (Morrel, 1958). The installed system is called Traffic Alert and Collision Avoidance System (TCAS) (Kuchar and Drumm, 2007). For automobile, the CAS commenced with Forward Collision Warning (FCW) system which alerts the driver through visual and/or audio when driver gets too close to the vehicle ahead (Kusano and Gabler, 2012). However, this system only alerts the operator and does not take any corrective actions even if there is no driver input. There are many more collision avoidance systems e.g. Adaptive Cruise Control, Autonomous Emergency Braking (AEB), Lane Departure Warning System, Parking Assistance, etc.

Agreeing with (D. Adams, 1994), maneuvering the steering alone would be more effective in case of collision avoidance. Even though many CAS technologies are contributing, they are still not sufficient to eliminate collision completely (Hayashi et al., 2012). In (Hayashi et al., 2012), Supported the statement of maneuvering the steering is supported by saying that evasive steering can be an alternate solution for collision avoidance. The advanced version of this solution is that, integrating steering with BAS (Hartmann and Rieth, 2011). However, in this project, there is no braking mechanism installed on the UGV, only the basic braking mechanism to stop the UGV from moving. From this case, this project is highly inspired with steering method for collision avoidance.

Object detection, especially using a non-contact sensing could be done in many ways, e.g. visual, light and sound etc. which depending in the type of applications (Liang et al., 2018). Each methods is very by its advantages and disadvantages. As for the visual object detection, which use camera through monocular and stereo techniques. This techniques could improve field of view and distance estimation respectively. The different between monocular vision and stereo vision is that mono uses a single camera while stereo uses two cameras. In (Mori and Scherer, 2013), it is said that monocular vision, the relative size used to detect frontal collisions and the process of detecting and avoiding frontal collision using monocular vision is challenging since there is no motion parallax and optical flow. Thus, the stereo vision was introduced. From (Mahlouji, 201/), stereo vision is highly inspired by the human vision. stereo algorithm can help in object detection as it can provide distance information (Oleynikova et al., 2015). Stereo camera provides much more accurate data on distance, however, the vision systems do not perform under certain environmental conditions e.g. plain wall and poor light conditions (Mohammad, 2009) and they are very expensive (Bhagat et al., 2016). Apart from visual technique, Light Imaging Detection and Ranging (LIDAR) is also used for collision avoidance (Hayashi et al., 2012). LIDAR is appealing because it offer a low cost option and due to its small size, it is easy to package. LIDAR works by building a figurative representation of the environment in terms of an obstacle map. However, the downside of LIDAR is, its inaccuracy in bad weather conditions and laser beams blocked by dirt build up on sensor lenses (Shaout et al., 2011). This is supported by the application of LIDAR in Volvo cars has to be mounted on top of windscreen to ensure a clear view since the area in front of the sensor is cleaned by the windshield wipers (Distner et al., 2009). Due to these factors, LIDAR is not considered for this project. In addition, radar method is also being widely used for collision avoidance (Braitman et al., Coelingh et al., 2010). Compare to LIDAR, radar is more reliable during bad weather, rain and fog. However, radar is not implemented in this project as it is not reliable to detect small obstacles (Bertozzi et al., 2008) and it also does not provide enough data points to detect obstacle boundaries. Its size and cost, which are bigger and expensive also make it less favorable for the project.

In report, (Panda et al., 2016) explains that four medium parameters has high effect on speed of sound. Air temperature is the most concern among the parameters. Nevertheless, the maximum percentage error of speed of sound mentioned by author is 0.33. Considering everything, ultrasonic sensor is chosen as the sensor for this project.

In the late 1960s, the internet began as link between a quite a number of university computer centres. I the 1970s and 1980s, with the number of users counted in thousands the internet usage was mainly dominated by e-mail and file transfer.in the 1990s,users were denominated in millions and web browsing became dominant.as of the end of 2004, there were some 875 million internet users worldwide (ITU, 2005). This report also support that today in the 2000s, we are heading into a new era of ubiquity, where the internet users will reach billions and where humans may become the minority as generators and receivers of traffic. Instead of having human to handle, the traffic will flow between devices and all kind of "things", thereby creating a much wider and more complex "Internet of things", the concept that being implemented in part of the project. The creation of IoT starts with connecting everyday objects and devices to large databases and networks. A most simple and cost effective system – and indeed to the network of networks, the internet. Only then data about things be collected and processed. Radio-frequency identification, RFID offers the possibility (ITU, 2005). This statement is also supported by (Madakam et al., 2015), saying the IoT was initially inspired by members of the RFID community and is the foundation and networking core of the construction of IoT, who referred to the possibility of discovering information about a tagged object by browsing an internet address or database entry that corresponds to a particular RFID or Near Field Communication Technologies. IoT, which is integrated with sensor technology and radio frequency technology. Here data collection can of course benefit from the ability to detect changes in the physical status of things. It is said that IoT has four important technological enablers: 1) *RFID* 2) *Sensor Technologies* 3) *Smart technologies* 4) *Nanotechnology*. RFID has the main function of identifying an object and to track the location of a labelled product rapidly and accurately. While Sensor technology provides information about the external environment and circumstances surrounding an object. RFID is to answer questions "what, which and where" while Sensor technology is to answer the "how?" question. This is a breakthrough of the IoT in making physical world and information world together (Lu and Neng, 2010). From this context, it is understandable that Sensor technology will play a quite significant role. From the brief explanation on Sensor technology, the idea is to use remote sensors attached to the UGV and operator from other location will receive information about the physical parameters surrounding, generating information raising awareness about context. So the changes of their environment can be monitored and the corresponding things can make some responses if needed (Lu and Neng, 2010).

"The number of devices involved in machine-to-machine (M2M) communications is expected to steadily grow till 2020. At that time, the number of smart objects able to talk to each other and other inter-operate with humans should be around 50 billions." (Grieco et al., 2014). This paper mentioned, the magnitude scale of internet will triple thus realizing and envisioned the revolution of IoT with its application and involvement in M2M, IoT-aided-robotics. According to Fleisch in (Fleisch, 2010), IoT is relevant in every step in every value chain. He has identified seven main value drivers and the first four based on value from machine-to-machine communication which is supported by (Coetzee and Eksteen, 2011). Out of the four values, one can be relate close to this project, Automatic Sensor Trigging – a smart thing can collect data via any type of sensor including temperature, acceleration, orientation, vibration and humidity. The thing senses its condition and environment, communicates the information which enables prompt decision making.

IoT is so vast and such a broad concept and the main problem with it that there is no proposed, uniform architecture. In order for IoT to work, it must consist of an assortment of sensor, network, communications and computing technologies. In (Madakam et al., 2015), explains some of IoT architectures or models that are given by several researches, authors and practitioners, and on of it is, *European FP7 Research Project.* This project is to be used as blueprint for IoT concrete architecture design.

In physical environments within large-scale, the deployment of UGV or even multiple UGVs and having it equipped with IoT could improve and deliver consistent system's Quality of Service (QoS) (Aldabbas et al., 2016). There are various IoT technologies for hardware platforms used in different applications; Arduino Mega, Intel Galileo Gen 2, Intel Edison, Beagle Bone Black, Electric Imp 003, Raspberry Pi B+ ARMmbed NXP LPC1768. For this project, Arduino Mega is used as hardware platform due to its simplicity and open source. Communication Protocols structure the foundation of IoT frameworks and empower organize availability and coupling to activities. It enable devices to trade information over the network. A paper by (Ray, 2018) compares different wireless communication technologies with respect to various parameters; WiFi, WiMax, LR-WPAN, 2G/3G/4G Mobile Communication, Bluetooth, LoRa. In this project, the communication protocols is ran by NodeMCU Wi-Fi Module. This single-board includes firmware which runs on the Wi-Fi and an open source IoT platform. Next, for data storing, cloud solutions is used. IoT cloud solutions cover the facilities like visualization, real time data capture, data analytics, device management related tasks and decision making related tasks through remote cloud servers. Numerous cloud service providers are gradually becoming popular in the several application domains such as Xively, Plotly and ThingSpeak. These three platforms provide public cloud service and at free cost. However, ThingSpeak is considered in this project as it used Matlab and the availability library for Arduino. The released of the latest updated version of the ThingSpeak Communication Library for Arduino, ESP8266 and ESP32 devices makes it compatible with the communication device - NodeMCU.

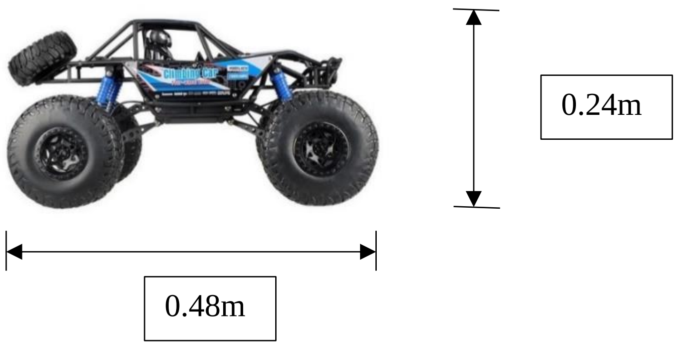
CHAPTER 3

METHODOLOGY

This chapter presents the methods used and developed for developing an IoT equipped autonomous vehicle.

3.1 Prototype of UGV

The body of the UGV used in this project is based on 1:10 scale RC Car that is commercially available as shown in Figure 3.1. The dimension of the vehicle is 0.48m × 0.24m × 0.24m. The chassis of the car is made from lightweight and strong material, Acrylonitrile Butadiene Styrene (ABS). The car runs on two separate DC motors, which makes the front and rear wheel spin independently. Complete specification of the car is stated in Table 3.1.



(a) Side View

(b) Bottom View

Figure 3. 1: RC Car

Table 3. 1: Specification of the RC Car

No.	Parameter	Value
1	**Class of Vehicle**	Four Wheel Drive (4WD)
2	**Steering**	Front Wheel Steering (FWS)
3	**Scale**	1:10
4	**Operating Voltage**	8V
5	**Operating Current**	4A (2A × 2 DC Motors)
6	**Maximum Speed**	15km/h
7	**Weight**	2.14kg
8	**Wheel Size**	140 × 45 mm
9	**Wheelbase**	500 mm

3.2 Components in the UGV

For this project, the commercial RC car was modified to accommodate the features of the proposed UGV.

3.2.1 Microcontroller

Microcontroller in this UGV will act as a central control unit that will execute all the coding during obstacle avoidance and path optimization; CAS and PPS. Microcontrollers in the market today are available in numerous types and brands. Nevertheless, a simple and basic microcontroller, Arduino Mega 2560 (Arduino) is chosen for this project. This microcontroller also consists more available I/O pins and a larger space in sketch which is great to accommodate other components. Moreover, Arduino uses IDE, an open source as its programming platform.

Figure 3. 2: Arduino Mega 2560 board (image courtesy of Arduino.cc)

The detailed specifications of Arduino Mega 2560 is stated in Table 3.2.

Table 3. 2: Specification of Arduino Mega 2560

No.	Parameter	Value
1	Operating Voltage	5V
2	Input Voltage	7V-12V
3	Digital I/O Pins	54
4	Analog Input Pin	16
5	DC Current per I/O Pin	40 mA
6	DC Current for 3.3V Pin	50 mA
7	Flash Memory	256 KB
8	SRAM	8 KB
9	EEPROM	4 KB
10	Clock Speed	16 MHz
11	Weight	37g

In addition to Arduino as the central controller, the system is equipped with NodeMCU. NodeMCU (node microcontroller unit) is an open source IoT platform that includes firmware, which on runs the ESP8266 act as a low cost WiFi module chip to support wireless capability for Arduino. This unique feature makes IoT application in this project much easier.

Figure 3. 3: NodeMCU V3

The specification of NodeMCU V3 is shown in Table 3.3.

Table 3. 3: Specifications of NodeMCU

No.	Parameter	Value
1	Operating Voltage	4V
2	Input Voltage	3.3V
3	Digital I/O Pins	10
4	Analog Input Pin	1
5	DC Current per I/O Pin	12 mA
6	DC Current for 3.3V Pin	550mA
7	Flash Memory	4MB
8	SRAM	50KB
9	Weight	7g

3.2.2 Motor Driver

In order for the Arduino to control the motors, a motor driver is needed to boost the drive current to the motor. However, this connection only allows the motor to run on single speed and this project demands the UGV to vary in speed during the navigation as one of the features. Therefore, the DC motors are controlled using the L298N.

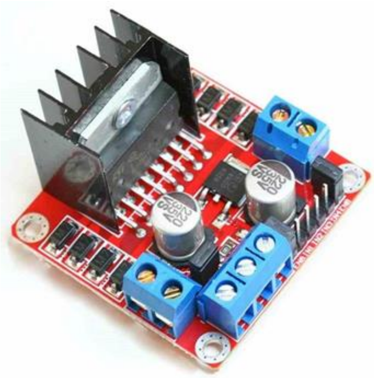


Figure 3. 4: L298N Motor Driver (image courtesy of google Inc.)

The L298N is a dual H-Bridge motor driver that allows speed and direction control of two DC motors at the same time. It takes PWM signal input from microcontroller and drive the motor at the respective speed accordingly. The module can drive DC motors that have voltages between 5V to 35V, with a peak current up to 2A. its light weight, small size and inexpensive makes it very suitable for this UGV project.

The specification of L298N motor driver is shown in Table 3.4.

Table 3. 4: Specification of L298N motor driver.

No.	Parameter	Value
1	Logical Voltage	5V
2	Drive Voltage	5V-35V
3	Logical Current	0-36mA
4	Drive Current	2A
5	Max Power	25W
6	Dimensions	43 × 43 × 26 mm
7	Weight	26g

3.2.3 Sensor

This project will be using two different sensors for different purposes. For collision avoidance purpose, the UGV has to be equipped with range sensors and Ultrasonic sensor HC-SR04 is used in this project. Ultrasonic sensor uses ultrasound to detect and obtain information about the distance of an object using time of flight. HC-SR04 sensor has measuring range of 2cm to 4m which is a within the operating range for UGV; sense and avoid obstacles within 1 to 2 meters range.

Figure 3. 5: HC-SR04 Ultrasonic Sensor

Table 3. 5: Specification of HC-SR04 Ultrasonic sensor

No.	Parameter	Value
1	Voltage	5V
2	Current	15mA
3	Frequency	20-40 kHz
4	Maximum Range	4m
5	Minimum Range	0.02m
6	Effectual Angle	15^{o}
7	Weight	10g
8	Dimension	45 × 20 × 15 mm

Another sensor that will be used is temperature sensor. In this case the Dallas Temperature; DS18B20 Temperature sensor (Figure3.6) has been chosen. The temperature sensor would collect or sensing the temperature reading of the environment at certain preset interval. The specifications of DS18B20 temperature sensor is listed in Table 3.6.

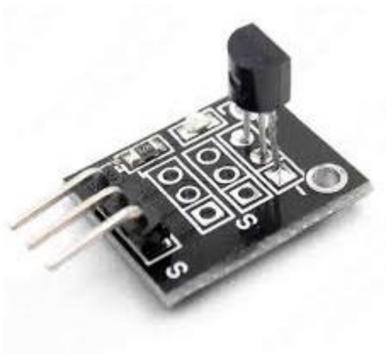


Figure 3. 6: *Dallas Temperature Sensor DS18B20*

Table 3. 6: Specifications of Dallas Temperature Sensor DS18B20

No.	Parameter	Value
1	Type	Programmable Digital Temperature Sensor
2	Operating Voltage (V)	3 ~ 5
3	Temperature Range (°C)	-55 ~ 125
4	Accuracy	±0.5
5	Output Resolution	9-bit to 12-bit
6	Conversion Time	750ms at 12-bit

3.2.4 Servo

Two kind of servo motors are used in this project. GWS Servo Naro Pro in

Figure 3.7 (a) and Hitec HS-5085MG Metal Gear Micro Digital Servo in Figure 3.7 (b). Servos are necessary in this project, as its ability to perform rotation is very much needed.

Figure 3. 7: (a) GWS Servo Naro Pro (b) Hitec HS-5085MG Metal Gear Micro Digital Servo

GWS Servo is used in detecting obstacles by widening the field of view of the ultrasonic sensor. Meanwhile, as for Hitec Servo, it is used for steering and maneuvering of the UGV. Hitec Servo uses metal gear set and has tolerable maximum torque range, making it suitable to control the wheels as the UGV itself will carry some weight. The specifications of both servos are listed in Table 3.7.

Table 3. 7: Specifications of GWS and Hitec Servo

No.	Specifications	GWS	Hitec
1	Operating Voltage (V)	4.8 ~ 6.0	4. ~ 6.0V
2	Speed (Second @ 60°)	0.12	0.17 ~ 0.13
3	Max. Torque Range (kg/cm)	1.60	3.6 ~ 4.3
4	Dimensions (mm)	27.0 x 12.7 x 24.65	29.0 x 13.0 x 30.0

5	Weight (g)	13.0	21.9

3.2.5 Power

The most important component in the system is power supply. For this project, two separate power supply is installed which are, LiPo battery in Figure 3.8 (a) and much smaller NiMH rechargeable battery in Figure 3.8 (b). The purpose of installing two batteries will be justified in next chapter.

Figure 3. 8: (a) LiPo battery (b) NiMH rechargeable battery

The specifications of both batteries are as in Table 3.8

Table 3. 8: Specfications of LiPo and NiMH battery

No.	Specifications	LiPo	NiMH
1	Type	Lithium Polymer Battery	Rechargeable Nickel Metal Hydride NiMH
2	Voltage (V)	11.1	4.8
3	Capacity (mAh)	3500	300
4	Dimensions (mm)	22 x 42 x 138	10 x 40 x 31
5	Weight (g)	290	140

3.3 Collision Avoidance System and Maneuver

As to enable the autonomous capability, Collision Avoidance System is a compulsory feature in any autonomous vehicle. As mention before, this UGV uses ultrasonic sensor for obstacle avoidance. In particular, ultrasonic sensor, HC-SR04 is used as a distance sensor.

3.3.1 Obstacle Detection

Ultrasonic sensor uses ultrasound, which is generally, knows as a sound frequency greater than 20kHz. This ultrasonic module has two eyes like projects in the front, which is the transmitter and receiver. The transmitter transmits an ultrasonic wave and when it is blocked by any object in the distance, it gets reflected back toward the sensor and received by the receiver as shown in Figure 3.9.

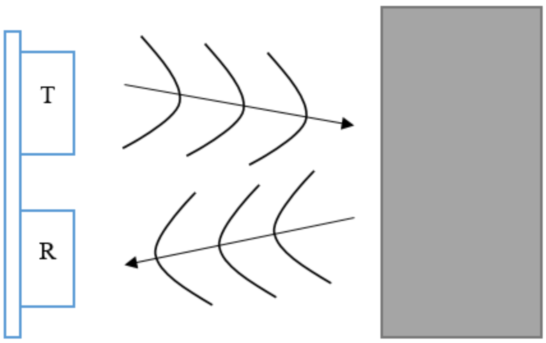


Figure 3. 9: Working Principle of Ultrasonic Sensor

The transmitter in HC-SR04 sensor module is “trigger” while the receiver is “echo”. The speed of sound waves is 343 m/s and it is known that

$$Speed = (Speed\ x\ Time) \tag{3.1}$$

Therefore,

$$d_t = (343\ x\ a) \div 2 \tag{3.2}$$

d_t = Distance travelled

a = Speed of sound or Time of High (Echo) Pulse

t = Time taken

Distance travelled is divided by 2 because the wave travels from HC-SR04 to object and returns back to the module.

Two sensors are placed on the UGV, one to detect obstacle during forward movement of the UGV (front), and the other one for detecting any obstacle during backward movement (rear) as illustrated in Figure 3.10. The concern of placing only one sensor on the front and one at the back is not a problem after the beam pattern of the sensor is studied and understood.

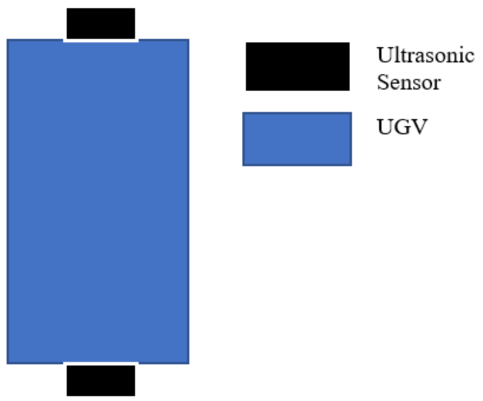


Figure 3. 10: UGV with Front and Rear Sensors

From studies, the beam pattern for HC-SR04 ultrasonic sensor is as in Figure 3.11. Even though the beam pattern on the left side degrades after 140cm, the area covered is large enough and further development can be done on this pattern to cover 180° field of view.

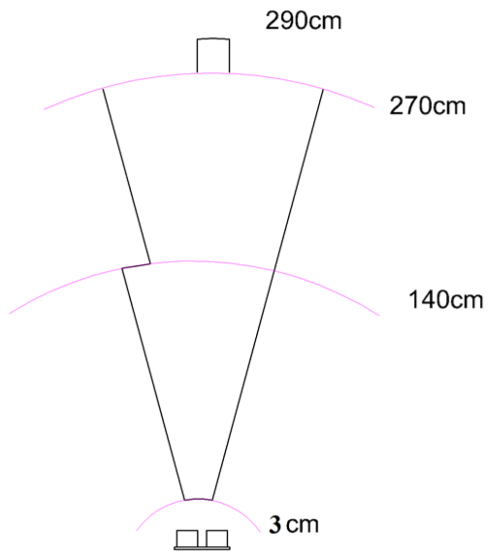


Figure 3. 11: Beam Pattern

The beam of ultrasonic sensor would extend up to 30 and in order to get 180 ^{o} view, the sensors are mounted on servomotor as shown in Figure 3.12. The servomotor used in this project has the ability to perform a rotation from 0 ^{o} to 180 ^{o}. However, having the ultrasonic sensor covering over a specific region, rotating the servomotor with the increment of 1 is not the best method.

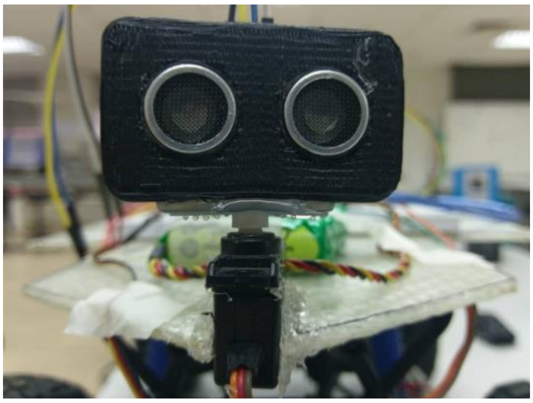


Figure 3. 12: Servo motor attached with ultrasonic sensor

Therefore, the idea of stepping the angle by 30 ^{o} is introduced. The servo motor will sweep from left to right with 6 different sensing angles. The sensing angle begins with 15 ^{o} with the increment of 30 ^{o} and sweep until 165 ^{o} as shown in Figure 3.13. Since the servo motor angle has limitations, 0 ^{o} to 15 ^{o} and 165 ^{o} to 180 ^{o} are the blind spot regions. This method allows the ultrasonic sensor to scan possible object distance at six different angle (15^{o} ,45^{o}, 75^{o}, 105^{o}, 135^{o}, 165^{o}) at one sweep.

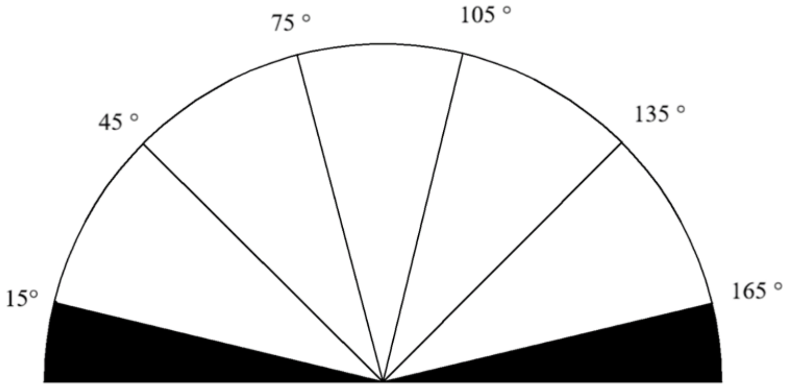


Figure 3. 13: Ultrasonic Sensor Sensing Angle

The system makes one complete sweep (from left to right) and then returns back to original position to start the next sweep. This system is considered as the sensor reached at sensing angle of 165 ^{o} (on the right most), the sensing angle of 15 ^{o} (left most) is already left unattended for a while. Therefore, it is better for the sensor to start again at the first position.

3.3.2 Obstacle Avoidance

Detecting obstacles from a distance is one part and with the addition of maneuverability in the picture, CAS then only can be complete and successful system. For this project, the UGV is equipped with servo motor as its maneuver tool, Hitec HS-5085MG. the servo is attached with a mechanism to the front wheels. When initiated, the servo will rotate to the right or left and at the same time moving the wheels as illustrated in Figure 3.14.

(a) Servo and wheels not actuated

(b) Servo and wheels actuated to the right

(c) Servo and wheels actuated to the left

Figure 3. 14: Servo as Maneuver

The servo has the range of 180 ^{o} rotation; from left to right. However, as shown in Figure 3.14, the wheels has limitation and could not perform a sharp 0 ^{o} or 180 ^{o}, this