Localization for Underwater Robot Using Camera and Light Source

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Localization for Underwater Robot Using Camera and Light Source

by

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TABLE OF CONTENT

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	Alternating Current
API	Application Programming Interface
AUV	Autonomous Underwater Vehicle
DOD	Department of Defence
FOV	Field of View
GB	Gigabyte
GPS	Global Positioning System
HDNO	Head Department of Navigation and Oceanography
IDE	Integrated Development Environment
IMU	Inertial Measurement Units
INS	Inertial Navigation System
LED	Light Emitting Diode
MP	Megapixel
NOAA	National Oceanic and Atmospheric Administration
OS	Operating System
RAM	Random Access Memory
RGB	Red, Green, Blue
SLAM	Simultaneous Localization and Mapping
USB	Universal Serial Bus
USD	United States Dollar

LOCALISATION FOR UNDERWATER ROBOT USING CAMERA AND LIGHT/LASER SOURCE

ABSTRACT

As of today, ocean is one of the major sources of food, oil and gas. There are so many wonders yet to be discovered under the ocean and it was no easy task as human cannot breathe underwater. Thus, it is better to let robots to do the job. Since they can survive without oxygen and can withstand a great amount of pressure before disfunction. The term we come with robot under water is autonomous underwater vehicle (AUV). However, while AUV does not require oxygen and can withstand great pressure which human cannot, they lack the ability and advantages as well. For example, AUV lacks the precision control as well as sense of direction. A robot does not know where it should go unless you tell it to. We can use Global Positioning System (GPS) to locate a robot on land so that it has "sense of direction", but GPS does not work well underwater. Advance AUV employs features such as sonar and radar for underwater localization. However, those modules are very expensive. A replacement of sonar and radar would be using camera and floating markers. Camera facing the surface of the water can take image of floating markers, where the position of the markers is already identified. Then, the image can be sent to microprocessor to process the image and position of the AUV can be pinpoint its own location, given the known location of floating markers, through a technique called trilateration. Trilateration is a technique used to determine the coordinate of an unknown point, given 3 distances from 3 points with known coordinate. The result shown the technique was successful.

LOKALISASI UNTUK ROBOT BAWAH AIR MENGGUNAKAN KAMERA DAN SUMBER CAHAYA

ABSTRAK

Dewasa ini, lautan adalah salah satu sumber utama makanan, minyak dan gas. Terdapat banyak lagi sumber yang belum diterokai di bawah lautan tetapi ia bukanlah tugas yang mudah kerana manusia tidak boleh bernafas di dalam air. Oleh itu, lebih baik membiarkan robot melakukan tugasnya. Hal ini adalah disebabkan meraka mampu bertahan dalam air tanpa bekalan oksigen dan menahan sejumlah besar tekanan air sebelum disfungsi. Robot yang berfungsi bawah air digelar sebagai *autonomous underwater vehicle* (AUV). Walaupun AUV tidak memerlukan oksigen dan boleh menahan tekanan hebat yang tidak boleh dilakukan oleh manusia, mereka mempunyai kelemahan juga. Salah satu kelemahan AUV ialah mereka tidak mengerti arah dan lokasi sendiri. Kita boleh menggunakan *Global Positioning System* (GPS) untuk robot di atas permukaan tanah menentukan lokasinya tetapi GPS tidak berfungsi di dalam air. AUV menggunakan sensor seperti sonar dan radar untuk lokalisasi di dalam air tetapi modul tersebut sangat mahal. Penggantian yang murah dan mudah ialah menggunakan kamera dan penanda terapung. Kamera yang menghadap ke permukaan air boleh mengambil imej penanda terapung, di mana kedudukan penanda telah dikenalpasti. Kemudian, imej itu boleh diproseskan dan lokasi AUV boleh dikenal pasti melalui teknik yang dikenali sebagai trilaterasi. Trilaterasi adalah teknik yang digunakan untuk menentukan koordinat titik yang tidak diketahui, diberi 3 jarak dari 3 koordinat titik yang berbeza dengan koordinat yang diketahui. Hasilnya menunjukkan teknik itu berjaya.

CHAPTER 1
INTRODUCTION

1.1 Research Background

According to the data and analysis published by Head Department of Navigation and Oceanography (HDNO) of The Russian Federation Ministry of Defence, The Earth surface area is roughly 510,100,000 km^2. Land covers about 148,800,000 km^2 which is 29.2% of the Earth total surface area and the World Ocean covers about 361,300,000 km^2 which is 70.8% of the Earth total surface area [1]. Thus, while man live on land, the ocean still covers a surface area much greater than land. No matter how far away you live from the shore, oceans still affect you and your life and everyone around you. The air we breathe, the water we drink, the food we eat, the products that keeps us safe, warm and entertained – most can come from or be transported through the ocean.

The ocean provides many benefits and resources such as goods, jobs and services for people all around the world and at the same time, ocean have immense economic importance. Resources that ocean provides include fuel, food, renewable energy, sand, minerals, tourism and more. However, with the oldest human started since roughly 6000 years ago [2], there are still many wonders that are yet to be discovered in ocean. In fact, as of the year 2000, the National Oceanic and Atmospheric Administration (NOAA) estimated that as much as 95 percent of the world's oceans and 99 percent of the ocean floor are unexplored [3].

There are so many wonders yet to be discovered under the ocean and it was no easy task as human cannot breathe underwater. Aside from oxygen supply issues, water pressure is also another major factor. At a depth of 100 feet, you will feel the pressure pressing your lung 4 times the normal pressure.

Thus, it is better to let robots to do the job. Since they can survive without oxygen and can withstand a great amount of pressure before disfunction. The term we come with robot under water is autonomous underwater vehicle (AUV). However, while AUV does not require oxygen and can withstand great pressure which human cannot, they lack the ability and advantages as well. For example, AUV lacks the precision control as well as sense of direction. A robot does not know where it should go unless you tell it to. We can use GPS to locate a robot on land so that it has “sense of direction”, but GPS does not work well underwater as signal with higher frequency attenuates rapidly underwater [4] and thus AUV has to rely on other methods to achieve localization underwater.

Advance AUV and underwater vehicles such as submarine employs advance technique to generate an accurate three-dimensional site plan using acoustic sensor such as sonar and radar which for underwater localization [5]. However, those modules are very expensive. In recent years, a more popular approach has been emerged is called Simultaneous Localization and Mapping (SLAM) technique [6]. This technique employs a combination of Inertial Measurement Units (IMU) and sonar which allow an AUV situated at an unknown initial location and creates a map and proceed to localizes itself in that particular map.

1.2 Problem Statement

In previous years, oceanic localization and navigation particularly for operation of AUV for scientific mission relies on Global Positioning System (GPS) signal and/or make use of existing sonar beacons. However, the limitation of this method requires periodic surfacing of the AUV to receive the signal [7].

Currently in submarine applications, Inertial Navigation System (INS) is the common solution [8]. INS consist of accelerometers and gyros to measure angular rates and accelerations. By using signals accelerometers and gyros, the three-dimensional vectors of velocity and position and attitude angle can be found. However, INS have drawback or limitation, which is that the error will accumulate along as time progress, and small calculation of error on IMU (Inertial Measurement Unit) may cause large error [8]. In addition, both methods require expensive module such as high precision sonar and it involve complex programing method.

In conclusion, the challenges of others oceanic localization and navigation technique is that periodic surfacing is required, accumulation of error after a period of time, and involves expensive module and sensor. Thus, this project will target to achieve underwater localization without the limitations mentioned specifically above.

1.3 Research Objectives

Based on the problems mentioned above, the objectives of this project are:

1. To design a technique or algorithm to achieve underwater localization on x-y plane that does not require expensive module such as sonar or radar and does not require periodic surfacing.

2. To calculate the coordinate of the AUV using the designed localization algorithm.

3. To compare the calculated experimental value of coordinate with the actual value of coordinate.

1.4 Research Scope

In our current context, the solution of underwater localization of AUV using camera and floating markers will be discussed. Although mainly existing solutions for underwater localization utilize acoustic sensor such as sonar and radar, but those are expensive and only used on ships and carriers. A cheaper approach suggested would be using laser or light source, or in simpler term – camera. Camera can capture image underwater, then the image can be sent to microprocessor to process the image and then the image can be processed to determine the location.

For this project, The AUV will be replaced with a dummy, which is a camera. The images will then be processed using an image processing algorithm to locate the position of the AUV in term of coordinate on the x-y plane

The scope of our research focus on the proof of concept of the said algorithm, which is the image processing algorithm and the AUV will be represented by a camera. The coding of the process is break down into 5 phases. The first phase is image filtering, followed by finding the contour and centers of the floating markers, calculation of distance between camera and markers, pixel distance to real distance conversion and lastly, estimation of coordinate by trilateration.

The two constraints are the camera need to be aligned perpendicularly to the surface of the water and all the floating markers are presence completely in the image taken and not partially presence.

1.5 Thesis Outline

This thesis consists of a total of five chapters which provide in-depth explanation and discussion of the project. Chapter 1 is the introduction. The background of the research will be briefly explained, followed by problem statements of past researches, the research objectives of this project and scope of this research. Coming up next is followed by chapter 2 which includes the literature review of this project which the previous work of underwater localization of AUVs are discussed and explained in detail. Besides that, the pros and cons of previous work will be discussed as well. Next, chapter 3 will be focusing on methodology which explained the method employed in this project. The environment set up particularly on the floating markers will be explained. The algorithm of image processing to determine the location of the camera in x-y plane will be explained. Chapter 4 is about result and discussion. The result of which is the location of the camera in term of coordinate will be calculated and determined by the system will be compared with the real location of the camera. Discussion will be based on the results. Lastly, chapter 5 is the conclusion which will summarize the thesis. In addition, future improvement and suggestion of this research will be discussed as well.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In this chapter, the study, interpretation and analysis for previous works will be summarized. The underlaying principle and their concept will be discussed and review. On top of that, the pros and cons of previous researches will be discussed in this chapter as well. Chapter 2.2 will discuss one of the older, and most common method to achieve localization and navigation of AUV and water vehicles in details which is the Global Positioning System (GPS). Chapter 2.3 will discuss the newer and more practical and efficient approach of underwater localization which is the Inertial Navigation System (INS) in details.

2.2 Global Positioning System

2.2.1 Introduction

Global Positioning System, or more commonly known as GPS, is a space-based radio-navigation system that provides one of the most precise open ocean navigation available. The GPS is a network of 24 Navstar satellite where each satellite will be placed in Earth orbit (roughly 11,000 miles) and gives a 12 hours period for the satellites [9].

The GPS system was originally set up by the U.S. Department of Defence (DOD). It cost around USD 13 billion at that time and everyone can access it for free including user from other countries. The GPS system's timing data and positioning are used for a variety of purposes ranging from land, air to sea navigation and localization, vessel tracking, mapping and surveying. The GPS system comes with military accuracy restriction but it was partially lifted in year 1996 and fully lifted in year 2000 [10]. As of today, GPS can pinpoint and location for objects even as small as coin anywhere on the Earth's surfaces.

The GPS working algorithm started with the GPS receiver, which can process special coded satellite signals used by the GPS system, which will then enable the receiver to measure and compute location, velocity and time. In normal operation, GPS works by implementing four of the 24 satellite signals to measure and compute location in three dimensions in the receiver clock. A user can triangulate their position anywhere on Earth by measuring our displacement from the satellites.

Every single GPS satellite contain an atomic clock which will continuously transmits and receives messages carrying the current time at the beginning of the message, parameters to measure and compute the position of the satellite, and the almanac which is the general system health. The signal transmit by the satellites is in the microwave range of the electromagnetic spectrum, which means that they travel as fast as the speed of light through vacuum, and slightly lower when moving through medium such as our atmosphere. The receiver uses the time required for the signal to arrive to calculate the distance from each satellite, which then it can find out the location of the receiver using mathematic principle such as trigonometry and geometry.

A GPS signal carries three different types of information, the ephemeris data (which is used to compute the location of each satellite), the almanac (the information about the status, or also known as health, of the satellite system), and a pseudorandom code (a code for identification purpose that will ping back to whichever satellite that are transmitting the signal).

2.2.2 Working Principle

To pinpoint a user's exact location using the GPS, we have to first measure the distance between us and a GPS satellite. Let that be d_1.

$$d_1 = \text{distance between a user and a GPS satellite}$$

Let d_1 = 11,000 miles or roughly 17700 kilometers. By knowing the value of d, distance from a particular satellite, we can narrow down every other potential position a user could have been in the whole of outer space to the surface of a planet that is centered by the satellite constellation system, having a radius of 17700 kilometers and for our case, that is Earth.

Then, the user will measure its distance to another satellite, and let the be d2.

$$d_2 = \text{distance between the user and second GPS satellite}$$

Let d_2 = 12,000 miles or roughly 19312 kilometers. That provide an extra information, that the user can be and can only be located in a position, within a radius of 12,000 miles or 19312 kilometers from the second satellite. Then, coupled with information we have gotten from d_1, we can compute that the user's location is somewhere on the intersection of the two sphere, centering the two respective satellites.

Then, we can repeat the same step, with distance between the user and a third satellite, d_3.

$$d_3 = \text{distance between the user and third GPS satellite}$$

Let d_3= 13,000 miles or roughly 20921 kilometers, this will narrow down the potential position of the said user down to two points, which we then can eliminate one of the point due to impractical reason (either the point is too far from Earth or it is moving at impractical velocity)

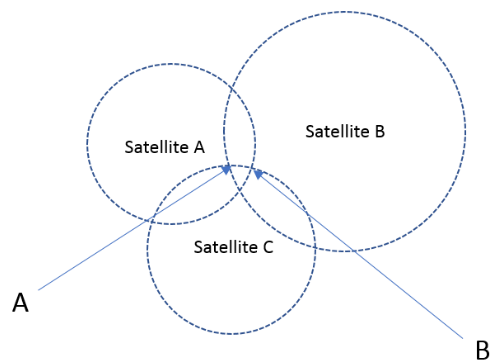

Figure 2.1 Two potential locations with three known distance between user and three different satellites

Figure 2.1 shows two potential locations with three known distance between user and three different satellites. If we want to have an even precise answer, employing the fourth variable, d_4, which is the distance between the user and a fourth satellite, and the location of the user will have to be at the intersection of the fourth sphere [11].

2.2.3 Implementation, Advantages and Disadvantages of GPS in AUV and Water Vehicle Navigation and Localization.

In normal operations, only four satellites are required but in special cases, fewer satellites are needed. Among the special cases, one of them is related to our research, which is during the condition when the altitude of a AUV or water vehicle is known as 0, a receiver can determine its location using only three satellites.

The advantages of GPS in the implementation of GPS in AUV and water vehicle navigation and localization are low weight, small and generally low in power [12]. These factors are possible with the development of single board GPS engines or receivers. On top of that, with the advent of GPS interface becoming more and more friendly as of today, the ease of interfacing and translating is also one of the advantage and top reasons why GPS is popular in AUV navigation.

The extremely precise accuracy of GPS is another advantage and top reasons why GPS is popular in AUV navigation. As of today, GPS's accuracy is 5 meters horizontal accuracy with 95% confidence interval [13]. This tops other method and sensors used for water vehicle localization.

The main disadvantage of GPS implementation in AUV navigation is that GPS signals, like any other electromagnetic signal, have zero water penetrating capability. Thus, to implement GPS in AUV localization, an antenna has to be set up and it has to be free of water. There are three types of antenna configurations – fixed, retractable and expendable. A fixed antenna, as its name implies, will be placed on the AUV and length will extend outside of the surface of water. A retractable antenna is a type of antenna where it would be retracted when submerging and extend when the AUV hovers near to water surface.

When information process is finished, it would then retract back to the AUV. The expendable works the same way as retractable except it is used once and then throw away. Normally this is used to determine the initial location of the AUV and then for the rest of the journey of the AUV will have to depends on other methods to achieve localization. The requirement to expose the antenna of GPS from water surface is the biggest disadvantage of implementing GPS in AUV and water vehicle navigation. Thus, in normal application, an AUV will have additional features to achieve localization such as inertial navigation and/or acoustic sensors.

2.3 Inertial Navigation System

2.3.1 Introduction

Inertial navigation is a self-contained, non-radiating, non-jammable, dead-reckoning navigation systems [14] in which it measurements rely on parameters provided by gyroscope (a type of sensor measuring velocity and orientation) and accelerometers (a type of sensor measuring acceleration). This technique and determine the orientation and position of an object or person relative to a known initial point, velocity and orientation.

It is normally comprised of two major parts. An inertial measurement unit (IMU) and a microprocessor or single board computer. The IMU will normally made up of three orthogonal accelerometers (measuring linear acceleration) and three orthogonal rate-gyroscopes (measuring angular velocity) in three different axes. The microprocessor or single board computer will then process the information taken from the signals and made the computation of location and orientation possible.

2.3.2 Working Principle

The theoretical working principle are as shown in Figure 2.2.

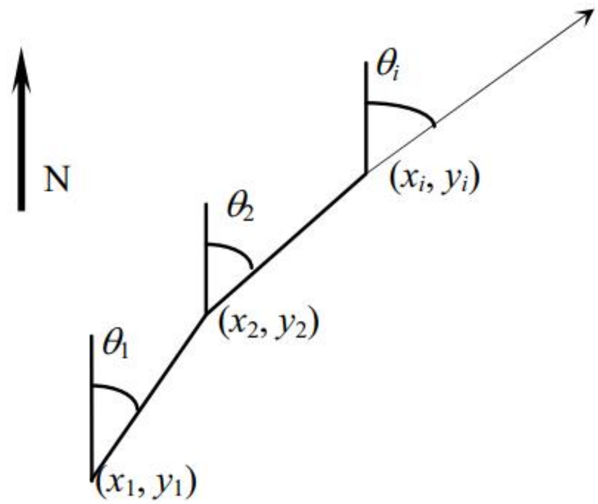

Figure 2.2 Theoretical Working Principle of INS

In the area of underwater navigation and localization, the accelerometer can measure the acceleration directly using accelerometers. If the system are not equipped with accelerometer, then the acceleration can be determined from the gyroscopes, given that it has high sampling rate.

$$d_i = v_i + \frac{1}{2} a_i t^2 \qquad \text{-------------(2.1)}$$

$$a_i = \frac{v_i - v_{i-1}}{t_i - t_{i-1}} \qquad \text{-------------(2.2)}$$

Where the acceleration of the AUV, a_i can be calculated from Equation (2.1). a_i is a constant and, d_i is the distance travelled of the AUV from the time t_{i-1} to t_i can be calculated from Equation (2.2). v_i is the velocity measured by the gyroscope at the time t_i

The position of the AUV in coordinate x and y at time t_i can then be calculated using Equation (2.3) and Equation (2.4).

$$x_i = x_0 + \sum_{i=0}^{i-1} d_i \cos\theta_i \qquad \text{-------------(2.3)}$$

$$y_i = y_0 + \sum_{i=0}^{i-1} d_i \sin\theta_i \qquad \text{-------------(2.4)}$$

.

where, θ is the orientation of the AUV at time t_i measured by the gyroscopes. x_0 and y_0 will be the coordinate of the AUV [15].

2.3.3 Implementation, Advantages and Disadvantages of INS in AUV and Water Vehicle Navigation and Localization.

INS has been used in a wide range of navigation and localization applications. It has been used in the navigation of tactical and strategic missiles, aircraft, spacecraft, and particularly AUVs and water vehicle. One of the reason why it is popular in underwater localization is due to the drawback of GPS being unable to operate underwater and thus INS serve as a good replacement as it is fully functional underwater.

The advantages of implementation of INS in AUV and water vehicle navigation and localization also including: fully autonomous, non-jammable and operates at all altitudes. INS also does not rely on any eternal source and signal. It is fully self-contained. Its sensor (accelerometers and gyroscopes) will be located inside the body of the object and doesn't have to extend to the outside of the said object such as GPS. This strong point also made INS a popular method for military underwater vehicle as it can be applied in covert operation as there is no external body such as antenna to be detected by enemy's sonar and radar [16].

The disadvantage of INS cost in AUV and water vehicle navigation and localization including the cost. The IMU is expensive at the time of purchase and the maintenance cost is not cheap too. Other disadvantages include the accumulation of navigation errors over time as it will be affected by inertial drift. In addition, the weight, size and power consumption are still higher compared to GPS receivers albeit it is reducing as technology develops [16].

2.4 Summary

The advantage of GPS is its high accuracy. The main disadvantage of GPS implementation in AUV navigation is that GPS signals, like any other electromagnetic signal, have zero water penetrating capability. Thus, to implement GPS in AUV localization, an antenna has to be set up and it has to be free of water. The advantage of INS is fully autonomous and self-contained. The disadvantage is the accumulation of error after a period of time. In conclusion, both methods have good and bad. Our project will target the limitations of both of the studied methods, which is GPS and INS to achieve underwater localization without the limitations of GPS and INS.

CHAPTER 3
METHODOLOGY

3.1 Introduction

In chapter 3, methodology, details about the steps and development of this research will be discussed. The methods and steps applied will be discussed and explain in-depth in this chapter. Section 3.2 is the implementation workflow of this project which will describe the flow of steps and methods taken in this project and it will be visualized with flowchart. Then, Section 3.3 will discuss about the limitations and assumptions of this project for the localization algorithm to work. Section 3.4 will discuss about the hardware involved for this research, which will be the camera that were required to take image of the floating marker. Section 3.5 will go through the software used to design and construct the coordinate computation through image processing which will be Microsoft Visual Studio with the support of OpenCV library. Section 3.6 will focus on the experimental set up of this research, which the image processing algorithm of underwater localization will be designed and tested. This is done by setting up an environment to simulation underwater condition. A big tank is used to simulate the underwater condition. Then, 3 floating markers of different colors were placed on the surface of the water, forming a triangle shape. Then, a camera was placed on the bottom of the tank, facing toward the surface of the water. Images were taken with camera at different positions in the tank (at the corner, center, and side). Then, the images taken will be were processed with a set of algorithms, which will determine the position of the camera. Then, the calculated position of the camera was compared with true location of the camera for accuracy testing. Section 3.7 will focus on the algorithm of this research which is the designing of the algorithm of the image processing that will achieve localization. The algorithm of this project, or in another word, the processing steps of this research will be divided into four stages, the first one is the image testing and filtering, relative distance of the camera to the markers, x-y plane coordinate identification, and lastly testing and evaluation. Then, section 3.8 will summarize the whole of chapter 3.

3.2 Project Implementation Workflow

The Figure 3.1 is the flowchart of the research methodology. The research methodology started with literature review. Previous works and researches that were relevant or related were studied with care. The methods employed by previous projects were read and understand thoroughly. Then, the limitations and assumption of the research were given attention. For this project, the limitations that were considered is the condition of underwater environment, which will distort light wave, and absorb almost any kind of microwave, including Bluetooth signal.

The previous works studied were the methods of localization underwater such as GPS and INS and it were stated in chapter 2 of this report. Aside from that, additional researches of the past that were gone through but not mentioned in this report included the sonar, radar, Simultaneous Localization and Mapping (SLAM), triangulation and trilateration.

Then, after studying relevant previous works, possible solutions for this project were brainstormed and drafted. The solutions were then examined and tested to extend that whether the proposed method is able to solve the problem stated by this project. This step was guided with supervisor advices and suggestions as well. The proposed method was trilateration on 2D plane using image processing the identify the parameters.

Next phase following the solution testing is the set up of experimental environment. The actions taken in this phase were the finding of the medium to simulate the underwater condition, which a big water tank was found. Then, the floating markers were prepared using several materials such as polystyrene ball, balloons and ping pong ball. The best material was chosen, which was the ping pong ball. The next phase would be the hardware preparation and set up. The hardware used in this project is the camera and the floating markers. The camera used is the camera of the mobile phone Samsung Galaxy J5. The floating markers were ping pong balls and sprayed with different colors.

Then, the next phase is the software development phase. In this phase, the coding for the algorithm was slowly developed and debugged. The coding was doing in C++ language using Microsoft Visual Studio with the support of OpenCV Library. The coding algorithm can be summarized as follows, image filtering, locating the center point of floating markers, calculate the relative distance between the camera and the floating markers in x-y plane, converting pixel distance to real distance and trilateration to estimate the coordination of the camera in x-y plane.

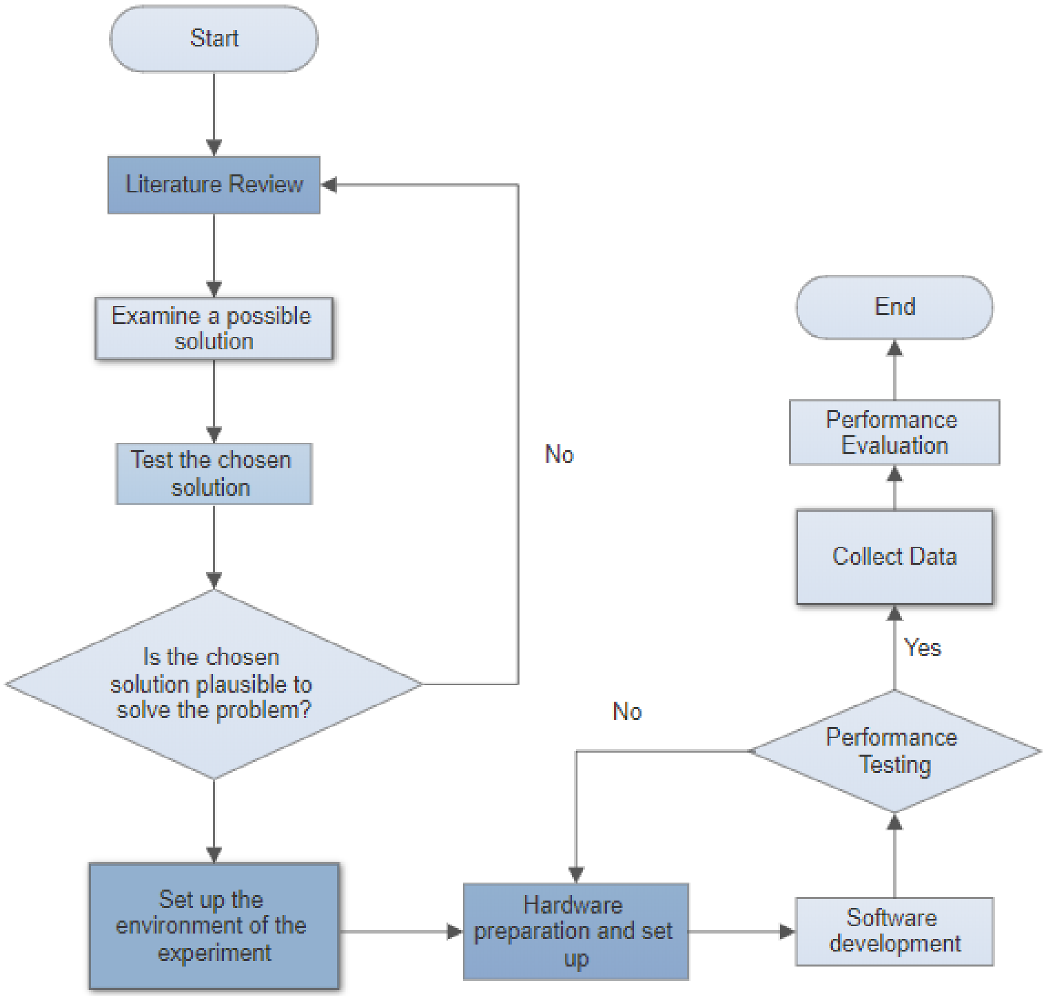

Figure 3.1 Flowchart of the Research Methodology

After the performance testing of the method implemented, the method was examined and tested whether it was plausible. Once the examination was showed green light, the project implementation workflow was moved to the next phase, which is the collection of data. The collected data is then evaluated and processed. Results were then tabulated in the form of table and graph.

3.3 Limitations and Assumptions

Methods proposed to solve the problem worked under few assumptions:

1. The camera is aligned perpendicularly to the surface of the water
2. The bottom of the water tank where the camera lies is flat
3. All the floating markers are presence completely in the image taken and not partially presence.
4. The images are taken in a period of time range where the intensity of the light doesn’t change much and the background noise is minimal.
5. The camera used is rectilinear, where the centre pixel of the image taken is in a straight line with the sensor of the camera.

3.4 Hardware

In this research, a camera was used to take image of the floating markers and then the images taken will be processed to identify its location underwater. The camera that was used is the rear camera of Samsung Galaxy J5 that were released in June 2015.

Figure 3.2 Samsung Galaxy J5 [17]

The rear camera of this phone has 13 megapixels (f/1.9, 28mm), comes with autofocus, and LED flash feature. The flash feature is very important as it lights up the floating color markers, makes color identification easier.

The specifications of the mobile phone are as follows:

Specifications	Model: Samsung Galaxy J5 Duos with dual-SIM card slots
Launch	2015 June
Storage	Card Slot: microSD, up to 256 GB (dedicated slot) Internal: 8/16 GB, 1.5 GB RAM
Display	Type: Super AMOLED capacitive touchscreen, 16M colors Screen Size: 5.0 inches, 68.9 cm2 Resolution: 720 x 1280 pixels
Battery	Battery type: Built-in Battery: Removable Li-Ion 2600 mAh battery Charge Way: AC-USB adapter
Camera	Primary: 13 MP (f/1.9, 28mm), autofocus, Features: Geo-tagging, touch focus, face detection Video: 1080p@30fps Secondary: 5MP (f/2.2, 23mm), LED flash
Features	Sensors: Accelerometer, proximity
Dimension/Weight	Product Weight: 146 g (5.15 oz) Build: Plastic body Size: 142.1 x 71.8 x 7.9 mm

3.5 Software

Microsoft Visual Studio is an integrated development environment (IDE) from the well-known multinational technology company that has developed Windows, Microsoft. An integrated development environment (IDE) is a software that are used to develop software. It provides comprehensive facilities and tools for programmers to develop software application.

Microsoft Visual Studio is used to develop software applications, computer programs, mobile apps, web apps, web sites ,and web services. Microsoft Visual Studio employs Microsoft software development platforms such as Windows Forms, Windows APIs, Windows Store, Windows Presentation Foundation and Microsoft Silverlight. It can produce both managed code and native code.

Figure 3.3 Microsoft Visual Studio Software Logo [18]

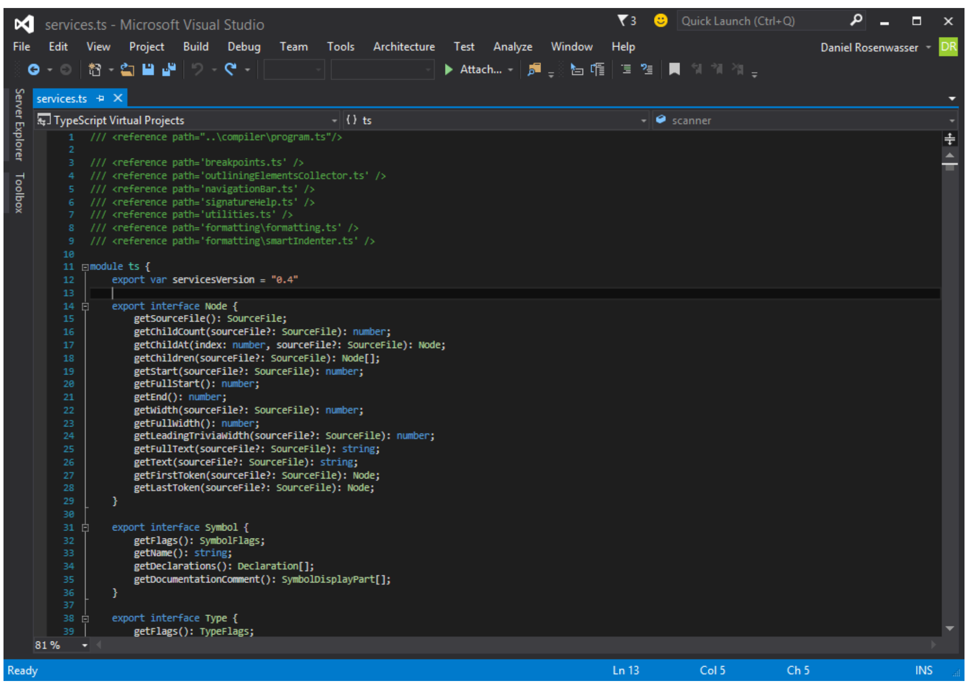

Figure 3.4 Print Screen of Microsoft Visual Studio

Microsoft Visual Studio will be used to process the image taken, coupled with the support of the library OpenCV (Open Source Computer Vision) , which is a library of programming functions commonly used for computer vision and image processing. It was originally developed by Intel, and later supported by Willow Garage and is now currently maintained by a company called Itseez, which is now acquired by Intel.

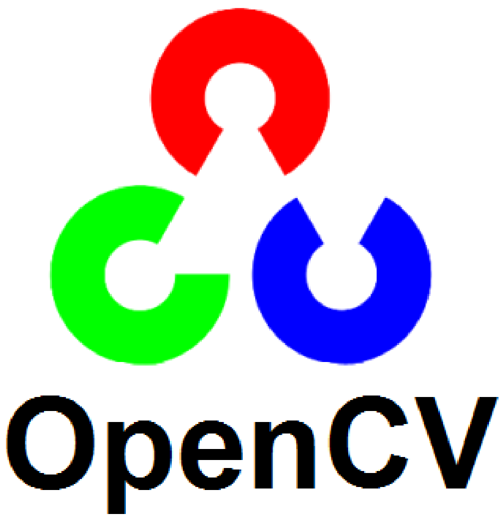

Figure 3.5 Logo of OpenCV library [19]

The library is open source (which is free) and cross-platform, one of the platform it support is Microsoft Visual Studio. It supports Java, Python, and C++ language and it interfaces with MATLAB. OpenCV support a wide range of operating system including Windows, Mac, Android and Linux OS. OpenCV incline to solve real-time computer vision and machine vision application.