FUNCTIONALITY AND PERFORMANCE STUDY OF IOT INTEGRATED MULTI-TANK WATER LEVEL MONITORING SYSTEM

by

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22677

Dissertation submitted in partial fulfillment of

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CERTIFICATION OF APPROVAL

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Approved by,

(Dr Tamiru Alemu Lemma)

UNIVERSITI TEKNOLOGI PETRONAS

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APRIL 2020

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(NANTHAR KUGARN A/L N.PARAMANANTHAN)

Abstract

The purpose of this study is to develop an IoT system which will give accurate and live data which is stored and accessible to anyone around the world in the push of a button. For that very purpose, an experimental model was developed which consists of eight water tanks. The IoT system developed will be used to monitor the water level in each of the tanks and the flow rate into the tanks with the help of sensors and Raspberry Pi to connect the sensors to the Internet of Things. The Node-Red programming tool is used as it gives a very nice user interface which can be used to analyse the data. Three tests were done to calculate the mean percentage error of the data displayed. The three tests were for the initial water level, final water level and the flowrate of the water inlet. The error mean values of 20.835%, 10.5% and 10.145% were obtained respectively for the initial water level, final water level and the flowrate reading. This means the system is 'Acceptable' for the initial water level reading and 'Good' for the final water level and flowmeter reading based on the system performance evaluation developed. This study also shows that the data of the trend of the water level in all eight tanks and the flowrate in all the flowmeters can be stored and used later as needed. This is done by storing the data in the Raspberry Pi. This study evaluates the performance of the IoT system to be used in similar up-scale systems in the near future where the IoT will have a huge role to play.

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CHAPTER 1 INTRODUCTION

1.1 Background

The Internet of Things (IOT), or also known as the Internet of Everything, is the future. It is essentially a global network of machines and devices which react with one another autonomously. It is also one of the most important areas of future technologies which attracts lots of managers from different industries to apply it in their respective fields[1]. It is also forecasted that there will be around 26 billion units of machines and devices which will be using the IOT concept by 2020, compared to 0.9 billion units in 2009[1]. This remarkable growth is said to grow even more as more industries are interested in applying this and even the governments want to implement this concept as the ‘Smart Cities’.

Cities in Europe like Barcelona already implemented the IOT concept where most of their technology initiatives are based on the concept. Examples of initiatives done in Barcelona includes the digital bus stop, smart parking spots, smart lighting and monitoring, smart garbage systems and smart use of energy[2]. This managed to transform the entire city of Barcelona which has badly hit in a crisis back in 2008 to a technologically edgy city. All the initiatives mentioned before are aimed to reduce time and energy wastage which remarkably improves productivity. In a few more years, all the technology in Barcelona will be found in all major cities around the world, thus it is important to properly plan the advancement of this technology.

In the Asia-Pacific, it is estimated that there will be 10 smart cities by 2025, and more than half will be in China[3]. In Malaysia, prime minister at that time, Datuk Seri Najib Razak had announced that there are 11 initiatives and projects that are aimed to make Cyberjaya as the country’s first smart city. Kuala Lumpur shall also join the list of smart cities by 2020 with the “Malaysia City Brain” project by Alibaba Cloud. This is the replication of what was done in Hangzhou in 2016[4]. This project is aimed to reduce traffic congestions in Kuala Lumpur by using video and image recognition technology to predict the real time traffic and autonomously control the traffic flow using traffic lights and other means necessary. This will also keep the city safe and the video and image recognition can be used for surveillance purposes as well.

The “Malaysia City Brain” project by Alibaba Cloud can reduce the average time stuck in traffic by 12 % or up to 10 minutes. Ten minutes saved per travel can save up to one hour a day if the person travels six times in a day. This is just the tip of the huge advantages of the IOT concept yet to be discovered. Simple thing like smart lighting of street lamps can save up to millions of dollars of electricity cost in long term. This money can be used for the development of the country and the IOT technology. Apart from saving energy, water and maximizing overall efficiency, the IOT concept also generates lots of job opportunities as there will be huge amounts of data that would need data analysts to manage.

The IoT has a big role to play in the future, which is why we would like to examine the functionality of the IoT system in simple applications such as monitoring the water levels in a multi tank. The water level and any leakage in a multi-tank is monitored as an effort to reduce or eliminate water wastage, reduce electricity consumption and generally improve efficiency. This idea can be used in smart cities for all kinds of applications such as for storage of drinking water, watering the plants in smart homes, making sure our pets have enough water and so on.

1.2 Problem Statement

The IoT technology is not widely applied yet even if it is proven to be very efficient and resourceful. There are many problems that this technology can eliminate. This problems are mainly inefficient use of resources, requiring human assistance and no data being stored or collected.

Efficient use of resource is the main problem in a world without IoT. Resources such as water, energy and time are widely going to waste due. In many cities nowadays, water is taken for granted to the point no one cares if it is being wasted. A faulty water faucet which leaks one drop of water per minute will add up to 128.7 litres of water per year[5]. In a town with a million faulty faucets, that is already 128.7 million litres of water being wasted per year, and this is only through faulty faucets and not counting all the other countless ways water can be wasted like letting water flow when brushing teeth and so on. All this water wastage is what a smart city of the future should be avoiding as water shortage can happen anytime and we must be prepared for it.

In Malaysia, water shortage may not be something common, but it does happen every now and then. In March 2019, there was water rationing being held for six states in Malaysia due to hot weather according to the Water, Land and Natural Resources Minister Xavier Jayakumar[6]. Dr Xavier stated that the water rationing in the six states are for Negri Sembilan, Johor, Perak, Kedah, Pahang and Kelantan due to lack of rainfall. These water rationing will affect the lives of millions of people and might cost more money to buy water from elsewhere. This is a problem to not be brought to the future, therefore by saving water, we hope to be prepared for situations like this.

Electricity wastage is also the problem here. A lot of current is being wasted by having lamps and fan turned on when no one is using them. One example is the road lamps which are turned on even though there are no cars in the roads. By having a motion sensor that can detect cars and autonomously turning the lights on and off can save lots of money in long terms although the initial cost to set up the sensors can be expensive. However, in long term, the cost comes in only when the sensors must be replaced, and a lot of electricity can be saved in cities where got lots of roads especially in mega cities.

Even technologically advanced countries like the United States waste up to 30% of their annual electricity costs of $190 billion, which means 57 billion US dollars go to waste every year[7]. Energy wastage must be avoided as well as the world is still finding for cleaner and efficient ways to produce energy. Most of our energy now comes from non-renewable sources like oil and gas which is not that efficient and releases gases like carbon dioxide which causes global warming. By saving energy, we can produce a greener environment where there would not be a need to burn lots of fossil fuels to produce energy and we can focus on other alternatives to produce clean energy.

Other than that, time is also wasted when things are done manually without applying the IoT. In commercial sense, time is money and productivity. By not applying the IoT, a lot of money is wasted as more time is required to do a task.

Human assistance is also required when doing a certain task. For example, well loggers who have to travel every time to obtain data from the sensor. This is the kind of problem we do not want to carry with us to the future. Lastly, data is also not properly collected when they are collected manually due to errors in writing them down.

1.3 Objective

The objectives of this project are as highlighted below:

- Utilize the IoT technology to develop a system for multi-tank water level monitoring.
- Experimentally investigate functionality and the performance of the system.
- Analyse the observations from the second objective to draw conclusions applicable for similar but up-scaled systems.

It is explained before about the significance of water and how we take it for granted. By developing an IOT system that can monitor and give real time data of the water level at our convenience, a huge portion of water wastage can be reduced if not eliminated. By manually doing these tasks, we tend to have at least some sort of wastage that can be reduced if a sensor or device is used. By having real and accurate results of the water resources, proper planning can be done to minimize water wastage as much as possible. Apart from just doing these tasks, sensors can also record and alert us if any leakage is to be found. There are cases where we take a long time to detect a leak due to the inaccessible location of the leakage due to space constraints. By having leak sensors around the tanks, we can get alert of a leakage much sooner which can reduce the time it takes to fix the leakage.

The other objective is saves time and overall human effort which increases efficiency. Having an IOT system around us to do simple tasks can make our life much easier. One good example is living in a “Smart Home”. We do not have to turn the light on anymore by turning the switch on, instead sensors can detect when you automatically walk in or if it is dark, it will then automatically turn the lights on. Simple things like this can save a lot of time, which can be spent productively to increase output. Not only it increases productivity, it also makes a better living where life is simple and you do not have to worry if you spill your water, as leak sensors can detect them and automatically mobilize the cleaning robot. Apart from setting a comfortable home, a “Smart Home” also gives a sense of security. In the case of fire, heat detectors can detect it easily and turn the sprinklers on as well as alert the occupants of the home as well as the fire brigade. This can also save countless life as fast response is necessary for fighting fire and sometimes, we might be unaware of the fire until it is too late.

Another objective is that we can save the pump life as well. Pump failure can be caused by running on dry conditions as explained earlier. By having a system to monitor the water level in a tank, we can know if the tank is going to be low on water. When that happens, we can turn the pump off and save the pump. Running on dry condition causes the pressure and flow to surge, causing overheating. This will eventually cause early pump failure. By having an intelligent system that can monitor and control the power given to the pump, the pump life can be maximized. Therefore, the overall cost can also be reduced as the pumps can last for a much longer time if it is switched off in dry conditions.

Monitoring the water tank also gives us information on the amount of water left for usage. By knowing how much water we have left we can plan and use the water accordingly as well, further reducing the water wastage. The IoT system can also alert us to fill up the tank as soon as a tank hits a certain level to prevent water disruption.

1.4 Application

The application of this idea can be in various areas. For example, the biggest scope of application will be in the household. This is because most of the water wastage happens in the household. Having an IoT system to monitor water level of different household appliance is very helpful for the User. Examples of tanks they can monitor can be the aquarium water level, house water tank, tank to supply water for pets and so on. Just one system can monitor water levels in multiple tanks which can then display results is the mobile phone for the User’s convenience. The User can have a better peace of mind when being away from home for some time as they can constantly check and make sure there is enough water for their plants and pets.

It can also be used in treatment plants where there are many tanks such as fixed roof tanks and floating roof tanks. The data can be accessed by the company staffs not only from the plant but also from anywhere around the world with the help of IoT. This can help the staffs manage the plant better as they are aware of their supply level even when they are far away from base. This system also gives accurate results, and accuracy is very crucial in the industry.

This concept can also be applied in the agriculture industry. Zagórda, et al. [8] states that modern technology is focusing on a strategy with higher knowledge and automation to grow their crops. They have also stated that machines used in agriculture are becoming heavier and heavier and smart farming is smart farming is made up of interaction of internal and external systems for the exchange of information. Rathinam, et al. [9] suggests methods to use Wireless Sensor Network in the agriculture industry. The Wireless Sensor Network can be used to monitor, measure temperature, irrigation system, measure water supply and so on. Similar to that proposed by Rathinam, et al. [9], we can also use the IoT concept in the agriculture industry to minimize human effort, save time and money as well as increase crop productivity.

CHAPTER 2 LITERATURE REVIEW

2.1 Internet of Things

The Internet of Things (IoT) is spoked in a way how people spoke of the World Wide Web (WWW) in the 1990s [10]. We are all aware of how important the Internet is in this point of time in 2019, but does that really tell about how the IoT is going to be in 2030? Researchers and practitioners lately are giving the IoT a lot of interests according to a study by a group of researchers in their study in 2012 [11]. According to them, the rise of the IoT era has opened doors in more ways than ever expected to live a better life in most of the novel applications. The IoT architecture from the study of [12] consists of three main parts. They are, IoT Sensing Layer, IoT Network Layer and finally IoT Application Layer. The IoT architecture is mostly important to understand the IoT concept and used mainly my IoT development teams to develop and do maintenance of IoT systems.

As for the application of IoT, the possibilities are endless with the IoT, that it can be applied to almost all the sectors, from manufacturing, agriculture, transportation, traffic management and so on. Even the medical sector have started adapting the IoT to integrate with their medical sensors in an attempt to reduce medical fees at the same time to provide better services to their customers [13]. Apart from that, the medical sector also gets other benefits such as increase in productivity, lower chance of spreading contagious diseases, shortens total time spent in a hospital and so on. According to Zeadally and Bello [13], the medical sector is the first sector to adopt the IoT concept as it helps productivity and also helps the medical sector to reduce their overall costs.

Apart from the medical sector, Elmer [14] has proposed a few solutions on how common IoT applications can be used in the oil and gas industry by Exploration & Production companies. Examples of adaptations that can be done to existing IoT products are listed in Table 2-1.

Table 2-1 Adaptations that can be done to existing IoT -products to be used in the oil and gas industry [14]

Existing IoT Product	Adaptations
Wi-Fi Smart Thermostat with Voice Control	This system can be improvised to set temperature set points in fired vessels such as boilers and so on.
Burglar System	Instead of alerting the Owner in the case of a break-in, the system can alert the operator when a certain condition is reached like a fixed temperature or pressure in an equipment.
Smart-Home	This system can be improvised to autonomously run operations when a certain condition is reached. For example, turn a particular pump on when the pressure in a pipe reaches a minimum limit.

Apart from the medical and oil and gas sectors, IoT can also be used in many aspects of life according to Gubbi, et al. [15]. Some of the aspects include personal and home, enterprise, utilities and mobile. Examples of personal and home application is creating an IoT environment for the care of elderly and sick people where doctors can be aware of the persons health and have consultation only when required. This can reduce the hospitalization cost. Home and energy can also be managed in a better manner by having an IoT system to autonomously control the lighting and the HVAC systems. Even social media is about to change as we are looking at the future where machines can start reacting with us through social medias, like a tank tweeting that it is getting low on water level.

However, Colistra, et al. [16] thinks otherwise that IoT actually has some problems or limitations which makes it unrealistic to be applied in all the sectors in the near future. One of the problems is integrating all the devices available in an autonomous was especially in a dynamic condition. One example would be while driving and we expect all the cars to receive and share their data with each other, but in reality, it is going to take a long time to actually have all the cars to autonomously connect and share information with each other. Efremov, et al. [17] also states the same that the first problem with IoT is using it in a dynamic condition. IoT would be ideal in a static condition like a ‘Smart Home’, but it is impossible to stay inside one’s whole life. Another problem stated is to update or to run commands in all the integrated IoT devices is going to be a difficult task for even a simple system. For big systems like ‘Smart Homes’, it might take a longer time as the current technology advancement is not efficient enough. That is why the major challenge for the application of IoT concept will be to connect millions of devices to connect and share information seamlessly. Apart from that, Harry Machado [18] also states that the IoT system is a complex system, therefore the rate of failure is rather high in application. Apart from that, it is also less secure, and it does not have an international standard for compatibility. Therefore, these challenges make us wonder if the IoT will truly be a part of the next decade with our current technological limitations. In our study, we shall study on the functionality on the IoT system to make human life easier, starting with something as simple as a multi-tank water level monitoring system.

2.2 Water Wastage

The chosen scope of application of the IoT concept is multi-tank water level monitoring. This is because water wastage is a huge problem in this modern day that everybody takes for granted. Many countries are having problem to meet their water demand. Even Jordan, an Arab nation which is situated on the east of the Jordan River have limited water resources. Hadadin, et al. [19] states that the rising natural population growth, together with an increase in the number of refugees has made their water supply not able to meet their water demand. The situation is so bad that water rationing has been implemented that citizens get water supplies once or twice a week. Hadadin, et al. [19] also says that water shortage has always been expected in the middle east, and it has already started in Jordan. It will not be long before the whole world will have trouble meeting its water demand. Apart from growing water demand, water wastage is also caused by our own habit. Examples given by Leroux, et al. [20] is simple household activities like bathing, washing dishes, washing the car and more on. Little attention is given to the frequency, intensity of water and total water used which causes water wastage. The use of IoT in saving water is not something new. It has already been done before in many ways and in different applications. Indian researchers Anisha, et al. [21] in 2017, have used IoT as a solution to reduce the consumption of water in homes by setting a limit for household water usages and restricting the water after 80% of the limit is reached. A microprocessor is used to monitor and control the water flow by using a solenoid valve. If this was implemented in every house hold, the amount of water wastage can be reduced significantly. I personally think this to be a great idea as this will make people rethink their water usage and not take water for granted. In 2013, another study was conducted also in India, where an autonomous system is introduced to fill up a tank and to stop filling when the water level reaches a certain limit by Guha, et al. [22]. In India, many housing complexes use manual pumps that had two buttons to either run or stop the pump with no data on the exact water level. This leads to water wastage as the pump is only switched off only when the operator turns it off and he or she has no information on the water level in the tank. This leads to an overflow of water due to the operator not knowing the exact water level in the tank. If the operator suddenly has something urgent to do, the water will just keep overflowing until someone else comes and turns it off. Therefore, an IoT system to monitor the water level in tanks in perfect for application as this as not only the operator, but everyone living in the apartment can know how much water is left by checking their devices. This is particularly useful in the case of water rationing. In 2018, Shankar and Dakshayini [23] have introduced the IoT system as the solution for saving water in overflowing tanks. Their study is mainly for overhead tanks and is not autonomous. Instead of having an autonomous system, sensors will show the water level in the overhead tanks. The pump action is controlled by the user instead by using their mobile phone. Although it reduces the human effort, it still requires someone to pay attention to the water level and stop the pump when the overhead tank is full to prevent overflow. Water overflow can cause serious wastage. For example, the Kaptai Hydro-Electric Power Plant in Bangladesh loses a lot of water in their dam through overflow of water during flood or heavy rainfall which reduces the efficiency of the power plant according to Chowdhury and Rahim [24] in 2012. Therefore, an IoT system is important to monitor the water level in the tanks so that we can be aware when the water level is low.

2.3 Cloud Computing

Cloud computing is basically an Information Technology (IT) service in which the resources are immediately available to the user across a network [25]. In this study, we are focusing on merging the IoT with cloud computing. Cloud computing like the IoT, is a concept that has developed greatly in recent times. Cloud computing generally means resources are available on the Internet whenever and wherever we are, independent of the device used [26]. Cloud computing, like the IoT concept requires the sharing of resources. However, in cloud computing, we can access any information from anywhere and anytime through the internet connection, which is different from the IoT which gives us resources from shared devices. Despite their differences, the combination of IoT and cloud computing is our aim for this study.

There are few main aspects of cloud computing which has been compiled in the Table 2-1 based on study done by Liu, et al. [25] .

Table 2-2 Aspects of Cloud Computing [20]

Aspect	Description
Ubiquity	Ability to connect and get resources at any time and any place easily.
Resource sharing	A database where resources are collected and distributed.
Elasticity	Also known as flexible. Service can be altered to meet customers' demand such as storage and bandwidth.
Scalability	Ability to be used or produced in a range of capabilities.
Pay per use	Users can be charged based on their service provided. The higher the service provided, such as more storage used, they would have to pay more.

In conclusion, cloud computing is a revolutionary step and is taking the IT infrastructure to a new level.

2.4 Raspberry Pi in IoT Application

The Raspberry Pi was developed mainly for educational purposes for kids in school to learn coding mainly. Apart from coding, Raspberry Pi is also used to teach computer science, computer architecture, engineering, robotics and many more [27]. A single unit Raspberry Pi can be bought for approximately 100 US Dollars or less, making it the third most sold computers in history, with 12.5 million units sold in a 5-year span. Raspberry Pi is used in both developing and developed countries as a tool for education due to its diversity. According to the United Nations Education, Cultural and Scientific Organization (UNESCO), Science, Technology, Engineering and Mathematics (STEM) education is important for both developing and developed nations. Therefore, the Raspberry Pi can play a big role in the STEM education. According to Yamanoor and Yamanoor [27], the Raspberry Pi is able to be part of the entire curriculum module for school. This can be done by teaching kids the initial set ups and programming in the beginning and slowly they can progress to applying the knowledge to build their own robots for example. Kids of today need a more dynamic environment and education no longer has to stick to the traditional whiteboards and markers. Having a fun environment to study will work wonders on the kids' progress.

Raspberry Pi has been used in IoT application recently. Recently in 2018, Sogi, et al. [28] have developed a smart ring based on Raspberry Pi using IoT. The ring is meant to be for the safety of women from sexual predators. When women feel like they are in danger, they can activate the ring which will send their location as well as the picture of the attacker, taken from the camera on the ring to the pre-determined emergency contact number or to the police force. According to the writer of that paper, a wearable device such as a ring is suitable as it is easy to conceal and has lower chance of being broken in a scuffle. The ring is connected to the Raspberry Pi and sends information to the respective party.

In 2017, Güleçi and Orhun [29] have developed a robot which can be controlled by Raspberry Pi. The Raspberry Pi from the robot is connected to an Android phone through Wi-fi. The robot then send live images from the camera to the phone and the robot can be controlled to perform simple functions like moving front and back from the Android phone. As there are more and more robots doing work for humans, controlling them from the mobile phones through Wi-Fi will be very convenient especially for those old people and handicapped. Apart from robots, Raspberry Pi is also used as a measure of the security system in Wireless Local Area Networks (WLAN). Users nowadays prefer to use Virtual Private Networks (VPN), as it provides higher security. From the results of the test of Quality of Service parameters relationship between different traffic conditions and CPU consumption in the VPN, we can get the relationship between the Quality of Service parameters and the different Raspberry Pi models used [30].

In a nutshell, the Raspberry Pi in IoT application can make wonders if planned properly. There are so many projects which have successfully implemented the Raspberry Pi in IoT application to increase efficiency and reduce overall effort and cost.

2.5 Water Level Monitoring in Multi-Tank

It is essential to know the amount of resources we have before we plan anything. There are lots of problems that arise from not knowing the amount of water left like overflow of water and so on. In 2010, Zhang, et al. [31] developed a system for multi-sensor integration for the application of water level monitoring. In China, the water level in the inland rivers play a big role especially during flood season. The previous way of determining the water level in the river is by manually observing and recording it, using a fixed water level gauge, using water level telemetry system, and also GPS Real Time Kinematics or Virtual Reference System. From the four methods, some of them require calibration and seem to give inaccurate results. Therefore, the researchers decided to use GPS Continuous Operational Reference System (CORS) which is a modern solution used in many cities. The only problem with the GPS CORS is that the data is stored within the device and an additional communication such as GPRS is needed to transmit the data from time to time. In Japan, Fukushima, et al. [32] have used electric double layer capacitor as a sensor to monitor water level in a rice field. The electric double layer capacitor was developed using material with low environmental load and charcoal. Combining the charcoal electric double layer capacitor with photovoltaic modules will give us a stable power supply for the wireless sensor network that transmits the data from a modified ultrasonic water level sensor to monitor the water level in rice fields. The ultrasonic sensor is modified to reduce the effect of dust mud and other impurities toward the actual result. The ultrasonic sensor uses the concept of using reflected time of ultrasonic waves to measure the water level. In 2018, Rahman, et al. [33] have proposed a system similar to our study and it uses a level sensor to monitor water level. Their system was a household water supplying and billing system. The system will autonomously switch on the DC pump when the water level is low and display the total amount of water used by each household in an LCD display. It uses a level sensor to measure the water level in the tank and a flowmeter to measure the total amount of water used. A microprocessor, Arduino mega 2560 is used and no IoT concept is involved in the system, which makes it different that our study. Another study in Indonesia by Sachio, et al. [34] uses IoT to monitor and control the water level in a container. The system is also an autonomous system and uses ultrasonic sensors to detect the water level. However, they use Blynk IoT service and Arduino ESP8266 controller. Thus, we can see how around the world different methods are being used to monitor water level as it is very important to monitor and manage our water resource. Therefore, a proper system must be developed for this purpose to benefit all mankind.

CHAPTER 3 METHODOLOGY

This section covers the project methodology, components used, system architecture, set-up of prototype, Gantt chart, as well as key milestones.

3.1 Project Methodology

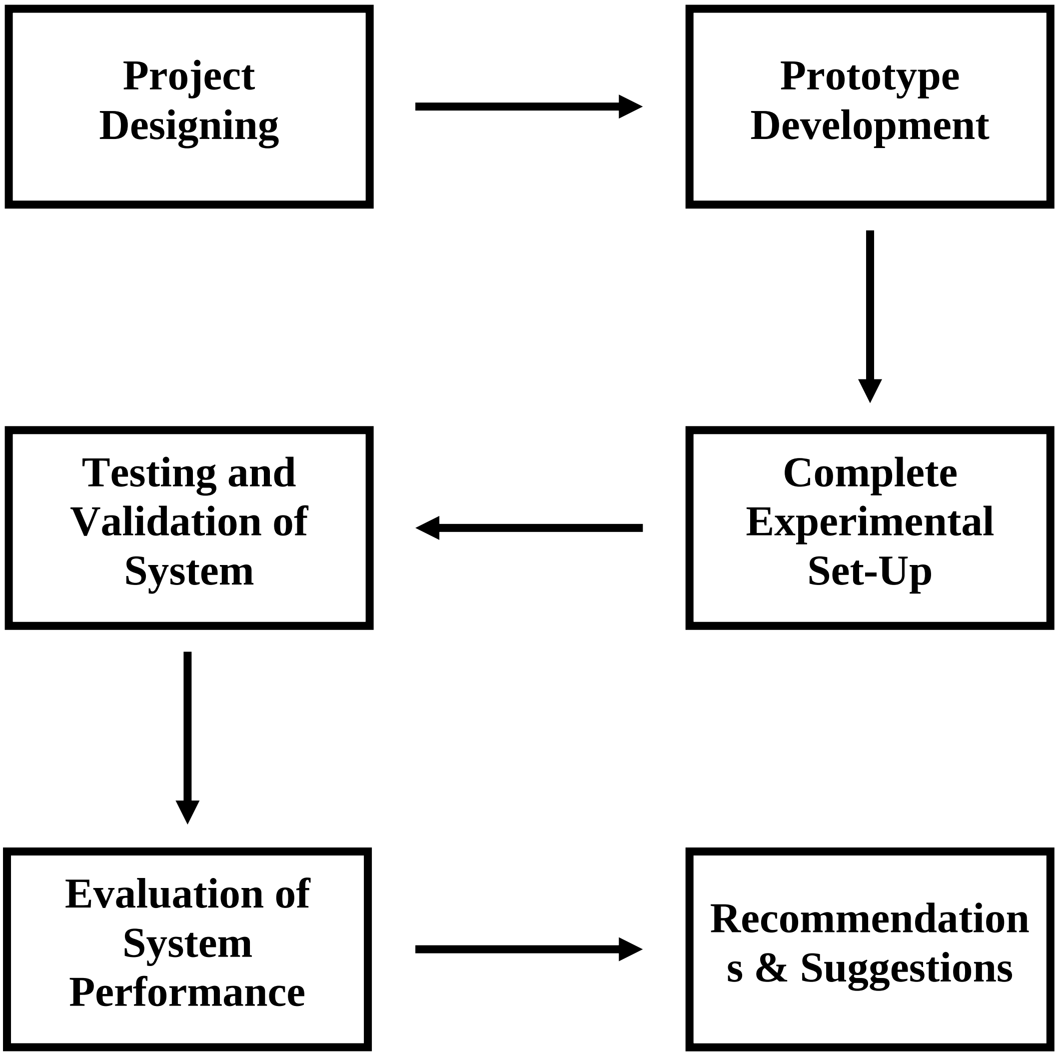

Figure 3-1 Project Methodology

3.2 System Description

In this experimental study, a multi-tank with six tanks and one sump tank is used. The experimental set-up is as shown in Figure 3-2. The system consists of Tank 1, Tank 2, Tank 3, Tank 4, Tank 5, Tank 6, Tank 7 and Tank 8. From Tank 7 and 8, two pumps are used to transfer water to Tank 1, Tank 2, Tank 3, Tank 4, Tank 5 and Tank 6 independently. The flow to each of those tanks are controlled by individual ball valves. Fluid then can be transferred from Tank 1 to Tank 3, Tank 2 to Tank 4, Tank 3 to Tank 5, Tank 4 to Tank 6, Tank 5 and Tank 7 and finally from Tank 6 to Tank 8. This forms a closed loop system which can be further divided into two loops as shown in Figure 3-6 and 3-7. All the transfer of water from one tank to another is regulated by a ball valve. The pipe used is a PVC type with a cross sectional area of S. The flow rate of Pump 1 is Q_1 and the flow rate of Pump 2 is Q_2. The water levels in each tank, h_1, h_2, h_3, h_4, h_5 and h_6 are measured by ultrasonic sensors and the real time results can be viewed in any device around the world. The ball valves are used to control the flow into each tank. The water flow and water level in the tanks are then measured by the IoT system and then the water levels are compared with our mathematical model to prove its accuracy.

3.3 Experimental Set-Up

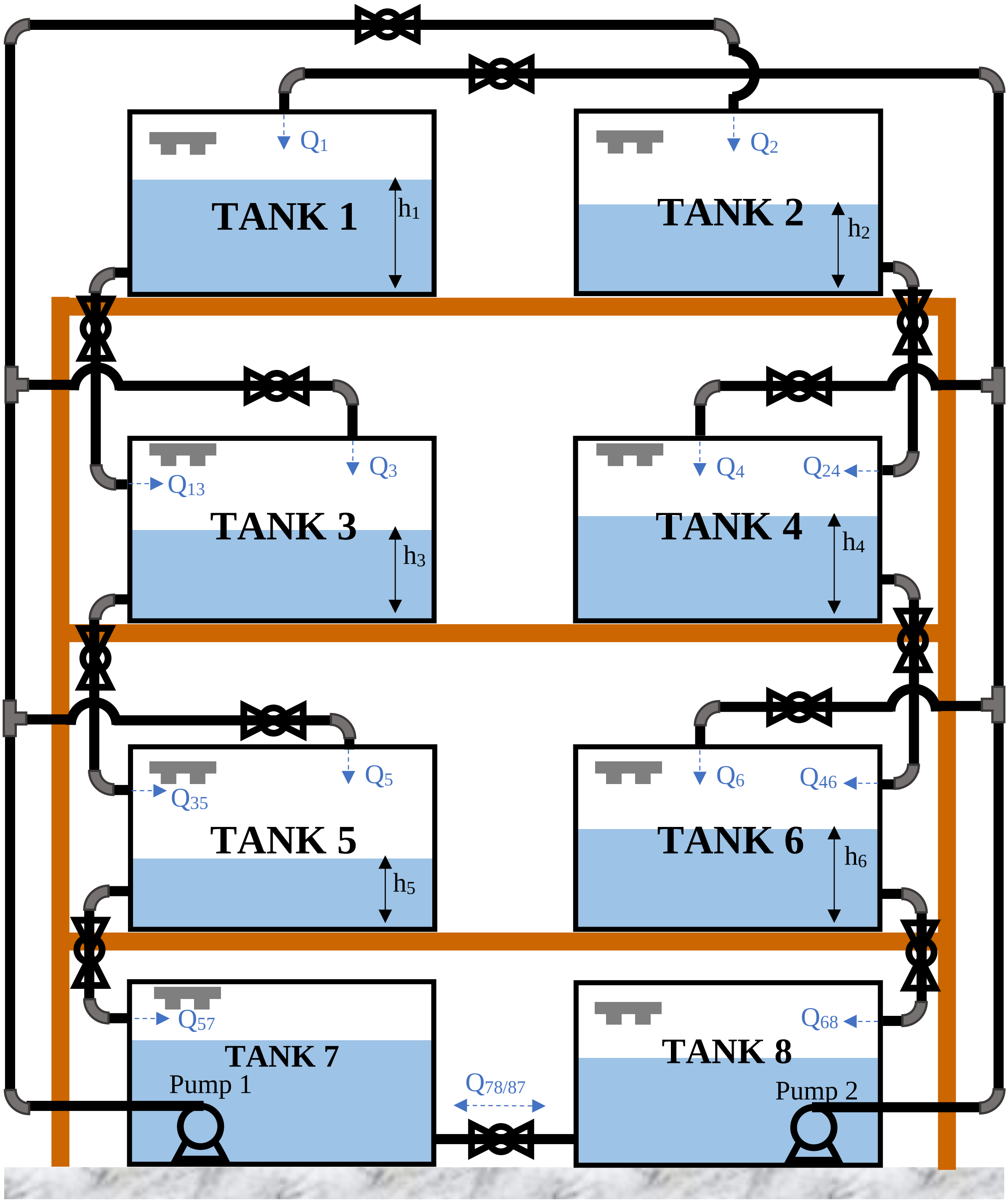

Figure 3-2 Schematic Drawing

Figure 3-3 Set-up of System Hardware

Since this project does not need much precision and depends mostly on the software, no engineering drawing is done. Instead, Figure 3-2 shows the schematic drawing of how the prototype should look like and Figure 3-3 is our built model based on the schematic drawing.

The experimental model shall have eight tanks arranged in four layers with two tanks per layer. They are to be positioned in a strong structure that can withstand the weight of all eight tanks when they are fully filled with water. The Figure 3-2 shows how the experiment model is arranged. From a main water supply, the water is pumped into Tank 1 and Tank 2. The flow into each tank is regulated by a hand operated ball valve. Then, from each of the tank in the top level, the water may flow to the outlet, or either one of the tanks in the level below. This can be controlled by the controlling the other valves which control the outflow of the tanks. Each possible outlet is controlled by individual valves as shown in Figure 3-2. The same thing happens in the second and third level where the tanks in the middle level can transfer water to the outlet, or to either of the tanks in the bottom level.

Therefore, the water level in the tank is hard to predict using calculations or any other means as there are many possibilities for the outflow of water in the tanks. For example, change in Tank 1 can either mean a change in Tank 3, or a change in Tank 4, or no change at all assuming there is no leakage. This makes this system to be a non-linear system, where the output is not linear with the input.

As a solution, we use the IoT concept to monitor and obtain real time water level reading in each tank accurately. Each tank is to have an ultrasonic sensor at the top to send information on the water level to the Raspberry Pi which shall then send the data to the cloud, to make it accessible from anywhere around the world.

Figure 3-4 shows how the ultrasonic sensor and the flowmeter are arranged on each tank. Both the ultrasonic sensor and the flowmeter are connected to the Raspberry Pi which is situated around 2 meters away by using multicore wires. The jumper wires from the sensors are connected to the multicore wires by using a wire connector. The arrangement of the jumper wires to the Raspberry Pi is as shown in Figure 3-5.

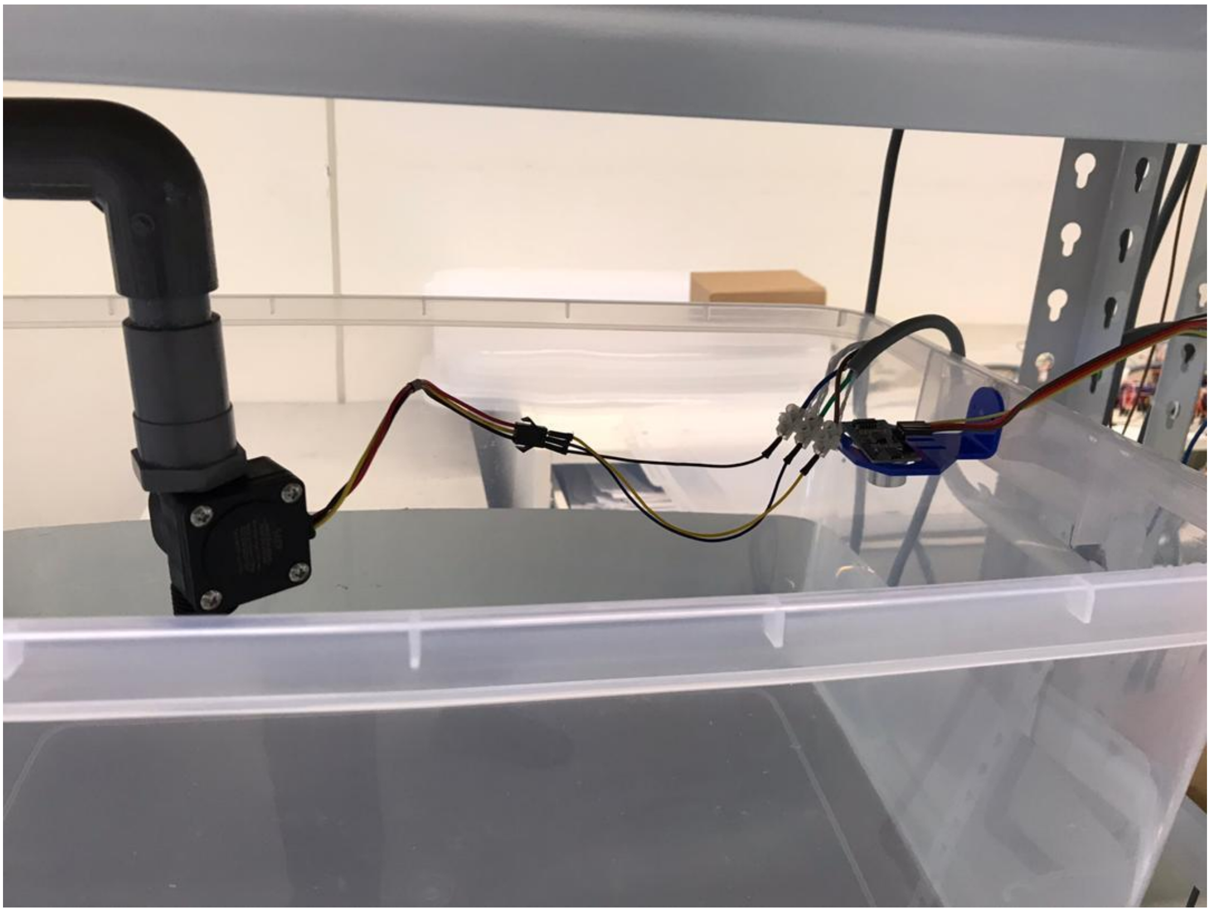

Figure 3-4 Placement of flowmeter and ultrasonic sensor on the experimental model

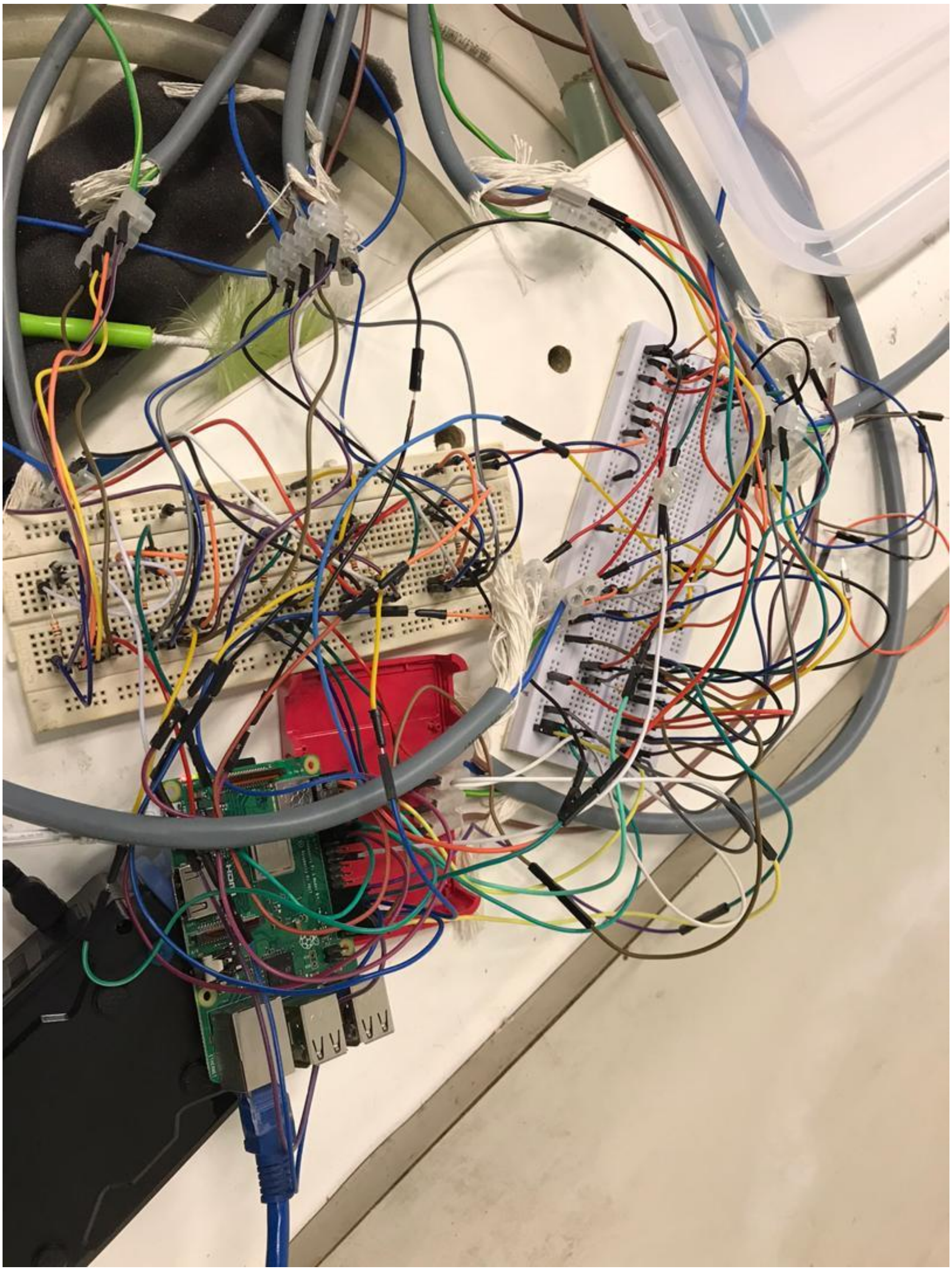

Figure 3-5 Arrangement of some of the jumper wires to the Raspberry Pi

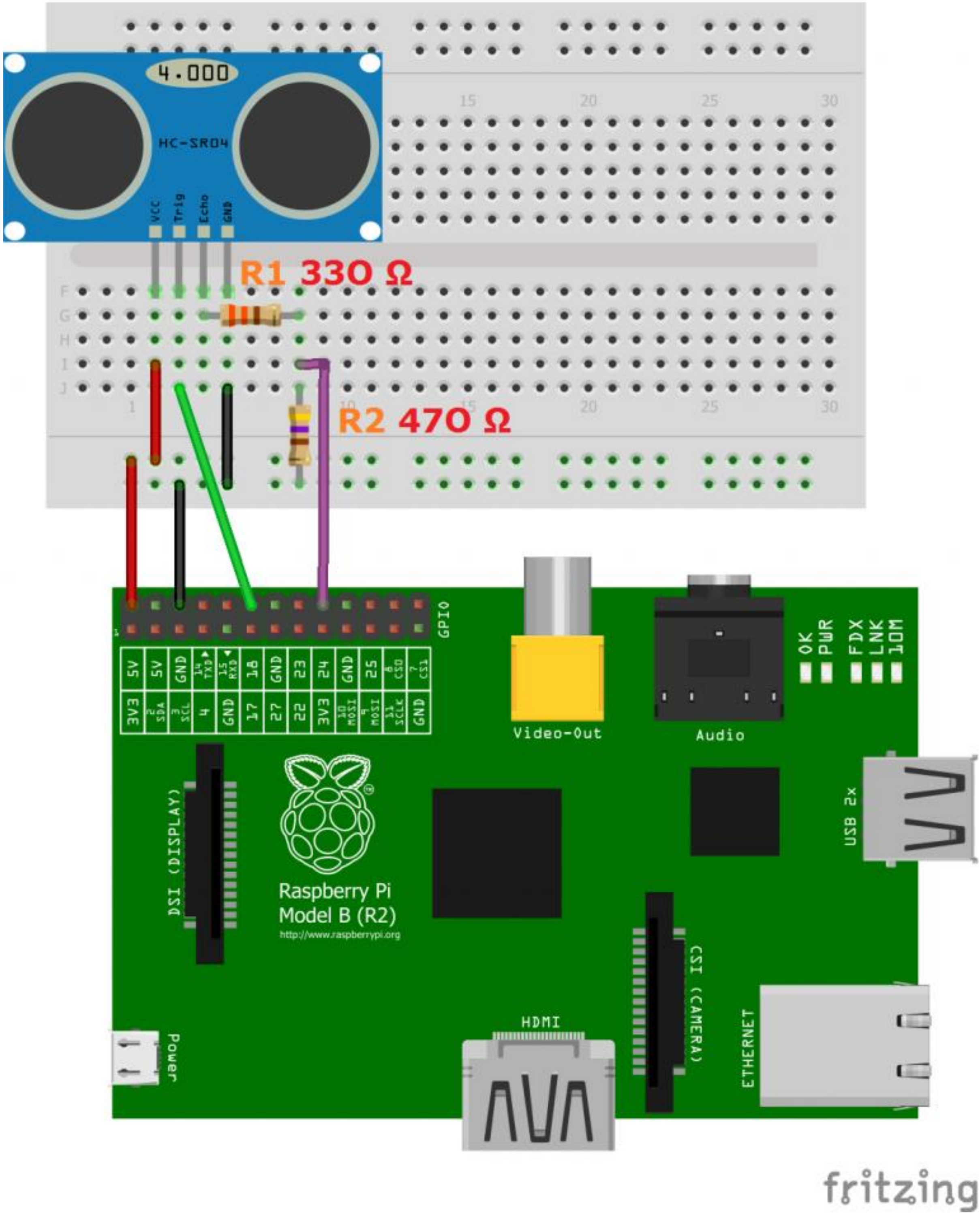

Figure 3-6 Connection of ultrasonic sensor to Raspberry Pi. Courtesy of Raspberry Pi Tutorials Webpage

Figure 3-5 shows all the jumper wires connected to the Raspberry Pi and the image can be confusing. Figure 3-6 shows how each of the ultrasonic sensors are connected to the Raspberry Pi. Each ultrasonic sensor has four wires. One for the 5 V power connection, one trigger connection, one echo connection and lastly one ground connection. The power and ground connections go straight to the Raspberry Pi while the trigger and echo pins have two resistors connected which acts as a voltage divider. The ultrasonic sensor has two connections to the Raspberry Pi's GPIO pins, one for the trigger and one for the echo.

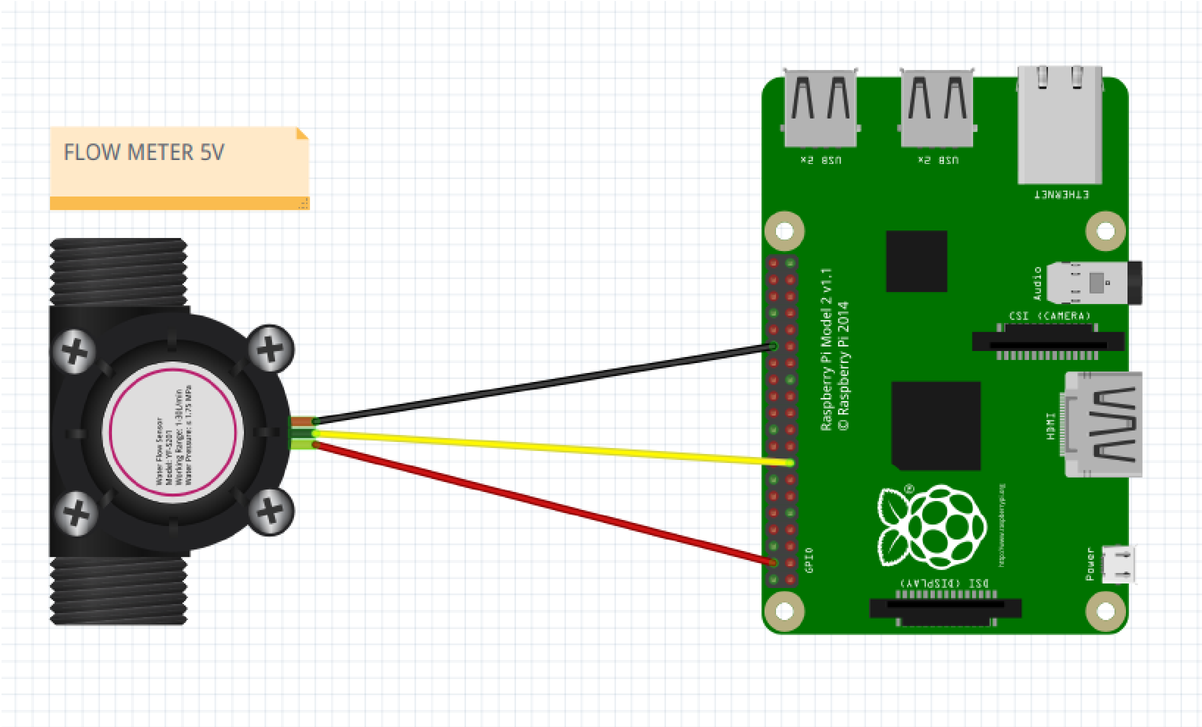

Figure 3-7 Connection of YF-S201 flowmeter to Raspberry Pi. Courtesy of Raspberry Pi Stack Exchange Webpage

Figure 3-7 shows the connection of each flowmeter to the Raspberry Pi. The connection is fairly simple to understand. The red wire connects to the 5 V power, the black wire goes to the ground and the yellow wire is connected to any of the available GPIO pins of the Raspberry Pi.

Therefore, the water level in the tank is hard to predict using calculations or any other means as there are many possibilities for the outflow of water in the tanks. For example, change in Tank 1 can either mean a change in Tank 3, or a change in Tank 4, or no change at all assuming there is no leakage. This makes this system to be a non-linear system, where the output is not linear with the input.

As a solution, we use the IoT concept to monitor and obtain real time water level reading in each tank accurately. Each tank is to have an ultrasonic sensor at the top to send information on the water level to the Raspberry Pi which shall then send the data to the cloud, to make it accessible from anywhere around the world.

3.4 Project Designing

The design of the experiment is done based on few factors such as the number of tanks, type of valves and many more.

Firstly, the integration of multiple tanks is crucial since our system is required to be a non-linear system. Having multiple tanks and multiple outlets introduce non-linearity in the system. After many considerations, the number of tanks is fixed to be six in the system. These six tanks shall integrate with each other to give an output which will be complex, therefore, the IoT concept can be tested to see its use in such applications.

The material for our tanks is chosen to be plastic. Since this is an experimental model, plastic is used as it is easy to work with. Holes can be easily drilled on them to easily create inlet and outlet. Plastic is also much lighter compared to steel tanks, meaning it would need less support from the structure. The plastic used must also be transparent or translucent for us to physically see the water level to compare the results with our results obtained.

The structure is to be built with steel structures. The steel structure integrity calculated to ensure it has enough strength to support to six tanks when they are fully filled with water.

1 ¼ inch PVC pipes are chosen as our pipes as they are cheap, and easy to work with. They can also be easily obtained from nearby shops. The pipe fittings and the valves are also cheap and easily available for the 1 ¼ inch PVC pipe.

The outflows of each of the tanks are controlled by ball valves. Ball valves are mainly chosen as they have quick shut down capability in case of any emergencies. The valves only need to be turned 90 degrees to fully close it. Therefore, the water flow can be adjusted very easily.

Each tank is to have an ultrasonic sensor attached at the topside. The ultrasonic sensor then senses the water level in each of the tank and sends it to the cloud. The data can then be monitored from anywhere around the world.

The system architecture is as shown in Figure 3-8.

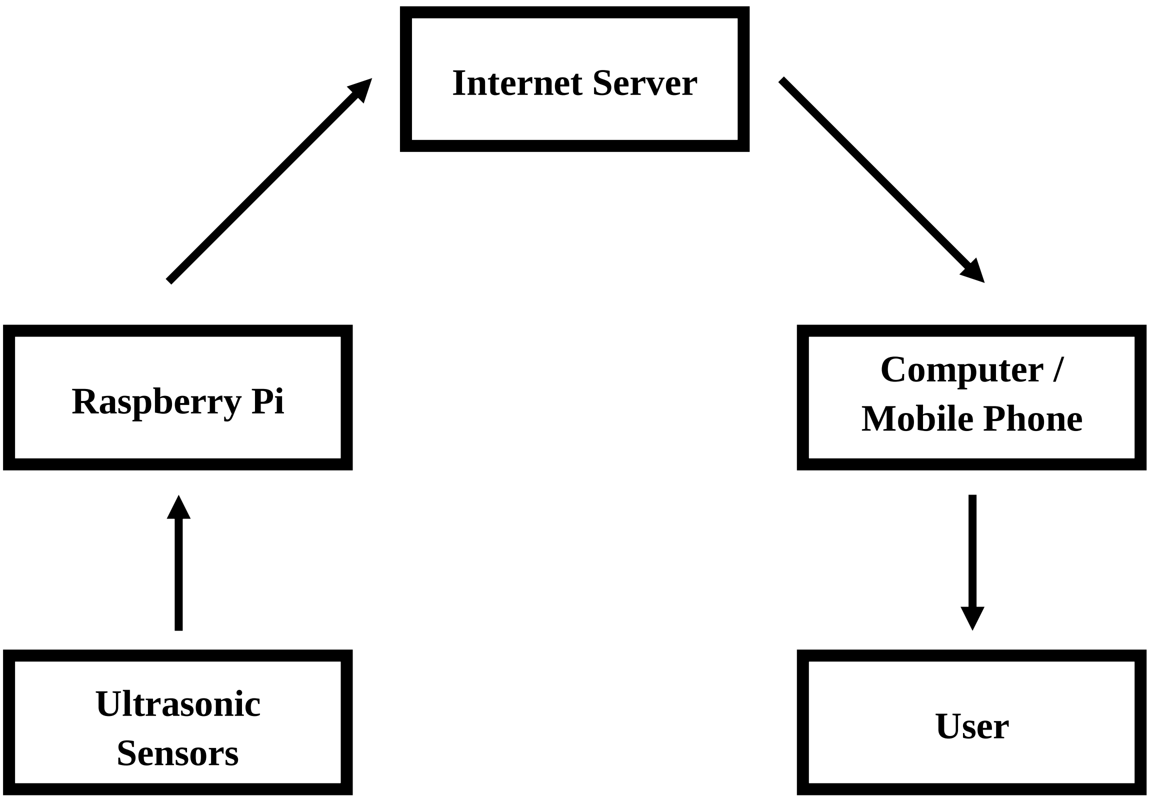

Figure 3-8 System Architecture

The prototype is to be developed as shown in Figure 3-3. Below is the working principle of our water monitoring system using IoT.

1. All eight of the Ultrasonic Sensors collect information of water level in the six tanks every one second.
2. The flowmeter will send data every one second as well.
3. The sensors then send the data to the Raspberry Pi. The Raspberry Pi sends the data to the cloud by connecting itself to the Internet.
4. The data of the water level in all eight tanks can be retrieved from anywhere around the world by using our device like mobile phones and computer. This gives real live data on the water level.

3.4.1 Python Coding for Ultrasonic Sensors

```
import RPi.GPIO as GPIO

import time

GPIO.setmode(GPIO.BCM)

TRIG = 23

ECHO = 24

GPIO.setup(TRIG,GPIO.OUT)

GPIO.setup(ECHO,GPIO.IN)

GPIO.output(TRIG, False)

time.sleep(2)

GPIO.output(TRIG, True)

time.sleep(0.00001)

GPIO.output(TRIG, False)

while GPIO.input(ECHO)==0:

pulse_start = time.time()

while GPIO.input(ECHO)==1:

pulse_end = time.time()

pulse_duration = pulse_end - pulse_start

distance = pulse_duration x 17150

distance = round(distance, 2)

print "Distance:",distance,"cm"

GPIO.cleanup()
```

3.4.2 Python Coding for Flowmeter

```
import RPi.GPIO as GPIO
import time,sys
GPIO.setmode(GPIO.BOARD)
inpt = 13
GPIO.setup(inpt ,GPIO.IN)
rate_cnt = 0
tot_cnt = 0
time_zero = 0.0
time_start = 0.0
time_end = 0.0
gpio_last = 0
pulses = 0
constant = 1.79
time_zero = time.time()
while True:
        rate_cnt = 0
        pulses = 0
        time_start = time.time()
        while pulses <=5:
                gpio_cur = GPIO.input(inpt)
                if gpio_cur !=0 and gpio_cur !=gpio_last:
                        pulses +=1
                gpio_last = gpio_cur
        rate_cnt += 1
        tot_cnt +=1
        time_end = time.time()
print(round((rate_cnt*constant)/(time_end-time_start),2)
GPIO.cleanup()
```

3.5 Prototype Development

Table 3-1 shows the list of components needed and their approximate price for estimating the project budget.

Table 3-1 List of components required with their costs

Num.	Item	Quantity	Price per unit	Cost
1	Plastic container	5	RM 20	RM 100
2	Steel Scaffolding	2	RM 120	RM 240
3	Raspberry Pi 3	1	Not Applicable	
4	Screen monitor	1	Not Applicable	
5	Mouse	1	Not Applicable	
6	Keyboard	1	Not Applicable	
7	Ultrasonic Sensor	6	RM 10	RM 60
8	Flow Sensor	6	RM 20	RM 160
9	Breadboard	3	RM 10	-
10	Resistors		RM 3	RM 3
11	Wires		RM 10	RM 10
12	1” inch PVC Pipe	8 meters	RM 2.5	-
13	PVC Pipe Glue	1	RM 10	RM 10
14	Ball Valve	12	RM 10	RM 120
15	Cable tie	1	RM 3	RM 3
16	Pump	2	RM 20	-
Total Cost				RM 706

The Table 3-1 is just an estimation of the cost required and may be subjected to change. Additional items may have to added to increase the performance of the system.

3.6 Mathematical Model

Loop 1

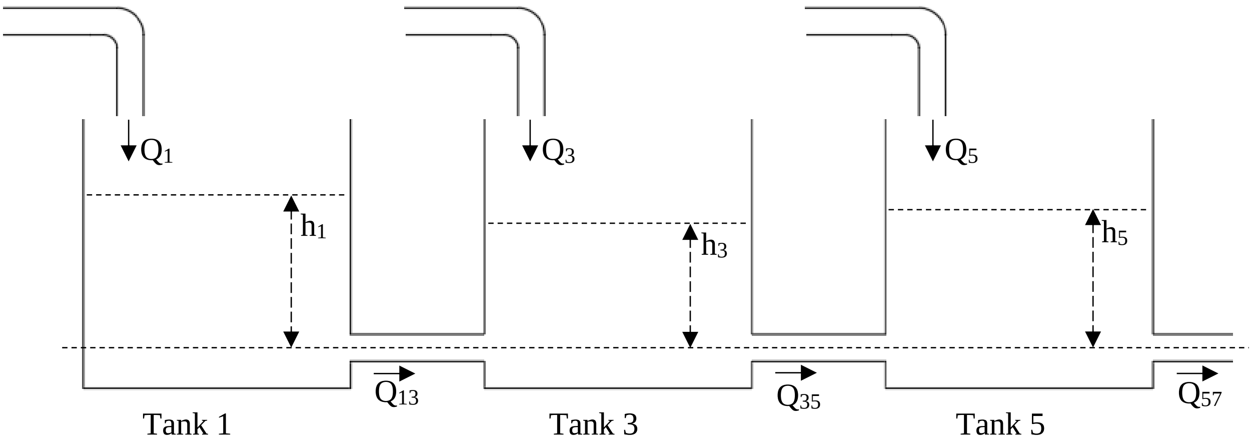

Figure 3-9 System Design for Loop 1

Loop 2

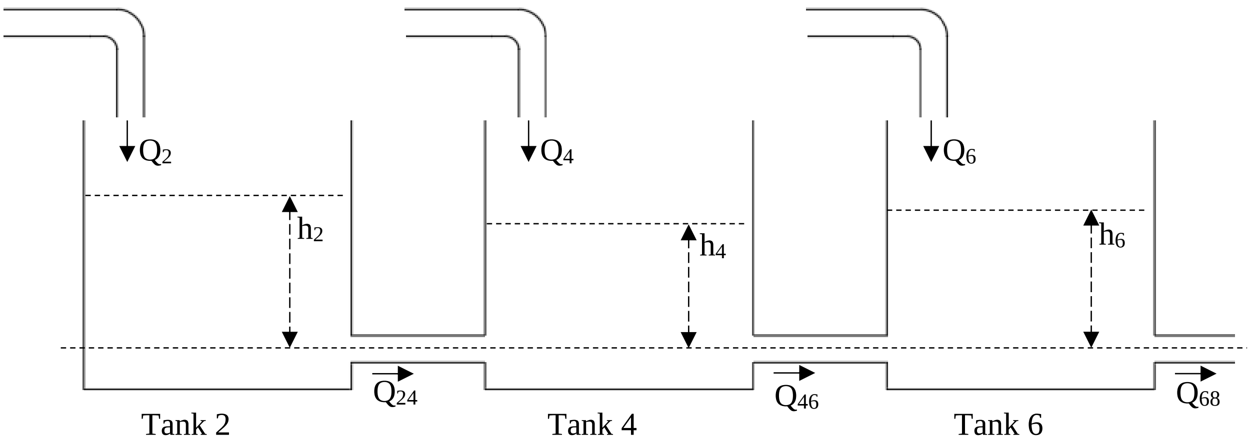

Figure 3-10 System Design for Loop 2

To develop mathematical model for our system, we use mainly the law of mass conservation and also the Torricelli's Law. The system can be divided into two loops as shown in Figure 3-9 and 3-10. The equations for each of the tank is developed as following.

Change in volumetric flow rate in each tank = Volumetric flow rate coming in - Volumetric flow rate going out

$$\Delta Q = Q_{in} - Q_{out}$$

For Tank 1, the equations are as following:

$$A\,\frac{dh}{dt} = Q_1 - Q_{13} + Q_{f1},$$

$$where\ Q_{f1}\ is\ the\ additional\ input\ or\ output\ if\ any$$

$$and\ A\ is\ the\ cross\ sectional\ area\ of\ tank$$

For Tank 2, the equations are as following:

$$A\,\frac{dh}{dt} = Q_2 - Q_{24} + Q_{f2},$$

$$where\ Q_{f2}\ is\ the\ additional\ input\ or\ output\ if\ any$$

$$and\ A\ is\ the\ cross\ sectional\ area\ of\ tank$$

For Tank 3, the equations are as following:

$$A\,\frac{dh}{dt} = Q_3 - Q_{13} - Q_{35} + Q_{f3},$$

$$where\ Q_{f3}\ is\ the\ additional\ input\ or\ output\ if\ any$$

$$and\ A\ is\ the\ cross\ sectional\ area\ of\ tank$$

For Tank 4, the equations are as following:

$$A\,\frac{dh}{dt} = Q_4 + Q_{24} - Q_{46} + Q_{f4},$$

$$where\ Q_{f4}\ is\ the\ additional\ input\ or\ output\ if\ any$$

$$and\ A\ is\ the\ cross\ sectional\ area\ of\ tank$$

For Tank 5, the equations are as following:

$$A\,\frac{dh}{dt} = Q_5 - Q_{35} - Q_{57} + Q_{f5},$$

$$where\ Q_{f5}\ is\ the\ additional\ input\ or\ output\ if\ any$$

$$and\ A\ is\ the\ cross\ sectional\ area\ of\ tank$$

For Tank 6, the equations are as following:

$$A\,\frac{dh}{dt} = Q_6 + Q_{46} - Q_{68} + Q_{f6},$$

$$where\ Q_{f6}\ is\ the\ additional\ input\ or\ output\ if\ any$$

$$and\ A\ is\ the\ cross\ sectional\ area\ of\ tank$$

For Tank 7, the equations are as following:

$$A\,\frac{dh}{dt} = Q_{57} - Q_x + Q_{78} + Q_{f7},$$

$$where\ Q_{f7}\ is\ the\ additional\ input\ or\ output\ if\ any$$

$$and\ A\ is\ the\ cross\ sectional\ area\ of\ tank$$

For Tank 8, the equations are as following:

$$A\,\frac{dh}{dt} = Q_{68} - Q_x + Q_{78} + Q_{f8},$$

$$where\ Q_{f8}\ is\ the\ additional\ input\ or\ output\ if\ any$$

$$and\ A\ is\ the\ cross\ sectional\ area\ of\ tank$$

To find the flow rate from one tank to another apart from the two bottom tank, we have to use the Torricelli's Law which equates the speed of the outlet fluid by the height of the water level from the orifice.

$$v = \sqrt{2gh}$$

$$Q_{i,j} = az_{i,j}\,S(sgn(\Delta h_{i,j}))\sqrt{2g\Delta h_{i,j}}$$

$$where\ S\ equals\ to\ cross\ sectional\ area,$$

$$az_{i,j}\ equals\ to\ the\ scaling\ coefficient\ and$$

$$sgn(\Delta h_{i,j})\ is\ the\ positive\ or\ negative\ sign\ from\ h_i - h_j$$

3.7 Testing and Validation of System

After the experiment is set up as shown in Figure 3-2, we can obtain the results. From the results obtained, we can analyze the results by testing and validating the system. Since we are interested in the accuracy of the system, the methodology on determining the accuracy of the system is as explained in Part 3.7.1.

3.7.1 Testing of System Accuracy

Firstly, testing is done to see if the results we are getting is accurate real time results or not. This is done by comparing the results obtained with our visual observation of the water level inside the tank as it is translucent or transparent. Accuracy is not highly expected. An error margin of 10% is set. We can measure the water level in each of the tank by marking lines along the tanks and measuring the water level manually. Then, we compare them with the results the system shows us for the water level in each tank from the cloud. If the error is said to be less than 10%, it is acceptable, and we say that the results are accurate. This is to prove the accuracy of the system.

After that, we change the water level in each of the tanks by playing with the inflows and outflows into the tanks. First, we record the water level in the tank. Then, we either drain the water out or allow water inflow and measure the time taken for the tank to be reach a certain pre-set level manually using a stopwatch. Using the data from the Cloud, we can calculate the accuracy of the system as shown in the Results part of this paper.

3.7.2 Water-Level and Flowrate Monitoring

In the Node-Red programming tool, the program is set to send data on the water level and flowrate at every 10 second. The valves are then used to change the water level in the tanks randomly with no particular order. After around 20 to 30 minutes, the Node-Red is stopped from running and the text files for each sensor is taken for analysis. The values from the 14 text files (one for each level sensor and flowmeter) are then imported to an excel file for better analysis of values. The trend is then recorded and plotted in graphical format.

3.8 Gantt Chart

For FYP I

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Title Selection	X	X	X											
Understanding Scope of Study		X	X	X	X									
Critical Literature Review		X	X	X	X	X	X							
Collecting Information on Programming				X	X	X	X	X						
Designing Hardware for the System						X	X							
Develop Experimental Procedure & Flowchart					X	X	X	X	X	X	X	X	X	🏆

Figure 3-11 Gantt Chart for FYP I

For FYP II

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Finish Coding and Able to Run Program	X	X	X	X	🏆									
Assemble Hardware of System				X	X	X								
Integrate Hardware and Software Together						X	X							
Testing and Validation								X	X					
Evaluation of System Performance										X	X			
Data Analysis and Report												X	X	🏆

Figure 3-12 Gantt Chart for FYP II

CHAPTER 4 EVALUATION OF SYSTEM PERFORMANCE

4.1 System Accuracy

Three types of test are done to measure the system accuracy. The first two test is used to determine the accuracy of the water level sensors. The first test is by comparing the initial water level in the tank with the actual water level recorded. The actual water level is measured physically and recorded. The second test is by comparing the final water level in the wank once it has reached a certain pre-determined level. The accuracy for both of these tests are done by dividing the difference between the actual level and the displayed level with the actual level. The error percentage is calculated by multiplying the previous value with 100%. The third test if to test the accuracy of the flowmeter. The time taken for the tank to fill up from a certain level to another level is recorded. The time taken is then used to calculate the actual flow rate by dividing the total volume filled with the total time taken. The total volume filled can be obtained by multiplying the base area of the tank with the height. The base area of the tank is 0.2184 m^2. The end results will be in percentage of the accuracy of the system. If the mean percentage error is less than 10%, the system is classified as 'Best Performance'. Else it falls under the second category and so on. Figure 4-1 shows how the accuracy of the system is classified based on the percentage error. Our target is to develop a system with 10% error in this case. A maximum mean percentage error of 20% is allowed as even the sensors have an accuracy ranging from ±1% to 3% for the ultrasonic sensors and ±10% for the flowmeter. To test the accuracy of the system, the mathematic model developed is used calculate the flow rate by calculating the change in level of water over change in time. For a pre-set time, we can calculate the change in the water level. A total of 20 readings are taken for this case and each reading will be classified as per in the Figure 4.1.

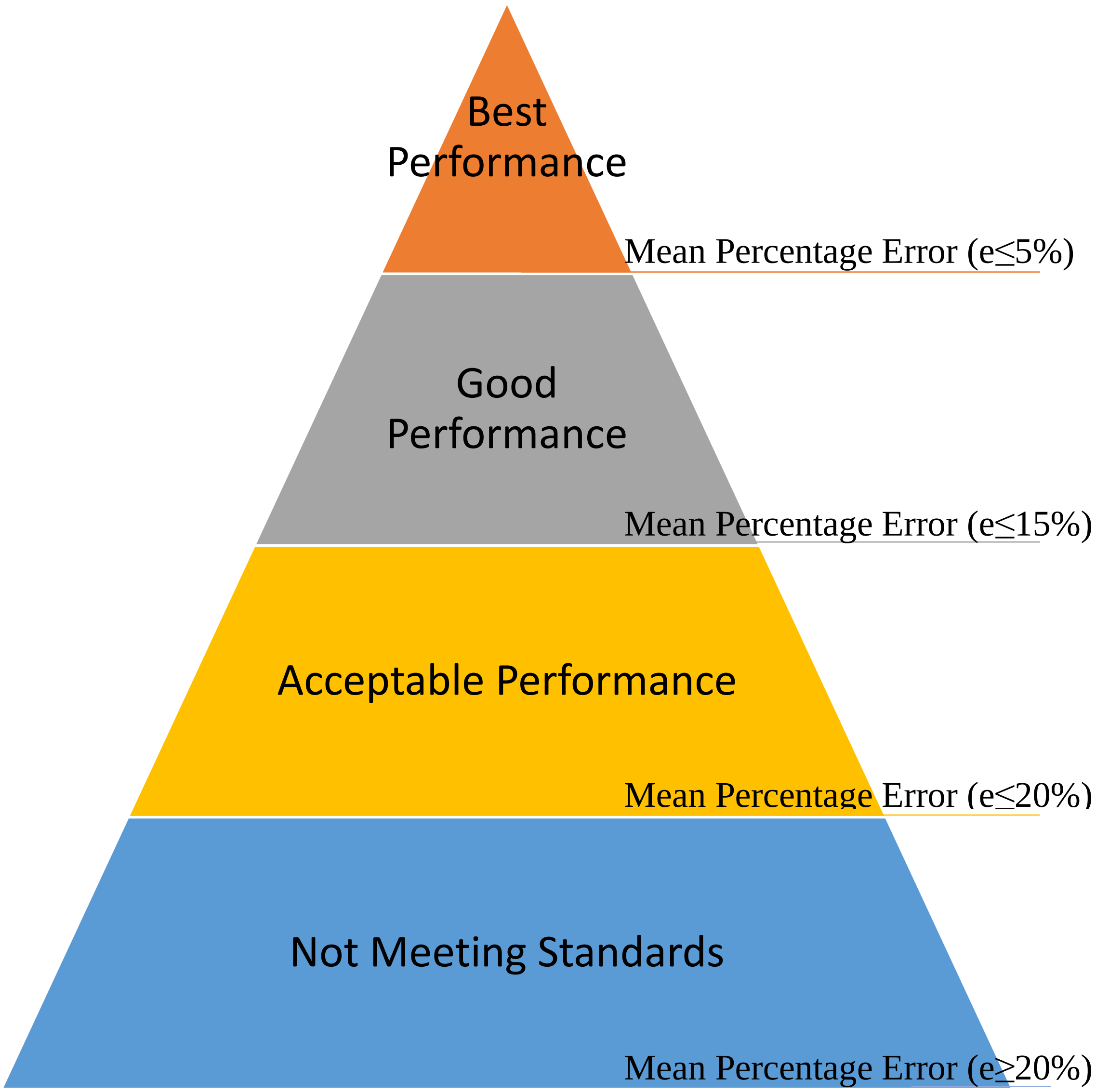

Figure 4-1 System Ranking Pyramid based on the Mean Percentage Error

CHAPTER 5 RESULTS

The results are obtained from the Node-Red in the User Interface Tab which can be accessed by any computer or laptop as long as they are connected to the same network. The results for the water level in the tanks are as shown in Figure 5-1.

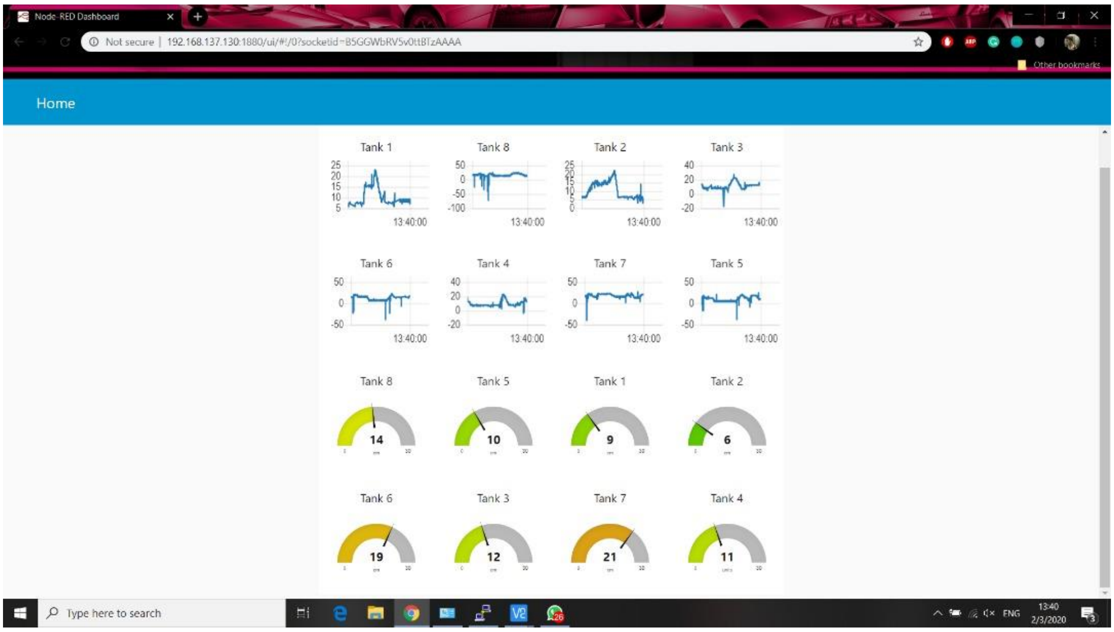

Figure 5-1 Results shown by Node-Red User Interface

As can be seen in Figure 5-1, the Node-Red User Interface displays the results in a very detailed and clear manner. Each tank has a gauge and a chart. The gauge shows the current water level while the chart shows the change in the water level in the past one hour. The data is used to calculate the accuracy of the system as we will use parameters such as the Final Height Shown, F_s and the time taken for the change in water level. There are many ways for Node-Red to display the results, but the gauge chart and the line chart was chosen to make it very simple and clear to read the data. By simply hovering the mouse on the graph, we can get the water level and the time at that point. It also shows the flowmeter readings for each of the flowmeters as shown in Figure 5-3.

For the flowmeter, the results as of now are as in Figure 5-1 and 5-2.

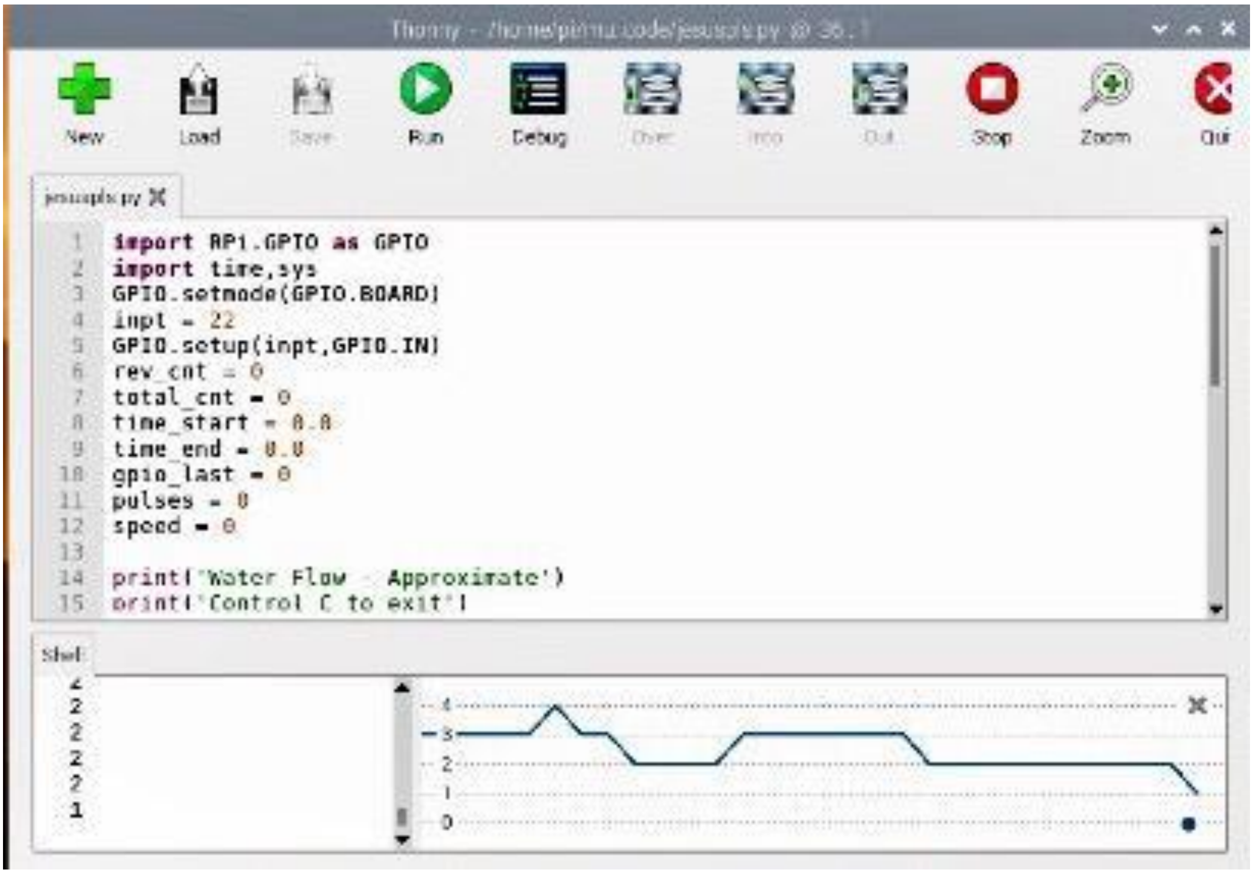

Figure 5-2 Results for Flowmeter from the Thonny Python Code Developer

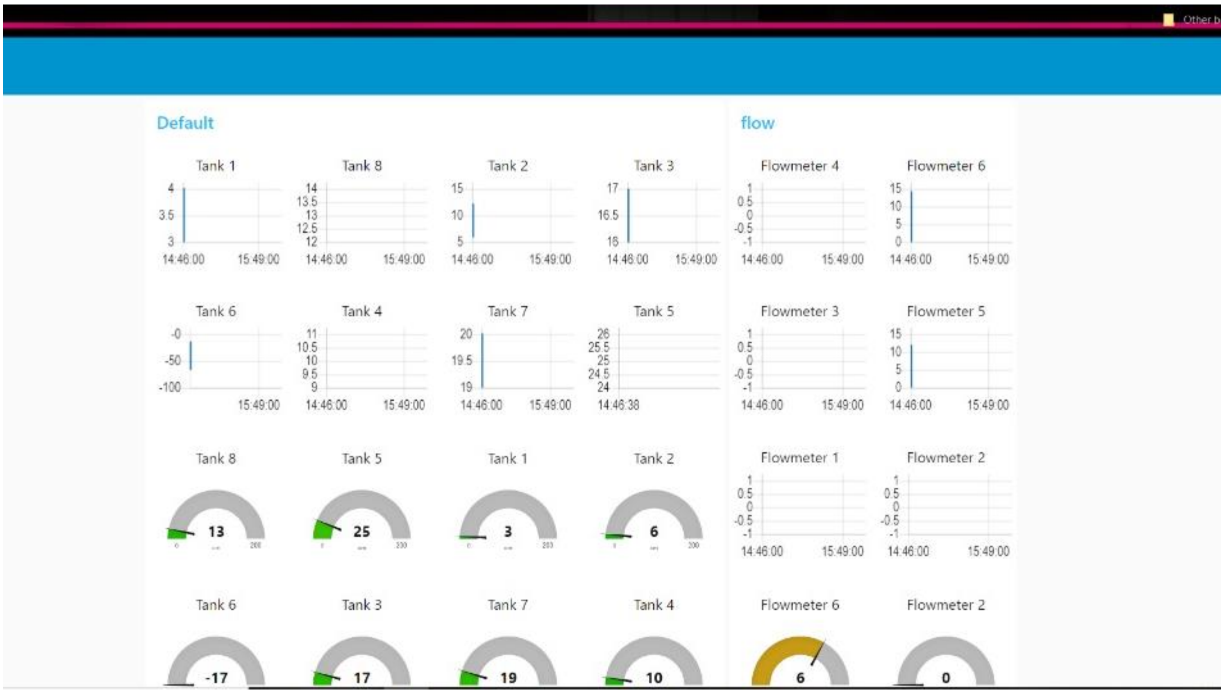

Figure 5-3 Shows the results for the ultrasonic level sensors and the flowmeter reading on the right

Figure 5-2 shows the results in digital formal and graphical format in the Thonny Integrated Development Environment in the Raspberry Pi. Similar result is also shown in the Node-Red platform. The Node-Red platform shows the result for all the flowmeters and the level sensors all in one go, therefore all the results are taken from Node-Red to simplify things.

5.1 Findings from the experiments

Table 5-1 Results from Experiment

Number of Runs	Tank	Initial Height Recorded	Initial Height Displayed	Error (%)	Final Height Recorded	Final Height Displayed	Error (%)	Height Filled	Flow Rate Displayed L/min	Calculated Flow Rate	Error (%)	Actual Time Taken(s)
1	1	10	12	20%	20	23	15%	10	2.8396	3.5037433	19%	374
2	5	5	7	40%	15	18	20%	10	3.7826	4.4420339	15%	295
3	4	5	6	20%	15	16	7%	10	5.679	5.9294118	4%	221
4	2	15	17	13%	20	23	15%	5	7.523	7.1217391	6%	92
5	6	10	12	20%	20	22	10%	10	7.5725	7.200000	5%	182
6	3	15	16	7%	20	22	10%	5	7.523	7.4454545	1%	88
7	3	10	12	20%	15	17	13%	5	6.626	7.7082353	14%	85
8	2	5	7	40%	10	11	10%	5	2.8396	3.4484211	18%	190
9	6	10	11	10%	15	16	7%	5	9.466	8.9753425	5%	73
10	5	5	5	0%	15	16	7%	10	2.8396	3.4758621	18%	377

Number of Runs	Tank	Initial Height Recorded	Initial Height Displayed	Error (%)	Final Height Recorded	Final Height Displayed	Error (%)	Height Filled	Flow Rate Displayed L/min	Calculated Flow Rate	Error (%)	Actual Time Taken(s)
11	1	5	6	20%	20	21	5%	15	5.679	5.1726316	10%	380
12	4	5	7	40%	20	22	10%	15	7.5725	7.2264706	5%	272
13	1	5	6	20%	10	11	10%	5	5.679	5.6482759	1%	116
14	5	15	16	7%	20	21	5%	5	3.7826	4.1207547	8%	159
15	4	5	6	20%	15	16	7%	10	5.679	5.4828452	4%	239
16	2	10	12	20%	15	17	13%	5	5.679	5.7473684	1%	114
17	6	5	5	0%	20	21	5%	15	2.8396	4.8774194	42%	403
18	3	10	12	20%	20	22	10%	10	6.626	7.200000	8%	182
19	3	5	6	20%	20	21	5%	15	5.679	5.600000	1%	351
20	2	5	8	60%	15	19	27%	10	3.7826	4.6303887	18%	283

5.2 Analysis of Results

Based on the results obtained from the experiments ran, Table 5-1 was developed. The findings are then further analyzed to find the performance of the system. The analysis is shown in Figure 5-4, 5-5 and 5-6. From the graphs developed, for the initial water level, the maximum error is 60% and the minimum error is 0%. The mean error is 20.835 %. As for the final water level, the maximum error is 27% and the minimum error is 0%. The mean error value is 10.5 %. The flowrate value shown by the flowmeter is cross checked with the flowrate calculated by dividing the total volume filled by the recorded time taken. The base area of the tank is 0.2184 m^2. The maximum error obtained is 42% while the minimum is 1%. Overall, the mean error for the flowrate is 10.145%.

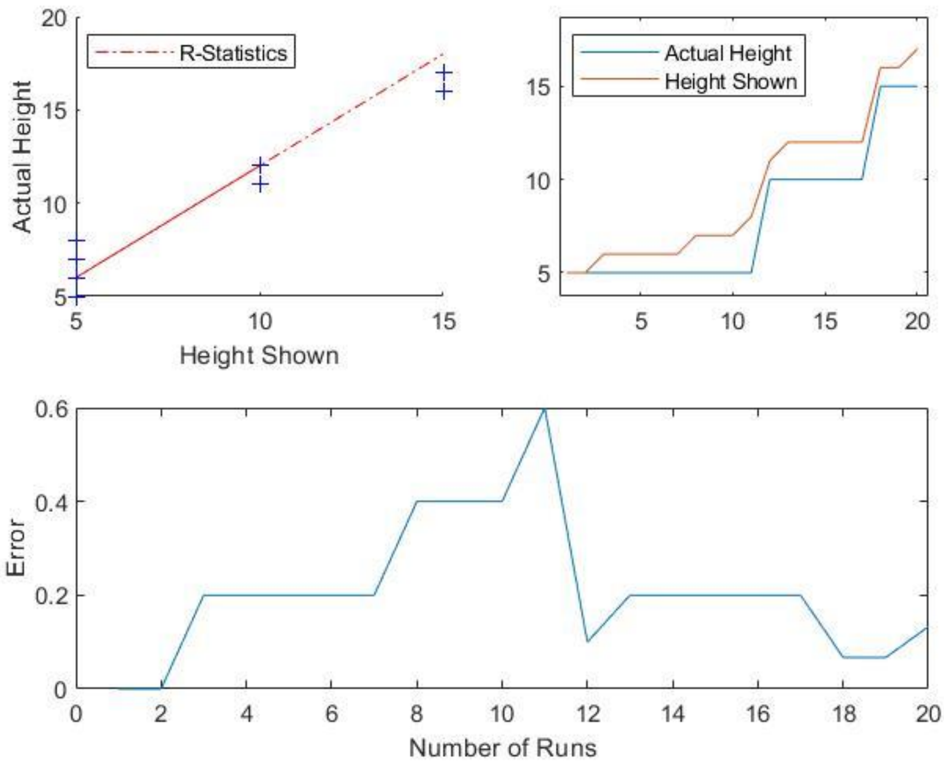

Figure 5-4 Analysis of Initial Water Level in Tanks

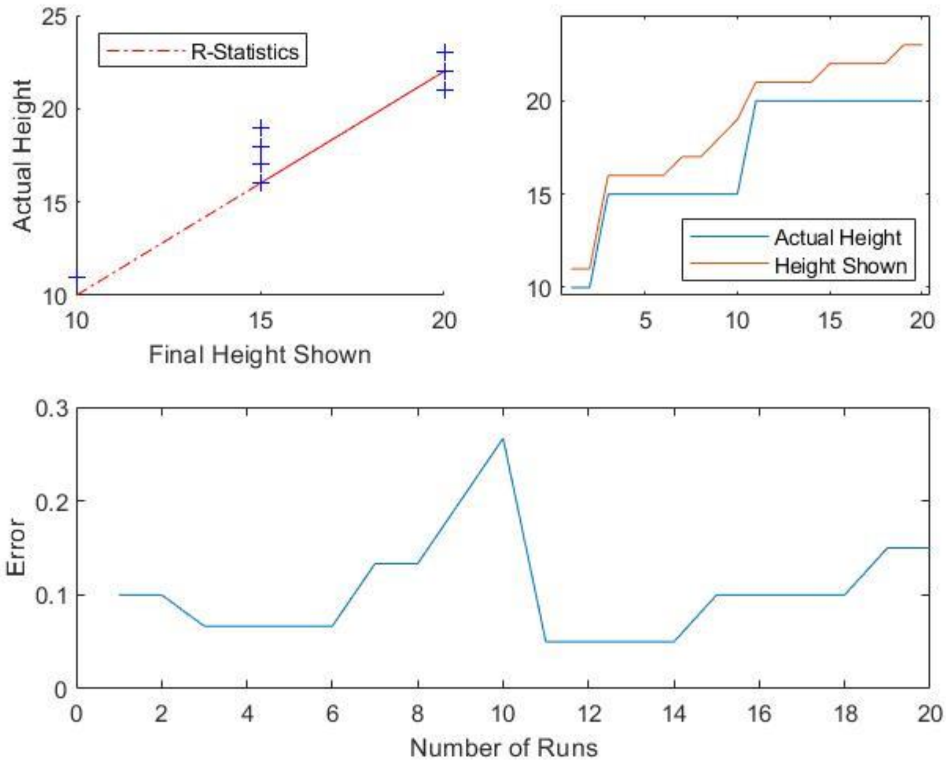

Figure 5-5 Analysis for Final Water Level in Tanks

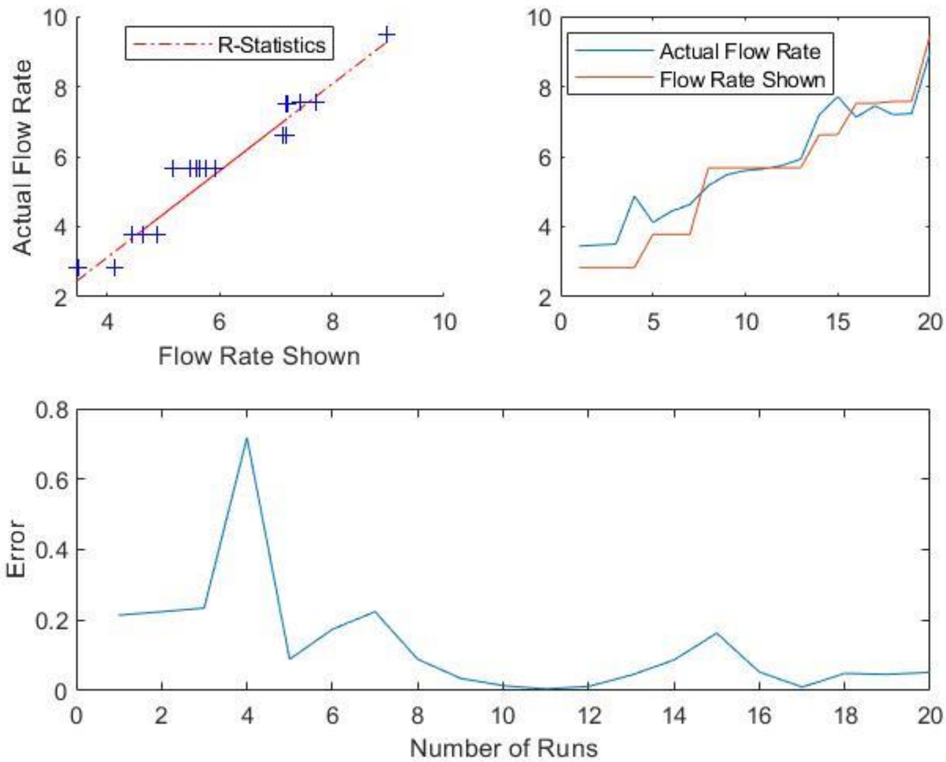

Figure 5-6 Analysis of Flowrate of Water Inlet

5.3 Water Level Monitoring

The water level is monitored using the Node-Red Programming tool. After displaying the real-time water level, storing the data in a file for future analysis is very crucial. Therefore, the data from the sensors are sent to a text file where it will receive and store the data every 10 seconds. The data is limited to one input every 10 seconds to prevent redundancy and to maintain consistent results from all the sensors. The limiting function can be done easily in Node-Red using the built-in node functions. The water level in all eight tanks for a fixed period of time of 2940 seconds in the text files are then exported to an excel file to further analyse the trend. The results are as shown in Figure 5-7 to 5-15. Table 9-1 in the Appendix shows the data of the water level in all the tanks in actual time.

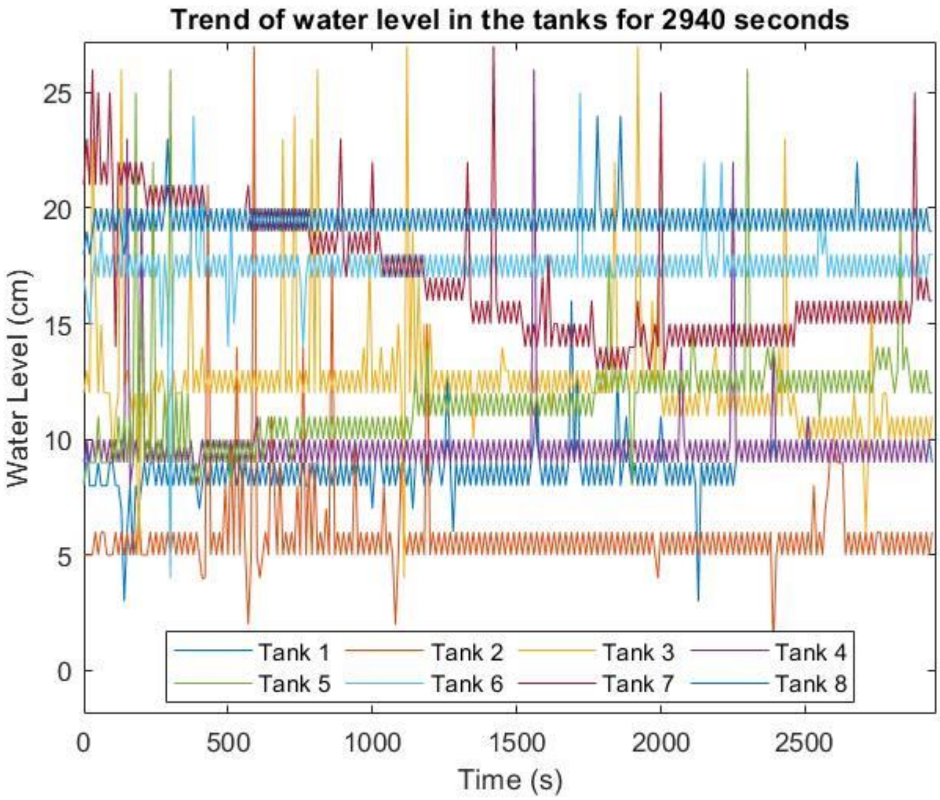

Figure 5-7 Results of monitoring the water level in all eight tanks

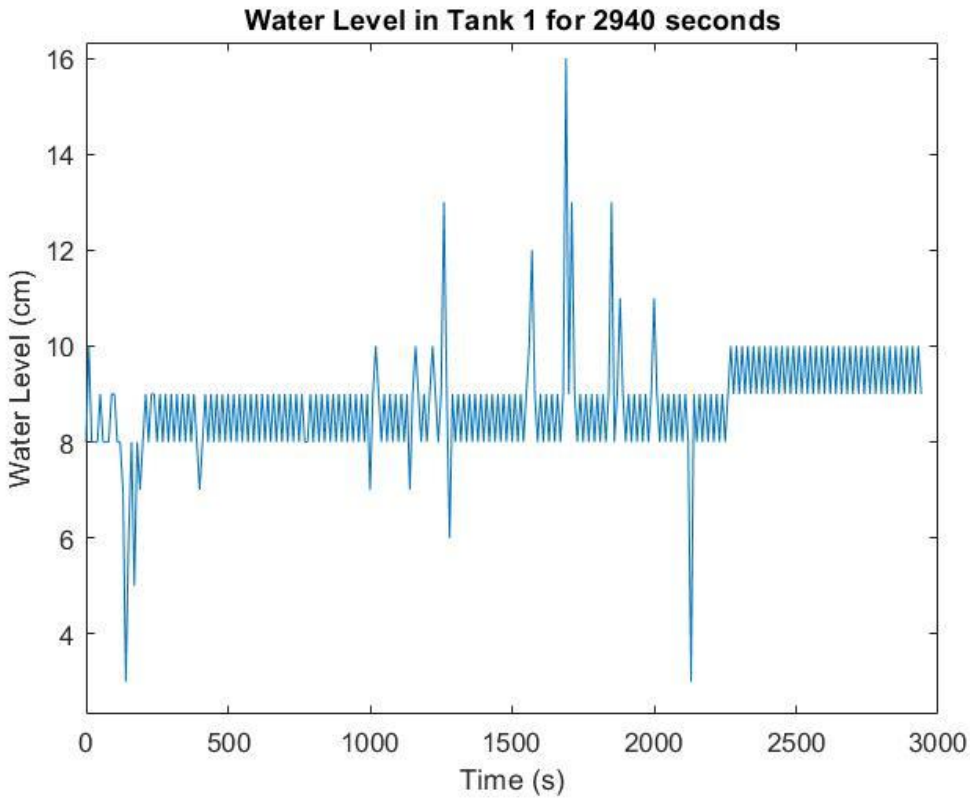

Figure 5-8 Trend of water level in Tank 1

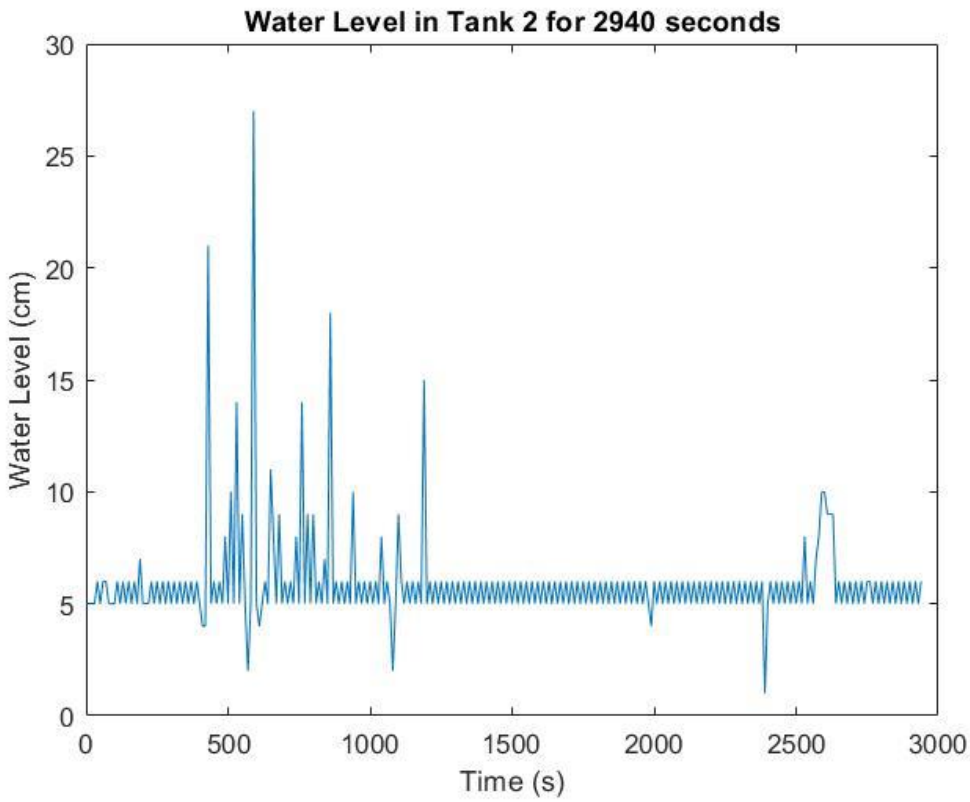

Figure 5-9 Trend of water level in Tank 2

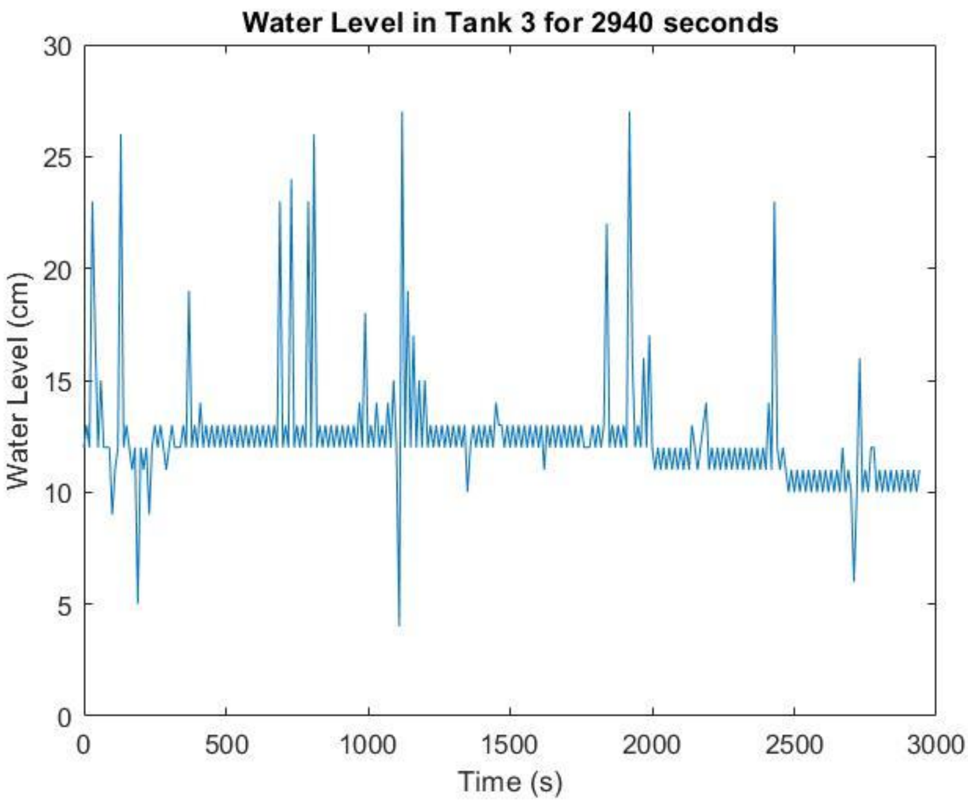

Figure 5-10 Trend of water level in Tank 3

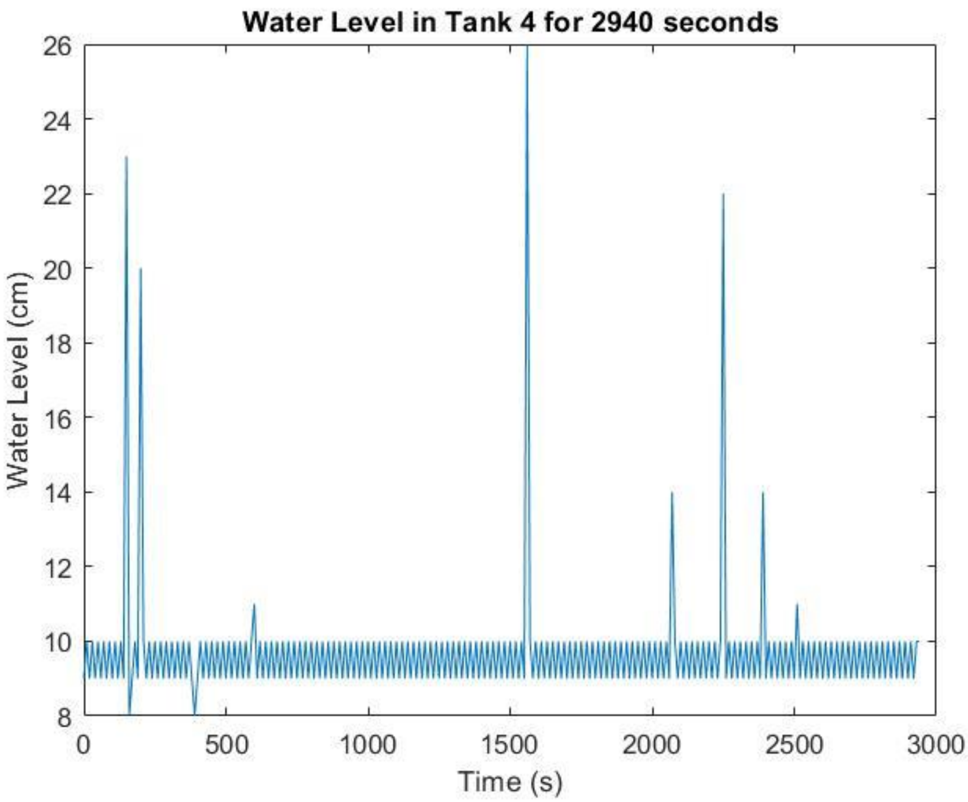

Figure 5-11 Trend of water level in Tank 4

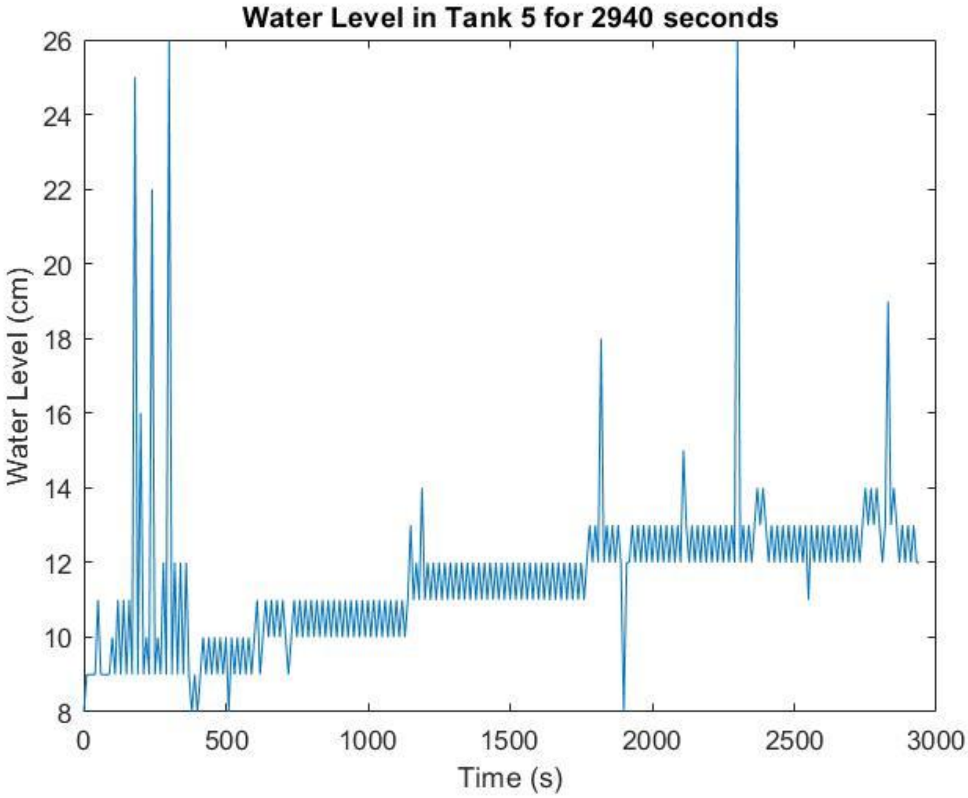

Figure 5-12 Trend of water level in Tank 5

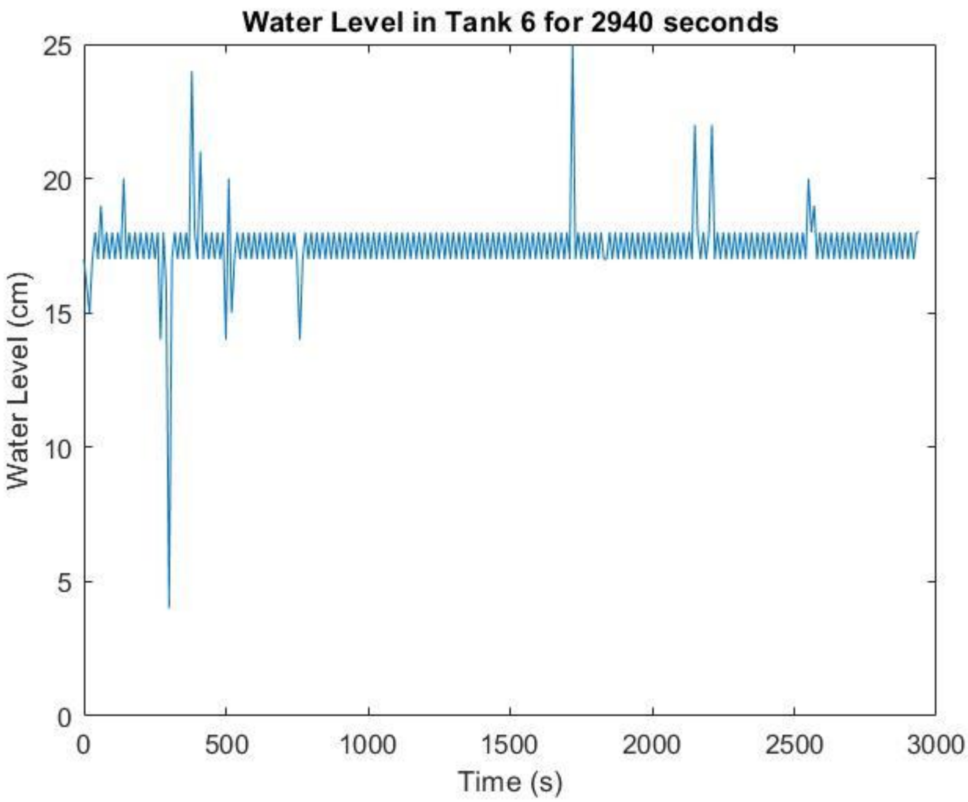

Figure 5-13 Trend of water level in Tank 6

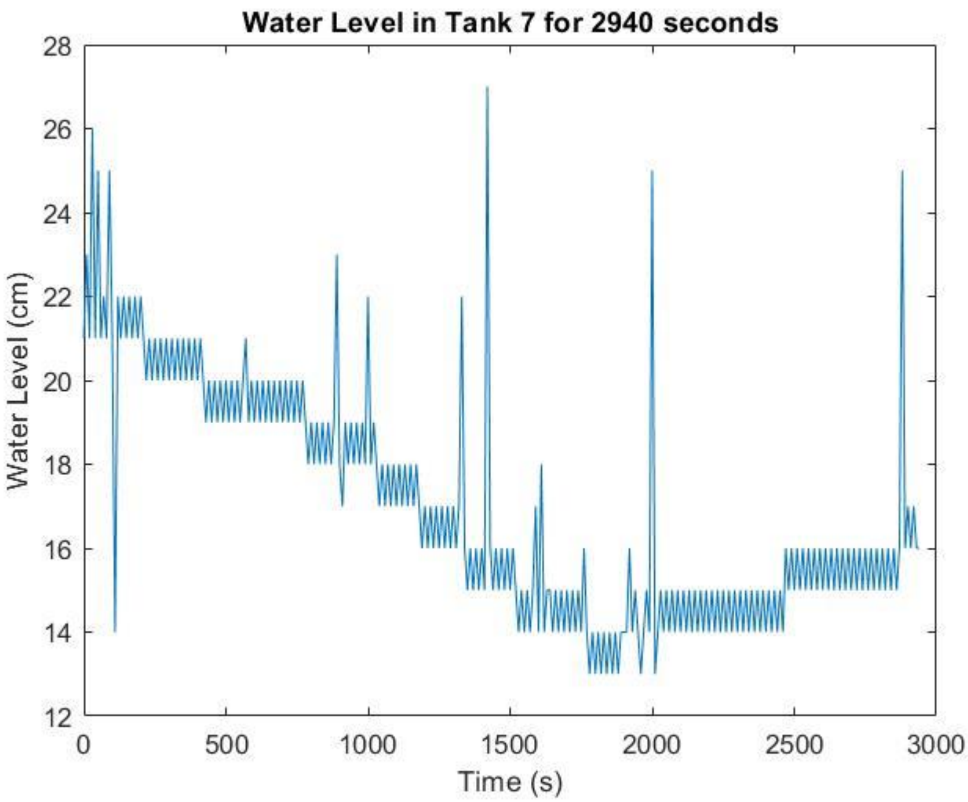

Figure 5-14 Trend of water level in Tank 7

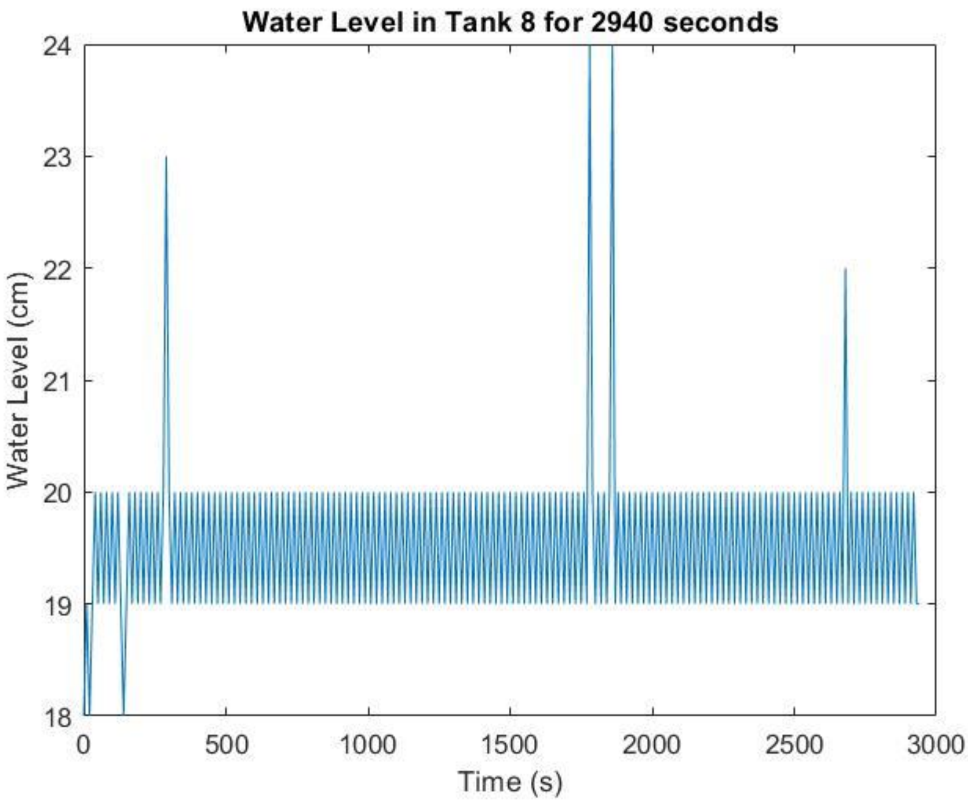

Figure 5-15 Trend of water level in Tank 8

5.4 Flowrate Monitoring

Similar to the water level monitoring, the data from all the flowmeters are not only shown in real-time, but the data is also stored in a text file for future use. In this case, the flowmeter readings are shown when they are run parallel with the water level monitoring. The results are as shown in Figure 5-16 to 5-22.

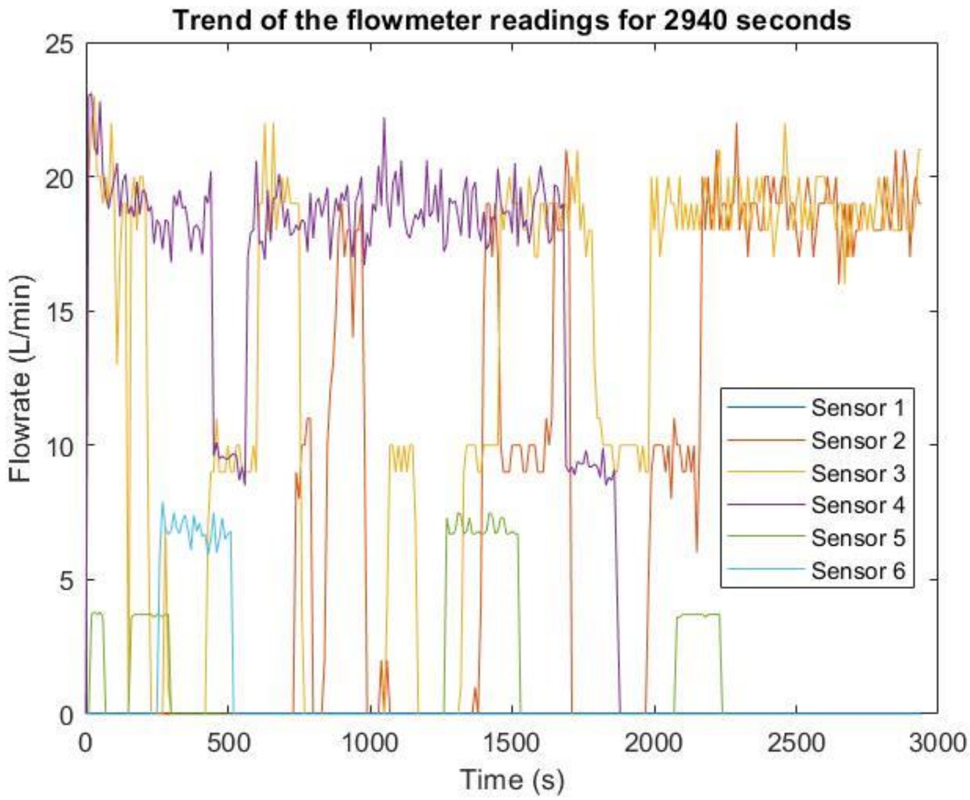

Figure 5-16 Trend of all six flowmeters for 2940 seconds

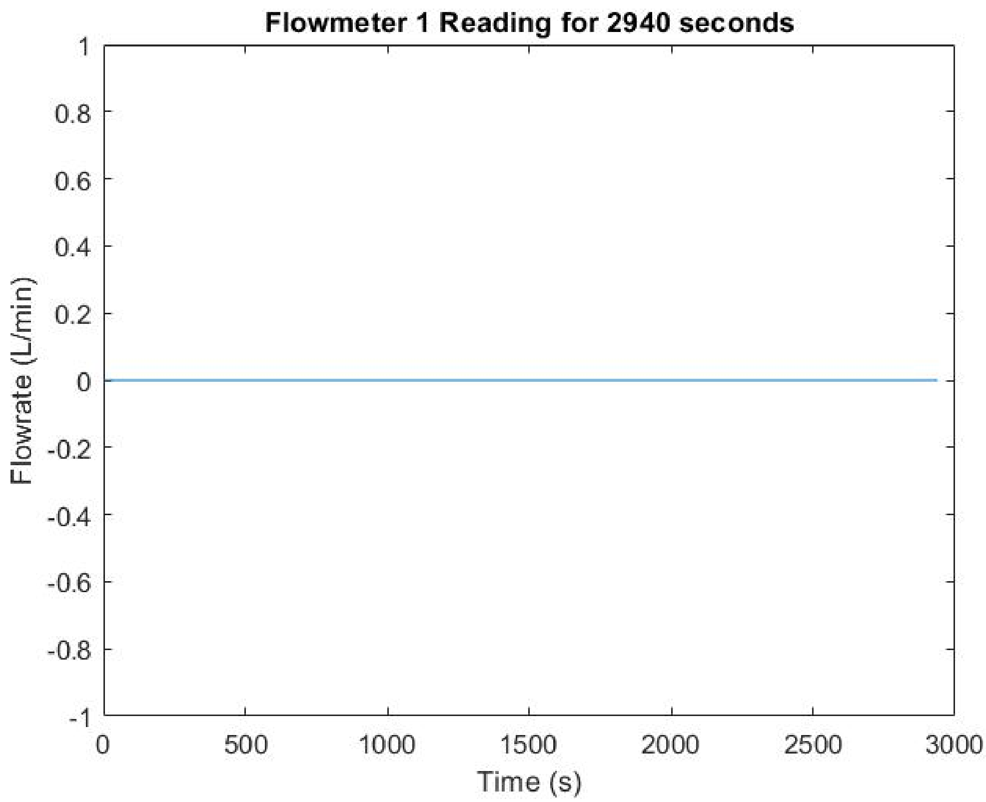

Figure 5-17 Trend of Flowmeter 1 Reading

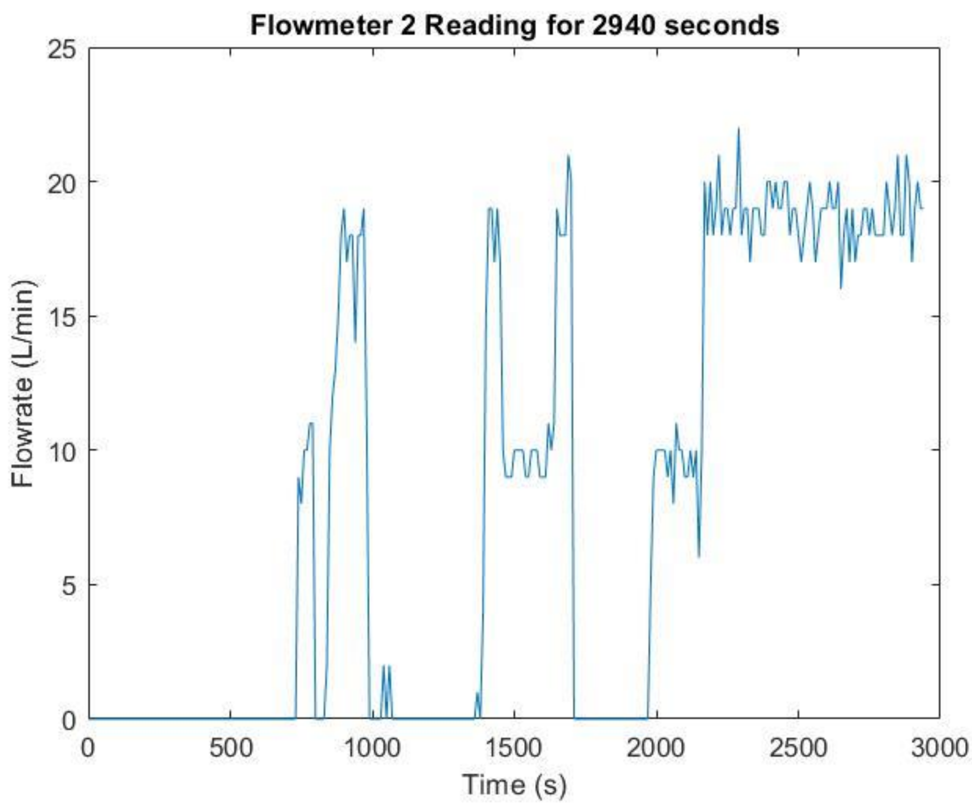

Figure 5-18 Trend of Flowmeter 2 Reading

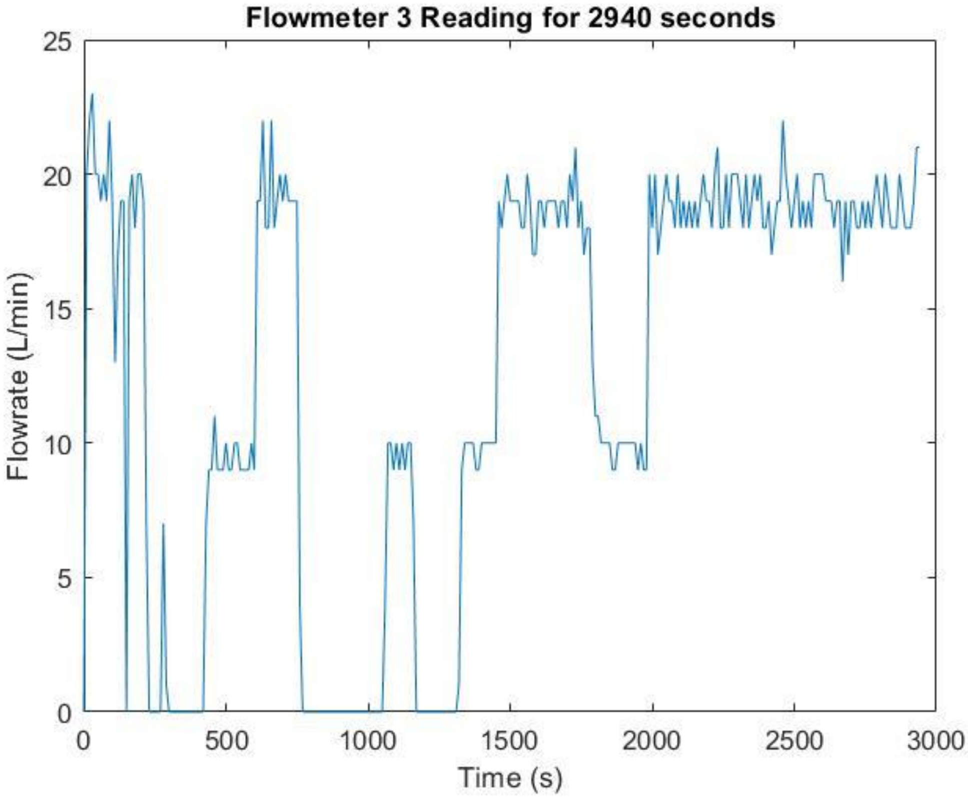

Figure 5-19 Trend of Flowmeter 3 Reading

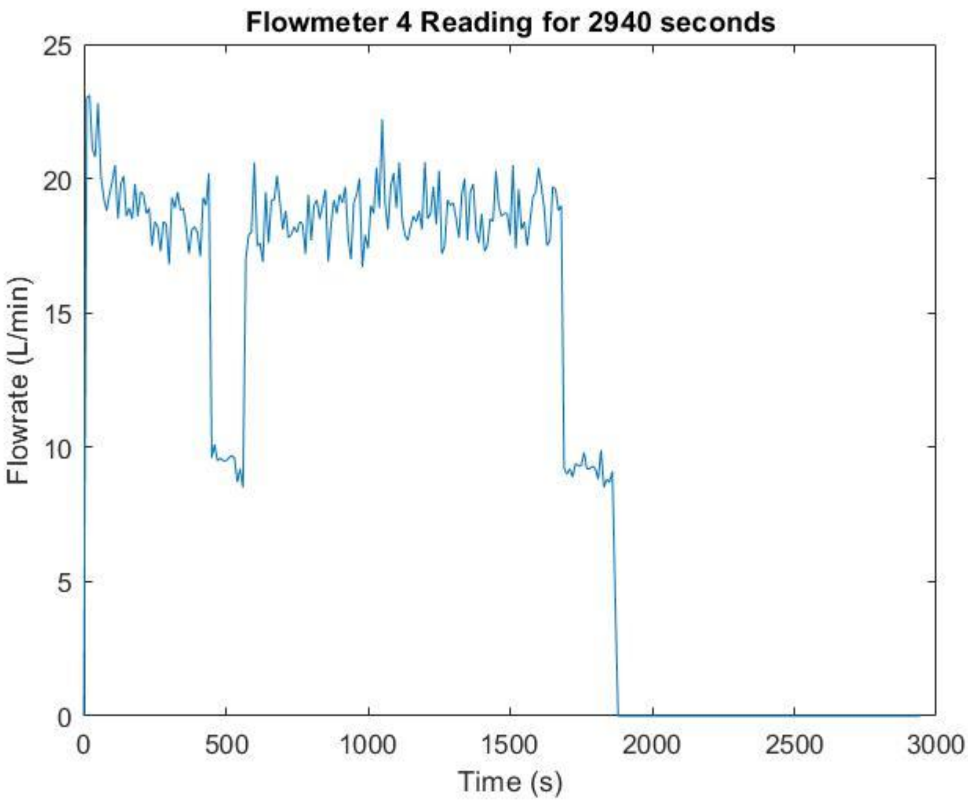

Figure 5-20 Trend of Flowmeter 4 Reading

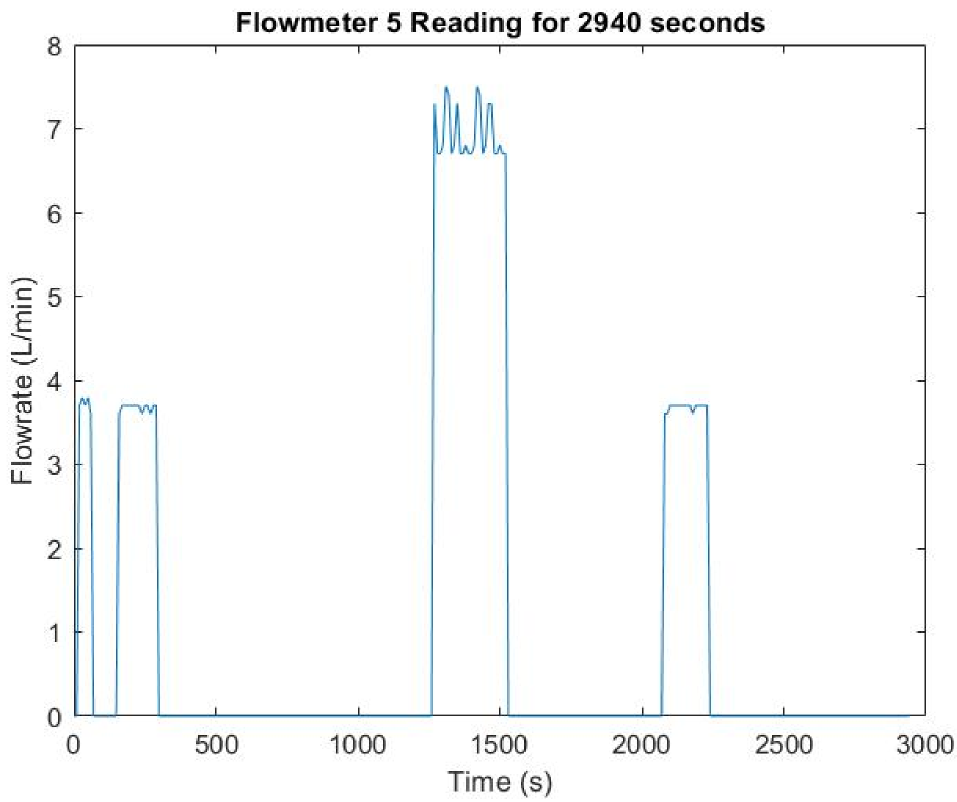

Figure 5-21 Trend of Flowmeter 5 Reading

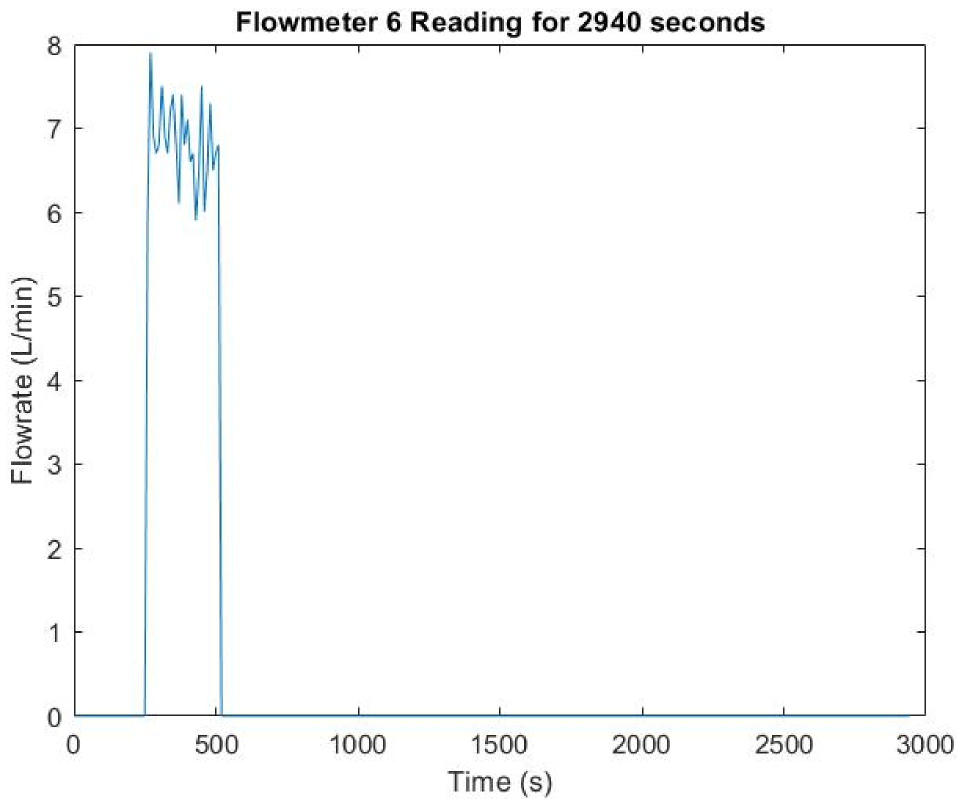

Figure 5-22 Trend of Flowmeter 6 Reading

CHAPTER 6 RECOMMENDATIONS & SUGGESTIONS

The first recommendations would be to add more sensors to the system and make all the different types of sensors integrate with one another to give better result. Examples of sensors that can be included are like strain gauge sensors to detect the weight of the water tanks, which can give us the water level in the tank. Having more sensors can give better results by combining all their results. The integration of many sensors to monitor the water level will result in more accurate and reliable results. Also, if one sensor goes faulty, we still have a backup sensor to get the water level reading. Extra measures should be taken when using strain gauges. This is due to the different densities of water at different temperatures and so on. It might cause a difference in the change of weight for the same volume. This very small change in weight might cause different water level reading giving inaccurate results. Therefore, the water in the tanks must be at constant temperature and density to get most accurate results of water level. Furthermore, the internet connection must also be very fast as this tends to affect the response time of the system. For us to get very low response time, a very fast internet connection is necessary. Slower connection also results in longer loading time for the Node-Red dashboard. A PC cooler might also be necessary to cool down the Raspberry Pi. This is because the Raspberry Pi tends to overheat from time to time until the point the chip becomes too hot to touch. In this system, a laptop air cooler was used to prevent overheating but there can still be room for improvement. Lastly, a nozzle for drain can also be included for the sump tanks. This is in case of any intervention such as for the replacement of faulty pumps and so on, the water can be easily drained out. The tank should also have a uniform base area throughout its height. This is to make sure the volume of the water filling up the tank is calculated correctly.

CHAPTER 7 CONCLUSION

In this study, an IoT system was developed for the purpose of monitoring water level in a multi tank with the help of sensors. This study serves to experimentally study the performance and the functionality of the system developed as well as to draw conclusions based on our findings for similar but up-scaled systems. The system consists of eight tanks which integrate with one another in a completely non-linear system. The Node-Red programming tool which is pre-installed in Raspberry Pi was used to obtain data from the sensors. Two types of sensors were used, ultrasonic sensors to monitor the water level as well as the flowmeter to monitor the flowrate. Both the water level and the water flow will be displayed in the Node-Red User Interface tab which gives real time data. The results obtained was compared with the actual results measured and the error is calculated to study the performance of the system. Therefore, this study is one of the very first study conducted in the efficiency of an IoT system as the IoT is still a rather new technology which has just began to gain popularity. The results of this experiment give us the error mean values of 20.835%, 10.5% and 10.145% respectively. This means the system is 'Acceptable' for the initial water level reading and 'Good' for the final water level and flowmeter reading based on the system performance evaluation developed. Although the accuracy can use some improvement, the system did a good job of monitoring the water level and giving real time data to the User. There were some glitches present where for some reason the values from the sensor tend to jump to another value for no reason. But such errors can be eliminated by having a signal conditioner. The system is also able to store the data instead of just displaying it which means we can always refer back in case of any failure analysis had to be done. The Node-Red programming tool also helped in giving a very user interactive graphic interface which can convey the data easily. The system can be made more accurate by incorporating the recommendations and suggestion stated in this paper. The results obtained from this study can be used in similar but up-scaled IoT systems in the near future as the IoT will play a huge role in the near future as predicted by many.

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CHAPTER 9 APPENDIX

Table 9-1 Water Level Trend for 2940 seconds

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
0	15:16:00	8	5	12	9	8	17	21	18
10	15:16:10	10	5	13	10	9	16	23	19
20	15:16:20	8	5	12	9	9	15	21	18
30	15:16:30	8	5	23	10	9	17	26	19
40	15:16:40	8	6	17	9	9	18	21	20
50	15:16:50	9	5	12	10	11	17	25	19
60	15:17:00	8	6	15	9	9	19	21	20
70	15:17:10	8	6	12	10	9	17	22	19
80	15:17:20	8	5	12	9	9	18	21	20
90	15:17:30	9	5	12	10	9	17	25	19
100	15:17:40	9	5	9	9	10	18	21	20
110	15:17:50	8	6	11	10	9	17	14	19
120	15:18:00	8	5	12	9	11	18	22	20
130	15:18:10	7	6	26	10	9	17	21	19
140	15:18:20	3	5	12	9	11	20	22	18
150	15:18:30	6	6	13	23	9	17	21	19
160	15:18:40	8	5	12	8	11	18	22	20
170	15:18:50	5	6	11	9	9	17	21	19
180	15:19:00	8	5	12	10	25	18	22	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
190	15:19:10	7	7	5	9	9	17	21	19
200	15:19:20	8	5	12	20	16	18	22	20
210	15:19:30	9	5	11	10	9	17	21	19
220	15:19:40	8	5	12	9	10	18	20	20
230	15:19:50	9	6	9	10	9	17	21	19
240	15:20:00	9	5	12	9	22	18	20	20
250	15:20:10	8	6	13	10	9	17	21	19
260	15:20:20	9	5	12	9	10	18	20	20
270	15:20:30	8	6	13	10	9	14	21	19
280	15:20:40	9	5	12	9	12	18	20	20
290	15:20:50	8	6	11	10	9	16	21	23
300	15:21:00	9	5	12	9	26	4	20	20
310	15:21:10	8	6	13	10	9	17	21	19
320	15:21:20	9	5	12	9	12	18	20	20
330	15:21:30	8	6	12	10	9	17	21	19
340	15:21:40	9	5	12	9	12	18	20	20
350	15:21:50	8	6	13	10	9	17	21	19
360	15:22:00	9	5	12	9	12	18	20	20
370	15:22:10	8	6	19	10	9	17	21	19
380	15:22:20	9	5	12	9	8	24	20	20
390	15:22:30	8	6	13	8	9	18	21	19
400	15:22:40	7	5	12	9	8	17	20	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
410	15:22:50	8	4	14	10	9	21	21	19
420	15:23:00	9	4	12	9	10	17	20	20
430	15:23:10	8	21	13	10	9	18	19	19
440	15:23:20	9	5	12	9	10	17	20	20
450	15:23:30	8	6	13	10	9	18	19	19
460	15:23:40	9	5	12	9	10	17	20	20
470	15:23:50	8	6	13	10	9	18	19	19
480	15:24:00	9	5	12	9	10	17	20	20
490	15:24:10	8	8	13	10	9	18	19	19
500	15:24:20	9	5	12	9	10	14	20	20
510	15:24:30	8	10	13	10	8	20	19	19
520	15:24:40	9	5	12	9	10	15	20	20
530	15:24:50	8	14	13	10	9	17	19	19
540	15:25:00	9	5	12	9	10	18	20	20
550	15:25:10	8	9	13	10	9	17	19	19
560	15:25:20	9	5	12	9	10	18	20	20
570	15:25:30	8	2	13	10	9	17	21	19
580	15:25:40	9	5	12	9	10	18	19	20
590	15:25:50	8	27	13	10	9	17	20	19
600	15:26:00	9	5	12	11	10	18	19	20
610	15:26:10	8	4	13	9	11	17	20	19
620	15:26:20	9	5	12	10	9	18	19	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
630	15:26:30	8	6	13	9	10	17	20	19
640	15:26:40	9	5	12	10	11	18	19	20
650	15:26:50	8	11	13	9	10	17	20	19
660	15:27:00	9	8	12	10	11	18	19	20
670	15:27:10	8	5	13	9	10	17	20	19
680	15:27:20	9	9	12	10	11	18	19	20
690	15:27:30	8	5	23	9	10	17	20	19
700	15:27:40	9	6	12	10	11	18	19	20
710	15:27:50	8	5	13	9	10	17	20	19
720	15:28:00	9	6	12	10	9	18	19	20
730	15:28:10	8	5	24	9	10	17	20	19
740	15:28:20	9	8	12	10	11	18	19	20
750	15:28:30	8	5	13	9	10	17	20	19
760	15:28:40	9	14	12	10	11	14	19	20
770	15:28:50	8	5	13	9	10	17	20	19
780	15:29:00	8	9	12	10	11	18	19	20
790	15:29:10	9	5	23	9	10	17	18	19
800	15:29:20	8	9	12	10	11	18	19	20
810	15:29:30	9	5	26	9	10	17	18	19
820	15:29:40	8	6	12	10	11	18	19	20
830	15:29:50	9	5	13	9	10	17	18	19
840	15:30:00	8	7	12	10	11	18	19	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
850	15:30:10	9	5	13	9	10	17	18	19
860	15:30:20	8	18	12	10	11	18	19	20
870	15:30:30	9	5	13	9	10	17	18	19
880	15:30:40	8	6	12	10	11	18	19	20
890	15:30:50	9	5	13	9	10	17	23	19
900	15:31:00	8	6	12	10	11	18	18	20
910	15:31:10	9	5	13	9	10	17	17	19
920	15:31:20	8	6	12	10	11	18	19	20
930	15:31:30	9	5	13	9	10	17	18	19
940	15:31:40	8	10	12	10	11	18	19	20
950	15:31:50	9	5	13	9	10	17	18	19
960	15:32:00	8	6	12	10	11	18	19	20
970	15:32:10	9	5	14	9	10	17	18	19
980	15:32:20	8	6	12	10	11	18	19	20
990	15:32:30	9	5	18	9	10	17	18	19
1000	15:32:40	7	6	12	10	11	18	22	20
1010	15:32:50	9	5	13	9	10	17	18	19
1020	15:33:00	10	6	12	10	11	18	19	20
1030	15:33:10	9	5	14	9	10	17	18	19
1040	15:33:20	8	8	12	10	11	18	17	20
1050	15:33:30	9	5	13	9	10	17	18	19
1060	15:33:40	8	6	12	10	11	18	17	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
1070	15:33:50	9	5	14	9	10	17	18	19
1080	15:34:00	8	2	12	10	11	18	17	20
1090	15:34:10	9	5	15	9	10	17	18	19
1100	15:34:20	8	9	12	10	11	18	17	20
1110	15:34:30	9	6	4	9	10	17	18	19
1120	15:34:40	8	5	27	10	11	18	17	20
1130	15:34:50	9	6	12	9	10	17	18	19
1140	15:35:00	7	5	19	10	11	18	17	20
1150	15:35:10	9	6	12	9	13	17	18	19
1160	15:35:20	10	5	17	10	11	18	17	20
1170	15:35:30	9	6	12	9	12	17	18	19
1180	15:35:40	8	5	15	10	11	18	17	20
1190	15:35:50	9	15	12	9	14	17	16	19
1200	15:36:00	8	5	15	10	11	18	17	20
1210	15:36:10	9	6	12	9	12	17	16	19
1220	15:36:20	10	5	13	10	11	18	17	20
1230	15:36:30	9	6	12	9	12	17	16	19
1240	15:36:40	8	5	13	10	11	18	17	20
1250	15:36:50	9	6	12	9	12	17	16	19
1260	15:37:00	13	5	13	10	11	18	17	20
1270	15:37:10	9	6	12	9	12	17	16	19
1280	15:37:20	6	5	13	10	11	18	17	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
1290	15:37:30	9	6	12	9	12	17	16	19
1300	15:37:40	8	5	13	10	11	18	17	20
1310	15:37:50	9	6	12	9	12	17	16	19
1320	15:38:00	8	5	13	10	11	18	17	20
1330	15:38:10	9	6	12	9	12	17	22	19
1340	15:38:20	8	5	13	10	11	18	16	20
1350	15:38:30	9	6	10	9	12	17	15	19
1360	15:38:40	8	5	12	10	11	18	16	20
1370	15:38:50	9	6	13	9	12	17	15	19
1380	15:39:00	8	5	12	10	11	18	16	20
1390	15:39:10	9	6	13	9	12	17	15	19
1400	15:39:20	8	5	12	10	11	18	16	20
1410	15:39:30	9	6	13	9	12	17	15	19
1420	15:39:40	8	5	12	10	11	18	27	20
1430	15:39:50	9	6	13	9	12	17	16	19
1440	15:40:00	8	5	12	10	11	18	15	20
1450	15:40:10	9	6	14	9	12	17	16	19
1460	15:40:20	8	5	13	10	11	18	15	20
1470	15:40:30	9	6	13	9	12	17	16	19
1480	15:40:40	8	5	12	10	11	18	15	20
1490	15:40:50	9	6	13	9	12	17	16	19
1500	15:41:00	8	5	12	10	11	18	15	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
1510	15:41:10	9	6	13	9	12	17	16	19
1520	15:41:20	8	5	12	10	11	18	15	20
1530	15:41:30	9	6	13	9	12	17	14	19
1540	15:41:40	8	5	12	10	11	18	15	20
1550	15:41:50	9	6	13	9	12	17	14	19
1560	15:42:00	10	5	12	26	11	18	15	20
1570	15:42:10	12	6	13	10	12	17	14	19
1580	15:42:20	9	5	12	9	11	18	15	20
1590	15:42:30	8	6	13	10	12	17	17	19
1600	15:42:40	9	5	12	9	11	18	14	20
1610	15:42:50	8	6	13	10	12	17	18	19
1620	15:43:00	9	5	11	9	11	18	14	20
1630	15:43:10	8	6	13	10	12	17	15	19
1640	15:43:20	9	5	12	9	11	18	15	20
1650	15:43:30	8	6	13	10	12	17	14	19
1660	15:43:40	9	5	12	9	11	18	15	20
1670	15:43:50	8	6	13	10	12	17	14	19
1680	15:44:00	9	5	12	9	11	18	15	20
1690	15:44:10	16	6	13	10	12	17	14	19
1700	15:44:20	9	5	12	9	11	18	15	20
1710	15:44:30	13	6	13	10	12	17	14	19
1720	15:44:40	9	5	12	9	11	25	15	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
1730	15:44:50	8	6	13	10	12	17	14	19
1740	15:45:00	9	5	12	9	11	18	15	20
1750	15:45:10	8	6	13	10	12	17	14	19
1760	15:45:20	9	5	12	9	11	18	16	20
1770	15:45:30	8	6	12	10	12	17	14	19
1780	15:45:40	9	5	12	9	13	18	13	24
1790	15:45:50	8	6	13	10	12	17	14	20
1800	15:46:00	9	5	12	9	13	18	13	19
1810	15:46:10	8	6	13	10	12	17	14	20
1820	15:46:20	9	5	12	9	18	18	13	19
1830	15:46:30	8	6	13	10	12	17	14	20
1840	15:46:40	9	5	22	9	13	17	13	19
1850	15:46:50	13	6	12	10	12	18	14	20
1860	15:47:00	8	5	13	9	13	17	13	24
1870	15:47:10	9	6	12	10	12	18	14	19
1880	15:47:20	11	5	13	9	13	17	13	20
1890	15:47:30	9	6	12	10	12	18	14	19
1900	15:47:40	8	5	13	9	8	17	14	20
1910	15:47:50	9	6	12	10	12	18	14	19
1920	15:48:00	8	5	27	9	12	17	16	20
1930	15:48:10	9	6	16	10	13	18	14	19
1940	15:48:20	8	5	12	9	12	17	15	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
1950	15:48:30	9	6	13	10	13	18	14	19
1960	15:48:40	8	5	12	9	12	17	13	20
1970	15:48:50	9	6	16	10	13	18	14	19
1980	15:49:00	8	5	12	9	12	17	15	20
1990	15:49:10	9	4	17	10	13	18	14	19
2000	15:49:20	11	6	12	9	12	17	25	20
2010	15:49:30	9	5	11	10	13	18	13	19
2020	15:49:40	8	6	12	9	12	17	14	20
2030	15:49:50	9	5	11	10	13	18	15	19
2040	15:50:00	8	6	12	9	12	17	14	20
2050	15:50:10	9	5	11	10	13	18	15	19
2060	15:50:20	8	6	12	9	12	17	14	20
2070	15:50:30	9	5	11	14	13	18	15	19
2080	15:50:40	8	6	12	10	12	17	14	20
2090	15:50:50	9	5	11	9	13	18	15	19
2100	15:51:00	8	6	12	10	12	17	14	20
2110	15:51:10	9	5	11	9	15	18	15	19
2120	15:51:20	8	6	12	10	13	17	14	20
2130	15:51:30	3	5	11	9	12	18	15	19
2140	15:51:40	9	6	13	10	13	17	14	20
2150	15:51:50	8	5	12	9	12	22	15	19
2160	15:52:00	9	6	11	10	13	18	14	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
2170	15:52:10	8	5	12	9	12	17	15	19
2180	15:52:20	9	6	13	10	13	18	14	20
2190	15:52:30	8	5	14	9	12	17	15	19
2200	15:52:40	9	6	11	10	13	18	14	20
2210	15:52:50	8	5	12	9	12	22	15	19
2220	15:53:00	9	6	11	10	13	17	14	20
2230	15:53:10	8	5	12	9	12	18	15	19
2240	15:53:20	9	6	11	10	13	17	14	20
2250	15:53:30	8	5	12	22	12	18	15	19
2260	15:53:40	9	6	11	9	13	17	14	20
2270	15:53:50	10	5	12	10	12	18	15	19
2280	15:54:00	9	6	11	9	13	17	14	20
2290	15:54:10	10	5	12	10	12	18	15	19
2300	15:54:20	9	6	11	9	26	17	14	20
2310	15:54:30	10	5	12	10	12	18	15	19
2320	15:54:40	9	6	11	9	13	17	14	20
2330	15:54:50	10	5	12	10	12	18	15	19
2340	15:55:00	9	6	11	9	13	17	14	20
2350	15:55:10	10	5	12	10	12	18	15	19
2360	15:55:20	9	6	11	9	13	17	14	20
2370	15:55:30	10	5	12	10	14	18	15	19
2380	15:55:40	9	6	11	9	13	17	14	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
2390	15:55:50	10	1	12	14	14	18	15	19
2400	15:56:00	9	5	11	9	13	17	14	20
2410	15:56:10	10	6	14	10	12	18	15	19
2420	15:56:20	9	5	11	9	13	17	14	20
2430	15:56:30	10	6	23	10	12	18	15	19
2440	15:56:40	9	5	12	9	13	17	14	20
2450	15:56:50	10	6	11	10	12	18	15	19
2460	15:57:00	9	5	12	9	13	17	14	20
2470	15:57:10	10	6	11	10	12	18	16	19
2480	15:57:20	9	5	10	9	13	17	15	20
2490	15:57:30	10	6	11	10	12	18	16	19
2500	15:57:40	9	5	10	9	13	17	15	20
2510	15:57:50	10	6	11	11	12	18	16	19
2520	15:58:00	9	5	10	9	13	17	15	20
2530	15:58:10	10	8	11	10	12	18	16	19
2540	15:58:20	9	5	10	9	13	17	15	20
2550	15:58:30	10	6	11	10	11	20	16	19
2560	15:58:40	9	5	10	9	13	18	15	20
2570	15:58:50	10	7	11	10	12	19	16	19
2580	15:59:00	9	8	10	9	13	17	15	20
2590	15:59:10	10	10	11	10	12	18	16	19
2600	15:59:20	9	10	10	9	13	17	15	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
2610	15:59:30	10	9	11	10	12	18	16	19
2620	15:59:40	9	9	10	9	13	17	15	20
2630	15:59:50	10	9	11	10	12	18	16	19
2640	16:00:00	9	5	10	9	13	17	15	20
2650	16:00:10	10	6	11	10	12	18	16	19
2660	16:00:20	9	5	10	9	13	17	15	20
2670	16:00:30	10	6	12	10	12	18	16	19
2680	16:00:40	9	5	10	9	13	17	15	22
2690	16:00:50	10	6	11	10	12	18	16	19
2700	16:01:00	9	5	10	9	13	17	15	20
2710	16:01:10	10	6	6	10	12	18	16	19
2720	16:01:20	9	5	10	9	13	17	15	20
2730	16:01:30	10	6	16	10	12	18	16	19
2740	16:01:40	9	5	10	9	13	17	15	20
2750	16:01:50	10	6	11	10	14	18	16	19
2760	16:02:00	9	6	10	9	13	17	15	20
2770	16:02:10	10	5	12	10	14	18	16	19
2780	16:02:20	9	6	12	9	13	17	15	20
2790	16:02:30	10	5	10	10	14	18	16	19
2800	16:02:40	9	6	11	9	13	17	15	20
2810	16:02:50	10	5	10	10	12	18	16	19
2820	16:03:00	9	6	11	9	13	17	15	20

Time(s)	Actual Time	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
2830	16:03:10	10	5	10	10	19	18	16	19
2840	16:03:20	9	6	11	9	13	17	15	20
2850	16:03:30	10	5	10	10	14	18	16	19
2860	16:03:40	9	6	11	9	13	17	15	20
2870	16:03:50	10	5	10	10	12	18	16	19
2880	16:04:00	9	6	11	9	13	17	25	20
2890	16:04:10	10	5	10	10	12	18	16	19
2900	16:04:20	9	6	11	9	13	17	17	20
2910	16:04:30	10	5	10	10	12	18	16	19
2920	16:04:40	9	6	11	9	13	17	17	20
2930	16:04:50	10	5	10	10	12	18	16	19
2940	16:05:00	9	6	11	10	12	18	16	19

Table 9-2 Flowmeter Reading for 2940 seconds

Time(s)	Actual Time	Flowmeter 1	Flowmeter 2	Flowmeter 3	Flowmeter 4	Flowmeter 5	Flowmeter 6
0	15:16:00	0.0	0.0	0.0	0.0	0.0	0.0
10	15:16:10	0.0	0.0	20.0	23.0	0.0	0.0
20	15:16:20	0.0	0.0	22.0	23.1	3.7	0.0
30	15:16:30	0.0	0.0	23.0	21.1	3.8	0.0
40	15:16:40	0.0	0.0	20.0	20.8	3.7	0.0
50	15:16:50	0.0	0.0	20.0	22.8	3.8	0.0
60	15:17:00	0.0	0.0	19.0	20.1	3.6	0.0
70	15:17:10	0.0	0.0	20.0	19.3	0.0	0.0
80	15:17:20	0.0	0.0	19.0	18.8	0.0	0.0
90	15:17:30	0.0	0.0	22.0	19.4	0.0	0.0
100	15:17:40	0.0	0.0	19.0	19.9	0.0	0.0
110	15:17:50	0.0	0.0	13.0	20.5	0.0	0.0
120	15:18:00	0.0	0.0	17.0	18.5	0.0	0.0
130	15:18:10	0.0	0.0	19.0	19.8	0.0	0.0
140	15:18:20	0.0	0.0	19.0	20.1	0.0	0.0
150	15:18:30	0.0	0.0	0.0	18.6	0.0	0.0
160	15:18:40	0.0	0.0	19.0	18.9	3.6	0.0
170	15:18:50	0.0	0.0	20.0	18.5	3.7	0.0
180	15:19:00	0.0	0.0	18.0	19.8	3.7	0.0
190	15:19:10	0.0	0.0	20.0	18.6	3.7	0.0
200	15:19:20	0.0	0.0	20.0	19.5	3.7	0.0
210	15:19:30	0.0	0.0	19.0	19.4	3.7	0.0
220	15:19:40	0.0	0.0	7.0	18.7	3.7	0.0
230	15:19:50	0.0	0.0	0.0	18.9	3.7	0.0
240	15:20:00	0.0	0.0	0.0	17.5	3.6	0.0
250	15:20:10	0.0	0.0	0.0	18.4	3.7	0.0
260	15:20:20	0.0	0.0	0.0	18.2	3.7	5.9
270	15:20:30	0.0	0.0	0.0	17.3	3.6	7.9
280	15:20:40	0.0	0.0	7.0	18.4	3.7	6.9

Time(s)	Actual Time	Flowmeter 1	Flowmeter 2	Flowmeter 3	Flowmeter 4	Flowmeter 5	Flowmeter 6
290	15:20:50	0.0	0.0	1.0	18.3	3.7	6.7
300	15:21:00	0.0	0.0	0.0	16.8	0.0	6.8
310	15:21:10	0.0	0.0	0.0	19.3	0.0	7.5
320	15:21:20	0.0	0.0	0.0	18.9	0.0	6.9
330	15:21:30	0.0	0.0	0.0	19.5	0.0	6.7
340	15:21:40	0.0	0.0	0.0	18.8	0.0	7.2
350	15:21:50	0.0	0.0	0.0	18.9	0.0	7.4
360	15:22:00	0.0	0.0	0.0	18.2	0.0	6.8
370	15:22:10	0.0	0.0	0.0	17.2	0.0	6.1
380	15:22:20	0.0	0.0	0.0	18.1	0.0	7.4
390	15:22:30	0.0	0.0	0.0	18.2	0.0	6.8
400	15:22:40	0.0	0.0	0.0	18.0	0.0	7.1
410	15:22:50	0.0	0.0	0.0	17.1	0.0	6.6
420	15:23:00	0.0	0.0	0.0	19.3	0.0	6.7
430	15:23:10	0.0	0.0	7.0	19.0	0.0	5.9
440	15:23:20	0.0	0.0	9.0	20.2	0.0	6.5
450	15:23:30	0.0	0.0	9.0	9.6	0.0	7.5
460	15:23:40	0.0	0.0	11.0	10.1	0.0	6.0
470	15:23:50	0.0	0.0	9.0	9.5	0.0	6.5
480	15:24:00	0.0	0.0	9.0	9.6	0.0	7.3
490	15:24:10	0.0	0.0	9.0	9.5	0.0	6.5
500	15:24:20	0.0	0.0	10.0	9.5	0.0	6.7
510	15:24:30	0.0	0.0	9.0	9.6	0.0	6.8
520	15:24:40	0.0	0.0	9.0	9.7	0.0	0.0
530	15:24:50	0.0	0.0	10.0	9.6	0.0	0.0
540	15:25:00	0.0	0.0	10.0	8.7	0.0	0.0
550	15:25:10	0.0	0.0	9.0	9.2	0.0	0.0
560	15:25:20	0.0	0.0	9.0	8.5	0.0	0.0
570	15:25:30	0.0	0.0	9.0	17.0	0.0	0.0
580	15:25:40	0.0	0.0	9.0	17.9	0.0	0.0
590	15:25:50	0.0	0.0	10.0	18.0	0.0	0.0

Time(s)	Actual Time	Flowmeter 1	Flowmeter 2	Flowmeter 3	Flowmeter 4	Flowmeter 5	Flowmeter 6
600	15:26:00	0.0	0.0	9.0	20.6	0.0	0.0
610	15:26:10	0.0	0.0	19.0	17.5	0.0	0.0
620	15:26:20	0.0	0.0	19.0	17.6	0.0	0.0
630	15:26:30	0.0	0.0	22.0	16.9	0.0	0.0
640	15:26:40	0.0	0.0	18.0	19.5	0.0	0.0
650	15:26:50	0.0	0.0	18.0	17.6	0.0	0.0
660	15:27:00	0.0	0.0	22.0	19.2	0.0	0.0
670	15:27:10	0.0	0.0	18.0	19.2	0.0	0.0
680	15:27:20	0.0	0.0	19.0	20.1	0.0	0.0
690	15:27:30	0.0	0.0	20.0	19.1	0.0	0.0
700	15:27:40	0.0	0.0	19.0	18.1	0.0	0.0
710	15:27:50	0.0	0.0	20.0	18.8	0.0	0.0
720	15:28:00	0.0	0.0	19.0	17.8	0.0	0.0
730	15:28:10	0.0	0.0	19.0	17.9	0.0	0.0
740	15:28:20	0.0	9.0	19.0	18.2	0.0	0.0
750	15:28:30	0.0	8.0	19.0	18.0	0.0	0.0
760	15:28:40	0.0	10.0	4.0	18.4	0.0	0.0
770	15:28:50	0.0	10.0	0.0	18.3	0.0	0.0
780	15:29:00	0.0	11.0	0.0	17.2	0.0	0.0
790	15:29:10	0.0	11.0	0.0	19.4	0.0	0.0
800	15:29:20	0.0	0.0	0.0	17.7	0.0	0.0
810	15:29:30	0.0	0.0	0.0	19.0	0.0	0.0
820	15:29:40	0.0	0.0	0.0	19.2	0.0	0.0
830	15:29:50	0.0	0.0	0.0	18.5	0.0	0.0
840	15:30:00	0.0	2.0	0.0	19.0	0.0	0.0
850	15:30:10	0.0	10.0	0.0	19.6	0.0	0.0
860	15:30:20	0.0	12.0	0.0	16.9	0.0	0.0
870	15:30:30	0.0	13.0	0.0	18.3	0.0	0.0
880	15:30:40	0.0	15.0	0.0	19.2	0.0	0.0
890	15:30:50	0.0	18.0	0.0	18.7	0.0	0.0
900	15:31:00	0.0	19.0	0.0	19.4	0.0	0.0

Time(s)	Actual Time	Flowmeter 1	Flowmeter 2	Flowmeter 3	Flowmeter 4	Flowmeter 5	Flowmeter 6
910	15:31:10	0.0	17.0	0.0	19.1	0.0	0.0
920	15:31:20	0.0	18.0	0.0	19.7	0.0	0.0
930	15:31:30	0.0	18.0	0.0	17.8	0.0	0.0
940	15:31:40	0.0	14.0	0.0	17.0	0.0	0.0
950	15:31:50	0.0	18.0	0.0	19.1	0.0	0.0
960	15:32:00	0.0	18.0	0.0	19.4	0.0	0.0
970	15:32:10	0.0	19.0	0.0	20.0	0.0	0.0
980	15:32:20	0.0	11.0	0.0	16.7	0.0	0.0
990	15:32:30	0.0	0.0	0.0	17.9	0.0	0.0
1000	15:32:40	0.0	0.0	0.0	17.4	0.0	0.0
1010	15:32:50	0.0	0.0	0.0	19.0	0.0	0.0
1020	15:33:00	0.0	0.0	0.0	18.7	0.0	0.0
1030	15:33:10	0.0	0.0	0.0	20.4	0.0	0.0
1040	15:33:20	0.0	2.0	0.0	18.9	0.0	0.0
1050	15:33:30	0.0	0.0	0.0	22.2	0.0	0.0
1060	15:33:40	0.0	2.0	4.0	19.1	0.0	0.0
1070	15:33:50	0.0	0.0	10.0	18.1	0.0	0.0
1080	15:34:00	0.0	0.0	10.0	19.7	0.0	0.0
1090	15:34:10	0.0	0.0	9.0	20.2	0.0	0.0
1100	15:34:20	0.0	0.0	10.0	18.9	0.0	0.0
1110	15:34:30	0.0	0.0	9.0	20.6	0.0	0.0
1120	15:34:40	0.0	0.0	10.0	18.5	0.0	0.0
1130	15:34:50	0.0	0.0	9.0	17.9	0.0	0.0
1140	15:35:00	0.0	0.0	10.0	17.7	0.0	0.0
1150	15:35:10	0.0	0.0	10.0	18.2	0.0	0.0
1160	15:35:20	0.0	0.0	7.0	18.6	0.0	0.0
1170	15:35:30	0.0	0.0	0.0	18.4	0.0	0.0
1180	15:35:40	0.0	0.0	0.0	18.8	0.0	0.0
1190	15:35:50	0.0	0.0	0.0	18.1	0.0	0.0
1200	15:36:00	0.0	0.0	0.0	20.6	0.0	0.0
1210	15:36:10	0.0	0.0	0.0	18.5	0.0	0.0

Time(s)	Actual Time	Flowmeter 1	Flowmeter 2	Flowmeter 3	Flowmeter 4	Flowmeter 5	Flowmeter 6
1220	15:36:20	0.0	0.0	0.0	18.7	0.0	0.0
1230	15:36:30	0.0	0.0	0.0	19.7	0.0	0.0
1240	15:36:40	0.0	0.0	0.0	18.3	0.0	0.0
1250	15:36:50	0.0	0.0	0.0	20.3	0.0	0.0
1260	15:37:00	0.0	0.0	0.0	17.2	0.0	0.0
1270	15:37:10	0.0	0.0	0.0	17.5	7.3	0.0
1280	15:37:20	0.0	0.0	0.0	19.2	6.7	0.0
1290	15:37:30	0.0	0.0	0.0	19.0	6.7	0.0
1300	15:37:40	0.0	0.0	0.0	19.1	6.8	0.0
1310	15:37:50	0.0	0.0	0.0	18.5	7.5	0.0
1320	15:38:00	0.0	0.0	1.0	17.8	7.4	0.0
1330	15:38:10	0.0	0.0	9.0	19.4	6.7	0.0
1340	15:38:20	0.0	0.0	10.0	20.0	6.8	0.0
1350	15:38:30	0.0	0.0	10.0	17.7	7.3	0.0
1360	15:38:40	0.0	0.0	10.0	19.5	6.7	0.0
1370	15:38:50	0.0	1.0	10.0	19.8	6.7	0.0
1380	15:39:00	0.0	0.0	9.0	18.1	6.8	0.0
1390	15:39:10	0.0	4.0	9.0	17.6	6.7	0.0
1400	15:39:20	0.0	15.0	10.0	18.7	6.7	0.0
1410	15:39:30	0.0	19.0	10.0	17.3	6.8	0.0
1420	15:39:40	0.0	19.0	10.0	17.5	7.5	0.0
1430	15:39:50	0.0	17.0	10.0	18.5	7.4	0.0
1440	15:40:00	0.0	19.0	10.0	18.4	6.7	0.0
1450	15:40:10	0.0	17.0	10.0	20.3	6.8	0.0
1460	15:40:20	0.0	10.0	19.0	19.0	7.3	0.0
1470	15:40:30	0.0	9.0	18.0	18.6	7.3	0.0
1480	15:40:40	0.0	9.0	19.0	18.7	6.7	0.0
1490	15:40:50	0.0	9.0	20.0	18.7	6.7	0.0
1500	15:41:00	0.0	10.0	19.0	17.9	6.8	0.0
1510	15:41:10	0.0	10.0	19.0	20.5	6.7	0.0
1520	15:41:20	0.0	10.0	19.0	17.4	6.7	0.0

Time(s)	Actual Time	Flowmeter 1	Flowmeter 2	Flowmeter 3	Flowmeter 4	Flowmeter 5	Flowmeter 6
1530	15:41:30	0.0	10.0	19.0	19.6	0.0	0.0
1540	15:41:40	0.0	9.0	18.0	18.1	0.0	0.0
1550	15:41:50	0.0	9.0	18.0	18.4	0.0	0.0
1560	15:42:00	0.0	10.0	20.0	17.5	0.0	0.0
1570	15:42:10	0.0	10.0	19.0	18.4	0.0	0.0
1580	15:42:20	0.0	10.0	17.0	19.3	0.0	0.0
1590	15:42:30	0.0	9.0	17.0	19.5	0.0	0.0
1600	15:42:40	0.0	9.0	19.0	20.4	0.0	0.0
1610	15:42:50	0.0	9.0	19.0	19.7	0.0	0.0
1620	15:43:00	0.0	11.0	18.0	18.9	0.0	0.0
1630	15:43:10	0.0	10.0	19.0	17.5	0.0	0.0
1640	15:43:20	0.0	11.0	19.0	17.7	0.0	0.0
1650	15:43:30	0.0	19.0	19.0	19.7	0.0	0.0
1660	15:43:40	0.0	18.0	19.0	19.6	0.0	0.0
1670	15:43:50	0.0	18.0	18.0	18.8	0.0	0.0
1680	15:44:00	0.0	18.0	19.0	19.0	0.0	0.0
1690	15:44:10	0.0	21.0	19.0	9.2	0.0	0.0
1700	15:44:20	0.0	20.0	18.0	9.0	0.0	0.0
1710	15:44:30	0.0	0.0	20.0	9.2	0.0	0.0
1720	15:44:40	0.0	0.0	19.0	8.9	0.0	0.0
1730	15:44:50	0.0	0.0	21.0	9.4	0.0	0.0
1740	15:45:00	0.0	0.0	18.0	9.3	0.0	0.0
1750	15:45:10	0.0	0.0	19.0	9.3	0.0	0.0
1760	15:45:20	0.0	0.0	17.0	9.8	0.0	0.0
1770	15:45:30	0.0	0.0	18.0	9.2	0.0	0.0
1780	15:45:40	0.0	0.0	18.0	9.2	0.0	0.0
1790	15:45:50	0.0	0.0	13.0	9.3	0.0	0.0
1800	15:46:00	0.0	0.0	11.0	9.2	0.0	0.0
1810	15:46:10	0.0	0.0	11.0	8.8	0.0	0.0
1820	15:46:20	0.0	0.0	10.0	9.9	0.0	0.0
1830	15:46:30	0.0	0.0	10.0	8.5	0.0	0.0

Time(s)	Actual Time	Flowmeter 1	Flowmeter 2	Flowmeter 3	Flowmeter 4	Flowmeter 5	Flowmeter 6
1840	15:46:40	0.0	0.0	10.0	8.8	0.0	0.0
1850	15:46:50	0.0	0.0	10.0	8.7	0.0	0.0
1860	15:47:00	0.0	0.0	9.0	9.1	0.0	0.0
1870	15:47:10	0.0	0.0	9.0	4.3	0.0	0.0
1880	15:47:20	0.0	0.0	10.0	0.0	0.0	0.0
1890	15:47:30	0.0	0.0	10.0	0.0	0.0	0.0
1900	15:47:40	0.0	0.0	10.0	0.0	0.0	0.0
1910	15:47:50	0.0	0.0	10.0	0.0	0.0	0.0
1920	15:48:00	0.0	0.0	10.0	0.0	0.0	0.0
1930	15:48:10	0.0	0.0	10.0	0.0	0.0	0.0
1940	15:48:20	0.0	0.0	10.0	0.0	0.0	0.0
1950	15:48:30	0.0	0.0	9.0	0.0	0.0	0.0
1960	15:48:40	0.0	0.0	10.0	0.0	0.0	0.0
1970	15:48:50	0.0	0.0	9.0	0.0	0.0	0.0
1980	15:49:00	0.0	5.0	9.0	0.0	0.0	0.0
1990	15:49:10	0.0	9.0	20.0	0.0	0.0	0.0
2000	15:49:20	0.0	10.0	18.0	0.0	0.0	0.0
2010	15:49:30	0.0	10.0	20.0	0.0	0.0	0.0
2020	15:49:40	0.0	10.0	17.0	0.0	0.0	0.0
2030	15:49:50	0.0	10.0	18.0	0.0	0.0	0.0
2040	15:50:00	0.0	9.0	19.0	0.0	0.0	0.0
2050	15:50:10	0.0	10.0	20.0	0.0	0.0	0.0
2060	15:50:20	0.0	8.0	19.0	0.0	0.0	0.0
2070	15:50:30	0.0	11.0	19.0	0.0	0.0	0.0
2080	15:50:40	0.0	10.0	18.0	0.0	3.6	0.0
2090	15:50:50	0.0	10.0	20.0	0.0	3.6	0.0
2100	15:51:00	0.0	9.0	18.0	0.0	3.7	0.0
2110	15:51:10	0.0	9.0	19.0	0.0	3.7	0.0
2120	15:51:20	0.0	10.0	18.0	0.0	3.7	0.0
2130	15:51:30	0.0	9.0	19.0	0.0	3.7	0.0
2140	15:51:40	0.0	10.0	18.0	0.0	3.7	0.0

Time(s)	Actual Time	Flowmeter 1	Flowmeter 2	Flowmeter 3	Flowmeter 4	Flowmeter 5	Flowmeter 6
2150	15:51:50	0.0	6.0	19.0	0.0	3.7	0.0
2160	15:52:00	0.0	10.0	18.0	0.0	3.7	0.0
2170	15:52:10	0.0	20.0	19.0	0.0	3.7	0.0
2180	15:52:20	0.0	18.0	20.0	0.0	3.6	0.0
2190	15:52:30	0.0	20.0	19.0	0.0	3.7	0.0
2200	15:52:40	0.0	18.0	19.0	0.0	3.7	0.0
2210	15:52:50	0.0	19.0	18.0	0.0	3.7	0.0
2220	15:53:00	0.0	21.0	20.0	0.0	3.7	0.0
2230	15:53:10	0.0	18.0	21.0	0.0	3.7	0.0
2240	15:53:20	0.0	19.0	18.0	0.0	0.0	0.0
2250	15:53:30	0.0	19.0	18.0	0.0	0.0	0.0
2260	15:53:40	0.0	18.0	20.0	0.0	0.0	0.0
2270	15:53:50	0.0	19.0	18.0	0.0	0.0	0.0
2280	15:54:00	0.0	19.0	20.0	0.0	0.0	0.0
2290	15:54:10	0.0	22.0	20.0	0.0	0.0	0.0
2300	15:54:20	0.0	18.0	20.0	0.0	0.0	0.0
2310	15:54:30	0.0	19.0	19.0	0.0	0.0	0.0
2320	15:54:40	0.0	19.0	18.0	0.0	0.0	0.0
2330	15:54:50	0.0	17.0	20.0	0.0	0.0	0.0
2340	15:55:00	0.0	19.0	18.0	0.0	0.0	0.0
2350	15:55:10	0.0	19.0	19.0	0.0	0.0	0.0
2360	15:55:20	0.0	19.0	20.0	0.0	0.0	0.0
2370	15:55:30	0.0	18.0	19.0	0.0	0.0	0.0
2380	15:55:40	0.0	18.0	20.0	0.0	0.0	0.0
2390	15:55:50	0.0	20.0	18.0	0.0	0.0	0.0
2400	15:56:00	0.0	20.0	18.0	0.0	0.0	0.0
2410	15:56:10	0.0	19.0	19.0	0.0	0.0	0.0
2420	15:56:20	0.0	20.0	17.0	0.0	0.0	0.0
2430	15:56:30	0.0	19.0	18.0	0.0	0.0	0.0
2440	15:56:40	0.0	19.0	19.0	0.0	0.0	0.0
2450	15:56:50	0.0	20.0	19.0	0.0	0.0	0.0

Time(s)	Actual Time	Flowmeter 1	Flowmeter 2	Flowmeter 3	Flowmeter 4	Flowmeter 5	Flowmeter 6
2460	15:57:00	0.0	20.0	22.0	0.0	0.0	0.0
2470	15:57:10	0.0	18.0	20.0	0.0	0.0	0.0
2480	15:57:20	0.0	19.0	19.0	0.0	0.0	0.0
2490	15:57:30	0.0	19.0	18.0	0.0	0.0	0.0
2500	15:57:40	0.0	18.0	19.0	0.0	0.0	0.0
2510	15:57:50	0.0	17.0	20.0	0.0	0.0	0.0
2520	15:58:00	0.0	18.0	18.0	0.0	0.0	0.0
2530	15:58:10	0.0	19.0	19.0	0.0	0.0	0.0
2540	15:58:20	0.0	20.0	18.0	0.0	0.0	0.0
2550	15:58:30	0.0	19.0	19.0	0.0	0.0	0.0
2560	15:58:40	0.0	17.0	18.0	0.0	0.0	0.0
2570	15:58:50	0.0	18.0	20.0	0.0	0.0	0.0
2580	15:59:00	0.0	19.0	20.0	0.0	0.0	0.0
2590	15:59:10	0.0	19.0	20.0	0.0	0.0	0.0
2600	15:59:20	0.0	19.0	20.0	0.0	0.0	0.0
2610	15:59:30	0.0	20.0	19.0	0.0	0.0	0.0
2620	15:59:40	0.0	19.0	19.0	0.0	0.0	0.0
2630	15:59:50	0.0	19.0	19.0	0.0	0.0	0.0
2640	16:00:00	0.0	20.0	18.0	0.0	0.0	0.0
2650	16:00:10	0.0	16.0	19.0	0.0	0.0	0.0
2660	16:00:20	0.0	18.0	19.0	0.0	0.0	0.0
2670	16:00:30	0.0	19.0	16.0	0.0	0.0	0.0
2680	16:00:40	0.0	17.0	19.0	0.0	0.0	0.0
2690	16:00:50	0.0	19.0	17.0	0.0	0.0	0.0
2700	16:01:00	0.0	17.0	19.0	0.0	0.0	0.0
2710	16:01:10	0.0	18.0	19.0	0.0	0.0	0.0
2720	16:01:20	0.0	18.0	18.0	0.0	0.0	0.0
2730	16:01:30	0.0	19.0	18.0	0.0	0.0	0.0
2740	16:01:40	0.0	19.0	19.0	0.0	0.0	0.0
2750	16:01:50	0.0	18.0	18.0	0.0	0.0	0.0
2760	16:02:00	0.0	19.0	19.0	0.0	0.0	0.0

Time(s)	Actual Time	Flowmeter 1	Flowmeter 2	Flowmeter 3	Flowmeter 4	Flowmeter 5	Flowmeter 6
2770	16:02:10	0.0	18.0	18.0	0.0	0.0	0.0
2780	16:02:20	0.0	18.0	19.0	0.0	0.0	0.0
2790	16:02:30	0.0	18.0	20.0	0.0	0.0	0.0
2800	16:02:40	0.0	18.0	19.0	0.0	0.0	0.0
2810	16:02:50	0.0	20.0	18.0	0.0	0.0	0.0
2820	16:03:00	0.0	19.0	20.0	0.0	0.0	0.0
2830	16:03:10	0.0	18.0	19.0	0.0	0.0	0.0
2840	16:03:20	0.0	19.0	18.0	0.0	0.0	0.0
2850	16:03:30	0.0	21.0	18.0	0.0	0.0	0.0
2860	16:03:40	0.0	18.0	18.0	0.0	0.0	0.0
2870	16:03:50	0.0	18.0	20.0	0.0	0.0	0.0
2880	16:04:00	0.0	21.0	19.0	0.0	0.0	0.0
2890	16:04:10	0.0	20.0	18.0	0.0	0.0	0.0
2900	16:04:20	0.0	17.0	18.0	0.0	0.0	0.0
2910	16:04:30	0.0	19.0	18.0	0.0	0.0	0.0
2920	16:04:40	0.0	20.0	19.0	0.0	0.0	0.0
2930	16:04:50	0.0	19.0	21.0	0.0	0.0	0.0
2940	16:05:00	0.0	19.0	21.0	0.0	0.0	0.0