جامعة الأمير محمد بن فهد

PRINCE MOHAMMED BIN FAHAD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

Fall 2019/2020

Senior Design Project

Adaptive Fountain Jet Using Fast Servo and Proximity Measurement

In partial fulfilment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

Team 15

Team members

	Student's name	Student's ID
1	Turki Almuhaisen	201302653
2	Abdulmohsen Alrajhi	201402969
3	Abdullah Alhumaidi	201403495
4	Mohammed Alkhalifa	200801097
5	Abdullah Khan	201600220

Project advisors:

Advisor Name: Dr. Nassim Khaled

Abstract

The project is an Adaptive Fountain Jet Using Fast Servo and Proximity Measurement. In this project, we have a water pump that will propulsion the water into six nozzles, and then it will launch the water into the tank through the receiving system to recycling the water. The nozzles will be connected by a fast servomotor to verify the angle. The main purpose of this project is to design a smart fountain jet that will read the movement of the people when they across the fountain. By using a control system, we will have a six smart fountain that will move independently. However, this project is about the entertainment field, which is one of the factors that represent the Kingdom's Vision 2030.

Acknowledgment

First, we would like to express our appreciation to our advisor Dr. Nassim Khaled for his continued support for our project and his sincere encouragement. In addition, we express our sincere thanks to our co-advisor Dr. Aalim Motasim for sharing his expertise and guidance. We would like to extend our thanks and appreciation to Dr. Faramarz Djavanroodi, chair of the Mechanical Engineering Department at PMU, for his continued encouragement. Lastly, we thank our parents for the unceasing encouragement, support, and attention.

List of Acronyms

Symbols	**Definition**
m	Mass Flow Rate
ρ	Density of the Fluid
v	Flow Velocity
A	Cross-Sectional Area
v	Mean Velocity of the Flow
D	Inside Diameter of the Pipe
μ	Dynamic Viscosity of the Fluid

List of Tables

List of figures	*Page*

Table of contents

Chapter 1: Introduction

1.1 Project Definition

Water fountains have been used for thousands of years for climate control, beautification, entertainment, and as a means for relaxation. These fountains elegantly combine engineering and artistic features. Our project is about Adaptive Fountain Jet Using Fast Servo and Proximity Measurement, where the project is mainly related to the entertainment field. Also, this project contains many mechanical ideas that need to be worked and realized on the ground. So, the most prominent of these ideas is how to determine the level of flow and whether it is laminar flow or turbulent flow. This determination depends on pump power, speed of servo motor, and outer flow of nozzles and how to use the equation to find accurate calculations. Furthermore, we need to pay attention to the projectile motion of water that comes out of the nozzles and use equations which ensure that the water reaches the cones accurately. The design of the cones is very important because it helps in receiving the largest amount of water and its flow into the tank. So, this helps in the balance between the water entering the tank and the water coming out of the tank. Finally, we chose this project because it is related to an important sector in the Kingdom which is entertainment and change from the traditional projects that revolve around the industrial field.

1.2 Project Objectives

The main important objectives in this project are:

1- Design a modern technology based fountain system.

2- Smart fountain system consider as an entertainment project and this is achieve the kingdom's vision 2030, which has five factors and the entertainment is one of these factors.

3- To learn how to use theoretical knowledge in practical application.

4- Main component of fountain jet system: pump, nozzle, servomotor, and control system.

1.3 Project Specification

The project is smart fountain and it is used in many places as an entertainment gate. Adaptive Fountain Jet Using Fast Servo and Proximity Measurement have been selected for this project which has the specifications listed in table 1.1. Also, we have used a Submersible Pump to push the water into Pipes by the givens in tables 1.2.

Table 1.3: The System Measurement.

Item	Size
Outer diameter of Nozzle	0.24 m
Pipe length	7 m
The volume of tank	200 L
Number of nozzles	4
Number of cones	4

Table 1.3(a): The Output of the Electrical Pump.

Maximum output power	0.42 KW

Chapter 2: Literature Review

2.1 Project Background

The history of fountains in our world goes back thousands of years. Moreover, the first to build fountains in ancient times are the Greeks and represented in their gods. Therefore, it was a complex idea that relied on the movement of waterfalls. Then came the golden age in which the Romans built fountains with a more complex system. Also, the world's most famous fountains were built between the 17th and 18th centuries. In modern times came electronic fountains, which include sounds and lighting.

2.2 Mechanical Part

2.2.1 Submersible Pump:

Nowadays submersible pumps are widely used in industrial and homes, duo to their high reliability and versatility. They are immersed fully in the water and do not need priming. In submersible pumps the water is pushed rather than pulled. They are efficient and safe from cavitation problem, which prevent bubbles to occur. The submersible pump is a centrifugal pump, which diverts the movement of water to outwards by using the impellers. The blades of impellers are curved backward. There is a single shaft inside connected with multiple impellers. This shaft is driven by an induction motor, which make the water driven into the eyes of the impellers. Because of the centrifugation action, the impellers are then radially thrown out. By doing this, the water will be pressurized and ready to pass to the next impeller efficiently by using a diffuser. This is one the most features of submersible pump that produces high pressure. After multiple impellers, water passes through an inbuilt inline check valve. This is trying to reduce the issue of hammer water. Through this process, the induction motor will heat up, and to cool it down we use water or filled oil.

Figure 2.1: Submersible pump

In this project, we studied the situation and found that the appropriate power of the pump is 7.5 kW. The pump is made of cast iron instead of stainless steel due to high cost and time of use.

2.2.2 Nozzle

As we know the nozzle is one of the studies of engineering devices in thermo fluids. It has a shape of convergent, which one big inlet and one small outlet. The volume of mass that enter the nozzle is equal to volume of mass that exit from it, which mean the mass is constant. There is opposite relationship between the velocity and diameter of the nozzle as it shown below in figure 2.1.2.

$$\dot{m} = \rho \quad (1)$$

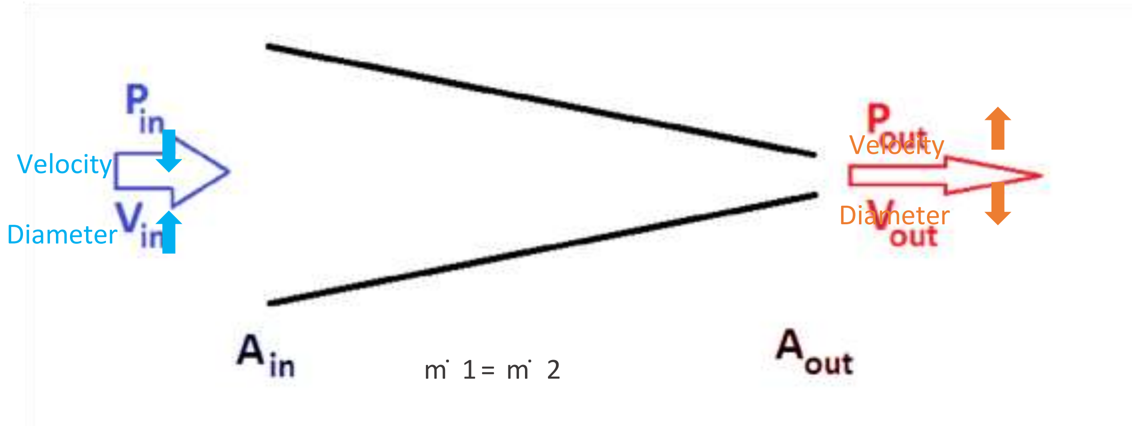

Figure 2.2: velocity & Diameter Relation in Nozzle

We will have in this project 6 nozzles to create an attractive view in public area. Water comes out as a wave and people can pass through it without getting wet.

2.2.3 Servo Motor

Servo motor is part of a closed loop system, which is contained of several parts such as a control circuit, servo motor, potentiometer, shaft, amplifier, drive gears and either a resolver or encoder. The basic function of the servo motor is to rotate parts of the machine efficiently at high speed. It works electrically. It is equipped with sensors and move automatically according to the data programmed inside the encoder. The servo motor can be moved in two dimensions or in a linear way.

In our project, nozzles and servo motors combined together as it shown in figure 2.1.3. It moves in one axis and it take one second to shift from 0 to 90 degrees. The speed of the servo motors is the most important requirement in our project.

Figure 2.2(a): Nozzle and servo motor device

2.2.4 Pipes Flow

There are two types of fluids flow in pipes. The first one is called laminar flow which involves smooth streamlined and highly ordered molecules (figure 4). The second one is turbulent flow which involves lot velocity fluctuations between the molecules within the pipe or stream line and high disordered (figure 5). To determine whether something is to be laminar or turbulent, we can use the Reynolds number (Re).

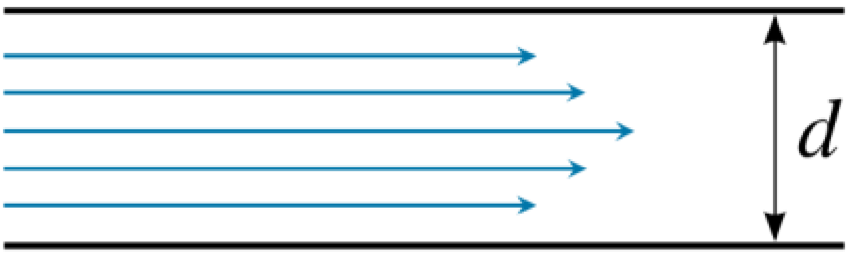

Figure 2.2(b): Laminar flow in the pipe

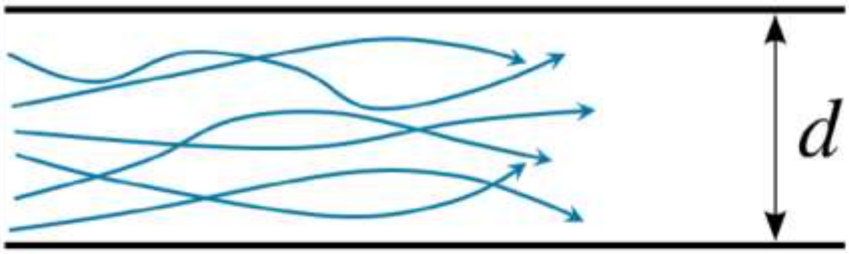

Figure 2.2(c): Turbulent flow in the pipe

$$Re = \frac{\rho v D}{u} \quad (2)$$

$Re \leq 2300$ → Laminar

$2300 \leq Re \leq 10{,}000$ → transition

$Re \geq 10{,}000$ → Turbulent

Our goal is to achieve the laminar flow by reducing "Re" value. We can control the flow to be laminar by changing the velocity of the fluid or the diameter of the pipe.

2.3 Simulations Modelling

With the rise of computers, simulation models have emerged beside the more traditional statistical and mathematical models as a third pillar for ecological analysis. Broadly speaking, a simulation model is an algorithm, typically implemented as a computer program, which propagates the states of a system forward. We prefer to take our data from simulation modelling to be more accurate and to run our system before pay the parts. Our project modelling seen in figure 6).

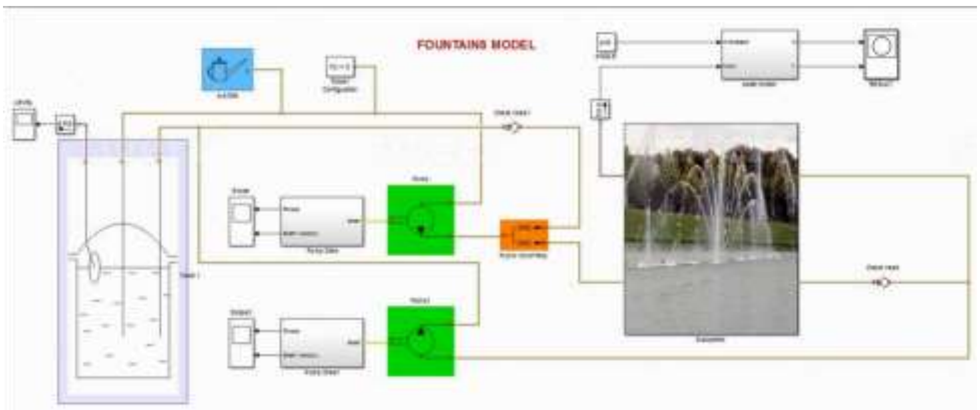

Figure 2.3: Project Modelling.

2.4 Control System

Control is used to modify the behaviour of a system so it behaves in a specific desirable way over time. For example, we may want the speed of a car on the highway to remain as close as possible to 60 miles per hour in spite of possible hills or adverse wind; or we may want an aircraft to follow a desired altitude, heading, and velocity profile independent of wind gusts; or we may want the temperature and pressure in a reactor vessel in a chemical process plant to be maintained at desired levels. All these are being accomplished today by control methods and the above are examples of what automatic control systems are designed to do, without human intervention.

Control is used whenever quantities such as speed, altitude, temperature, or voltage must be made to behave in some desirable way over time. To design a controller that makes a system behave in a desirable manner, we need a way to predict the behaviour of the quantities of interest over time, specifically how they change in response to different inputs. Mathematical models are most often used to predict future behaviour, and control system design methodologies are based on such models. Understanding control theory requires engineers to be well versed in basic mathematical concepts and skills, such as solving differential equations and using Laplace transform.

The role of control theory is to help us gain insight on how and why feedback control systems work and how to systematically deal with various design and analysis issues. Specifically, the following issues are of both practically important and theoretically interesting:

1. Stability and stability margins of closed-loop systems.
2. How fast and smooth the error between the output and the set point is driven to zero
3. How well the control system handles unexpected external disturbances, sensor noises, and internal dynamic changes.

Moreover, the main task of the control system is to drive the angle of the nozzles based on proximity. The input to the control system is the measurement of the proximity sensors (we propose 3). The output is the angle command (PWM- pulse width modulation) sent to the RS485 communication boards. These boards drive are connected to the controller of the servomotor of the nozzle.

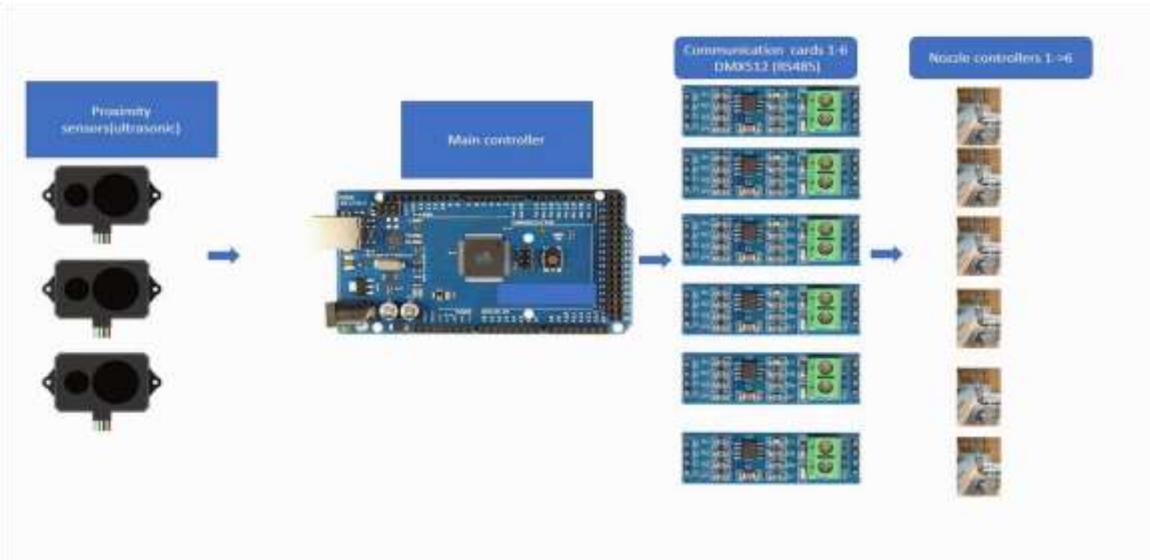

Figure2.4: Parts of the Control

As figure 8 shows, the proposed layout for the 3 proximity sensors. Their intent is to measure the location of the people with respect to the water nozzles 1 through 6.

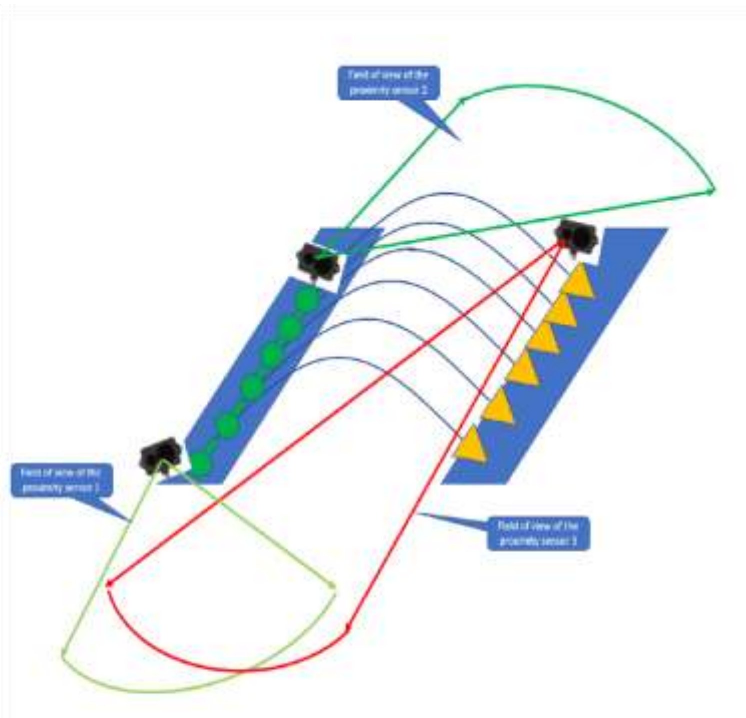

Figure 2.4(a): Dr. Nassim design

Chapter 3: System Design

3.1 Design Constraints and Design Methodology

3.1.1: Geometrical Constraints

We have faced many challenges in this project in several things such as lack of equipment in the local market and the quality required to operate the project with high efficiency. The first problem we encountered was finding the pump and the ability to pump water to six nozzles and a height of at least two and a half meters. The second problem that took a long time is finding a high-speed servo motor to lift the nozzle, what we found here in Saudi Arabia and even some international websites is a slow-moving servo motor, which will not achieve satisfactory results. When a person approaches to cross from under the fountains, the Arduino sends commands to the sensor attached to the servo motor to rise 45 degrees approximately. This process should be quick so that the person does not get wet when crossing. What we found is a nozzle and a servo motor in one part, which moves in one axial direction in one second from 0 to 90 degrees, and that's enough to run it professionally.

3.1.2 Sustainability

We have many challenges in this project for the sustainability issue because of the chance of getting corrosion. Water will pass through all the equipment used in our projects such as pump, pipe, and nozzles, which are all made of steel or cast iron. As known that water is a catalyst for corrosion. To prevent the problem, we might use a coating on the metal components to protect the project for a long life. Furthermore, we need to save the amount of water used in this project from the nozzle (inlet) until it reaches the cone (outlet) exactly with no loss of water. We can fix this issue by generating a laminar flow of water to prevent sprinkles. The velocity and cross-section area of the exit is the key to converting water characteristic.

3.1.3 Environmental

In our system, there is no combustion. We rely on electricity to generate power for the submersible pump, sensors, and lights. Water is the main factor in our project so there will be no pollution to the environment. In addition, we must clean it or use chemicals so as not to contaminate.

3.1.4 Social

This system can be used in places where people gather, such as shopping malls, parks, and compounds. It provides a majestic view and increases the fun for anyone who passes through it. When the person approaches it, the nozzle rises and the water rises as well, and when he comes out, the nozzle goes down slowly.

3.1.5 Economic

On the economic side, in this system, we use one source of energy: the electric power of the submersible pump to exert direct pressure through the pipes. Although the submersible pump is expensive compared to other types, according to data that we need in this project, it is considered the most efficient. The power of the pump used in this project is 7.5 kW. The cost of electricity consumption in Saudi Arabia is about 18 halals per kilowatt-hour. If we run it for ten hours a day, it will cost us 54 riyals per month. The project is semi-economic in the long run.

3.1.6 Safety

For safety issues, we must take care of any electrical source to keep it away or cover it up since we are dealing with water all the time. Moreover, Water should be permanently altered or treated with chemicals such as chlorine to protect parts from corrosion and filter them from dirt and dust.

3.1.7 Ethical

We just improved this system and combine the previous works which are dancing fountain and Residential fountain, and we used the control system to be adaptive fountains. I think this project will be a kind of future entertainment that interacts with people.

3.2 Engineering Design Standards

Engineering standards should be followed in each component of our system. In this section, we described each component that has been selected for our project. The selected components are the following; PVC Pipe and Submersible pumps. PVC pipe standards are instrumental in identifying, testing and evaluating the physical, mechanical, design, and structural requirements of plastic, polymeric or flexible pipes, tubes, and fittings, including seals, yarns, and joints that connect them. These products are intended for use in high-pressure storage vessels, water distribution systems, Fountains system, drainage systems, drainage fields and septic tanks, sewer repair, and existing channels. Submersible pumps are a type of centrifugal pump that can be installed under the water body. This standard provides minimum requirements for submersible vertical turbine pumps utilizing a discharge column pipe assembly for installation in wells, water treatment plants, water transmission systems, and water distribution systems.

Table 3.1: Engineering Standards

Components	Engineering Standards
PVC Pipe	ASTM D1785
CPVC Pipe	ASTM F441
Submersible Pumps	API & ISO 16330:2003
Sensor	SJ-GU-TFmini-01
Arduino	ATmega2560

3.2.1 PVC Pipe:

D=200mm

L=7m

t=50mm

3.2.2: Submersible pumps:

D=200mm

Power= 0.43kw

Head height= 18m

3.3 Theory and Theoretical Calculations

3.3.1 Water Fountain Performance

The performance of our project depends on two parts. The first one is the speed of the system's response to people's movement, which related to the control system. The second one is the amount of flow rate, see equation 3.1 for the volume flow rate. Volume flow rate and the power which is reversely proportional to the density, gravity g, and height changing.

$$Q = \frac{P}{\rho g \Delta H} \qquad (3.1)$$

3.3.2 Water Fountain Analysis

The pump will push the water through the nozzles to increase the velocity of the water to reach a specific point. Three displacement sensors will read the movement of the people two sensors for the right and left the side and the third one for the inside region. The ultrasonic sensors read the movement then send a command to the Arduino to change the angle of the nozzles, which will allow people to walk through.

For the required data for calculation, see equation 3.2 for the projectile motion for the height, equation 3.3 for the projectile motion for the range, equation 3.4 Reynolds number.

$$H = \frac{v^2 (sin\theta)^2}{2g} \qquad (3.2)$$

Where, **H** is the height, **V** is the velocity, **g** is the gravity force, $\boldsymbol{\theta}$ is the angle.

$$R = \frac{v^2 (sin2\theta)}{g} \qquad (3.3)$$

Where, **R** is the range, **V** is the velocity, **g** is the gravity force, $\boldsymbol{\theta}$ is the angle.

$$R_e = \frac{\rho VL}{\mu} \qquad (3.4)$$

Where, **Re** is the Reynolds number, **ρ** is the density of the fluid, **V** is the velocity of the fluid, $\boldsymbol{\mu}$ is the viscosity of fluid, and **L** is the length or diameter of the fluid.

3.3.3 Result

First, we apply the projectile motion equations to find the final design of the project. Through these equations, we had the velocity and the range of the fountain. Also, the place of the cone part.

$\boldsymbol{H_f = 3m}$ **,** $\boldsymbol{\theta_f = 60°}$**,** $\boldsymbol{\theta_i = 30°}$

Step 1: Using equation 3.2 to find the outer velocity of the nozzle **V:**

$$3 = \frac{V^2 (sin(60))^2}{2 * 9.81}$$

$$\boldsymbol{V = 8.86\, m/s}$$

Step 2: Using equation 3.2 to find initial **H (V=8.86 m/s,**$\boldsymbol{\theta_i = 30°}$**):**

$$H = \frac{(8.86)^2 (sin(30))^2}{2 * 9.81}$$

$$\boldsymbol{H = 1\, m}$$

Step 3: Using equation 3.3 to find the range **R:**

$$R = \frac{(8.86)^2(sin2(30))}{9.81}$$

$$\boldsymbol{R = \ 6.93\ m}$$

Moreover, since our project depends on the control system, we have a code for programming the project. Also, for the Reynolds number, we are still working on the calculations and this part will come when we have the exact numbers.

3.4 Product Subsystem and Selection of Components

As seen in Figures 3.1 and 3.2, some parts have CAD drawings. For figure 3.1 we can see the base of the pipe, which carries out the pipe and the nozzles. For figure 3.2, we can see the water tank that will provide the pump.

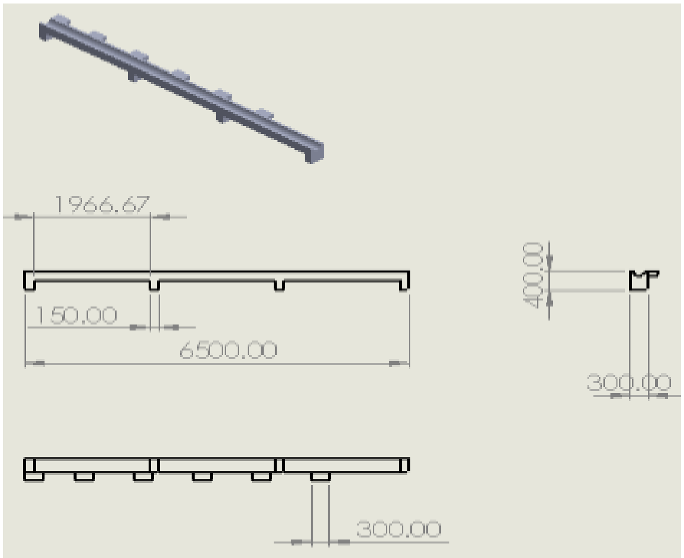

Figure 3.4: CAD drawing for the base

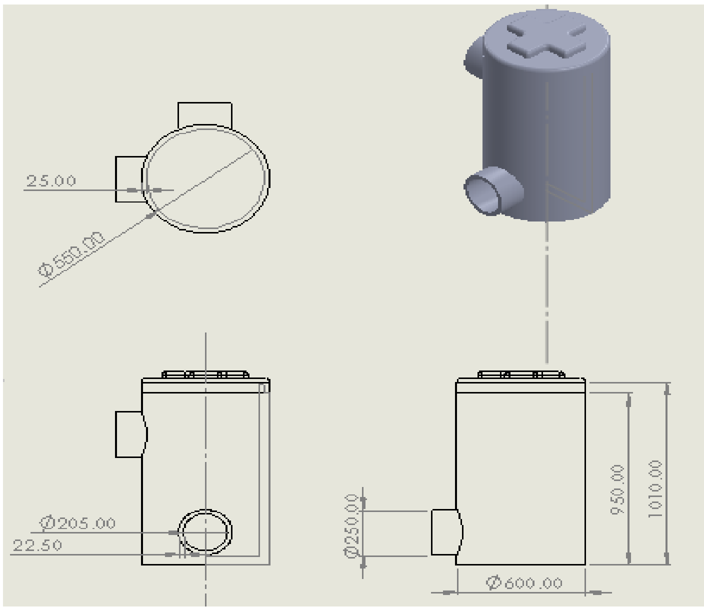

Figure 3.4(a): CAD drawing for the water tank.

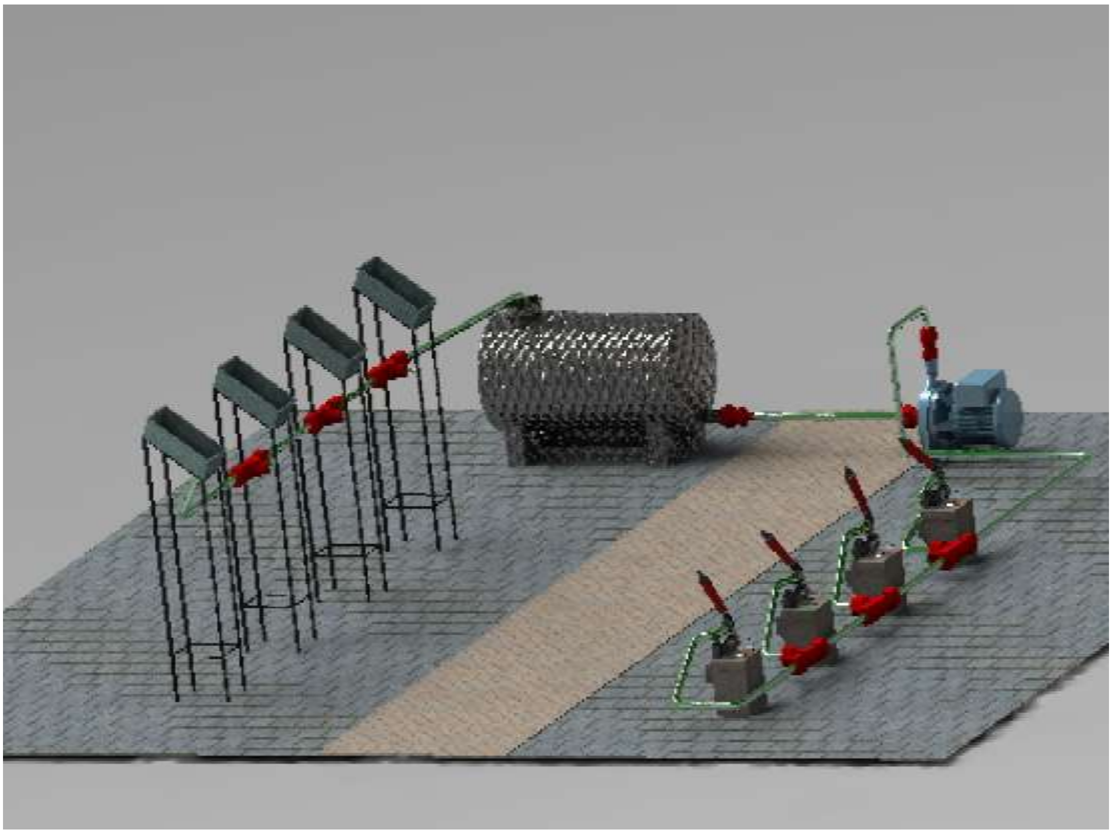

Figure 3.4(b) CAD Model of Adaptive Fountain Jet

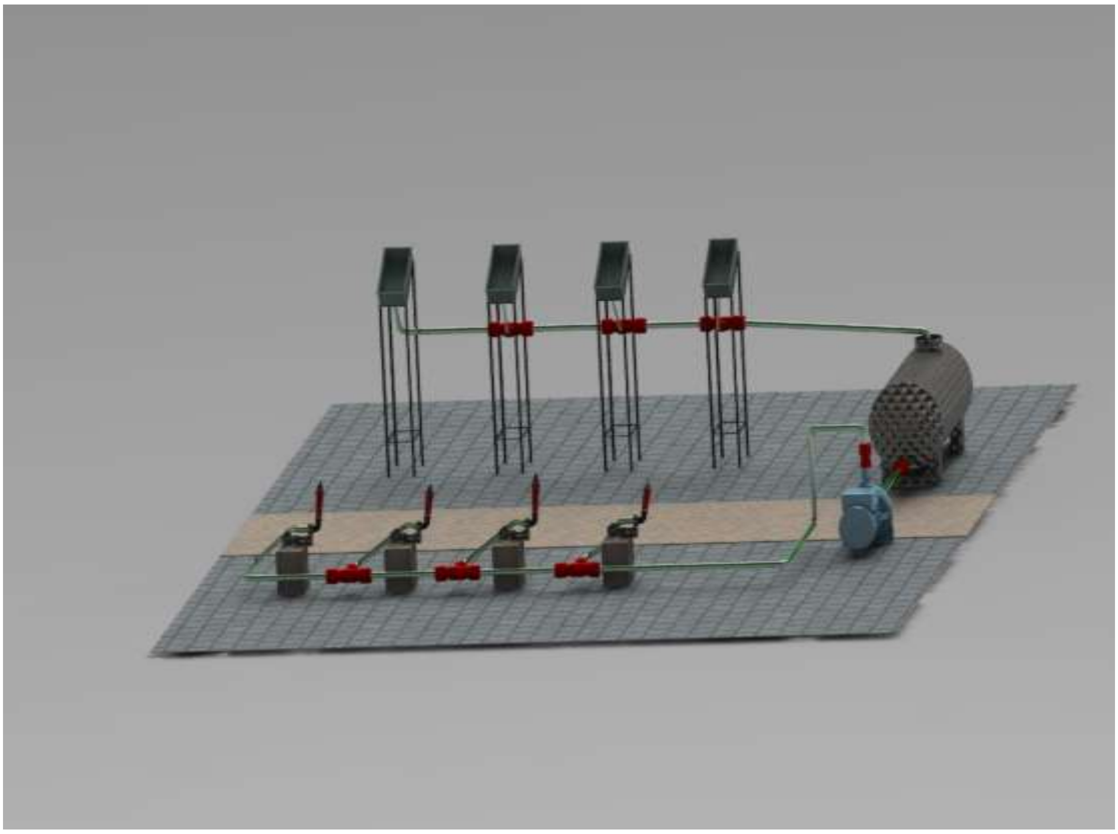

Figure 3.4(c): CAD Model of side view of Adaptive Fountain Jet

Chapter 4: System Testing and Analysis

4.1 Experimental setup, sensors and Data Acquisition System

4.1.1 Proximity Sensor

Ultrasonic proximity sensors are a common type of proximity sensor used in many manufacturing and automation applications. Ultrasonic sensors work by using sound frequencies higher than the audible limit of human hearing (around 20 kHz), which is typically in the range of 25 to 50 kHz. A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact.

A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between the sensor and the sensed object.

Proximity sensors are used in our project of design of adaptive fountain jet using fast servo and proximity measurement to collect the exact data during the performance of the fountain jet.

Table 4.1: Specifications of sensor

Product Name	**TFmini**
Operating range	0.3m-12m
Maximum Operating range at 10% reflectivity	5m
Average power consumption	0.12w
Applicable voltage range	4.5V-6V
Minimum Resolution Ratio	5mm
Test Frequency	100Hz
Test accuracy	1%(less than 6m), 2%(6m-12m)
Distance detection unit	mm
Operating Center Wavelength	850mm
Size	42mm x 15mm x 16mm
Operating Temperature	-20C-60C
Anti-Ambient Light	70,000lux

Weight	6.1g

4.2 Results, Analysis and Discussions

First of all we found the inlet velocity of the nozzle for this we used the following equation .To find the inlet velocity of the nozzle we applied continuity equation:

(Inlet velocity for one nozzle)

$$A_i V_i = A_o V_o \qquad \rightarrow \qquad V_i = V_o(\frac{A_o}{A_i})$$

$$V_i = 8.04 * \left(\frac{\frac{\pi}{4}(0.5*0.0254)^2}{\frac{\pi}{4}(1.5*0.0254)^2}\right) = 0.893 \ m/s$$

Now this is the inlet velocity for one nozzle and we have used 4 nozzles in our setup that will be calculated accordingly. Then to find that how much water at this above calculated velocity is being flow at a particular rate we used **Q = A x V.** So the volumetric flow rate for the inlet of the nozzle**:**

$$Q = A * V = \frac{\pi}{4} * (1.5 * 0.0254)^2 * 0.893 = 1.018 * 10^{-3} \, m^3/s$$

Now calculating total flow rate for four nozzles

$$Q_t = Q * 4 = 1.018 * 10^{-3} * 4$$

$$Q_t = 4.072 * 10^{-3} \ m^3/s \ = 14.66 \, m^3/hr$$

Velocity was calculated in both scenarios before attaching the pump to setup and also after attaching the pump to setup to have good comparison based on facts and figures and rather than assumptions.

Velocity before the pump

$$V = \frac{Q}{A} = \frac{4.072 * 10^{-3}}{\frac{\pi}{4}(1 * 0.0254)^2} = 8.04 \, m/s$$

Velocity after the pump

$$V = \frac{Q}{A} = \frac{4.072 * 10^{-3}}{\frac{\pi}{4}(1.5 * 0.0254)^2} = 3.57 \, m/s$$

Head losses

Now after calculating the velocity we found out the head losses since we have four major flow lines which are as follows

1- The pipe after the tank.

2- The pipe after the pump.

3- The inlet flow of the nozzle

4- The outlet flow of the nozzle

$$H_L = H_{major} + H_{minor}$$

Now Applying Reynolds Number to determine the fluid state (old design)

$$Re_1 = \frac{\rho VD}{\mu} = \frac{1000*12*1*0.0254}{8{,}90*10^{-4}} = 342{,}471.9 \quad (Turbulent)$$

$$Re_2 = \frac{\rho VD}{\mu} = \frac{1000*5.33*1*0.0254}{8{,}90*10^{-4}} = 228{,}171.9 \quad (Turbulent)$$

$$Re_3 = \frac{\rho VD}{\mu} = \frac{1000*0.893*1*0.0254}{8{,}90*10^{-4}} = 38{,}228.4 \quad (Turbulent)$$

$$Re_4 = \frac{\rho VD}{\mu} = \frac{1000*8.04*1*0.0254}{8{,}90*10^{-4}} = 229{,}456.18 \quad (Turbulent)$$

Apply Reynolds Number to determine the fluid state (new design)

$$Re_1 = \frac{\rho VD}{\mu} = \frac{1000 * 8.04 * 1 * 0.0254}{8{,}90 * 10^{-4}} = 229{,}456.18 \quad (Turbulent)$$

$$Re_2 = \frac{\rho VD}{\mu} = \frac{1000 * 3.75 * 1 * 0.0254}{8{,}90 * 10^{-4}} = 107{,}022.48 \quad (Turbulent$$

$$Re_3 = \frac{\rho VD}{\mu} = \frac{1000 * 0.893 * 1 * 0.0254}{8{,}90 * 10^{-4}} = 38{,}228.4 \quad (Turbulent)$$

$$Re_4 = \frac{\rho VD}{\mu} = \frac{1000 * 8.04 * 1 * 0.0254}{8{,}90 * 10^{-4}} = 229{,}456.18 \quad (Turbulent)$$

Major losses faced in old design

For PVC pipes the friction value will be $f = 0.0119$

$$H_{major,1} = f\frac{LV^2}{D2g} = 0.0119 * \frac{3*8.04^2}{(1.5*0.0254)(2)(9.81)} = 3.087\ m$$

$$H_{major,2} = f\frac{LV^2}{D2g} = 0.0119 * \frac{5.26*3.57^2}{(1.5*0.0254)(2)(9.81)} = 0.61\ m$$

Head losses for the connection pipe from the main pipe to the nozzles where**:**

$$f = 0.0119\ ,\ L = 0.16\ m\ ,\ D = 1.5" * 0.0254 = 0.0381\ m$$

$$H_{major} = \sum H_{major} = 3.7577\ m.$$

Table # 4.2: showing velocity while major losses in old design

	Velocity	$\boldsymbol{H_{major} = f\frac{LV^2}{D2g}}$
1	3.57	0.0325
2	2.667	0.0181
3	1.784	0.00811
4	0.891	0.00202
Total		**0.0607**

Minor losses

$\boldsymbol{H_{minor} = K_L \frac{V^2}{2g}}$

$$H_L = H_{major} + H_{minor} = 3.7577 + 2.3726 = 6.13m$$

$$P_i + \frac{1}{2}\rho V_i^2 + \rho g z_i + H_P = P_o + \frac{1}{2}\rho V_o^2 + \rho g z_o + \rho g H_L$$

$$\Delta P = \frac{1}{2}\rho\left(V_i^2 - V_o^2\right) + \rho g(z_i - z_o) + \rho g(H_P - H_L) \quad ,$$

where $\boldsymbol{\Delta P = 0}$, $\boldsymbol{V_i = 0}$

$$H_p = \frac{0.5(-8^2) + g(1-0.4) + gH_L}{g} = 9.99\ m$$

$$\Delta P_{pump} = \rho g H_P = 1000 * 9.81 * 9.99 = 98.001\ KPa$$

$$Power = \Delta P_{pump} * Q = 95.058 * 4.072 * 10^{-3} = 0.399\ KW$$

Table # 4.2(a): friction factor at different points in the setup

Type	Friction factor K_L		H_{minor}
Ball Valve	0.05	full open	0.1647 m
Elbow 90°	0.9	threaded	0.878 m
Tea	2	branch flow	0.2439 m
	0.9	line flow	0.826 m
Nozzle	0.02	θ = 30°	0.260 m
Total			**2.3726 m**

Major losses new design

For PVC pipes the friction value will be $f = 0.0119$

$$H_{major,1} = f\frac{LV^2}{D2g} = 0.0119 * \frac{3*8.04^2}{(1*0.0254)(2)(9.81)} = 4.63\ m$$

$$H_{major,2} = f\frac{LV^2}{D2g} = 0.0119 * \frac{5.26*3.57^2}{(1*0.0254)(2)(9.81)} = 1.61\ m$$

Head losses for tubes after the splitter, where:

$$f = 0.0119\ ,\ V = 0.893\ m/s\ ,\ D = 1" * 0.0254 = 0.0254\ m$$

$$H_{major} = \sum H_{major} = 6.324\ m.$$

Table # 4.2(b): Major losses at different lengths

	Length	$H_{major} = f\frac{LV^2}{D2g}$

1	1.5	0.0286
2	0.7	0.0133
3	0.7	0.0133
4	1.5	0.0286
Total		**0.0838 m**

Minor losses

$\boldsymbol{H_{minor} = K_L \frac{V^2}{2g}}$

$$H_L = H_{major} + H_{minor} = 6.324 + 0.4613 = 6.79m$$

$$P_i + \frac{1}{2}\rho V_i^2 + \rho g z_i + H_P = P_o + \frac{1}{2}\rho V_o^2 + \rho g z_o + \rho g H_L$$

$$P = \frac{1}{2}\rho\left(V_i^2 - V_o^2\right) + \rho g(z_i - z_o) + \rho g(H_P - H_L)$$, where $\Delta P = 0,\ V_i = 0$

$$H_p = \frac{0.5(-8^2) + g(1-0.4) + gH_L}{g} = 10.65\ m$$

$$\Delta P_{pump} = \rho g H_P = 1000 * 9.81 * 9.99 = 104.495\ KPa$$

$$Power = \Delta P_{pump} * Q = 95.058 * 4.072 * 10^{-3} = 0.425\ KW$$

Table # 4.2(c) showing friction and minor losses at different points

Type	**Friction factor K_L**	$\boldsymbol{H_{minor}}$
Ball Valve	0.05 full open	0.1647 m
Elbow 90°	0.9 threaded	0.0366 m
Nozzle	0.02 θ = 30°	0.260 m

Total	0.4613 m

Results

Table # 4.2(d): angle and height ratio

Angle	Height
35°	120 CM
80°	260 CM

The table shows that the angle and the height will be less when there is no one on front of the nozzles, however when someone walk in front of the nozzles the angle and the height will increase.

Chapter 5: Project Management

5.1 Project Plan

The project consists of many different tasks which were assigned almost equally to every member of our team. Each member of the team were given a benchmark and a specific time in order to successfully accomplish their part in the project for prosperous results. The following table.

Table # 5.1: Tasks and their Duration

<table>
<tr><th>S. No.</th><th colspan="2">Tasks</th><th>Start</th><th>End</th><th>Duration</th></tr>
<tr><td>1.</td><td colspan="2">Chapter # 1: Introduction</td><td>09/09/19</td><td>15/09/19</td><td>7</td></tr>
<tr><td rowspan="3">2.</td><td rowspan="3">Chapter # 2: Literature Review</td><td>Project Background</td><td rowspan="3">16/09/19</td><td rowspan="3">28/09/19</td><td rowspan="3">14</td></tr>
<tr><td>Previous work</td></tr>
<tr><td>Comparative Study</td></tr>
<tr><td rowspan="3">3.</td><td rowspan="3">Chapter # 3: System Design</td><td>Design Constraints and Design Methodology</td><td rowspan="3">16/09/19</td><td rowspan="3">26/09/19</td><td rowspan="3">10</td></tr>
<tr><td>Engineering Design Standards</td></tr>
<tr><td>Theory & Theoretical Calculations</td></tr>
</table>

		Product Subsystems & Selection of Components			
		Manufacturing & Assembly			
4.	Chapter # 4: System Testing & Analysis	Experimental Setup, Sensors and Data	20/12/19	28/12/19	**7**
		Results, Analysis & Discussions			
5.	Chapter # 5: Project Management	Contribution of team Members	01/01/20	06/01/20	5
		Project Execution Monitoring			
		Challenges and Decision Making			
		Project Bill of Materials and Budget			
6.	Chapter # 6: Project Analysis	Impact of Engineering Solution	10/01/20	13/01/20	2
		Contemporary Issues Addressed.			
7.	Chapter # 7: Conclusion & Recommendation	Conclusion	15/01/20	16/01/20	1
		Future Recommendation			
8.	Design of Prototype		27/09/19	02/10/19	5
9.	Parts Purchase		05/10/19	07/12/19	3

10.	Manufacturing	05/12/19	23/12/19	14
11.	Testing	16/01/20	16/01/20	1

Table # 5.1 (a): Assigned Members for Tasks

S. No.	*Task*	*Assigned Members*
1.	Chapter # 1: Introduction	Abdul Mohsen
2.	Chapter # 2: Literature Review	Abdullah Khan & Mohammed
3.	Chapter # 3: System Design	Turki & Abdullah Alhumaidi
4.	Chapter # 4: System Testing & Analysis	Everyone
5.	Chapter # 5: Project Management	Abdul Mohsen
6.	Chapter # 6: Project Analysis	Abdullah Alhumaidi
7.	Chapter # 7: Conclusion & Recommendation	Abdullah Khan
8.	Design of Prototype	Everyone
9.	Parts Purchased	Turki & Mohammed
10.	Manufacturing	Everyone
11.	Testing	Everyone

5.2 Contribution of Team Members

Since our team has played a role in accomplishing the requirements for the project, each of the members contributed their amount of effort and time depending on the ability of their work and their efficiency. The table below depicts about how much contribution was made by each team member:

Table # 5.2: Contribution of Tasks

S. No.	*Tasks*		*Assigned Member*	*Contribution*
1.	**Chapter # 1: Introduction**		Abdul	100 %
2.		Project Background	Abdullah. K	50 %

<table>
<tr><td></td><td>Chapter # 2: Literature Review</td><td>Previous work</td><td>Mohammed</td><td>50 %</td></tr>
<tr><td rowspan="5">3.</td><td rowspan="5">Chapter # 3: System Design</td><td>Design Constraints and Design Methodology</td><td>Turki</td><td>20 %</td></tr>
<tr><td>Engineering Design Standards</td><td>Turki</td><td>20%</td></tr>
<tr><td>Theory & Theoretical Calculations</td><td>Abdullah A</td><td>20 %</td></tr>
<tr><td>Product Subsystems & Selection of Components</td><td>Abdullah A</td><td>20 %</td></tr>
<tr><td>Manufacturing & Assembly</td><td>Both</td><td>20 %</td></tr>
<tr><td rowspan="2">4.</td><td rowspan="2">Chapter # 4: System Testing & Analysis</td><td>Experimental Setup, Sensors and Data</td><td rowspan="2">Everyone</td><td rowspan="2">100%</td></tr>
<tr><td>Results, Analysis & Discussions</td></tr>
<tr><td rowspan="4">5.</td><td rowspan="4">Chapter # 5: Project Management</td><td>Contribution of team Members</td><td rowspan="4">Abdul Mohsen</td><td rowspan="4">100%</td></tr>
<tr><td>Project Execution Monitoring</td></tr>
<tr><td>Challenges and Decision Making</td></tr>
<tr><td>Project Bill of Materials and Budget</td></tr>
<tr><td rowspan="2">6.</td><td rowspan="2">Chapter # 6: Project Analysis</td><td>Impact of Engineering Solution</td><td rowspan="2">Abdullah A</td><td rowspan="2">100%</td></tr>
<tr><td>Contemporary Issues Addressed.</td></tr>
<tr><td rowspan="2">7.</td><td rowspan="2">Chapter # 7: Conclusion & Recommendation</td><td>Conclusion</td><td rowspan="2">Abdullah K</td><td rowspan="2">100%</td></tr>
<tr><td>Future Recommendation</td></tr>
<tr><td>8.</td><td colspan="2">Design of Prototype</td><td>Everyone</td><td>100%</td></tr>
<tr><td>9.</td><td colspan="2">Parts Purchase</td><td>Turki & Mohammed</td><td>100%</td></tr>
<tr><td>10.</td><td colspan="2">Manufacturing</td><td>Everyone</td><td>100%</td></tr>
</table>

11.	**Testing**	Everyone	100%

5.3 Project Execution Monitoring

In order to avoid any hurdles or distractions and to keep the project developing step by step, we had meetings to attend with team members and with the supervisor and advisor as well. Whereas all these efforts of meeting and discussion could not accomplish and proved to be secondary as we faced issues during the ordering and receiving of the ordered material as it took month to get hold of ordered parts of prototype. Along with these issues held our meetings on time as we had to submit initial stage reports and midterm presentations and all of these were managed and executed on time.

Table #5.3: Dates of Activities and Events

Time/Date	***Activities/Events***
Once in week	Assessment Class
Bi-Weekly	Meeting with the group members
Weekly	Meeting with the Advisor
13th January, 2020	First Finished Prototype
14th November, 2019	Midterm Presentation
14th January, 2020	First Test of System
20thJanuary, 2020	Finishing Final Prototype
21st January, 2020	Test of the System
03th February, 2020	Final Submission of Report
03th February, 2020	Final Presentation

5.4 Challenges and Decision Making

Working on project is usually a challenging task to get everything right and to deliver on time. Initial challenges were faced at the time of designing the prototype. But we kept our minds open and listen to each other's opinion and also sought guide from our advisor. After doing some research on internet and in the market that which type is achievable we decided mutually to do the project on the adaptive fountain jet using fast servo and proximity measurement. Another major problem faced by us was delay in getting the delivered items on as it took almost two month when we received our ordered parts and materials from the Saudi port.

5.4.1: Equipment and Device Problems

Pump

Since our whole setup depends on the pump as our prototype requires water to be flowed at a certain pressure and speed. At first in the designing phase we were using displacement pump and we ordered the desired pump from some Chinese company online but when the pump was delivered it was submersible pump so to avoid any further delays by sending it back and asking for the right one we decided to go with what we have received and it turned out to be so well.

5.4.2: Testing and Safety Issues

Our system requires electric supply to function as designed and our setup also involves water so during the control system testing we used isolation boxes in case of any problem with electricity. Also we used wooden base for the nozzle to protect it from being earthed and cause any unwanted electrical disturbances.

5.5 Project Bill of Materials and Budget

Project requires investment of time, effort and money. Similarly we had to spend money in order to purchase materials and parts for the constructions of the prototype. Our setup proved to be very expensive and is not at all ideal for individuals as it incurs more cost then the benefits it provides. Following table shows the prices of the materials and the total cost incurred in Saudi Riyal.

Table # 5.5: Project Bill

Materials	**Pcs**	***Cost (SAR)***
Simulation Modelling		590.6
Pump-cast Iron		1462.5
Centrifugal Pump		420
1d digital nozzle and motor	6	8100
Wooden case	1	375
Light –stain steel	12	810

Arduino	2	300
Communication part	6	54
TF-mini Sensor	3	505.68
Ultrasonic sensor		120
cone	6	200
Base of the cone	6	1030
Nozzle’s base		900
Nozzle’s fitting	6	90
Pipes (PVC))		250
Fitting		75
Wires		110
Transformer		1260
Transformer’s wires		90
Tank		200
Shipping		6897
Total		**23,839.78**

Chapter 6: Project Analysis

6.1 Life Long Learning

While working on our project of making an Adaptive Fountain Jet using fast servo motor and Arduino to set achievable goals was our first priority. We worked on our project as a team and we made sure that each member should have ostensible knowledge on the subject. Proper research was conducted regarding execution of the design before starting our project. According to the pre-planned assessment we tried our best to utilize proper equipment for a research. Trial and error method was use. We learned from our mistakes and blunders throughout the process and the outcome turned out to be exceptional.

6.1.1: Software Skills:

In beginning when we started our project we researched online websites regarding fast servo motor and Arduino to familiarize ourselves that which designs are available in market and how can we made improvements. Then we designed our project by finding all restraints and started doing simulations. With the help of the Arduino and servo motor we were actually able to solve all the problems effortlessly and on time regarding the Adaptive Fountain Jet.

6.1.2: Hardware Skills:

Simple and straightforward hardware skills were used for our project. For manufacturing purpose the best and suitable parts were used for our engineering standards. We used proper guidance to install the submersible pump in our setup as initially we had displacement pump in or model. The team was professionally provided with database to support hardware system in operating system.

6.1.3: Time Management:

During working on project one of the main challenges for the team was to manage time. At first it seems stress-free because water fountains have been used for thousands of years for climate control, beautification, entertainment, and as a means for relaxation, and the project is mainly related to entertainment. But later when we started working on project we came to realize that it is not as tranquil as it seems. These fountains elegantly combine engineering and artistic features. We also learned that some prospects are simply uncontrollable just like delivering the materials from abroad was a factor in our scenario proved to be unmanageable as it took two months to get hold of our ordered material as after being delivered from it was stuck on the port in Saudi Arabia. Also this project contains many mechanical ideas that need to be worked and realized on the ground. Gantt chart plays vital role in helping us supervision of our time in performing different tasks. Team ideas, design and concepts were shared and discuss for making the finest in suitable allocated time.

6.1.4: Project Management:

Project management is one of the most important factors that cannot be ignored. To fulfil any task on time project management is an important issue. Before we start working on our project the first and foremost thing we did is to make Gantt chart. Gantt chart is kind of a project management plan, in which each member was assigned some task, their due dates were also mentioned in this chart and who was responsible doing those tasks. Everything was divided amongst everyone equally. It was necessary for each member in the team to focus on the task and give enough time for previewing and reviewing the assignments according to the work plan which shows the responsibilities and dedication in all stages.

6.2 Impact of Engineering Solutions

6.2.1: Society:

Water fountains have been used for thousands of years for climate control, beautification, entertainment, and as a means for relaxation. Fountain jets have become very popular over the last decade and everyday people are realizing the benefits a fountain can have. The surrounding zone with setting of a fountain jets affects its potential to alleviate noise, by increasing evaporation and dispersing the cooled air, air flow or currents also influence the cooling potential of fountains. In the Kingdom of Saudi Arabia fountains are designed to better take advantage of air flow to increase a cooling effect.

6.2.2: Economy:

The cost of manufacturing was the big concern for us during the project. We tried to use simple and less expensive parts for this purpose. Our project is modest so there will be lesser chance of breaking down of system and it will lead to less maintenance cost. The most prominent of these ideas is how to determine the level of flow and whether it is laminar flow or turbulent flow. This determination depends on pump power, speed of servo motor, and outer flow of nozzles and how to use the equation to find accurate calculations.

6.2.3: Environment:

Efforts for environmental preservation are the most important implication for this system functionality. With the implementation of the simple machinery, there is chance of increase of production fountain jet globally. Any future investment in entertainment sector can become an attractive proposal or idea. A successful implementation of system can be helpful in struggle against the climate change.

6.3 Contemporary Issues Addressed

With the increase in the issue of global warming, scientific technologies have been modifies which do not promote global warming. Good energy resource includes adaptive fountain jets to cool down the surroundings. We run many tests for the control system to examine the behaviour of the system. We tested the TF-mini sensor and we soon realized that theses ultrasonic sensors are not designed for outdoor or uncontrollable setups as catches all the random movements either that of birds or sunlight.

Another basic issue addressed through this proposal is that the adaptive fountain jet using fast servo is not for individual use as it incur undesirably high cost which is way too expensive. We also faced problem in coding that have been affecting the nozzle’s movement. However we faced the issue with the cost and availability of the materials in the local market. We had to get these parts imported as there were no easy accesses in the local market. This led to delay in completion of the project than expected.

Chapter 7: Conclusion & Future Recommendations

7.1 Conclusion

To sum up all the skills methods and expertise that we utilize in this project, we face so many ups and downs that made us learn new problem solving skills. During the interim of 3-5 months we came across many skills and the software that we were not aware of. We can proudly say that we were not demotivated but we encouraged each other to learn about new software and hardware skills. The current project is based on the Adaptive fountain Jet our main aim was to develop an adaptive and controllable fountain jet using fast servo motor and proximity measures. The fountain jet contains water and flows it around according the set pattern which in result cools down the temperature of the surrounding and creates a cooling affect.

7.2 Future Recommendations

The goals of this project were outlined keeping in mind the timeline and resources that were attainable. This initial design was improved later on and we realize and understand that there can be more changes and alterations done to the existing prototype to make function and perform efficiently and cost effectively. The materials and spare parts used in this project are ordered online from china and are made in china as well. We found our material and project related spare parts very expensive. We feel the need that these materials and spare parts must be manufactured locally and sold at reasonable cost to decrease the cost of the Adaptive fountain jet. As we have to bear high cost because of unavailability. The Adaptive fountain jet using servo motor should be introduced in Saudi Arabia informally and professionally as a business opportunity so that every single person should get the benefit.

References

1- Andrew Duffy. Boston University. Retrieved on 25 September, 2019

http://physics.bu.edu/~duffy/py105/Bernoulli.html

2- *Assignment on Servo Motor*. (2018). Retrieved from 25th September, 2019 file:///C:/Users/Abdulla Khan/Downloads/Servomotor.pdf

3- Mathew A. (09 March, 2014). Electrical Submersible Pumping (ESP) System. Retrieved on 1st October, 2019

https://fac.ksu.edu.sa/sites/default/files/4-electricalsubmersiblepumps.pdf

4- Said, S. (2004). "Micro-controlled water fountain: a Multidisciplinary Project," Tempus Publication vol.20, No. 4. Retrieved on 5th October, 2019

https://pdfs.semanticscholar.org/66b6/a1aca201306b4601d4fb6d684c358678d2d2.pdf

5- Slatter, P. T. and E. J. Wasp (2000) "The Laminar/Turbulent Transition in Large Pipes," Proc. 10th Int. Conf. on Transport and Sedimentation of Solid Particles, AUV, Wrocław, Poland (2000), pp. 389–399. Retrieved on 5th October, 2019

6- Wilson K. C. and Thomas A. D. (2006) "Analytic model of laminar turbulent transition for Bingham plastics,'' Canadian Journal of Chemical Engineering. Retrieved on October 10, 2019

https://www.thefreelibrary.com/Analytic+model+of+laminar-turbulent+transition+for+Bingham+plastics.-a0159508078