Project Systems Testing 2018

Project #1
WATER-CONTROL

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Group member:

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1. Introduction

1.1. Purpose

The purpose of this project is to present a WATER - CONTROL system which controlled by a microcontroller. We will explain how the system works and how to control the water salinity in a specified range. By doing this project, we could understand how an automatic insulin pump help diabetic patients.

1.2. System overview

Our system is mainly divided into three parts. The control unit with the mbed LPC 1768 microcontroller (Fig. 1), the water control plant and the software - mbed online compiler. The box contains a breadboard, front and back panels with switches, potentiometers, LEDs, buzzers, LCD screen, and connecting wires. The WATER-CONTROL is a computer-regulated wet environment, it contains salinity sensor, temperature sensor, immersion heater, water tank, stir station, injection syringe pumps and stepper motors.

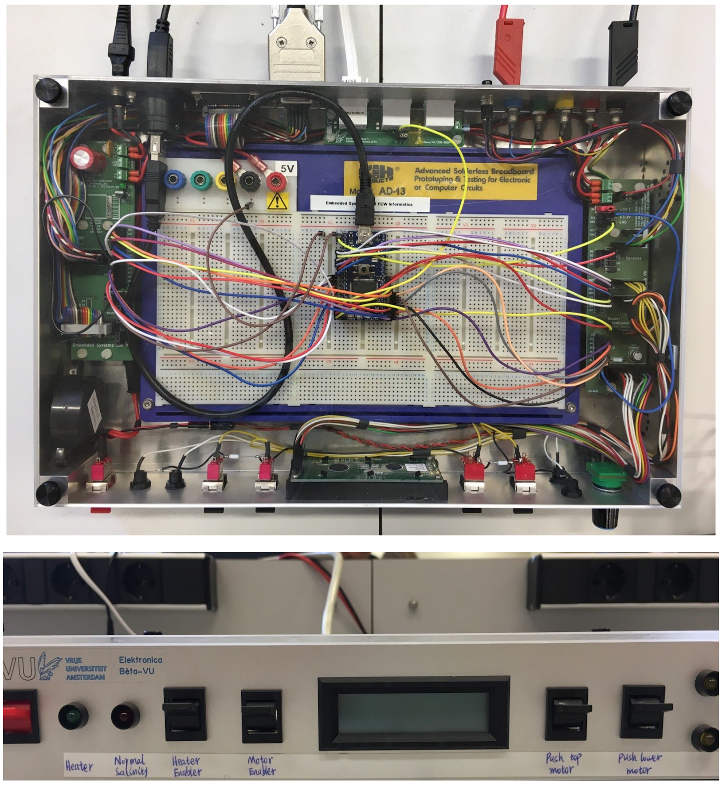


Fig.1

The working principle of WATER-CONTROL system is: the microcontroller controls the two injection syringe pumps to keep the salinity in a specified range (20.0 - 30.0 ppt) by injecting fresh water or salty water to the tank. To change the temperature, we use ice and immersion heater, by controlling the immersion heater, we could increase the temperature.

2. Overall description

2.1. Product perspective

We use a WATER-CONTROL system mimics an automatic insulin pump which help diabetic patients to keep the blood sugar in a safe range. Considering patients privacy and safety concerns, also it is not easy to build a insulin pump in reality. Therefore, we emulate it with a WATER-CONTROL which contains a water salinity and temperature control plant. By controlling this system, we use the mbed online compiler to control the salinity and temperature in a safe range.

2.2. Operating environment

For this project, we use C++ language to write code on the mbed online compiler. The source code needs to be compiled into a binary machine code, which is downloaded to the microcontroller (the first left light flashing), placed in your WATER-CONTROL System.The mbed board needs to be powered by a standalone power supply or from a PC via an USB cable. The motors we use two DRV 8825 Stepper Motor Driver Carriers[1].

2.3. Design and implementation constraints

Constraints	Description
C 1	We choose an Eutech Salt6+ [2] as the test oracle. There is slightly differences between the testing values and actual values, we aimed for a lower-upper bound approach by mbed to contain the error.
C 2	When we start/stop heating, it takes 10 - 20 seconds to start/stop the changing. And the temperature increases fast, we can not get the precisely number (i.e 50.0 ℃). When we stop the heater, the temperature still goes up a little (0.6 - 1.5 ℃).
C 3	There are air bubbles in the pipe connecting with injection syringe pump sometimes. Moreover, when we pump fresh water or salty water, the dose is not 5ml precisely.

[1] https://www.pololu.com/product/2987
[2] https://www.eutechinst.com/pdt_para_salinity_tse_salt_6plus.html

C 4	The pipe of salty water could be stuck by salt, it could affect the result slightly.
C 5	In our system, the microcontroller and water-control plant are separate, we use long cables to connect, thus there could be some signal delay problems affecting the values.
C 6	In our system, you can not test water salinity while using the immersion heater.

Requirements Specification

3. Functional requirements

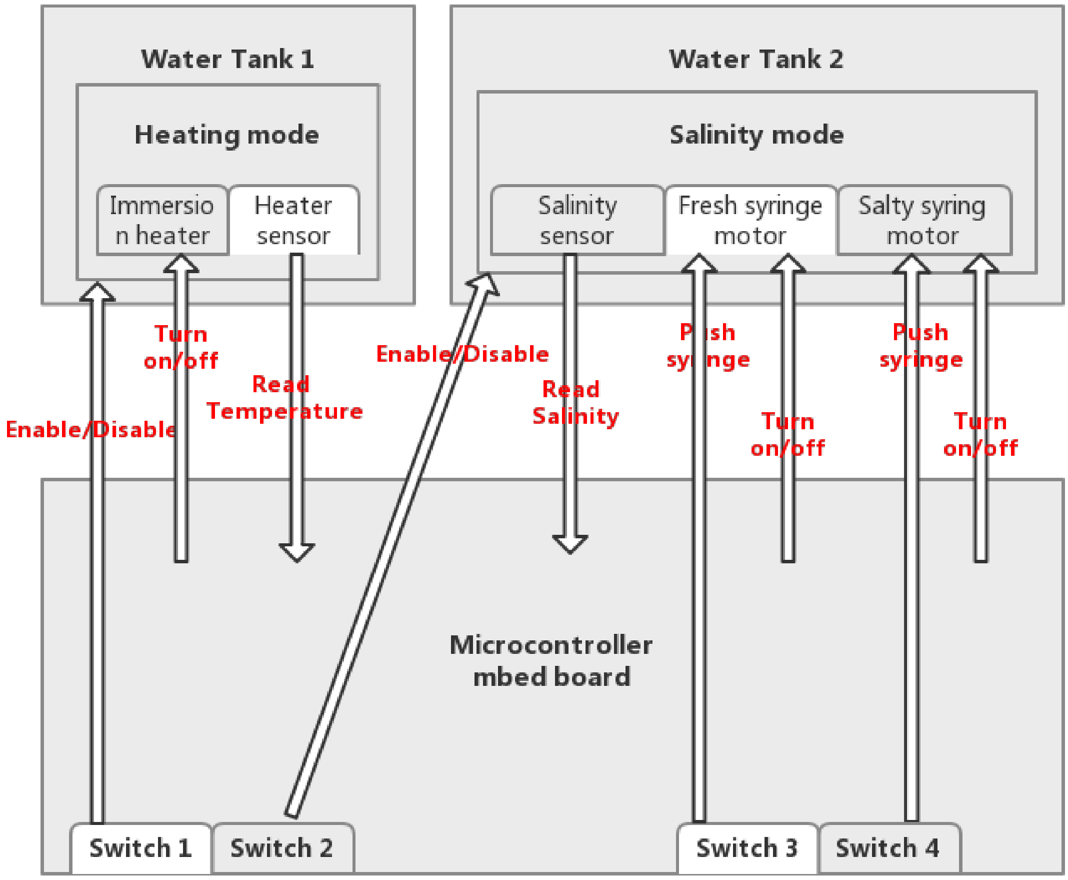
Functional Requirements	Description
FR 1	The system should first keep the temperature in water tank 2 normal between 35 - 40 ℃.
FR 2	The system then should keep salinity in water tank 1 normal between 20.0 - 30.0 ppt.
FR 3	Switch 1 should enable/disable the heating mode. In heating mode, the immersion heater turns on if the temperature is below 35℃ and turns off if the temperature is equal to 35 ℃.
FR 4	The injection syringes switch rotations have 3 position. [closed - open toward reservoirs - open toward water tank].
FR 5	Switch 2 should enable/disable the stepper motors mode. In this mode the salinity will be read and fresh pump will be activated in case salinity > 27.5 ppt and salt water pump will be activated in case salinity < 22.5 ppt.
FR 6	The system should have an initialization phase where switches 3 and 4 push water out of the fresh/salt syringes when switch 1 and 2 are disabled.
FR 7	After reaching the normal salinity and temperature, the system should keep checking for changes in the temperature and salinity.

4. Non-functional requirements

Non - functional Requirements		Description
Reliability	NFR 1	The system should be able to withstand all the possible hazards in section 7.4 to be reliable. But testing that during the scope of this course is not possible as the system needs to be running for hours and an operator should count the faults that the system suffers from.
Efficiency	NFR 2	The heater should reach the normal temperature [35 - 40 ℃] from an initial temperature (30 ℃) in 15-18 seconds.
Accuracy	NFR 3	The system tolerate an error of ± 2.5 ppt when reading salinity.
	NFR 4	The system tolerate an error of ± 1.2 ℃ when reading temperature.
	NFR 5	The system should be able to deal with a loss of 1.1 - 1.3 ml when trying to push/suck 30 ml using the syringes.
Safety	NFR 6	The system should should keep measure of the initial volume of the flask as well as the maximum volume of the flask as to continuously check for cases of water overflow when dispensing salt/fresh water.
	NFR 7	The injection syringe can go from a range of 0 - 35 ml. Our system should starts at 2.5 ml and ends at 32.5 ml in order to keep a safe distance of 2.5 ml on each side.
	NFR 8	If the heater was not turned off after reaching a normal temperature, switch 1 should be turned off by hand.
	NFR 9	Before removing the salinity sensor from the water tank, switch 2 (stepper motors enabler) should be turned off.
	NFR 10	In case of a wrong switch rotation in the syringes, like pushing water into the reservoirs or if the switch is closed and motors will rotate. Power should be turned off before rebooting the system.
	NFR 11	When the system appears to have any other abnormal operations, the operator should turn off the power.

Design

5. High level design —— Architecture



For the above system we decided that the operator should be able to protect the system in case the system started to act weirdly. We decided to have switches 1 & 2 as enablers/disablers switches. Meaning when switch 1 is turned on, only then the heating mode gets activated. When the heating mode gets activated, the controller start reading the temperature and the heater would be turned on if needed. Otherwise, if we detect any fault, turning off switch 1 shuts down the heating mode. The same thing applies for switch 2 which is responsible for the salinity mode.

As for switches 3 & 4, these switches as said before only used in initialization phase where their role is to push fresh/salt water syringes to 2.5 ml as to the start the sucking process. Switches 3 & 4 only work when both switches 1&2 are turned off.

We also use two LED lights available to us in the controller. We decided to use led 1 to show that the heater is on. LED 2 was used to indicate that a normal salinity was achieved.

The LCD screen displays the temperature values as well as salinity values so that the operator could make sure that the system is actually doing the correct procedure.

6. Low level design

6.1. Algorithms

Check the appendix for full code.

6.2. Calibration

The salinity sensor was giving different values at times and checking against the oracle didn't prove helpful. Therefore we have created our own salty water samples of different salinity levels (5 ppt, 10 ppt, 20 ppt and 30 ppt) and we came up with a linear function to represent the salinity reading. However due to the salinity sensor's unpredicted reading we had a different function every day. On the other hand, temperature sensor was accurate and no further calibration was needed after it was set.

6.3. Error adjustment

We have found that the mbed gives different voltages that affect the temperature and salinity read. Therefore we decided to have a bounded range to our values. So we would expect that the actual temperature is bit lower/higher than what we actually read. Another adjustment was when we were first trying to test the syringes and we found out that if we aim to push by 30ml, the syringe only pushes 28.8 meaning a loss of 1.2 ml. This is to be calculated and added to the flask volume as to detect overflow when it occurs.

Risk Analysis: STAMP

7. Hazards analysis

In this project, there are three factors could cause risks: temperature, fresh water, salty water.

7.1. Hazardous situations associated with temperature, pumping salty water, and pumping fresh water.

Control Action	CA not given	Incorrect CA given	CA is given at the wrong time or in the wrong order	CA is stopped too soon or applied too late
Heating the tank	H 1-The temperature dropped lower than the normal range (35 - 40℃) but heater was not turned on. H 2- The temperature got higher than the normal range but the heater was not turned off.	H 3- The temperature is in the normal range but the heater is turned on. H 4- The temperature is below the normal range but the heater was turned off.	H 5- Heater is turned on long after it was necessary. H 6- Heater is turned off long after it was necessary.	H 7- Heater is stopped before reaching a normal temperature.
Pumping Salty Water into the tank	H 8- The salinity is below 20 ppt but the pump is not turned on. H 9- The salinity is higher than 30 ppt but the pump was not	H 10- The salinity is normal but the pump is turned on. H 11- The salinity is below normal but the pump is turned off.	H 12- Pump is turned off long after it was necessary. So the salinity is now high.	H 13- Pump is stopped too soon and normal salinity is not reached.

	turned off.			
Pumping Fresh Water into the tank	H 14- The salinity above 30 ppt but the pump is not turned on. H 15- The salinity become normal but the pump is not turned off.	H 16- The salinity is normal but pump is turned on. H 17- The salinity is above normal values but the pump is turned off.	H 18 - The pump is turned off long after it was necessary. So the salinity is now low.	H 19- The pump is stopped too soon and normal salinity is not reached.

7.2. Additional Hazards : Rotation of Syringes

Assume switch position 1 is connected to the salty water / fresh water
Assume switch position 2 is connected to the water tank
Assume switch position 3 is when the switch is closed

Identified Hazard	Hazard Description
H 20	Switch position 2 and sucking water out of the tank
H 21	Switch position 2 and sucking water from tank- Switch position 1 and pump water to the salty solution
H 22	Switch position 1 - sucking some salt water followed by Switch position 2 and sucking water out of the tank => syringe has mixed salt and water from tank
H 23	Switch position 2 and sucking water out of the tank
H 24	Switch position 1 and pump into the fresh solution
H 25	Switch position 1 - sucking some fresh water followed by Switch position 2 and sucking water out of the tank => syringe has mixed fresh water and water from tank
H 26	Switch position 3, pumping or sucking would damage the motors.

From the above hazards we can see that any rotation of the syringe toward position 2 followed by a sucking action is risky and should be avoided. Moreover, whenever an action (pump/suck) takes place one should make sure that the switch is not closed.

7.3. Test scenarios

Identified Hazard	Test Scenario
H 1	start with normal temperature (37 ℃) and add ice till the temperature is (30 ℃) - make sure the heater turns on for 15-20 seconds and that it stops when temperature hit 36.2 ℃.
H 2	start with high temperature (41.5 ℃), The heater should not be on.
H 3	start with normal temperature (37 ℃), make sure that the heater is not turned on.
H 4	start with low temperature (30 ℃), make sure the heater turns on.
H 5	start with low temperature (30 ℃) and and check that the heater instantly gets turned on and does not underwent any delay.
H 6	start with low temperature (30 ℃), make sure that the heater stops when temperature hits 36.2 ℃.
H 7	start with low temperature (30 ℃), make sure that the heater stops when temperature hits 36.2 ℃.
H 8	start with normal salinity (25 ppt), add fresh water till the salinity is (15 ppt) and check if the salt pump is turned on until salinity reaches 22.5 ppt
H 9	start with low salinity (15 ppt) and check that the salt pump stops when salinity reaches 22.5 ppt.
H 10	start with normal salinity (25 ppt) and see if salt pump turns on
H 11	start with low salinity (15 ppt) and check if salt pump turns on and stops when salinity reaches 22.5 ppt.
H 12	start with low salinity (15 ppt) and check that the salt pump stops when salinity reaches 22.5 ppt.
H 13	start with low salinity (15 ppt) and check that the salt pump

	stops when salinity reaches 22.5 ppt.
H 14	start with normal salinity (25 ppt), add salty water till the salinity is (35 ppt) and check if fresh pump turns on until the salinity is brought to 27.5 ppt where it stops.
H 15	start with salty water (35 ppt) and check that the fresh water pump stops when salinity reaches 27.5 ppt.
H 16	start with normal salinity (25 ppt) and check if the fresh pump turns on
H 17	start with high salinity (35 ppt) and check if the fresh pump turns on and stops later when salinity is 27.5 ppt.
H 18	start with salty water (35 ppt) and check that the fresh water pump stops when salinity reaches 27.5 ppt.
H 19	start with salty water (35 ppt) and check that the fresh water pump stops when salinity reaches 27.5 ppt.

7.4. Hazards for WATER-CONTROL

Identified Hazard	Estimated Risk	Acceptability
H 1	High	Intolerable
H 2	High	Intolerable
H 3	Medium	Acceptable if it stops when reaching the maximum normal temperature
H 4	High	Intolerable
H 5	High	Intolerable
H 6	High	Intolerable
H 7	High	Intolerable
H 8	Medium	Acceptable if the salinity is not too low
H 9	High	Intolerable
H 10	Medium	Acceptable if the pump is

		stopped when reaching the maximum normal salinity
H 11	Medium	Acceptable if the salinity is not too low
H 12	High	Intolerable
H 13	Medium	Acceptable if the salinity is not too low
H 14	High	Intolerable
H 15	Medium	Acceptable if the pump stop when maximum normal salinity is reached.
H 16	Medium	Acceptable if the pump stops when minimum normal salinity is reached.
H 17	High	Intolerable
H 18	High	Intolerable
H 19	Medium	Acceptable if the pump stopped and salinity is not far away from the maximum normal salinity.
H 20	Medium	Acceptable if the syringe is emptied in the water tank before any other action
H 21	High	Intolerable, Salt water reservoir is ruined
H 22	High	Intolerable, Syringe has mixed water
H 23	Medium	Acceptable if the syringe is emptied in the water tank before any other action
H 24	High	Intolerable, Fresh water reservoir is ruined
H 25	High	Intolerable, Syringe has

		mixed water
H 26	High	Intolerable, Stepper motors destroyed

7.5. Introducing faults

ID	Faults	Effect
F 1	Temperature sensor is not working	Deadly Risk
F 2	Temperature sensor is not accurate	Could be acceptable if not by much
F 3	Salinity sensor is not working	Deadly Risk
F 4	Salinity sensor is not accurate	Could be acceptable if not by much
F 5	If one or more stepper motors are dead	The system could still work by relying on manual injection by an operator.
F 6	If temperature is higher than normal value (35 - 40 ℃)	The system can not bring it down and salinity could be affected as temperature cools down but the system should be fixing salinity at all stages.
F 7	Empty reservoirs (fresh or salt)	They need to be manually replaced or else the syringe will be pumping/sucking air.
F 8	Power outage	Deadly risk

Testing

8. Test Plan

8.1. Test strategy

Since the the hazardous situations could be too many as we have found out above, our testing strategy would initially be based on testing the hazards with the most impact first meaning the intolerables and then the other hazards if time permits.

From section 5.4 we can see that the hazards with high risk are (H1,H2,H4, H5,H6,H7,H9,H12,H14,H17,H18,H21,H22,H24,H25,H26)

In addition to the following hazards we have introduced some fault injection scenarios and in the next couple of sections we are going to show some test cases as well as mitigations to certain risks..

8.2. Test cases

We used EP + BVA in order to come up with the following test cases.

In the table below, there are test cases where the “Actual Result” is **Not Tested.** This is due to our decision to focus on testing a couple of values in each class.

T = Temperature (℃)
S = Salinity (ppt)

We assume the safe temperature is 35 - 40℃.
We assume the safe salinity is 20 - 30 ppt.

Note: As we anticipate an error of ± 1.2℃ in temperature as well as ± 2.5 ppt in salinity. Our sensor readings are in the safe range when:
Temperature: 36.2 - 38.8 ℃.
Salinity: 22.5 - 27.5 ppt.

Controlled Processes	Test cases	Input	Expected output	Actual Result
Temperature	TC 1	T = 0 ℃	Use immersion heater	Not tested
	TC 2	T = 1 ℃	Use immersion heater	immersion heater was

				turned on until 36.2 ℃
	TC 3	T = 20 ℃	Use immersion heater	immersion heater was turn on until 36.2 ℃
	TC 4	T = 34 ℃	Use immersion heater	Not tested
	TC 5	T = 36.2 ℃	Normal/Heater off	Heater was off.
	TC 6	T = 36.5 ℃	Normal/ Heater off	Not tested
	TC 7	T = 37 ℃	Normal/ Heater off	Heater was off
	TC 8	T = 38 ℃	Normal/ Heater off	Heater was off
	TC 9	T = 38.8 ℃	Normal/ Heater off	Not tested
	TC 10	T = 39 ℃	No action wait to cool down/ Heater off	Not tested
	TC 11	T = 70 ℃	No action wait to cool down/ Heater off	No action/ wait to cool down between 36.2-38.8 ℃
	TC 12	T = 99 ℃	No action wait to cool down/ Heater off	Not tested
	TC 13	T = 100 ℃	No action wait to cool down/ Heater off	Not tested
Salinity	TC 14	S = 0 ppt	Pump salty water into the tank	Not tested
	TC 15	S = 1 ppt	Pump salty water into the tank	Not tested

	TC 16	S = 10 ppt	Pump salty water into the tank	Not tested
	TC 17	S = 18 ppt	Pump salty water into the tank	Pump salty water until salinity is 22.5 ppt
	TC 18	S = 19 ppt	Pump salty water into the tank	Pump salty water until salinity is 22.5 ppt
	TC 19	S = 22.5 ppt	Normal/ Don't pump anything	Normal/ Don't pump anything
	TC 20	S = 24 ppt	Normal/ Don't pump anything	Normal / Don't pump anything
	TC 21	S = 25 ppt	Normal/ Don't pump anything	Normal / Don't pump anything
	TC 22	S = 27 ppt	Normal/ Don't pump anything	Not tested
	TC 23	S = 27.5 ppt	Normal/ Don't pump anything	Normal/ Don't pump anything
	TC 24	S = 31 ppt	Pump fresh water into the tank	Not tested
	TC 25	S = 32 ppt	Pump fresh water into the tank	Not tested
	TC 26	S= 40 ppt	Pump fresh water into the tank	Pump fresh water until salinity is 27.5 ppt
	TC 27	S = 49 ppt	Pump fresh water into the tank	Not tested
	TC 28	S = 50 ppt	Pump fresh water into the	Not tested

			tank	

8.3. Testing Route / Steps for a working system

A normal scenario of running the system starts when the operator set the water tank’s current volume as well as maximum volume in the code.

To make sure the temperature is normal in the water tank, switch 1 needs to be turned on. It detects the temperature and accordingly the heater will turn on/ off to reach a normal temperature.

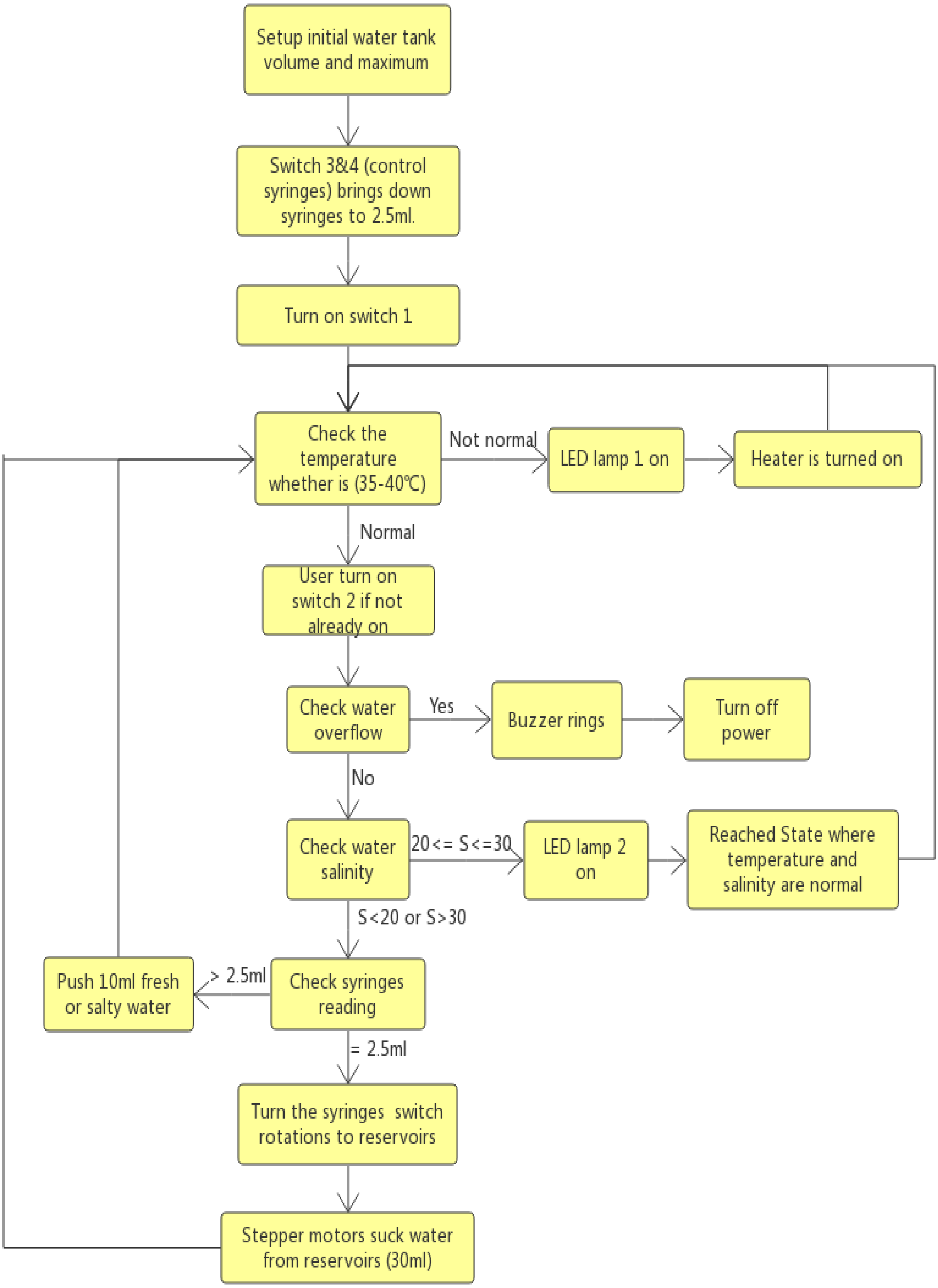
Switch 1 could now be turned off in order to work on the salinity without the heater affecting the salinity sensor.

Switches 3 and 4 bring down the fresh and salt syringes to 2.5 ml respectively. The operator then turns the pump switches toward the reservoirs.

The salinity Sensor should be placed in the water tank and then switch 2 needs to be turned on.

According to the water salinity, the stepper motors suck water from the reservoirs (30 ml) , the operator then turns the switch toward the water tank and the motor then executes a push action (pushing 10 ml of water and then pausing to check salinity). The operator has small time of 10 seconds to turn the switches back to the reservoirs.

The above procedures continues until the salinity in the water tank is normal, at which the LED lamp 2 lights. The operator then can turn switch 2 off otherwise the system could still be checking any changes in the temperature and salinity. The below figure summarizes the complete system states.


Setup initial water tank volume and maximum
Switch 3&4 (control syringes) brings down syringes to 2.5ml.
Turn on switch 1
Check the temperature whether is (35-40℃)
Not normal
LED lamp 1 on
Heater is turned on
Normal
User turn on switch 2 if not already on
Check water overflow
Yes
Buzzer rings
Turn off power
No
Check water salinity
20<= S<=30
LED lamp 2 on
Reached State where temperature and salinity are normal
S<20 or S>30
Push 10ml fresh or salty water
> 2.5ml
Check syringes reading
= 2.5ml
Turn the syringes switch rotations to reservoirs
Stepper motors suck water from reservoirs (30ml)

8.4. Integration Testing

Test Case	Test Case Description	Expected Result
TC 29	Temperature is normal (37℃), Salinity is not normal (S = 18 ppt).	Salt water will be pumped until salinity is normal (S = 22.5 ppt)
TC 30	Temperature is not normal (T = 30 ℃), Salinity is not normal (S = 18 ppt).	Immersion heater will be turned for about 13-15 seconds until temperature is normal at T = 36.2 ℃, then salt water will be pumped as in TC1.
TC 31	Temperature is normal (37 ℃), Salinity is not normal (S = 32 ppt) but then Ice added to the tank.	Fresh water was being added to the tank, but when temperature dropped below normal, the pumping stopped and the heater is turned on to bring the temperature back to normal. The heater stops when temperature = 36.2 ℃ and fresh water then continues to be added until salinity = 27.5 ppt.
TC 32	Temperature is normal, salinity is normal. Then both ice and salt are put in the tanks.	Immersion heater will turn on until temperature is brought back normal, then fresh water will be pumped until salinity is normal.
TC 33	Temperature is not normal (T = 43 ℃), salinity is not normal (S = 35 ppt)	Since temperature is higher than > 38.8 ℃ and the system can not cool the water. Then in this case salinity will be fixed where fresh water is expected to be dispensed until salinity =

		27.5 ppt.

8.5. Assumptions, risks and mitigations

Hazard	Mitigation
H1	Use another thermometer to check against the system's thermometer and use the heater directly with a power outlet until the normal temperature is reached.
H2	Use another thermometer / the operator can remove the heater by hand when temperature is normal.
H4	Use another thermometer to check against the system's thermometer and use the heater directly with a power outlet until the normal temperature is reached.
H5	Use heater manually with a power outlet until the temperature is normal.
H6	The operator removes heater when temperature seems to be continuously rising although normal temperature has been achieved.
H7	Use heater manually with a power outlet until the temperature is normal.
H9	Shut off the system and add fresh water manually
H12	If the light is on meaning that the solution is normal yet the pump is still running then shut off the system. Double check the salinity with another salinity sensor.
H14	Add fresh water manually.
H17	Add fresh water manually.

H18	If the light is on meaning that the solution is normal yet the pump is still running then shut off the system. Double check the salinity with another salinity sensor.
H21	Shut off the system and replace the reservoirs
H22	Shut off the system and replace the syringe
H23	Shut off the system and replace the syringe
H24	Shut off the system and replace the reservoir
H25	Shut off the system and replace the syringe
H26	Shut off the system and turn the switch correctly
F1	Use another temperature sensor to make sure reading is correct / Shut off the system and replace the system's temperature sensor
F2	Check against another temperature sensor and detect how faulty it is. Replace the sensor if it is too faulty
F3	Replace the salinity sensor
F4	Check against another salinity sensor and detect how faulty it is. Replace the sensor if it is too faulty
F5	Shut off the system and replace the dead motor
F6	Accept as is
F7	Shut off the system and replace the reservoirs
F8	Let the system run on another source of electricity available, back-up generator.

By looking at the above risks and mitigation, it seems vital to have always another temperature/salinity sensors in the water tank as to make sure that the readings are somewhat the same. Another safety measure is really shutting down the system whenever an obstacle is really of high risk and could lead to deadly results.

Reflection

1. *Our approach*

We decided to follow a simplistic approach in dealing with the problem at hand. We decided that the temperature is more important for us to fix at first and then when temperature is normal we focus on salinity. We started the first couple of days tinkering with switches and LED lights and seeing what could be done. We decided on where the buzzer could be used and what the LED lights would mean in such a system. We then started testing the thermometer and salinity sensors and understand the scope of the problem. After that we wanted to decide on whether choosing STAMP or FMECA would get us going. Although the system has a lot of small components that would fail, we decided to go with STAMP as to try and stop/mitigate as many wrong control actions as possible. We assumed that the system is composed of 2 water tanks, a thermometer, salinity sensor, heater, 2 pump motors, 2 syringes and 2 syringe-switches. The system is not big and so STAMP could really prove helpful as it is a top-down approach and would help us see the hazards faster than FMECA's bottom up approach.

2. *How did our testing suffer under time pressure?*

In our report there are many test cases that we found using equivalence partitioning as well as boundary value analysis. We could not test each individual temperature and salinity value so this gives less trust in the system to surely fill the requirements. Also we could not go for white box testing on the code, such as 100% decision/condition coverage because we found ourselves more focused on making sure that the components work and do what is intended of them to do. (fresh water motor activated when salinity is high, salt water motor activated when salinity is low). However, the code we written was incrementally laid as to write-test and not face a lot of surprises. First the module for checking temperature was written and then the salinity module. If we had more time, we wanted to experiment with different motor speeds because currently we had safety in mind and we wanted to accelerate and then decelerate safely, but we did not really see what the motors true potential can be.

3. *How did we limit our scope?*

I believe limiting our scope happened when we decided on the switches and LED lights. There are many creative ways to handle the functionality of how the system work. We aimed for safety measures in stopping heater/pumps in case any wrong procedure happened. We also limited our scope when we decided to handle the problem by giving an ordered solution where temperature is to be brought normal first and then salinity.

4. Where did we invest most of our time?

Actually a lot of time was spent in creating a reliable salinity reader. This proved to be a tiring process where values were changing over night and everyday a new linear function was found. However since this part is connected directly to motors and syringes, then this is basically a big part of the system. So it was time well spent but the sensor was not that reliable in the end. The demo proved that the sensor values were also changed than the last successful run and adding a lot of salt was not affecting the salinity by much.

5. What did we learn?

We have learnt a lot of things during this course. Mainly the importance of time management and specifying priorities to different tasks. At some point in time we were focused on coding and our report looked like a mess. At other times, we had days pass without a single change in lines of code but we were just testing some test cases. We have seen how testing a single component and having some positive results would not mean that it might work when the complete system is tested. Integration testing brings all the faults to the table and the LCD screens went bizarre at times. We expected a certain output, and what we have seen is something completely different. An important aspect of this course is to really start thinking of the hazards and how to stop them from happening or when to manually intervene if necessary. It was also proved vital at times that the whole system should be turned off because any mistake could be fatal (pushing water into the reservoir - example of something that should never happen).

6. What went fine?

The temperature sensor was actually reliable and worked according to the specifications and formulas provided. Its values did not change from the start of the experiment until the demo and this what made the temperature part a bit easy and that the heater would be able to perform its action successfully. Another thing that went well is the connection of motors to the board, it was not as difficult as we thought it would be.

7. What went wrong?

The syringes at one point gave us a headache where we were trying to push 35 ml (full syringe volume) but it always pushed further or stopped before. This frustrated us for a couple of days and the things is that sometimes this time lost really affect some other tasks whether it is writing more test cases or even testing existing one. Other than that again the salinity sensor would be the major disappointment in this experiment. Though it’s a real test of what could go wrong in real life and the most important thing is to protect the tank or the human in case it is the insulin example.

8. What could have been done better?

The way we displayed our readings on the LCD could have been done way better. We did not write the fanciest of code when it came to the LCD screen where we were more interested in seeing actions more than readings, so we were confident that our system does it functionality by looking at the pumps, tanks and the heater. We were able to know what will happen because we wrote the code, but yeah a good interface could let the users of the system be more in touch with what was really happening..

Future work

In our one month work in the lab, there are still some parts we could not finish as we prioritized certain tasks over others.

When we had a working motor movement we did not focus really on the speed, we just went along and implemented the other important functions. However, the system could have benefited from a faster motor rotation as to cut down the time needed to reach a normal salinity and make the system more efficient. Another thing that could have turned a lot better is the information we could have displayed on the LCD screen. Now we display the salinity reading after every pump action or suck action but showing things at all time would be more optimal for the operator and make him/her more involved with the system.
Finally, we wanted to have at least a picture of how reliable the system is but that would require us to run the system for a lot more than the 2 hours allotted to us each day. Therefore, even if we had some successful runs in certain days we can not be sure that the system would not face problems if ran for 3 days non stop.

Appendix

Full code:

https://drive.google.com/file/d/1gk6MGxnzKu2T3V_IcXDz-3IY3MsP8eom/view?usp=sharing