SIT 123 Data Capture Technologies

Trimester 2, 2021

DEAKIN UNIVERSITY

Student Declaration – Final Project

Plagiarism is a serious academic misconduct. It means when you use someone else's intellectual output (text, idea, images etc.) and present them (without appropriate and standard way of acknowledging the source) as your own.

PLEASE READ THE FOLLOWING STATEMENTS AND SIGN BELOW TO INDICATE THAT YOU HAVE UNDERSTOOD THE STATEMENTS:

- I declare that this assessment is my own work and demonstrates my own abilities and knowledge and does not involve plagiarism.
- I have taken serious precautions to make sure other students do not copy my work.
- I declare that I have properly provided all the citations and references to the original sources when I had to present ideas that are not my own.
- I understand very clearly that plagiarism can results in penalty of zero marks for the assessment.
- I understand that serious offences of plagiarism (e.g. submitting work of students from previous semester, or hired services work) will be forwarded to the faculty for further actions.

Student name: Chloe Hulme

Signature: CHulme

Date: 23/9/21

SIT 123: Data Capture Technologies

Water Intake Monitoring System

A Sensor Based Solution to Monitoring your Pet's Health

Chloe Hulme

ID: 221007028

TABLE OF CONTENTS:

BACKGROUND AND PROBLEM STATEMENT:

Sudden changes in the water intake of your pet can often indicate they may be experiencing illness. For example, polydipsia (increased drinking) can be a sign of a serious underlying health conditions such as kidney failure (Davies Vet Specialists, 2021). Likewise, reduced intake of water can be symptomatic of health conditions such as diabetes or kidney disease (Veterinary Emergency Group, 2021). However, monitoring quantitative changes in your pet's drinking habits can be difficult to do manually. To solve this problem, a water intake monitoring system has been developed within the Sense-Think-Act paradigm, and tested over the course of a week.

The basic design of the system includes a gravity fed water dispenser, placed on top of a force sensing resistor (FSR); a motion sensor, a temperature and humidity sensor (DHT22), and light are also installed. The system has three primary functions and conforms to the Sense-Think-Act paradigm as follows: When the pet approaches the bowl, an active signal is picked up by the motion sensor (Sense), this signal is then recognised as the event that triggers a white light (Think), the white light is activated for 10 seconds to provide visibility for the pet (Act). The second function oversees data collection. Readings are taken from each of the sensors (Sense), while the program keeps a 10 minute timer. The system recognises when 10 minutes has passed (Think), then the latest sensor readings are committed to the .csv file as the 10 minute interval elapses (Act). The final function notifies when the dispenser is empty by sensing the pressure it applies to the FSR (Sense). The system then recognises that this pressure is below a specified threshold (Think), and a red light begins to blink (Act).

The subject participating in the testing of this system is Jordy, a 1.5 year old male Border Collie weighing 17.5kg. Adequate water intake for a dog is dependent on size, a healthy dog should be drinking between 30-50ml of water per kilo of body weight each day (Samford Pet Resort, 2018). For Jordy, this equates to ~525-875ml each day.

HYPOTHESIS:

To determine whether monitoring the water intake of pets can provide us with an adequate description of their regular water habits, and thus enable us to detect changes in water habits that could indicate an illness. This will involve converting FSR readings (Ohms) to millilitres of water, then taking the difference from the volume at the start of the day versus the end to determine total water intake within a day.

This project will address the following research questions:
- Is a sensor based water monitoring system able to record the regular water habits of pets?
- Can this system accurately determine daily water intake in millilitres?
- Can this system give an indication of unhealthy water intake and therefore underlying illness?

SYSTEM ARCHITECTURE:

<u>Hardware:</u>

The initial system design (see Figure 1) was implemented by a custom-designed gravity-fed water dispenser that was to be 3D printed. The 3D shell (see Figure 2) would be printed from Polypropylene (PP), a food safe plastic ensuring safe drinking water for the pet. A water jug that would be inserted into the shell would be made from a plastic drinking bottle and a tube to fill the bowl. However, inability to access a 3D printer due to the Covid-19 lockdown in Victoria resulted in this design being abandoned.

The final implemented design (see Figure 3) involved purchasing a pre-made gravity fed water dispenser* and creating a removable sensor 'belt' that sits on top of the jug component of the dispenser. The belt was made out of electrical tape and wraps around the circumference of the jug, then another strip of electrical tape connects the 'belt' over the top of the jug. Sensors were then attached to the 'belt' with wire. This situates the light towards the back of the jug, acting as a back light. The DHT22* sensor sits to the side away from potential splashing as the dog drinks, and the motion sensor on the front, allowing accurate motion detection as the dog approaches the bowl. The microcontroller and wiring is placed behind the dispenser shielded from water, thus preventing damage to the system.

The DHT22 sensor and PIR motion sensor* models (see Figure 4) were chosen as they had already been tested and are proven to be effective and reliable. The light used is the Adafruit NeoPixel stick* (see Figure 4) as this allows use of the NeoPixel library, which simplifies code operating the light. Additionally, the NeoPixel stick is small (8 LEDs) yet still achieves good brightness. This is attractive given that available space on the sensor 'belt' is limited. An alternative that was considered was a regular non-addressable LED strip light. However, an entire roll would have to be purchased, causing a lot of waste. Also, the input voltage required for this is 12V, yet the Arduino Uno microcontroller* used only supplies 5V. This would complicate the wiring for the entire circuit, however the NeoPixel stick only requires 4-7V as the input voltage, therefore it was the most favourable option.

Finally, the FSR* (see Figure 5) was chosen as this sensor changes resistance based on the amount of force applied to it. Hence, we can place the FSR directly under the jug to measure the resistance (Ohms) caused by water in the jug, then determine force (grams) from this using a calibration curve. Since water has a density of ~1g/mL, grams is effectively equivalent to millilitres. We can therefore determine the amount of water drank by taking the difference between the amount of water in the bowl at the start versus the end of the day. An alternative to this that was considered was a load sensor to directly measure the weight of the water in the jug. However the cumbersome design of this sensor made it difficult to integrate into the system, so the slim FSR was implemented instead.

* See Appendix 1.1 for the list of materials used in the implemented system design.

<u>Software:</u>

The program coordinating the water monitoring system had to perform the 3 functions described above. To do this, we need to handle the program constants, variables, and objects. This involves including required libraries, SD card and .csv file setup, sensor setup/object creation where required, LED setup, and timer variable creation. It was decided prior to program design that committing data to the .csv file every time void loop() ran would result in a lot of unnecessary data and therefore a lot of data to clean. The delay() function is not useful here as it disables other functions from operating, thus a timer had to be implemented to commit data every 10 minutes. This was done so by recording current millis() each loop and then checking whether ten minutes had elapsed (600,000 milliseconds). In the void setup() method, we initialise the Serial Monitor, input pins, NeoPixel stick, SD card, RTC connection, and create a new .csv file and log the headers for the file.

In the void loop() method we can now implement the system's three functions. The system is event driven so we can do this by creating 3 control flow statements, as show in figure 6. An 'if' statement that handles whether 10 minutes has elapsed, then commits data to the .csv file if true and restarts the timer. Then an "if/if else" block handles the light's functionality: If pressure is below the specified value, the light will flash red until the pressure increases (jug refilled). Else, if the signal from the motion sensor reads 'active' the white light will activate for 10 seconds.

Hardware and Software Diagrams:

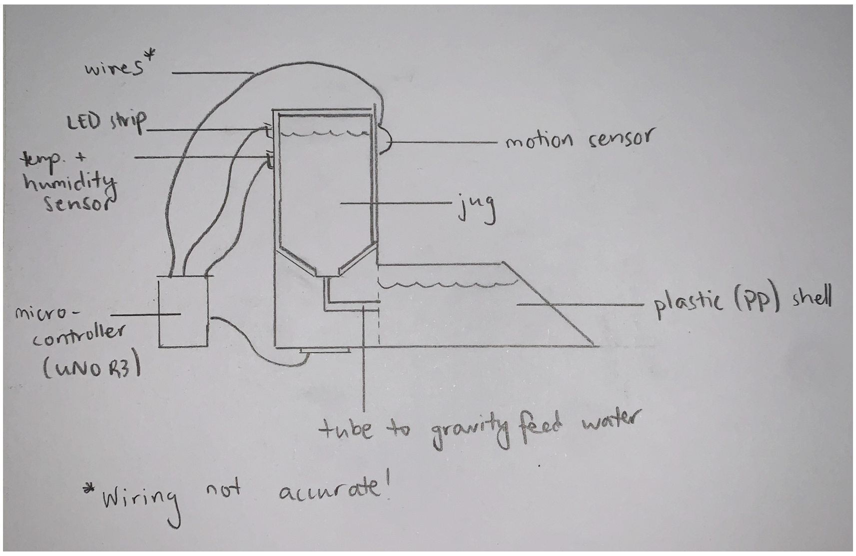


Figure 1. Scientific Diagram of Initial Hardware Design.

The initial draft hardware design.

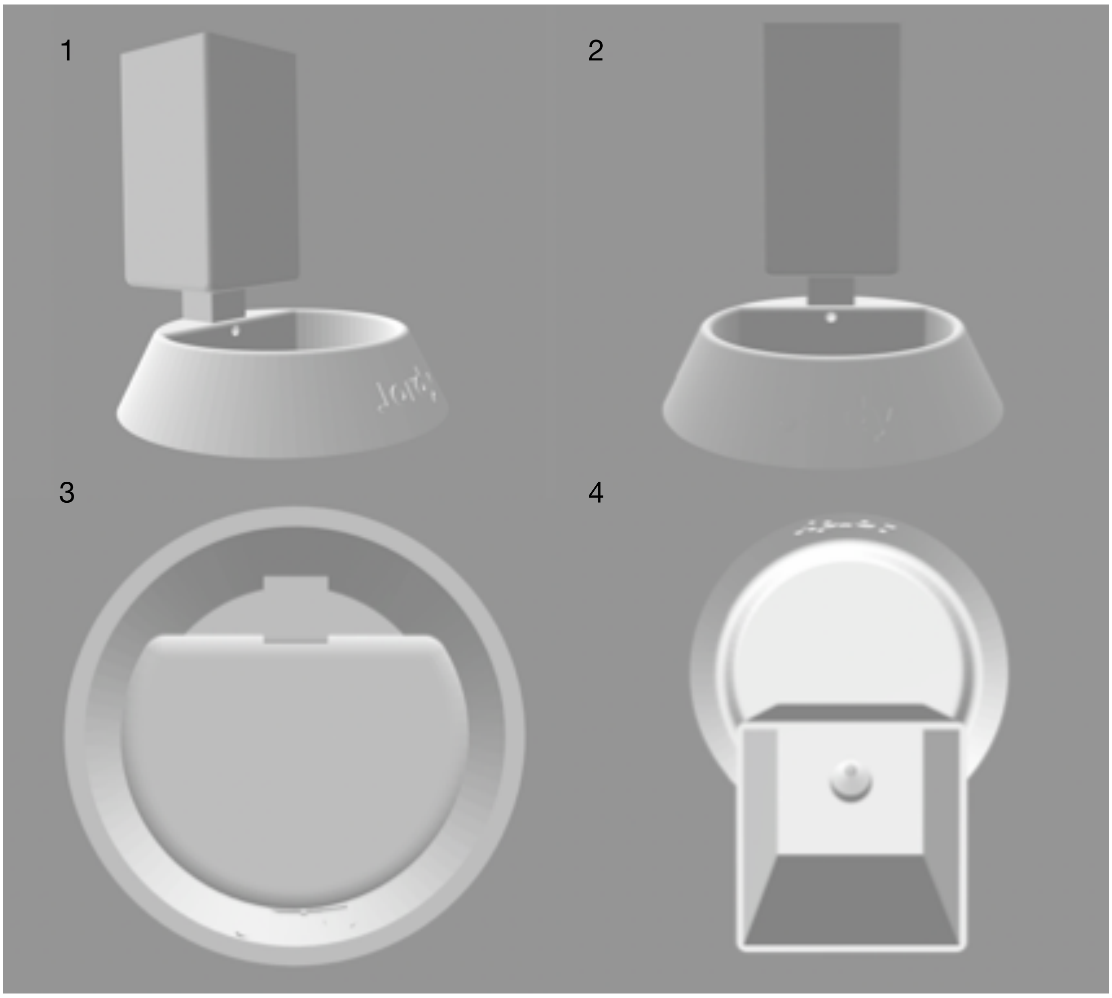


Figure 2. 3D CAD model for the Polypropylene shell.

Image 1 depicts a side on view of the model, showing the hole that the tube from the jug would go through to fill the bowl with water. Image 2 shows a front on view of the model. Image 3 depicts underneath the bowl, it is hollowed out to save on materials which would have been both cost effective and less wasteful. The square plate extends underneath the jug, the FSR would have sat on this plate allowing pressure from the water in the jug to be recorded. In image 4, we see a birds-eye-view of the model, showing where the jug would have sat and how the tube would have fed into the bowl.

See Appendix 1.2 for the full 3D render of this model.

Figure 3. The final design in action, with white light activated.

This is the final implemented design showing the 'belt' with attached sensors, and the microcontroller has been placed in a plastic bag to avoid water damage. A wooden plate was cut and attached to the bottom of the dispenser underneath the jug, this is where the FSR sits.

See Appendix 1.3 to view a demonstration of the red blinking light.

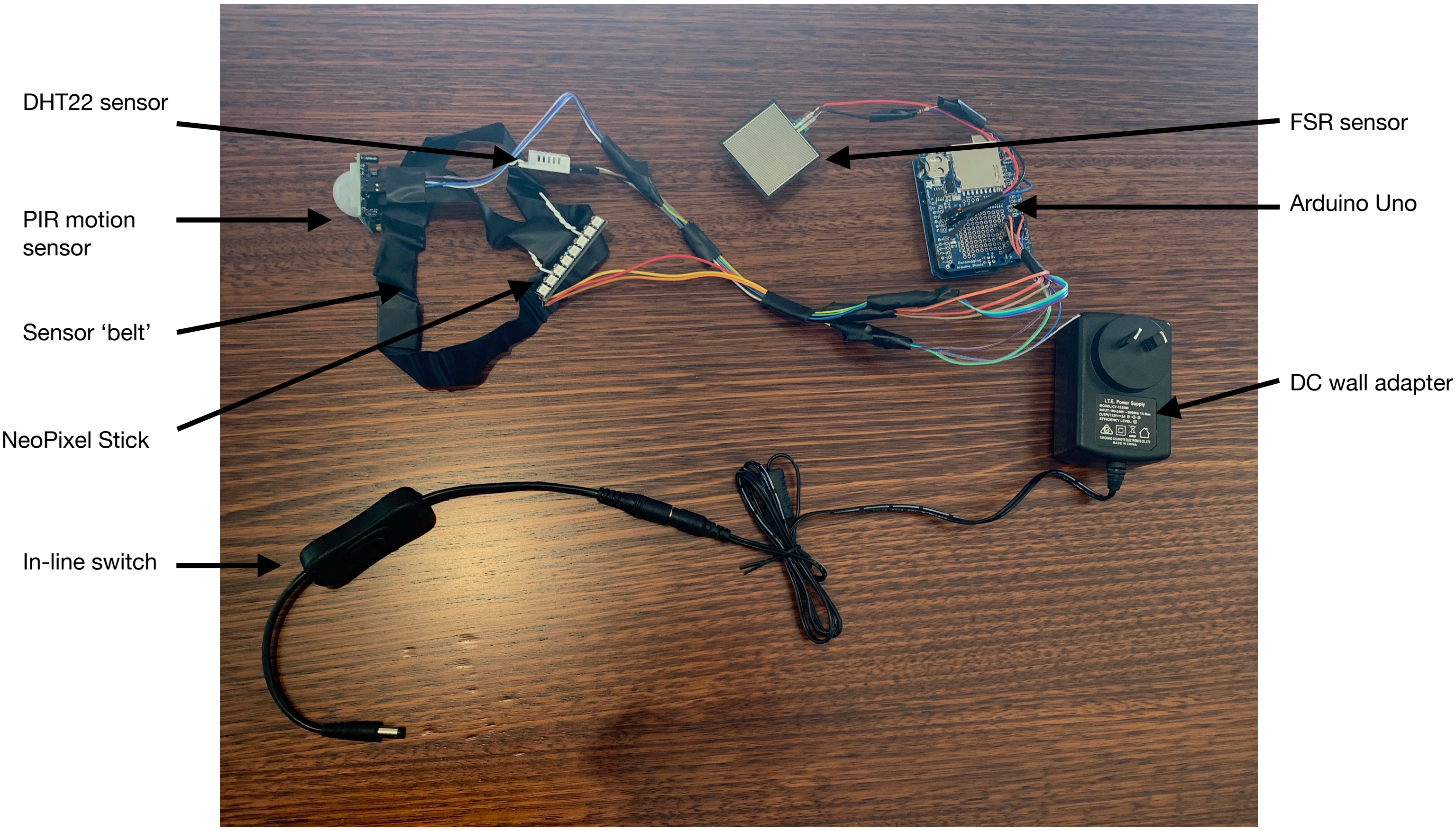


Figure 4. Sensor attachments.

This provides a view of the system’s sensor layout.

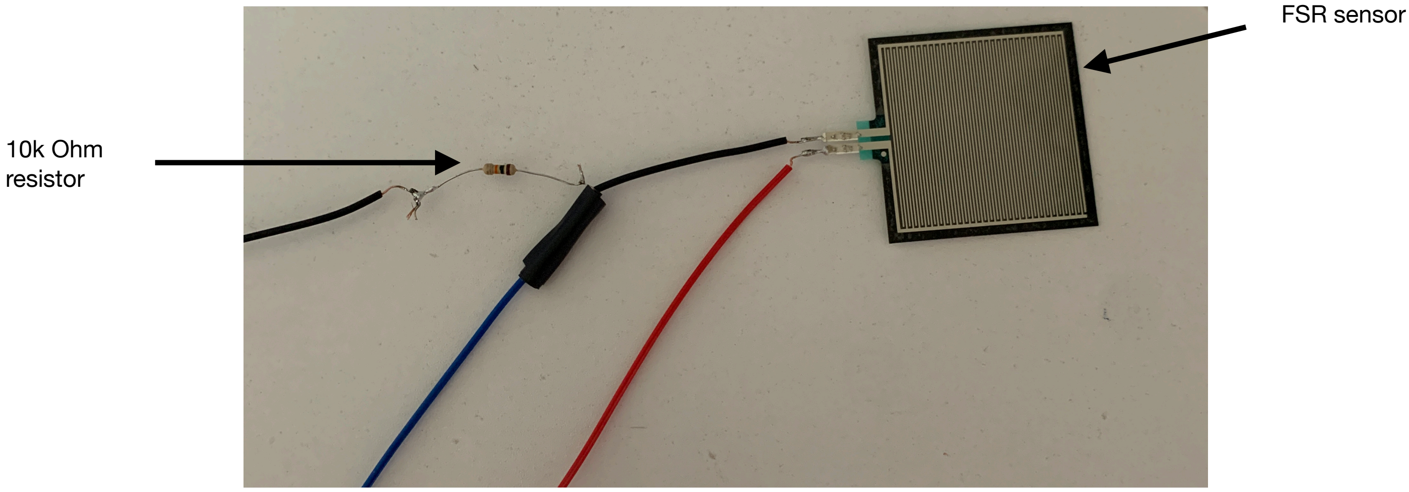


Figure 5. Wiring required for functional FSR sensor.

This demonstrates how the FSR is wired, enabling it to attach to Arduino pins.

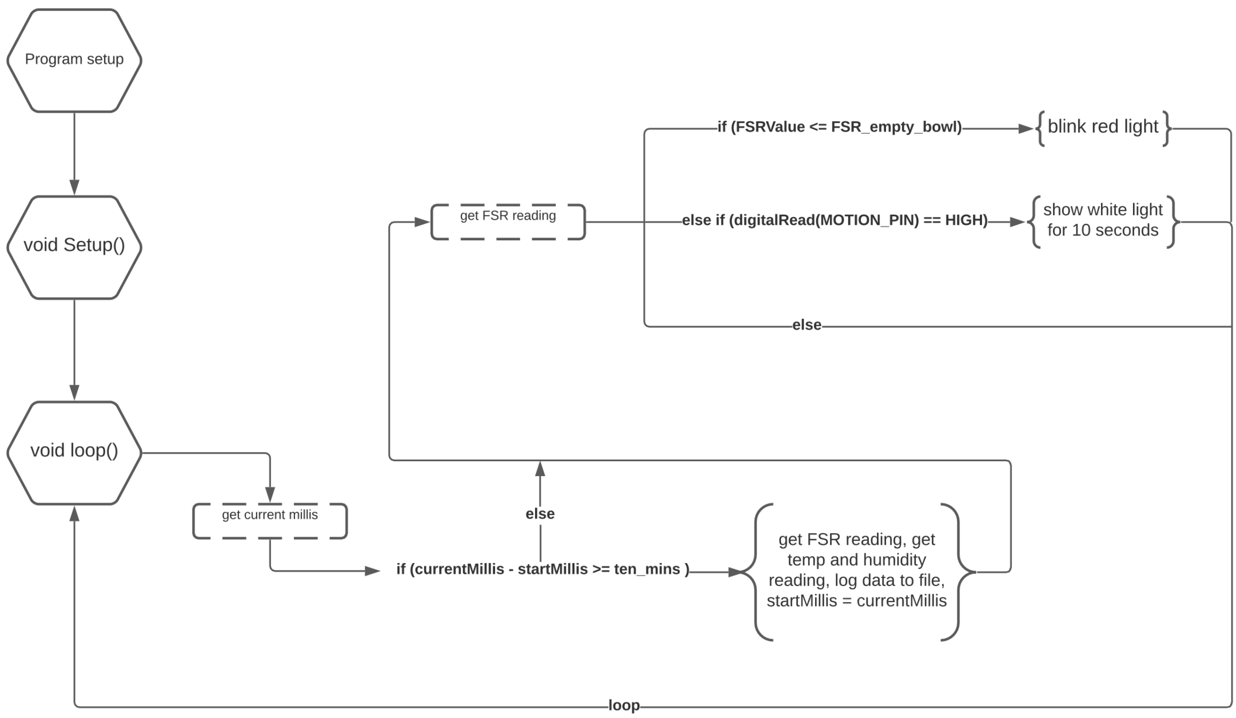


Figure 6. Program flow diagram.

Depicts the program flow inside the void loop() method, describing the functionality of the program as a whole.

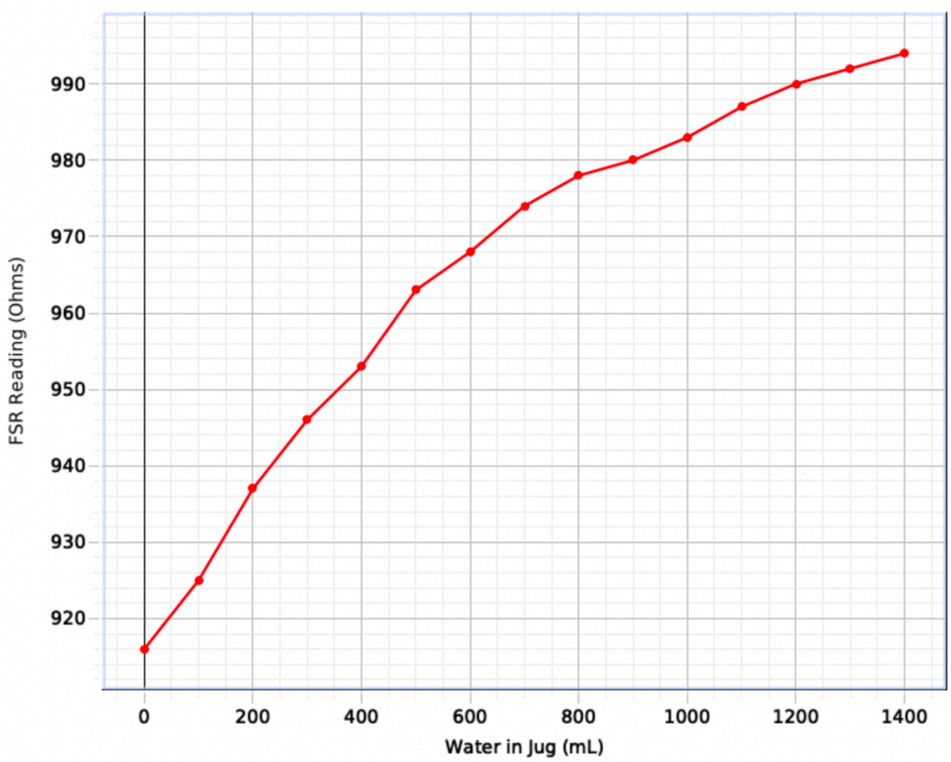
See Appendix 1.4 for the full program code.

DATA COLLECTION PROCESS:

To prepare for data collection, a calibration curve was created that enables conversion of FSR readings (Ohms) to force (grams) which is equivalent to millilitres (for water). This was achieved by measuring the resistance of known weights (Tekscan, 2016). The FSR reading of the empty jug was recorded, which was done using using the test code (see Appendix 1.5). Then an FSR reading was recorded with each addition of 100mL of water. This was repeated until the jug was full (~1400mL), and produced the following data:

mL in jug	FSR reading
0	916
100	925
200	937
300	946
400	953
500	963
600	968
700	974
800	978
900	980
1000	983
1100	987
1200	990
1300	992
1400	994

Using PASCO Capstone software, the following calibration curve was obtained:



FSR vs mL Calibration Curve

Collecting data involved replacing Jordy's current water bowl with this water monitoring system from 2:30pm Sunday 29th August, to 2:30pm Sunday 5th September. This week was chosen for the experiment as it varied in temperature, allowing us to note water habits on cold and warmer days. The data collected includes the date and time, temperature, humidity, and FSR reading (see Appendix 1.6). This data was logged to the .csv file, that is created by the program and stored on the SD card, in 10 minute intervals. At the conclusion of the data collection period, the data was analysed and cleaned (see Appendix 1.7). The .csv file had duplicated every second result, so duplicate results were removed in Google Sheets using the 'remove duplicates' function. The date and time column was then formatted so that it was uniform, as well as the temperature and humidity columns. After this, a column was added to store millilitres, and the calibration curve and FSR results were used to fill this column with data. It was then decided that only whole days would be included in the data for better analysis, so results from both Sunday 29th August and Sunday 5th August were removed, leaving only data from Monday 30th August to Saturday 4th August inclusive. The total millilitres of water drank was then calculated, as well as the maximum temperature and humidity using Google Sheets' sort function.

ETHICAL CONCERNS:

Ethical concerns of data collection for this water monitoring system mainly involve potential security breaches. Given that a pet's water intake is reflected in the collected data, if there is no change in the FSR reading for an extended period of time, it can be assumed that the pet is not home; and perhaps the home is vacant. This could result in break-ins and theft, should the data be unethically obtained. Additionally, if this system became a product available to the public, data could be sold to companies that offer pet insurance. Companies may then be charge owners a premium for their services citing the pets' poor health; which is information they may only have gained from their water drinking habits, infringing on the owner's privacy.

Ethics regarding decision-making and acting by this system are care-based. Other than recording data, the only action the system performs is operating a light, which guides a pet to the bowl, or notifies the owner that the jug needs to be refilled. The system centres itself on monitoring the dogs health, intending to alleviate potential suffering the pet may otherwise endure.

Additional ethical concerns include Jordy's safety throughout the experiment, given that there is risk of electrocution with water so close to an active circuit. However, measures were taken to mitigate this risk, including taping over all exposed wires and solder, placing the microcontroller in a closed plastic bag, and placing all wiring behind the jug to shield it from water splashes.

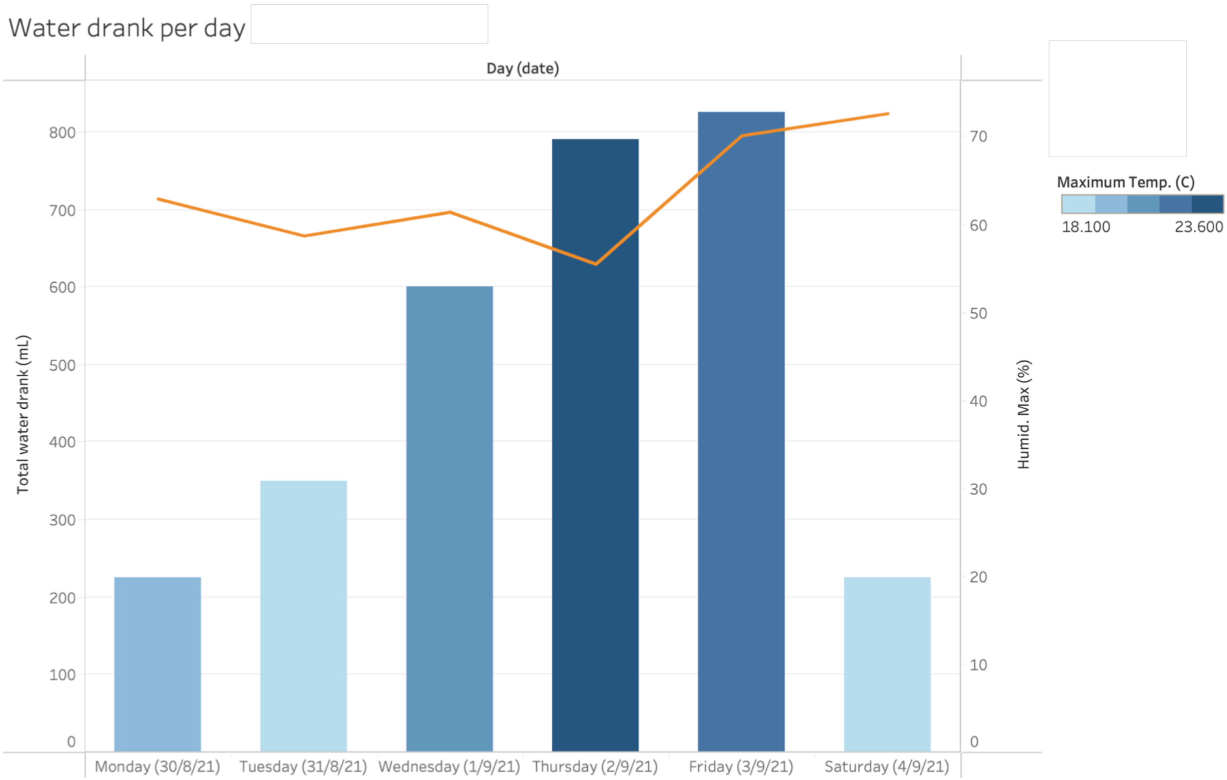
RESULTS AND DISCUSSION:

The following summary was produced from the collected data:

Day (date)	Temp. Max (C)	Humid. Max (%)	Total water drank (mL)
Monday (30/8/21)	20.10	62.90	225
Tuesday (31/8/21)	18.90	58.70	350
Wednesday (1/9/21)	21.20	61.40	600
Thursday (2/9/21)	23.60	55.50	790
Friday (3/9/21)	21.50	70.10	825
Saturday (4/9/21)	18.10	72.60	225

The data aligns with Jordy's activity throughout the week, as he was being looked after at a family member's home on Monday 30th, and spent much of the day at the dog park on Saturday 4th; at both of these locations Jordy was provided with water. Thus from the data collected, we can see that this water monitoring system is able to provide us with an adequate description of our pets regular water habits, and will be able to detect changes in these water habits that could indicate illness.

Position and colour are used to clearly visualise the summarised data, given that the data collected is primarily quantitative. Bar length is used to represent the total water drank (ratio data type), while a colour scale is used to illustrate the temperature (interval data type). Humidity (ratio data type) is represented positionally and has been made a different colour to aid readability.



The trends of sum of Total water drank (mL) and sum of Humid. Max (%) for Day (date). For pane Sum of Total water drank (mL): Color shows sum of Temp. Max (C). For pane Sum of Humid. Max (%): Size shows sum of Temp. Max (C).

From the visualisation we can determine that Jordy drank within the required range for a dog his size (525-875mL per day) on both Wednesday and Thursday, however he did not drink enough water on Tuesday. Jordy was not present at home for most of Monday and Saturday, however he did drink 225mL on both these days in his limited time spent at home, so it is reasonable to assume he had drank adequate water; but it cannot be determined for certain.

The water monitoring system successfully tested the hypothesis, as it was able to provide us with an adequate description of Jordy's water drinking habits by converting FSR readings to millilitres of water. The total intake over the day was then calculated by taking the difference from the start versus end of the day. Likewise, It is clear that a sensor based water monitoring system is capable of recording a pet's regular water habits over time. Additionally, this system can indeed determine the daily water intake in millilitres of a pet with a good degree of accuracy, as Jordy's activity throughout the week is well reflected in the data.

Moreover, we can see that as temperature increases, Jordy's water intake is towards the higher end of his healthy range, which is as expected. There is also a notable difference between humidity on Tuesday and Thursday, compared to Friday. Meaning Jordy is drinking more on days with higher humidity. From the data, it is reasonable to assume that Jordy is drinking mostly within a healthy range, and that his water intake increases as temperature and humidity increases. This indicates that Jordy is a healthy dog (Turner J., 2017), and we should not suspect any underlying health issues where water intake is an indicator, as his daily water intake is not a cause for concern. Therefore, this system can provide insight into a pet's current health status, where water intake or lack thereof is symptomatic of illness.

CHALLENGES AND LESSONS:

The biggest challenge faced was getting Jordy comfortable drinking out of the bowl. He was quite apprehensive initially but warmed up to it after his old water bowl was placed nearby. This allowed him to make the association that the contraption in front of him was a new water bowl. Additionally, it was only realised after the conclusion of the data collection period that using the delay() function to operate the white light for 10 seconds ceased other functions for 10 seconds, which is relatively insignificant. However, it did alter the timer and threw out the 10 minute data collection intervals slightly. This did not impact the end result, but in future a second timer should be used in place of the delay() function.

PROPOSAL FOR EXTENSION:

An extension of this system could include modelling an equation in PASCO Capstone that relates Ohms to millilitres. This would require measuring a wider range of data, and therefore determining the resistance of a much larger range of known weights (~0-20kg). Then inputting this equation into the program code to log millilitres to the file immediately; rather than first logging FSR readings, and converting to millilitres manually at the conclusion of the data collection period. Then to extend upon this even further, an LCD display could be input onto the jug. This could display the current water intake for the day, and a rolling weekly average for your pets daily water intake, which negates the need to check the .csv file data altogether.

REFERENCES:

Calder Vets, 2021, 'Why is my dog or cat drinking so much water?'. Calder Vets, accessed August 23 2021,
<*https://www.caldervets.co.uk/pet-help-advice/general-pet-advice/pet-health/110-why-is-my-dog-or-cat-drinking-so-much-water*>

Davies Vet Specialists, 2021, 'Polydipsia in Dogs and Cats (increased drinking) Fact Sheet'. Linnaeus Veterinary Limited, accessed August 23 2021,
<*https://vetspecialists.co.uk/fact-sheets-post/polydipsia-in-dogs-and-cats-increased-drinking-fact-sheet/*>

Dr. Paul M., 2015, 'My Dog is Drinking a Lot of Water (Polydipsia)'. PetHealthNetwork, accessed August 23 2021,
<*https://www.pethealthnetwork.com/dog-health/dog-diseases-conditions-a-z/my-dog-drinking-a-lot-water-polydipsia*>

Limor Fried, 2012, 'Force Sensitive Resistor (FSR)'. Adafruit, accessed August 27 2021,
<*https://learn.adafruit.com/force-sensitive-resistor-fsr*>

Samford Pet Resort, 2018, 'How Much Water Should My Dog Drink?'. Samford Pet Resort, accessed August 27 2021,
<*https://www.samfordpetresort.com.au/how-much-water-should-my-dog-drink/*>

Tekscan, 2016, 'How to convert Resistance (Ohms) to Force (lbs)?'. Tekscan, accessed August 28 2021,
<*https://www.tekscan.com/support/faqs/how-convert-resistance-ohms-force-lbs*>

Turner J., 2017, 'Why is My Dog Drinking so Much Water?'. AnimalWised, accessed August 28 2021,

<*https://www.animalwised.com/why-is-my-dog-drinking-so-much-water-2281.html*>
Veterinary Emergency Group, 2021, ‘Reasons Why Your Dog Won’t Drink Water’. Veterinary Emergency Group, accessed August 23 2021,
<*https://veterinaryemergencygroup.com/blog/dog-wont-drink-water/*>

APPENDIX 1

1.1 LIST OF MATERIALS

- DHT22 Temperature and Relative Humidity Sensor
<*https://core-electronics.com.au/dht22-temperature-and-relative-humidity-sensor-module.html*>

- PIR Infrared Motion Sensor
<*https://core-electronics.com.au/modmypi-pir-infrared-motion-sensor-hc-sr501.html*>

- Force Sensitive Resistor (Square)
<*https://core-electronics.com.au/force-sensitive-resistor-square.html*>

- Adafruit NeoPixel Stick
<*https://core-electronics.com.au/neopixel-stick-8-x-ws2812-5050-rgb-led-with-integrated-drivers.html*>

- Adafruit Assembled Data Logging Shield for Arduino
<*https://core-electronics.com.au/adafruit-assembled-data-logging-shield-for-arduino.html*>

- In-Line Power Switch
<*https://core-electronics.com.au/in-line-power-switch-for-2-1mm-barrel-jack.html*>

- Kmart Pet Water Dispenser
<*https://www.kmart.com.au/product/pet-water-dispenser/831473*>

- 12V 2A DC Power Adapter
<*https://www.auselectronicsdirect.com.au/12v-dc-2a-compact-power-adapter-with-2.1-dc-plug?gclid=CjwKCAjw7fuJBhBdEiwA2lLMYUr7VSLx-3zVxBMCLCkPPitUqo2B40sGvK7XvO-bhDzr9uEVg6u_VBoCcqsQAvD_BwE*>

1.2 3D RENDER OF INITIAL DESIGN

Accessing the link below will allow you to download the full 3D render of the initial system design.

<*https://drive.google.com/file/d/118PTujmQwqe-KasKwvNdjmonW7pwsx4Z/view?usp=sharing*>

1.3 RED BLINKING LIGHT

Accessing the link below will allow you to view a video of the red blinking light in operation.

<*https://video.deakin.edu.au/media/t/1_l2v9n3pa*>

1.4 PROGRAM CODE

Accessing the link below will allow you to download the full program code for the system as a .txt file.

<*https://drive.google.com/file/d/1elxKpytirAbN6Ccf7T0JhYCpDdGLL8_6/view?usp=sharing*>

1.5 TEST CODE

Accessing the link below will allow you to download code used to generate the calibration curve for the system as a .txt file.

<*https://drive.google.com/file/d/1vmMO3pExLG03WckeIVU-DAE00LuXLlzW/view?usp=sharing*>

1.6 ORIGINAL DATA

Accessing the link below will allow you to download the original data collected by the system.

<*https://drive.google.com/file/d/1p1dafXTc-zF4Fa5IcAzezdnOR1eJ3ASG/view?usp=sharing*>

1.7 CLEANED DATA

Accessing the link below will allow you to download the cleaned data.

<*https://drive.google.com/file/d/1Q79Xr03NGnCAKg918ifNWZA4X_S8MJF-/view?usp=sharing*>

For Jordy <3