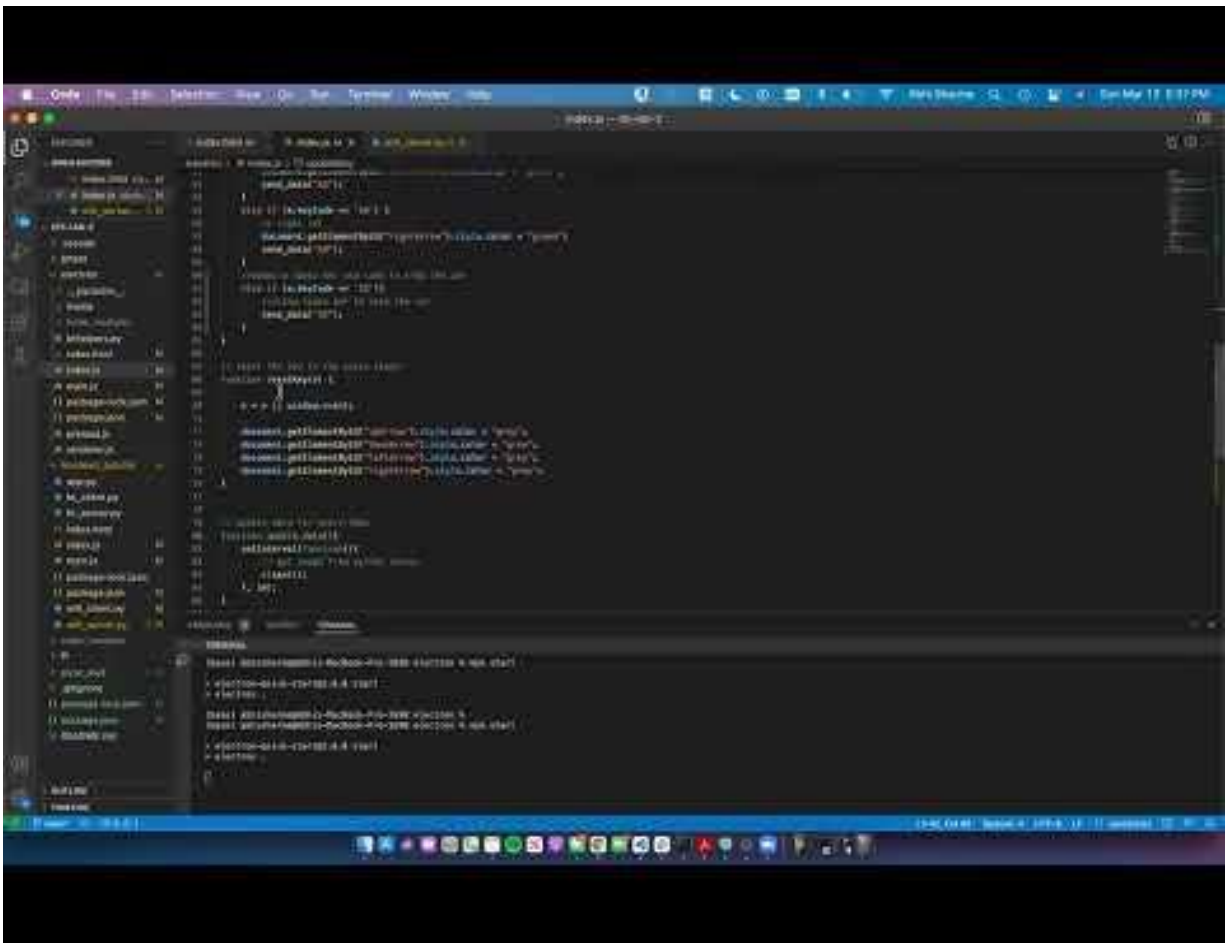
CS437: Internet of Things

# Lab 5: Wildlife Conservation

## Technical Solution/Specification Report

Code: https://gitlab.engr.illinois.edu/asharm92/lab-2-edge-networking-asharm92-kgulati2-nkgowda2

Video: IOT Lab 2 Video (asharm92, kgulati2, nkgowda2)



**Team members**

| Names | ID | Responsibilities/Contributions |
|---|---|---|
| Karan Gulati | kgulati2@illinois.edu | • Arduino building and setup, code implementing.<br>• Simulation running and data collection<br>• Report writing and analysis of data |
| Abhi Sharma | asharm92@illinois.edu | • Arduino building and setup, code implementing.<br>• Data parsing and graph implementation<br>• Report writing and analysis of data |
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## Purpose

Purpose of this report is to document the design of a device that can monitor the safety and health of zebras and the population of zebras. To do this we must consider aspects of their environment, including predators that hunt them, sources of food, and migration/mating patterns.

### a. Design of the Device

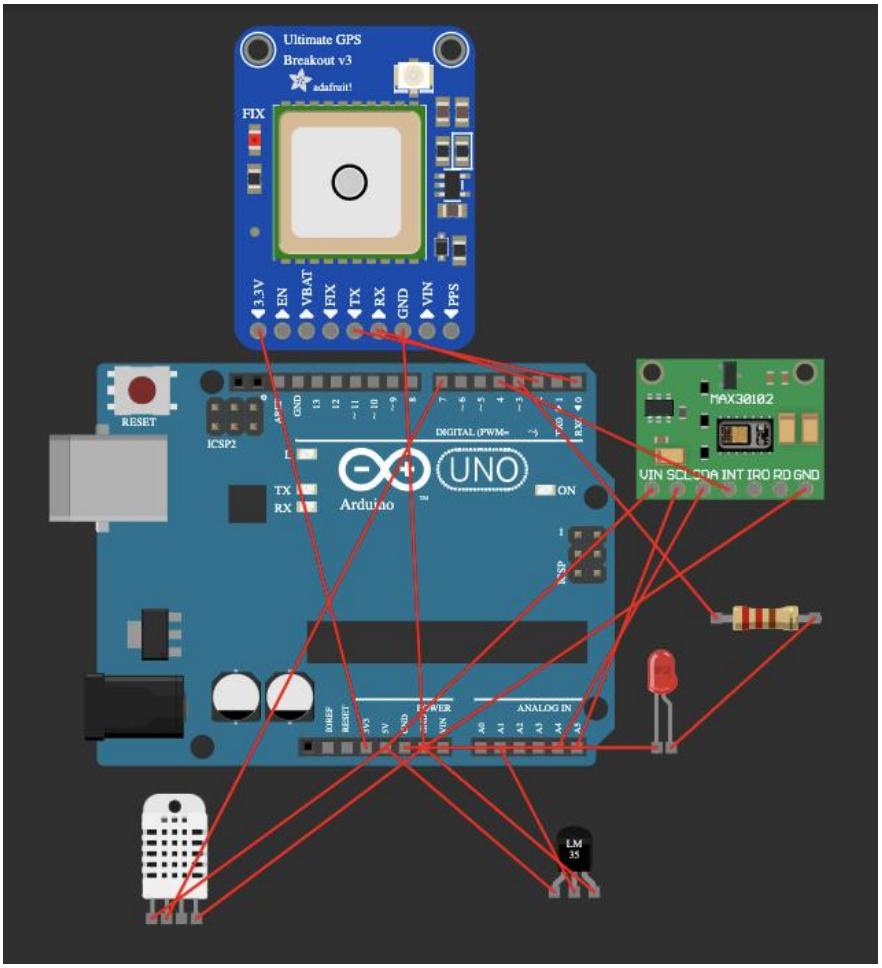
In order to design a proper device that considers all the above aspects, we must start with a design and some basic questions regarding what that design should include.

1. *What sensors would you need?*
   The two main sensors that we need to incorporate in our design are GPS and Vitals. GPS is especially important as it will give us information on herd location and movements, which can allow for understanding of migration patterns and favorable locations for the zebra. Vitals are of obvious importance, as knowing the blood oxygen and heart rate can tell us whether the environments the zebras are encountering are generally healthy. Two other sensors we believe would be helpful for use are the temperature and humidity sensors, as those can give us deeper insight on the environments that the zebras are visiting.
2. *How would they be connected?*
   Using Arduinos, we can connect these sensors and pull data through output. This way, all the data will be pulled and then send to the Arduino for our use. We can then establish a network to download that data remotely with Arduino connection.
3. *What sort of code would you run on there?*
   The code we would run would essentially check if there is data to be pulled, pull the readings from each device, and then format them accordingly. For example, with a value like temperature, we may need to do some conversions to format it in the correct units. The code would also include lines to help with displaying the data readings in an organized fashion.
4. *Where would you put the sensors on the animal?*
   After consulting an Animal Sciences Major we are in contact with, we determined that the best place to put the sensor system is as a collar the Zebra can wear. This will decrease the chances of the zebra interfering with it or somehow removing it. One thing we considered is the fact that if a predator were to go for its neck, such as a lion, the device may be damaged. In the case that readings from a sensor are quickly lost, if we cannot reestablish connection with it, it may be safe to assume that the zebra has been killed by a predator.
5. *Physical construction? (waterproof? weight? where would you put it on the animal?)*
   Construction should be lightweight, as a noticeable weight would make the zebra more likely to try to take it off. The Arduino and wiring will be kept in a lightweight titanium casing, as that will be lighter than most casing and much more durable than a plastic. This

would of course be waterproof, as zebras will go into many environments that may not be suited for electronics. Again, it should be placed around the neck as a collar, as that is the safest spot for both the animal and keeps it away from the animals reach.

### b. Implementing the Device

Based on our chosen sensor types, we used the available devices in the IoT playground application. The configuration for the wiring can be seen below, where we have the GPS, Vitals sensor, temperature sensor, and humidity sensor.




Below is the code that we used to read in the data using the “Lab 5 tips and common issues” we were able to manipulate that code to be utilized with all the devices. The “setup()” portion of the code sets the pins for each of the sensor and begins the sequence.

```
Adafruit_GPS GPS;
PulseOximeter pox;
void setup() {
   pinMode(A1, INPUT); //temperature
   pinMode(7, OUTPUT); //humidity
   pinMode(2, OUTPUT); //gps

   pinMode(4, OUTPUT); //vitals
   pinMode(3, OUTPUT); // Oxygen

   Serial.begin(9600);
}
```

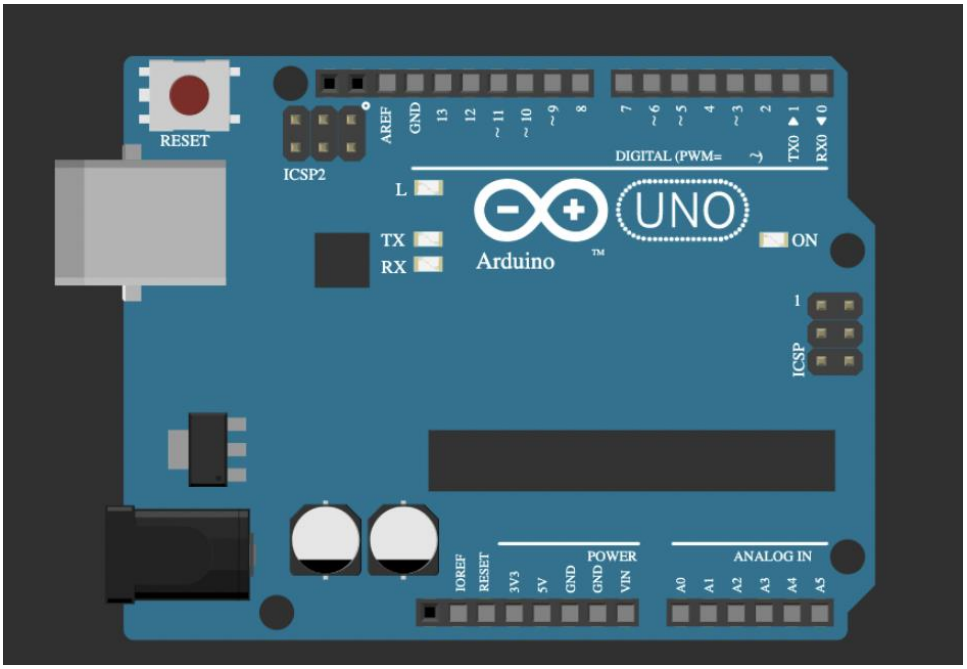
The loop() portion pulls the data and prints it in the log. For some values of the data conversions need to be done, such as temperature where we convert to the correct units. This is done for each of the data values that we are logging for each device. The final line for each of these data values is the Serial.sendMessage() line. This line corresponds to the networking aspect of the code which will be discussed further in the next section, but this line essentially reads the message of the data to the other Arduino.

```
void loop() {
   //CODE FOR TEMPERATURE
   float temp = analogRead(A1) / 1023.0 * 5.0 * 100.0;
   string msg_temp = "Temperature: " + to_string(temp);
   Serial.println(msg_temp);
   Serial.sendMessage(A1, msg_temp);

   //CODE FOR HUMIDITY
   float h = digitalRead(7);
   string msg_hum = "Humidity: " + to_string(h);
   Serial.println(msg_hum);
   Serial.sendMessage(7, msg_hum);

   //CODE FOR GPS
   if (Serial.available() > 0) {
      string gpsResult = GPS.read();
      string msg_gps = "GPS: " + gpsResult;
      Serial.println(msg_gps);
      Serial.sendMessage(2, msg_hum);

  } else {
      Serial.write("No data");
      Serial.sendMessage(2, "No data");
  };
```

```
//CODE FOR VITALS
if (Serial.available() > 0) {
    if (pox.begin()) {
        string spO2_res = pox.getSpO2();
        string hb_res = pox.getHeartRate();

        string msg_vital = "Oxygen percentage: " + spO2_res + "| Heart rate: " + hb_res;
        Serial.println(msg_vital);
        Serial.sendMessage(4, msg_vital);
    }
    digitalWrite(3, HIGH);
} else{
    Serial.write("No data");
    digitalWrite(3, LOW);
}
delay(1000);
```

### c. Networking the Device

Below is the layout for the second Arduino we are using for the networking, which is simply the Arduino.




Below is the code used on the second Arduino to receive that data. It reads in the data only if there is an available message, and sets a new string equal to that message and prints it. Thus the logs the same data that the original Arduino with the sensor set up sees. This will allow for us to monitor the zebras data without physically collecting from each zebras device. We were unable to implement the gossip protocol due to the limitations of the platform but if we were to implement it, each Zebra would have a receiver as well as a sender attached to them. This way, they could receive data from nearby animals that they interact with and then we would only need to sample one zebra to get data of other zebras that they came in close contact with.

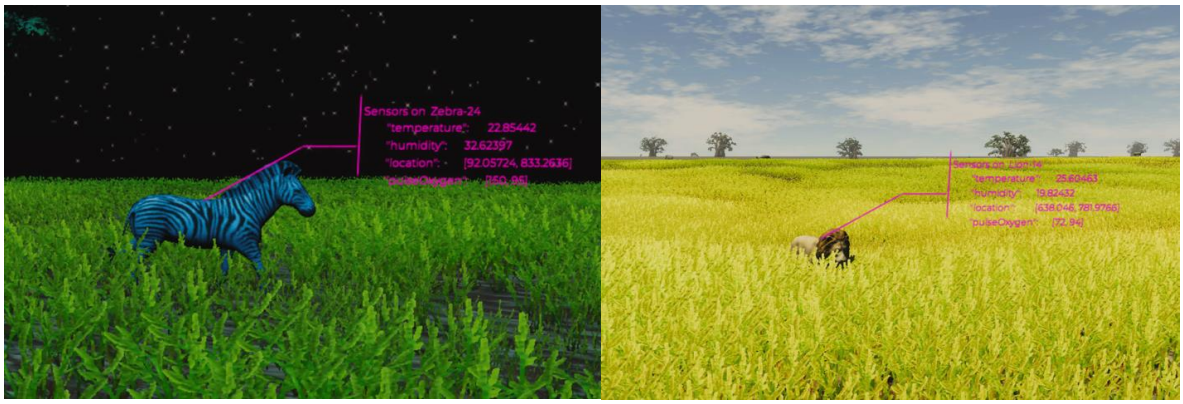
```
1   void setup() {
2
3     Serial.begin(9600);
4   }
5   void loop() {
6     if (Serial.availableMessage() != 0) {
7         string mystr = Serial.readMessage();
8         Serial.println("Printed by receiver: " + mystr);
9     }
10    delay(2000);
11  }
```

**d. Game Simulation**

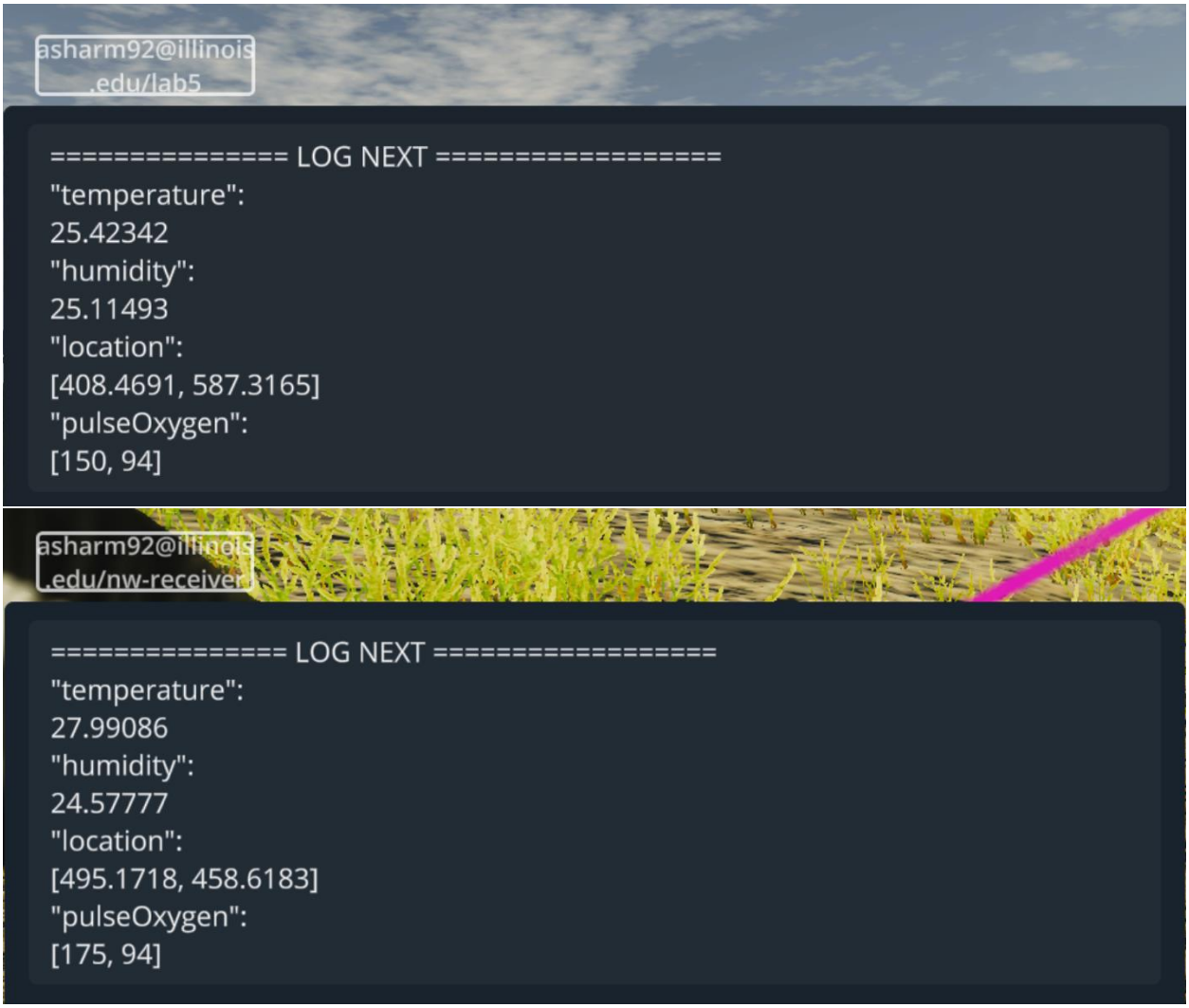
Now, the goal is to tag as many animals as possible so that we can monitor their movement within the simulation. Using our above described Arduino systems, we have the original Arduino named “lab5” as well as our receiving device “nw-receiver”. Below we see some of the tagged animals, which includes 14 zebras, 10 elephants, and 5 lions. This should allow for us to collect significant data on the movements of each species.


Here is an example of some of the animals we captured, more animals were captured over a longer period of time (2-3 days within the simulation, sunrise to sunset) to ensure we had enough usable data.

Below we can see that the data displays for each of these animals, including all the sensors we have implemented: temperature, humidity, location, and blood oxygen. This proves clearly that our logging for the original Arduino with the sensors is functioning correctly.




To check if our networking is working correctly, we also attached the “nw-reciever” to each of the animals. This is to allow us to view the logs of this device to see if data is being transmitted. Below we can see the logs of both the original Arduino “lab5” as well as the “nw-reciever”

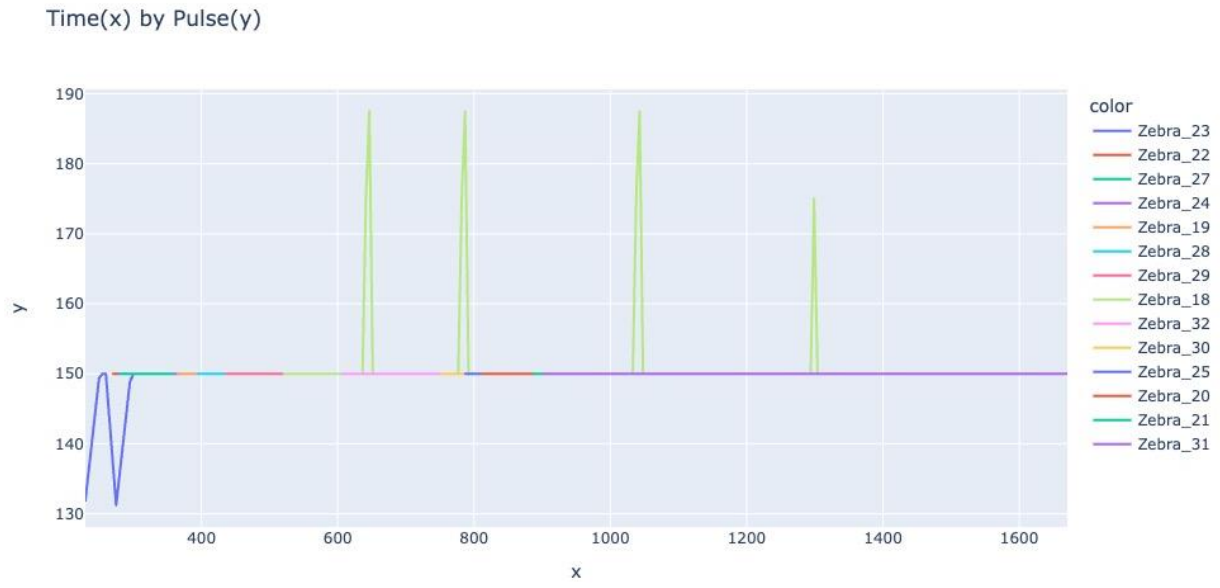


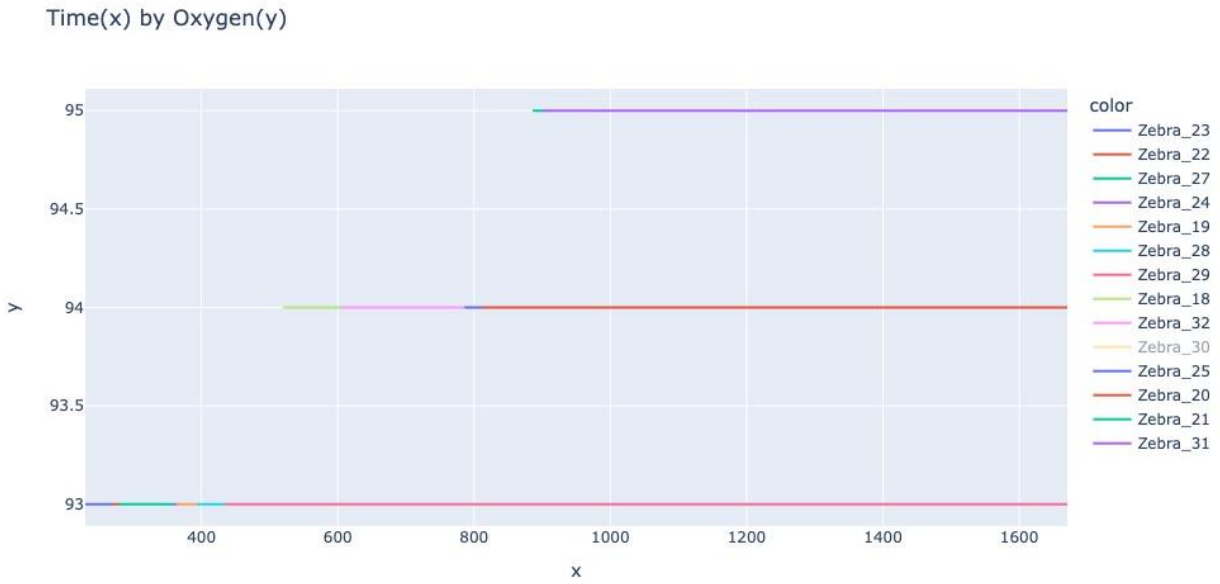

As we can see, both the logs are displaying the correct data and there is a log for both the "lab5" device as well as the "nw-receiver" device. This means that the data on the original device is transmitting data to the receiver, proving our networking functionality is working as expected.

**e. Analyzing the Data**

1. *Is the Zebra population healthy? Make a thoughtful case one way or another.*

To answer this question, we can look at our vitals data. This includes both oxygen levels and pulse of the animals, and to understand the health of the zebra population we decided to graph these with time.




From our data, we can see that only one zebra, “Zebra_18” had spikes in their pulse. This signifies a possibly dangerous or life-threatening event, and because the pulse does not fall out, we can assume this zebra survived these events. The oxygen levels for each of these zebras also stays constant, at between 93-95. Because none of the zebras pulses go out and their oxygen levels are constant, we can conclude that they are healthy in this environment.

2. *Do the Zebras have enough room to move around in?*

To see if the Zebras have enough room to move around in, we decided graphing all the x and y positions and sectioning them by Zebra was the best way to track their movement. We added a circle where the source of water is located at [600,600] for a better idea of the geography. Below we can see the produced graph:


As we can see, the Zebras have plenty of space to move around in and if anything do not utilize all of it as much as they could. We encountered a couple glitchy Zebras, such as "Zebra_29", "Zebra_27", and "Zebra_25" that do not move at all. Aside from this the other Zebras seem to be moving normally. The Zebras tend to stay around the areas they are already located in, migrating slowly around, with even some almost doing circles such as "Zebra_32".

3. *Do you see any signs of poachers? If so, where are they?*

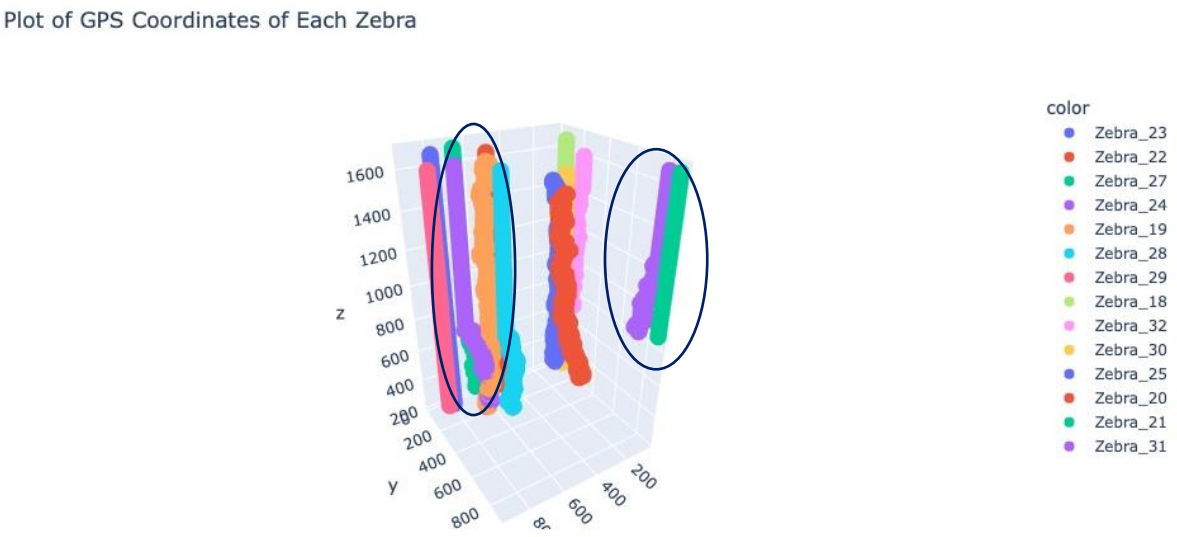
None of our Zebras died during our experiment, thus either there are no poachers in the area during our experiment runtime or they are bad at poaching!

4. *Plot a CDF of the movement speed of Zebras. What do you observe?*

5. *Do Zebras make friends? Do you see pairs that tend to stay together?*

Looking at the "Plot of GPS Coordinates of Each Zebra" Graph, we can see that perhaps "Zebra_24" and "Zebra_19" were friends, as they tend to stay near one another for the duration of data collection. We can also see that "Zebra_24" in the top left corner is getting closer to "Zebra_27" indicating maybe they want to be friends as well.

We can investigate this even further by producing a 3D plot of the x and y coordinates over time for the Zebra. Below is that graph:



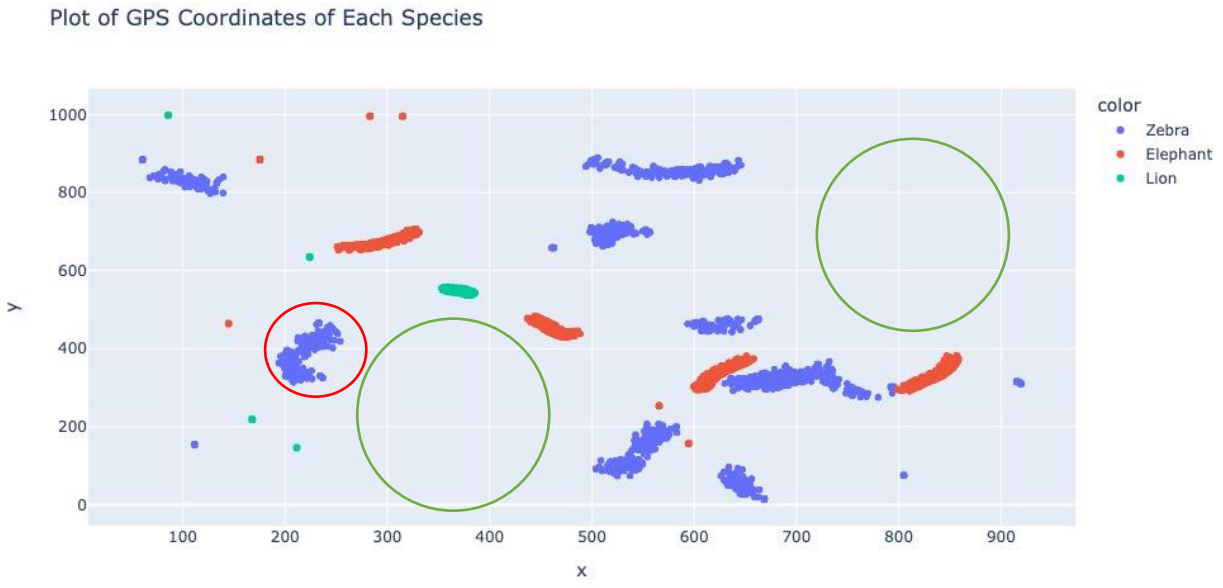

Upon using the timestamps to see the movement of the Zebra population more clearly, we can see that in fact “Zebra_24” and “Zebra_19” diverged from one another. Perhaps they were friends before, but are no longer friends. We can also see that “Zebra_24” and “Zebra_27” did become friends, as over time they tend to converge to one another.

6. *What locations do Zebras tend to congregate at? Why do they tend to go there?*

Most of the Zebra tend to hang around the center of the map around [500-700,500-700]. This makes sense, as this is the body of water that all the animals in the environment share, thus this being a congregation location is very sensible.

7. *Are there any locations Zebras tend to avoid?*

To understand this question, we decided graph the same GPS data but instead sectioned by species. We also circled the main areas where there are no trees. Below is the produced graph:

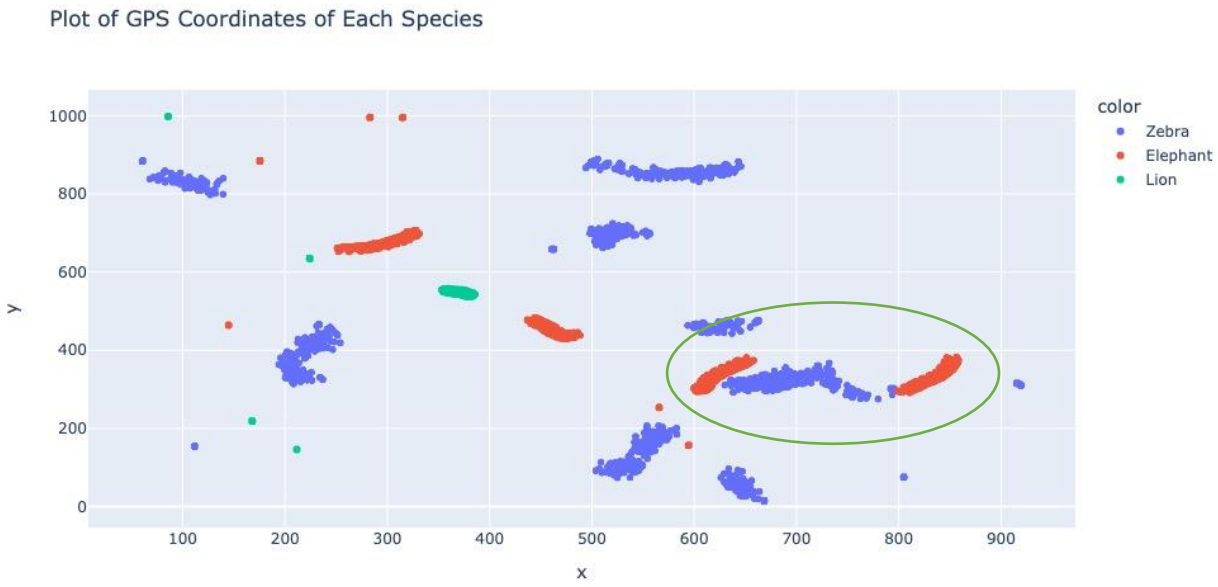


We didn't notice too much interaction between the lions and the Zebra, as most of our lion population remained stationary. But, as we can clearly see, the areas that the Zebras tend to avoid are the ones with little to no coverage, or the no tree areas circled above. This makes sense as the coverage will provide protection from the sun as well as predators, so it would make sense for the zebra population to generally avoid this. We also noticed that one zebra (circled in red), turned in a "U" motion during the length of the experiment. We believe this could be due to the presence of the two lions underneath on the graph, thus forcing the Zebra to change direction.

**f. Further Investigation**

*8. How do Zebras interact with other animals, non-predatory to its species?*

To investigate this topic, we can again refer to our species based sectioning of GPS location of each animal. Below we have the graph along with a circled interaction of elephants and Zebra:




In this interaction, we can clearly see that Zebra have no issue migrating into areas where Elephant may be present, and same vice versa. Specifically, the elephant in this area almost offer a layer of protection, as no lions are present in this area and perhaps lion will find it difficult to attack Zebra if large Elephants are able to fend off the lions. This could be the implication of a positive relationship between Elephants and Zebras in this simulation, where if the Zebra stay near the Elephant they have a higher chance of survival.