CS437: Internet of Things
Lab 5

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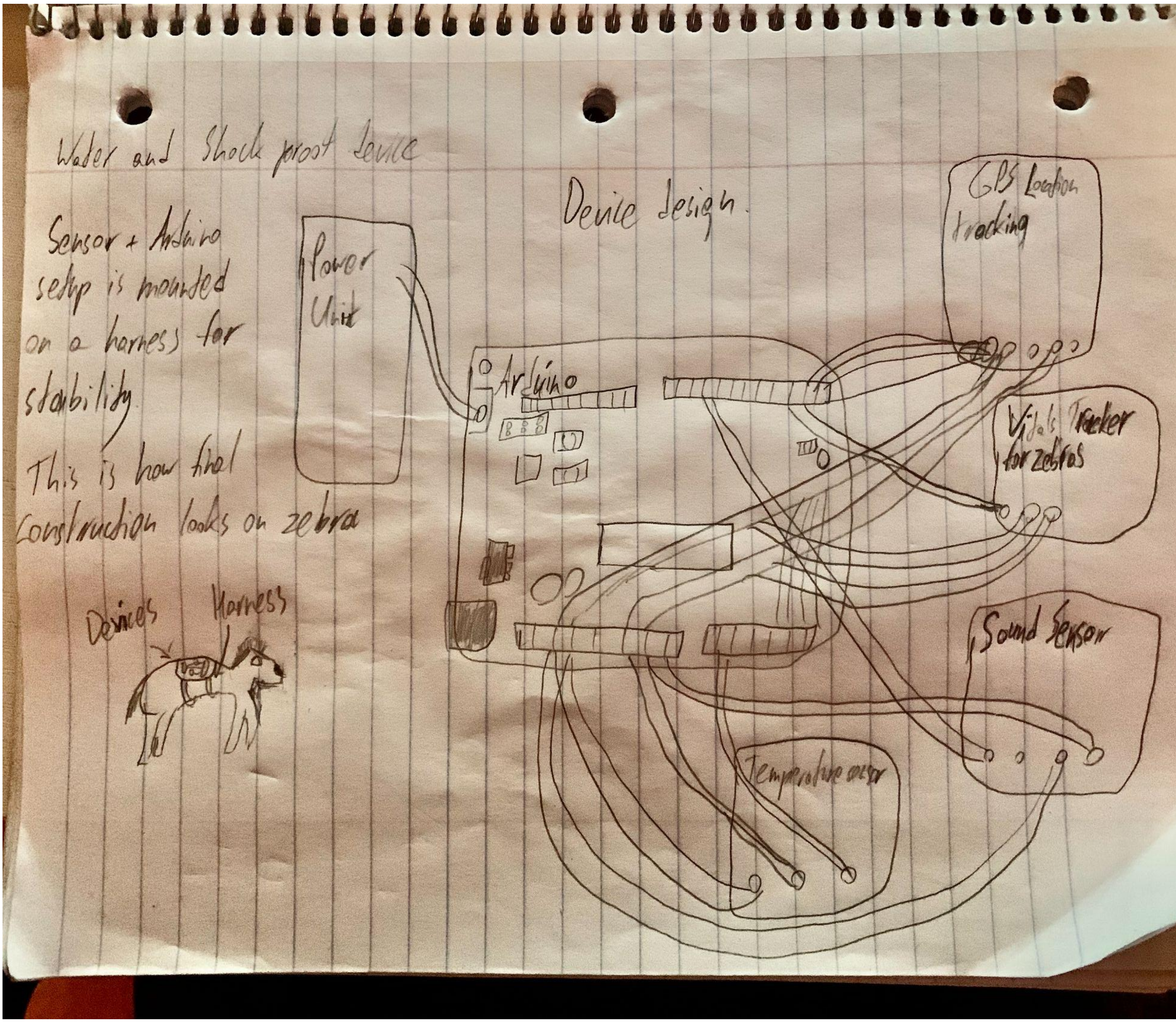
Late days used: 0
Video Link: https://youtu.be/9iMI5eEx5VM

Part 1: Circuit Design and Considerations

Below is a rough sketch of a sensor device that we would deploy on the animals.



1. For our design we have picked 4 sensors in addition to the main Arduino board. Those are GPS location tracker, Vitals reader, Sound Sensor, and Temperature sensor as indicated on a drawing. We came to a conclusion that this combination will give us enough data to make reasonable assumptions about the zebra population as a whole as well as individual zebras.
2. All of the sensor components draw power from the Arduino and read/write signals periodically not to waste too much battery. You can see an approximate wiring on the drawing sketch. As a rule of thumb every sensor needs a ground, wiring, and a set of pins to listen/write to.
3. All code is written for main Arduino unit. It works on a basic principle of a loop. Our device is asleep most of the time. After some time has passed it wakes up does the

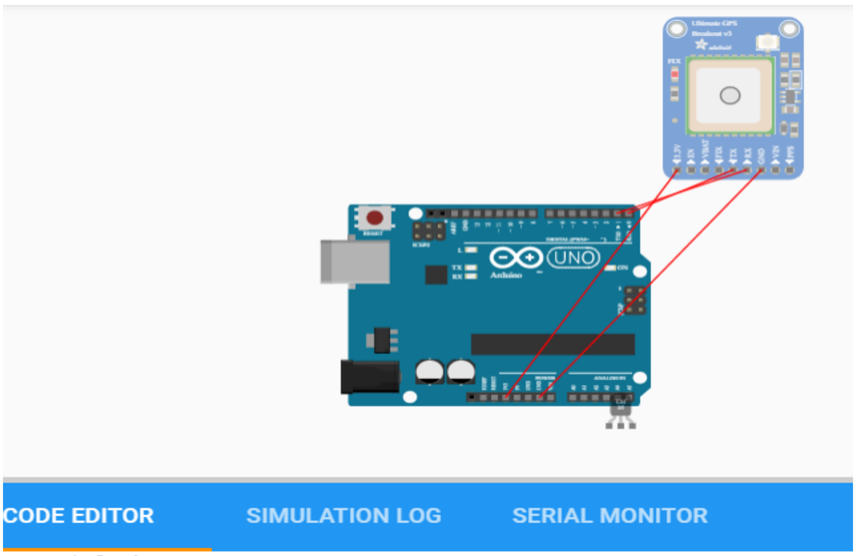
readings for all of the sensors, potentially transfers data to other devices and/or receives “gossip” from neighbouring zebras’ devices, and goes back to sleep. Examples of the code can be seen on video in Virtual playground setup overview.

4. Optimal placing setup is to be fixated on the middle of animals back. We have a harness made that wraps around the whole animal and fixes our digital components in place in case zebra decides to run or makes any rapid movements.
5. Sensors and setup itself are not very heavyweight. We do need however to ensure that the construction is waterproof and resistant to light shocks. We achieve it by using harness and potential casing for the component. We decided that all of these precautions are worth having additional weight placed on an animal.

The main design choices we had to make for our device were what sensors to pick, how many sensors to pick, and how to construct the mount so that the system is safe all throughout the animal’s day. After thinking about data to correct in order to able to answer the questions for this experiment we went with standard GPS and Vitals as well as Sound and Temperature setup. For the mount design we included a casing for the sensors as well as made it waterproof. It added on to the weight of the setup but it is vital to getting good readings and not losing the devices themselves. Final construction is being secured on an animal’s back with a harness and we are good to start the experiment.

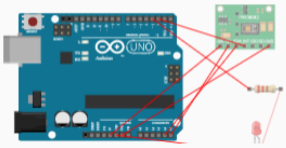
Part 2: Circuit Implementation in Playground

GPS Circuit + Sender Piece



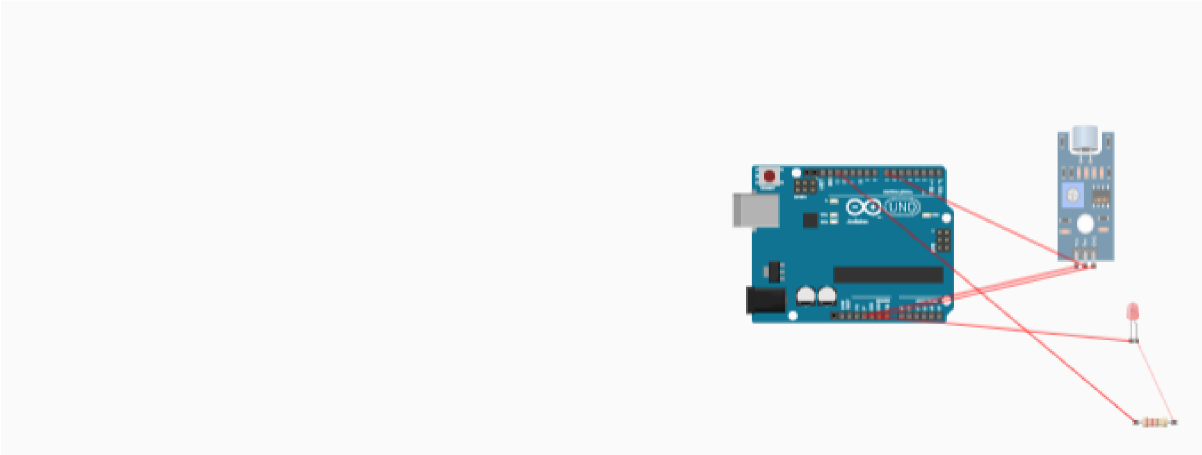

```
Adafruit_GPS GPS;
void setup() {
  Serial.begin(9600);
  pinMode(0, OUTPUT);

}
void loop() {
  if (Serial.available() > 0) {
    string gpsResult = GPS.read();
    Serial.sendMessage(0, gpsResult);
    Serial.println(gpsResult);
  } else {
    Serial.write("No data");
  }
  delay(1000);
```

Vitals Reader Circuit



```
PulseOximeter pox;
void setup() {
  pinMode(2, INPUT);
  pinMode(3, OUTPUT);
  Serial.begin(9600);
}

void loop() {
  if (Serial.available() > 0) {
    if (pox.begin()) {
      string spO2_res = pox.getSpO2();
      string hb_res = pox.getHeartRate();
      Serial.println("Othis is oxygen percentage: " + spO2_res + ";. Hthis is heart rate: " + hb_res);
    }

    digitalWrite(3, HIGH);
  } else{
    Serial.println("No data");
    digitalWrite(3, LOW);
  }

  if (Serial.availableMessage() != 0) {
    string mystr = Serial.readMessage();
    Serial.println("Printed by receiver: " + mystr);
  }

  delay(1000);
}
```

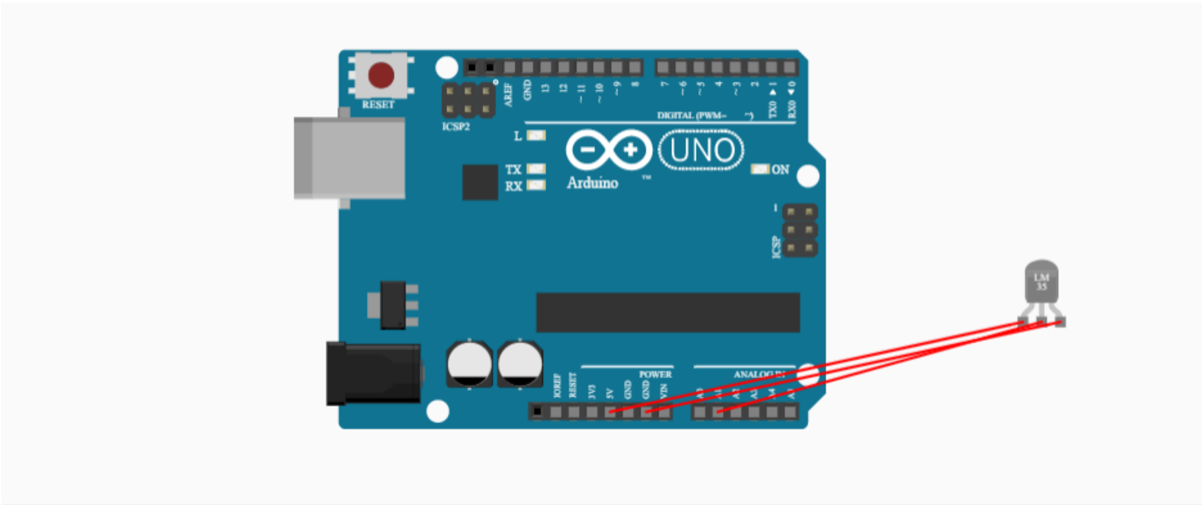
Sound Sensor Circuit



CODE EDITOR SIMULATION LOG SERIAL MONITOR

```
int ledPin=13;
int sensorPin=7;
int val = 0;

void setup() {
    pinMode(ledPin, OUTPUT);
    pinMode(sensorPin, INPUT);
    Serial.begin (9600);
}

void loop() {
    val = digitalRead(sensorPin);
    if (val==HIGH) {
        digitalWrite(ledPin, HIGH);
    } else {
        Serial.println(val);
        digitalWrite(ledPin, LOW);
    }
    delay(100);
}
```

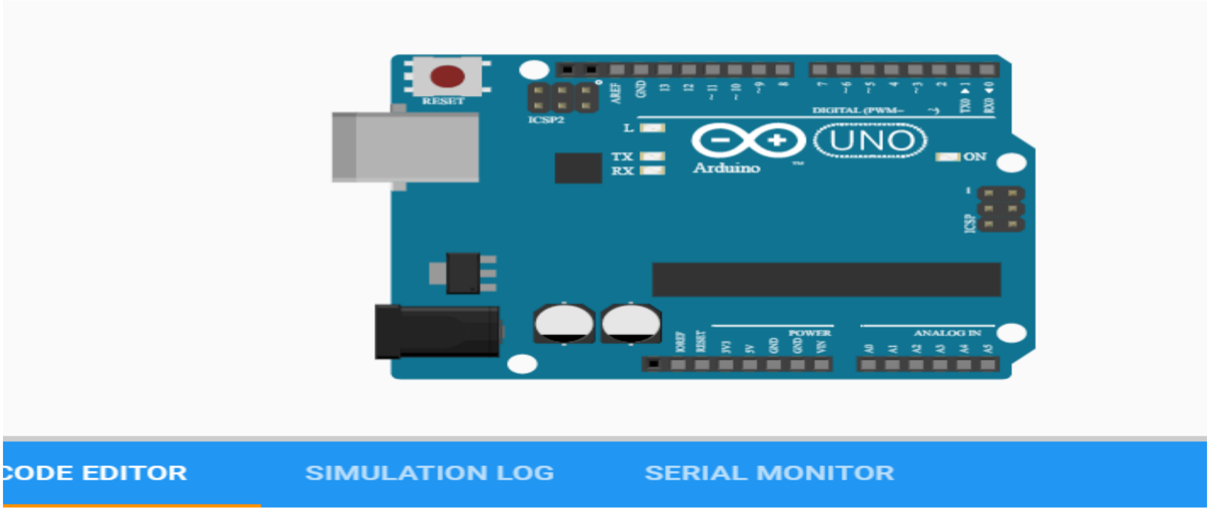
<u>Temperature Reader Circuit</u>



CODE EDITOR | SIMULATION LOG | SERIAL MONITOR

```
void setup() {
    pinMode(A1, INPUT);
    Serial.begin(9600);
}

void loop() {
    float temp = analogRead(A1) / 1023.0 * 5.0 * 100.0;
    Serial.println("temperature: " + to_string(temp));
    delay(1000);
}
```

<u>Receiver Circuit(just Arduino with the receiver code running on it)</u>




```
void setup() {
  Serial.begin(9600);
}
void loop() {
  if (Serial.availableMessage() != 0) {
    string mystr = Serial.readMessage();
    Serial.println("Printed by receiver: " + mystr);
  }
  delay(2000);
}
```

Part 3: Deploying in Savanna Simulation

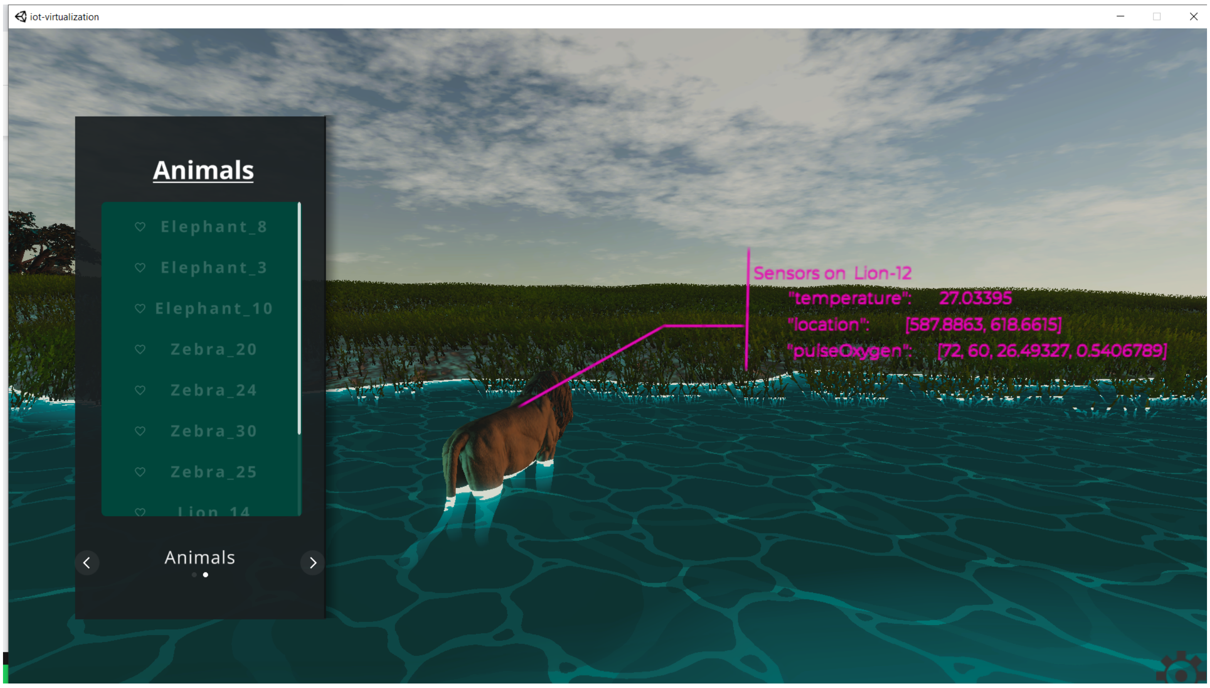
In the Savanna simulation, we tried our best to deploy sensors on every animal in the confined space. For each animal, we deployed the following:

- Vitals Sensor
- GPS Sensor
- Sound Sensor
- Temperature Sensor
- Receiver (for networking purposes)

In total, we deployed sensors on 30 animals in the simulation. We let the sensors collect data for roughly 6 hours of real time, generating substantial amounts of data that could be used for analysis in the next step.

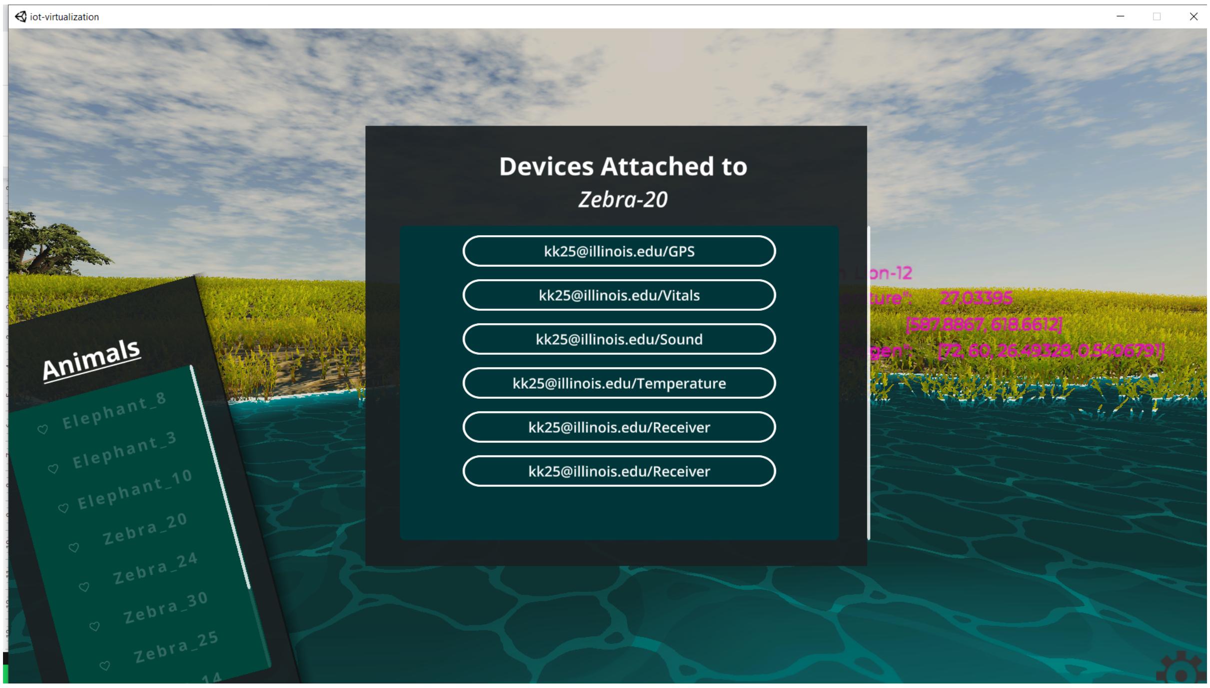
On the next page is an example of what the visible data from the animal looked like after the sensors were deployed. We got data from the GPS, PulseOximeter, and Temperature sensors. A potential bug in the program was that we did not see sound data present in this visualization, but we were still able to collect sound data on some of the animals from the log.

Animals with Deployed Devices



Below is the device setup for each animal. It appears that we accidentally deployed two receivers on this animal, when in general only one was supposed to be deployed per animal. The accidental deployment of an extra receiver on this animal did not negatively affect our ability to collect data and did not result in duplicate data, either. .

The device setup per animal



Part 4: Data Analysis and Visualization

During the data collection phase, we tried to deploy sensors on every animal. We successfully deployed sensors on 30 of the 33 animals that had keys in the simulation .txt files:

- 14 Zebras *(missed zebra 32)*
- 7 Lions
- 9 Elephants *(missed elephants 6 and 9)*

Bugs

While running the simulation, we noted a couple bugs, one of which was frequently referenced by other classmates and substantially inhibited our ability to collect good vital data on the animals in the confined space. The bugs that we faced follow.

1. Pulse oximeter data issues: After starting the sim and deploying on about 10 animals, we were able to properly receive PulseOximeter data from the sensors for a short time (roughly 200 timestamps worth), but after about the 300 timestamp mark, we stopped receiving arduino messages in our logs. From then on, we had the same problem as others in the class, where we were receiving 4 values in the logs instead of two. This issue is discussed in post #631 on campuswire, where the pulse oximeter data was returning four values, instead of two. The first of the four values matched those seen for the pulse values in some of our messages from shorter test simulations, so we took the first value of the four to be the pulse. None of the other values made sense for the SpO_2 value, so we decided to take the second number for that. This made it difficult to directly use the values that we obtained to assess the health of the animals, so we instead looked for stability in the values seen from animal to animal. It sounds as if the development team is already aware of this issue.

2. When working on multiple monitors and transitioning the game from a laptop to a larger monitor screen (and back), the size of the game window would shrink by about 15% in both dimensions. The window is not resizeable so eventually the game window became too small to be usable. Uninstalling and reinstalling the game files did not fix the issue, and I ended up having to work around the problem by booting up a Windows VM and running the game through there to get the data. I have been in touch with Gabrielle regarding this issue, and she is aware of it.

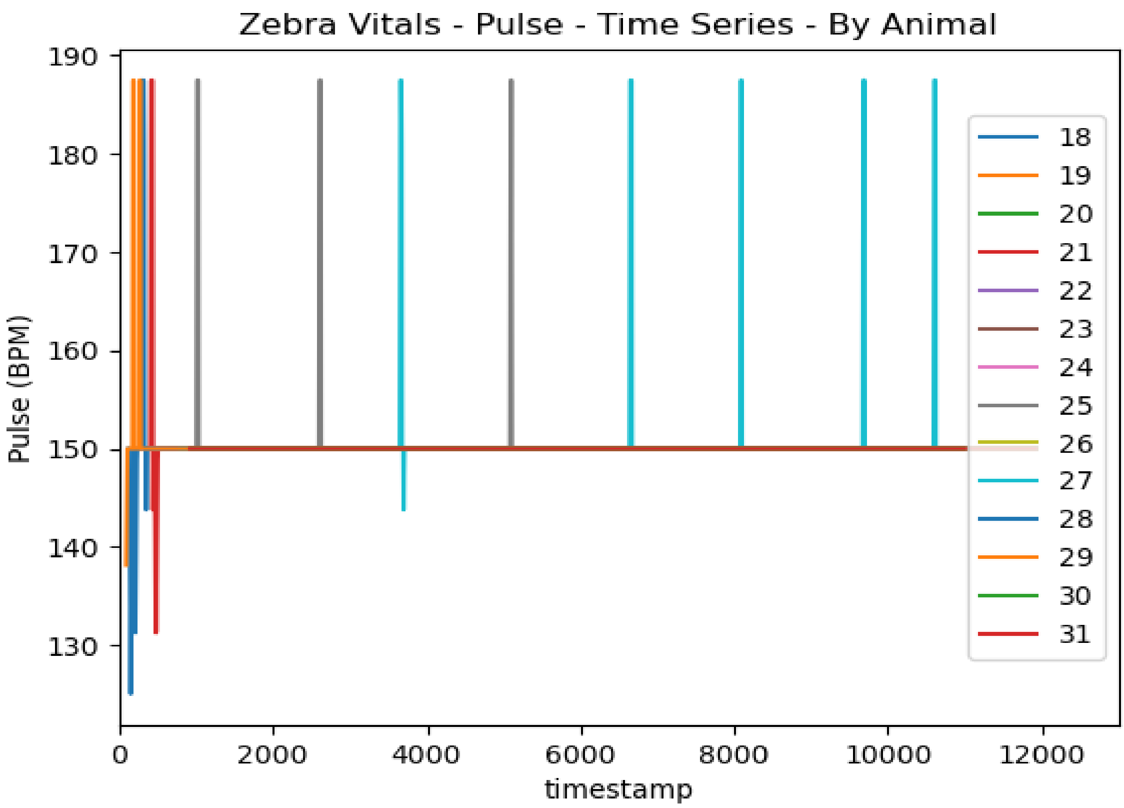
Questions and Answers

Below are the answers to the questions posed in the lab.

Question 1: Is the zebra population healthy?

To answer this question, we will utilize the data collected from the Pulse Oximeter devices across the zebras that the sensors were deployed on. Given the data issues that we ran into with the POX devices, we answer this question to the best of our ability with the data that we were given.

Plotting the pulses of all of the zebras across the experiment give a very positive indication of the Zebra's health, because while the data points are not consistent with what we would expect a zebra's vitals to be in real life, the data points are consistent with each other. Consider the following plot:



The key on the right shows which colored line corresponds to which animal id, and the pulse of each animal is plotted with respect to time. A couple of key observations can be gathered from this plot.

First, the pulse readings are extremely high across the board, roughly twice what we would expect for a normal zebra. These numbers, though high, are consistent across the entire set of zebras. It is hard to believe that all of the zebras have equally abnormally high pulses, and much more easy to believe that the high values are just a result of a software issue.

It should also be noted that the lowest pulse recorded for a zebra across the entire data collection phase it roughly 125bpm. This, of course, rules out the idea that any of the zebras were killed by lions or poachers. So, even if we are unsure of the exact health of the zebras due to the high pulse rates, stability in the pulse values and the fact that no zebras were killed are indicative of a relatively healthy and stable zebra population.

Question 2: Do the zebras have enough room to move around in?

To answer this question, we consider the GPS data of the zebra population during the whole data collection phase. We consider zebras who stay away from the edge of the map content with the amount of space that they have, and consider zebras who frequent the edge to be more yearning for a larger space to run around in.

We define the outer edge of the map to be within 2% of the edge of the confined space. So, if an animal is frequently within 20 units of the edge of the confined space, it is more likely that those animals are interested in exploring areas outside of the confined space.

After writing a pandas query to filter the data and grouping by the animal-id, we get the following results:

animal-id	edge_count
19	2014
20	2246
22	2322
23	1796
25	700
26	1897
30	74

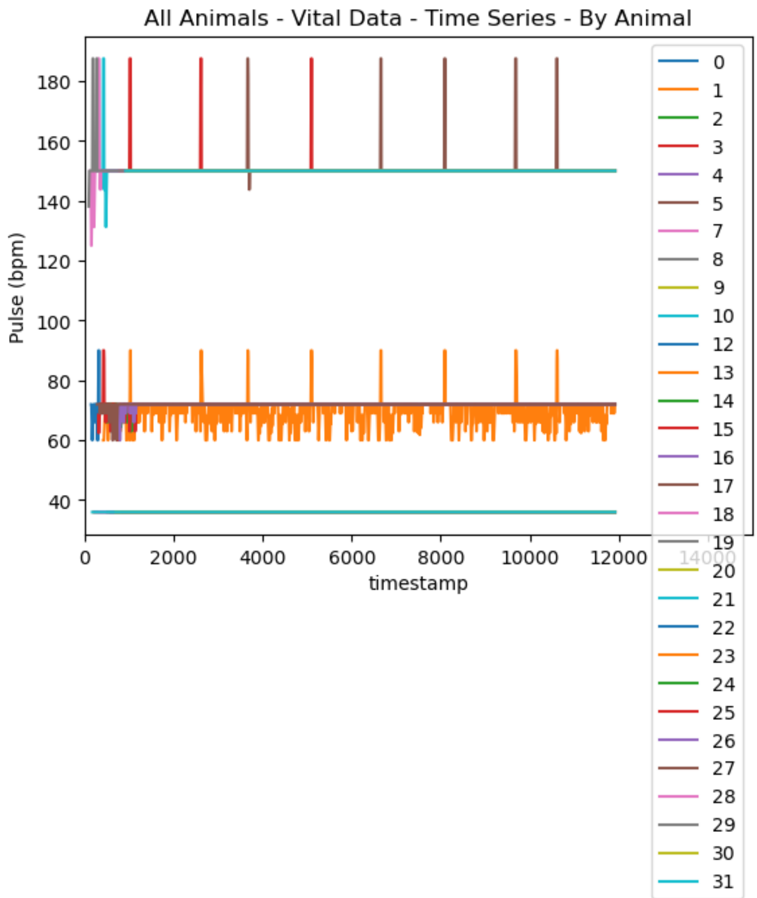
We find that five animals (19, 20, 22, 23, and 26) make up nearly 93% of the time spent around the edge of the confined space. Thus, we can conclude that while certain animals are more interested in exploring areas outside of the confined space, in general the zebra population seems fairly content with the amount of area that they have to explore.

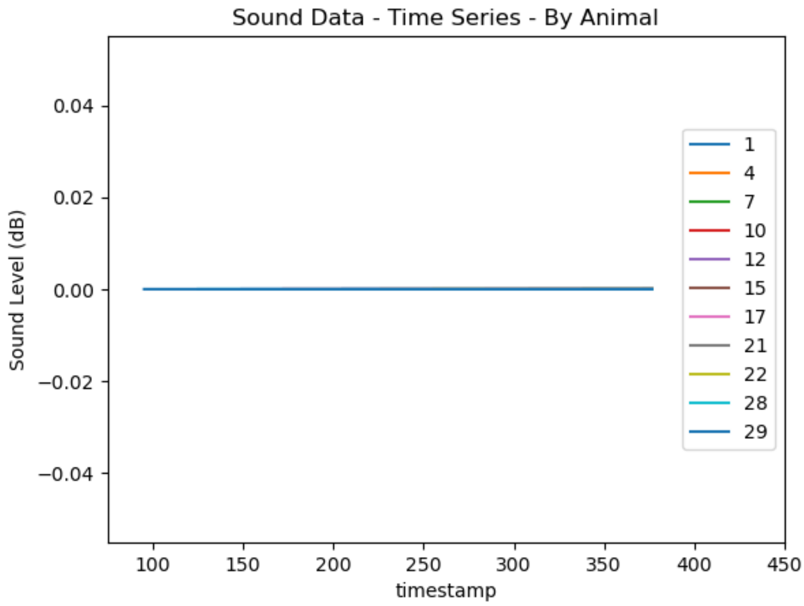
Question 3: Are there any signs of poachers?

To answer this question, we can again reference the pulse data, but this time of all animals in the confined space. The reason for using all animals, as opposed to just zebras, is because poachers may not exclusively target zebras. We can also reference the audio data to sustain the hypothesis forwarded by the pulse data.

Consider the plot of the pulse data for all animals across the data collection phase on the next page. We notice that the pattern of no zero-pulse observations is persistent across all animals in the confined space. This is evidence that supports there being no poachers in the area.

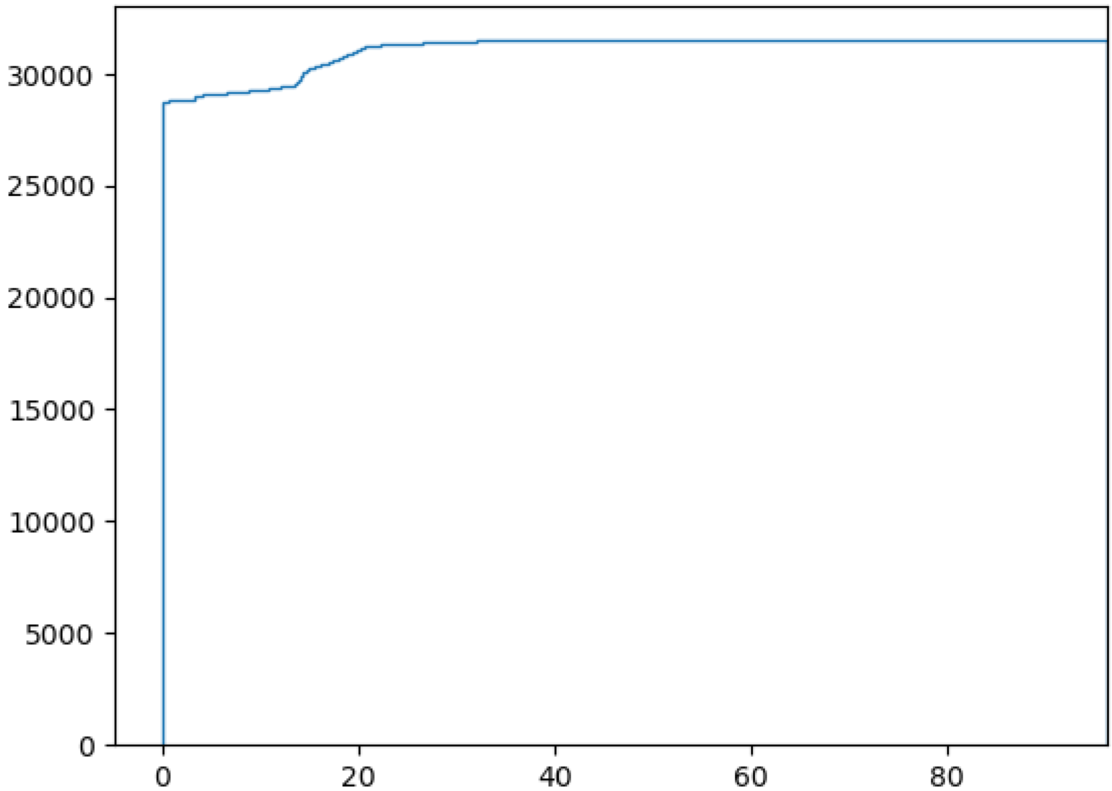
We can also consider a time series plot of the sound data being emitted from each animal across the data collection phase, which is also on the next page. The sound data does no show any indication of any abnormal sounds, such as gunshots or pain cries from animals. Thus, it can be concluded that there are no poachers in the area, and more so that poachers are not currently a risk to the animals in the confined space.





Question 4: Plot a CDF of the movement speed of zebras. What do you observe?

On the next page is the CDF of the movement speed. The primary observation from this CDF is that there is a lot of time where zebras are not moving at all. Additionally, the vast majority of speeds observed when the zebras are moving, is less than 20 units of distance per unit of time, with what appears to be the maximal speed seen more than one being approximately 33 units of distance per unit of time. The observations noted below make



sense when the social patterns of zebras (that is, them organizing into families and then herds) most of the time they will be stagnant or moving slowly with the herd.

Question 5: Do zebras make friends? Do you see pairs that tend to stay together?

To answer this question, we can consider the GPS data grouped by timestamp. At each timestamp we calculate the distance between every zebra using a Euclidean distance metric. If two zebras are within 50 units of each other (that is, 5% of the confined space) they are considered to be congregating.

Proceeding with this method yields the following classifications from the program:

```
Zebra 19 and zebra 20 spent some time together, being within 50
units of each other 8 times.
Zebra 21 and zebra 28 were together extremely frequently, being
within 50 units of each other 2292 times!
Zebra 21 and zebra 29 were together extremely frequently, being
within 50 units of each other 2292 times!
Zebra 23 and zebra 25 spent some time together, being within 50
units of each other 716 times.
Zebra 23 and zebra 26 spent some time together, being within 50
units of each other 52 times.
Zebra 25 and zebra 26 spent some time together, being within 50
units of each other 738 times.
```

```
Zebra 28 and zebra 29 were together extremely frequently, being
within 50 units of each other 2339 times!
Zebra 30 and zebra 31 were together extremely frequently, being
within 50 units of each other 2103 times!
```

Thus, we can see four groups of zebras congregating and “making friends” throughout the timlapse:

- Zebras 19 and 20
- Zebras 21, 28 and 29
- Zebras 23, 25 and 26
- Zebras 30 and 31

Question 6: What locations do Zebras tend to congregate at? Why do they tend to go there?

From the previous question, there were four congregations of zebras during the observation process. For this question, we need a little bit of information…where are the zebras congregating precisely congregating at?

To answer this question, we return to the zebra GPS data and go through a very similar process to the previous question, but rather than storing the number of interactions between two animals, we store the locations at which those interactions take place. Every time a new interaction takes place, a bounding box that confines the locations of the interactions is redefined based on the new interaction coordinates.

Going through this process yields the following four areas of congregation, corresponding to the bullet points from the previous answer. These are in *(xmin, ymin, xmax, ymax)* format:

```
[(884.3915, 580.6487, 925.921, 621.8133), (59.10231, 799.5557,
89.85838, 825.0352),
(583.7156, 14.59119, 645.6477, 133.1295), (202.2533, 49.22305,
244.0658, 113.0704)]
```

Zebras tend to congregate due to either climate reasons (i.e. lower temperatures in the area) or to make themselves less susceptible to predator attacks. For each zone above, we queried the lion’s GPS data to see if there were any predators in the areas where zebras congregated.

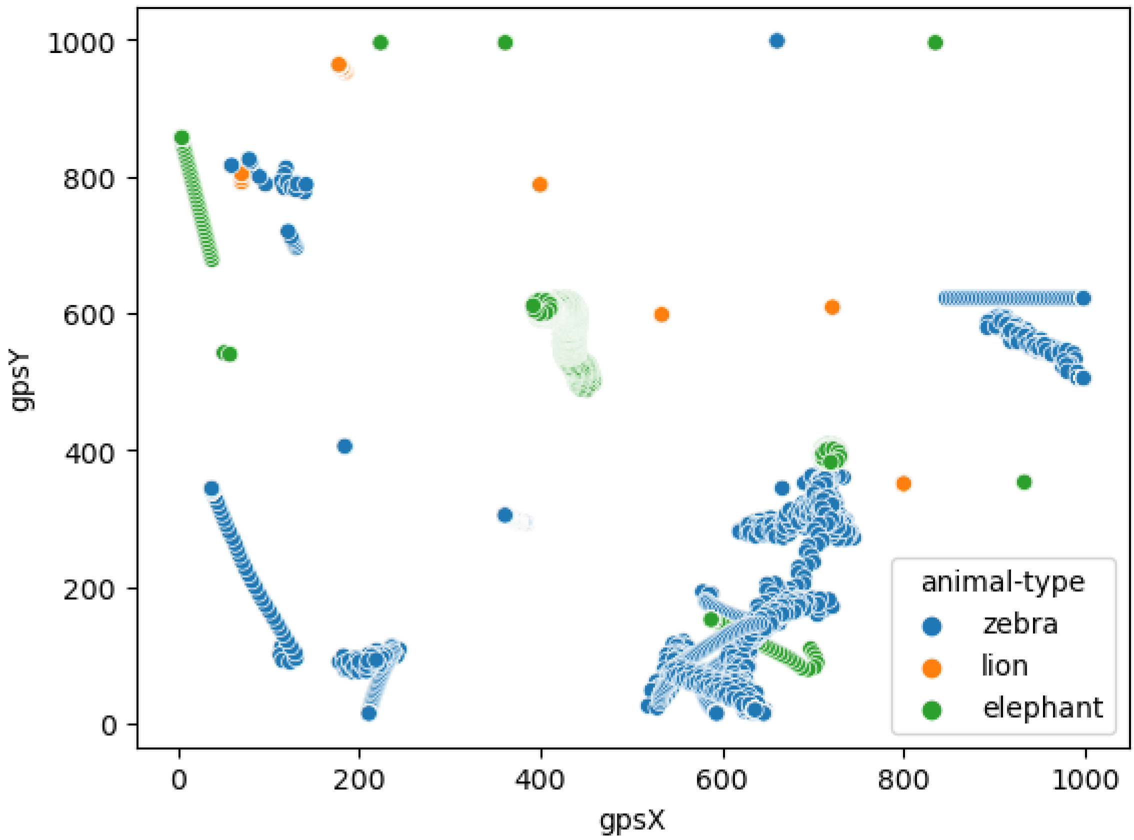
We found that zebras 21, 28 and 29 congregated to protect themselves from predators, and the other zebras congregated because of trees present in the area that were throwing shade and lowering the temperature.

It is also worth noting that the zebra congregations were in distinct areas of the confined space, roughly one in each corner. This also follows the confines of zebra social structure, where groups of zebras will congregate in small herds called families, then congregate into larger herds later on.

Question 7: Are there any locations that the zebras tend to avoid?

To answer this question, we plot all of the GPS data for all of the animals. We split the animals by their ID, where any number <= 11 is an elephant, between 12 and 17 is a lion, and 18-31 are zebras.

The location data is colored by the animal type, rather than the animal ID. See the plot below:



This visualization shows anywhere that any animal ever went while the simulation was recording for 6 hours. We find that generally, the zebras congregated closer to the edges of the confined space, whereas the lions and the elephants congregated towards the center of the map more frequently. It is likely that the zebras chose to avoid the center of the map because that is where their predators frequently congregate.

Our Question: Can the general movement patterns of each species seen in research be sustained by the movement of the animals in the simulation?

The research associated with part 1 of this lab led to the discovery of different movement patterns for each of the species tracked in the simulator. It was said that of the three species, zebras were the most mobile, followed by elephants, then lions. This was due largely to the differences that different animals spent sleeping and awake. Lions likely moved the least because they spent the least amount of time awake, and zebras moved the most because they spent the most amount of time awake.

Referring to the chart used to answer question 7, we can observe that these movement patterns are reflected in the game world as they are expected to be in the real world. Over the course of the 6 hours that we collected data, the lions hardly moved at all, with only two showing any movement. The elephants were the next most mobile animal, with three of the elephants making movements over the course of the 6-hour observation phase, and the zebras were the most mobile, with all but four zebras moving substantially over the course of the observation phase.

Further research also indicates that zebras and elephants opt to sleep standing up in African regions. This could be construed as further indication that the stagnation in some of the animals may have been because they were asleep.

Appendix: Work Distribution

Below is the work distribution for this lab. Everyone in the group contributed roughly equally across different steps of the lab.

Name	netID	Contribution
Konstantin Kovalchuk	kk25	33%
Ben Granados	bgg3	33%
Nick Gambirasi	nag8	33%