CS437 - IoT
Lab 5
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Demo Video

ZebraNet Summary (3 paragraphs because I talk too much)

When reading through the paper I kept thinking the things they were trying to solve and limitations in networking they were working to overcome are commonly seen today. I was trying to figure out, outside of making a device operate autonomously for a year, what was so special about this paper when most of the technologies they use are common. Then I realized it was 2002 and I forgot what technology was like back then. My dad was still a former C developer complaining about how much he hated Java 1. The internet was slow. Smartphones didn't exist and even mobile phones weren't very mobile. Peer to peer networks were new. GPS' were standalone heavy bricks and super expensive. So many of the technologies they had to develop at that time would have been cutting edge. It's easy to say in hindsight, living in an infinitely connected world, that it would be easy today. I wear a dual band gps watch that even tracks heart rate and location underwater, has unlimited battery with enough sun, and can last almost a week with non-stop gps tracking. I think it's amazing the thing they were able to develop given the technology at the time.

On a second read through (after I had run my 3 hour simulation) I realized I misunderstood their data polling mechanism. 3 minutes every hour means poll 3 minutes of data every hour. The first time around I read it as 3 or 2 minutes and ignored the every hour part to which I polled data every 2 minutes for simplicity with gps and vital data. This makes sense as to why I had so much extra data (220mb jsonl file) and it was hard to read some of the plots without averaging it down.

I didn't know this but I shouldn't be surprised by the zebras' intermittent sleep schedule given the relatively hostile predator filled environment. According to the study zebras don't tend to roam terribly far and spend most of their time grazing or turning gradually as they walk. Their grazing habits show a surprising level of intelligence. They Actively choose to stay in areas of low grass where predators would have a hard time hiding. This is consistent with the zebra trajectory and location heat map of the simulation where zebras stayed in the south where the grass was shorter. Even in the simulation when trying to place trackers on lions who were in the north it was difficult to find them amongst the tall grass.

Design

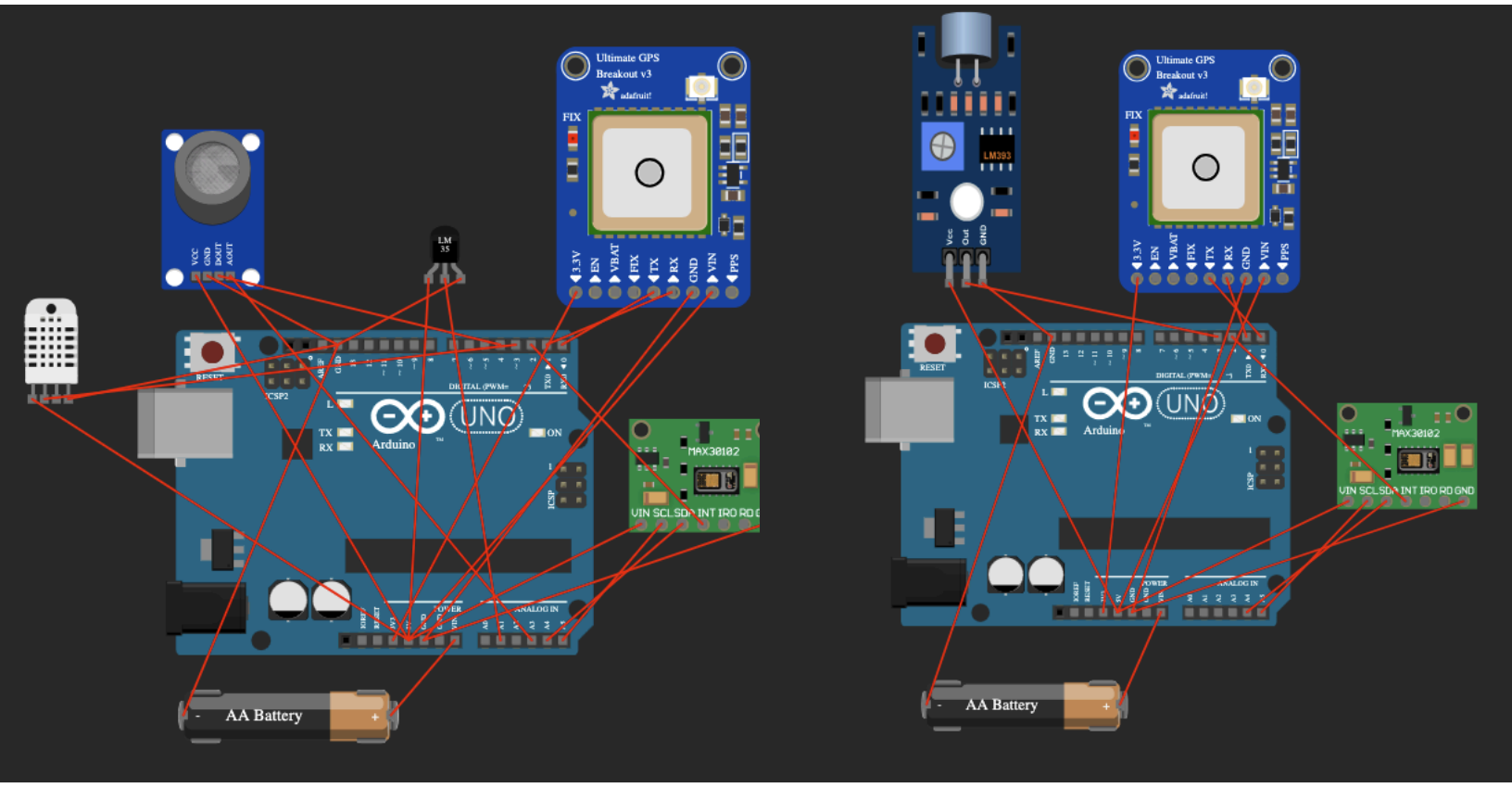
Device Sensors

I opted to have 2 arduino designs to try and balance power usage. Each device would have a vital and gps sensor but to divide power consumption between the other components one zebra would get a device that additionally have environment sensors for air quality, temperature, and humidity. The other simpler device would contain an additional sound sensor. Given the Zebra's social tendencies where animals should generally be around each other I attached at least one device with environment sensors to a single zebra and the rest our get the simpler sound sensing device.

Ideally if the animals tend to stick close to one another a single sound sensor would probably suffice for the herd but given the extra three sensors already on the environment sensing device I thought the power draw would become too costly.

One environment sensing device should be enough for the entire dazzle assuming they stick together but as a redundancy in my simulation I attached two zebras with environment sensors though I did not validate beforehand if the two would stay paired together.

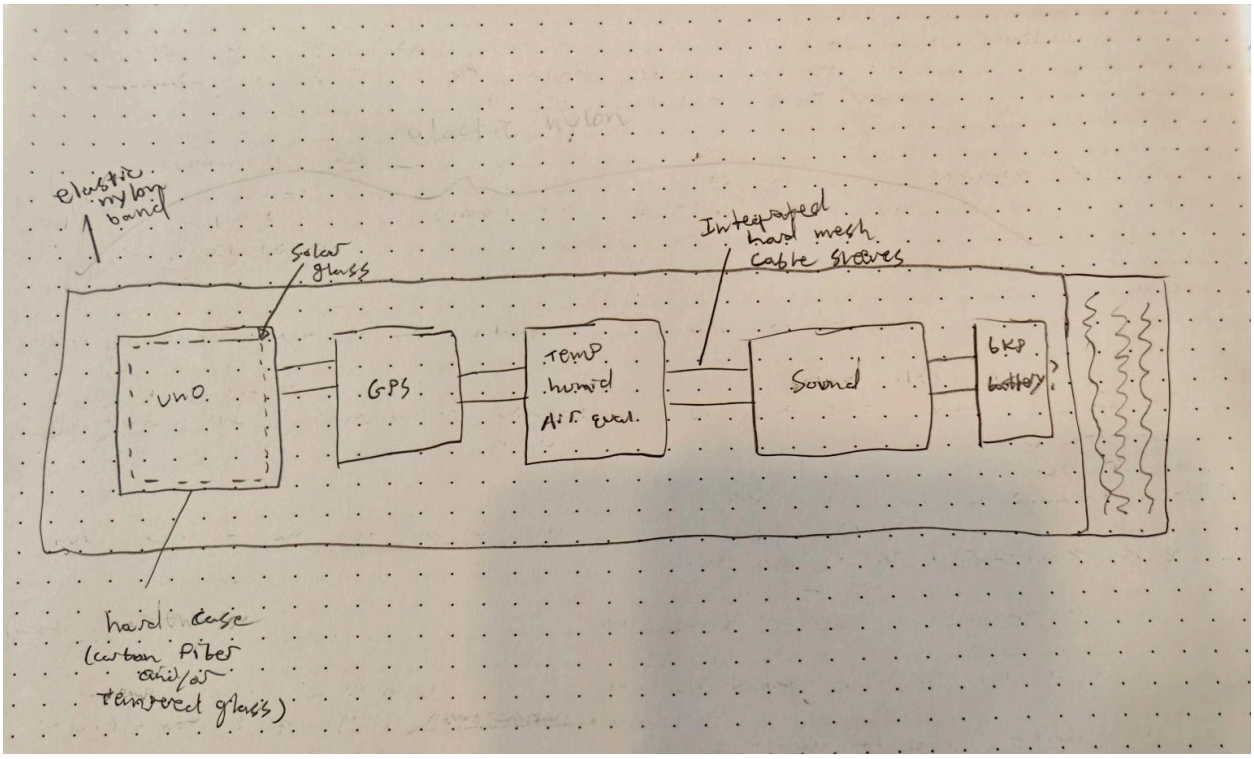
In a real life scenario I thought sound data could be useful to correlate against movement, vital data, and environmental sounds to correlate and compare any patterns such as predator or poacher sounds.

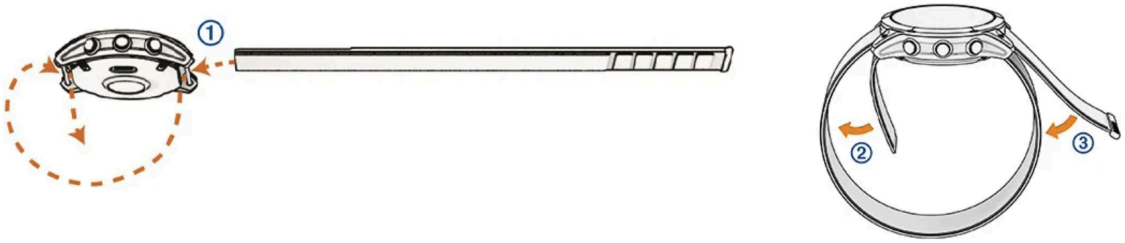


Sensor Connection and Physical Construction

I would probably solder the wires between devices together so there is less of a concern of things becoming disconnected. Each component would be in a small lightweight container with some sort of tempered or sapphire glass front to support solar charging. Each container would be connected with a rugged mesh or rubber tube with some sort of rubber gasket or O ring for waterproofing where the wires have to enter. A backup rechargeable battery would be included to compensate for whatever the solar charger can't make up for in power draw.

The containers would be securely attached to an elastic nylon band similar to the garmin ultrafit band. I've been wearing one non-stop for 4 years and only take it off every 30 or so days to charge. In my personal experience the slight snugness of the band helps track my own vitals better but the elasticity of it allows for movement and breathability without getting irritating.





Example of using velcro with garmin elastic nylon band

Device Code

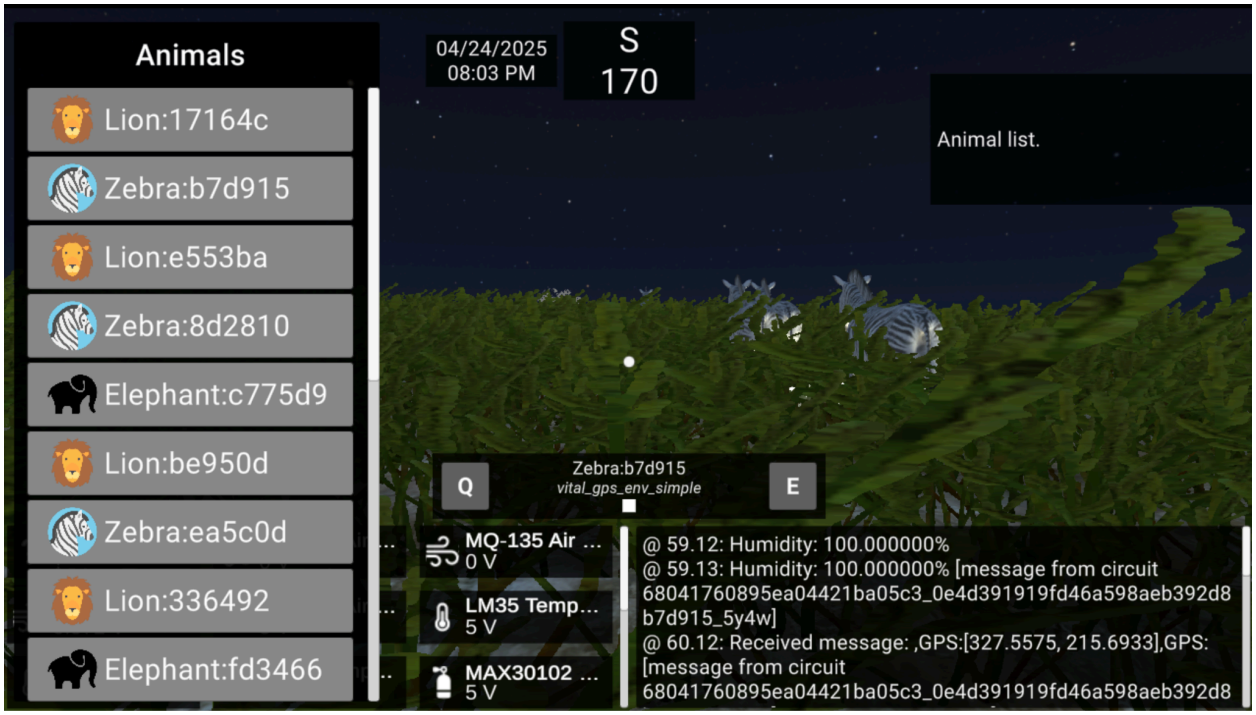
I coded my devices to capture gps and vitals every two minutes since it was easier to poll all data every two minutes than working through interrupts and multithreading. In real life practice this wouldn't be viable and would likely result in too much data and power draw. The final data set was almost too large to work with and made reading the plots difficult. I ultimately had to transforma and aggregate it into an event timeline for better understanding. In my simulation I did not make any battery optimizations but in production I would likely take advantage of the enable pins on some of the devices like the gps to completely stop power draw during the off period. Swapping an arduino uno for a nano and an RTC or nano esp32 with its integrated RTC would likely help with time keeping.

Device Attachment Location

The zebra anatomy poses a particular challenge due to the ratio of their neck and head. I would likely try to attach the collar higher closer to the head and hope the elastice design doesn't irritate them or the mane. Attaching it too low on the neck risks it falling off. Given the zebras grooming habits, social behaviors, and tendency to roll around in the dirt midsection attachment might impede normal behaviors though it would likely be more secure. The tail seems too risky and potentially too heavy for this device size. The legs are too skinny, and I don't think zebras like wearing hats. High neck attachment seems like the least invasive of all the options.

Device Networking (networking was done from a different simulation)

Zebra:b7d915 publishing and subscribing to data

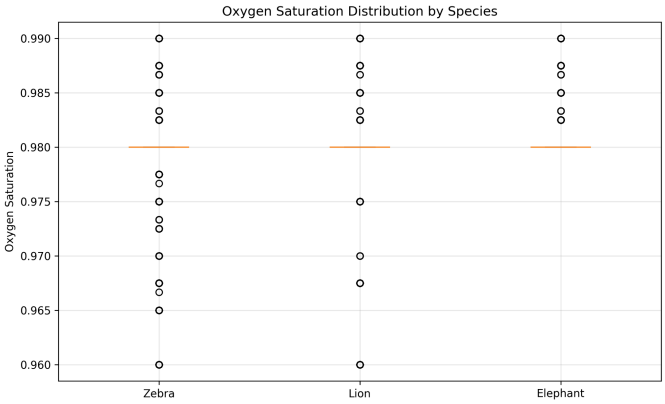


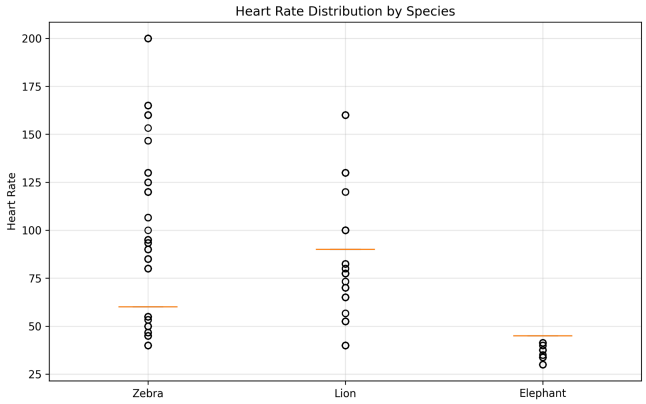
Zebra:ea5c0d subscribing to data

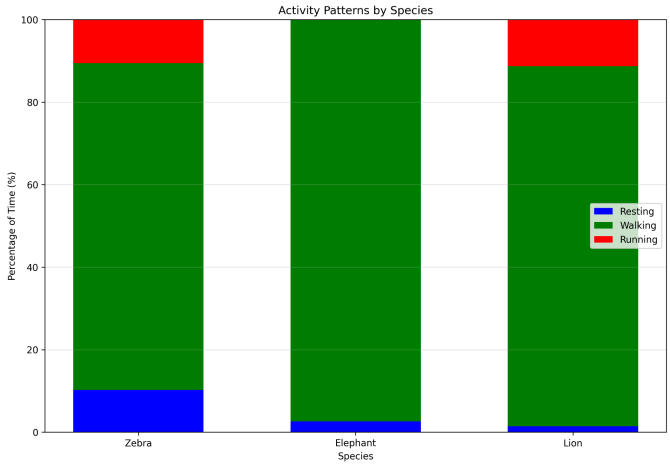
Deployed Devices (without networking)

Zebra	Elephant	Lion
Zebra:58b55b	Elephant:7e075d	Lion:10a6bf
Zebra:bbae03	Elephant:ea6686	Lion:d1a31a
Zebra:016702	Elephant:86839f	Lion:59479c
Zebra:8ed6b9	Elephant:bc5b6c	Lion:891a07
Zebra:adc48a	Elephant:dadb7b	Lion:ad9926
Zebra:ba319e		
Zebra:c9ebb2		
Zebra:36377f		

1. ***Is the Zebra population healthy?***
   There are 2 graphs and 1 piece of evidence I believe determines the zebra population is healthy. There is almost double the zebra population compared to lions meaning they outnumber their predators. Based on the heart rate percentage table and heart rate distribution the zebras spend more time resting or walking than running. If the zebras are not running erratically or constantly with a large fluctuation in heart rate it can be reasoned they are healthy

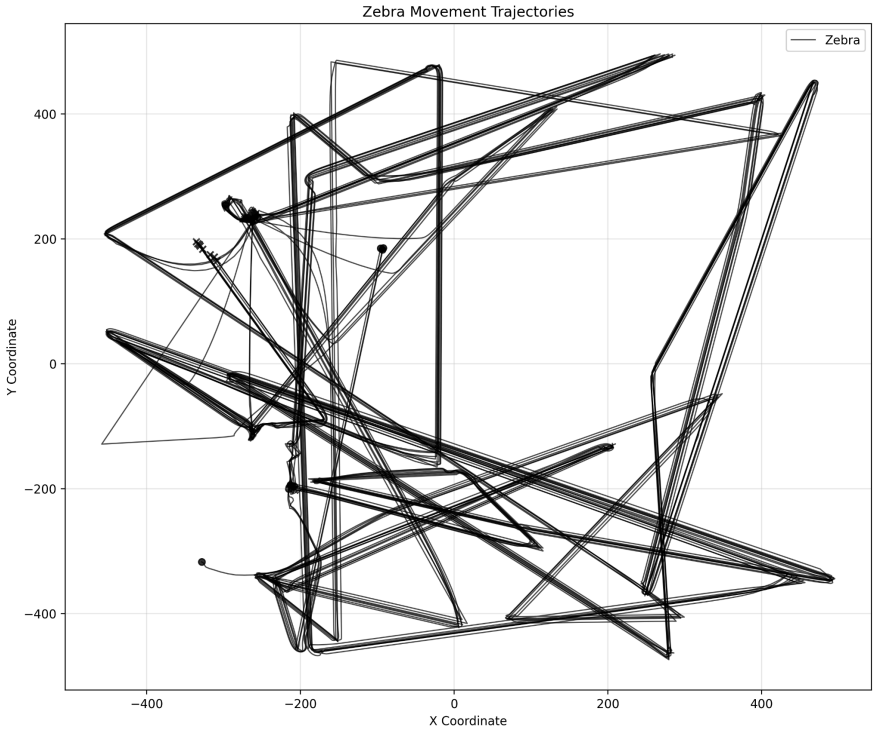






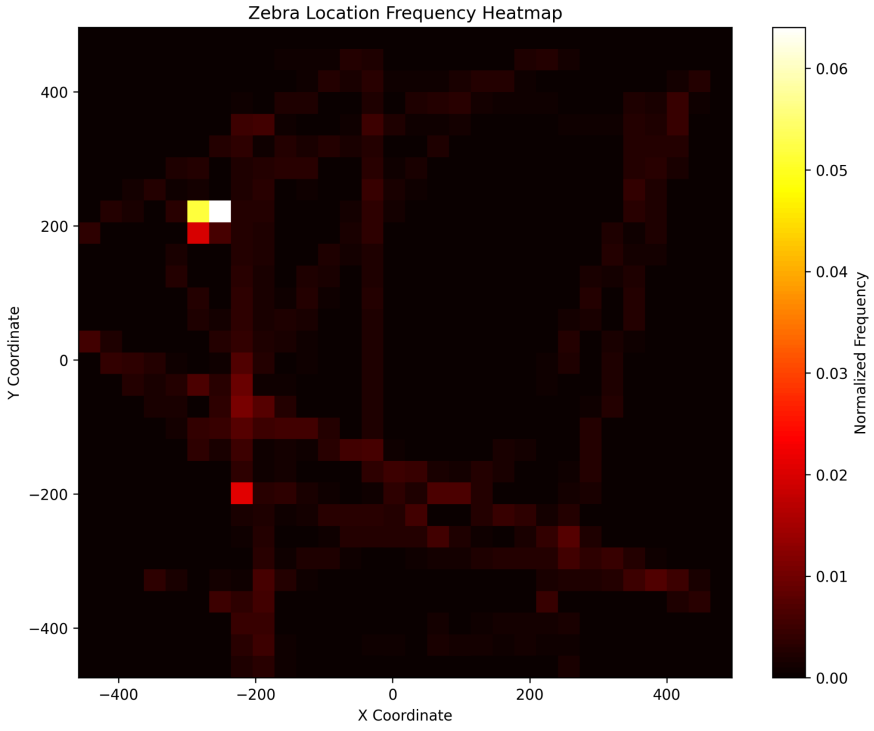
and safe. In later graphs we will look at predator/poacher encounter events that support this view as well.

2. ***Do the Zebras have enough room to move around in?***
   Given the large amount of data over a 2.5 hour period I found the 3d location trajectory data to be hard to read. Instead I created an activity map and heat map. Based on the zebra travel patterns and location there is a large portion of the map they don't spend much time on. Based on this data it can be assumed there is plenty of room for them to move around in.



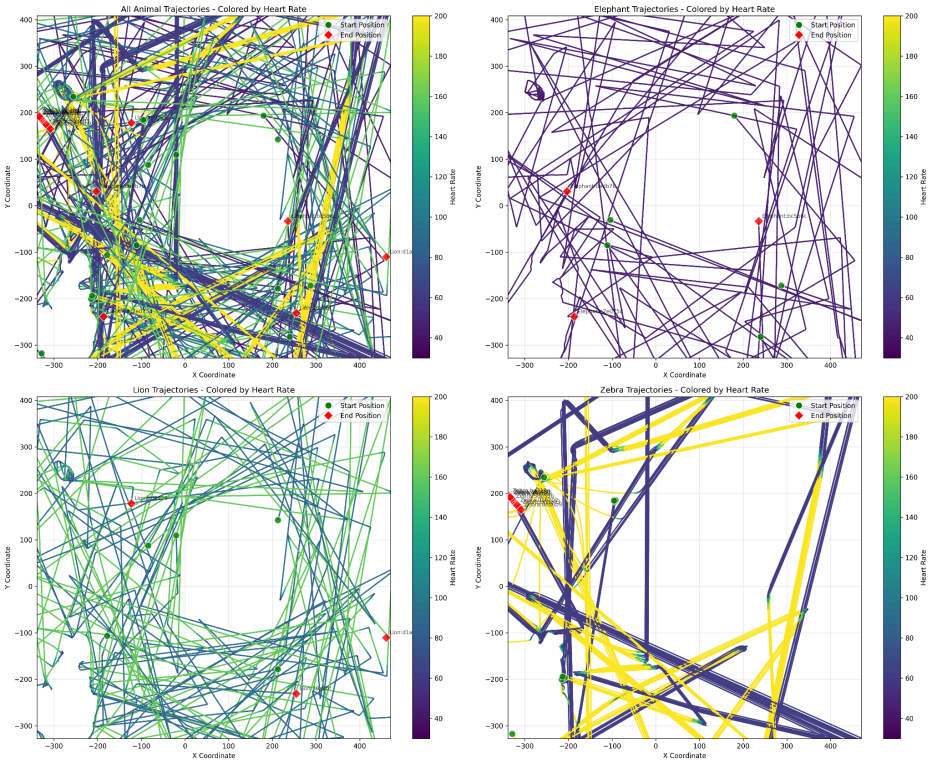
Zebra trajectories

Poorly colored heat map but I like dark mode more than light theme so whatever



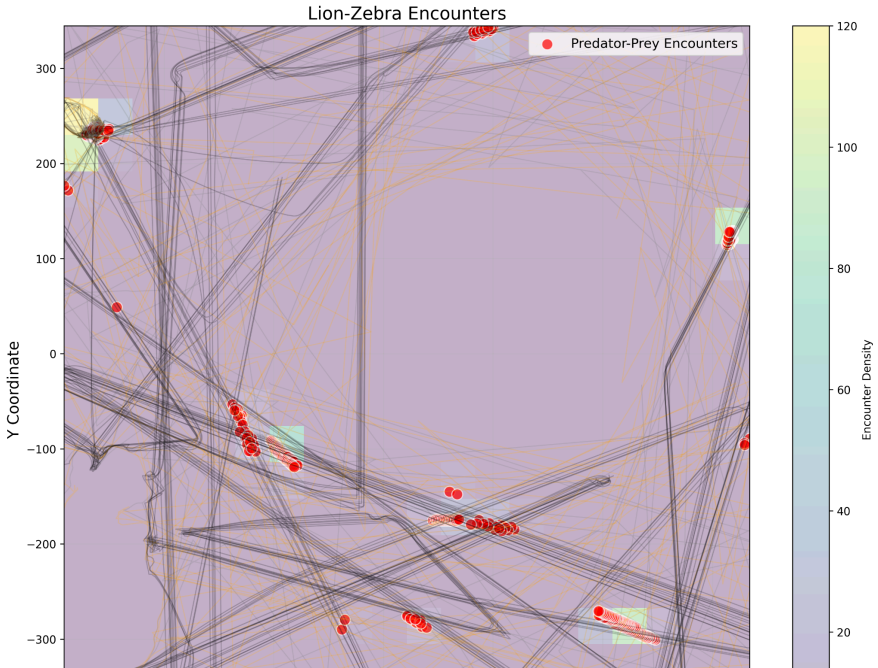
3. ***Do you see any signs of poachers?***

Several plots and 2 questions are important to determining if there are poachers in the area. Are there any areas animals tend to avoid, and do movement patterns and high vitals correlate to anything other than predator encounters? Looking at animal location trajectory compared to heart rate, and lion-zebra animal encounters the zebras' elevated zebra heart rate and erratic movements coincide with suspected predator encounters. This is also consistent with the plot above where zebra elevated heart rate times are consistent with the lions. With this data it can be inferred only predator attacks are the cause of zebra increased movement and vitals.

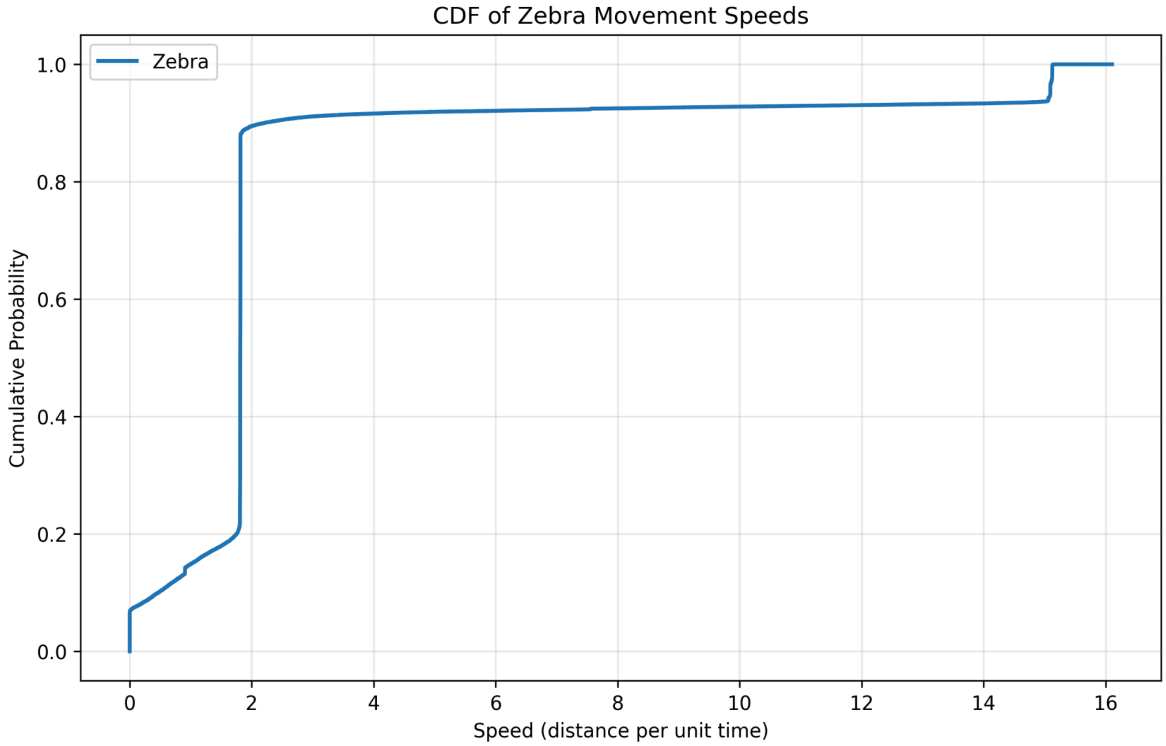


Animal trajectories color coded by elevated heart rates

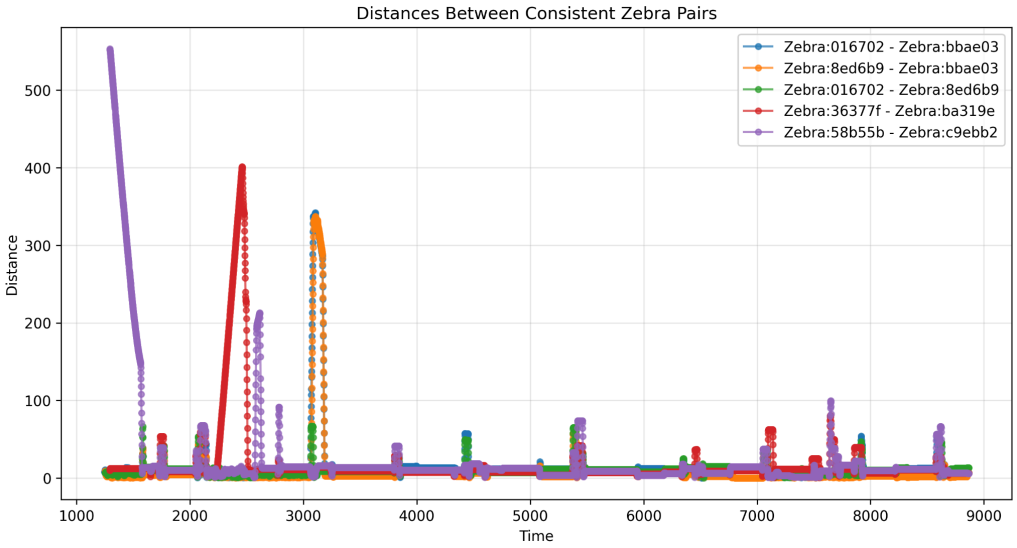
Suspected predator-prey encounter locations based on heart rate and proximity within a 20 point distance



4. ***Plot a CDF of the movement speed of Zebras. What do you observe?***
   During observation the zebras spent most of their time slowly walking between places with a high probability to either walk or gallop with a lower probability of remaining stationary. This is consistent with the heart rate timing chart.

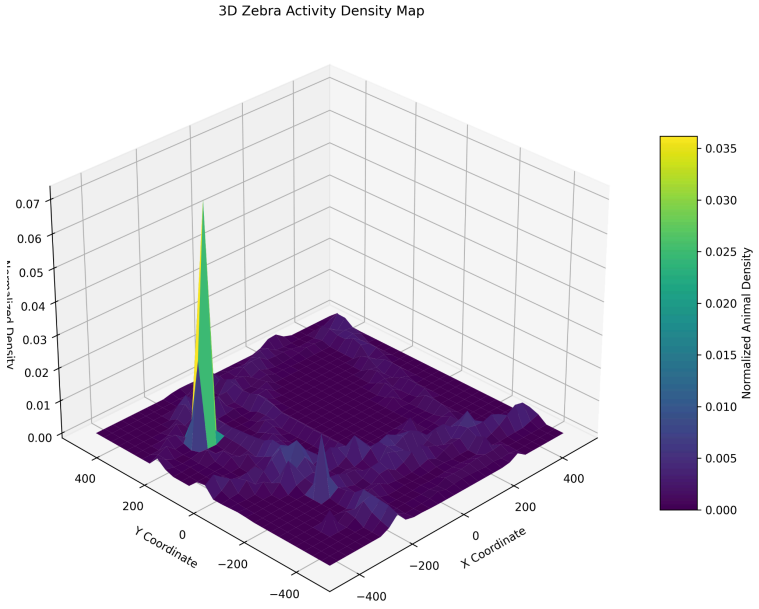


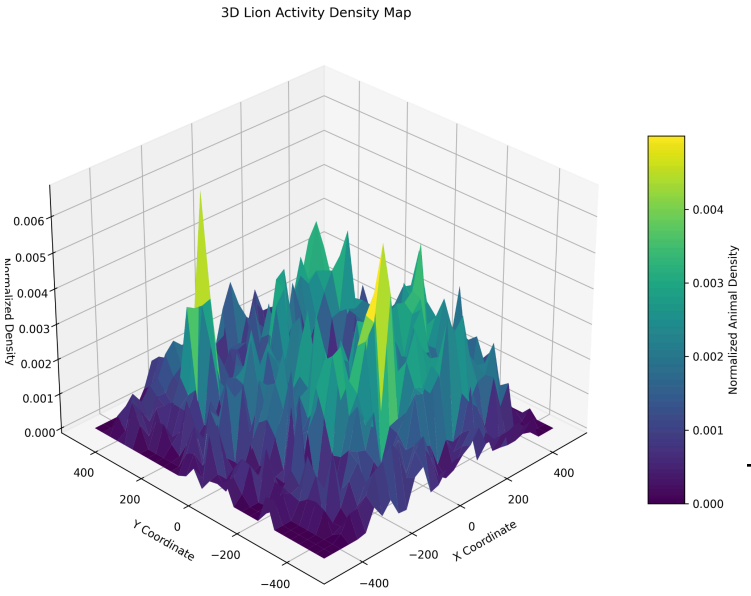
5. ***Do Zebras make friends? Do you see pairs that tend to stay together?***
   The zebras spent most of their time in a herd (also known as a dazzle lol) but there were some instances either during evasive maneuvering or otherwise where certain pairs of zebras would stay together even when breaking away from the larger group.

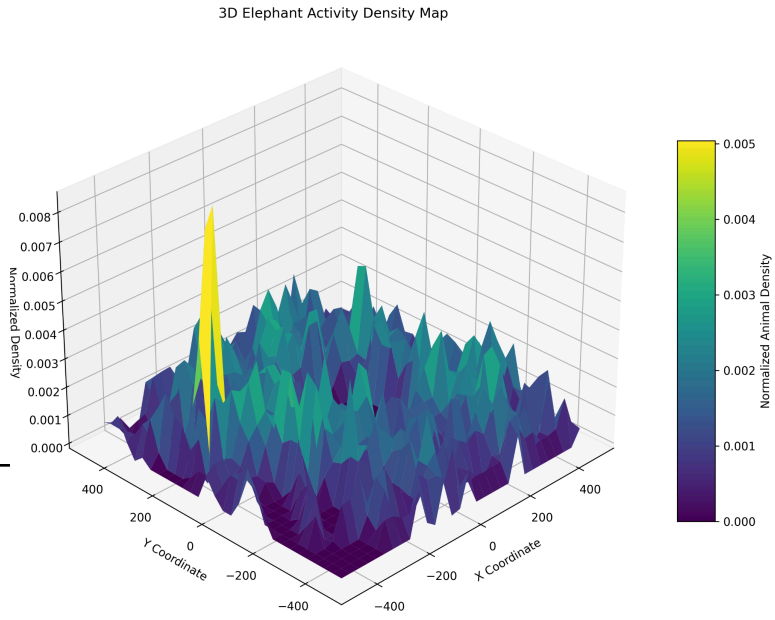


6. ***What locations do Zebras tend to congregate at? Why do they tend to go there?***
   All animals spent 0 time in the water during monitoring and little time on the mountainous area. All animals including the zebras spent a large amount of time stuck in the hole to the north-west and a lot of time running into the mountainous region which might offer some sort of protection or good grazing areas. The zebras tend to walk in a herd and pattern that is far less varied than the other animals. The zebras stayed in the south and followed predictable patterns similar to what the ZebraNet paper outlines. They likely stayed south where the grass is lower and harder for predators to hide in.

7. ***Are there any locations Zebras tend to avoid?***
   The zebras generally stayed away from the eastern region possibly to avoid something, poachers maybe but there was no heart rate data to support this and referring to the elephant and lion density maps they have shown no reason to stay away from that area. Outside of getting stuck in the northwest hole the zebra movement patterns stayed away from the north where the grass was taller. No animals were recorded in the water itself.







Member	Contributions
Lucas Damler (ldamler2)	Everything