BIRD MIGRATION NETWORK

ES 404 NETWORK SCIENCE | PROF. UDIT BHATIA

AUTHORS

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INTRODUCTION

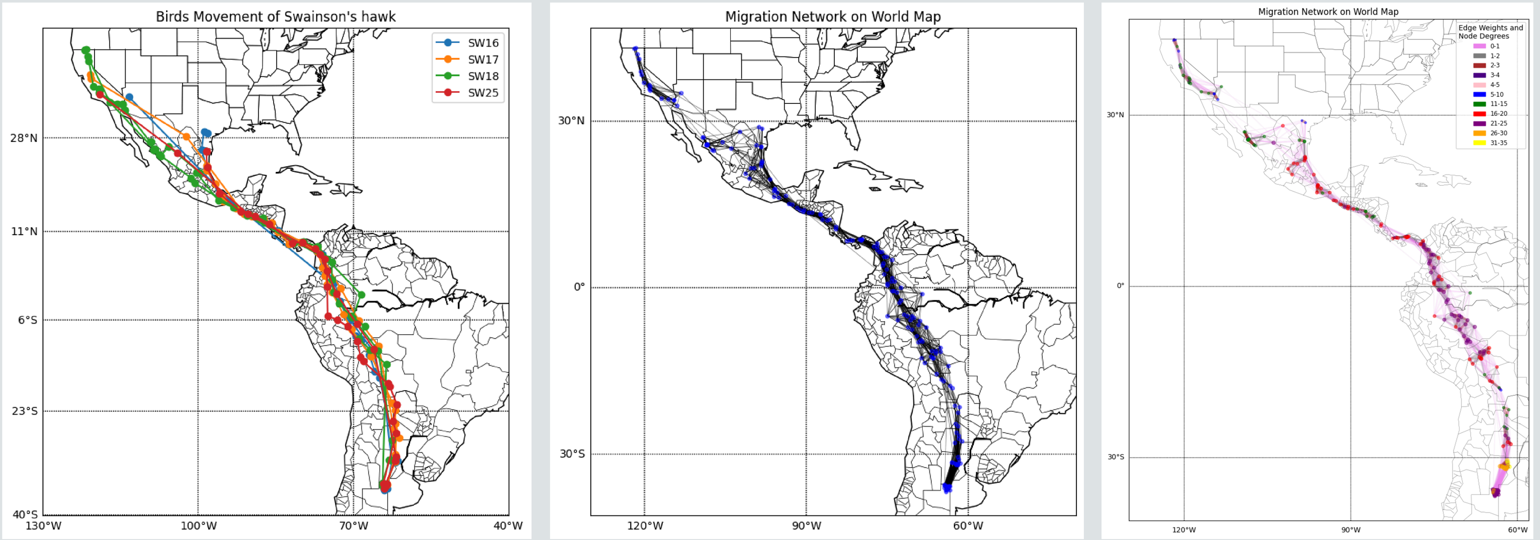
Many migratory bird species are deeply affected by human activities and climate change, some even on the verge of extinction in recent years. Through this project we wish to come up with a network methodology which can be further developed to encompass a wider array of species and eventually aid the conservation efforts of birds.

We aim to identify potential vulnerable sites in the migratory route of birds, and figure out possible alternate flight plans if these get affected.

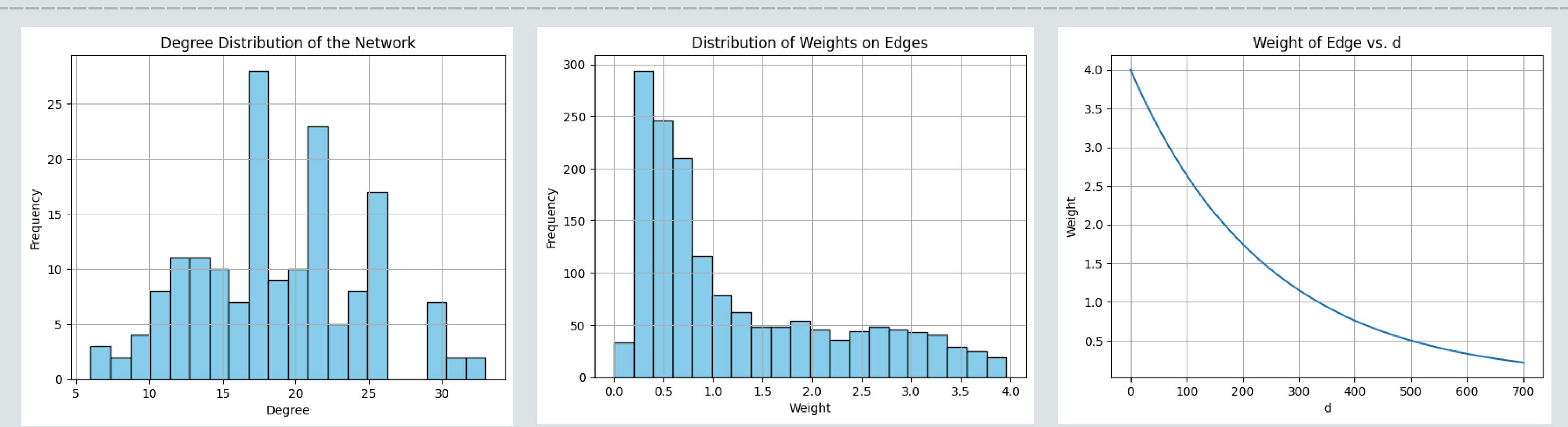
Our Protagonist - SWAINSON'S HAWK

Swainson's Hawk *(Buteo swainsoni)* is a magnificent raptor known for its impressive migratory journeys spanning thousands of kilometers. These hawks breed in North America, primarily in the western United States and western Canada, before embarking on their annual migration to their wintering grounds in South America.

NETWORK CONSTRUCTION



Plotting trails of four tagged SWHs using their coordinates over the year → Making connections between all nodes whose haversine distance is less than the migratory stretch → Adding weights to the links to quantify internode dispersal probabilities



DEFINITIONS

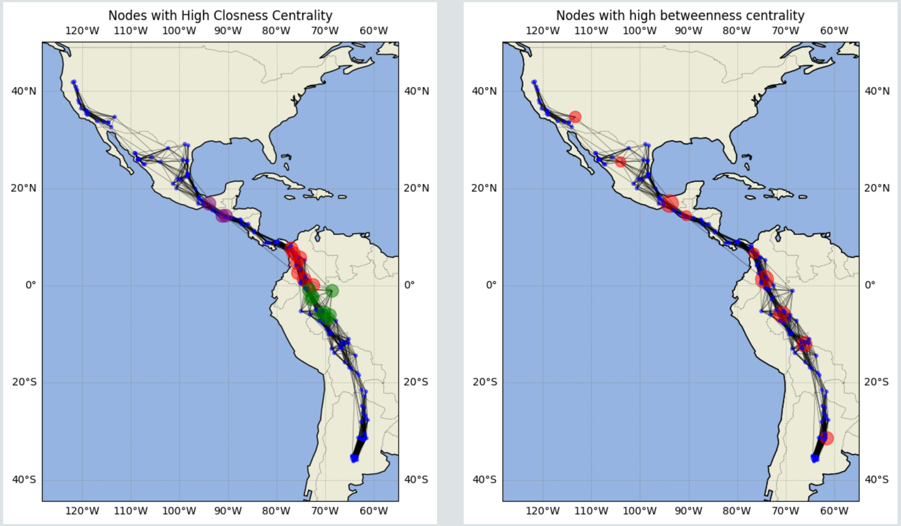
Migratory Stretch: Maximum distance a SWH can travel in a day. Used as threshold to form links between nodes.

Haversine Distance: Measures shortest distance between two points on a sphere, considering Earth's curvature; Unlike Euclidean, it's spherical, making it more suitable for measuring distance over the globe.

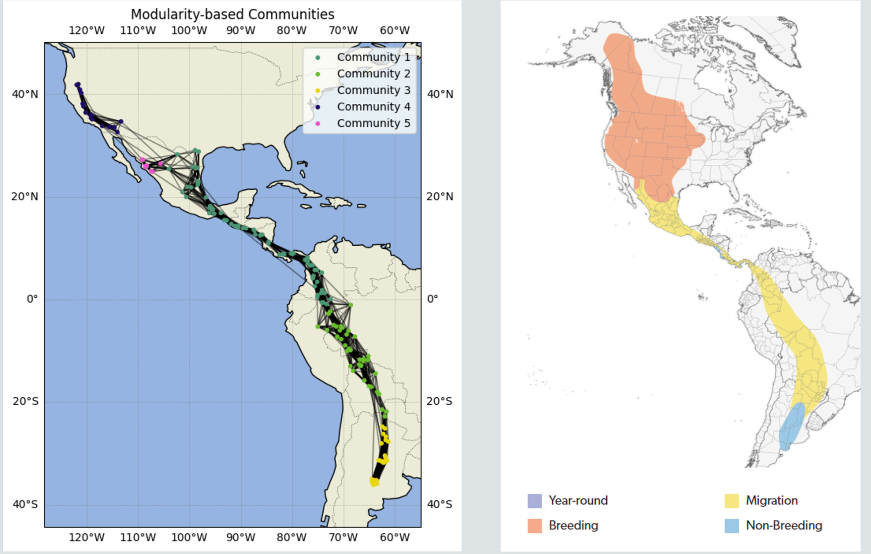
Weight of an edge between nodes u and v, $W = N * P_{uv}$; N is the no. of birds, P_{uv} is internode dispersal probability

Dispersal Probability, $P_{uv} = \exp(-k*d_{uv})$, where d_{uv} is the haversine distance between nodes u and v, and k is the dispersal coefficient. Its value is set using bisection method such that P is close to 0.5 for median migratory stretch,

STATISTICAL ANALYSIS



- Examining Closeness Centrality led us to some important points which were around -10 and 10 degree latitude. Most important node we filtered was just above the equator.
- High Betweeness centrality nodes give us important nodes within communities. We also try out network robustness on these points.



- Community-Detection also align with the different regions of Swainson's Hawk (Breeding grounds, wintering grounds, etc.)
- Searched for Ecological corridors of the Hawk along the migration network which again resulted in similar set of points hence backing their importance.
- Other measures such as assortativity, average shortest path length and average clustering coefficients also suggest densely connected network.

TRAIL RECONSTRUCTION

Problem : Amidst the loss of a designated region, can the Swainson's Hawks navigate alternative routes to complete their migration?

Solution : Create 4 separate network trails for the four labelled SWH birds and find all the nodes that are vulnerable (i.e. they lie in the designated region). Then remove these nodes and their corresponding edges from the four trails and the overall migratory network for SWH. This step can break the trails in upto 3 disjoint components. For each trail we identify the coordinates from which the connection were broken and between the corresponding pairs of points we try to find the least cost path utilising the remainder edges from the migratory network so that a complete trail of migratory movement can be restablished for that bird.

Algorithm: We devised a variation of the Bellman-Ford algorithm for undirected network to find the minimum cost path from the start to the end node. We have defined the cost of movement from one location to another as -

COST = cost_edge(weight,distance) + cost_opp_motion(lat1,lat2,distance) + func(path_length)

discourage choosing longer routes

Cost function derived using ridge regression

Utilises weights of edge to output cost of choosing that route. Distance is used to smoothen the resultant function output.

(for exact weights and parameters refer to the presentation slides or github repo of the project)

penalise for motion against the wind stream

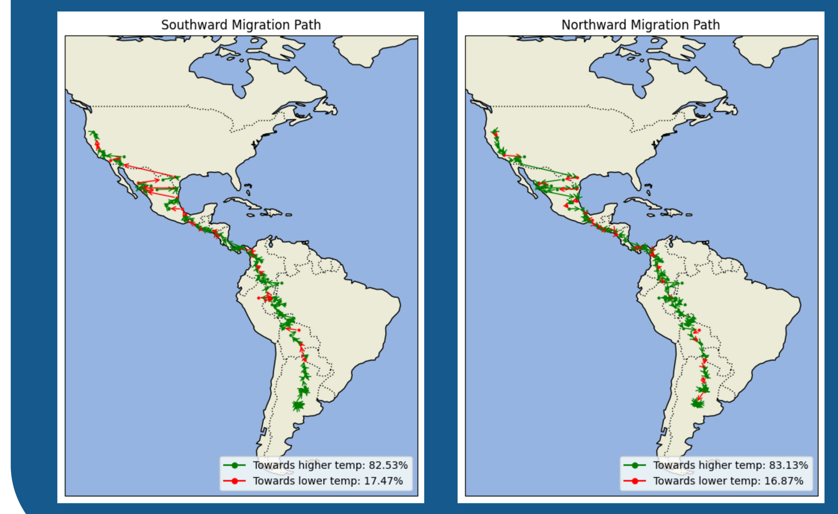
$$= \begin{cases} \dfrac{\text{distance} * ((\text{lat1}-\text{lat2})+1)^2}{\text{median\_distance}} & ; \text{for lat1} > \text{lat2} \\ 0 & ; \text{otherwise} \end{cases}$$

discourage longer hops

$$f(n) = \begin{cases} n*\log(n+1) & ; \text{if node is the end node} \\ 0 & ; \text{otherwise} \end{cases}$$

for paths with nearly equat costs, assists in choosing the one with smaller path length

INFLUENCE OF TEMPERATURE ON MIGRATION PATH

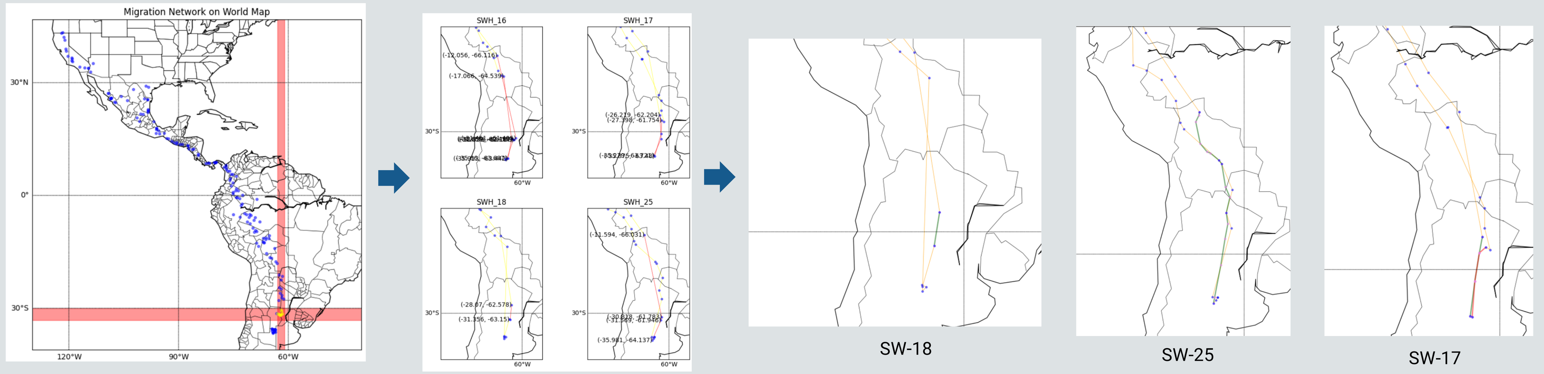


- **Temperature as a Migration Compass:** Swainson Hawk follows a preferential migration path advancing towards higher temperatures.
- **Thermally Guided Journeys:** Over 80% of the migration paths were green edges, highlighting its preference for warmer regions during their extensive migrations.
- **Climate-Influenced Routes:** This predominance of green edges suggests potential vulnerability to global climate changes.

POSSIBLE VULNERABABLE LOCATIONS

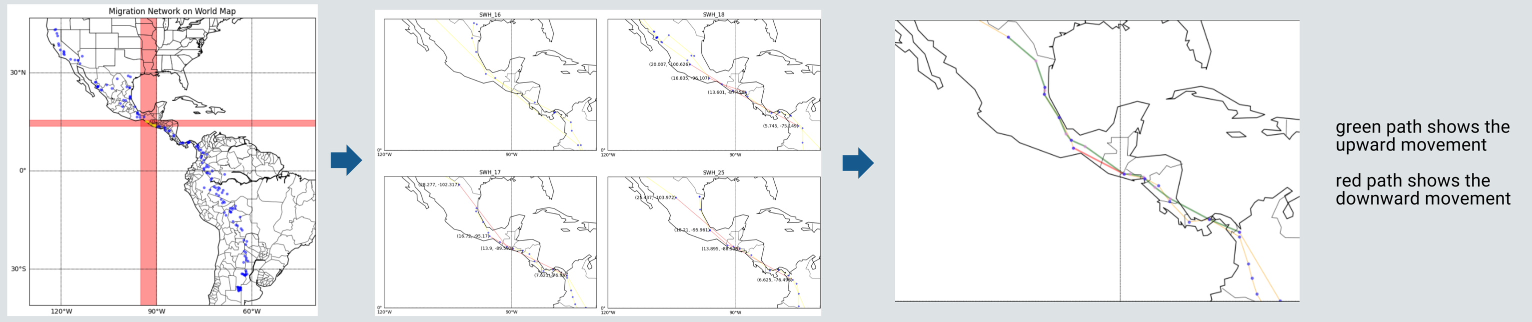
We ran our trail resonstruction algorithm for potential crucial regions in the network, yielding the following results:

- **Pampas Region in Argentina and Brazil:** These regions are crucial for Swainson's Hawks during their wintering period. The alterations due to intensified agriculture and potential climate extremes may affect the availability of prey and suitable conditions for the hawks to thrive during winter.

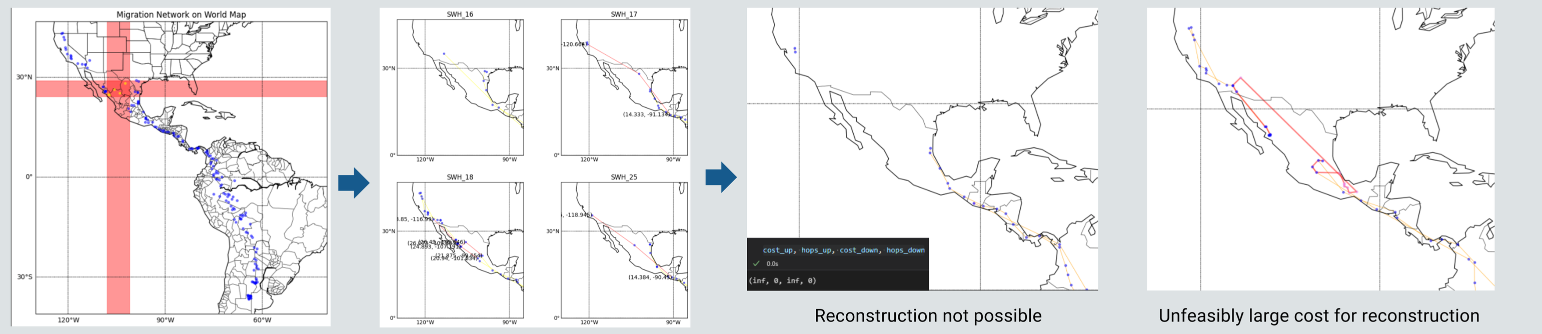


Intersection denotes the vulnerable region → Paths in trails that are affected → Reconstructed paths in the trails

- **Regions near El Ocote Biosphere in Mexico:** These regions play a crucial role in migration corridors, exhibiting significant Betweenness Centrality. They serve as vital links connecting breeding and wintering habitats. Any negative impacts in these zones could disproportionately disrupt the migration network due to their narrow geographical span.



- **Western and Central United States:** These are important regions for Swainson Hawk's breeding. The bird could lose about 77% of its current summer range in the Western US due to climate shifts in the next decades



Reconstruction not possible

Unfeasibly large cost for reconstruction

PRESENTATION SLIDES

INFERENCES

We showed the general notion of the birds migrating to areas with warmer climate holds true for the Swainson Hawk as well. The vulnerable migratory points were identified, and then a path was predicted for the birds in case if any of those points become inhabitable for the bird in near future. The communities identified in our research study aligns with the actual community zones during their annual migration cycle further validating our network analysis.

FUTURE WORK

We can expand our research study to include more specific migratory birds. We could focus on the specific effects of climate change on the migration routes. This could involve modelling future climate scenarios like climate prediction modeling for temperature/rainfall changes or assessing how changes in climate could affect the availability of food and suitable habitats. We can also try to derive insights from old vs new migratory costs.

ACKNOWLEDGEMENTS

This research was conducted with the invaluable guidance of Prof. Udit Bhatia for the Network and Complex Systems course at IIT Gandhinagar. We extend our heartfelt thanks to Adrija Dutta for her unwavering support throughout this project. We also express our gratitude to our teaching assistants, Progyan Das and Mihir Agrawal, for their guidance.

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