Using Graph Coloring Algorithms to Optimize Species Reintroduction

Grand Challenges Scholars Program

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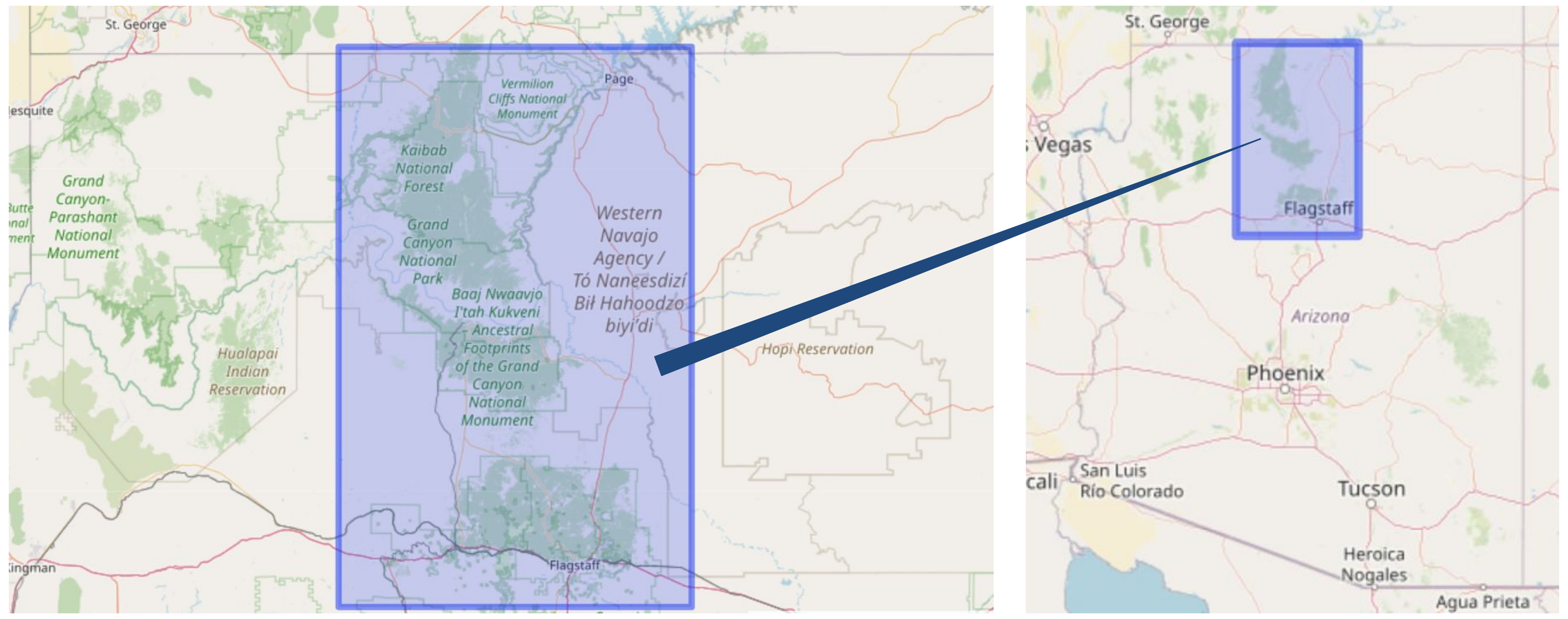
Abstract

This project aims to use a graph coloring algorithm to identify optimal sites for reintroducing endangered species bred in captivity. By translating species interactions into a graph, the graph can be assigned colors such that no adjacent vertices share the same color. The coloring algorithm will then color the graph such that species will not be adjacent to unfit environmental conditions. This approach will help improve the chances of successful species reintroduction and long-term survival.

Research Methods

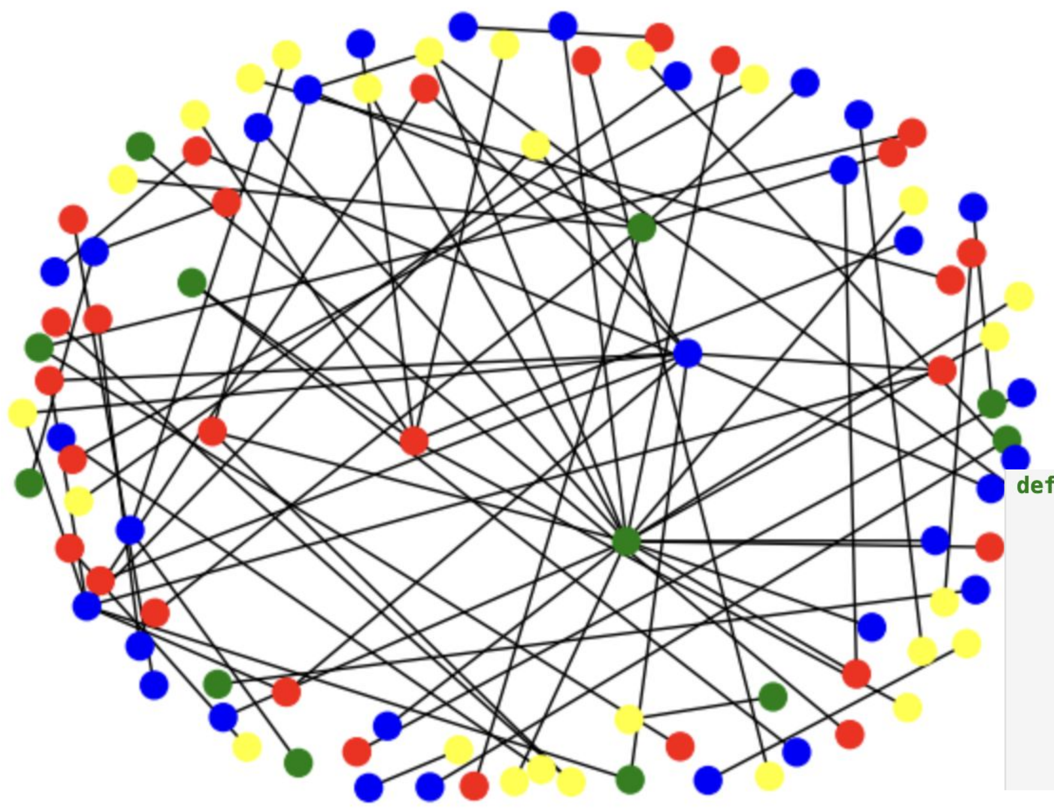
The computer program is written in Python and utilizes the *NetworkX* library[1]. Data was sourced from the *globalbioticinteractions.org* website, an open source repository for biological interaction spreadsheets[2]. The data was filtered to interactions where one species eats the other, within the bounds of northern Arizona.. The data was further filtered to only two columns– the predator and the prey, and this was the data that became translated to a *NetworkX* graph. The unique entries across the predator and prey columns became vertices, and each row entry between predator and prey became an edge. The program utilizes a coloring algorithm to color the graph such that adjacent vertices, or vertices with an edge between them, could not be the same color.

Northern Arizona, with blue box representing where the interaction data was filtered to.



Results

The resulting graph needs just four colors to be properly colored. In the context of the northern Arizona ecosystem, this means that endangered species will be in different colors from their predators. The species may be separated into different local areas by color, thus creating space for endangered species and improving their chances of reintroduction survival.



Resulting graph representation of the species interactions. Vertices are colored either red, yellow, blue, or green to represent separate locations for reintroduction.

```
colors = ['red','yellow','green','blue']
nodes = test_graph.nodes()
edges = test_graph.edges()
print(nx.is_planar(test_graph))
color_lists = {
    node: random.sample(colors, 4) for node in nodes
}
nx.set_node_attributes(test_graph, color_lists, 'species')
```

```
def five_list(G):
    coloring = {}
    for node in nodes:
        adjacent_colors = {coloring[neighbor] for neighbor in G.neighbors(node) if neighbor in coloring}
        color_list = G.nodes[node]['species']
        for color in color_list:
            if color not in adjacent_colors:
                coloring[node] = color
                break
    return coloring
```

'Greedy' coloring algorithm used to color the graph. Each vertex (node) is given a choice from one of the four colors, and if its adjacent vertices are not colored it can simply use any of the four colors.

Conclusion & Future Steps

The graph coloring would significantly benefit from inputs of other factors. Since the graph only draws edges from species to species, it fails to account for other important aspects such as lack of food, weather, and pathogens. Some factors may be more important that others and could also be weighted differently, or factors may conflict with each other. For example, locations with less predators may also be a location with less food. These are all considerations that would be beneficial to the accuracy of the future coloring algorithm. It would also be good to combine this algorithm with other types of ecological models. For example, environmental niche modeling (ENM) relies on the geographic occurrences and/or abundance of a species to map habitat suitability[3]. While combining this with graph coloring was too complex to implement within the semester, it would be a great step moving forward.

References

[1]"Reference — NetworkX 2.5 documentation," *networkx.org*. https://networkx.org/documentation/stable/reference/index.html

[2]*Globalbioticinteractions.org*, 2024. https://www.globalbioticinteractions.org/browse/?bbox=-112.69088745117188%2C35.04798673426734%2C-111.1376953125%2C37.022593019794286&interactionType=eats&resultType=json

[3]"Environmental Niche Modeling - an overview | ScienceDirect Topics," *www.sciencedirect.com*. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/environmental-niche-modeling

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