Novel Algorithmic Coverage Method for Environment Sampling with an Autonomous Surface Vehicle

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Introduction:

- Recent research has demonstrated that Automated Surface Vehicles (ASVs) have significant potential for surveying, exploring, and monitoring riverine environments [1].
- In addition, previous algal bloom studies make note of the difficult, time consuming, and resource intensive task it is to use humans to monitor for such Harmful Algal Bloom (HAB) events [2].
- For a good understanding of the dynamics which influence HABs, it is necessary to have frequent and regular spatial and temporal observation/sampling [3].
- The full coverage algorithm, boustrophedon , struggles with narrow and winding passage ways and limited resource situations.
- The aim of this paper is to resolve both of the aforementioned challenges as part of a solution to the difficulties of automated monitoring of marine enviornments.

Preliminary Skeletons

Fig. 1. Lake Sevan lee skeletonization

Fig. 2. Lake Okeechobee medial axis skeletonization

Fig. 3. Lake Sevan Eerie thinned (bushfire) skeletonization

Problem Statement: Given a large body of water like Lake Murray, what is the most efficient way to program an autonomous jetyak to cover the surface?
Inputs: Satellite image of operation area, coordinates of launch point
Outputs: Zig zag coverage path along skeleton, Chinese postman solution to path tree, mission file of coordinate waypoints

Intermediary steps

Fig. 4 . Intrepid scientist and jetyak in action

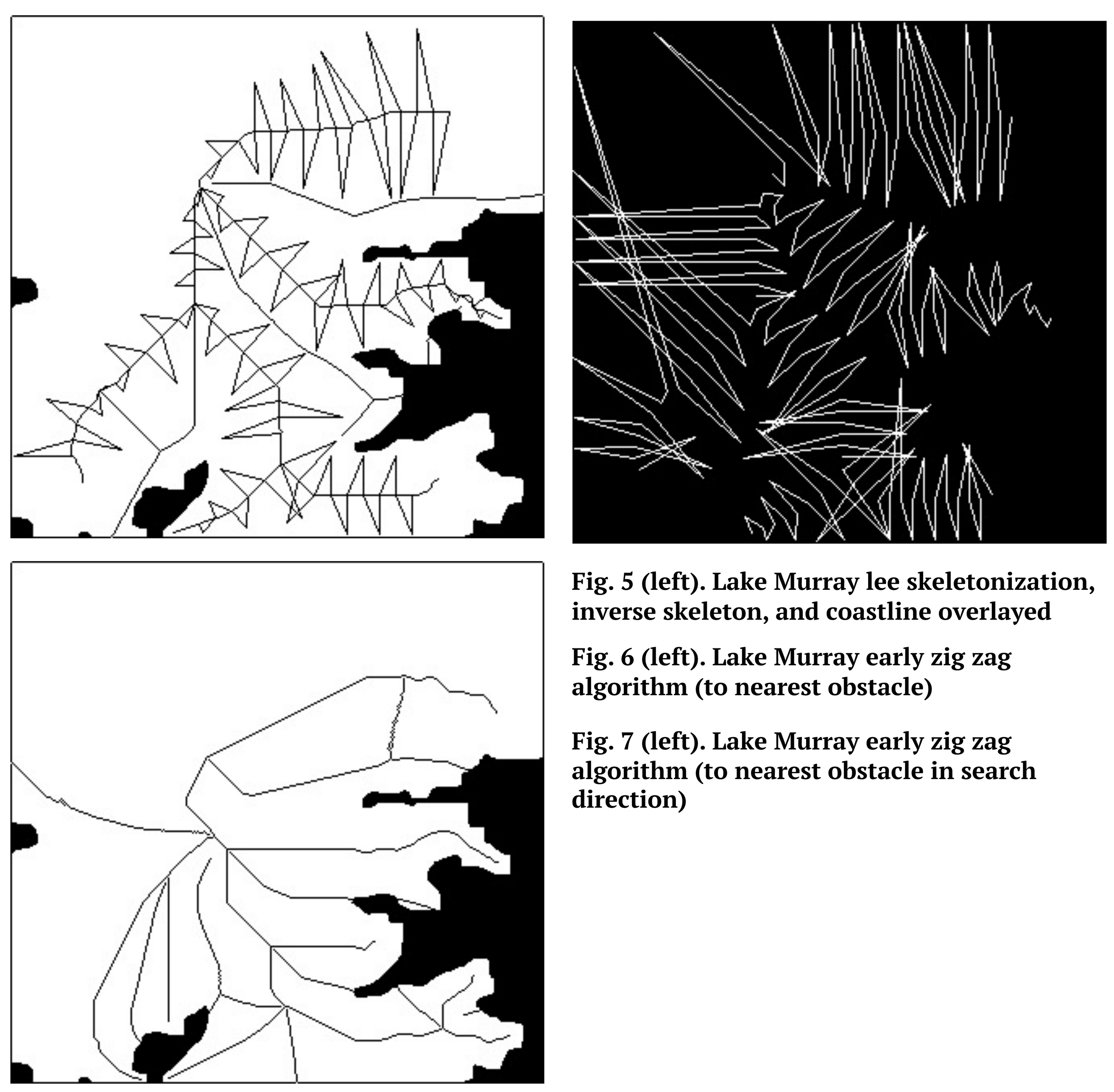

Fig. 5 (left). Lake Murray lee skeletonization, inverse skeleton, and coastline overlayed

Fig. 6 (left). Lake Murray early zig zag algorithm (to nearest obstacle)

Fig. 7 (left). Lake Murray early zig zag algorithm (to nearest obstacle in search direction)

Conclusions/Future Work:

- **This paper puts forward a novel coverage algorithm for environmental sampling in complex waterways with limited resources.**
- **This algorithm could be improved by implementation of rural postman problem which would allow the backtracking paths of the algorithm to be more efficient.**
- **Future investigation can be done into optimization, with every increase in path, there is a corresponding increase in coverage, with diminishing returns. An optimization function that create many paths simultaneously and then picks the best one would be beneficial.**
- **In addition, it may be beneficial to include as an input the resource limitations of the mission (time/fuel/etc.) to inform the shape and spacing of the zig zag pattern.**
- **In addition, the effectiveness of the algorithm should be compared with other conventional coverage patterns, like the boustrophedon method, using metrics like average distance to closest sampled point.**

Algorithm Description:

- *Preprocessing*
- *Skeletonization*
  - *Medial Axis, Skeleton Classic, Lee, Thinned*
- *Skeleton Pruning*
- *Inverse Skeletonization*
- *Zig Zag*
  - *Maximum size that avoids overlapping*
- *Chinese Postman/ Rural Postman*
- *Conversion to Mission File Waypoints*

Intermediary steps

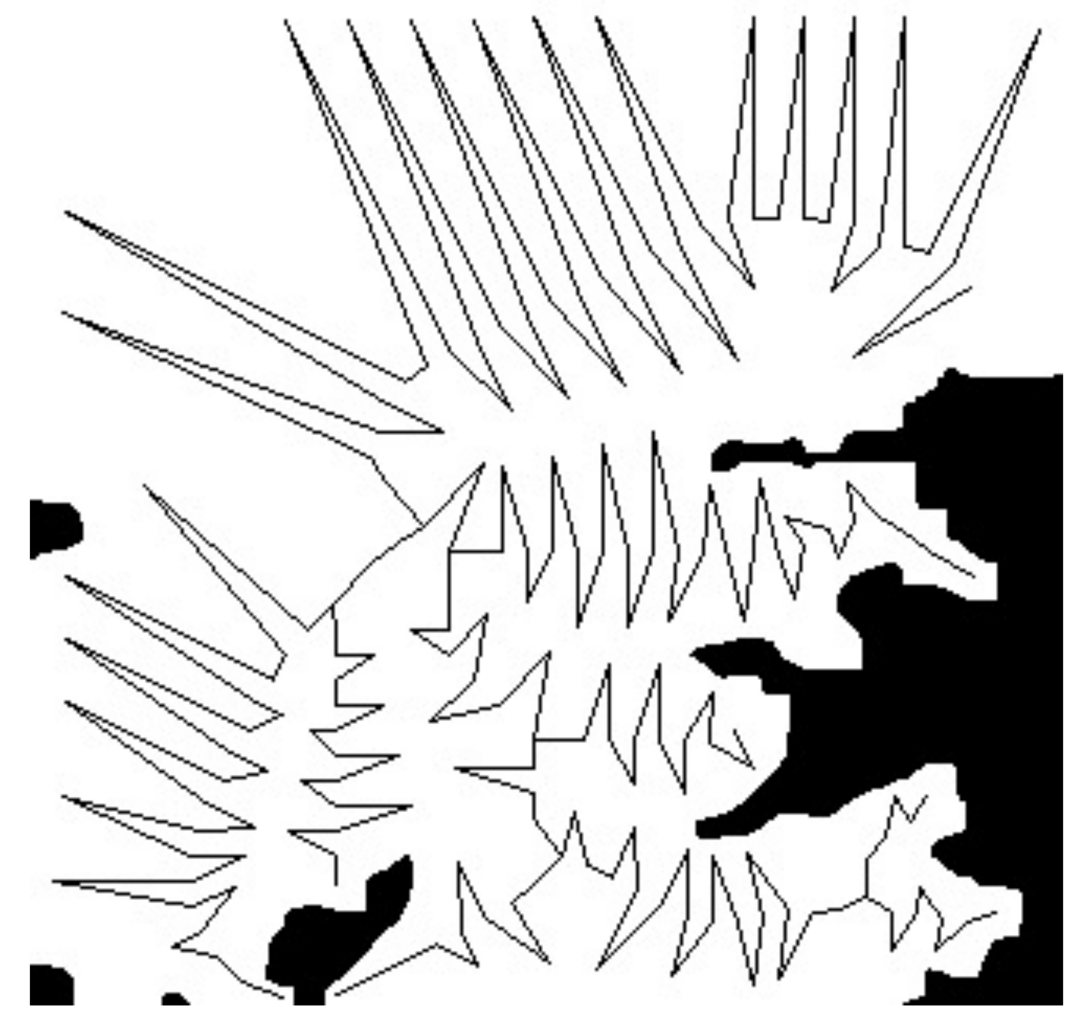

Fig. 8. Lake Murray zig zag algorithm complete

Fig. 9. For reference a satellite image of actual area in Lake Murray

Experimental Results:

- **The algorithm succeeded in creation of a path in a 3 square kilometer region on Lake Murray, which can be seen in Figure 2. The zig zag algorithm is such that it covers inside inlets and open areas. In addition, no part of the path overlaps.**

Acknowledgements

We thank Dr. Jason O'Kane, the Department of Computer Science, as well as all those involved in the NSF REU program. We also thank Marios Xanthidis and Pooyan Jamshidi for supporting this research.

Literature Cited:

[1] N. Karapetyan, A. Braude, J. Moulton, J. A. Burstein, S. White, J. M. O'Kane, and I. Rekleitis, "Riverine coverage with an autonomous surface vehicle over known environments," in 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2019, pp. 3098– 3104.
[2] E. Zohdi and M. Abbaspour, "Harmful algal blooms (red tide): A review of causes, impacts and approaches to monitoring and prediction," International journal of Environmental Science and Technology, vol. 16, p. 1789–1806, 03 2019.
[3] S. K. Moore, J. B. Mickett, G. J. Doucette, N. G. Adams, C. M. Mikulski, J. M. Birch, B. Roman, N. Michel-Hart, and J. A. Newton, "An autonomous platform for near real-time surveillance of harmful algae and their toxins in dynamic coastal shelf environments," Journal of Marine Science and Engineering, vol. 9, no. 3, 2021. [Online]. Available: https://www.mdpi.com/2077-1312/9/3/336