Depth Adaptive Hydrographic Survey Behavior for Autonomous Surface Vessels

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A large portion of autonomous ocean mapping surveys are currently performed by autonomous underwater vehicles, which have the ability to maintain a constant vertical distance above the seafloor by controlling their altitude. This allows for a multibeam sonar system with a fixed angular swath to maintain the same width of coverage along a trackline. Therefore, even in environments where the depth is previously unknown, survey missions can be planned before deployment using fixed line intervals [1]. Many autonomous surface vessels (ASVs) have inherited this operational paradigm and execute linear survey tracklines with preplanned waypoints. However, since ASVs are limited to operation on the surface, the swath width varies with depth and preplanned paths will leave gaps in coverage or reduce efficiency by acquiring unnecessary overlap between subsequent lines [2].

To achieve the most efficient and complete surveys without human guidance, a set of algorithms and behaviors have been developed to guide sonar survey acquisition in real-time. The inputs to the path planning system are a polygonal region to be surveyed and starting line. In typical operation, the starting line would be chosen as the offshore (deeper) side of the polygon and would be oriented parallel to bathymetric contours. The autonomous control system navigates the vessel along the starting line, acquiring depth data from the sonar system. At the end of the path, the recorded swaths from the sonar are processed to determine an accurate edge of coverage, eliminating poor quality pings if necessary. A subsequent path is then planned to achieve desired coverage.

The path is based on the minimum swath widths over a specified interval to ensure full overlap at all locations. The minimum width points are used to create a new line along the edge of the coverage, from which perpendicular offsets of the swath width are used to determine the waypoints of the next survey track line. An overlap percentage may be specified to compensate for increased uncertainty in outer beam measurements. After generating the initial new trackline, this line is analyzed for conditions that would be detrimental to survey acquisition, such as sharp turns, looping segments and departure from the desired survey region. Removing waypoints in this step will sometimes leave gaps in subsequent survey coverage, but increases data quality through more predictable and smooth ASV motion. As a final step, tracklines are extended to the edges of the desired coverage region for full coverage. This operation is similar to that presented by Bourgeois [3], but uses a different methodology to guarantee overlap for subsequent lines.

The new trackline is sent to the autonomous control system which will plan a turn to the beginning of the next line, taking into account the minimum radius of the ASV and executing a modified Williamson turn if necessary. A lead to the first point is taken into account to allow the vessel to have a steady heading when entering the survey region. The process of acquiring coverage and planning tracklines is repeated until the survey region has been fully covered, at which time the data is analyzed for gaps resulting from the smoothing step or poor data. These can then be addressed following an optimal path to ensure complete coverage of the region.

At any time during the survey, if the sonar data indicates reliable shallower depths than a specified threshold, or exceeds a gradient approaching that depth, the ASV will break the planned survey path and return to known safe water from previously acquired data. It will then proceed near the detected underwater obstacle along the edge of the previous swath to determine if a safe passage is possible. Subsequent trackline planning then takes into account this obstacle and attempts to determine if safe passage is possible inshore (for an isolated rock or sandbar), or if the survey should be concluded for that region (for example when the shoreline is reached).

A simulator that uses a previously acquired gridded depth data has been developed to test the path planning algorithms, with some example results shown in the Figure 1 below.

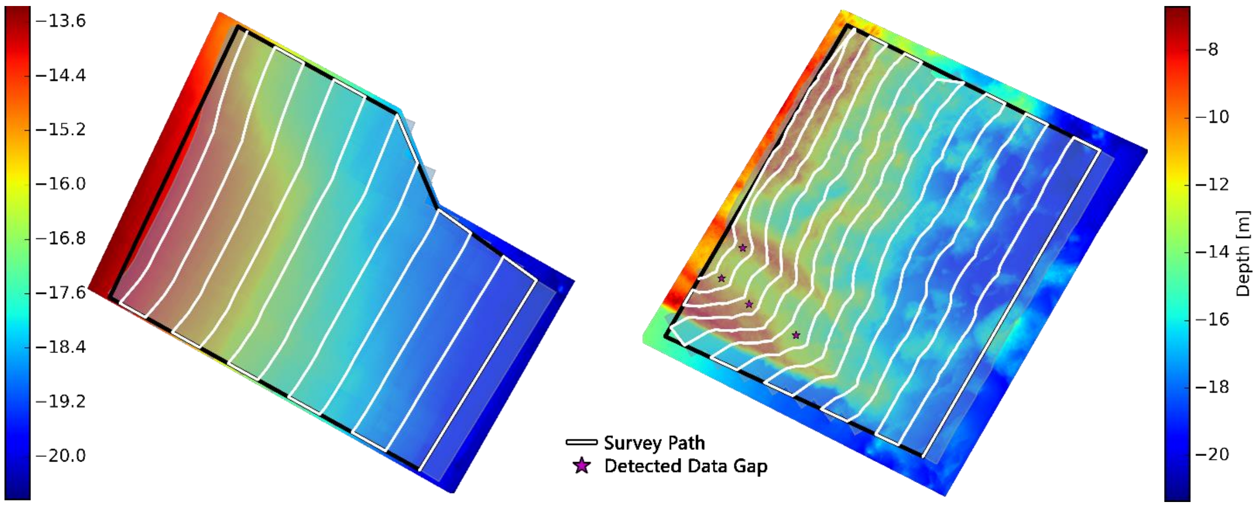

Figure 1: Simulated survey paths for relatively flat (left) and complex (right) regions.

The path planning algorithm and survey behaviors have also been implemented for the MOOS-IvP marine autonomy system for application to survey ASVs. While no swath sonar capable ASV is currently available for testing at the University of New Hampshire, the basic operation of the system is being tested with single beam sonar data on a 5 ft NOAA EMILY ASV.

References

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[3] B. S. Bourgeois and A. Martinez et. al. "Autonomous Bathymetry Survey System," *IEEE Journal of Oceanic Engineering,* vol. 24, no. 4, pp. 414-423, 1999.