# Related Works – Mapping of Ancient Water Storage Systems with an ROV for Visualization – An Approach Based on Fusing Stationary Scans within a Particle Filter

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## I. Related Works

The recent advances of underwater robot sensing technology (e.g. sonar, imaging, doppler velocity logging) have led to the ability to conduct Simultaneous Localization and Mapping (SLAM) [1] in the underwater domain [2]. In many SLAM algorithms, it is common to use robot odometry to predict the new robot position with respect to the map before using exteroceptive sensor measurements to correct the robot's position and update the map itself [3].

Such techniques have proven to work well for applications. In [4], the sonar probabilistic model spIC was used to localize a mobile robot by analyzing raw sonar data to correct odemetry errors for short robot trajectories. This helped minimize the displacement between noisy and sparse measurements.

Analyzing raw sonar data, as opposed to extracting geometric features from a map, is known as scan matching. In the underwater environment, scan matching was implemented using a probabilistic model with acoustic data gathered by an AUV in an unfamiliar environment to successfully localize an AUV and map a pier [5].

Other recent research has focused on generating maps in real-time using a complex motion model in order to associate each sonar measurement with a corresponding location in the map. For example in [6], a pose-based algorithm was developed to map unstructured and unfamiliar environments using a probabilistic scan matching technique. The scan matching techniques that extract ranges from sonar beans explained in [4], [7], and [6] are most similar to the techniques developed in this paper.

In the previous expeditions dedicated to mapping Maltese cisterns, the mapping techniques included sonar mosaicking, and underwater robot SLAM with both a stationary and moving robot. Sonar mosaics are images generated by piecing together several different parts (scans) of the image to create a single full image. This is a manual and time consuming job, but can be used to successfully localize an ROV by manually calculating distances between the positions of the ROV in each of the sub images. For underwater robot SLAM, inadequate motion modeling led to reduced accuracy in robot localization and hence mapping [8]. To ensure highly accurate maps, the subsequent expeditions focussed on obtaining a series of stationary sonar scans from several positions in the tunnel [9].

The work reported here differs from the scan matching techniques developed in [6] and [4] in that our robot has a limited payload and no motion model or odometry is used to predict the robot's location with respect to a map being built. Instead, mapping is done offline. A particle filter is first used to calculate relative positions of the robot between each pair of stationary scans. Then, a weighted least squares approach uses these relative positions to calculate the absolute position of the robot for each individual sonar scan. Finally, the scans and their estimated positions are used to create a 2D occupancy grid map. A detailed description of this approach is presented below.

## References

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