

# Underwater Acoustic Localisation in the context of Autonomous Submersibles

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# Declaration

I certify that, except where otherwise stated, the contents of this thesis are my own original work based on research conducted at the Department of Information Engineering, College of Engineering and Computer Science at The Australian National University. No part of this has been submitted for a higher degree to any other university or institution. To the best of my knowledge, this does not contain any material previously published or written by any other person except where due reference is made in the text.

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# ***Abstract***

With the advancement of the field of underwater robotics, the amount of autonomy embodied in the vehicles themselves have considerably increased while making it possible to build and deploy swarms of small autonomous underwater vehicles (AUVs). Apart from the many environmental and mechanical challenges encountered in the underwater domain, the swarming paradigm demands the need for each vehicle to be aware of the positions of at least its near neighbours. The Serafina AUV project which was initiated with the goal of developing swarming technology for the small and highly agile Serafina class AUVs requires a localisation system which could cope with the dynamic and fast changing vehicle configurations while being small, reliable, robust, and energy efficient and not dependent on pre-deployed acoustic beacons.

The acoustical relative localisation system proposed here uses hyperbolic and spherical localisation concepts and provides each vehicle with the azimuth, range and heading of its near neighbours. The implementation utilises an acoustically transmitted maximum length sequence (MLS) signal which provides extremely high robustness against interference by stochastic and systematic disturbances which are typical for underwater environments. The azimuth is obtained via hyperbolic positioning with improved resolution and accuracy with respect to conventional methods. Range and heading estimation is performed utilising two independent methods for increased robustness. The first method uses the implicit synchronisation provided by the underlying inter-vehicle communication scheduling system to measure the difference in time of arrival of the acoustic and long-wave radio signals to estimate the time of flight (TOF) of the acoustic signal and hence measure range. The second method relies on multiple time differences of arrival (TDOA) and a *reverse hyperbolic* localisation scheme to measure range without any explicit knowledge of the sending times of the acoustic signals.

The localisation system performance with regard to accuracy, precision and robustness against interference is experimentally evaluated. Results of experiments conducted at a test tank as well as those obtained during open water lake experiments are presented along with detailed analyses of the behaviour of the errors associated with the measurements.



*To my parents Padmini & Neil with gratitude  
& to my wife Himadhu with affection*



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*“If you cause your ship to stop, and place the head of a long tube in the water, and place the other extremity to your ear, you will hear ships at a great distance from you”*

-Leonardo da Vinci (1452-1519)

(MacCurdy, 1948)