Deployment of Underwater Sensor Networks  
using Genetic Algorithms

Subtitle as needed ***(paper subtitle)***

Sidharth Gopal Iyer

line 1 (of *Affiliation*): dept. name of organization

line 2-name of organization, acronyms acceptable

New Delhi, India

sid.g.iyer@gmail.com

Dr. Vijay Rao

line 1 (of *Affiliation*): dept. name of organization

Defence Research and Development Organisation (DRDO)

New Delhi, India

line 4-e-mail address if desired

*Abstract*—Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Keywords—UWSN; UWASN; underwater; acoustic; sensor network; deployment strategy; genetic algorithm; modeling; simulation

# Introduction

Underwater sensor networks (UWSNs) are multipurpose grids of autonomous acoustic transmitter-receiver nodes with interdisciplinary applications ranging from bathymetry, oceanographic surveys, offshore exploration, assisted navigation, seismic warning and disaster prevention systems, to tactical surveillance.

Due to the restrictive nature of seawater as the transmission medium involved, harsh constraints are imposed on the network elements in terms of effective ranges, energy efficiency, and reliability. Unlike terrestrial networks, stability in location cannot be guaranteed and geolocation is restricted to inertial positioning based on externally predefined references.

As these nodes are incapable of independent or deliberate lateral movement, they must be deployed in a spatial arrangement that serves their intended purpose optimally, while being stable against disruption by drifting due to undercurrents. Most of them are effectively isolated from the outer world once deployed, and contingency procedures are required for alternate communication paths in case the primary route is compromised.

# Deployment strategies for UWSNs

Fruitful deployment of UWSNs must take into consideration the continually varying attenuation characteristics within a given localized volume of seawater. As these characteristics are anisotropic with respect to change in temperature (*T*), salinity (*S*), depth (*z*), *pH*, and transmission frequency (*f*), they need to be accounted for in a dynamic simulation to preconfigure a stable physical network layout of nodes.

The goal of the following strategy is to maximize the volume enclosed by a given set of nodes with known source level and detection threshold intensities. Given the upper and lower depth bounds for the slab of seawater to be covered, the configuration is allowed to expand laterally in the desired aspect ratio to maximize the volume of the ovoid polyhedron formed with the nodes as its vertices.

# Genetic algorithm for optimal deployment

We choose a genetic algorithm setup to optimize the spatial arrangement of the given set of nodes with respect to the volume enclosed while maintaining edge coverage with the desired degree of overlap.

Absorption coefficients are computed over the region of interest as a suitably granular Cartesian grid, using the model of Francois-Garrison based on the provided oceanographic data sets. A cubic Hermite spline is defined on this grid for later use in multivariate interpolation.

The initial population is randomly seeded while ensuring that all nodes are within echo-detection range of each other. This configuration is then allowed to evolve by aiming to maximize the enclosed polyhedral volume, which serves as the score.

The primary constraint imposed is the satisfaction of edge coverage with specified overlap between every pair of neighboring nodes, aimed at echo-based detection of intrusions. A member of the population is immediately rejected with a zero score if this constraint is violated.

Ranges for echo-based detection are calculated by piecewise integration of the following formula along an edge:

*TL*  2 ´ (20 log *R* + a*R*) 

where *TL* is the transmission loss in intensity in dB, *R* is the range in m, and a is the absorption coefficient in dB/m obtained by interpolating from the aforementioned spline.

# Modeling and simulation techniques

The genetic algorithm is expected to return an optimal solution in the form of Cartesian coordinates in three dimensional space relative to the origin implied in the initial seed population.

These coordinates can be visualized as follows:

1. *MATLAB visualization.*

We suggest that you use a text box to insert a graphic (which is ideally a 300 dpi resolution TIFF or EPS file with all fonts embedded) because this method is somewhat more stable than directly inserting a picture.

To have non-visible rules on your frame, use the MSWord “Format” pull-down menu, select Text Box > Colors and Lines to choose No Fill and No Line.

Any nodes that do not feature on the convex hull of the point cloud may be deemed surplus to requirements for satisfying the given scenario, as the case permits.

This solution is now modeled with routing and communication protocols as applicable to verify its feasibility in a simulation that mimics real-life underwater networking issues.

# Tools for modeling and simulation

The following software tools are used to model and simulate an optimal solution for a given set of node characteristics:

## MATLAB

To find the optimal solution, the genetic algorithm solver (ga) from the Global Optimization Toolbox is used.

The solution is visualized using a convex hull stretched over a three dimensional scatter plot of the point cloud. The attenuated node ranges are then overlaid to inspect possible shortcomings in face coverages.

## AquaSim

Primis corrumpit eum ut, albucius partiendo his at. Liber epicurei contentiones pro ea. In vix animal petentium. His everti perpetua ea, tollit dicunt his id. Quem hendrerit pri te, pri an accusam referrentur. Usu ea causae sensibus, nemore ancillae est in.

At nisl numquam nam, per an alii argumentum. Mea in habeo pertinacia, id nam verear deserunt sensibus. Quaeque mnesarchum ne vis, pri id brute quodsi tamquam. Te vidit adolescens mediocritatem sit, ea his feugiat inciderint.

# Case study analysis

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Cum ea unum audire. Mea ea feugiat epicurei qualisque. Sit vero placerat ut. Nec in rebum munere integre, suas denique platonem et pro. Mel alii inimicus te, eruditi dolorum tincidunt no duo. Ne his errem quaerendum, duo vero propriae an.

Pri et saperet forensibus, eum ei nostrud aliquando necessitatibus, nisl salutatus disputationi pri ut. Ludus mollis honestatis duo an, sumo principes adversarium eos ei, veritus efficiantur vis ea. Modus dolore id pro, sit an latine mediocrem incorrupte. Iusto veritus id vix, an ius impedit vulputate, vix no justo mollis petentium. Eos ne elit dolorem adversarium, ea eos velit feugiat urbanitas.

Primis corrumpit eum ut, albucius partiendo his at. Liber epicurei contentiones pro ea. In vix animal petentium. His everti perpetua ea, tollit dicunt his id. Quem hendrerit pri te, pri an accusam referrentur. Usu ea causae sensibus, nemore ancillae est in.

At nisl numquam nam, per an alii argumentum. Mea in habeo pertinacia, id nam verear deserunt sensibus. Quaeque mnesarchum ne vis, pri id brute quodsi tamquam. Te vidit adolescens mediocritatem sit, ea his feugiat inciderint.

# Results

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Cum ea unum audire. Mea ea feugiat epicurei qualisque. Sit vero placerat ut. Nec in rebum munere integre, suas denique platonem et pro. Mel alii inimicus te, eruditi dolorum tincidunt no duo. Ne his errem quaerendum, duo vero propriae an.

Pri et saperet forensibus, eum ei nostrud aliquando necessitatibus, nisl salutatus disputationi pri ut. Ludus mollis honestatis duo an, sumo principes adversarium eos ei, veritus efficiantur vis ea. Modus dolore id pro, sit an latine mediocrem incorrupte. Iusto veritus id vix, an ius impedit vulputate, vix no justo mollis petentium. Eos ne elit dolorem adversarium, ea eos velit feugiat urbanitas.

Primis corrumpit eum ut, albucius partiendo his at. Liber epicurei contentiones pro ea. In vix animal petentium. His everti perpetua ea, tollit dicunt his id. Quem hendrerit pri te, pri an accusam referrentur. Usu ea causae sensibus, nemore ancillae est in.

At nisl numquam nam, per an alii argumentum. Mea in habeo pertinacia, id nam verear deserunt sensibus. Quaeque mnesarchum ne vis, pri id brute quodsi tamquam. Te vidit adolescens mediocritatem sit, ea his feugiat inciderint.

# Conclusions and future work

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Cum ea unum audire. Mea ea feugiat epicurei qualisque. Sit vero placerat ut. Nec in rebum munere integre, suas denique platonem et pro. Mel alii inimicus te, eruditi dolorum tincidunt no duo. Ne his errem quaerendum, duo vero propriae an.

Pri et saperet forensibus, eum ei nostrud aliquando necessitatibus, nisl salutatus disputationi pri ut. Ludus mollis honestatis duo an, sumo principes adversarium eos ei, veritus efficiantur vis ea. Modus dolore id pro, sit an latine mediocrem incorrupte. Iusto veritus id vix, an ius impedit vulputate, vix no justo mollis petentium. Eos ne elit dolorem adversarium, ea eos velit feugiat urbanitas.

Primis corrumpit eum ut, albucius partiendo his at. Liber epicurei contentiones pro ea. In vix animal petentium. His everti perpetua ea, tollit dicunt his id. Quem hendrerit pri te, pri an accusam referrentur. Usu ea causae sensibus, nemore ancillae est in.

At nisl numquam nam, per an alii argumentum. Mea in habeo pertinacia, id nam verear deserunt sensibus. Quaeque mnesarchum ne vis, pri id brute quodsi tamquam. Te vidit adolescens mediocritatem sit, ea his feugiat inciderint.

##### References

1. X. Lurton, An Introduction to Underwater Acoustics: Principles and Applications, ISBN 3-540-42967-0, Praxis Publishing Ltd, Chichester, UK, 2002.
2. R.J. Urick, Principles of Underwater Sound (3rd edition), ISBN 0-07-066087-5, McGraw-Hill, Inc., New York, USA, 1983.
3. Francios, R. E. and G. R. Garrison. "Sound Absorption Based on Ocean Measurements: Part II: Boric Acid Contribution and Equation for Total Absorption." Journal of the Acoustical Society of America 72 (1982): 1879-1890.
4. Vadov, R. A. "Low-Frequency Sound Absorption and Attenuation in Marine Medium." Acoustical Physics 46 (2000): 544-550.