Cooperative Autonomous Marine Vehicles for Adaptive Passive Acoustic Monitoring

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Introduction

A large part of the oceans and marine life is still greatly unexplored. This is mainly due to the lack of the technology required by scientists to carry out these studies, without the need to be present on the field.

Aim

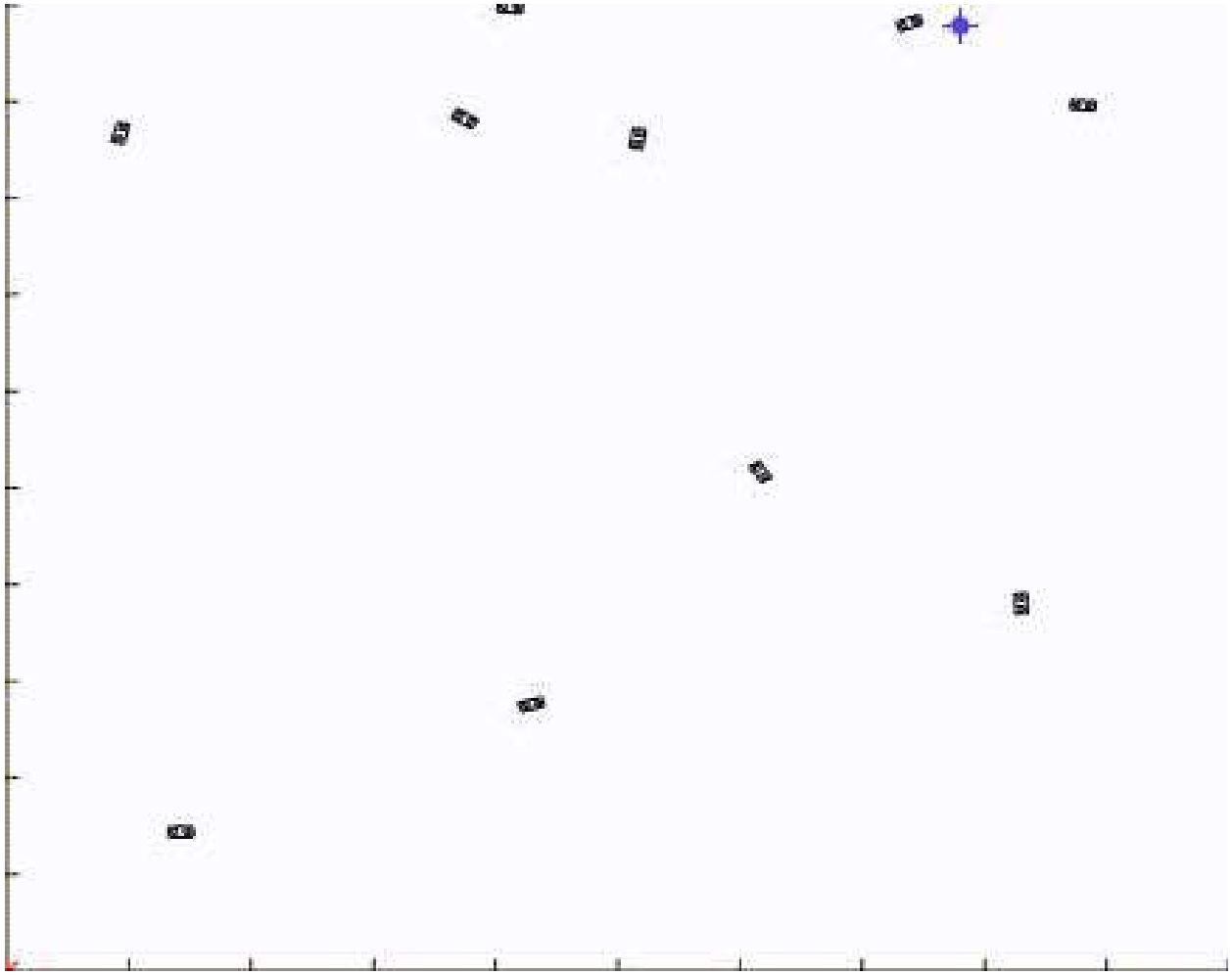
To work towards a system of cooperative marine vehicles, for passive acoustic surveillance. To do this, swarm intelligence algorithms that are already used by the research community, need to be modified to use underwater acoustic signals.

Objectives

1. Select an appropriate target-localisation algorithm for use in marine swarm robotics
2. Modify the algorithm to use underwater acoustic information
3. Demonstrate and validate the new algorithm

Target Localisation Algorithm
Amplitude Particle Swarm Optimisation (A-PSO)

Particle Swarm Optimisation [Kennedy and Eberhart, 1995]



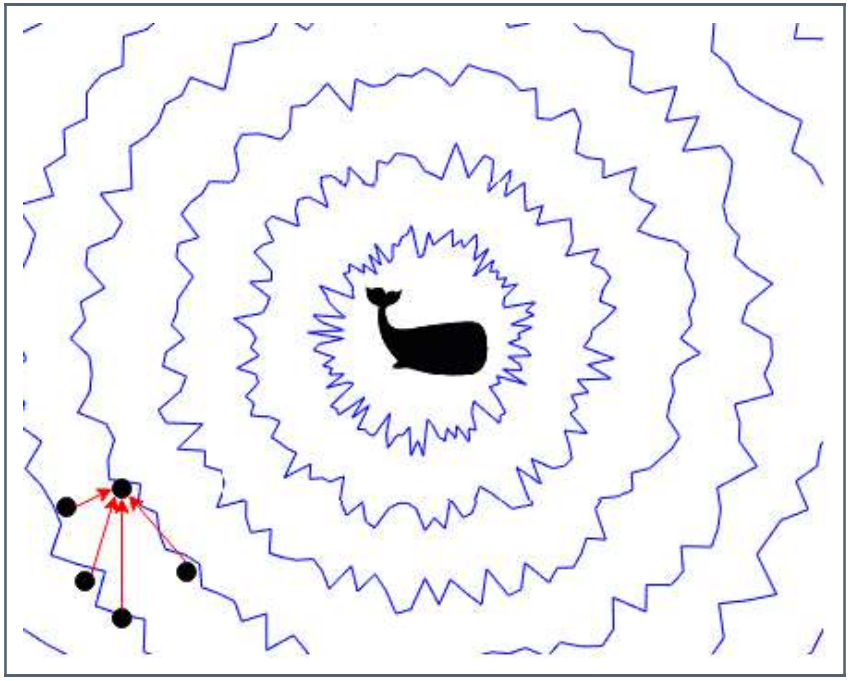
Such an algorithm is dubbed Amplitude-PSO or A-PSO

Target Localisation Algorithm

Particle Swarm Optimisation: Problem

Problems with acoustic signals

- Acoustic signals have variable intensity
- Difficult to move to a location of higher intensity
- Slow convergence towards the target



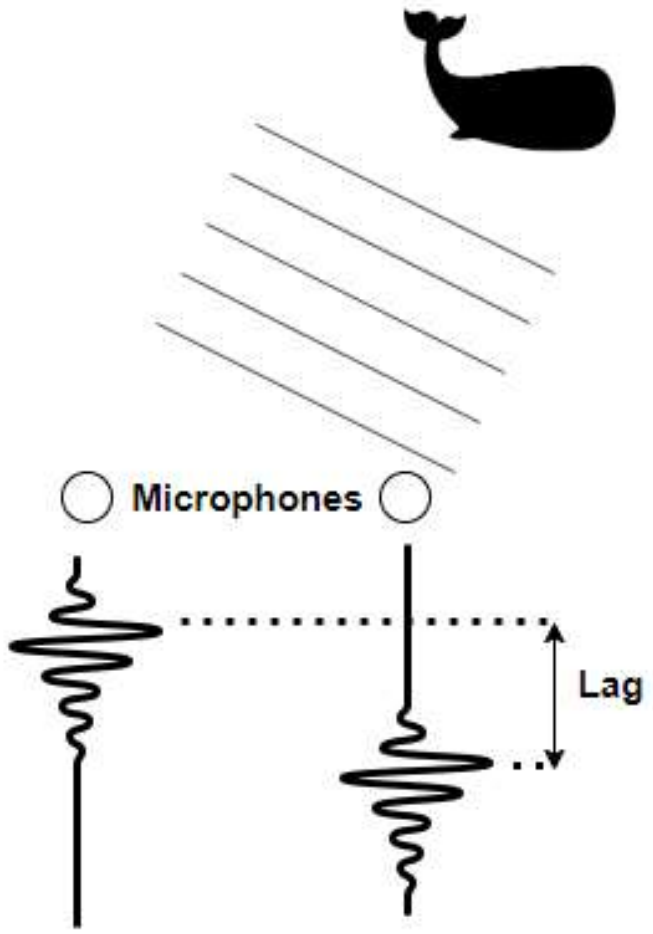
Target Localisation Algorithm

Particle Swarm Optimisation: Solution

Solution: Wavefield Correlation Information

Cross-Correlation Outputs:

- Coherence between the two signals
- Lag between the two signals (used to calculate the direction to the source)



Target Localisation Algorithm

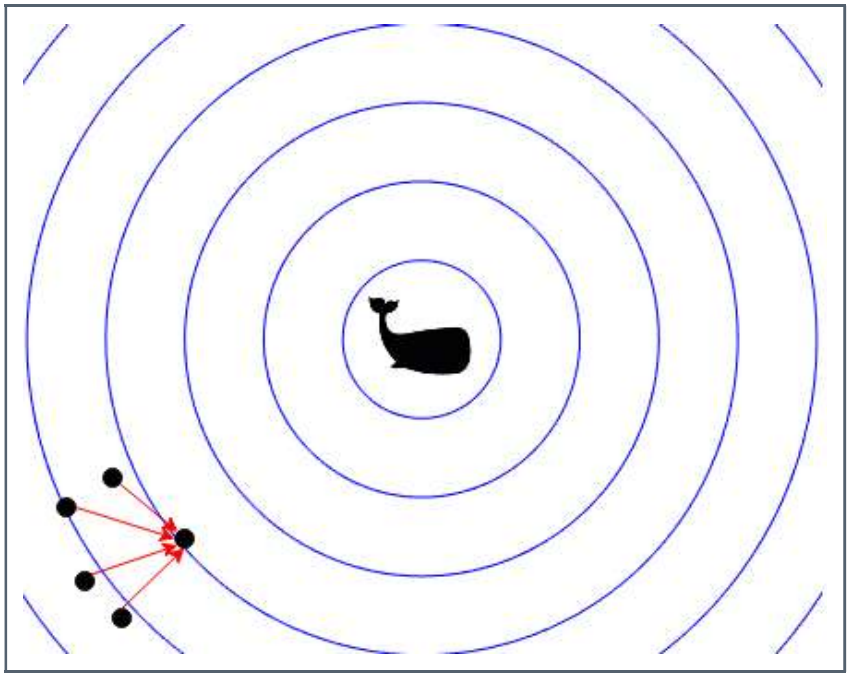
Coherence-Bearing Particle Swarm Optimisation (CB-PSO)

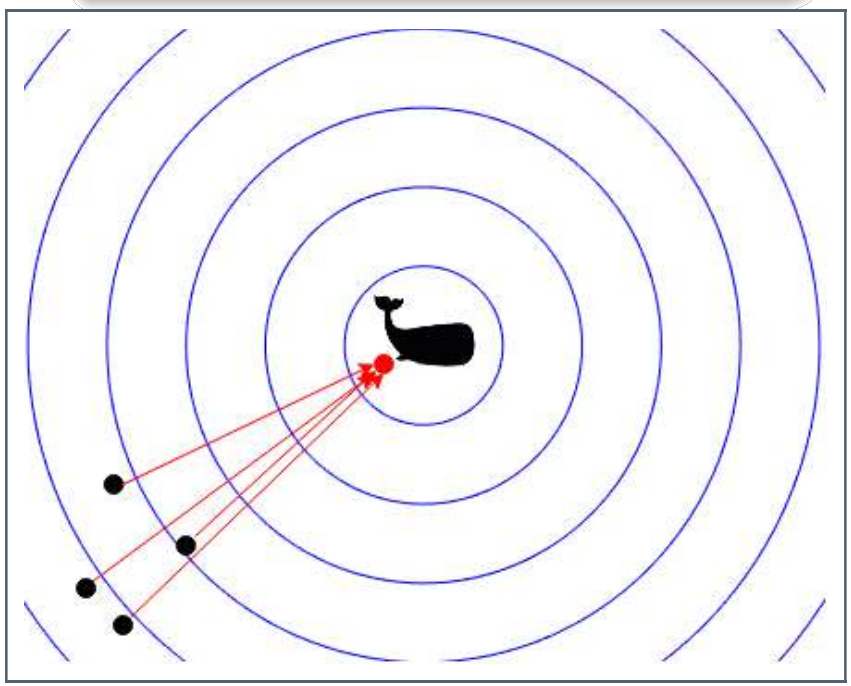
A-PSO (Original)

Gradually finds the location with the highest intensity

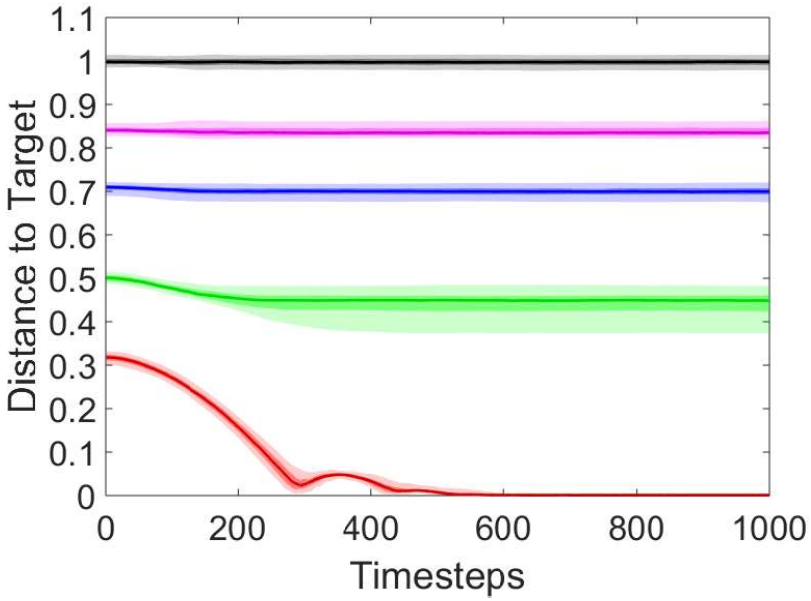
CB-PSO (New)

Predicts the location with the highest intensity using triangulation. Uses coherence information to remove bad predictions

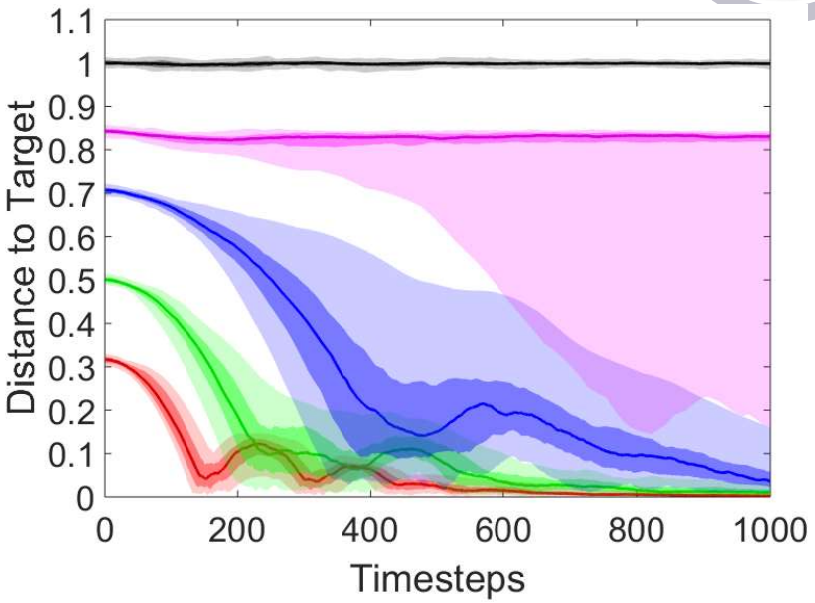




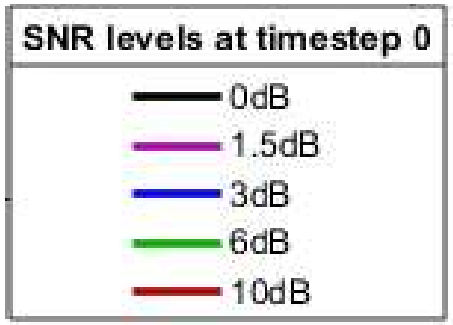
Simulation Results



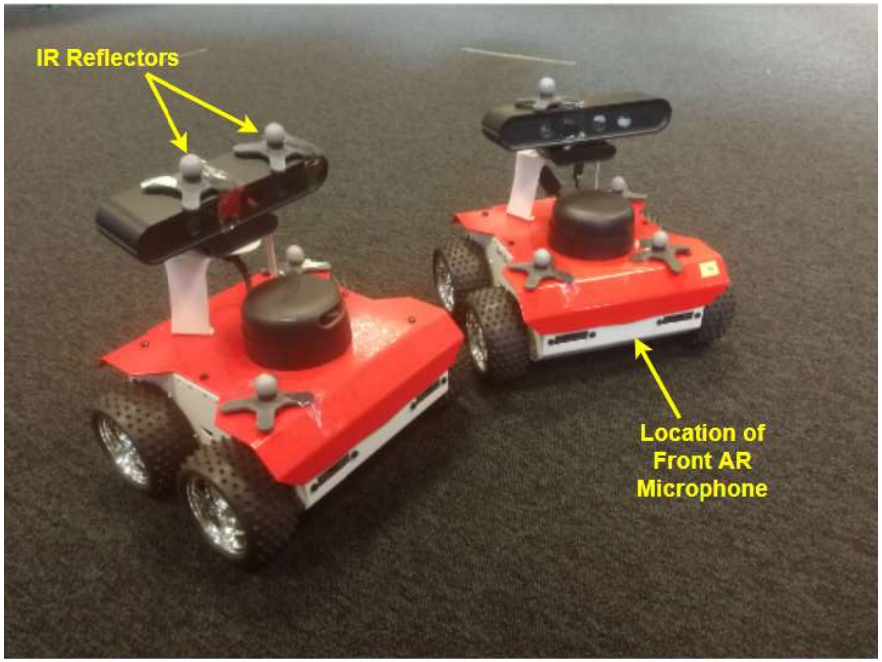
a) A-PSO (Original)



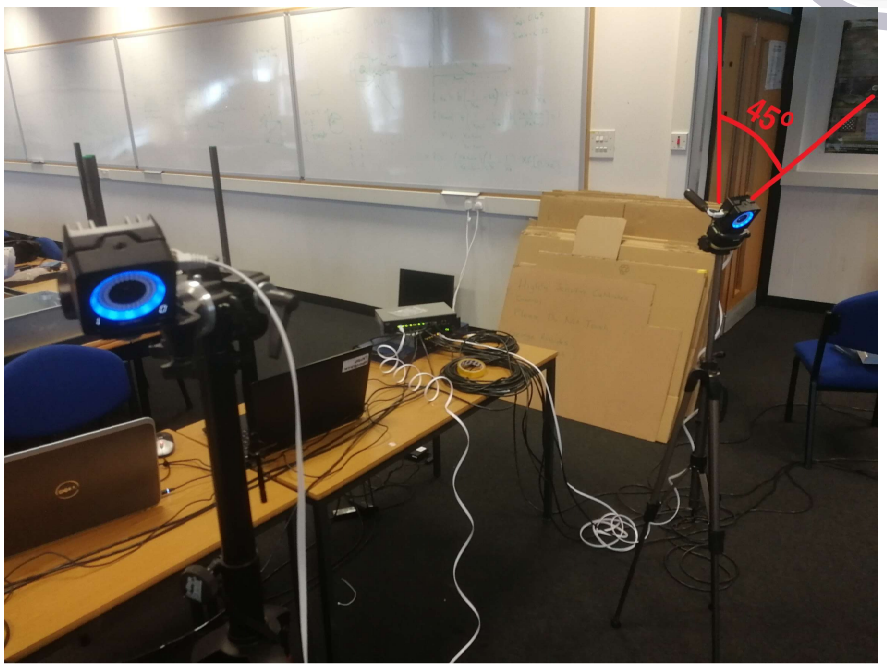
b) CB-PSO (New)



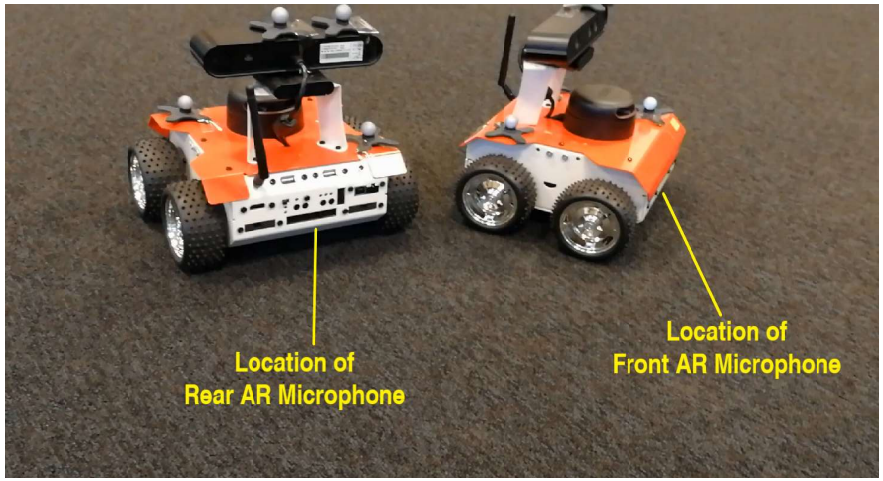
Experimental Demonstration



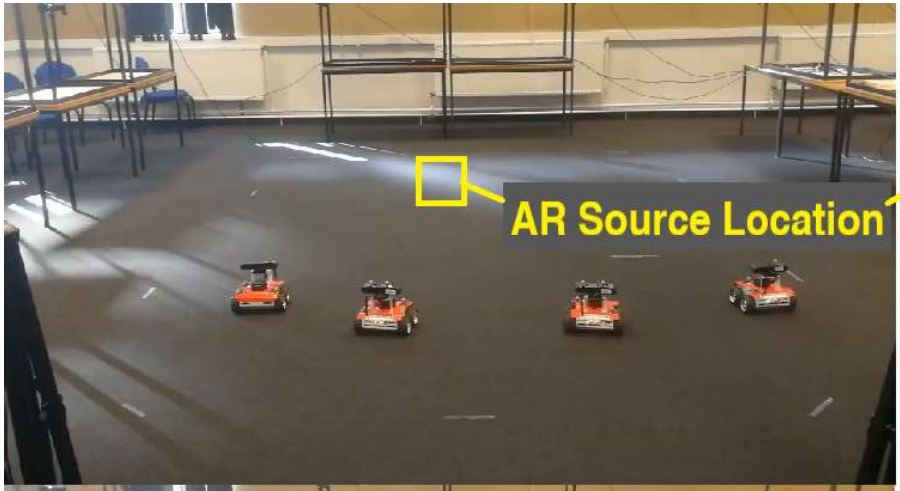
(a) ROSBots 2.0

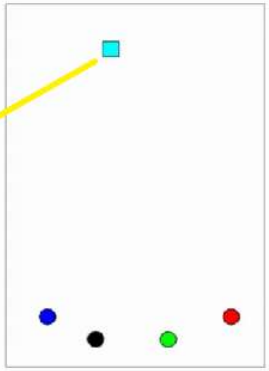


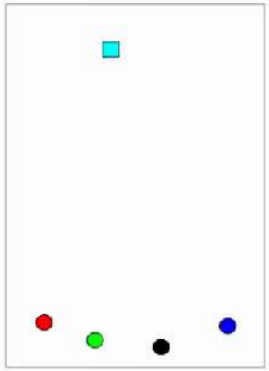
(b) OptiTrack Prime13 Motion-Capture Cameras



Experimental Demonstration



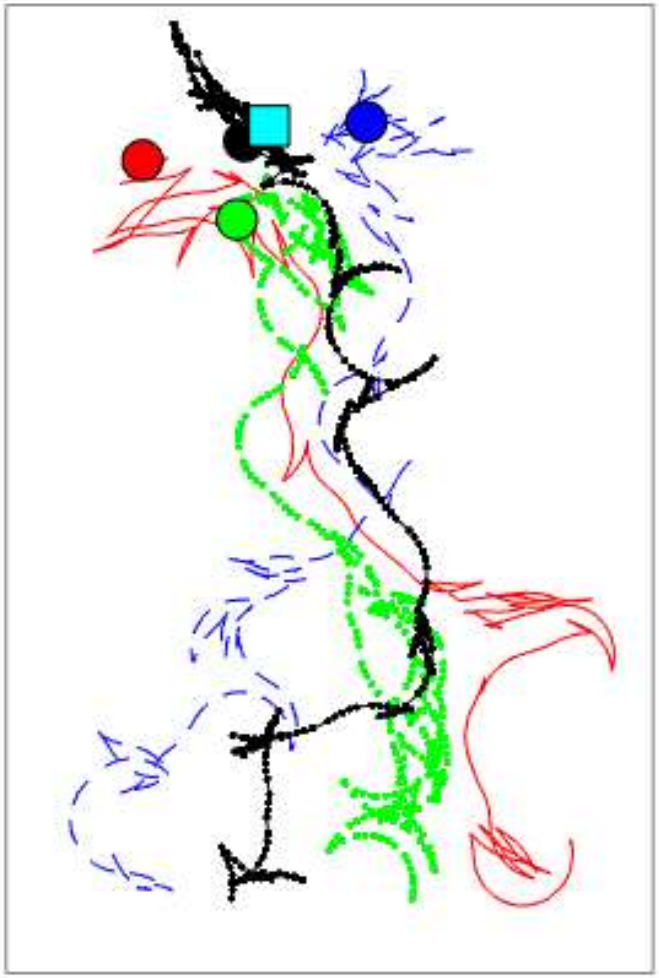




A-PSO (Original)
10dB SNR at initial positions
x5 speed

CB-PSO (New)
10dB SNR at initial positions
x5 speed

Experimental Demonstration
10dB SNR

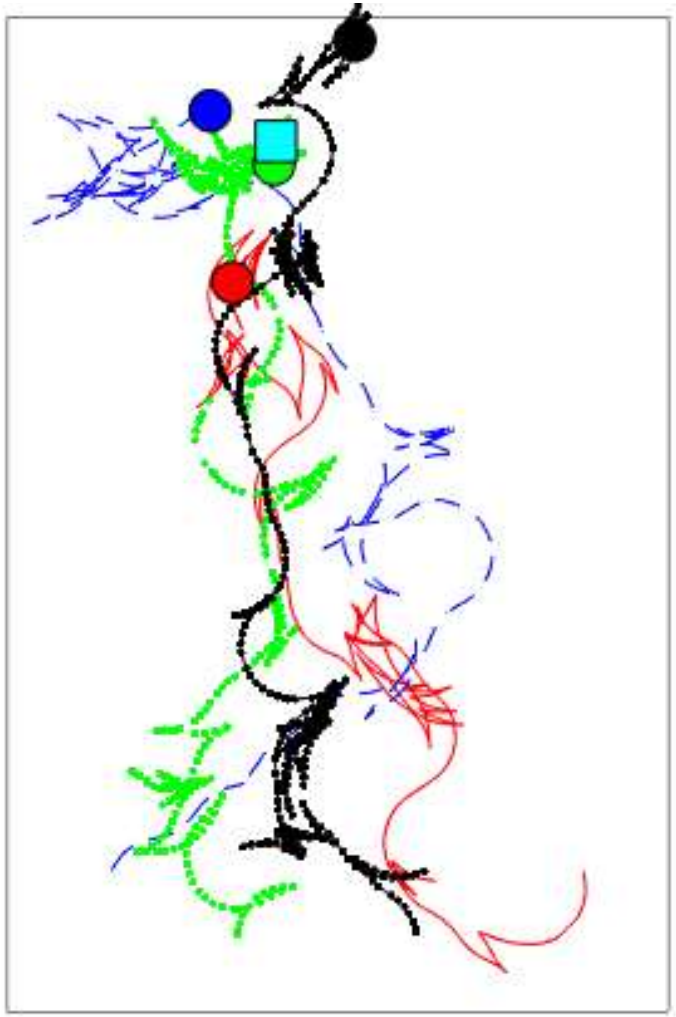


(a) A-PSO (10dB)

(b) CB-PSO (10dB)

Experimental Demonstration
3dB SNR

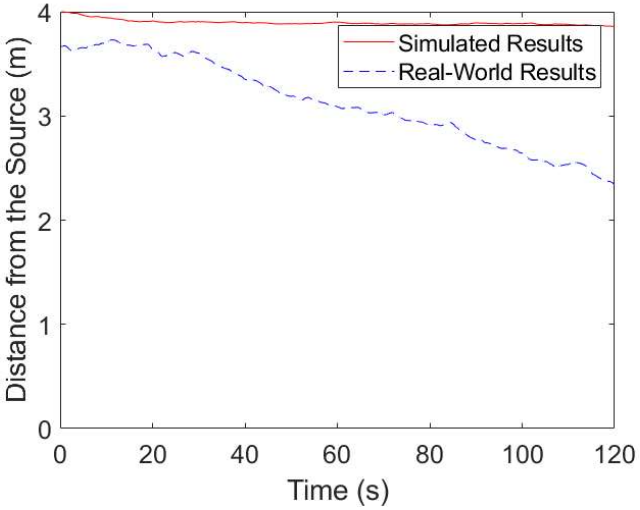
(a) A-PSO (3dB)



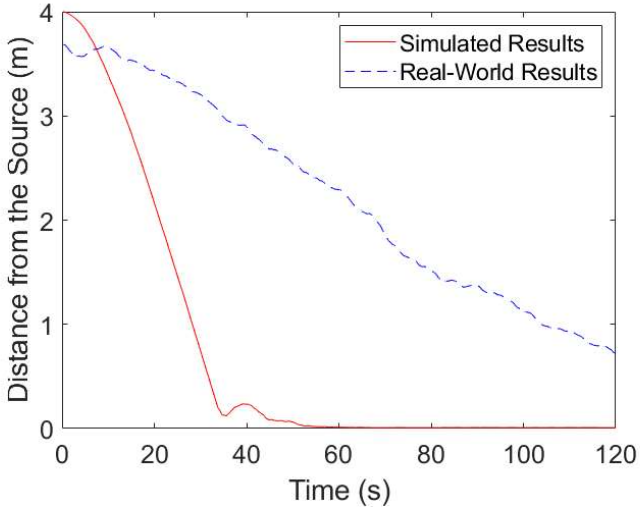
(b) CB-PSO (3dB)

Experimental Demonstration

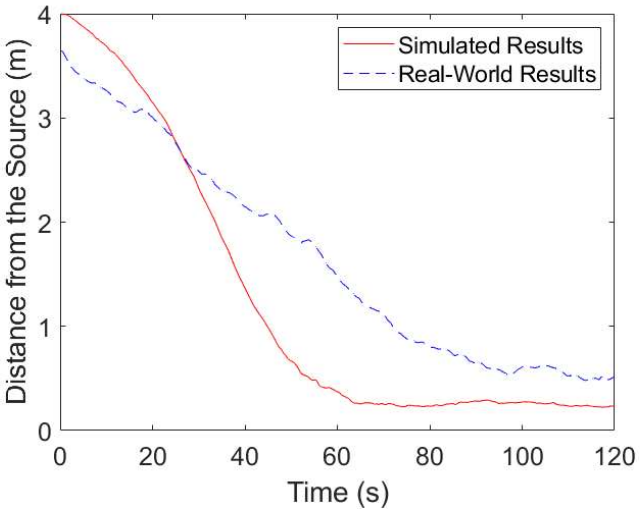
Comparison with Simulation Results



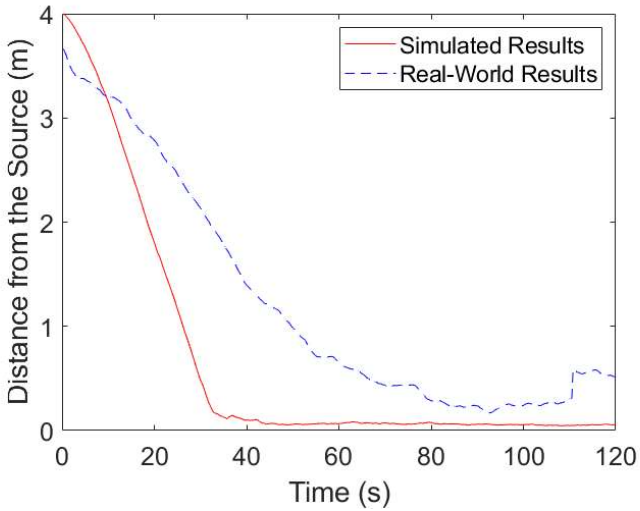
(a) A-PSO (3dB)



(b) A-PSO (10dB)



(c) CB-PSO (3dB)



(d) CB-PSO (10dB)

Conclusion and Future Work

- Particle Swarm Optimisation was successfully modified for use with underwater acoustic signals.
- The new alogirthm (Coherence-Bearing Particle Swarm Optimisation) uses information from acoustic wavefields to overcome problems of the original algorithm.
- The superiority of the new algorithm has been observed using simulations.
- Experimentally demonstrated using a swarm of 4 robots and an augmented-reality source.

Future work will aim to properly validate the simulations by carrying out experiments over a larger area, with a larger swarm and a physical acoustic source and microphones.