A metaheuristic approach for the configuration of heterogeneous multistatic sonar networks

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In the context of Anti-Submarine Warfare (ASW), sonar systems have been used extensively for decades as an efficient way to probe the dimness of the ocean in an effort to search, locate and track underwater threats.

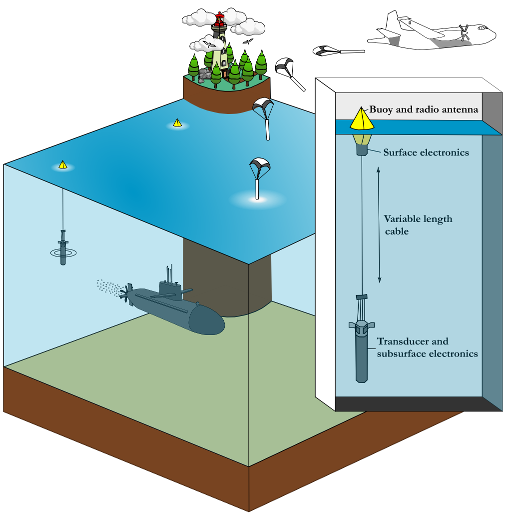

Figure 1: A simplified illustration of the operational context.

More precisely, there are two main types of sonar systems: passive and active. A passive sonar is made up of a receiver listening to sounds emitted by a target, while an active sonar system has a source emitting a sound pulse (ping) and a receiver listening to the reflection of the wave on the target, known as the echo [1]. Within the scope of this study, we focus solely on the case of active sonar systems, which are further divided into two distinct configurations [2]. The first one, named monostatic, is made up of a colocated source and receiver, while the second one, referred to as bistatic, is based on a non-collocated source and receiver. By extension, a Multistatic Sonar Network (MSN) is thus comprised of a set of sources and receivers deployed across a given Area of Interest (AoI), which, taken in pairs, form system units in monostatic and/or bistatic configuration. Herein, the active sonars will be exclusively sonobuoys, a portmanteau for sonar and buoy. These are disposable acoustics units dropped from an airborne carrier onto the AoI in the form of cylinder-shaped containers that unfolds upon impact with the water surface, immersing the core of the system to a predetermined depth. The simplified operational context depicted here is illustrated in figure 1.

In this work, we therefore propose a metaheuristic approach to the Area Coverage (AC) problem [3] in the context of heterogeneous MSNs while taking into account existing coastlines. To date and to the best of our knowledge, there are no works concerning the resolution of this problem for heterogeneous MSNs (see most recent works [4, 5]). For this problem, the objective is to determine the optimal spatial layout of the MSN, i.e. the one that maximize the overall coverage of the AoI with regard to a limited number of sensors and a given probabilistic detection model. In order to do so, an AoI is first discretized through a Digital Elevation Model

(DEM), i.e. a regular rectangular grid where the maritime cells are the ones with an elevation less than or equal to zero (arbitrary choice). Then, a target and a deployment position are placed in the center of each grid cell, which are said to be covered when the probability of detection of the target in its center exceeds a certain threshold set upstream (usually close to 1). For the metaheuristic part, an initial solution will be obtained using an efficient constructive heuristic through a sector-based approach and which will then be improved using a local search procedure that may improve the solution up to 10%. Whenever possible, these solutions will also be compared with exact solutions obtained by solving a Mixed Integer Linear Program (MILP) with a state-of-the-art solver. An exemple of solution is given in figure 2.

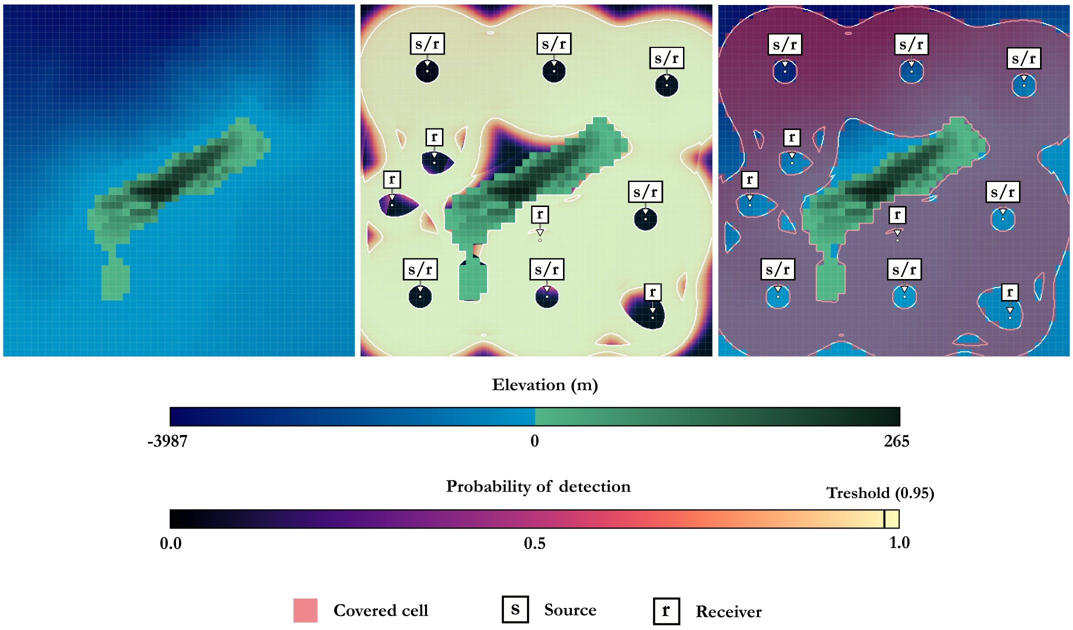

Figure 2: Example of a spatial configuration of an MSN.

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