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# A hybrid multi-objective evolutionary-based and multi-criteria decision making approach for cooperative marine spatial planning (MSP)

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## 1 Introduction

Over the last decades, the more the population grew, the more the demand increased for marine space uses. Hence, the increasing demand has led to conflicts due to the overlapping of various human activities (e.g., renewable energy equipment, aquaculture, fishing, etc.) occurred for economic development, social objectives, and environmental protection purposes (European Commission of Maritime Affairs, 2017). To urgently address these potential conflicts, a planning approach is required to analyze and allocate the spatial and temporal distribution of human activities in marine areas [1]. This planning process is usually called *Marine Spatial Planning* (MSP), an ecosystem-based spatial organization process that aims at allocating marine spatial zones to multiple actors to ensure that human activities at sea take place in an efficient, safe and sustainable manner [2].

The goal of this contribution is twofold: 1) Proposing a practical description of MSP and a comprehensive review of related articles, and 2) Developing a spatial decision support system to allocate maritime space to multiple actors, in which actors interact/negotiate and seek compromises, in order to reach an agreement despite their potentially conflicting objectives/constraints.

## 2 State of the art

To ensure the effective development of MSP, a number of key phases should be fulfilled as follows. MSP begins with a *Pre-planning* phase (Phase 1) that includes the definition of planning objectives, conflicting uses, and very importantly, the organization of stakeholder engagement in the process [1]. *Analysis for planning* (Phase 2) pertains to the definition and analysis of both present (As-Is) and future conditions (To-Be) (e.g., ecological, oceanographic), by collecting and mapping of data on existing biophysical conditions and human activities, and identifying of corresponding overlaps including conflicts and compatibility. Based on the collected information, having developed and analyzed alternative scenarios according to stakeholders' preferences, a desired future spatial vision should be selected. In the *Management plan development* (Phase 3), while management actions are spatially explicated, an ocean zoning scheme is developed to support their implementation [3]. Zones are usually defined using a number of analytical and decision support tools available to support zoning (e.g., Geographical Information Systems) [4].

Despite numerous research articles addressing MSP, it is still a non-straightforward issue as many technological, spatial, economic, environmental and social objectives/constraints should be considered for each actor and these objectives/constraints are usually in conflict. Zeng *et al.* [5] developed a procedure that solves trans-boundary water conflicts in the Gaunting reservoir basin based on a hybrid game theory and mathematical programming model to optimize water use and pollutant discharge, while maximizing the net aggregate benefits and reducing the costs for water supply and pollution removal. Fox *et al.* [6] applied a connectivity-based method for multi-objective optimization to the design of marine protected area networks. The authors developed a meta-heuristic algorithm to search for the Pareto optimal set for networks up to 100 sites by examining two real-world marine networks. Zhao *et al.* [7] studied the conflicts formed by the double contradiction between the development and utilization of the sea area and the ecological protection by calculating the Ecosystem Service Value (ESV). The results show the advantages of sea area (Dengsha estuary area) utilization optimization based on a genetic algorithm. It can solve the problem of multi-sector sea conflict and produce a different space layout optimization plan.

## 3 Proposed approach

Reviewing the gaps in the literature, we can see that the challenge is to choose an appropriate allocation strategy within wider spatial decision-making processes, where marine actors interact with each other to reach a spatial allocation agreement. Reaching such an agreement is not straightforward due to the actors' objectives which are mostly in conflict. To cope with this issue, we develop a multi-objective evolutionary-based decision-making process that: I) first looks for optimal allocation solutions that guarantee Pareto efficiency, where all claimed space is allocated. This optimization step supplies the actors with a set of allocation alternatives and permits them to negotiate; and II) secondly provides a negotiation-based decision-making system among the actors to finally select a single alternative that maximizes the allocated benefit to them and guarantees the fairness and ensures actors' satisfaction with the allocation for long-term cooperation. The above approach is an evolutionary-based semi-posterior-interactive approach that provides a set of Pareto alternatives by asking for the actors' preferences and then by selecting the most appropriate solution. The performance of the approach on artificially generated data will be presented at the conference.

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