EasyChair Preprint

№ 3979

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Son Duy Dao, Antoine Mallégol, Patrick Meyer,
Mehrdad Mohammadi and Sophie Loyer

July 31, 2020

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Son Duy Dao[1,*], Antoine Mallégol[1], Patrick Meyer[1,*], Mehrdad Mohammadi[1], Sophie Loyer[2]

[1] IMT Atlantique, Lab-STICC, UMR CNRS 6285, F-29238 Brest, France
{son-duy.dao, antoine.mallegol, patrick.meyer, mehrdad.mohammadi}@ imt-atlantique.fr
[2] Shom, F-29200 Brest, France
sophie.loyer@shom.fr

Keywords: *Genetic algorithm, optimization, spatial zoning, marine spatial planning, hydrographic survey planning.*

1. Introduction

The Spatial zoning problem (SZP) is an optimization problem in which the goal is to find the location and shape of spatial zones, given some constraints (e.g., surface, distance, shape, etc.) while maximizing or minimizing an objective function, defined on spatial or geographical data. The SZP can be found in various domains such as hydrographic survey planning (i.e., determining a zone of a given area to make a hydrographic survey, while focusing on high priority areas), conservation planning (i.e., determining a zone of a fixed area to protect the fauna or flora), military planning, etc.

Finding an optimal solution to an optimization problem is very challenging, especially for complex large-scale problems and SZP is not an exception. There are two main optimization solution methods, namely deterministic and stochastic methods [1]. Stochastic methods are more popular than deterministic methods for solving complex large-scale problems [2]. The latest data on Scopus database indicates that Genetic Algorithms (GA) are the most popular stochastic optimization algorithms for solving a wide variety of optimization problems. In this paper, we develop an innovative GA for the spatial zoning problems.

2. Problem Description

Given a spatial/geographical map (as shown in Figure 1a-d for example) and the required size of the interest zone, the goal is to find the location and shape of a zone (e.g., a quadrangle) that maximizes the coverage of the high-valued areas of the map (calculated as shown in Figure 1f).

3. Proposed Genetic Algorithm

In this paper, we develop an innovative GA with a new dynamic solution representation for determining the optimal spatial zones. Unlike the classical GA, the proposed GA employs three crossover operators, two mutation operators, and a local search operator. As shown in Figure 1e, a solution of the problem is a quadrangle, which is defined by a central point *O*, four angles α_i (i = 1, ..., 4), and four radiuses d_i (i = 1, ..., 4). The crossover, mutation and local search operators operate on this solution representation. In addition, this GA has a mechanism to restart its search process if it gets stuck in local optima.

[*] Corresponding authors: Son Duy Dao and Patrick Meyer

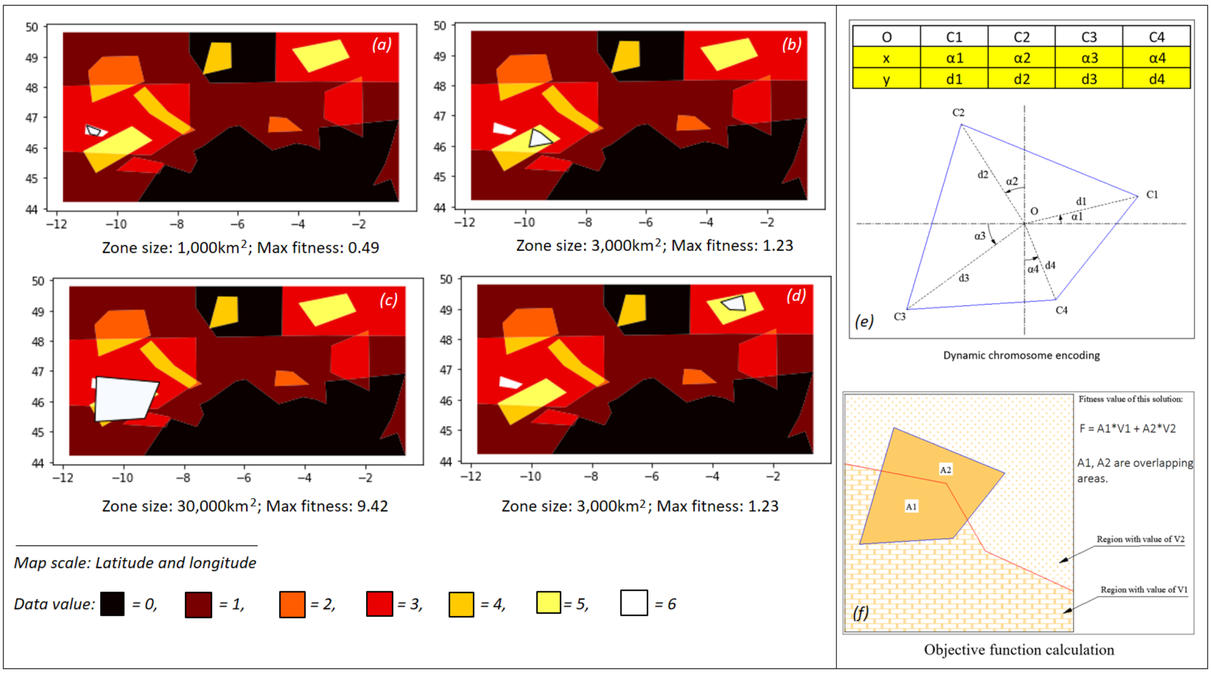

FIG. 1 - Spatial zoning optimization problem and proposed dynamic solution representation

4. Performance Testing

The proposed GA was coded in Python, and its performance has been validated against classical GA and a hybrid GA (the traditional GA hybridized by a local search) on multiple spatial datasets. The parameters of the proposed GA as well as other optimization algorithms were tuned by the Taguchi experimental design method [3]. Table 1 presents a subset of our experiments. It shows that the proposed GA always find the best solutions within 60 seconds of computing time. In addition, the proposed GA provides, on average, 11.2% and 10.8% better solutions, compared to the traditional GA and the hybrid GA, respectively.

No.	Computing time in each run	Number of independent runs	Traditional GA				Hybrid GA				Proposed GA			
			Min	Max	Average	Std	Min	Max	Average	Std	Min	Max	Average	Std
1	15	20	0.409	0.483	0.427	0.025	0.408	0.488	0.441	0.030	0.409	0.491	0.486	0.018
2	30	20	0.409	0.486	0.431	0.032	0.409	0.489	0.437	0.028	0.487	0.491	0.490	0.001
3	45	20	0.409	0.485	0.443	0.030	0.409	0.489	0.441	0.032	0.486	0.491	0.490	0.001
4	60	20	0.409	0.489	0.459	0.029	0.409	0.490	0.447	0.034	0.489	0.491	0.491	0.000

Note: The larger fitness value, the better. Zone size: 1000 km2

TAB. 1 – Performance comparison

5. Conclusion & Future Work

The proposed GA could handle the dynamic shape requirement of the interest zone in the spatial zoning problem. It is capable of jumping out of local optima to achieve global optimal solution(s), and outperforms both the traditional GA and the hybrid GA. As a future research direction, we will test the robustness of the proposed GA on more spatial datasets and against more optimization algorithms. In addition, we aim at developing a multi-objective GA for spatial zoning problems.

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