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A simulated annealing algorithm for zoning in planning using parallel computing

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ABSTRACT

There is an increasing demand for tools that support land use planning processes, particularly the design of zoning maps, which is one of the most complex tasks in the field. In this task, different land use categories need to be allocated according to multiple criteria. The problem can be formalized in terms of a multiobjective problem. This paper generalizes and complements a previous work on this topic. It presents an algorithm based on a simulated annealing heuristic that optimizes the delimitation of land use categories on a cadastral parcel map according to suitability and compactness criteria. The relative importance of both criteria can be adapted to any particular case. Despite its high computational cost, the use of plot polygons was decided because it is realistic in terms of technical application and land use laws. Due to the computational costs of our proposal, parallel implementations are required, and several approaches for shared memory systems such as multicores are analysed in this paper. Results on a real case study conducted in the Spanish municipality of Guitiriz show that the parallel algorithm based on simulated annealing is a feasible method to design alternative zoning maps. Comparisons with results from experts are reported, and they show a high similarity. Results from our strategy outperform those by experts in terms of suitability and compactness. The parallel version of the code produces good results in terms of speed-up, which is crucial for taking advantage of the architecture of current multicore processors.

1. Introduction

The design of a land use map is a laborious task that requires deep knowledge and expertise. The development of new automatic processes and tools to help public administrations and technicians in this task is of strategic importance. In this work a novel mechanism to achieve near-optimal solutions to this problem is introduced. It is formulated in terms of a multiobjective optimization problem in which plots are allocated to the most appropriate land category for it. **Plots** are land basic elements that can be assigned one category, in our case they are cadastral plots. Fig. 1 shows a group of 15 plots that are used as an example in this paper. Objectives to be considered often include land suitability for the land category (Arentze, Borgers, Ma, & Timmermans, 2010; Cromley & Hanink, 2003; Eastman, Jin, Kyem, & Toledano, 1995). Also, some authors consider spatial criteria, especially the compactness of the regions allocated to one single category (Aerts, Eisinger, Heuvelink, & Stewart, 2003a; Duh & Brown, 2007; Janssen, van Herwijnen, Stewart, & Aerts, 2008; Nalle, Arthur, & Sessions, 2002; Stewart, Janssen, & van Herwijnen, 2004) because an irregular allocation of land categories in small, scattered, unconnected areas is usually undesirable in terms of economic and technical impact.

The problem of allocating different categories to specific land units can be established formally as a combinatorial optimization problem. A large number of alternative solutions can be usually found, and their quantitative comparison is usually important to validate the quality of the solutions and to justify them. Moreover, the number of plots involved in a municipal land use plan is usually large. Because these two factors lead to a high computational load, the search for the optimal solution usually calls for the use of heuristic algorithms capable of achieving near-best solutions in a reasonable time (Matthews, Craw, & Sibbald, 1999). As a consequence, heuristics are used to obtain near optimal solutions. In particular, a number of authors have used algorithms based on the simulated annealing technique to optimize the allocation of land uses to spatial entities (Aerts & Heuvelink, 2002; Aerts, van Herwijnen, & Stewart, 2003b; Boyland, Nelson, & Bunnell, 2004; Duh & Brown, 2007; MartÃ-nez-Falero, Trueba, Cazorla, & Alier, 1998;

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