# A Labeling Problem for Symbol Maps of Archaeological Sites

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## Introduction

Given a set of $n$ rectangles embedded in the Euclidian plane, we consider the problem of modifying the layout to avoid intersections of the rectangles. The objective is to minimize the total displacement under the additional constraint that the orthogonal order of the rectangles must be preserved. We call this problem MINIMUM-DISPLACEMENT OVERLAP REMOVAL (MDOR). We define the *total displacement* in the new layout as the sum of the Euclidian distances between the initial position $(x, y)$ and the final position $(x', y')$ of the centers of all rectangles. A layout adjustment is *orthogonal-order preserving* if the order of the rectangles with respect to the $x$- and the $y$-axis does not change. More formally, the order is preserved if and only if for any pair of rectangles $r_i$ and $r_j$ it holds that $x_i \leq x_j \Rightarrow x'_i \leq x'_j$ and that $y_i \leq y_j \Rightarrow y'_i \leq y'_j$.

## Motivation

Our interest in this problem is motivated by the application of displaying metadata of archaeological sites. The most popular way of representing data of this kind is to use a *symbol map*, where each site is represented by a symbol that conveys (a selection of) the metadata about the site, and these symbols are placed on the map at the site's geographical coordinates. Overlap needs to be removed so all symbols are visible, but the symbols need to stay close to the corresponding sites, and because cardinal relations between sites are often important the orthogonal order should be maintained. Many GIS packages commonly used in archaeology do offer automated map production, but when it comes to the arrangement and scaling of objects they generally perform poorly [1]. Figure 1 shows examples as published in [2] (left) and [4] (right).

## Contribution

MDOR is closely related to MINIMUM-AREA LAYOUT ADJUSTMENT (MALA), which is known to be NP-hard [3]. The difference is that the objective in MALA is to minimize the area of the drawing, rather than the total node displacement. We show by reduction from MONOTONE ONE-IN-THREE SAT that MDOR is NP-hard.

**Theorem 1.** MINIMUM-DISPLACEMENT OVERLAP REMOVAL *is NP-hard, even for equal-size squares at integer coordinates.*


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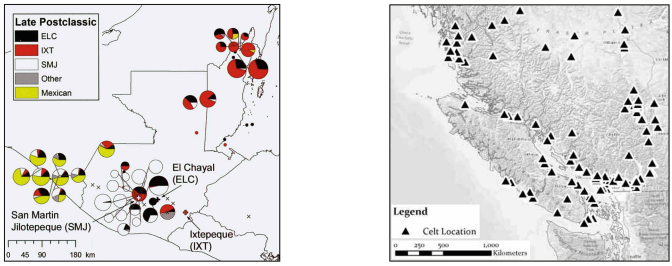
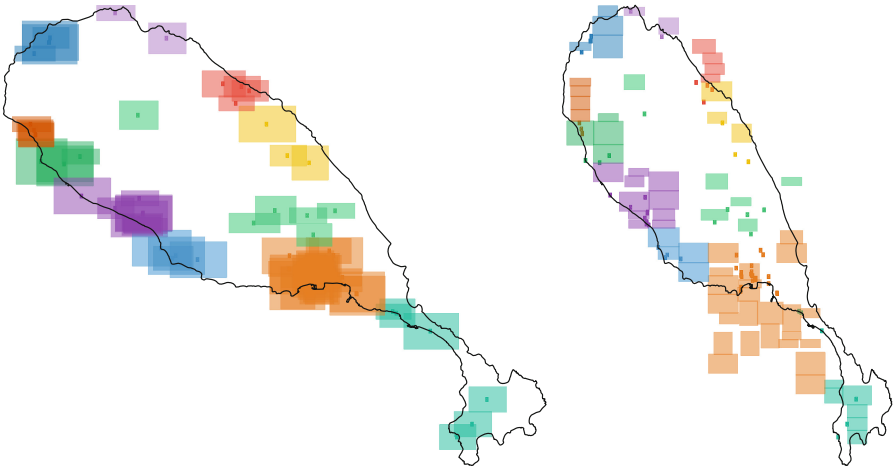



**Fig. 1.** Archaeological symbol maps produced by commonly used GIS software.

Because MDOR is NP-hard, we turn to heuristic approaches to find a feasible solution to our problem. The objectives of existing overlap removal algorithms are not ideal for our application, therefore we present a new heuristic for solving the problem. The core of this algorithm is a loop that contains three steps:

1. Compute all pairs of overlapping nodes using a sweep line
2. Remove the overlap for each pair with local minimum displacement
3. Repair the orthogonal order using a variation of MergeSort

These three steps are repeated until there are no more overlapping pairs (Fig. 2).



(a) Input data (b) Resulting layout

**Fig. 2.** Input (a) and result (b) of the heuristic for a dataset of 70 cultural heritage sites on St. Kitts. In (b), the island map is distorted to fit the new bounding box.

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