A Labeling Problem for Symbol Maps of Archaeological Sites

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Introduction

We define Minimum-Displacement Overlap Removal (MDOR) as follows:

Input A set of **rectangles** embedded in the plane
Objective Modify the layout to **avoid overlap**
Optimization Minimize the **total displacement**
Constraint Preserve the **orthogonal order**

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 (*i.e.*, 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 $y_i \leq y_j \Rightarrow y'_i \leq y'_j$).

MDOR is closely related to the Minimum-Area Layout Adjustment problem, which is known to be NP-hard [1].

Motivation

In the context of a collaboration with Caribbean archaeologists, 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 or close to the site's geographical coordinates.

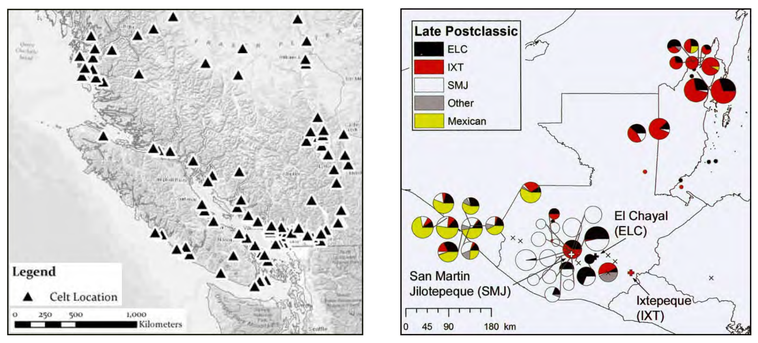

Figure: Automatically produced symbol maps often have overlap (left [2]) or poor symbol placement (right [3]).

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 [4].

On a good symbol map all symbols should be **visible**, so any overlap has to be removed. The symbols need to stay **close** to their corresponding sites, so they can be easily identified. Since **cardinal relations** between sites are often important in archaeology, the orthogonal order of the site symbols should be maintained. This leads to the problem of minimum-displacement overlap removal with orthogonal ordering constraints.

Hardness result

Theorem Minimum-Displacement Overlap Removal (MDOR) *is NP-hard, even for unit-size squares with integer coordinates.*

We can show that MDOR is NP-hard by reduction from monotone one-in-three SAT.

Heuristic

Because MDOR is NP-hard, we turn to **heuristic solutions** for our problem. The objectives of existing overlap removal algorithms are not ideal for our application, therefore we introduce reArrange, a new heuristic for solving the problem.

The core of the algorithm consists of three steps:

1) **Detect** overlapping pairs using a sweepline
2) **Remove** the overlap for each pair with the local minimum displacement
3) **Repair** the orthogonal order in both dimensions using an adaptation of MergeSort

These steps are repeated until there are no more overlapping pairs.

Data

To illustrate our heuristic we apply it to a dataset of **70 cultural heritage sites** on the island of St. Kitts, obtained through a crowdsourcing project [5]. The metadata consist of:

Name describing the site
Type of heritage
Picture of the site (opt.)
Description of additional site information (opt.)

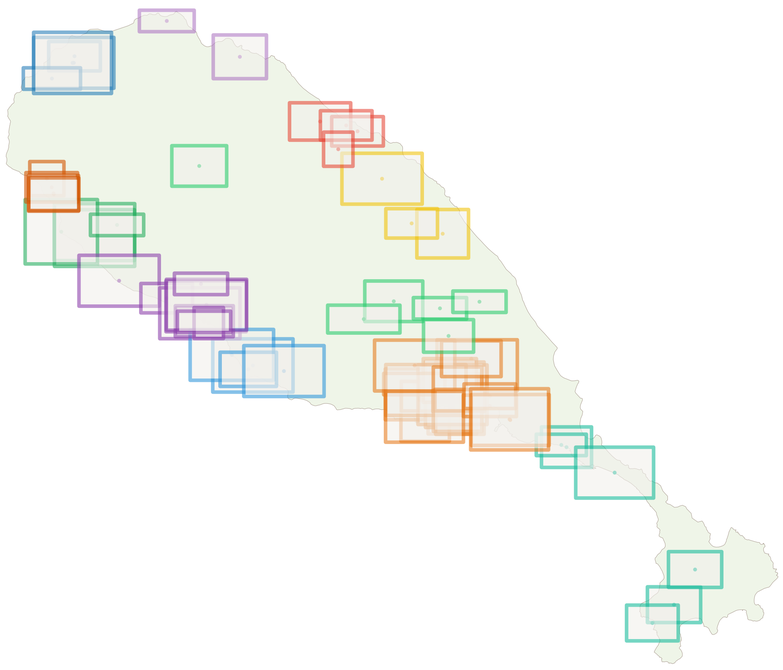

Figure: Initial layout of the heritage sites

Layout Result — Cultural Heritage Sites on St. Kitts

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[4] Conolly & Lake. (2006) Maps and Digital Cartography. Chapter in *Geographical information systems in archaeology.*
[5] See `www.culturesnaps.kn` for more information about the crowdsourcing project.