A Labeling Problem for Symbol Maps of Archaeological Sites
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Introduction

We define Minimum-Displacement Overlap Removal (MDOOR) 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 Euclidean 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 \(y\)-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 \(y_i \leq y_j \Rightarrow y'_i \leq y'_j\)).

MDOOR 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.

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 (MDOOR) is NP-hard, even for unit-size squares with integer coordinates.

We can show that MDOOR is NP-hard by reduction from **MONOTONE ONE-IN-THREE SAT**.

Heuristic

Because MDOOR 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.)

![Image: Initial layout of the heritage sites](image)

**Figure:** Initial layout of the heritage sites

![Image: Automatically produced symbol maps often have overlap (left) or poor symbol placement (right).](image)

**Figure:** Automatically produced symbol maps often have overlap (left) or poor symbol placement (right).

**References**


[5] See [crowdsourcing project](https://www.example.com) for more information about the crowdsourcing project.