

Data and text mining

Shuffle & untangle: novel untangle methods for solving the tanglegram layout problem

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Abstract

Motivation: A tanglegram is a plot of two-tree-like diagrams, one facing the other, and having their labels connected by inter-tree edges. These two trees, which could be both phylogenetic trees and dendrograms stemming from hierarchical clusterings, have thus identically labelled leaves but different topologies. As a result, the inter-tree edges of a tanglegram can be intricately tangled and difficult to be analysed and explained by human readers. To better visualize the tanglegram (and thus compare the two dendrograms) one may try to untangle it, i.e. search for that series of flippings of the various branches of the two trees that minimizes the number of crossings among the inter-tree edges. The untangling problem has received significant interest in the past decade, and several techniques have been proposed to address it. These techniques are computationally efficient but tend to fail at finding the global optimum configuration generating the least tangly tanglegram.

Results: We leverage the existing results to propose untangling methods that are characterized by an overall slower convergence method than the ones in the literature, but that produce tanglegrams with lower entanglements.

Availability and implementation: One of the algorithms is implemented in Python, and available from <https://github.com/schlegelp/tanglegram>.

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1 Introduction

A common strategy to visually compare two different dendrograms relative to the same sets of terminal vertices is by using tanglegrams, i.e. comparative drawings (embeddings) of a pair of dendrograms, side-by-side, with matching objects connected by straight-line segments called inter-tree edges (Andreas *et al.*, 2012). A crossing occurs in a tanglegram when two inter-tree edges intersect, while there is no crossing inside the individual trees. The number of crossings, in its turn, depends on the layout (also known as drawing) of the two dendrograms in the tanglegram. In practical terms, layouts, which lead to a high number of crossings are harder to interpret (Andreas *et al.*, 2012). This calls for finding a drawing of the tanglegram with as few crossings as possible. Finding a tanglegram layout (TL) of two trees that produces zero crossings, sometimes referred to as a drawable layout (Fertus *et al.*, 2010), is known as the planar embedding problem (Andreas *et al.*, 2012). It is known that every pair of trees of size smaller or equal to three has a drawable layout (Fertus *et al.*, 2010). However, only special cases allow for a layout with zero crossings. The problem of finding a graphical layout of

two trees that gives the minimum number of crossings is known as the TL problem (Ramsal *et al.*, 2009), or the two-tree crossing minimization (TTCM) problem (Fertus *et al.*, 2010). The TTCM problem is known to be NP-complete, meaning that there is no known algorithm to solve this problem in polynomial time with the tree size, but only in exponential time (Fertus *et al.*, 2010).

When one tree is fixed, the problem above is referred to as the one-tree crossing minimization (OTCM) (Fertus *et al.*, 2010). For arbitrary trees, the OTCM problem can be solved in $O(n \log n)$ time (with n the number of leaves) as in Venkatasubram *et al.* (2009) and Fertus *et al.* (2010). Ramsal *et al.* (2009), instead, presented an $O(n \log^2 n / \log \log n)$ algorithm for a generalized tanglegram.

A heuristics-based algorithm to tackle the TTCM problem was proposed in Dwyer and Schreiber (2004). Here, the authors repeatedly solve the OTCM problem for each tree, and eventually provide 2.5D graphical representations of the results. Another approximation algorithm for complete tanglegrams is provided in Buchin *et al.* (2009).

The TTCM for binary trees problem was shown in Fertus *et al.* (2010) to be fixed parameter tractable (FPT) with parameter k (the

Untangle A Novel

JA Banks



Untangle A Novel:

Rewriting Wrongs Angela Kimyongür, Amy Wigelsworth, 2014-10-02 *Rewriting Wrongs* French Crime Fiction and the Palimpsest furthers scholarly research into French crime fiction and within that broad context examines the nature functions and specificity of the palimpsest Originally a palaeographic phenomenon the palimpsest has evolved into a figurative notion used to define any cultural artefact which has been reused but still bears traces of its earlier form In her 2007 study *The Palimpsest* Sarah Dillon refers to the persistent fascination with palimpsests in the popular imagination embodying as they do the mystery of the secret the miracle of resurrection and the thrill of detective discovery In the context of crime fiction the palimpsest is a particularly fertile metaphor Because the practice of rewriting is so central to popular fiction as a whole crime fiction is replete with hypertextual transformations The palimpsest also has tremendous extra diegetic resonance in that crime fiction frequently involves the rewriting of criminal or historical events and scandals This collection of essays therefore exemplifies and interrogates the various manifestations and implications of the palimpsest in French crime fiction

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serve the study of TS including large well characterized patient cohorts and specialized epidemiological databases such as the unique resource of the Netherlands Twin Register This research topic showcases current large scale collaborative efforts aiming to elucidate the genetic and neurobiological background of TS through diverse approaches from genomewide association studies aiming to identify common variants associated to the disorder to neuroimaging studies and animal models Furthermore current approaches on the clinical assessment and management of the disorder are presented Propelled by the gradual availability of large scale TS cohorts novel methodologies and importantly sheer enthusiasm by multiple researchers working together across different countries the new era of the neurobiology of TS holds the promise to identify novel targets for improved therapies

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Table of Contents Untangle A Novel

1. Understanding the eBook Untangle A Novel
 - The Rise of Digital Reading Untangle A Novel
 - Advantages of eBooks Over Traditional Books
2. Identifying Untangle A Novel
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Untangle A Novel
 - User-Friendly Interface
4. Exploring eBook Recommendations from Untangle A Novel
 - Personalized Recommendations
 - Untangle A Novel User Reviews and Ratings
 - Untangle A Novel and Bestseller Lists
5. Accessing Untangle A Novel Free and Paid eBooks
 - Untangle A Novel Public Domain eBooks

- Untangle A Novel eBook Subscription Services
- Untangle A Novel Budget-Friendly Options
- 6. Navigating Untangle A Novel eBook Formats
 - ePub, PDF, MOBI, and More
 - Untangle A Novel Compatibility with Devices
 - Untangle A Novel Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Untangle A Novel
 - Highlighting and Note-Taking Untangle A Novel
 - Interactive Elements Untangle A Novel
- 8. Staying Engaged with Untangle A Novel
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Untangle A Novel
- 9. Balancing eBooks and Physical Books Untangle A Novel
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Untangle A Novel
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Untangle A Novel
 - Setting Reading Goals Untangle A Novel
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Untangle A Novel
 - Fact-Checking eBook Content of Untangle A Novel
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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