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Deformable Part Models for Automatically Georeferencing Historical Maps

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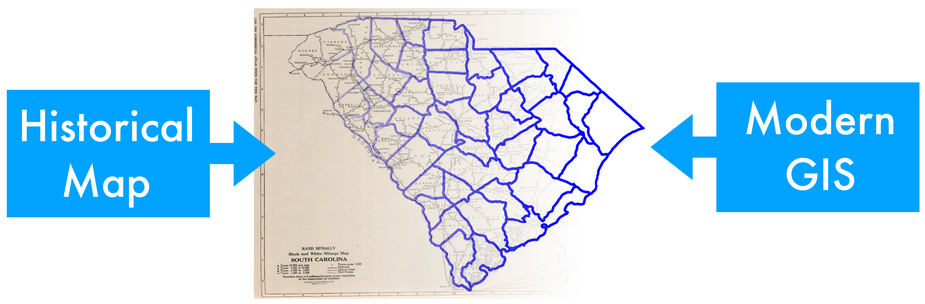
Overview



Aligning map images with geographical coordinates is a painstaking, time-consuming manual process.

We align historic maps to a modern geographic coordinate system using probabilistic shape-matching.

Starting from an approximate initial alignment, we optimize the match between a deformable model built from GIS contours and ink from the binarized map image.

On an evaluation set of 20 historical maps from states and regions of the U.S., the method reduces average alignment RMSE by 12%.

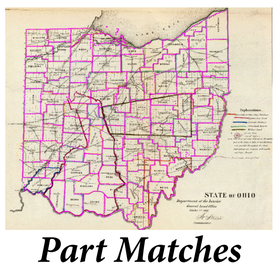
Proposed Approach

The model deforms control points of a GIS shape to better match ink locations, while retaining a bias for the original shape. Dense correspondences arise from a parametric affine fit or a robust thin plate spline (TPS).

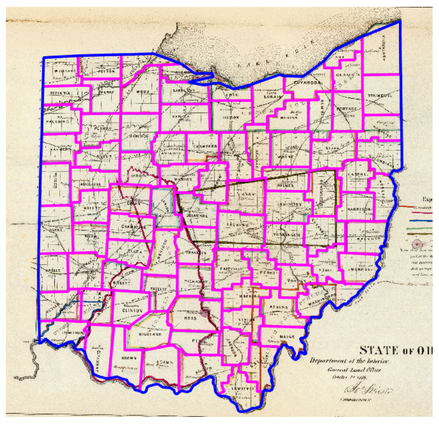
Map Image

Binarized Ink

Deformable GIS

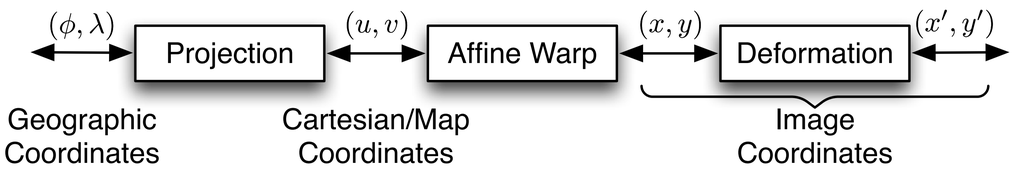


Part Matches

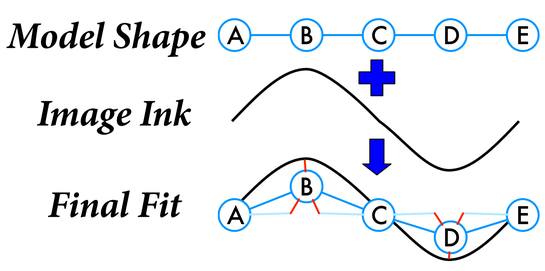


Dense, Aligned Fit

Coordinate Frames



Deformable Parts Model



A straight model fitting to a curve adopts a layout that balances proximity to image ink with model deformation.

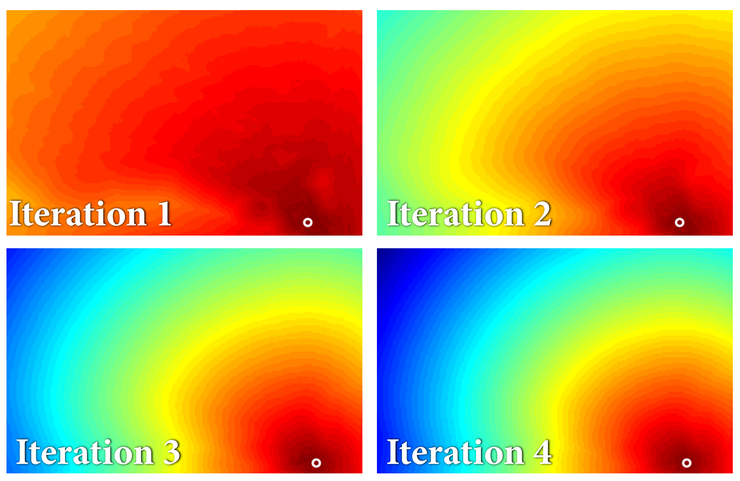
Generally, models seek part locations that minimize the squared minimum distances to image ink and deviations from expected model part positions.

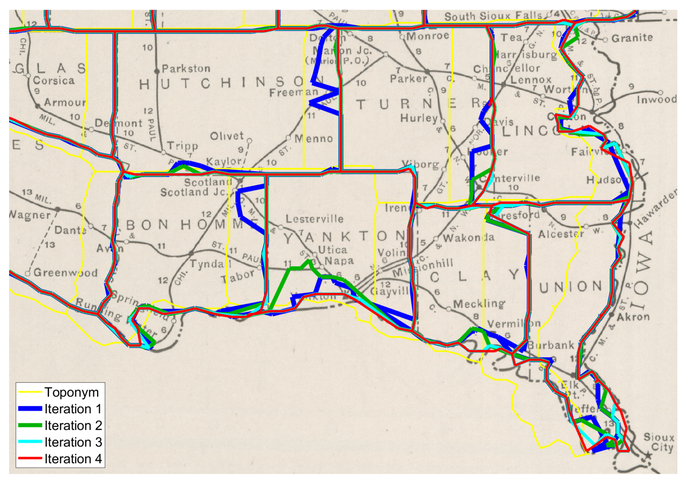
$$E\left(\{\mathbf{x}_i\}\right) = \sum_i D\left(\mathbf{x}_i\right)^2 + \sum_{i \sim j} \left\| \left(\mathbf{x}_i - \mathbf{t}_{ij}\right) - \mathbf{x}_j \right\|^2$$

Minimization is exact for acyclic, tree-shaped models.

Model Part Evolution

Model part locations are embedded within belief functions. Iterative belief updates penalize both the part's distance from image ink and deviation from the preferred model shape while considering neighbor's part location beliefs.





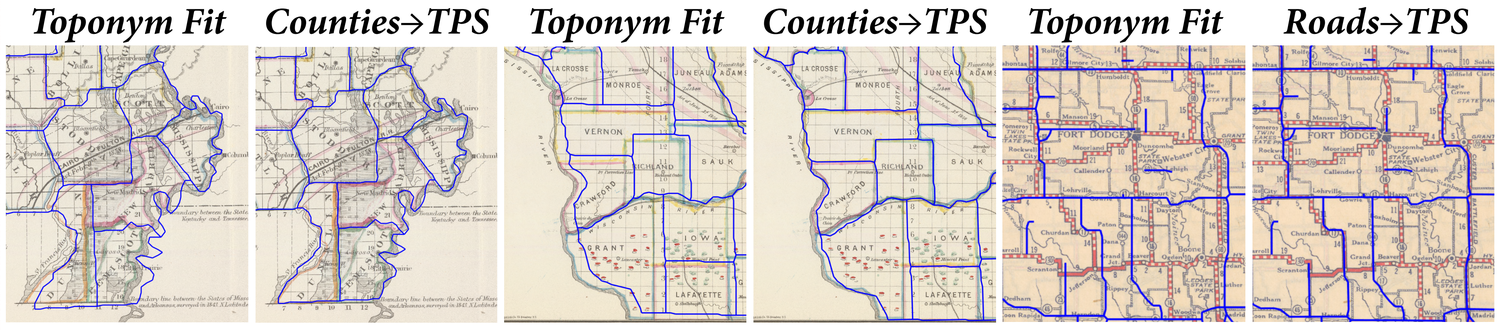
Example: Belief function evolution of model part for Sioux City, SD (lower right point of model).

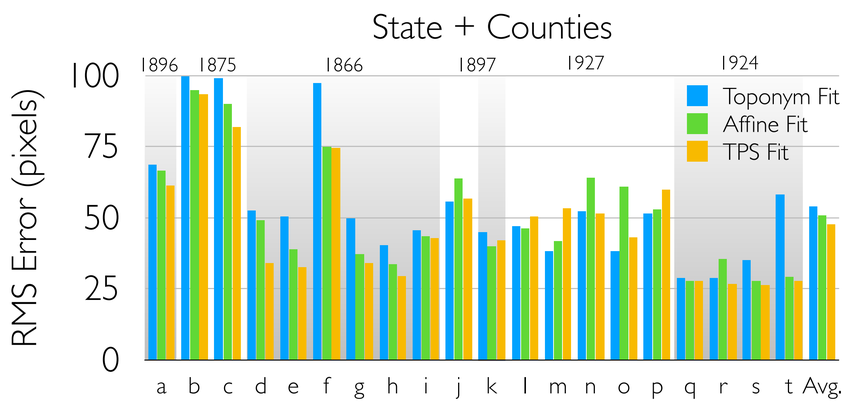
Data

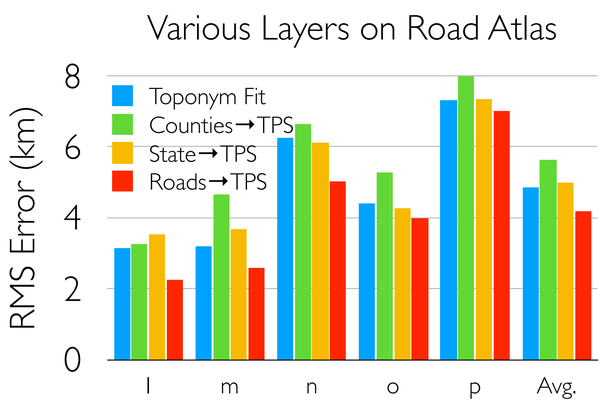
- 30 U.S. maps (city, multi-county, state/multi-state) from 8 atlases, 1866–1927
- 6,200 ground truth point correspondences total (geographic/image coordinates)

Experimental Results

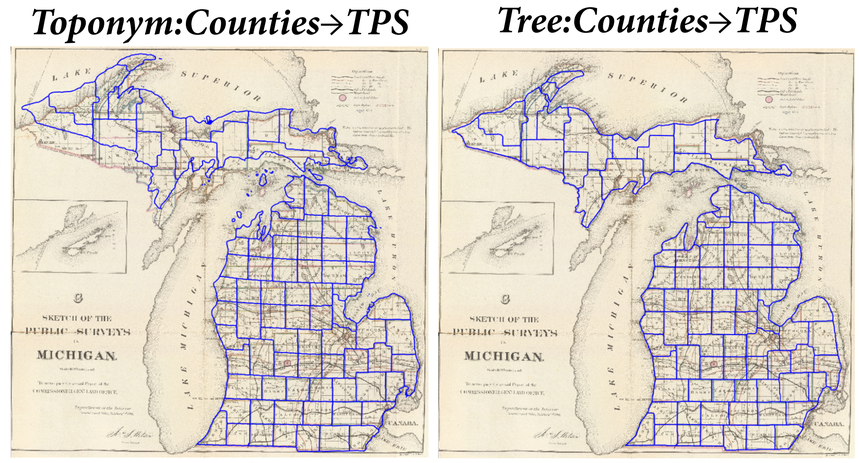
Initial model configurations are derived from toponym-based georeferences.† Results are optimal when the model's GIS shape layers coincide with map contents.

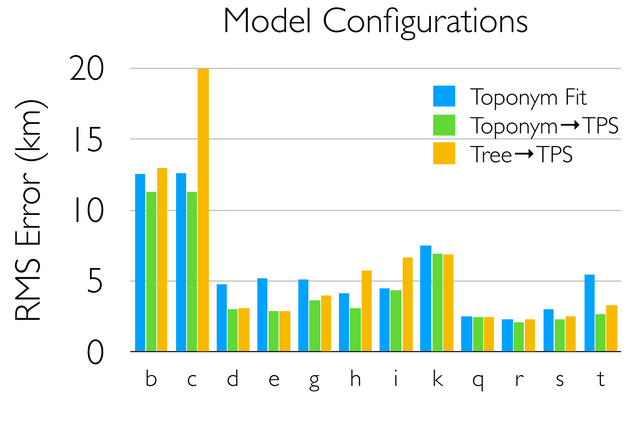




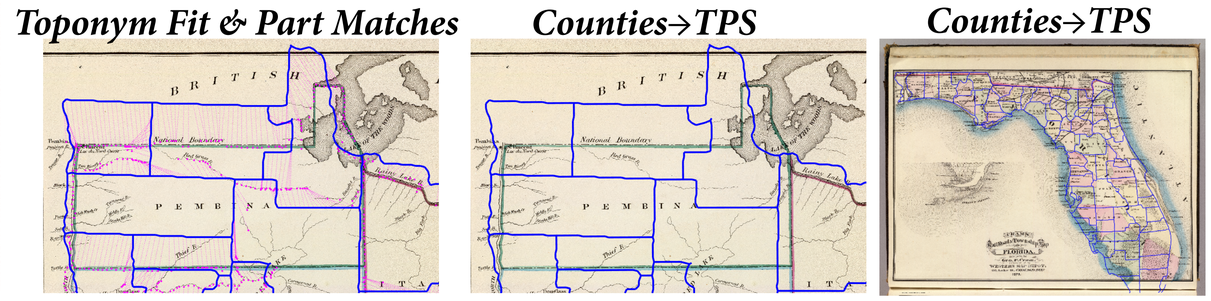


We also propose a novel approach that directly creates configurations—bypassing projection and initialization—by efficiently fitting multiple spanning-tree models.





For either initialization, even when deformable parts match well, densification can still fail if the initial projection is ill-suited for the map.



Reference

†Weinman, J. (2017). Geographic and style models for historical map alignment and toponym recognition. In *Proc. Intl. Conf. on Doc. Analysis and Recognition (ICDAR).*

Acknowledgment

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