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Leveraging Diffusion Models for Urban Change Detection and Classification from Historical Maps

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1 Introduction

Urban change detection is essential for understanding historical transformations and guiding future planning decisions. While remote sensing has enabled large-scale monitoring in recent decades, historical maps provide valuable insights into long-term urban evolution. The project explores a novel approach that leverages diffusion models to generate synthetic historical map tiles conditioned on manipulated vector data, simulating urban changes such as building addition and road construction. Additionally, urban change detection identifies and analyzes modifications in geospatial features over time, providing a systematic approach to tracking urban development and assessing the effectiveness of the generated map tiles.

2 Goals

- Conceptualize and categorize urban change types and manipulate vectors for different urban change scenarios
- Leveraging diffusion models to generate pre- and post-change historical maps given the vector input
- Train the change detection model using the simulated data and utilize the trained model to infer the changes in real datasets

3 Methodology

1. Conceptualize and categorize urban change types and manipulate vectors using python libraries such as geopandas, shapely, and networkx (see Table 1).

Table 1: Urban change type definition and manipulation

Feature Class	Change	Sub-change	Implementation
Building	Addition		Copy and move buildings
	Deletion		Delete buildings
	Morphology		Make buildings overlap
Road, railway	Expansion	Addition	Extend from existing nodes
		Longer	Extend from existing nodes
		Wider	Not implemented
	Shrinkage	Deletion	Remove line segments
		Shorter	Remove line segments
		Narrower	Not implemented
River, lake	Expansion	Addition	Copy and move river, lake
		Larger	Create outward buffer
	Shrinkage	Deletion	Delete river, lake
		Smaller	Create inward buffer
Stream	Expansion	Addition	Copy and move stream
		Longer	Add nodes
	Shrinkage	Deletion	Delete stream
		Shorter	Delete nodes
Forest	Expansion		Create outward buffer
	Shrinkage		Create inward buffer

2. Vector data is used as a conditioning input to guide the generation of synthetic historical map tiles using trained ControlNet (by Claudio Affolter [1]) for Old National style map

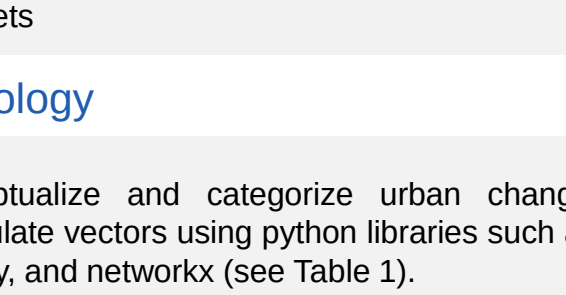

Figure 1: Old National Style map tile generation

3. Utilize two change detection architectures - the transformer based ChangeFormer [2], state space models (SSMs) based ChangeMamba [3] for change detection

4 Results

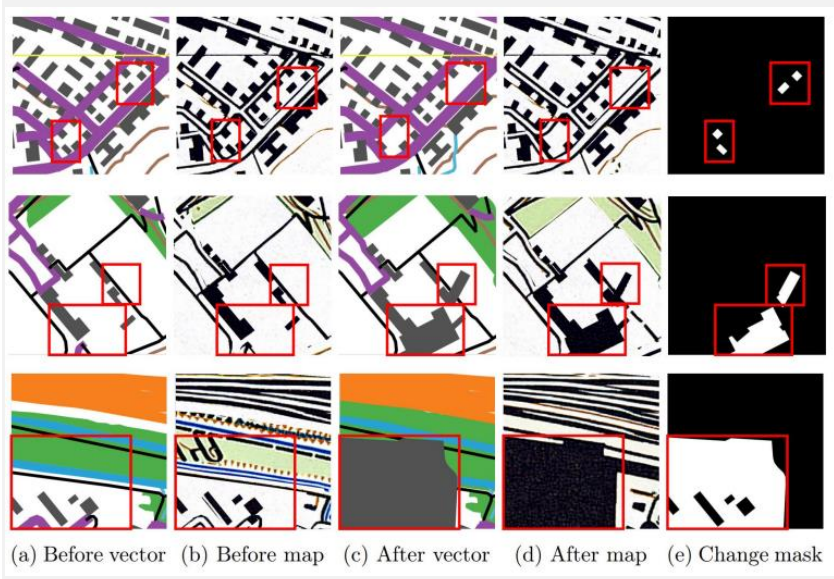

Figure 2: Vector manipulation example (building)

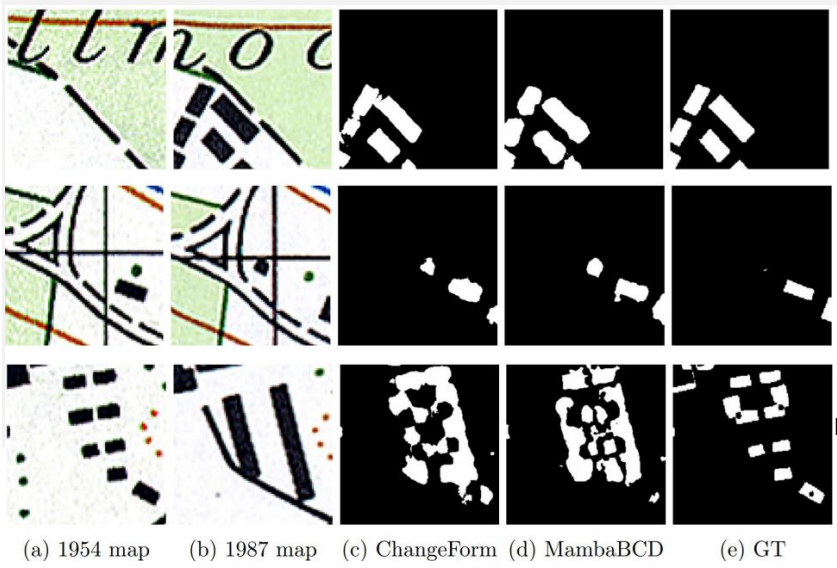

Figure 3: Change detection result example (building)

4 Conclusion and Outlook

Conclusion

- Urban change in historical map can be simulated through various geospatial object change scenarios.
- The specialized ControlNet for generating Old National-style map tiles can produce maps with textures and structures similar to those in real-world datasets. However, discrepancies exist (e.g., road classes are not represented correctly and trees are not generated.) .
- Synthetic map can be used for change detection (but only accurate for certain features, such as buildings) .

Outlook

- Establish conflict detection rules to generate more realistic synthetic maps.
- Define broader urban change types for a more comprehensive classification.
- Perform semantic change detection on urban changes.

References

[1] Affolter, C. (2024). From vector features to stylized maps – exploration of stable diffusion applied to maps [Master's thesis]. ETH Zurich.

[2] Bandara, W. G. C., & Patel, V. M. (2022, July). A transformer-based siamese network for change detection. In IGARSS 2022-2022 IEEE International Geoscience and Remote Sensing Symposium (pp. 207-210). IEEE.

[3] Chen, H., Song, J., Han, C., Xia, J., & Yokoya, N. (2024). Changemamba: Remote sensing change detection with spatio-temporal state space model. IEEE Transactions on Geoscience and Remote Sensing.