Reflections on the Development of Spatially Explicit Methods for GeoAI

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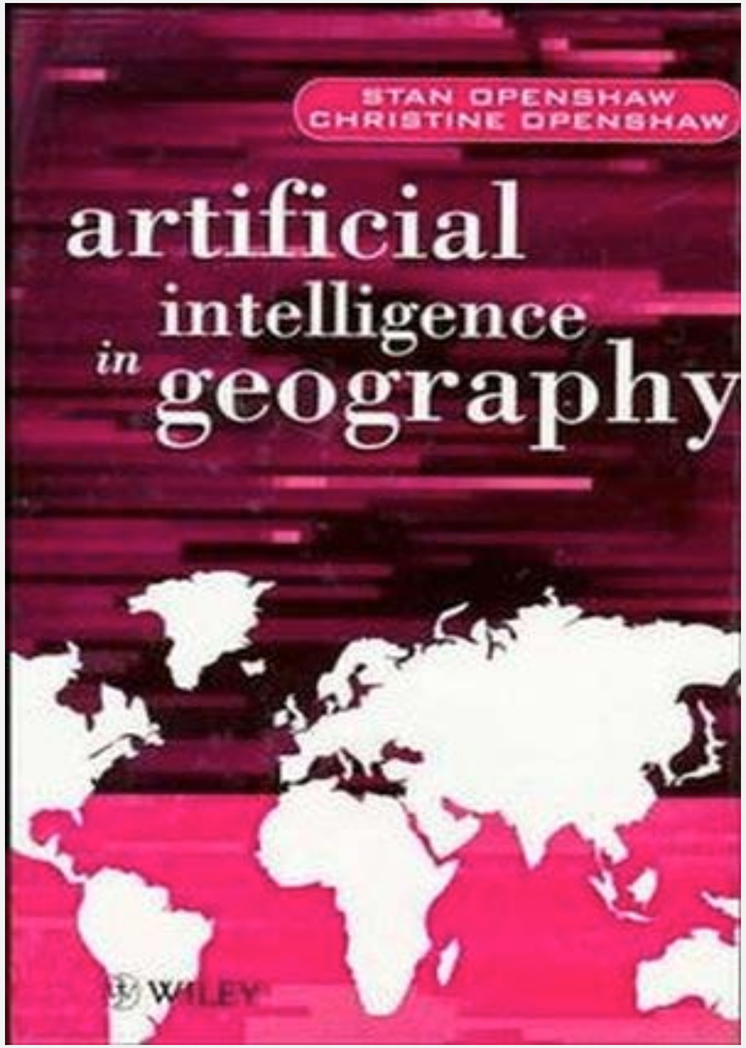
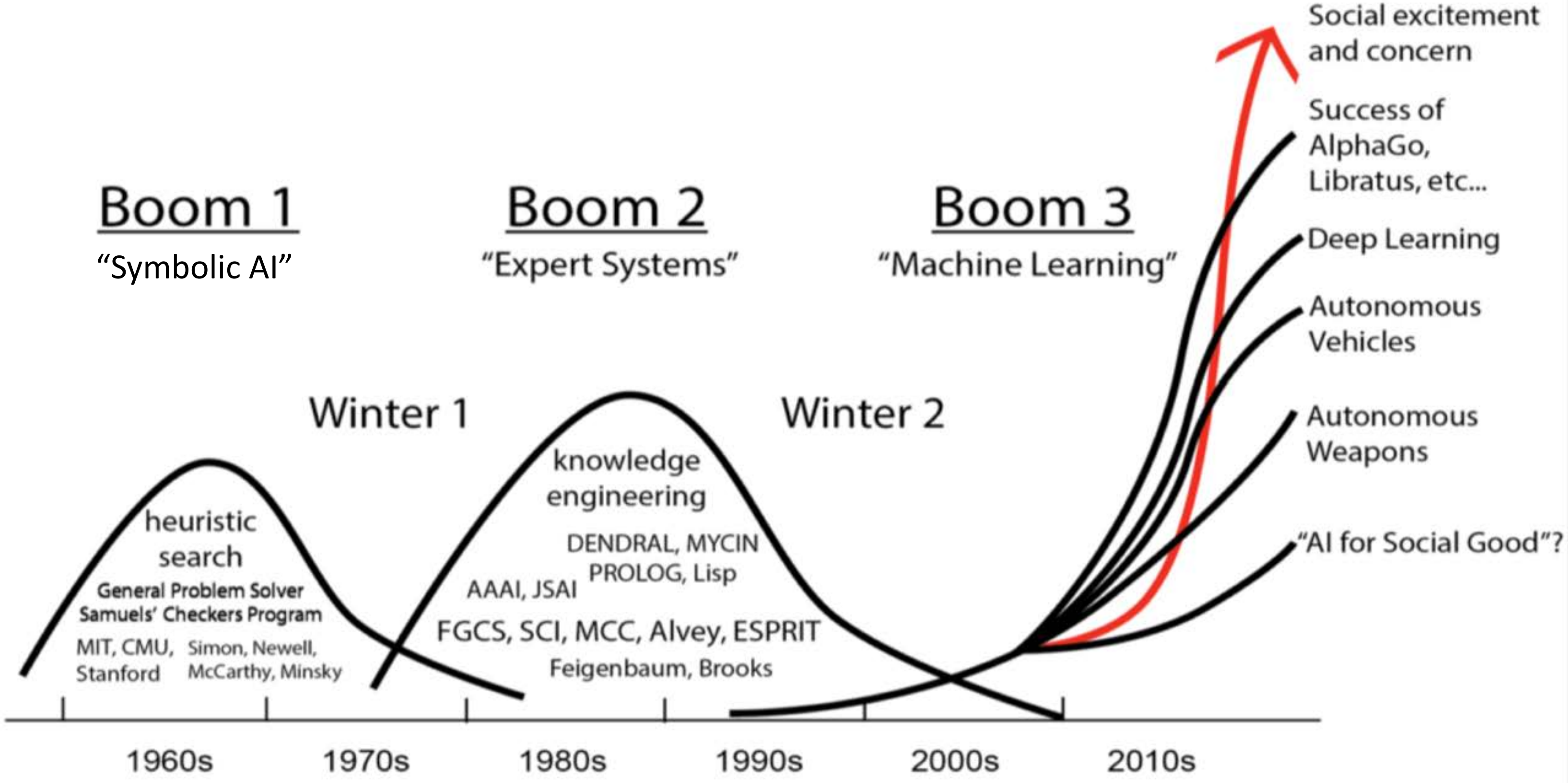
Historic Roots of GeoAI





https://www.technologystories.org/ai-evolution/

Stan Openshaw, Christine Openshaw (1997). *Artificial Intelligence in Geography*, Wiley.

GeoAI Events

- IJGIS, GeoInformatica, TGIS GeoAI Special Issues
- ACM SIGSPATIAL GeoAI Workshops (GeoAI'2017, 2018, 2019, 2021)
- AAG GeoAI and Deep Learning Symposium (AAG 2018, 2019, 2020, 2022)
- GIScience GeoKG & GeoAI Workshop (2021)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GeoAI: spatially explicit artificial intelligence techniques for geographic knowledge discovery and beyond

Krzysztof Janowicz, Song Gao, Grant McKenzie, Yingjie Hu & Budhendra Bhaduri

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Spatially Explicit AI Models

- **Invariance test:** The results of spatially explicit models are not invariant under relocation of the studied phenomena.

- **Representation test:** spatially explicit models contain spatial representations of the studied phenomena in their implementations.

- **Formulation test:** spatially explicit models make use of spatial concepts in their formulations, e.g. the notion of a neighborhood.

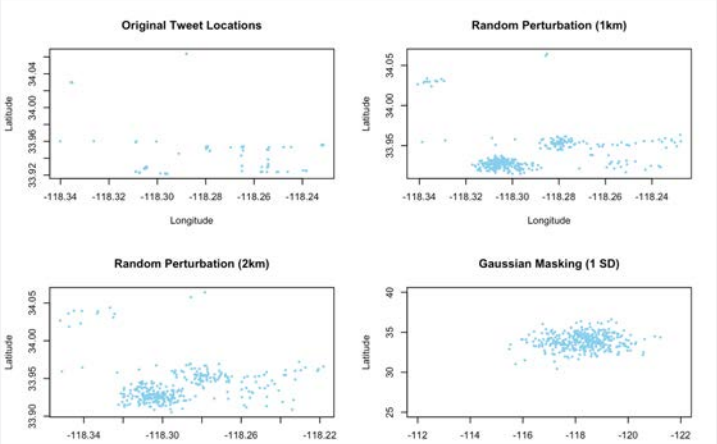
- **Outcome test:** spatial structures/forms of inputs and outcomes are different.

Goodchild, M., 2001. Issues in spatially explicit modeling. *Agent-based models of land-use and land-cover change report and review of an international workshop, October 4-7. Irvine, CA.*

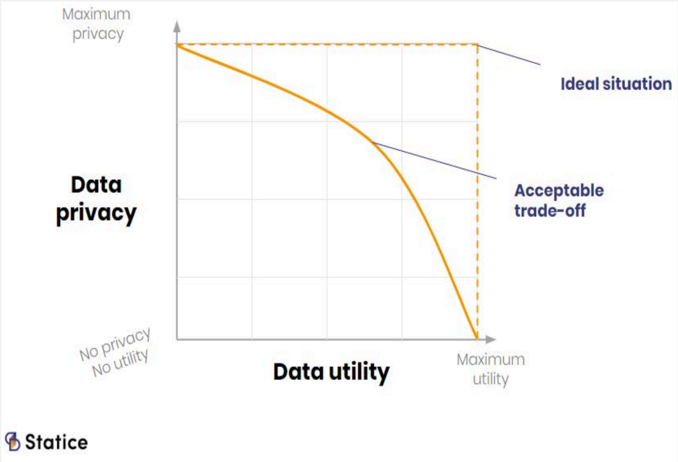
Janowicz, K., Gao, S., McKenzie, G., Hu, Y. and Bhaduri, B., 2020. GeoAI: spatially explicit artificial intelligence techniques for geographic knowledge discovery and beyond. *International Journal of Geographical Information Science*, 34(4), pp.625-636.

GeoAI for location privacy protection

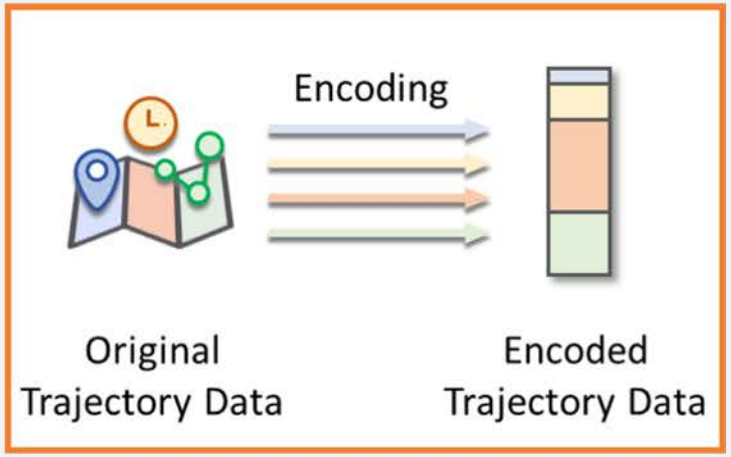
Real Trajectory Data



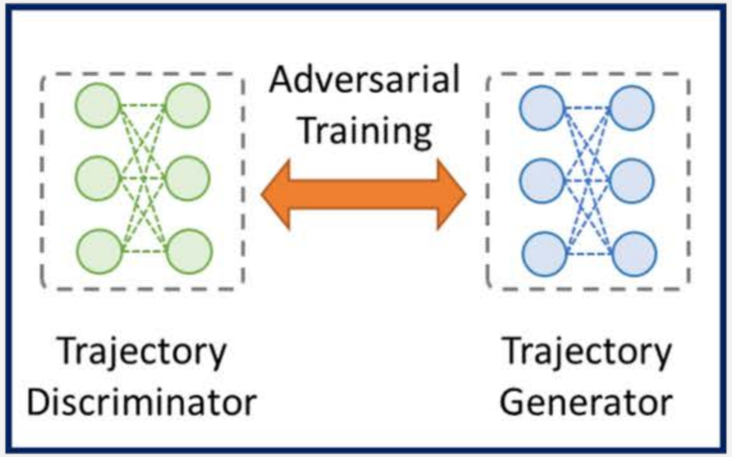
Trajectory Privacy Protection



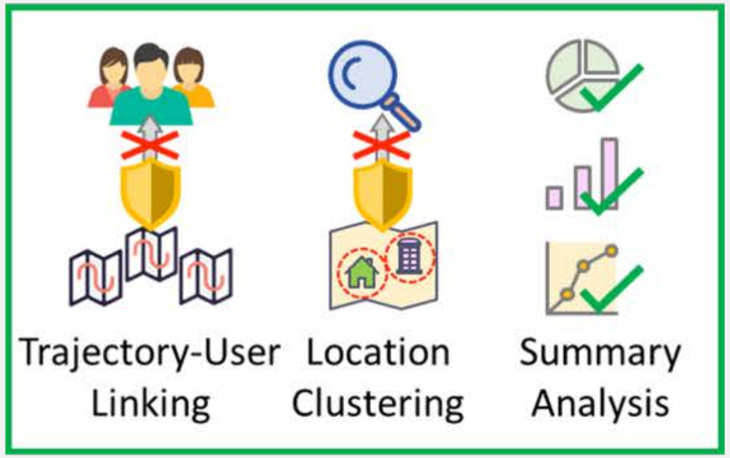
Synthetic Trajectory Data



Trajectory Encoding Model



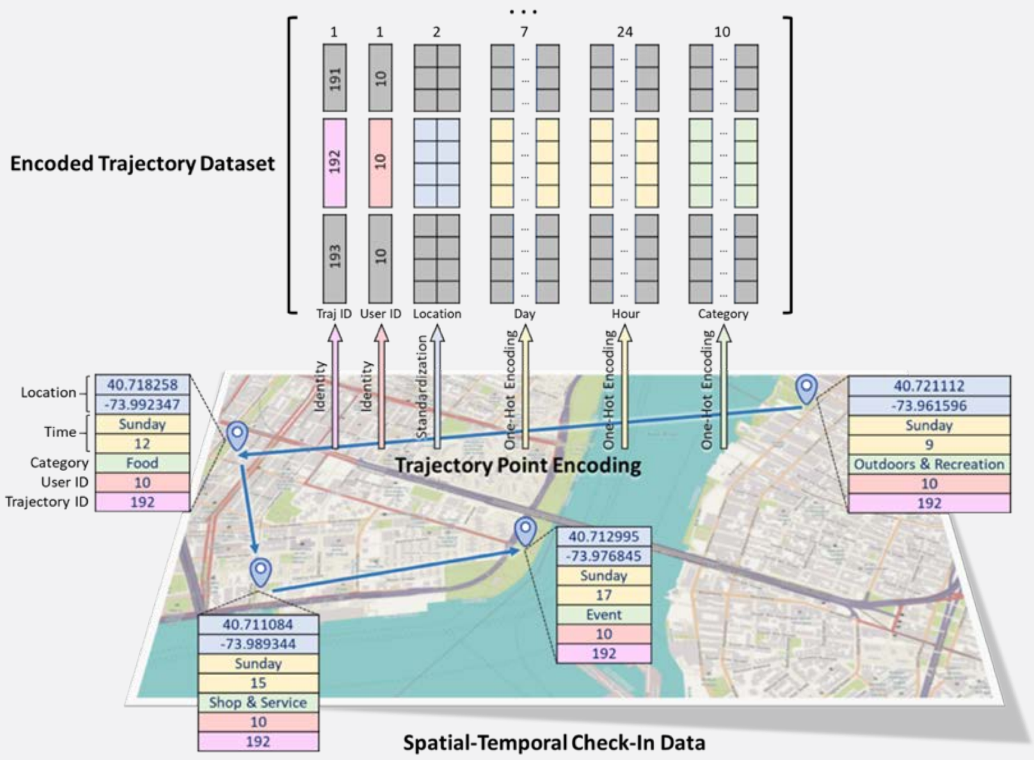
LSTM-TrajGAN Model

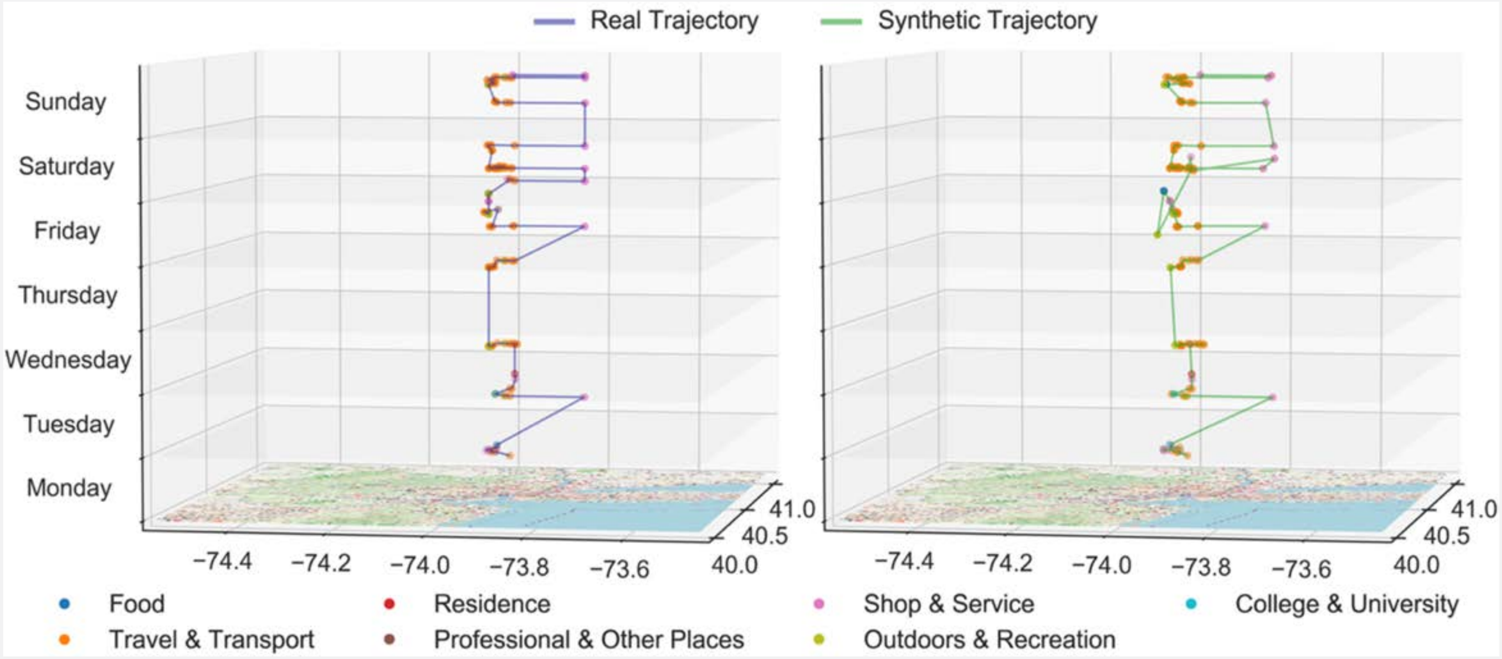


Application Scenarios

Rao, J., Gao, S., Kang, Y., & Huang, Q. (2020). LSTM-TrajGAN: A Deep Learning Approach to Trajectory Privacy Protection. *In the **Proceedings of the 11th International Conference on Geographic Information Science (GIScience 2021)**, No. 12; pp. 12:1–12:17.*

Trajectory Loss Function Design

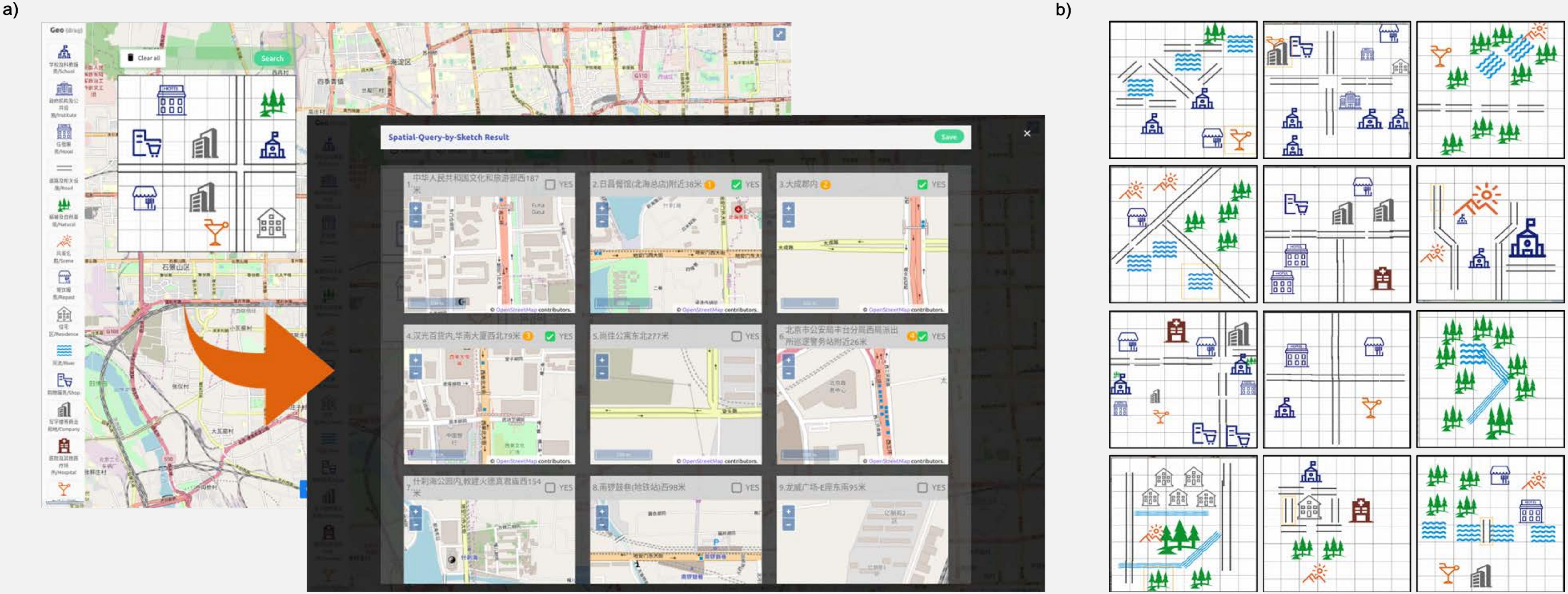




$$TrajLoss(y^r, y^p, t^r, t^s) = \alpha L_{BCE}(y^r, y^p) + \beta L_s(t^r, t^s) + \gamma L_t(t^r, t^s) + c L_c(t^r, t^s)$$

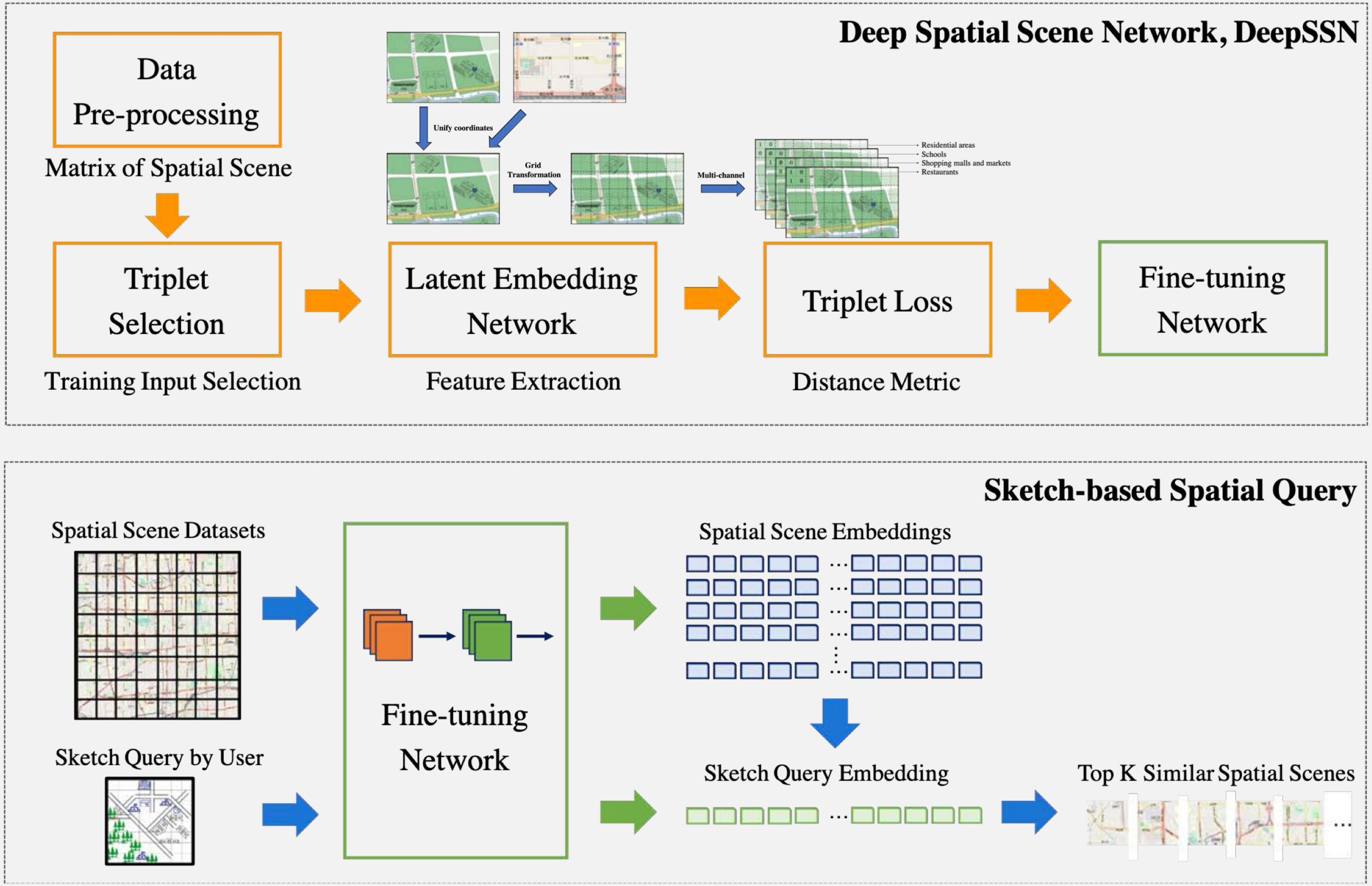
Rao, J., Gao, S., Kang, Y., & Huang, Q. (2020). LSTM-TrajGAN: A Deep Learning Approach to Trajectory Privacy Protection. *In the* ***Proceedings of the 11th International Conference on Geographic Information Science (GIScience 2021)****, No. 12; pp. 12:1–12:17.*

Spatial Scene Search



Guo, D., Ge, S., Zhang, S., Gao, S., Tao, R., & Wang, Y. (2022). DeepSSN: a deep convolutional neural network to assess spatial scene similarity. ***Transactions in GIS***. DOI: 10.1111/tgis.12915

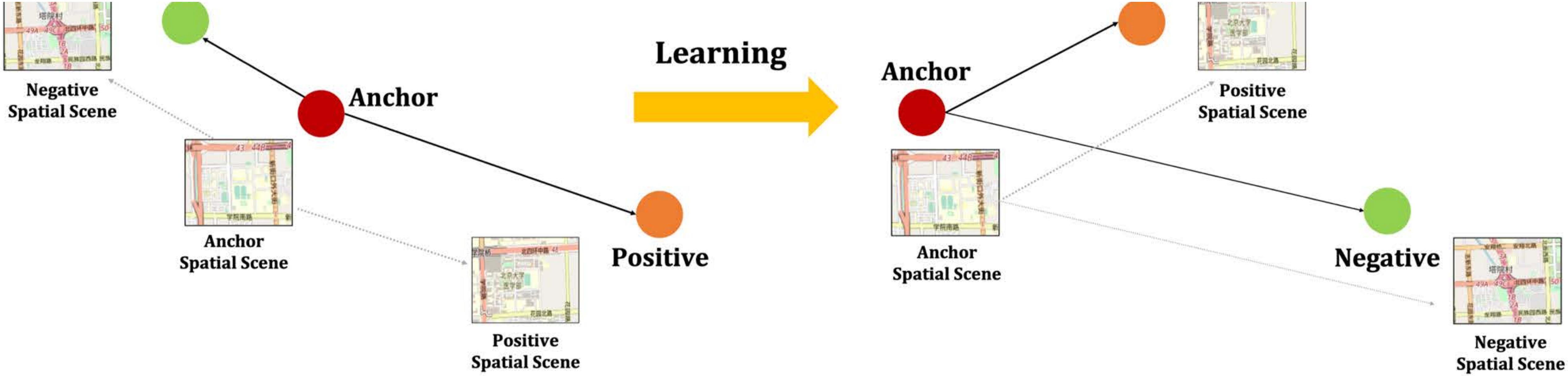
Deep Spatial Scene Neural Network



Guo, D., Ge, S., Zhang, S., Gao, S., Tao, R., & Wang, Y. (2022). DeepSSN: a deep convolutional neural network to assess spatial scene similarity. ***Transactions in GIS***. DOI: 10.1111/tgis.12915

Triplet Loss Function

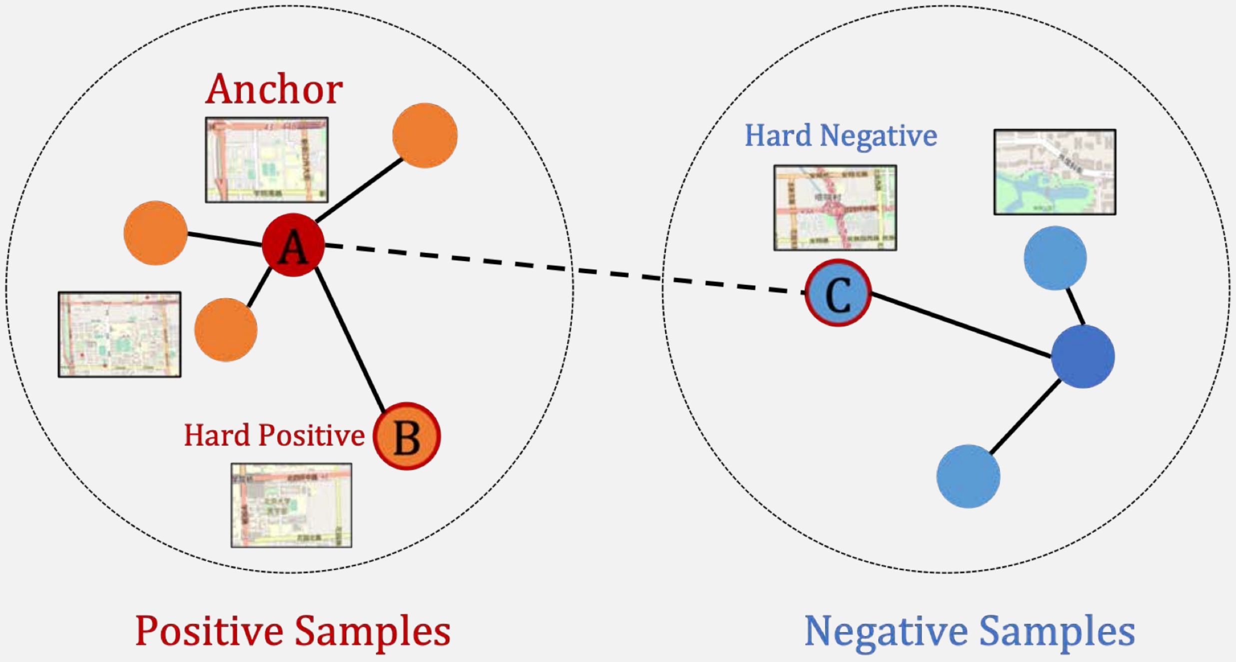
$$L = \sum_{i=1}^{N} [D(f(x_i^a), f(x_i^+)) - D(f(x_i^a), f(x_i^-)) + m]$$

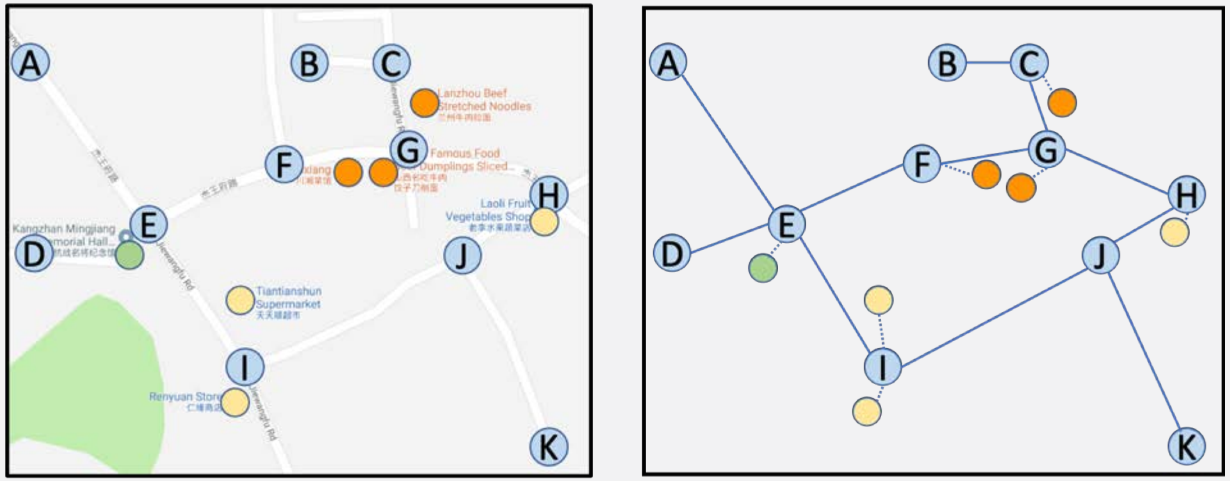


Guo, D., Ge, S., Zhang, S., Gao, S., Tao, R., & Wang, Y. (2022). DeepSSN: a deep convolutional neural network to assess spatial scene similarity. ***Transactions in GIS***. DOI: 10.1111/tgis.12915

Triplet Sampling Strategy

- A **hard positive** sample refers to the spatial scene whose **intra-class distance** to an anchor spatial scene is maximum.
- A **hard negative** sample refers to the spatial scene whose **inter-class distance** to an anchor spatial scene is minimum.





Qualitative Constraint Networks

Guo, D., Ge, S., Zhang, S., Gao, S., Tao, R., & Wang, Y. (2022). DeepSSN: a deep convolutional neural network to assess spatial scene similarity. ***Transactions in GIS***. DOI: 10.1111/tgis.12915

Results

Table 4.: Comparison between the cross-entropy loss and the triplet loss.

	MRR	Precision@1	Precision@3	Precision@5	Precision@10
Cross-entropy loss	0.054	0.050	0.0567	0.060	0.063
Triplet loss	0.641	0.576	0.678	0.714	0.752

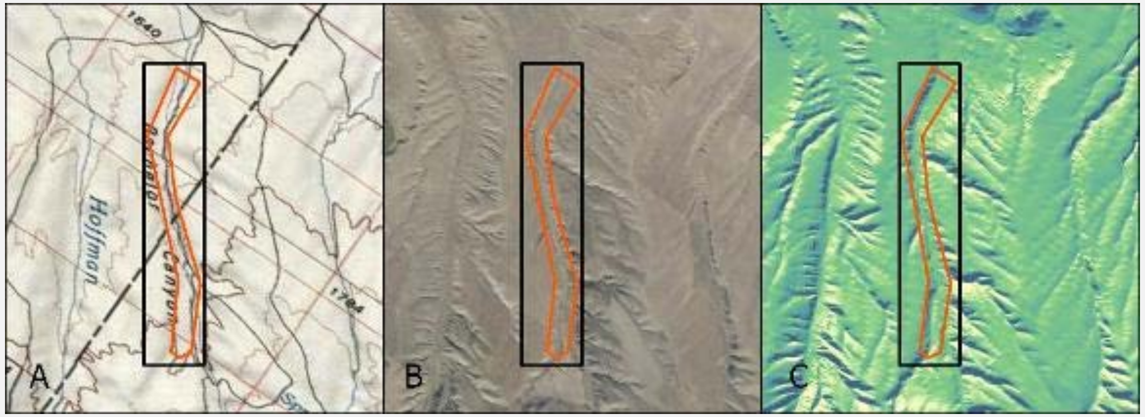
Table 5.: The performance comparison of different mining strategies

	MRR	Precision@1	Precision@3	Precision@5	Precision@10
Random sampling	0.529	0.452	0.576	0.608	0.676
Triplet mining	0.641	0.576	0.678	0.714	0.752

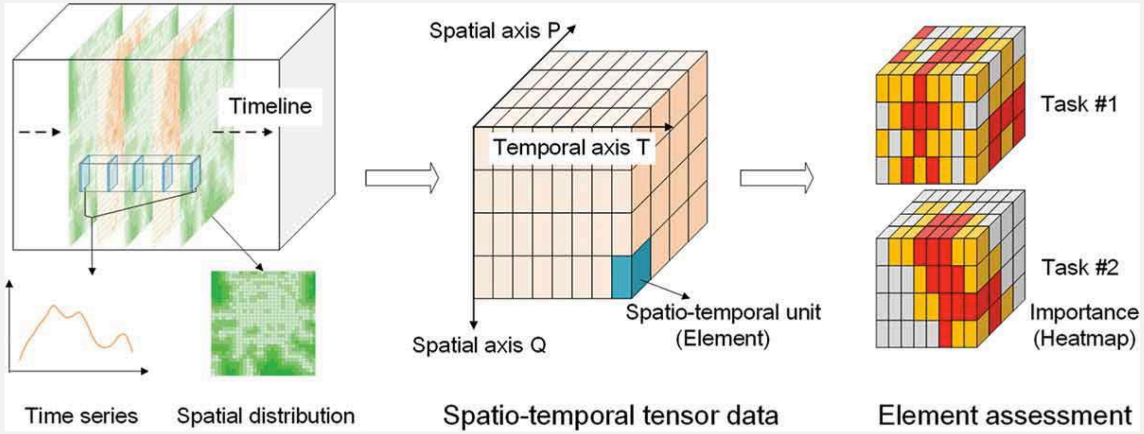
Guo, D., Ge, S., Zhang, S., Gao, S., Tao, R., & Wang, Y. (2022). DeepSSN: a deep convolutional neural network to assess spatial scene similarity. ***Transactions in GIS***. DOI: 10.1111/tgis.12915

Challenges in GeoAI studies

- labelled data
- interpretability and explainability
- Bias, privacy, and fairness
- Replicability and reproducibility



Arundel et al. 2020, TGIS



Cheng et al. 2020, IJGIS

GeoAI Research and Education

- AI <--> Geography (Spatial concepts and thinking)
- AI <--> GIScience (Spatially explicit AI models)
- National AI institute for Intelligent Cyberinfrastructure with Computational Learning in the Environment (ICICLE)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Song Gao
LAST MODIFIED: 24 MARCH 2021
DOI: 10.1093/OBO/9780199874002-0228

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