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GUEST EDITORIAL

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Explainable artificial intelligence in the spatial domain (X-GeoAI)

Recent advances in artificial intelligence (AI) research, the significant increase in computational power, and the large-scale availability of data have ushered in a new era of data-intensive science. In the context of GIScience, GeoAI aims to employ AI methods to analyze complex geographic phenomena. The majority of GeoAI applications rely on machine learning (ML) algorithms to extract generalizable predictive patterns in the form of mathematical models that provide useful insights about the phenomenon in question. ML excels in efficiency, scalability, and accuracy; however, this comes at the cost of reduced explainability. A clear reasoning path from data to conclusions is not always evident, but is readily available in traditional analysis of geographic phenomena using a combination of conceptual and statistical models. In addition, the integration of ML techniques in the geographic context is not always straightforward.

One solution to this dichotomy is through methods that bring together the knowledge contained within conceptual and statistical spatial models and the capabilities of GeoAI models, resulting in what can be termed as explainable GeoAI (or X-GeoAI). Such hybrid approaches can, among others: (1) improve trust and transparency in GeoAI by promoting interpretability in decision-making; (2) assist in evaluating results and ensuring they conform to existing knowledge, common sense and rules that govern spatial information; and (3) support the fundamental scientific process of conceptualizing the real world by revising existing conceptual and statistical models, allowing them to capture complex phenomena of high dimensionality.

This special collection is the culmination of a 2-year long process that began with a workshop on "Reasoning in GeoAI," organized by the Centre for Spatial Studies at the University of California, Santa Barbara in October 2020. Seven submissions were presented and discussed with a panel comprising five domain experts and AI specialists. The special issue call was launched a year later, seeking contributions from both workshop participants and other researchers that aim to achieve the fusion of GeoAI methodologies with existing conceptual and statistical models in a range of themes, from human mobility and urban dynamics to crime behavior and social sensing. Eight full articles were considered, with four ultimately being selected as fitting within the scope of the special issue in terms of exploring the integration of traditional conceptual and statistical models with ML techniques.

The four articles included in this collection explore different avenues to define X-GeoAI approaches and fall under a variety of themes and application areas. The first explores urban planning evaluation methods that are based on human perception. The second details an approach to predict traffic volume in scenic spots by integrating geographic data with historical traffic data. The third presents an automated spatial reasoning system for geospatial intelligence applications. The fourth conducts an exploration of geospatial knowledge graphs, spanning knowledge modeling, representation, and acquisition.

The first article, by Yunhao Li, Chunxiao Zhang, Chang Wang, and Zhe Cheng, advances the computer vision literature in the domain of urban planning. They introduce an urban planning evaluation system that imitates human perception while analyzing street view images. They propose a pipeline of deep learning-oriented procedures that aim to convert two-dimensional input street views into three-dimensional features, which are aligned to what people perceive when evaluating street view information. The presented computer vision algorithms with attention mechanisms allow for improved model performance and urban planning evaluation based on human perception.

Yuan Gao, Yao-Yi Chaing, Xiaoxi Zhang, and Min Zhang explore traffic prediction using information about scenic spots, in the second article. Traffic forecasting models are enhanced with information related to the topological structure of a city, and the accessibility and popularity of scenic spots. The authors utilize graph technology to aggregate and organize various geographic data sources. This technology allows scenic spots to be depicted as nodes that are interconnected with other thematic or spatiotemporal entities. An ensemble of spatial and temporal models, then, enables the discovery of various dependencies between these graph features that results in higher accuracy than baseline algorithms.

In the third article, Matt Duckham, Jelena Gabela, Allison Kealy, Mustafizur Khan, Jonathan Legg, Bill Moran, Shakila Khan Rumi, Flora D. Salim, Shaila Sharmeen, Yaguang Tao, Kerry Trentelman, and Maria Vasardani present NEXUS, a prototype system for automated spatial reasoning for geospatial intelligence applications. NEXUS relies on established upper-level ontologies to semantically describe occurrences in the world, in terms of when and where they take place. This allows supporting queries as well as explanations about conclusions reached by the system. A wide range of explanation types are exemplified, including statistical, case-based and trace-based explanations.

In the fourth article, Xueying Zhang, Yi Huang, Chunju Zhang, and Peng Ye explore a variety of processes related to Geoscience Knowledge Graphs (GeoKG). They first propose a multi-layered mechanism to categorize geoscience knowledge, followed by a knowledge representation framework that applies a state-process and a condition-result model. This framework is exemplified in the case of creating a knowledge model for assessing the risk status of alpine skiing events. Finally, a knowledge acquisition framework is proposed to extract geospatial knowledge from text, existing knowledge graphs, and other multimodal data.

We envision that these four articles will form the impetus for further research in X-GeoAI and will bring stronger visibility to the need for explainability in the context of related approaches. The articles also illustrate the breadth of potential X-GeoAI approaches. The first two rely on primarily non-interpretable data-driven techniques, which are supplemented by traditional models (either graph-based or based on human perception) which afford explainability. The latter two rely on inherently explainable AI approaches, based on semantic web and knowledge graph technologies, achieving explainability by design.

The editorial team wishes to extend their special thanks to workshop participants, article authors, and article reviewers for their contributions to this special issue. We hope that the presented research will provide valuable food for thought to the audience of Transactions in GIS and bring forth new ideas for research at the confluence of GIScience and explainable AI.

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