Special issue on spatio-temporal theories and models for environmental, urban and social sciences: where do we stand?

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From early and landmark works in the late '80s and early '90s, temporal geographical information systems (TGIS) and the development of associated spatiotemporal theories have significantly prospered. This includes research for example, on spatiotemporal reasoning frameworks (Hornsby and Egenhofer, 2000; Galton, 2004; Goodchild *et al.*, 2007; Pultar *et al.*, 2010; Stell *et al.*, 2011; Chen *et al.*, 2015), movement trajectories and activity patterns (Kwan 2004, Dodge *et al.*, 2008; Dodge *et al.*, 2012), events and processes (Peuquet and Duan 1995; Claramunt and Thériault, 1995; Worboys, 2005; Kulik *et al.*, 2007), spatiotemporal visualization (Andrienko and Andrienko, 2007; Demsar *et al.*, 2010) and spatiotemporal data mining (Roddick *et al.*, 2001; Cheng *et al.*, 2014; *Zhou et al.*, 2015), as well as privacy issues (Giannotti and Pedreschi, 2007), big spatiotemporal data (Manyika *et al.*, 2011, Yang *et al.*, 2011) and spatiotemporal analysis using social media (Barthélemy, 2001; Tsou and Leitner, 2013). Although this body of research has led to significant methodological and theoretical advances, the progress made by disciplines including geography, computer science, and cognitive sciences still requires further consideration in order to improve the impact and usability of spatiotemporal theories, particularly when considering environmental, urban, and social questions. This special journal issue follows a workshop organized in conjunction with the 11th International Conference on Spatial Information Theory (COSIT 2013) in September 2013 in Scarborough, UK. The objective of this international workshop was to bring together representatives from these different disciplinary communities, and integrate academics, students, and practitioners for a one-day workshop on spatiotemporal concepts and theories. The format of the workshop encouraged discussions and interactions amongst the approximately sixty participants. The papers presented at the workshop were asked to address the following five broad topics:

- What are the theoretical research breakthroughs in the last 25 years that have got us to where we are today?
- Are the spatiotemporal concepts, models, and reasoning frameworks developed so far, generalizable across all fields? Is a unified theory of spatiotemporal information feasible and a worthwhile goal across all disciplines?
- What are the main achievements and contributions of spatiotemporal theories and models for environmental, urban and social sciences? Where are the scientific success stories?
- What are the major scientific problems in environmental and urban sciences for temporal GIS research in the next 5 years? In the next 10+ years?
- What are the remaining research challenges or unsolved problems for which an interdisciplinary approach is needed to come up with comprehensive theoretical solutions?

The program for the workshop included contributions on the following topics that have generated intensive discussions and insights into possible further research:

- Urban and environmental sciences: the challenges of `big data: identifying novel ways

to reuse existing data and extracting meaningful information (Wood, 2013).

- Commonsense cognition of geospatial dynamics: towards bridging the gap between geography, artificial intelligence, and cognitive science. While big data provides many novel opportunities for the analysis of spatiotemporal phenomena, big data also generates numerous research challenges as the interpretation of series of large geographical data sets still requires a better integration between data structures, manipulation algebra, and cognitive interpretation capabilities (Bhatt and Wallgrün, 2014).
- Multi-scale spatio-temporal analysis of raster data: where are we and when will we arrive there? While the complementary uses of raster and vector data have been long studied (Peuquet, 2001), novel mechanisms for the representation and visualization of continuous and discrete geographical data (i.e., data varying simultaneously over time and space) are still to be explored (Qiang *et al*, 2014)
- Relating space, time, and granularity (Stell, 2013).
- The representation of life trajectories (e.g., movement paths of individuals over space-time) and the development of novel conceptual and computational frameworks continue to be an active research area (Vandersmissen *et al.*, 2009).
- The role of spatiotemporal theories for information retrieval and modeling human environment interactions: developing new theories and rule-based reasoning mechanisms for extracting spatio-temporal event information from unstructured text documents on the web, enriching the semantic information associated with geographical data, and coupling computational approaches with natural language processing and information retrieval (Wang and Stewart, 2013).
- Some "missing" ideas about time and space-time in GIScience. There is a call for novel theories that support the manipulation of spatiotemporal data at different levels of hierarchy, complementary visions of time to develop richer interpretations of time, and appropriate computational data structures and algorithms to represent them (Yuan 2008)
- Towards a framework for representing and reasoning about geographic phenomena where the main idea is to provide advanced formal mechanisms to reason about geographic events and processes while integrating the concept of vagueness (Campelo and Bennett, 2013)
- Discovering order in chaos by deriving spatio-temporal data on the fly. While new geographical data models are still being developed, another direction to explore is the identification of novel interacting reasoning facilities that can be applied to unstructured geographical data sources (Stock *et al.*, this special issue)
- Holistic spatial design: functional tool-sets as repositories of people-centered spatial design principles. While spatial information theories have often been applied in geographical contexts, many novel domains of applications are nowadays explored. This is particularly the case for indoor and architectural spaces where holistic design approaches can be combined with spatial reasoning capabilities (Bhatt *et al.*, 2014).

As a result of this workshop, the plan for this special issue of *Spatial Cognition and Computation* was developed. An open call for papers was announced shortly after the workshop and widely distributed to the spatiotemporal research community to capture ongoing work that addresses these open research challenges on spatiotemporal data modeling and related topics. This special issue presents three papers that showcase three novel research endeavors where spatiotemporal aspects for environmental, urban, or social sciences are a key factor in the analysis.

The first paper, 'Analyzing spatio-temporal patterns and their evolution via sequence alignment' by Sam Stehle and Donna Peuquet (Pennsylvania State University) discusses the extraction and analysis of space-time political events from RSS feeds of news reports where sequences of events may reveal insights about the nature and patterns of political events, and possibly uncover elements that point to higher-level happenings, such as the political instability of regions. In this work, the authors discuss a system that identifies sequences of events sourced from RSS news feeds using a sequence alignment technique that has its roots in DNA sequencing.. The paper discusses one of the key features of the sequence alignment approach, temporal deviation distance, in detail. This discussion will be of interest to researchers studying information retrieval, especially geographic information retrieval or spatiotemporal information retrieval, as well as researchers interested in space-time pattern analysis. This research combines an interest in event modeling shared by the temporal GIS community with the new challenges and possibilities of working with unstructured text data.

The next paper by Gao Song (University of California at Santa Barbara), 'Spatio-temporal analytics for exploring human mobility patterns and urban dynamics in the mobile age' explores human mobility patterns and intra-urban communication dynamics. The study uses mobile phone data, statistical analytical techniques, and geographic visualization to understand spatiotemporal mobility patterns and urban dynamics. 3D visualization techniques such as vertical Bezier curves are applied to represent flows of movements in 3D urban spaces. This contribution highlights how different visualization approaches for big spatial data derived from mobile phone trajectories can contribute to knowledge discovery and decision support relating to urban mobility patterns and urban informatics.

The third paper, 'Discovering order in chaos: using a heuristic ontology to derive spatio-temporal sequences for cadastral data' is co-authored by Kristin Stock, Didier Leibovici, LuCiene Delazari and Roberto Santos. The authors develop a novel approach that evaluates the probability of evolution sequences of administrative boundaries. The framework is applied to experimental cadastral data in Australia. The originality of the model relies in the combination of an ontology of geographical changes with a heuristic whose objective is to predict the categories of change that are actually derived from the experimental data set. The changes identified cover the thematic, spatial and temporal dimensions and capture geographical evolutions that match the semantics exhibited by cadastral changes. The approach offers novel perspectives for the analysis and prediction of geographical changes. The framework is expected to be useful for modeling in many environmental and urban application contexts.

This special issue contributes to current progress on theoretical and practical issues of the cross-disciplinary and emerging field of temporal GIS, and we look forward to seeing how these works trigger new and transformational ideas using spatiotemporal data and approaches.

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