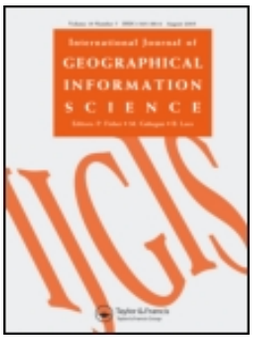

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Special issue of the International Cartographic Association Commission on GeoVisualization

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EDITORIAL

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1. Introduction

This issue has a specific focus on TIME. The research articles contributed here deal with the temporal nature of geospatial phenomena in novel and sophisticated ways in the context of geospatial visual analytics. The special issue originates from a workshop organized by the International Cartographic Association Commission on GeoVisualization (http://geoanalytics.net) at the AGILE 2010 conference.

Since the mid-1990s, the ICA commission has regularly coordinated research workshops and published the results of scientific endeavour in journal special issues and edited books that reflect the state of the art and the developing research agenda in geovisualization (MacEachren 1994, MacEachren and Kraak 1997, MacEachren and Kraak 2001, Dykes *et al.* 2005, Andrienko *et al.* 2007, Fabrikant and Lobben 2009). The rapid growth in the volumes of data that now require visual representation and analysis and the increasing complexity of the data and analytical problems associated with this activity have given rise to a new scientific discipline – Visual Analytics (Thomas and Cook 2005, Keim *et al.* 2008).

The key idea of Visual Analytics, which is emerging rapidly and having impact across the sciences, is to integrate interactive visualization with efficient computation and database processing for effective problem solving that exploits and combines the strengths of human and computational data processing. These aims are in line with many of the research issues identified by the ICA Commission through its research efforts: the *Research Challenges in Geovisualization* collectively documented a decade ago (MacEachren and Kraak 2001) focussed specifically on *Novel Graphical Representation* (Fairbairn *et al.* 2001), *Cognitive, Usability and Interface Issues* (Cartwright *et al.* 2001, Slocum *et al.* 2001) and importantly in the context of Visual Analytics the *Integration of Geographic Visualization with Knowledge Discovery in Databases and Geocomputation* (Gahegan *et al.* 2001). The geovisualization community continues to work in these areas contributing to the new broader discipline by sharing knowledge and experience and considering the specifics and complexities of space and time and proposing appropriate solutions (Andrienko *et al.* 2008). Progress on spatial analysis and representation has been significant, as demonstrated by many of the contributions made in the publications listed above, and much of this work has contributed to Visual Analytics as it develops. But the complex temporal nature of phenomena has perhaps received less attention: hence the focus on 'time' at the GeoVA(t) workshop.

We have close links with the Visual Analytics community and were lucky enough to welcome Jim Thomas to our workshop, which took place in Guimaraes, Portugal, in May 2010. Jim is considered to be the founding father of Visual Analytics and delivered a keynote presentation in which he acknowledged the advanced level of research achieved by the

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geovisualization community in topics relevant to the Visual Analytics research agenda. However, he noted that integrated consideration of space and time in analytics still needs further work, which necessitates considerable research effort and funding for the next decade.

With its specific focus on time in Geovisual Analytics, in addition to its distinguished speakers, the GeoVA(t) workshop attracted a large number of submissions and participants: despite the volcanic ash cloud that covered much of Europe and made travel difficult for many and impossible for some. Of the 35 extended abstracts submitted to the workshop, 10 were selected by the editorial team to be invited for development into articles for this special issue. Each subsequent submission was reviewed by two guest editors and two external reviewers. After two rounds of reviewing, seven articles were accepted, resulting in a 20% overall acceptance rate. We express our gratitude to the workshop participants – for their feedback to the authors, the external reviewers – for their timely reviews and constructive recommendations and the authors – for their willingness to improve their articles in such a short time. We expect this special issue to reflect the current status and to set trends for future developments in Geospatial Visual Analytics and effective and efficient reviewing and editing are all part of this process.

And so to the content. We open the special issue with two articles describing applications of Visual Analytics.

In *Assessing the quality of simulation models with visual analytics methods – Examples from earth science* Doris Dransch *et al*. address the needs of earth scientists, in particular, to efficiently evaluate the outputs of simulation models. The authors worked with domain specialists to reveal and analyse the reasoning processes involved in model assessment. On this basis, they designed and developed visual analytics tools to support the task. A user study confirms that the visual analytics approach results in improvements in terms of understanding the workings of simulation models in comparison with traditional statistical methods.

In *Using space–time visual analytic methods for exploring the dynamics of ethnic groups' residential patterns* Itzhak Omer, Peter Bak and Tobias Schreck propose a methodological framework for investigating the residential pattern dynamics of ethnic minority groups in cities. The methodology combines interactive visualizations with self-organizing map computations for implementing two complementary analytic approaches: analysis of the temporal dimension of different land-use configurations and analysis of the geographic distribution of identified types of land-use configurations according to their effect on ethnic residential change. The authors examine how local land-use configurations shape residential dynamics of minorities and affect the level of minority/majority segregation identifying strong spatial and temporal trends in their case study.

The next four articles propose new methods for analysing and modelling different types of spatio-temporal data.

In *Visualization of attributed hierarchical structures in a spatiotemporal context* Stefan Hadlak and colleagues propose a novel visualization technique that enables analysts to consider space, time, data and structure simultaneously. Hierarchical structures are embedded into regions of a map. Temporal aspects are represented by layering and animation. The validity of the approach is demonstrated by applying the method to human health data.

In *Analysing spatio-temporal autocorrelation with LISTA-Viz* Frank Hardisty and Alexander Klippel show how existing spatial statistical methods can be adapted to deal with temporal measurements. They describe a spatio-temporal extension of an important spatial statistic – Local Moran's I – and develop a tool for interacting with the spatio-temporal

structure uncovered by the statistics. Their system implements a novel display coordination strategy. The method is applied to the 2009 H1N1 pandemic data for detecting a critical spatio-temporal "inflection point" at which the pandemic changed its character in the United States.

In *Space–time density of trajectories: exploring spatiotemporal patterns in movement data* Urška Demšar and Kirsi Virrantaus generalize a standard 2D kernel density around 2D point data to deal with the more complex kinds of data to which analysts are now applying geovisual analytical methods. They compute 3D densities around 3D polyline data – the trajectories of moving objects in this case. The authors present an algorithm for computing the space–time density, test it on simulated data, show basic visualizations of the resulting density volume and observe particular types of spatio-temporal patterns in the density distribution that are specific to trajectory data. This article demonstrates an application of the method to vessel movement trajectories acquired using the Automatic Identification System.

In *An integrated approach for visual analysis of a multi-source moving objects knowledge base* Niels Willems *et al*. also deal with objects that move in time. They present an integrated multi-disciplinary approach to analysing the behaviour of such objects. The proposed architecture integrates trajectory generalization, trajectory compression and trajectory modelling. The system that is presented allows a maritime traffic operator to visually test hypotheses about vessels using time-dependent sensor data and on demand external knowledge. Annotated movement data are stored in a knowledge base that supports the reasoning process and enables analysts to search for spatio-temporal patterns.

A common feature of all these articles is that they deal with real data sets associated with real-world problems that are of significant importance. Two further articles are less applied, addressing methodological issues that are of general importance to Visual Analytics.

In *Exploring the efficiency of users' visual analytics strategies based on sequence analysis of eye movement recordings* Arzu Coltekin, Sara Fabrikant and Martin Lacayo address a crucial problem that underlies all of the work presented here – they consider how the extent to which visual analytics really works can be observed and measured. This article proposes a generic approach to the evaluation of interactive visual interfaces that combines theory and data-driven methods. The approach is demonstrated using a spatio-temporal data set of eye movement recordings collected during a controlled human subject experiment with dynamic visual analytic displays. The analysis of the eye movements uncovered significant differences in the display interaction strategies applied by fast- and slow-performing users. Hence, the methodology suggested in this article contributes to a better understanding of how people make inferences and decisions with highly interactive visualization tools and complex displays.

We conclude the special issue with an invited reviewed article *Space, time and visual analytics* by Gennady Andrienko, Natalia Andrienko, Urška Demšar, Doris Dransch, Jason Dykes, Sara Fabrikant, Mikael Jern, Menno-Jan Kraak, Heidrun Schumann and Christian Tominski. This article has been developed as part of a collaborative activity to define a roadmap for future Visual Analytics research in Europe through the collective effort of the scientists participating in the European Coordination Action VisMaster (http://www.vismaster.eu). This article draws attention to the core and unique characteristics of phenomena in space and time and the data and methods that we use to understand them in the context of Visual Analytics. In a way, this article shows how far things have moved since the early days of the ICA Commission on Geovisualization. Many of the issues that commission members have been wrestling with and resolving over the past two decades are enabling us to deal with more complex phenomena more effectively and in a wider range of applications areas – as we can see in the case of much of the work presented above. Cartographers and geographic information scientists work increasingly with natural scientists, computer scientists and

other domain experts to leverage the combined power of people and computers. Although tools for visually supported spatial analysis have been developed for many years, the temporal aspects of phenomena still require closer attention and deeper consideration as Jim Thomas reminded us in Guimaraes.

This article develops around an example scenario involving possible usage of spatio-temporal visual analytics tools by varied and broad categories of people. The argument that we develop is that spatio-temporal analysis is beneficial, that effective visual analytics tools are essential for spatio-temporal analysis and that practically everybody is a spatio-temporal analyst. People need useful and usable analytic tools, and their needs must be addressed by researchers such as those publishing in this special issue: whether they are developing evaluation methodologies to ensure that our methods work, exploring the ways in which cities or processes in earth science or pandemics evolve over time or developing methods that help us undertake such analysis in particular sets of circumstances to analyse ship trajectories or, dare we mention it, volcanic ash clouds. This article describes the recent trends in spatio-temporal analysis such as evaluating the effectiveness of visual techniques, collaborative visualization, and dealing with large data sets. Challenges and opportunities that the research community needs to address in the near future identified include:

- dealing with diverse spatio-temporal data (e.g. spatial time series, events, movement data, sequences of satellite images) and integrated analysis of different types of data;
- supporting analysis at multiple scales and verification of discovered patterns and relationships across scales;
- understanding and adequately supporting diverse users by improving the understanding of human perceptual and cognitive processes and developing effective solutions for different user categories and
- reaching a broad body of users by developing lightweight, easily deployable and usable software that allows flexible customisation and combination of tools.

Examples of approaches that address some of these challenges can be found in this special issue, and we encourage researchers to address others as we collectively move GeoVisualization and GeoVisual Analytics forward.

The organisation of the workshop and preparation of this special issue were supported by the EU within coordination actions VisMaster and MODAP (http://www.modap.org/) and by DFG (German Science Foundation) within a priority research program on Visual Analytics. Because of the aforementioned volcanic ash cloud, four members of the editorial team and several participants could not manage to travel to Portugal for the workshop. We express our gratitude to those who did – often through circuitous routes and at significant unexpected expense. Heidrun Schumann and Jim Thomas are to be thanked especially for their excellent management of the workshop on site.

2. Addendum

We learned of Jim Thomas' untimely death just as we were finalizing this introduction and the special issue in general. It's difficult to write anything meaningful when the news is so recent, and we do not purport to do so here. However, with great sadness, we take the opportunity to say a few simple things at this time and in this forum as Jim contributed so directly to the workshop, the special issue and the discipline that is our focus here.

Jim's contribution in Guimaraes was particularly significant, in terms of both his keynote and the vision communicated and also his willingness to take on a coordinating role when travel became so difficult for so many of us. More broadly, his leadership and tireless energy

in developing and promoting the discipline of Visual Analytics have helped all of us with our work in all kinds of direct and indirect ways and enabled the diverse communities listed and discussed above to work together for the greater good. As GeoVisualization has engaged with Visual Analytics, both have advanced and benefited.

All in the Visual Analytics community and associated sciences will be shocked and deeply saddened by this news and lament the loss of such a vibrant, influential and valued colleague. As time goes by we will all continue to benefit from Jim's efforts in establishing Visual Analytics so effectively and yet we will all be affected by Jim's passing: Visual Analytics will be much the poorer without his vision, leadership and vital scientific contributions.

Gennady Andrienko, Natalia Andrienko, Jason Dykes, Menno-Jan Kraak and Heidrun Schumann
ICA Commission on GeoVisualization

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