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EDITORIAL

Innovation in geoprocessing for a Digital Earth

Online geoprocessing, the provision and the use of spatial analysis functionality on the Web, is a powerful technological approach to fully realise the vision of a Digital Earth. The Digital Earth objectives include the integration of information across diverse domains in order to address environmental and societal challenges as well as the interactive and exploratory provision of information to a wide audience (Craglia et al. 2008). In research and science contexts, Digital Earth may be seen as 'world-wide laboratories' to enable collaborative research, exploration, reproduction and validation of theoretical and practical research constructs related to phenomena that leave spatio-temporal traces. Behind the scenes, approaches to support efficient and reliable online geoprocessing that alleviate the tension between the access to multiple and disparate spatial data sources and that support the coherent exploration of these data sources for knowledge discovery are more necessary than ever. Progress on online geoprocessing approaches is thus absolutely necessary, almost imperative, to turn Digital Earth's vision and objectives into tangible, usable 'tools' that for instance allow research teams to perform multi-disciplinary research or ease the *ad hoc* and timely generation of tailored information for citizens and in sum ensure the advancement of our body of knowledge (Bernard et al. 2014). This special issue provides a state-of-the-art overview on recent developments and real-world applications of online geoprocessing in the view of the given objectives. In the following, we briefly present the seven contributions to this special issue. Subsequently, we discuss trends in research in the area of online geoprocessing.

In the first group of papers on on-demand, online geoprocessing, we have three papers on the development of frameworks for storing, managing and processing of big data collections. We start with the paper entitled 'Geospatial web services pave new ways for server-based on-demand access and processing of Big Earth Data'. Wagemann et al. (2017) advocate in their paper a transfer of traditional data analysis workflows into service-oriented workflows. They demonstrate that web services have the potential to mitigate limitations of Big Earth Data analyses caused by restricted storage space and processing power at the user side. Wagemann et al. (2017) show four applications using standardized web services, more specifically Web Coverage Services (WCS) 2.0 and Web Coverage Processing Services, in marine, climate, planetary and Earth observation sciences. They complement the demonstration of the applications with a discussion of benefits and challenges for data providers, technical users and end users or decision makers. The following two papers pay similar attention to online geoprocessing using standardised web services. The second paper focuses on large-scale light-detection and ranging (LiDAR) data processing. LiDAR data constitute a valuable data source in a wide range of environmental applications. Extracting information from LiDAR data efficiently, requires new approaches for storing, managing and processing big data collections. This challenge is addressed by in the contribution of Li, Hodgson, and Li (2017) with the title 'A General-purpose Framework for Parallel Processing of Large-scale LiDAR Data'. They evaluate the benefits of a general-purpose framework, which uses a data decomposition and parallelization strategy for efficiently processing the data on parallel machines. The proposed framework further reuses existing software tools and data structures. The performance gained through parallelization supports users' experimentation by allowing for quick changes of parameter values during analyses and thus help in a more efficient optimization of results. The third paper in the series on online geoprocessing frameworks builds upon the WPS specification for supporting real-time geoprocessing. Herle and Blankenbach (2017) in the paper entitled 'Enhancing the OGC WPS interface with

GeoPipes support for real-time geoprocessing' propose GeoPipes to overcome existing limitations of the WPS interface standard specification to process spatio-temporal data in (near) real-time. GeoPipes use an extended version of the message queue and telemetry transport (MQTT) protocol called GeoMQTT for sharing data in a push-based manner.

The second group of papers focusses the integrated processing of distributed spatial data for environmental applications. The work by Stasch et al. (2017) demonstrates how to link online analysis functionality and online sensor observations using standardized web services. In their paper 'Coupling Sensor Observation Services and Web Processing Services for Online Geoprocessing in Water Dam Monitoring', the authors present a concise application case of a water dam monitoring system called TAMIS that requires the immediate processing of time-series data based on an integration of sensor observation services (SOS) and web processing services (WPS). The authors present a tight coupling solution of SOS with WPS to avoid bottlenecks in the communication between services as compared to loose coupling approaches. In addition, they propose a representational state transfer application programming interface to ease use and integration of WPS in Web clients. This paper is followed by the contribution entitled 'Ad-hoc combination and analysis of heterogeneous and distributed spatial data for environmental monitoring – design and prototype of a web-based solution'. In their paper, Wiemann, Karrasch, and Bernard (2017) address the challenge of integrating data from various sources for deriving information in environmental applications in a user-friendly manner. They propose geoprocessing patterns to facilitate discovery and usage of geoprocessing functionality. Geoprocessing patterns are descriptions of domain-specific geoprocessing workflows that include constraints on data inputs and outputs and functional principles. Based on the characteristics of input data as well as formalized target and process descriptions, appropriate processing patterns for a certain task can be suggested to a user. The authors demonstrate the approach with a prototype web-application supporting different tasks in river management.

In a third and last group, two papers in this special issue address semantic interoperability issues in online geoprocessing. The work by Sudmanns et al. (2017), with the title 'Semantic and syntactic interoperability in online processing of big Earth observation data', addresses the derivation of information from big Earth observation data in a comprehensive and reproducible manner. They developed an online system that allows the definition of world models, i.e. semantic analyses of time-series data, which can be applied to a chosen data set and time period. The specification of parameters of an analysis is translated into a WPS request and forwarded to a Rasdaman database where the queries are executed. These low-level interactions with the server are hidden from the user, which makes the approach usable for non-experts. World models are developed as a community and crowd sourcing effort and are collected and published in a common knowledge base. One of the application examples is the extraction of potential glacier loss and glacier gain from land cover data. Scheider and Ballatore (2017) contribute a method and a tool to semantically annotate geoprocessing workflows for successful search, interpretation and reuse of workflows. In their paper 'Semantic typing of linked geoprocessing workflows', they propose vocabularies for basic geodata data types, geoprocessing operations and relations which are used to describe the geoprocessing provenance of a data set. Using an off-the-shelf GIS and resource description framework and web ontology language mechanisms for (semi-automatic) annotation of geoprocessing workflows and processing provenances are showcased. Applications of the resulting annotated workflows can support the appropriate selection and adaptation of input data or the recommendation of tools.

The contributions to this special issue demonstrate that geoprocessing technology bears considerable potential for Digital Earth applications. In conclusion, the focus of the contributions was on:

- the demonstration of the benefits of server-side computing for resource intensive tasks;
- the real-time integration and analysis of (sensor) data through service-oriented implementations;
- better support of users to more efficiently derive information from data and
- the increase of reusability of existing analysis workflows using semantic artefacts.

The research questions addressed in the contributions overlap with elements of the research agenda for geoprocessing services from 2009: efficient service orchestration, semantic descriptions for discovery and orchestration and the increase in efficiency (Brauner et al. 2009). Several papers show the progress in a better formalisation, management and usage of geoprocessing semantics, including semantics of the processing input, output, operations, workflows and provenance (Scheider and Ballatore 2017; Stasch et al. 2017; Sudmanns et al. 2017; Wiemann, Karrasch, and Bernard 2017). Especially, these papers demonstrate that and how semantics of data and operations can be exploited to support users to more efficiently generate information and to increase reusability of existing workflows. To further advance geoprocessing in this direction, a stronger community effort for establishing a registry of processing profiles (Stasch et al. 2017) or world models (Sudmanns et al. 2017) is requested. The best practice examples and demonstrations included in this special issue clearly provide various stimuli and valuable input to further develop and improve online geoprocessing approaches and to foster reproducible geoprocessing for the Digital Earth.

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