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Thomas Blaschke is a Full Professor for Geoinformatics and Co-Director of the Department of Geoinformatics – Z_GIS, University of Salzburg, Director of the Doctoral College GIScience, and vice-president of the Association for Geoinformatics, GeoIT & Navigation.

He leads an active graduate and post-doctoral research programme in multiscale spatial analysis with an emphasis on the integration of GIS, Earth Observation and place-based research, putting humans in the centre of the research, including participatory pathways and mixed-methods research. Blaschke is the recipient of numerous scholarships, research grants and awards of excellence. His research programme is substantially supported by the Austrian Science Fund. Blaschke has been supervising 26 PhD students as main advisor at the University of Salzburg and has been involved in various supervisory and examination roles worldwide. Currently, he is serving on ten international journal editorial boards and supports various international organizations and conferences. Prior positions comprise several lecturer, senior lecturer and professor positions in Germany, Austria, and the UK as well as temporary scholarly affiliations in several countries. His academic achievements include 400+ publications, including 17 books as author or editor, several academic prices and awards including the Christian-Doppler Prize 1995. His publications are highly cited with an H-index of 49 (Google Scholar). He is an elected corresponding member of the Austrian Academy of Sciences. More recently, Blaschke's research has tried to connect the technical details of GIS and Earth Observation to larger issues of humans and place, yielding more translational and outreach activities. For example, he initiated the foundation of a University spin-off company and serves as a mentor in the European Copernicus programme and as a member of the European Space Agency (ESA) Earth Observation Advisory Committee.

Spatial Data Science:
Integration of GIScience, Geoinformatics, and Earth Observation

Is Spatial Still Special?

The discipline of Geography is literally founded on the belief that spatial is special. Likewise, the field of Geographic Information Science—or GIScience in short—has been defined based on this hypothesis. Goodchild coined the term GIScience in an article in 1992." The field of GIScience has developed since 1992 but with many limitations. It seems that mainly North American Geography pushed this term and related epistemologies while other disciplines were reluctant to use a term that is epistemologically and linguistically tied to Geography as a discipline. The 2019 Spatial Data Science

Symposium appropriately suggests rethinking the "spatial is special" realm in light of the recent developments in machine learning, AI, and computational linguistics. My contribution aims to position the recent usage of the term GIScience and the community behind it in light of this development and calls for integration with the remote sensing / Earth Observation world.

Geographic Information Science—GIScience

Blaschke and Merschdorf (2014) described the highly dynamic nature of GIScience, which is continuously developing and evolving to encompass new subject fields and methods. They analysed the contents of such a dynamic field based on scientific literature and assessed the multidisciplinary and multiparadigmatic nature of GIScience. They found a surprisingly low number of publications that explicitly mention GIScience or Geographic Information Science and terminological variations. Likewise, Biljecki (2016) investigated a selection of GIScience related journals and pragmatically counted all articles of specific journals. From a 2019 perspective, if searching for the use of "Geographic Information Science" (including variations) or "GIScience" in titles, keywords, or abstracts, Scopus yields 1522 hits (20 August 2019). These figures exemplarily reveal that the field is relatively small compared to others ("remote sensing" yields 223,500 hits, "Geography" 155,740). In addition, both mentioned articles found strong regional and cultural biases. I, therefore, hypothesise that "Geographic Information Science" and its short form GIScience do not comprehensively represent the field of research that they imply.

Earth Observation vs Remote Sensing

The 2019 Spatial Data Science Symposium announcement addresses new challenges that relate to the diversity of the utilised data and the underlying conceptual models from various domains, the opportunistic reuse of existing data, developments in machine learning, big data storage and retrieval, etc. Essentially, the same diversification is occurring in the field of remote sensing (RS) or Earth Observation (EO), which has widened its original fixation on pixels – whereby the term *remote sensing* does not comprise information from ground measurement. The term *Earth Observation* is more comprehensive. It is strongly promoted by the European Commission and the European Space Agency to the extent that one can see the power of EO and the European *Copernicus programme* advertised on large screens in airport arrival halls in Brussels, Amsterdam, or Rome. Spatial data science needs to incorporate EO methodologies and methods.

Spatial Data Science: Beyond Geography

The 2019 Spatial Data Science Symposium calls for setting the spatial data science agenda. This short statement highlights the need for an integration of the historically separated worlds of Geoinformatics / GIScience and of EO/RS. I argue that the size and complexity of the currently debated 'grand challenges' call for a true synergy between the Geoinformatics or GIScience world on the one hand and the world of EO/RS on the other. It is necessary to combine the forces of these related disciplines to fully utilize the power of computational techniques and the human capabilities of monitoring and analysing spatial phenomena. The term *spatial data science* may then be appropriate to represent the spatial view more comprehensively while incorporating the

achievements of geographic information science, EO/RS, geovisualization, spatial statistics, data mining and machine learning, decision science, cognitive science, and other disciplines. The term *spatial data science* may also attract the attention of scientists with domain expertise and interest in the grand challenges that are different from the core disciplines of Geoinformatics, GIScience and EO/RS while facilitating multi- and interdisciplinary efforts. Still, I doubt if the definition used for the 2019 symposium "Spatial data science is concerned with the representation, modelling, and simulation of spatial processes" is so broad that essentially any environmental process and most social interactions are concerned. While the term "*geographic*" limits the field at least to a range of scales clearly larger than molecules or cells, the term spatial is, in principle, applicable to any scale. Consequently, if we are not able to define the field unambiguously (although I argue for not demarcating boundaries), how can the following statement from the symposium's call be justified "spatial data science does not only utilise advanced techniques from fields such as machine learning or big data storage and retrieval, but it also contributes back to them". Considering these disciplines work spatially, surely they should be considered as part of spatial data science already in the first place.

Full Integration of "Vector Worlds" and "Raster Worlds"

In analogy to the characterisation of GIScience as a multidisciplinary and multiparadigmatic field (Blaschke and Merschdorf, 2014), little agreement as to the exact contents and boundaries of spatial data science would be needed. Because of the highly dynamic nature of the problems studied, new areas are constantly added, and rigid borders may have a constraining influence on the field. Still, spatial data science as a field may need some agreed upon definitions and principles; however, if a field is described as being very open, dynamic and with vague boundaries, the search for general principles may become difficult. Therefore, rather than attempting to demarcate exact boundaries for spatial data science as a discipline or a multidisciplinary field I attempt to analyse the contents of such a dynamic field on the basis of scientific literature and to assess the multidisciplinary and multiparadigmatic nature of spatial data science with an emphasis on the full integration of "vector worlds" and "raster worlds." Historically, these communities used to be separated. Either, remote sensing was seen as a tool to gather data for GIS usage, or GIS datasets were used as ancillary information to improve products derived from remote sensing (see, e.g. Wilkinson, 1996). In 2019, the situation is clearly different. While, for instance, climate modelling almost naturally uses GIS and remote sensing techniques, the fields seem to be separated in terms of theories and epistemologies. Couclelis (1997) pointed out that human cognition appears to make use of both the object and field views, but at different geographic scales, and for different purposes. Particularly in a world of big data and big EO data, organising principles are needed which are not dictated or limited by remnants of early database developments or early design pattern in EO / RS systems. The traditional file-based storage of images and bands may make less sense in a data-affluent world, and 'unintelligent' data storage concepts make less sense than they used to – even though they triggered the developments of sophisticated information retrieval systems. A fully integrated spatial data science may, therefore, also need to tackle these challenges.

Conclusion

I argue for the integration of—technically speaking—the vector and the raster worlds and, in terms of scientific communities, for the integration of Geoinformatics and GIScience with EO/RS. I am aware of inevitable difficulties and wish to point out two challenges in particular. (1) How should this integration work? It may not be enough to teach methods of both subjects side by side. I refer to Goodchild (2013, p.1072) who argues that the integration of Geography "is normally interpreted by geographers as a straddling of the environmental–social divide, but a more profound interpretation stresses the issues involved in coupling environmental and social processes: a science of integration rather than an integration of sciences." (2) If the academic community switches from the term GIScience to the term spatial data science, a massive promotion (branding) of this term might be needed. While I mentioned 1522 hits for GIScience and related terms, a similar search in Scopus for "spatial data science" currently yields 18 hits. As Blaschke and Merschdorf (2014) point out, such a naming discussion is not purely of academic nature, but also bears implications beyond academic discourse, in terms of external scientific funding and research grants.

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