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# Information geography: The information revolution reshapes geography

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**Abstract** The information revolution has been one of the driving forces to the innovation in geography. However, environmental remote sensing, geographic information science and technology, and geocomputing, which once resided within the family of geography, are gradually moving close to information science but are alienated from geography. Therefore, it is necessary to reexamine the interactive convergence of geography and information science, and advance the disciplinary system of geographic science to accommodate the researches with information as subjects and methods. In this paper, we propose to reformulate the relationship between geographic science and information science with a new discipline, i.e., information geography, which not only refers to the geography of information but also a methodological system for studying geography using information science. This paper summarizes the background of information geography's emergence, its definition, and the difference and similarities with other disciplinary concepts. The impact of information geography on geographic paradigm shift is also investigated from the ontological, epistemological, and methodological perspectives.

**Keywords** Information geography, Geography, Information revolution, Methodology, Geographic paradigm

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## 1. The impact and challenges of the information revolution for geography

"Information is information, not matter or energy" (Wiener, 1948). Although information became a subject of scientific research after matter and energy, and it only joined mainstream scientific methodology recently, information has already had a profound impact on science and human society. Since the beginning of the information age, information has become an element that must be considered in all scientific disciplines, and a cyberspace corresponding to the physical world has consequently been constructed. Information science, first imperceptibly and then dramatically changed the traditional "physical science", and challenged the paradigm in all scientific disciplines, leading to a new scientific edifice with a meteoric rise that lies at the intersection of information science and physical science.

Under the profound influence of the information revolution, geography has also experienced an information revolution. The quantitative revolution of geography began in the 1950s, marked by *Exceptionalism in Geography: A Methodological Examination* (Schaefer, 1953), and was followed by the rapid development of remote sensing technology and the geographic information system (GIS). By the early 1990s, GIS had developed to be in full bloom and deeply changed the field of geography, resulting in the emergence of geographic information science (GIScience) (Goodchild, 1992). In the 21st century, the application of big data and artificial intelligence in geosciences is advancing rapidly, giving birth to geographic data science (Singleton

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and Arribas-Bel, 2021). The technological advances in the past 70 years have constantly inspired the rethinking of the quantitative revolution and ever-growing demands for theoretical and methodological advances in geography (Sheppard, 2001; Kwan and Schwanen, 2009; Wolf et al., 2021). The impact of the information revolution, on the one hand, has quietly produced a paradigm shift in geographic research, driving innovation and comprehensive integration in geography (National Academies of Sciences, Engineering, and Medicine, 2019); on the other hand, it has also extended to the territory of society and the public. Geographic information services have melded with daily life, resulting in a geospatial revolution (Downs, 2014).

However, environmental remote sensing, geographic information science and technology, and geocomputing, which once resided within the family of geography, have revealed a strong technology-driven tendency; they are gradually moving close to information science but are alienated from geography. However, neither GIScience nor geographic data science fully reflect the impact of the information revolution on geography. Other complicated conceptual systems (Appendix Table S1, https://link.springer.com) have further blurred the boundaries between geographic ontology and epistemology (Graham and Shelton, 2013). We are reaching a critical juncture characterized by the information revolution further propelling the geographic paradigm while geography advances towards geographic science. Therefore, it is urgent to reexamine the broad and interactive convergence of geography and information science, reconstructing the disciplinary system of geographic science using the new concepts and information as both the research subjects and methods, and thus join the effort to advance the study of the temporal evolution and regional differentiation of the human living environment on the Earth's surface and human-environment interactions (Chen et al., 2019).

Therefore, we aim to use information geography to reformulate the relationship between geographic science and information science with the following considerations. (1) Ontologically, epistemologically, and methodologically, information passes through geophysical observation technologies, e.g., remote sensing and social sensing, into geographic information science and technology, and geographic big data, so that the information is the very common element in these fields. (2) Physical geography and human geography are considered the two major branches of geography, both in China and worldwide. Information geography represents a new branch of geography and fits perfectly into the field in terms of literal definitions and symmetry with existing disciplines. Therefore, information geography is intrinsic to geographic science on the basis of its literal meaning and harmony with existing disciplines, reflecting a tripartite system of nature, humans, and information.

## 2. Definition and meaning of information geography

Information geography not only refers to the geography of information but is also a methodological system for studying geography using information science. Information geography is characterized by (1) reinstating the fundamental geographic principles; (2) using information as a research subject and a methodology; and (3) unifying the features of the information revolution that have shifted the geographic paradigm.

The paradigm shift in geography induced by the information revolution is reflected in the profound changes in geography from ontology to epistemology to methodology (Figure 1).

Ontology: Information geography is ontologically attached to the concept that "information is information". Following

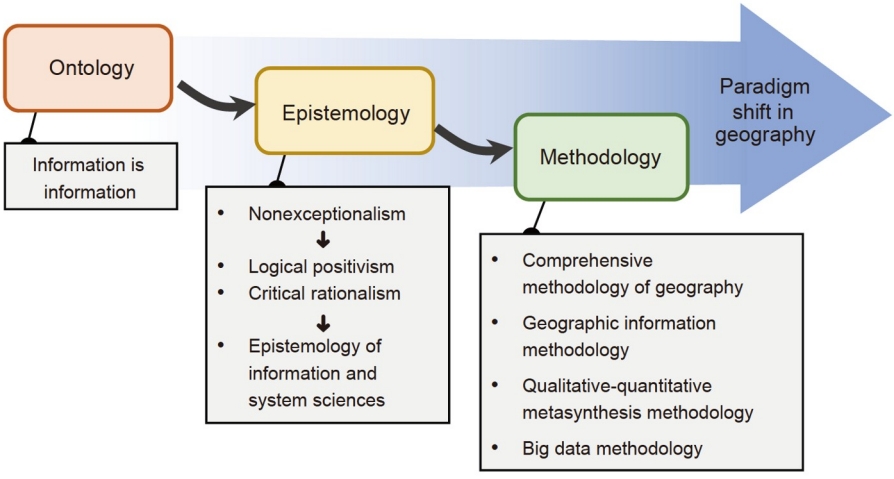


**Figure 1** Paradigm shift in geography driven by the information revolution: A profound change from ontology to epistemology to methodology.

the spatial tradition of geography (Pattison, 1964), it takes the space and distance of information as distinct research subjects.

Epistemology: Since the quantitative revolution of geography, there has been a lingering epistemological debate regarding topics such as logical empiricism, critical rationality, and radical geography, which were inspired by the "exceptionalism" debate in geography. Without intending to bring these epistemological debates to a conclusion, we would point out that the information revolution, especially the development of big data and social sensing in recent years (Liu et al., 2015; Guo et al., 2017), has not only substantially changed physical geography but also made it possible to verify and falsify the values, norms, and cultures that are research subjects in human geography. This has once again fundamentally impacted the descriptive epistemological tradition of geography. The practice has preceded the theory, and the epistemology of geography is deeply imprinted with the modern methodology of information and system sciences.

Methodology: The methodology of information geography has been nourished by both geography and information science. From within geography, the comprehensive methodology of geography should remain an methodological source of information geography. From the branches of information geography, the empirical tradition of remote sensing, the depth of spatial analysis in GIScience, and the quantitative capability of big data analytics in taming unstructured problems are the direct sources of the methodology of information geography. From the perspective of information science, countless methodological innovations since the information revolution have served as the driving forces of geography. Driven by all the aforementioned areas, information geography has the following characteristics of methodology: (1) Mathematical concepts and methods with distinctive geographic characteristics have been bred in the field of spatial analysis (especially autocorrelation, geographic regression, and spatial heterogeneity). (2) Spatial simulation inherits the tradition of simulating complex spatial phenomena with simple principles that were pioneered by John von Neumann. In this case, cellular automaton and agent-based modeling are methodologically distinct from the modeling approaches constructed using the dynamical framework of classical mechanics (Li et al., 2020). (3) The methodological dilemma of unstructured and wicked problems (Rittel and Webber, 1973), which has long plagued geography, have gradually been tamed by harnessing the powerful quantitative processing ability of big data technology for unstructured problems. (4) Integrated research methods in watershed science that combine hard and soft integrations were developed under the framework of a qualitative-quantitative metasynthesis methodology (Qian et al., 1990) to address the integrated research of human-nature complex giant systems (Cheng and Li, 2015). We believe that further abstraction and enhancement of the generality of the aforementioned methodologies can produce a more theoretically based geographic methodology to help complete the ongoing scientific revolution in modern geography and even contribute to the methodological integration of the natural and social sciences.

## 3. Relationships and differences among existing disciplinary concepts

Information geography has three main branches: Geographic remote sensing science, geographic information science, and geographic data science (Chen et al., 2021; Li et al., 2021). Many disciplinary concepts have successively emerged in these fields and are detailed in Appendix 1. Here, we focus on the distinctions between information geography and two highly related but subtly different disciplinary concepts, i.e., GIScience and geoinformatics.

The concept of GIScience is widely accepted by the academic community. It concentrates on GIS and cartographic traditions, but it cannot fully cover remote sensing and other science and technology related to geographic observations, nor does it concern the dynamical simulation of surface Earth systems. Thus, the shift from GIScience to information geography reflects an extension of the research subjects and methodologies of the discipline.

Geoinformatics, "the science and technology dealing with the structure and character of spatial information", is a field that extends far beyond the scope of geography. Geoinformatics is an interdisciplinary science coving the whole of geoscience and information science, and it also includes the information methods of other branches of geoscience. In addition, geoinformatics is a branch of informatics, which belongs to information science, representing an inconsistency with the geographic properties of information geography.

## 4. Summary

Information science has infused a new spirit into geography, and a new scientific field, termed information geography, has emerged from the intersection of these two fields. From the viewpoint of the history of geography, information geography is the outcome of more than 70 years of quantitative revolutions and technological leaps in geography. Today, with the ongoing rapid transformation of geography, information geography is becoming a collection of mature methodologies and theoretical abstractions in geography. In the future, information geography will engage with more clear research subjects and distinct scientific questions, and it will become capable of pro-

moting the development of the whole discipline of geography in return, thus joining the forces of physical and human geography as well as greatly contributing to a more mature geographic methodology.

The purpose of this short paper is to initiate a discussion on information geography rather than providing a definitive description of it. As information geography is by no means a closed boundary, extensive discussion of this topic is encouraged and critical for promoting the development of the discipline (Lü et al., 2022; Liu, 2022). We are confident that all three aspects of the geographic paradigm, i.e., ontology, epistemology, and methodology, have been fundamentally changed by the impact of the information revolution. Thus, we quote Kuhn's interpretation of paradigms as the conclusion of this short paper: "They (paradigms) are the sources of the methods, problem-field, and standards of solution accepted by any mature scientific community at any given time". ..... "When paradigms change, the world itself changes with them" (Kuhn, 1962, p. 103, p. 111). As information has profoundly transformed human society in the 70 years since World War II, why is it not natural for information to reshape the old yet nascent field of geography and facilitate the maturation of the geographic paradigm?

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