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Core or edge? Revisiting GIScience from the geography-discipline perspective

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1. Geographical information science

Geographical information science (GIScience) is an important branch of geo-informatics. As software tools, geographical information systems (GISs) implement the scientific research results of GIScience. With the support of information techniques, GIS collects, manages, analyzes, and visualizes geospatial data. Following the "data-information-knowledge-wisdom" hierarchy, GISs provide a series of methods such as geospatial simulation, prediction, and optimization. These methods help us uncover distribution patterns, interactions, evolutions, and underlying mechanisms of geographical phenomena, thereby contributing to spatial decision support (Li et al., 2021). The emergence and development of GISs benefited from information technology. Meanwhile, the quantitative revolution also provided a rich source of analysis methods (Johnston and Taylor, 1995). GIS has been playing an essential role in geographical research and applications since its birth. Nevertheless, scholars recognize the need to investigate the scientific issues in creating, processing, storing, and using geospatial information. Following this direction, Goodchild (1992) proposed the concept of geographical information science, with the intent to explore fundamental problems during implementation and application of GIS. For example, the three major research topics proposed by NCGIA (National Center for Geographical Information and Analysis in the United States) include: "cognitive models of geographical space", "computational methods for representing geographical concepts", and "geographies of the information society" (Goodchild et al., 1999). In this regard, GIScience focuses on the representation of basic concepts and laws of geography in the context of information systems, thereby building a theoretical foundation for GISs (Mark, 2004).

2. GIScience in the geography discipline

At present, GIScience is one of three sub-disciplines of geography together with physical geography and human geography. In the geography discipline, GIScience plays a unique and indispensable role through three aspects (Figure 1). First, it provides geospatial data management and analysis tools in support of sectorial geography, emphasizing geography as an observational discipline (Niu et al., 2020). Second, to achieve the above objective, it is necessary to represent the basic concepts and laws in geography, thus consolidating the theoretical foundation by emphasizing "spatial thinking". Third, via developing software tools, the methodological outcomes of geography research can be adopted by other fields, resulting in knowledge spillovers.

Let us revisit the four traditions of geography: spatial analyses, regional studies, human-land relationships, and

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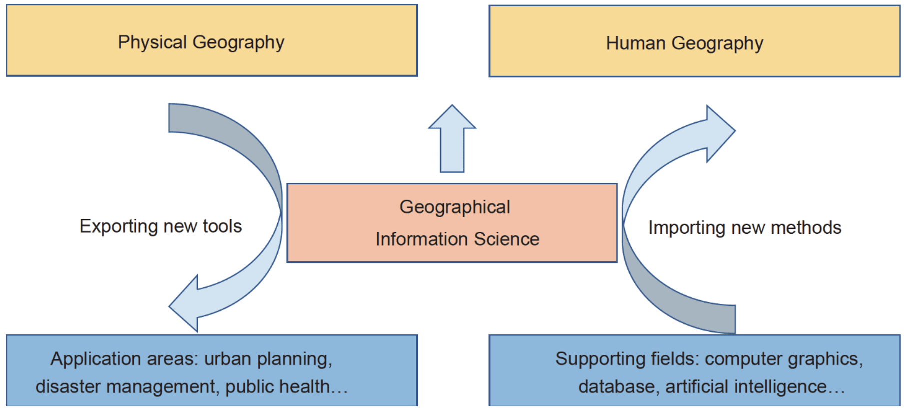

Figure 1 GIScience in the geography discipline.

Earth sciences (Pattison, 1964). GIScience obviously inherits the spatial analyses tradition, that is, paying attention to the distribution pattern of spatial configuration and interaction of geographical phenomena, the general laws behind the patterns, and the spatial generalization of the laws. GIScience has become a critical research field because "spatial is special" (Longley et al., 2014). With respect to "spatial", heterogeneity is the disciplinary foundation of geography (Fu, 2017). The existence of spatial heterogeneity has led to two directions of geographical research (Longley et al., 2014). One can be called "idiographic geography", which focuses on describing geographical forms with an emphasis on the uniqueness of different geospatial units. The second is "nomothetic geography", which aims to identify laws and rules of universality. In practice, it is common to apply general geographical laws to a specific area and combine them with specific local conditions to obtain new knowledge about the area. For example, the quantitative model between slope, lithology, vegetation cover, and landslide susceptibility obtained from an area can be transferred to another area with a similar landslide mechanism, thus allowing the landslide susceptibility in the new area to be mapped. The implementation of GISs considers both generality and particularity. On the one hand, variant spatial data sets depict the characteristics of different regions, thereby representing spatial heterogeneity. GISs have constructed a series of methods to deal with spatial local heterogeneity and spatial stratified heterogeneity (Wang et al., 2016). On the other hand, the analysis methods are applicable to processing data collected from different areas, suggesting the universality of geographical laws. It is worth pointing out that many spatial analysis methods, such as geographically weighted regression (Fotheringham et al., 2002), reflect the compromise between generality and particularity in geographical research (Goodchild, 2004).

Computer software abstracts and solidifies the knowledge of our world (Yang and Mei, 2008) via algorithms and data structures. "Solidify" mentioned here is roughly equivalent to "formalize". From the software perspective, GIScience formalizes core concepts and laws of geography through the models of spaces, phenomena, and features in the geographical world. For example, regarding data models, the two basic conceptual models, object and field, represent the spatial distribution of geographical phenomena and the properties of geographical features in a unified form, no matter whether phenomena and features are studied by physical geography or human geography. Additionally, spatial analysis methods embody "spatial thinking". A typical illustration is Tobler's first law of geography (TFL, Tobler, 1970), which expresses the impacts of distance on the patterns of geographical distributions. In general, TFL has two implications (Miller, 2004). The first is the similarity (or spatial dependence) of geographical distribution, i.e., spatially close locations tend to have similar properties. Second, spatial interactions, measured by flows of population, materials, and information, are governed by the distance decay effect. GISs provides analysis methods to "solidify" the ideas expressed by TFL. For instance, spatial interpolation and spatial autocorrelation measurement reflect the former meaning well, whilst the gravity model is used to quantify the relationship between spatial interaction and distance, referring to the latter meaning. Undoubtedly, the above methods are applicable to both physical and human geography. Therefore, GIScientists pay attention to more generalized concepts abstracted from concrete geographical phenomena, such as spatial heterogeneity, spatial dependence, scale, and distance decay. In this manner, GIScience plays an irreplaceable core role in the geography discipline, as stated by Professor Shupeng Chen, "It helps to unify different branches of geography"[1)].

1) Communication with Dr. Jingfeng Wang.

3. GIScience as an inter-discipline

As an inter-discipline, GIScience bridges geography and other research realms at two levels: data and methods. Regarding the former, GIScience develops production, transmission, and visualization methods of different geospatial data, builds data quality and uncertainty evaluation models, and addresses data usage problems in applications. Hence, it has a close relationship with the sciences of surveying and mapping, which provide an important data source by investigating precise geospatial data acquisition. Among them, the rapid development of technologies such as remote sensing and global satellite navigation systems has greatly enriched data types of GIScience (e.g., global land cover data, three-dimensional data of cities and buildings, individual-scale trajectory data). At present, geographical research has entered the era of big data. Big geo-data include the long-term accumulation of human geographical knowledge, and the high-resolution observations of geographical phenomena and features (including individuals) supported by new technical means (Liu et al., 2015; Pei et al., 2019). The combination of big geo-data and traditional data greatly expands the depth and breadth of geographical information applications.

In terms of methods, GIScience has benefited from the rapid development of information science and technology, which undoubtedly has changed, and will continue to profoundly change, almost all disciplines. In recent years, with the support of artificial intelligence, scientific knowledge and laws can be automatically extracted and discovered (Granda et al., 2018; Iten et al., 2020). Geography is no exception to this trend (Guo et al., 2020). Throughout history, the architecture of geographical information applications has continuously evolved, from stand-alone tools to Internet based services. At present, new technologies bring new opportunities to GISs, as well as new research topics to GIScience. High-performance computing provides powerful analysis and simulation capabilities, and artificial intelligence improves the understanding of complex spatio-temporal patterns (Reichstein et al., 2019; Janowicz et al., 2020). The technical advancements strongly support the discovery of geographical laws, the prediction of geographical processes, and the optimization of geospatial decision-making, thereby enabling geography to overcome the difficulties encountered in the quantitative revolution era. From the perspective of knowledge spillover, GIScience also enriches methods for information science and serves the applied research of related disciplines.

Therefore, as an inter-discipline, GIScience supports the innovative development of geographical research. It borrows and integrates new data sources and analysis methods generated in other disciplines while remaining aware of the special nature of geographical spaces, keeping the entire discipline vigorous.

4. Conclusions and prospects

The advent of the information age has expanded the research objects of geography from natural and human elements to information elements (Lü et al., 2021). Facing the future, GIScience represents a tightly integrated direction of geography and information technology. First, we must focus on the introduction of new information techniques to geography. Second, it is necessary to promote the export of geography methods to other related disciplines. The future breakthroughs in GIScience lie in the areas of geographical complexity modeling, geographical intelligence, and large-scale geological problem solving (Song et al., 2018). Together, they will improve our understanding of the complex giant man-land coupling system and support human society is facing critical issues, including global climate change, environmental pollution, natural disasters, population growth, and economic development. Towards the above objectives, the geography discipline will become stronger along with two directions: strengthening the theoretical foundation and promoting the practical applications.

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