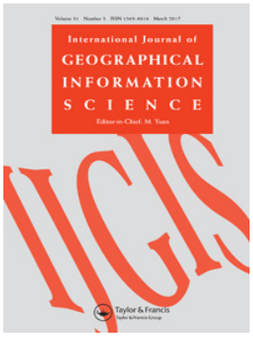

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30 years of *IJGIS*: the changing landscape of geographical information science and the road ahead

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ABSTRACT

The *International Journal of Geographic Information Science (IJGIS)*, established in 1987, is the first academic journal devoted solely to Geographical Information Science (GIS) research. This editorial highlights milestones of the journal development and its influences on the field. *IJGIS* research articles and special issues have been effective in publishing the state of the art and emerging research accomplishments. In light of the changing landscape of GIS, *IJGIS* welcome papers on meta-analysis studies, literature reviews, and research foresight. This editorial outlines the underlying thinking and expectations for these papers in future volumes. *IJGIS* aspires to publish research of high novelty and broad interest that pushes the boundary of fundamental and applied GIS. As an independent, multidisciplinary journal driven by the community of authors, reviewers, and readers, community support is key to realizing the aspiration of a major influence on GIS research.

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Introduction

Since Roger Tomlinson coined the term Geographic Information System (GIS) in his report to the National Land Inventory in the Canadian Department of Agriculture (Tomlinson 1963), the rest is history (Coppock and Rhind 1991). In less than 50 years to date, GIS has grown from a privileged technology available only to few established institutions to an all-access platform available to the public. Many milestones have marked the outstanding accomplishments in the field, among which is the establishment of an international journal devoted solely to advancing research and knowledge in GIS. The *International Journal of Geographic Information Systems* (*IJGIS*), established in 1987, was the first scholarly journal for this then-emerging field of study.

Terry Coppock and Eric Anderson, the founding editors of *IJGIS*, intended for the journal to bring an international readership from a diverse community of researchers, developers, users, and decision makers to share and advance knowledge on GIS, broadly defined (Coppock and Anderson 1987). Specifically, Coppock and Anderson scoped a list of subject areas: spatial data structures, data updates and archives, benchmark systems, spatial data standards, vector and raster data, spatial data quality, spatial data sampling, hardware infrastructure, spatial data use, research questions afforded by spatial data,

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institutional adoption and implementation, case studies of systems and project management, cost-benefit analysis, and applications of GIS in developing countries. The apparent emphases on spatial data, systems, projects, and applications were a reflection of rapid GIS technology development and adoption at that time.

IJGIS started publishing four issues in 1987 and has been since at the forefront of publishing research on the theory and application to GIS. The vision of Coppock and Anderson for the journal was well received with approximately 380 pages published in each of the first three years and then an increase to 480 pages in Volumes 4 and 5. The thriving field of GIS research pushed for marked increases in the numbers of issues and pages published annually over the years: six issues in 1992–1995, eight issues in 1996–2004, 10 issues in 2005–2007, and 12 issues since 2008 (Figure 1). The latest volume (Volume 30 in 2016) published over 2500 pages. Meanwhile, *IJGIS* editorial teams were expanded to cope with the growing demand on processing manuscripts and peer reviews. Peter Fisher took over the editorship in 1994 and expanded the editorial team of European and American editors to the addition of Western Pacific editor (later revised to Asia-Pacific editor). The added regional editor was to recognize a disproportionately large number of papers submitted to *IJGIS* from Australia (Fisher 1994) and later papers from Asia (Lees 2011).

In 2008, Brian Lees succeeded Fisher as the editor in chief and gradually expanded the editorial team to six members (Editor in Chief, American Editor, two European-African Editors, and two Asia-Pacific Editors) to manage the journal's growth. In 2015, the editorial team and special issue editors handled 931 submissions to *IJGIS*. To reduce backlogs for timely publications, Lees worked successfully with the publisher Taylor and Francis to significantly increase page counts since 2008 (Figure 1). Nevertheless, the key challenge for the editorial team remains, as was experienced by all of the former *IJGIS* editors: finding the right reviewers and getting quality reviews back to make timely editorial decisions (Fisher 1994).

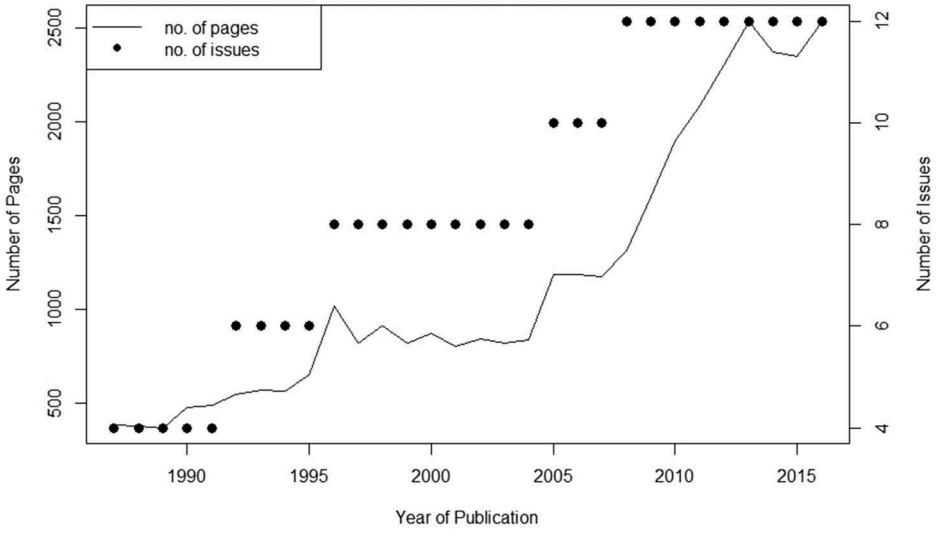

Figure 1. Volumes and pages published by *IJGIS* from 1987 to 2016.

Over the 30 years of publications, *IJGIS* has published many seminal papers in building conceptual and computational foundations for theories, methods, applications, and technologies associated with geographical information. As Fisher noted, *IJGIS* started when there was only one single-authored GIS textbook (Burrough 1986), and the journal had 'a *profound influence on the acceptance of the term GIS, in academic circles providing as it did a major outlet for publication of research articles*' (Fisher 1997, p. 1). By 2016, there are more than 20 journals publishing GIS-related research. A bibliographic analysis of 12,436 articles from 20 journals over 15 years concluded a complex global ecosystem of GIS publications and influences (Biljecki 2016).

Numerous *IJGIS* papers broke new theoretical ground, invoked novel insights, and reported innovative applications. The publication of Goodchild's paper that challenged the meaning of 'S' in GIS (Goodchild 1992) triggered a series of name changes in GIS organizations, journals, and academic curricula to replace 'systems' with 'science.' After 10 years of publication under the title *International Journal of Geographical Information Systems*, the journal changed its name to the *International Journal of Geographical Information Science* but retained its acronym in 1997. Hence, GIS is used interchangeably as GISystem and GIScience in this editorial. It goes without saying that *IJGIS* discourages submissions based on studies that are confined to any GIS software package (e.g. Esri's ArcGIS or Clark Lab's IDRISI). *IJGIS* rejects the common misconception that equates GIS with a particular commercial software. The term geospatial is gaining popularity, in part due to the misconception. From the perspective of *IJGIS*, GIS, systems or science, is the field that studies geographic information and epistemology, and with the understanding to develop new methods and applications using location-referenced data to advance our knowledge about forms and processes in the world, solve spatial problems, and support decision making. *IJGIS* papers contribute broadly cognitive, conceptual, methodological, and computational advances in GIS and applications.

While assessing the impact of a publication is a complicated task, and no metrics can do justice to all measures worthy of considerations, the numbers of downloads are convenient quantities for a quick overview. The numbers of downloads are generally correlated with the numbers of citations that are used to calculate a journal's impact factor. While both downloads and citations favour early publications, the numbers of downloads appear less sensitive than citations to the year of publication. For example, the second all-time top downloaded *IJGIS* paper was published in 2016 and has been downloaded almost 11,000 times in 6 months (Table 1). The top 10 most downloaded *IJGIS* papers since 1987 (as of 18 August 2016) highlight the topics of great interest to our readers over the years. Two of these papers were published in 1991, a sign of lasting interest, and the two papers are also among the most cited papers in *IJGIS* (Lees 2011). Both are considered GIS classics on two fundamental topics: point-set topological spatial relations (Engenhofer and Franzosa 1991) and multi-criteria evaluation (Carver 1991). Multi-criteria modelling continues to be one of the popular topics in *IJGIS* publications. Four out of the 10 top downloaded papers are on the topic, and Malczewski's paper on GIS-based multi-criteria decision analysis is the most downloaded paper of all times in *IJGIS* publications (Malczewski 2006). The 10 papers cover topics with emphases on both theories and applications and with studies involving GPS, remote sensing, *in situ* observations, and social media data. This is a testament of the diverse and broad scopes of *IJGIS* papers, and so are the journal's impacts and contributions.

Table 1. Ten *IJGIS* publications with the highest downloads since 1987 as of 18 August 2016.

Download	Citation	Publication date	Article title	Authors
12282	831	Vol. 20, No. 7, August 2006	GIS-based multi-criteria decision analysis: a survey of the literature	Jacek Malczewski
10891	6	Vol. 30, No. 2, February 2016	Why GPS makes distances bigger than they are	Peter Ranacher, Richard Brunauer, Wolfgang Trutschnig, Stefan Van Der Spek, Siegfried Reich
8068	1018	Vol. 5, No. 3, January 1991	Integrating multi-criteria evaluation with geographical information systems	Stephen Craver
6992	403	Vol. 11, No. 7, October 1997	Mapping urban air pollution using GIS: a regression-based approach	David J. Briggs, Susan Collins, Paul Elliott, Paul Fischer, Simon Kingham, Erik Lebret, Karel Pryl, Hans Van Reeuwijk, Kirsty Smallbone, Andre Van Der Veen
5189	1917	Vol. 5, No. 2, January 1991	Point-set topological spatial relations	Max J. Egenhofer, Robert D. Franzosa
5094	757	Vol. 9, No. 3, May 1995	Integrating geographical information systems and multiple criteria decision-making methods	Piotr Jankowski
4553	310	Vol. 21, No. 3, March 2007	Towards a general theory of geographic representation in GIS	Michael F. Goodchild, May Yuan, Thomas J. Cova
4546	406	Vol. 15, No. 2, March 2001	Using GIS and outranking multi-criteria analysis for land-use suitability assessment	Florent Joerin, Marius Thériault, Andre Musy
4225	251	Vol. 24, No. 6, April 2010	ESP: a tool to estimate scale parameter for multi-resolution image segmentation of remotely sensed data	Lucian Drăguț, Dirk Tiede, Shaun R. Levick
4115	160	Vol. 25, No. 11, November 2011	The convergence of GIS and social media: challenges for GIScience	Daniel Sui, Michael Goodchild

As *IJGIS* enters its 31st year of publications, new challenges and opportunities emerge. The three principles of peer reviews and editorial decisions set by the founding editors remain: (1) quality: well structured, well written, and saying something that is new and significant; (2) relevance: topics relevant to the development and the applications of geographic information science; and (3) comprehensibility: clear and simple writing with minimal technical jargon (Coppock and Anderson 1987, Lees 2008). Nevertheless, GIS, systems or science, has evolved significantly over the last 30 years. *IJGIS* must embrace the vibrant and diverse GIS research communities and proactively create opportunities to publish papers that are intellectually new, scientifically significant, and grounded in real-world applications. The next section will outline the key changes in GIS. It is not to provide a comprehensive account of the history of GIS development but to understand the changing landscape of GIS research. The section that follows attempts to contextualize *IJGIS* in the understanding and upcoming new additions to assure that *IJGIS* continues not only publishing highly qualified, relevant, and comprehensible papers to GIS communities, but also provides a source for knowledge and research inspiration that is of great value to GIS researchers in advancing Geographical Information Science.

The changing landscape of geographical information science

GIS by its very nature is interdisciplinary, multidisciplinary, and transdisciplinary, as evident by the multitude of names associated with the field, for example, geospatial science, spatial science, spatial information science, spatial data science, spatial computing, geoinformatics, and geomatics. These names are popular in communities with different research emphases (Table 2). Consequently, any attempt to summarize research developments in the field would be inevitably biased towards one's academic background. However, some general trends may be agreeable: research has migrated from GIS-enabling computerization of geographic data processing and mapping to GIScience enquiries into the essence of geographic information and epistemology.

Goodchild (2010) reviewed 20 years of research and institutional accomplishments since the funding of the US National Center for Geographic Information and Analysis

Table 2. GIS-related names adopted by communities with difference emphases.

Term	Primary communities	Special emphases
Spatial Science or Geospatial Science	Geography, Cognitive Science and other domains that apply mapping and spatial methods	Mapping, Spatial Analysis, Spatial Modelling, Spatial Reasoning, Spatial Cognition
Spatial Information Science	Management Information Science or Library Science	Spatial databases, Information management
Spatial Computing	Computer Science	Algorithm development, Spatial Indexing and query Communication and Infrastructure
Spatial or Geospatial Data Science	Geography, Statistics, Computer Science	Spatial Statistics, Spatial Big Data, Machine learning,
Geoinformatics	Geosciences, Geology, Computer Science	Earth Science Data Management and Visualization Geostatistics, 3D Modelling
Geomatics	Geodetics, Survey Engineering, Geophysics	Geoid, datums, land surveys, mapping

and highlighted key research progress in spatial representation, spatial uncertainty, and spatial analysis. In addition, GIS research leverages growing cyberinfrastructure and mobile technologies to develop new thinking of geographic problems. New kinds of spatial data are acquired from crowdsourcing, web harvesting, open data portals, motion videos feeds, real-time sensor networks, trajectories from GPS-enabled mobile devices, text documents, and many non-traditional data sources. Riding along the data waves are new research questions that seek to understand disaggregated behaviours and emergent patterns for new insights into complex, dynamic, and multi-scalar human activities, environmental and ecological processes, human–environmental interactions, and planning for smart and connected communities and sustainable future. *IJGIS* has constantly published papers that define and scope new GIS research directions on these research forefronts, such as space, time, and visual analytics (Andrienko *et al*. 2007), spatial video and GIS (Lewis *et al*. 2011), (Hardy *et al*. 2012), CybreGIS software (Wang *et al*. 2013), space-time research in GIScience (Kwan and Neutens 2014), crowdsourcing urban form and function (Crooks *et al*. 2015), everyday space-time geographies (Ahas *et al*. 2015), GPS measurements (Ranacher *et al*. 2016), and open geographic information science (Singleton *et al*. 2016).

These forward-looking papers are among the top 10 downloaded *IJGIS* papers in each volume from 2010 (vol. 24) to 2016 (vol. 30). A further analysis of the top 10 downloaded papers from each of the last 5 years reveals popular emergent topics on spatial data mining, movement (trajectories), crowdsourcing, and volunteered geographic information (VGI), and social networks as well as sustained topics on multi-criteria analysis, space-time, and spatial modelling. Moreover, novel applications remain prominent in papers on either emergent or sustained topics. With the progress, GIS research landscape is becoming even more diverse and sophisticated in representation of geographic phenomena, conceptualization of geographic problems, computation and visualization of geographic data, and communication of geographic interpretations. In a nutshell, GIS software technologies consist of database management, computer mapping, spatial statistics, and geovisualization. The initial development of GIS technologies was very much map-centric in that the map metaphor penetrated in the design of all its four software components. The current state of GIS development is multi-pronged. Many GIS software packages remain map-centric, but there are statistics-centric GIS (e.g. R with spatial libraries), database-centric GIS (e.g. PostGIS), computation-centric GIS (e.g. Python with spatial libraries), and visualization-centric GIS (e.g. CARTO). Furthermore, the ideas of 'platform' and 'service' prevail in the current GIS software development that promotes interoperability, integration, and mobility with cloud GIS and high-performance computing with cyberGIS.

Our world is changing rapidly with the advances in the shared economy, Internet of Things, driverless cars, smart and connected communities, and personalized location-based services. GIS researchers engage in understanding our complex, dynamic environmental, social, and technological systems as well as spatial cognition and reasoning that helps us interact and make decisions. Similar to Big Data, the production of GIS research experiences high velocity, volume, variety, and veracity (4 V's). As a result, it may be challenging to grasp key intellectual advances in the diverse publications.

How *IJGIS* facilitates the road ahead

With the rapid, and at times overwhelming, GIS publications across journals and conference proceedings, *IJGIS* will proactively bring forward innovative research, emergent topics, meta-analysis and review studies, and foresight papers. Currently, general submission of research articles and calls for submission to special issues constitute two major avenues for publications in *IJGIS*. In light of the growing 4 V's in GIS research, *IJGIS* welcomes submissions of findings from meta-analysis papers that elicit novel insights and trends through meta-analysis of existing research as well as foresight papers that project new research directions. Meta-analysis, review, and foresight papers together provide a big picture of accomplishments, challenges, and opportunities in GIS research, while research articles highlight the latest advances and special issues catalyse research on focused emergent topics.

Research articles

Research articles are the most significant scholarly contributions and will remain the major component of *IJGIS* publications. Currently, *IJGIS* publishes 12 issues per year, 8–12 articles per issue for a total of 130–140 articles per year. The capacity and frequency of publications allows timely dissemination of research findings online (approximately 1 month after acceptance) and a short backlog for prints (approximately 6 months after acceptance). *IJGIS* is widely abstracted and indexed in *ACM Guide to Computing Literature; British Library Inside; CompuMath Citation Index®; Current Contents®/ Social and Behavioural Sciences; EBSCO Databases; ERIC; GEOBASE; INSPEC®; Science Citation Index®; Science Citation Index Expanded™; Social Sciences Citation Index®; New Jour; SciBase; SCOPUS and Zetoc*. While editorial decisions depend highly on the support of reviewers to provide timely quality reviews, the *IJGIS* editorial team attempts to make a decision within 60 days of submission.

Special issues

IJGIS covers emergent topics of great promise and demonstrable accomplishments through special issues. GIS researchers with research credentials in the topic area are welcome to discuss ideas with any member of the *IJGIS* editorial team and submit special issue proposals for consideration. An editorial decision with specific guidelines on special issues is normally made within a week. *IJGIS* practices the principle of open calls, so every special issue is open for submissions without preconditions. Every submission to a special issue is subject to the same peer review process as the regular submission to assure quality. Special issues will continue to be *IJGIS* catalysts for novel papers on focused areas of growing importance and major development. On average, *IJGIS* publishes two special issues per year, but more special issues are possible. For example, four special issues were published in 2016.

Meta-analysis and review papers

GIS research is thriving at a wide range of conceptual, cognitive, and computational fronts with profound influences from and in other disciplines. Advances in spatial thinking, spatial analysis, spatial modelling, and mapping have stimulated new approaches to understand geomorphic processes, biodiversity, crime distribution, and human interactions, for example. Publications may propose a new conceptual model or method to address certain properties of spatial problems or report innovative applications of GIS workflows with multiple methods to spatial problems in a study area. Often, even though studies may be on different subjects, the proposed methods may share many common characteristics. While each publication is of good intellectual contributions on its own right, collective advances in GIS may not be apparent. Meta-analysis papers may evaluate existing relevant GIS publications through systematic reviews of findings from independent studies to identify the nomothetic and idiographic nature of these findings and the robustness of GIS methodology adopted in these studies. Examples of meta-analysis papers may evaluate the proposed methods from multiple GIS studies to conclude new ways to frame spatial problems or cross-examine results from GIS modelling of the same subject (e.g. land-use and land-cover change), but from different studied areas, to elicit the methodological advantages of different GIS methods on the subject in different places.

Complementary to meta-analysis papers are review papers that synthesize major developments and trends and are particularly important for GIS as a diverse, fast-growing field of research. Common review papers on a particular group of methods (e.g. spatial data mining) and their applications are of great value to GIS researchers, especially graduate students. That Malczewski's review on GIS-based multi-criteria decision analysis (Malczewski 2006) remains the most downloaded paper of *IJGIS* of all times is a testimony of the community's interest in literature-review papers. In addition to reviewing GIS methods, *IJGIS* also welcomes papers that review GIS contributions and potential to new insights and advances in other disciplines. Many established disciplines (e.g. ecology, hydrology, economics, sociology, or humanities) commonly employ GIS methods of analysis, modelling, and mapping. A comprehensive literature review of GIS applications in a particular discipline and its related disciplines reveal not only the value of GIS in the field, but also GIS potential to transformative research, which is evident by the so-called spatial revolution or spatial turns that lead to the emergence of spatial ecology, spatial history, spatial epidemiology, and other spatial sciences and humanities. A review paper on methodological progress in spatial hydrology, for example, will inform and stimulate both GIS and hydrology research communities.

Foresight papers

Space and time are ubiquitous and essential to all scales of geography as well as to exciting new areas of research, such as Big Data, Internet of Things, smart and connected communities, and self-driving cars. As space-time is at the core of GIS research, there are ample opportunities for GIS researchers to make significant contributions to these exciting research areas that can transform ways of living in future generations. Foresight papers are expected to serve three purposes: (1) elucidate emerging sciences

and technologies, big societal issues, and national and international research initiatives to the GIS research community, (2) relate GIS knowledge and methods of relevance, highlight possibilities for new GIS research, and (3) recommend paths forward for GIS researchers to engage in these and future new research opportunities. Moreover, foresight papers may also reflect GIS research development, alert shortfalls or oversights, and anticipate promising research outlooks in the future.

Concluding remarks

To date, *IJGIS* has established 30 years of GIS scholarship and continues striving for novel methods to understand geographic information and its applications, to advance geographic knowledge, and to solve geographic problems. The world is becoming more and more complex and dynamic, which is driving the creativity and sophistication of research published in *IJGIS*. Unlike many other academic journals, *IJGIS* is independent of professional organizations. The founding editors set forward the vision that *IJGIS* is 'a source of information on advances and experiences and a meeting place' to reflect the 'diversity and communality' of this rapidly developing field 'lying at the intersections of many disciplines' (Coppock and Anderson 1987, p. 3). Hence, *IJGIS* is fundamentally community-driven and has been inclusive in publishing papers with perspectives from many disciplines.

Expanding upon the foundation and reputation established by former editors, *IJGIS* will continue to facilitate the exchange of research findings and perspectives of a wider knowledge that foster anew scientific discoveries and application innovations. Research articles and special issues represent the state of the art in GIS research. The new additions of meta-analysis studies, review articles, and foresight papers synergize findings and perspectives for a bigger picture of research progress, challenges and opportunities, and promising directions. *IJGIS* aspires to be a major influence on GIS research with support from the community of our authors, reviewers, and readers. We, the *IJGIS* community, can see further than others by standing upon the shoulder of giants over 30 years of *IJGIS* publications. We can make *IJGIS* the journal of choice to look for exciting new findings, emerging research topics, major progress, and visionary outlooks of new challenges and opportunities in GIS, broadly defined.

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No potential conflict of interest was reported by the author.

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