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AGILE 2012 +/- 15: Some reflections on past, present and future directions in GI Science

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Abstract

This paper reflects on the evolution of the GI research agendas in the US and Europe since the mid 1990s. The starting points are the European Science Foundation-National Science Foundation sponsored Summer Institutes in GI Science organised by the GISDATA programme in Europe and the NCGIA in the US. The paper compares the key topics then with those identified as important by the AGILE 2012 call for paper, and then looks forward to the topics likely to be particularly important in the years to come as we move from GI Systems, to GI infrastructures, and from these towards implementing the vision of Digital Earth.
Keywords: Research agenda, Spatial Data Infrastructure, Digital Earth

1 Introduction

Just over 15 years ago, I had the pleasure to collect in two volumes, one edited with Helen Couclelis [1], and the other with Harlan Onsrud [2], the papers presented by early career scientists from Europe and the US at the two Summer Institutes on GI Science held in Maine (1995) and Berlin (1996). These Summer Institutes were the flagships of a coordinated research effort between the European Science Foundation 's GISDATA programme, and the National Science Foundation sponsored National Center for Geographic Information and Analysis (NCGIA).

The two Summer Institutes included almost 100 participants of whom just over 60 were young scientists selected on both sides of the Atlantic through open competitions, and about 40 were senior scientists. The Summer Institutes lasted one week each, allowing in depth discussion and exchange of ideas among the young researchers, and between them and the more senior colleagues. The value of this exchange was increased by the cross-disciplinary background of the participants which made it possible to generate that Medici Effect [3] that we have since successfully recaptured in the Vespucci Initiative for the Advancement of GI Science and its Summer Institutes, now in their 10th edition (www.vespucci.org). It is also worth noting, that many of the so-called young researchers or early-carer scientists have now been leading the GI field for many years as well established university professors or leaders in the private sector!

These two ESF-NSF Summer Institutes give a good overview of what were considered to be the most important research topics in GI Science in the mid 1990s. With this in mind, Section 2 of this short paper reflects on what has changed since, and how the research agenda, and the interest of young researchers, have evolved in the last 15 years. Section 3 will then considers some of the topics that are emerging now and that will probably feature in the research agenda of GI Science in the coming decade.

2 The research priorities in the mid-1990s

The topics of the two Summer Institutes included most, if not all, of those of the GISDATA scientific programme in Europe and the NCGIA's in North America. These in turn had been chosen through a process of consultation with the scientific community, and the sponsor organisations. Table 1 shows the topics of the two Summer Institutes divided into those addressed by the NCGIA and those by GISDATA.

Table 1: Themes of the Two ESF-GISDATA and NSF-NCGIA Summer Institutes 1995 and 1996.

NSF-NCGIA	ESF-GISDATA
Representing Spatial Data Quality	Data Quality
Formalising Cartographic Knowledge	Generalisation
Human and Organisational factors in GIS implementation	GIS Diffusion in Europe
Collaborative Spatial Decision Support	GIS and Spatial Analysis
Cognitive Perspectives on Spatio-Temporal Reasoning	Spatial Conceptual Models for Geographic Objects with Undefined Boundaries
National Spatial Data Infrastructures	European Data Availability
GIS and Societal Issues (including aspects of ethics and law)	Geographic Information, the European Dimension
Visualisation and Interfaces	GIS and Multimedia
Application areas from Global Change to Health	GIS and Remote Sensing for Urban Analysis + GIS and Health

As the table indicates, although the formulation changed slightly, there was much synchronization between the topics researched in the US and Europe. Clearly, the topics show a strong interest in GIS as a technology, in data issues including quality, applications, and analytical methods. This is the traditional core of GI Science. It is however important to note that three sets of issues were already emerging as important:

1. Aspects of spatial cognition, conceptualization, and data modelling;
2. The complex relationship between (spatial) technology, organisational dynamics, and society;
3. Data availability and use, and spatial data infrastructures.

Before considering the evolution of the field, it is also worth reviewing the two prostcripts provided by Mike Goodchild and Ian Masser respectively to the two Summer Institutes volumes, in which they tried to identify new directions for GIS research.

Goodchild [4] started from the research agenda identified in 1986 by Ron Abler at the inception of the NCGIA. Then, the key priorities were technical, and focused on spatial analysis and spatial statistics, spatial relationships and database structures, artificial intelligence and expert systems, and visualisation. As almost an afterthought, a fifth topic was added to include social, economic and societal issues. Ten year later, it was clear to see that the technical core had started to include a wider set of disciplines and a greater interest for social issues, including matters of data access, use and impacts. With this in mind, Goodchild identified three main areas in which more GI science research was needed:

Metadata: although not at first hand a major research topic, Goodchild argued that the increasing use of the Web to publish data required increasing efforts in documenting them so that they could be found, accessed, and reused. To do so, needs agreed terms to describe the data, and this in turn requires the development of a sound general theory of geographic information on which a unified approach for data classification and labelling could be based.

Paradigms of spatial decision making: here Goodchild argued that new technological developments and client-server architectures were making computing accessible and easier to use than ever before, allowing non-experts to interact with the technology and utilise more widely in their decision-making.

Data fusion: this term was used as a short hand for the research issues that need to be addressed to access, use and quality control data on a world characterised by the proliferation of distributed data sources.

For his part Masser [5] took as starting position the 1987 Chorley report [6] in the UK which put particular emphasis on digital data availability, access, education and awareness. Ten year later, much more data had become available in digital format, but policy issues were constraining access, and technical issues, were constraining effective use. These same issues were in his view likely to be relevant for years to come, particularly in the European context which is characterised by multiple institutional set up, histories, and traditions affecting the production, dissemination and use of geographic information.

As in any forward-looking exercise, something you get right, something you get wrong, and others you just do not see coming, or coming quite the way you expect them. Both Goodchild and Masser were correct in the prediction that the use of the Internet as mechanism for data and information sharing would become much more pervasive. This would require an increasing emphasis from GI systems to GI infrastructures, which in turn would require greater efforts for data documentation, and classification, data integration, and data policies for access and use.

Among the issue that did not quite happen as foreseen, the quest for a grand unifying theory of GI Science has (yet) to bear its fruits, and in fact the increase multi-disciplinary nature of the stakeholder community suggests that it may not be possible (or even desirable?) to develop such unifying theory. A more limited approach is however taking place through the many efforts, particularly in Europe in the framework of INSPIRE [7], to define shared vocabularies, classifications, and taxonomies, and common data models across diverse communities of practice. This is already difficult enough, but Goodchild was right in seeing it as an essential component for data interoperability.

Similarly, the widespread use of computing in society has developed much further than could be predicted. This has not resulted in a great uptake of decision-support systems but certainly in a much greater participation of the public, with the emergence of social networks, and volunteered Geographic Information [8].

3 Where we are now?

What better way to gauge the current major interests of the GI community than to look at the topics proposed in the AGILE 2012 call for papers?

Table 2 lists the topics proposed. As shown, there is a strong degree of continuity with those of the mid 1990s. There is a strong emphasis on applications (broadly from 25 to 33 and 38), spatial analysis and modelling (3,4, 18, 21, 22), and data interpretation, integration, generalisation, and fusion (19, 35, 36, and 37). Recurrent themes are also visualisation and representation (5,20), social issues (14, 23, 24), spatial data infrastructures (8), and cognitive issues (1, 2).

Topics that have increased their profile are semantics, and ontologies (6, 9), web and location-based services (10, 11), and the time dimension (3-6), particularly in respect to real time data flows (7, 10). The new kids of the block are sensors, and the sensor web (13), volunteered geographic information (15), and mobile applications (12).

The evolution of research topics since the 1990s is interesting because it marks at least three main shifts.

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Table 2: Topics of AGILE 2012

1.	Perception and Representation of Geographic Phenomena Spatial Cognition, Space Appropriation
2.	Cognitive Aspects of Human-Computer Interaction for Geographic Information Systems
3.	Spatio(temporal) Data Modelling and Reasoning
4.	Spatio(temporal) Data Analysis
5.	Spatio(temporal) Data Visualisation
6.	Spatio(temporal) Data MiningKnowledge Discovery Spatial Semantics and Spatiotemporal Ontology
7.	Real time GIS, 3D GIS, temporal GIS
8.	Spatial Data Infrastructures
9.	Semantic Web and GIS
10.	Web Services, Geospatial Systems and Real-time Applications, Webmapping,
11.	Location Based Services and Mobile GI Applications, Networks and Ubiquitous GIS
12.	Mobility of Persons, Objects and Systems, Transports anc Flows, Trajectories Analysis,
13.	Geosensors Networks
14.	Public Participation GIS and Participatory uses of Geospa Information Systems and Technologies
15.	Volunteered Geographic Information
16.	Geospatial Decision Support Systems, Spatial Decision Making Support
17.	GIScience and Spatial Analysis Education and Training
18.	Complex Spatial Systems, Simulation of Spatial Phenome
19.	Integration, Fusion, Multi-scale and Automatic Generalization for Spatial Information
20.	Spatial Data And Knowledge Bases, Knowledge Representation and Engineering
21.	Modelling and Management of Uncertainty in Space and Error Propagation, Sensitivity Analysis
22.	Spatial Analysis, Geostatistics
23.	Epistemology and Philosophy of Spatial Thinking and Planning
24.	Uses and Socio-Economic Impacts of Geographic Information (Legal, Economic, Networks of Actors)
25.	Modelling and Spatial Analysis of Urban Dynamics
26.	GIS for Coastal Management, Seashore
27.	GIS for Change of Land use
28.	Demographic and Socioeconomic Spatial Modelling
29.	Environmental/Ecological and Urban/Regional Modelling using GIS and Spatial Analysis
30.	Health, Epidemiology and Medical Geocomputation
31.	GIS and Spatial Analysis for Natural Resources Managen and Monitoring
32.	GIS and Spatial Analysis for Disaster and Risk Managem Spatial Vulnerabilities
33.	GIS and Spatial Analysis for Global Change Modelling, Impact on Space
34.	Very High Resolution (VHR) Imagery & LIDAR Data fo Geospatial Intelligence
35.	Segmentation and Classification Issues in Delineating Information from Imagery
36.	Geographic Object Based Image Analysis Methodologies
37.	Bridging the Gap between Remote Sensing and GIS, Field/Object based Models and their Relationship
38.	GIS, Spatial Analysis for Landscape Ecology

1. the transition from technologies and analytical methods on the desktop towards distributed infrastructures and web services also providing analytical and modelling functions (which are necessary for mobile access),
2. a shift from relatively static data sources towards dynamic data flows from sensors and people,
3. a change of end users from technical experts who would collect or access the data from distributed sources and then do the analysis themselves, towards mass-market users and producers of geographic information, or produsers [9].

This could be marled as a democratization of GI systems and infrastructures, or the getting into the mainstream of technological and societal evolution.

4 Where are we going next?

Almost at the same time as the GISDATA Summer Institutes, U.S. Vice-President Al Gore articulated in 1998 a vision of “Digital Earth” as a multi-resolution, three-dimensional representation of the planet that would make it possible to find, visualize, and make sense of vast amounts of geo-referenced information on the physical and social environment. Such a system would allow users to navigate through space and time, access to historical data as well as future predictions based for example on environmental models, and support access and use by scientists, policy-makers, and children alike [10]

At the time, this vision of Digital Earth seemed almost impossible to achieve given the requirements it implied about access to computer processing cycles, broadband internet, interoperability of systems, and above all data organization, storage, and retrieval. As an example, with the technology then available, it was going to take more than 100 years to download the data needed to cover the Earth’s surface at 1 meter resolution, and more than a human lifetime to view it.

Since then, many of the elements of Digital Earth are not only available but also used daily by hundreds of millions of people worldwide thanks to innovative ways to organize and present the data and rapid technological advancements, Geo-browsing (browsing digital geographic information over the web) has become a major industry and introduced novel ways to explore data geographically, and visualize overlaid information provided by both the public and private sectors, as well as citizens who volunteer new data. Moreover, several regional and global initiatives have been launched that contribute to turning the Digital Earth vision into reality. They include for example, the many developments of spatial data infrastructures at local, regional, national, and supra-national level (e.g. INSPIRE in Europe), the Global Monitoring for Environment and Security programme (www.gmes.info), the development of the Global Earth Observation System of Systems (http://earthobservations.org), and the many initiatives in government and science under the banner of Open Data which are gaining considerable momentum (see for example data.gov in the US, data.gov.uk in Europe, Open Science Data, the Science Commons, and the Open Data challenge http://opendatachallenge.org/).

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In addition to these technological and policy-led developments, there is also an increasing recognition that a key challenge of our time is to increase our understanding of the complex interactions between our physical world, and the processes that govern its dynamics, and society, both in terms of the impact of environmental change on society, and of society on the environment. The International Council for Science [11] argued that to address this grand challenge for Global Sustainability Research requires a stronger involvement and greater integration of the social sciences, health sciences, engineering and humanities, along with the natural sciences. In other words, there is a strong need to move from disciplinary research to multidisciplinary research. Moreover, an effective response to global environmental change requires not only better science but also more focused collective action by all stakeholders. This entails two key priorities:

- Communicating science more effectively to close the gap with citizens and policy makers;
- Engaging the public in the scientific process such as helping monitoring the environment, reporting observed and perceived changes and impacts for example via social networks.

With these considerations in mind, several scientists in the academic, government, and private sector felt necessary to review the developments that had taken place since the Al Gore vision of Digital Earth, and update this vision to reflect better new opportunities and challenges. Craglia et al. [12] identified some of the elements of a revised vision, and focused then on the research challenges that need to be addressed to implement this vision. Annoni et al [13] looked at the problem form a European perspective and how best to channel the many policy initiatives and research funding opportunities to make a serious contribution to the new vision, while Craglia et al [14] articulated the vision further from an international perspective, and tried to provide some examples of Digital Earth applications.

For the purpose of this paper, it is useful to look in particular at the 10 research challenges identified in [12] which include:

1. Information integration (multi source and heterogeneous, multi-disciplinary, multi-temporal, multi-resolution, and multi-media, multi-lingual)
2. Space-time analysis and modelling (i.e. universal elements and language for dynamic modelling, algebra of space-time change)
3. Schemes for tiling the curved surface of the Earth and for use in data management, analysis, simulation, visualization
4. Intelligent descriptions (automatic, user driven) of data, services, processes, models, searching and filtering
5. Visualization of abstract concepts in space
6. Computational infrastructures to implement vision (architecture, data structures, indexing, interfaces)
7. Trust, reputation and quality models for contributed information and services
8. Governance models and collaborative frameworks (business, institutional, voluntary, communities of practice)
9. Data sharing and open access policies
10. Social and economic impacts of Digital Earth.

Of course we see a large degree of continuity with the research themes from the 1990s and AGILE 2012 with some added twists. In particular I think it is worth considering further the points under 5, 7, and 10.

Visualization of abstract concepts in space: this includes transformations from lower level, physical observations through indicators defined on them, to abstract concepts like quality of life or vulnerability that need to be modelled and implemented, to support visualization and reasoning. It can also be argued that the increasing citizen-centred use of Digital Earth will shift the focus from geographical space and spatial relations to place, culture, and identity, spanning the physical and virtual space. It will thus emphasize the analysis of networks and flows, and relationships between places (e.g. cultural influences, links established through migratory flows or history) in addition to the traditional spatial analysis.

Trust, reputation and quality models for contributed information and services: Progress from traditional provider perspectives on data quality to broader notions of fitness for use, trust, and reputation is already happening in the context of Volunteered Geographic Information. Models of spatiotemporal expertise can be developed and used in reasoning about the suitability of data and services for specific applications. Research in progress indicates that data cross-referencing, clustering and ranking are suitable means to start validating the quality of contributed information (VGI) [15].

Social and economic impacts of Digital Earth: this includes not just to develop appropriate theoretical and methodological frameworks to assess the social and economic impacts of geo-spatial information, and related infrastructures, but also to consider carefully the ethical and social implications of ubiquitous information systems at time where every one and everything (Internet of things) will be on line at all times. Some research in this direction has started [16] but much more need to be undertaken and discuss in the public sphere.

5 Conclusions

The paper has considered the evolution of the research priorities in GI Science over the last 2 decades, and perhaps the next two. Clearly we can see that we are shifting from GI systems, to distributed infrastructures, and from infrastructures to diffused computing-enabled environments. The agenda is retaining many core aspects of GI Science such as spatio-temporal analysis, and data integration, but also addressing new topics that involve the cognitive sciences, linguistics, sociology, political science, and in general a greater mix of contribution from multiple disciplines. Economics remains somewhat at the margins but the calls for a better understanding of the social and economic impacts of these developments are getting louder, and a more concerted effort in this area is likely to emerge in the near future. Whilst more disciplines are contributing to GI Science, it is also arguable that GI Science is increasingly contributing to the

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multidisciplinary research effort needed to address global sustainability research. This is good news for science in general and GI science in particular.

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