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VIEWPOINT PAPER

ICA Research Agenda on Cartography and GI Science

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The paper presents the ICA research agenda on Cartography and GIScience. The first part discuses the research topics and the second part deals with the 'implementation' of the agenda by the ICA Commissions and Working Groups.

Keywords: Research Agenda

BACKGROUND TO THE ICA RESEARCH AGENDA

Maps and geographic information (GI) have special power through their ability to connect and integrate data sets by the inherent geographical location, and present the information contents in a user-friendly and understandable visual and tactual way. Such ability has long been recognized as an intrinsic property of the map artefact, as well as contemporary geodatabases. The power of maps and geographic data handling has been recently recognized in many real world applications and strategic decision making situations related to current topics like crisis management, early warning systems, efforts for supporting sustainability and decreasing global poverty.

The international cartographic association (ICA), as a globally well represented and internationally visible organization, has a special position and role as a promoter of the development of cartography and GI science. Research and development in ICA aim in general to create theory and methods for cartography and GI handling. By applying theories and methods in various fields, new tools can be created for cartographic and GI practice. Such topics are addressed at the main work-forums of ICA, its Commissions. These organizations are formally established by vote at the quadrennial ICA General Assemblies, although interim Working Groups can also be established between General Assemblies by the ICA Executive Committee (EC) to address specific short-term issues.

The idea of the ICA Research Agenda on Cartography and GI Science was initially considered at ICA Executive Committee meetings during the 1990s but the specific decision to work on a structured Research Agenda was taken at the London EC meeting in 2001, with a plan to organize a session on the issue at the International Cartographic Conference in Beijing in 2001. This session included several valuable presentations (including those from Professors Gruenreich, Meng, Mullen and Ormeling). The work plan for the Research Agenda development was made during the Mexico City EC meeting in 2005. It was realized that several ICA Commissions had overlapping research concerns while some new challenging topics were outside of any Commission's field. A formal Research Agenda would have a significant role in informing Commission members, General Assembly Delegates and ICC attendees, of the integrated nature of research activity in Cartography and GI Science, the expanding scope of research and the role of ICA in promoting such activity. It should be realized that the content of the agenda represents a snapshot in time. Agenda like these should anyhow be considered to be living documents adapting to new technological and methodological developments over time. This paper consists of two major parts, the content of the research agenda and the current 'implementation' by the ICA's Commissions and Working groups.

THE GOAL OF THE RESEARCH AGENDA

The goal of this agenda is primarily to give some guidelines for the Commissions' work as well as to lead to tighter cooperation between Commissions. The agenda can also support the development of the flexible Commission structure of ICA. From a practical point of view the agenda may outline the future contents of the proposed International Yearbook for cartography and GI science.

More widely, the agenda is written in order to show ICA's actual and potential contribution to scientific research within our global society, and to serve as a moderator for discussions in that forum. In order to implement its own strategic mission, 'to ensure that geospatial information is employed to maximum effect for the benefit of science and society' (ICA Strategic Plan, 2003), ICA must have a clear agenda for research covering all fields and topics under the title Cartography and GI Science. This agenda, therefore, documents current research activity in these fields, suggests areas where more

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intensive or renewed effort is required, and also discusses the methods by which some of this research can be undertaken – within ICA Commissions, through international collaboration with sister societies, and under suggested programmes of integrated research stimulated, we hope, by the presentation of this summary. It also reveals the gaps, e.g. items important for the agenda but not intensively covered by the research activities of the Commission and Working Groups.

PROCESS OF DEVELOPING THE RESEARCH AGENDA

The first preliminary study on research topics within the remit of ICA was made in the 2003 Budapest meeting of the EC and Commission chairs, who tried to outline the topics of interest to each Commission. The work was continued in 2005 in the Mexico City EC meeting as well as in A Coruña in 2005 in two brainstorming sessions for Commission and Working Group chairs and co-chairs, and the first draft documents outlining the research interests of Commissions were created. In the meetings the Mind Map technique was used and, based on that work, the first draft document was written, presented to the 2006 Moscow EC meeting, discussed and subsequently sent to the Commissions for comments. Commissions have been asked to provide additional text with relevant literature references on the topics that they feel important. The second draft was discussed in the EC meeting in Brno in 2007 and the plan for finalizing the agenda as well as publishing it in the Moscow ICC Proceedings was made. Before presentation, another round of comments among the Commission chairs has been organized. After the Moscow conference the new Terms of Reference of the Commissions and Working groups were analyzed based on their 'relevance for research'. Via an online survey among the chairs of the Commissions and Working Groups these were matched with the content of the research agenda, revealing gaps and overlap among Commission and Working Group research activities.

THE STRUCTURE OF THE RESEARCH AGENDA

The scope of the agenda is wide including both Cartographic and GI Science issues. Depending on the background of the interested researcher, the entire field can be approached by several ways. It is impossible to make a generic structure of the topics that fits all opinions. It is also impossible to create a non-overlapping hierarchy of research topics. What has been done on the basis of common discussions has now been organized under subtitles or keywords. The definitions as presented by ICA (2003), have also influenced the scope of this agenda – a primary intention is to ensure that the topics discussed here fall within the accepted extent of Cartography and GI Science, and that we can also see synergies with closely related fields, notably in spatial data collection and handling.

KEYWORDS

The keywords have been extracted from the mind maps produced in the brainstorming sessions referred above. Short discussion on the keywords has been added in order to explain the role and/or meaning of each keyword. In the following text the important research topics are in bold. References to supporting fields of science or technologies are written in italic. It must be kept in mind that the topics cannot be organized totally hierarchically under the main keywords, but there are several topics that could be linked to more than one keyword.

The keywords are:

1. Geographic information: we have decided to mainly use 'geographic information' in this document. Geospatial Information is considered as a synonym, and Geospatial is used in contexts where it is commonly used.
2. Metadata and SDIs: in the text spatial data infrastructures (SDIs) have a synonym of 'geospatial data infrastructure'; by adding the geoprefix we can emphasize the real contents of the data in question.
3. Geospatial analysis and modelling: the emphasis is on the extraction of added value from the processing of spatial data on maps and the use of analysis and modelling techniques to initiate, support and supplement the mapping process.
4. Usability: this keyword covers a range of issues which connect the human user of spatial data with its representation, its processing, its modelling and its analysis.
5. Geovisualization, visual analytics: here the visual representation of spatial data, in map and in other forms, is discussed, along with methods of using such representations.
6. Map production: this keyword stands for the numerous stages in mapping and map production as technical processes, but also production of various map types from atlases to Internet maps.
7. Cartographic theory: the fundamental concepts which form the basis of all our spatial data handling are incorporated under this keyword.
8. History of cartography and GI science: the importance of the development of methods and practices throughout history was recognized in the brainstorming session: all current-day activity is informed by detailed accounts of such development.
9. Education: to ensure a valid and viable future for our current activity, we need to research and implement methods to educate and train future generations: methods of doing this fall under this research heading.
10. Society: a dominant research topic throughout has been the examination of how such spatial data handling is grounded in societal structures and how it is undertaken by different groups of people.

These keywords, with their related research topics are summarized in Figure 1.

Geographic information

Geographic information is the core of both cartography/mapping and GI science/GI systems applications. Geographic information can be studied from various points of view: modelling, storing, processing and semantics.

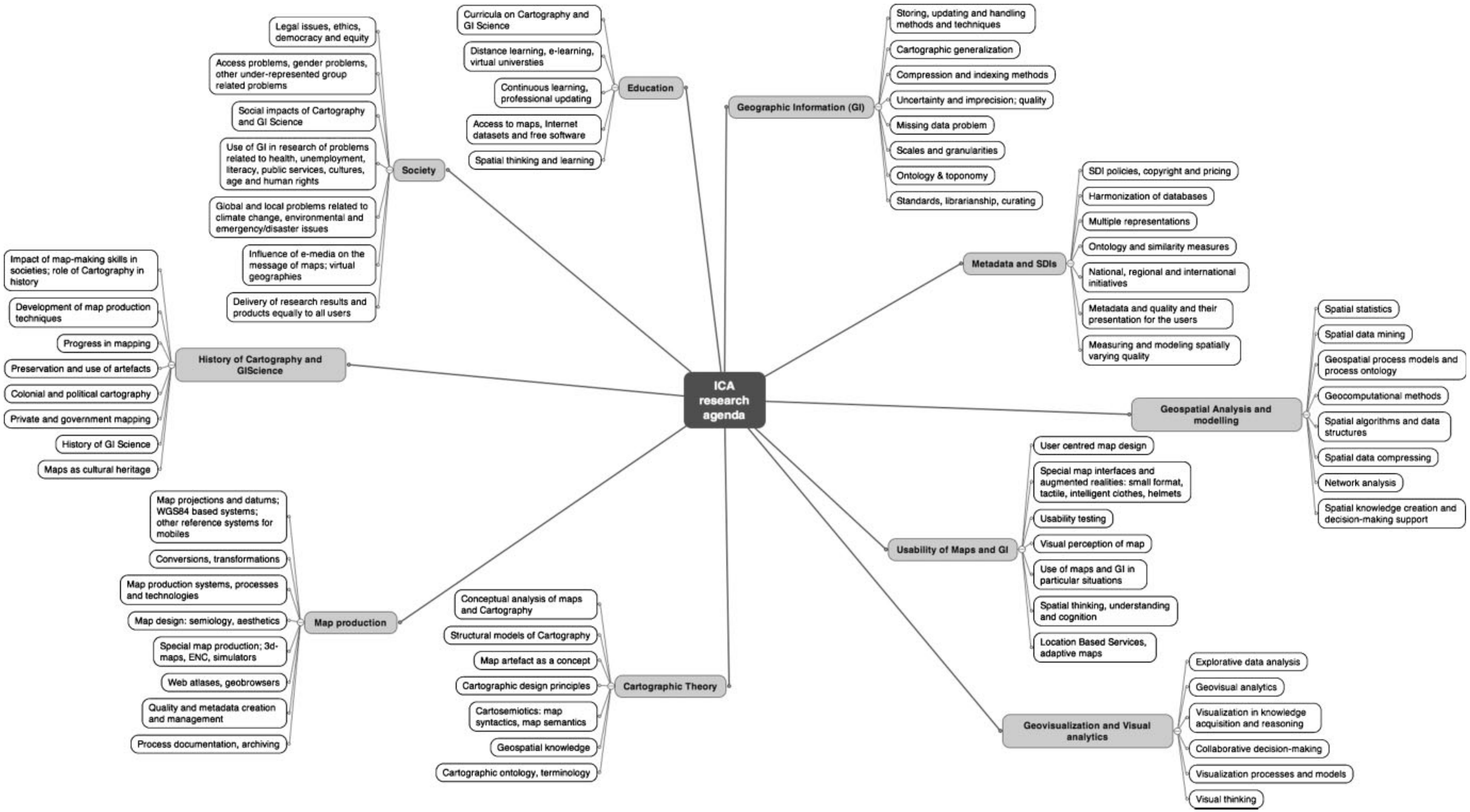

Figure 1. The main items of the ICA research agenda and their sub-topics

Geographic information represents the natural and man-made, tangible and intangible world. Two main established models are used to represent various phenomena: discrete objects and field models. In addition to precise, crisp data, GI can also be imprecise and imprecise information needs special modelling approaches. Thus, it is important to consider research into **imprecise geospatial data models**, such as **fuzzy models** and **rough sets**.

Geographic information needs to be stored and handled as data in databases. The main methods of storage involve raster and vector organization. Spatial databases tend to be huge and spatial queries need to be supported by adequate **spatial indexing**. Some solutions already exist – like quad-trees and R-trees – but the topic is still relevant for further study in the context of GI. The dimensionality of spatial data – two-, three- and sometime four-dimensional in nature – adds to the complexity of handling such data. Advanced indexing methods exist but they need to be applied to the context of GI (see also the section on 'Geospatial analysis and modelling').

Databases need to be continuously updated and the techniques for updating are problematic. Basically two main approaches exist:

1. Continuous updating, usually used when maps are derived from larger scale maps (e.g. detailed municipal large scale maps), and supplemented by other updating methods such as field-based methods.
2. Updating based on digital images by using change detection methods or replacing maps entirely by newly interpreted ones. Thus research is needed to address **incremental updating and versioning** of vector format geographic databases and updating of map databases by using digital images and **change detection methods** on images.

Geographical databases themselves are huge, and via the Internet one can reach even more information in integrated databases than is possible to manage. Using new methods of **spatial data mining and visual data mining** users can create new information and knowledge from the stored data. Satellite images as well as other gridded data products can also be mined and novel information and knowledge can be extracted from them by **image mining and automated knowledge extraction**.

Satellite data and orthophotos are often used without interpretation as additional information in image maps. When combining interpreted, usually vector, and non-interpreted, usually raster, information together, problems of **scales and granularities appear**.

The distribution of geospatial data across the Internet is becoming widespread, but there are many barriers to simple and effective access to geospatial data. **Open geospatial consortium standards for serving data** (www.opengeospatial.org) are designed to assist, but they are not universally applied: there are implications of the contemporary geobrowser (e.g. Google Earth) model for cartographers to address, in handling, compiling and presenting geospatial data.

The semantics of GI links research to various application fields with related taxonomies of concepts. **Ontology** is an approach that aims to produce a common framework for different terminologies. **Toponymy** is related to GI in the sense of semantics as well. These topics affect attribute tagging, name (including geographical name) determination and processing flow lines in geodatabases.

Metadata and SDIs

Complete geospatial data infrastructures (SDIs) consist of contemporary, comparable and integrated GI at global, regional or national levels along with services that enable an efficient use of the information. There are numerous research issues associated with the design, implementation and use of SDIs. **Spatial data infrastructures policy** including the political and administrative procedures required to initiate and maintain SDIs can be studied in order to enhance their utility. In practical terms there are problems such as **copyright and pricing policies**. **Harmonization** of databases can be based on appropriately applied **ontology schemas** and developed **similarity measures**. The fact that detailed geographic data are collected at different levels (municipal, regional, national) means that SDIs are likely to contain **multiple representations** in order to obtain the vertical integration. Effective **generalization** of maps as well as organization of multiple representations in databases could rationalize the production of topographic maps and assist in updating of databases. Such generalization requires significant consideration of conceptual schema, geometrical and spatial properties and visual appearance. It can be undertaken in real time (**on-the-fly generalization**) and it has links with Geovisualization and with the modelling described in the next section.

Metadata is the key for geospatial data infrastructures at both national and global levels, and the derivation, storage, scope and use of metadata have been addressed through mature national and **ISO standards** on metadata of GI (ISO 19115:2003) as well as its extension to gridded and imagery data (ISO 19115-2:2007). A special part of metadata describes **quality information**. There is also an ISO standard on geographic data quality (ISO 19113:2002) with definitions of quality elements and measures to be used. However, the **uncertainty** issues are not solved only by publishing standards and by forcing the data producers to document metadata of the produced datasets. The users need to be able to evaluate also **the uncertainty of the results of the analyses** in which they combine several datasets of different quality. Thus evaluation of the uncertainty of the GI analysis results and estimating **the risks of subsequent decision-making** are further research issues of importance.

Metadata is inherently multivariate and **metadata representation by multivariate visualization methods**, along with the usability of such visualizations needs to be examined. The linkages among metadata, data quality and visualization are potentially valuable. The metadata standard for gridded and imagery data, for example, introduces the 'two-dimensional quality coverage concept' and the 'spatially varying quality concept'. These could be used for other data set types as well.

The **visualization of data quality** in general, and such **spatially varying quality** in particular, are examples of how

map quality – including **generalization quality** – can be addressed.

Geospatial analysis and modelling

Using geospatial analysis we try to describe, explain and predict geographical phenomena. Theories and methods adopted from mathematics, statistics, computer graphics and information theory have been integrated with GI Science approaches to yield a mature and useful toolbox for such analysis.

Spatial statistics represents one of the most important and core methodologies. Although not a new area in GI science, there is a scope to expand its applications considerably. In **spatial data mining** it is one of the core techniques and specific topics such as **geostatistics**, **spatial autoregressive processes and point processes** deliver techniques of considerable interest. When applied to **multivariate analysis**, further specialist methods such as traditional principal components analysis and factor analysis, or more recent self-organizing maps and k-means clustering analysis can be used.

The development of realistic **geospatial process models** and those which incorporate time (**spatio-temporal models**) in a realistic manner will lead to improved representations of the real world. The models themselves must be understandable, applicable to a range of data sets and situations and must be capable of integration with others in processing workflows: **geospatial process ontology** needs development to ensure compatibility and interoperability.

Several computational methods can be used in implementing these geospatial modelling and analysis methods. Intelligent agents, cellular automata, neural networks and fuzzy logic are examples of **geocomputational methods**, which have not yet been adopted as standard computational solutions in GI applications. **Algorithm development** is often undertaken on an ad hoc basis for specific tasks, but it may well use particular **spatial data structures,** such as Voronoi and TIN (Triangular Irregular Network) models, or use particular approaches, such as **data compression** (e.g. wavelets) or **network analysis** based on *graph theory*. The latter, in particular its extensions (e.g. labelling and weighting of graphs), has not been researched and applied enough in spatial problem solving.

All these techniques to get spatial information and **create spatial knowledge**, related to data quality and risk issues, can be implemented to support **spatial decision-making**.

Usability of maps and GI

The starting point in the study of usability is the users themselves. These may be professional users such as administrative personnel and planners; some important groups of dedicated map users including children, the visually impaired, tourists, military, mass media, Internet users, ubiquitous/mobile users; along with occasional and amateur users.

Because of the large number and variation of users, map design should always be user oriented (**user-centred design**) and be based on good knowledge about the elements of usability. Today, maps are most often digital and interactive and thus users are able to dynamically retrieve data for display and analysis from data bases. The representation of information needs to be different for different user groups. The previous situation where maps were graphical presentations with limited data contents that needed interpretation no longer applies. The limitation of the map now is more often the **small size of the screen** in the display equipment. The **design of map interfaces** for Internet, mobile devices etc. creates a most demanding design problem. The special users of maps like visually impaired people would enjoy also various forms of interaction using **tactual and audio interfaces** to maps. For navigation and way finding applications even more exciting interfaces have been developed like **augmented realities in helmets** and **intelligent clothes**. The creation of **usability tests** – both qualitative and quantitative – for new maps and other visualizations, for example **multivariate visualization techniques**, is a challenging field.

Understanding cartographic communication is the starting point for both map design and usability analysis. **Cognition** and **visual perception** have been analysed in order to get theoretical basis for **map design rules**. Perception of maps leads to information acquisition and learning about the topic. Research in *psychology* and *physiology*, which cartographers should be aware of, continuously reveals new knowledge about the human perception processes: it would seem valuable to follow this and ensure that visual perception, as well as **audio and tactual perception** is taken into account. *Learning theories* based on contemporary approaches to perceptual studies also support **map design** and **map use research.**

The users themselves are finding, querying, reading and applying maps in different ways than before. Research into methods of **data assimilation** and **use of maps and geospatial data in particular situations** (e.g. personal navigation) is necessary to assess the impact of contemporary displays in, for example, satellite navigation systems, public map displays and through unconventional media such as mobile devices. The role and meaning of **mental maps**, **cartoids and cartograms** are emphasized among researchers of **cartographic communication**. The skill of **spatial thinking** and **spatial understanding** of problems must be kept as the basis of map design.

It is clear that an increasingly large number of map users are accessing cartographic products through mobile and position-enabled devices. It is absolutely essential that such forms of map use, here related to the broad field of **location based services**, are effectively undertaken, and both the technology and the use of location based services are areas of prime concern to cartographic researchers. **Adaptive maps** modify themselves according to their location as well as the preferences and situation of the user. Contemporary research on *navigation systems*, satellite systems like the global navigation satellite system and other *positioning methods* should be carefully examined by cartographers to detect synergies.

Geovisualization and visual analytics

Because there will always be a demand for paper mapping, studies of the **effectiveness of static two-dimensional products**, as well as (for example) three-dimensional scale models products are always needed. But Geovisualization techniques have extended the map medium to embrace **dynamic, three- and four-dimensional data representation** using methods which are interactive, capable of being supplemented by augmented and virtual realities, integrated with geodatabases, and flexible in application, platform, scale and content. In many cases these involve multi-dimensional and multivariate representations such as parallel coordinates plots and star diagrams, along with interactive techniques such as brushing.

A research agenda for Geovisualization was published by the ICA Commission on Visualization in 2001, and progress since then has addressed research areas such as **representation methods** (including virtual environments), **database linkages for visualization** and **cognitive issues** in Geovisualization and knowledge acquisition through visualization.

The more recent subject of **'visual analytics'** extends the geovisualization metaphor further to embrace integrated **data mining** and the development of **decision making** techniques through **spatial thinking, visualization, analytical reasoning** and **knowledge engineering**. Further new visualization developments in the field of *games and simulators* can be profitably examined in order to adopt novel and effective tools and methods for geovisualization. Visualization is tightly linked to analysis by the means of **explorative analysis**.

The importance of **collaborative decision making** supported by spatial representations and data sets is growing in many areas of human activity. For example, instead of one planner and decision-maker there is a group of people at the same time around the same planning/decision-making task or accessing the same representation. Collaborative methods try to support these kinds of situations. In collaborative visualization instead of one person, there is a group of persons who are able to see the visualizations at the same time. This can happen in one space (for example, on a large or multi-screen or in a virtual reality cave automatic virtual environment) or in many places. Using the Internet it is possible to transfer both the visualization and the interactions of several users to allow for remote collaboration. There are technical issues such as updates, synchronization of the data transfers and management of conflicts, which need to be solved. Collaborative tools as well as single user tools enjoy the existence of **multi-media**.

It is important to realize that the focus of research in Geovisualization is not on the technical execution of the representation (although this is fundamental to the process), but is more directed to the data management to enable this, to possible tasks and application areas, and most notably to the role of the user in the **visualization process**. Thus, the impact of the visualization on **knowledge acquisition** (does the map present unknown information, or is it used to display and confirm previously known information?), its role as an **investigative tool** (is the map for private study, or is it part of a more public decision making process?), and its **didactic capabilities** (is the map being used interactively or is being read passively?) can be researched through **models of visualization**.

Map production

Map production has long been a core practice of cartography. Based on *geodetic, photogrammetric, remote sensing or laser scanning* based methods, topographic map production is a part of the *surveying* process. In each country, topographic mapping has its own traditions, including selection of the **map projections and datum**. Nowadays in many countries the geocentric **WGS84 based systems** are applied, but it is still an important part of cartography to know the properties and applications of various projections and manage their application and the **conversions** between them. In practice many GIS software tools offer transformations from projections and coordinate systems to others, while mobile and ubiquitous applications might sometimes require **transformations on the fly**. Map projections and transformations, along with associated mathematical studies of **distortion**, are valid areas of cartographic research. It is noteworthy that it is not only topographic mapping which must address these issues: the importance of **reference frames to mobile applications**, and the study of **transformations of raster imagery** (from satellite, aerial platforms and ground-based) are also essential, as is the reference system adopted within GI layers.

Map production technology is a rapidly developing field. The new mapping technologies of *satellite remote sensing, laser-scanning technologies and advanced global navigation satellite system technologies* offer both fast and accurate acquisition of topographic data. However they also give new challenges for research and development as well as innovations for several application areas. A continuously developing range of field and remote data collection techniques ensures that **map production flow lines** must be able to handle spatial data varying in source, format, scale, quality, reliability and area of coverage.

The role of cartographic knowledge as applied to map production is still important. **Map design**, already mentioned in connection with usability, covers issues such as symbolization, text and label placement, generalization, colour selection and layout design. Such tasks always require understanding of the data compilation, the information compatibility and skills for aesthetic design. In cases of multi-lingual countries and production of printed maps, label placement is a challenging subtask in map design. Collection and standardization of **place names** as such is an important part of map production and has important links to **ontology** and **information management** issues.

The applications of map production processes and their development are core topics for public and private mapping organizations. There is a continuous interest in rationalizing and modernizing the production of maps and geospatial data sets. Such processes can differ depending on the map type: topographic or thematic, large or small scale, printed or digital. In topographic map production processes, the actual problems can come from **quality management** and **harmonization** needs, which may themselves be guided by the requirements of geospatial data infrastructures. In many countries there are attempts to rationalize and synchronize municipal and national mapping by trying to harmonize the data contents and take care about the quality management of production. **Quality models**, **up-to date metadata descriptions** and associated **process documentation** are central issues.

An enormous number of different categories of maps can be, and are, produced by a variety of methods. Thematic maps address particular concerns and portray specific data. Each category may have research issues associated with it. Some examples from specific ICA Commissions include: mountain maps, which must efficiently portray **three-dimensional representations**; marine charts, which must incorporate ongoing developments in **electronic nautical charting**; environmental maps, which are valuable contributors to **risk mapping** for early warning applications; military mapping, which can also assist in civil crisis management, but is also responsible for planning and execution of complex, technologically advanced military manoeuvres and campaigns, both in real-time and in **simulators**. Examples of other thematic map categories which could benefit from applied research work include tourist maps, orienteering maps, advertising maps, artistic maps, fantasy maps, geological and geophysical maps, cadastral maps, personalized maps, aeronautical maps, poverty maps, maps in text books, and mass media maps. Some thematic maps have global relevance because of the application: maps supporting scientific investigations into immediate problems, such as climate change and sea-level rise, are among the most important of these.

Other mapping functions for which production (perhaps as well as compilation and design) is a major issue include **atlases** and **atlas information systems**. The future of atlases has been debated for a long time, since the first versions of digital and interactive atlases were introduced. Multimedia atlases came soon after and now the concepts of Atlas Information Systems and **web-atlases** have been introduced and supplemented, supported by **geobrowsers** such as Google Earth and Wikipedia. Technologies to support the cartographic and GI data handling requirements of such products have to develop. Tactile and audio maps need special design and production technology; they cannot be side products of regular maps and are often not easily derived from the data.

The established tasks of map production, in addition to being subject to variability in data handled, method of representation and application area, are subject to overriding practical issues such as **economic, legal and security matters** (including confidentiality). Legal issues include **copyright, privacy, liability and illegal use detection** (using cartographic traps). Economic issues which can be researched include production models and map marketing. Finally, once the maps have been produced or the databases have been implemented, there is a need to manage the archive which they represent. This covers areas such as **archiving, updating, metadata extraction** and **recording** and further **librarianship** issues. As unique documents which need specialist curators and library resources for acquisition, storage and consultation, the role of maps in the contemporary library is changing. And as spatial data becomes increasingly available in non-standard media, the role of the curator must expand to incorporate new skills.

Cartographic theory

Fundamental cartographic theory has been addressed by the ICA Commission on theoretical cartography over many years, recognising that from a methodological point of view, **conceptual analysis** in Cartography is very important. Various **structural models** of cartography (or its parts) have attempted to describe the process of mapping as a science, an academic discipline, a technology, or an inherent human impulse. Furthermore, the tasks of **cartographic design** can be deconstructed, and the **map artefact** itself (e.g. is it a model, a language, a communication channel, a decoration or an archive?) can be examined.

Since the mid-1990s, **cartosemiotics** has undergone development. It has general (theoretical) and applied (user-oriented) subdivisions, the latter encountered in both cartographic and non-cartographic traditions. Outside of the cartographic tradition, cartosemiotics may be applied in biology, geography, ecology, geology, linguistics, etc. The **map semiotic approach** to Cartography allows us to examine **map syntactics** (which links the graphical representation with *aesthetics* and other parameters of design), **map semantics** with **map sigmatics** (indeed this can form the basis of many studies of cartographic ontology) and **map pragmatics** (which attempts to cover the entire area of human experiences with maps, from perception and cognition, through use for navigation, to employment in *artistic, cultural and literary* works). Such an investigation can improve the effectiveness of representations and data modelling.

There are various communication and visualization models as presentation forms in Cartography. Furthermore, cartographic representation entails **conceptual modelling** of the world and can thus itself be studied as a **cognitive process**. The new term **'conception-analytical approach'** is a research area which has significant links to diverse conceptual models and spatial data handling in GI systems. More properly allied to spatial analysis, analytical cartography makes use of the spatial representations which cartography produces in order to examine patterns, trends and measures in the data. Analysis transforms geospatial data into knowledge. The nature of such **map/cartographic/geospatial knowledge** must be recognized, along with methods for describing and managing that knowledge. Cartographic theory may also assist in producing **cartographic ontologies**, which can be fundamental to the exploitation of cartographic databases and their applications. **Terminology** within cartographic fields themselves can be identified and developed: for example, glossaries of definitions and terms used in specialist areas.

History

Cartography and the visualization of GI have a long and well-documented history. Considerable research is ongoing into a range of issues which can be regarded as dealing with the history of cartography. These include **the impact of map-making skills in societies** throughout history, the way in which maps and GI have been used (both practically and for political and symbolic purposes), and the **development of methods of production** and the **effect of changing technology**.

In addition, historical studies have examined **'progress' in mapping** (e.g. increasing accuracies, scale, content, reliability throughout history – although not necessarily unidirectional) and have also been concerned with the **preservation of the artefacts** themselves. Within these broad approaches, specific issues can be identified. The history of **printing technology** is of considerable interest; the role of **colonial cartography** has been immense, especially in the 19th and 20th centuries; the dichotomy between **private and government mapmaking** has been fluid over many centuries. Such specific issues can be added to by considering the way in which recent and **contemporary history of cartography** is being addressed. It is important to document the rapidly changing and artefact-poor recent **history of GI science** and digital cartography.

In addition to the history of cartography as a discipline, **the role of cartography in history** has been researched by cartographers. Here the task of mapping, the role of maps, the propensity to map and the resultant impact of maps on a wide range of other human activities have all been recorded.

Perhaps the most active research area currently which has links to this section is considering **maps as cultural heritage**, part of the patrimony and cultural inheritance of a society. But such maps are more than artistic relics – they are working documents which can be used for cultural investigation over a wide range of fields (including *history, genealogy, archaeology, politics, architecture, sociology and geography*). There are significant applications in this field for the application of contemporary digital techniques, and specialist geospatial databases have been created based on historical data, but capable of being examined using modern scientific cartographic analysis.

Education

From a practical viewpoint, it is clear that many of the highly skilled operations associated with cartography and GI handling require training and experience. This, itself, is an area of concern for ICA. In the research context, however, education can be divided into scientific education in universities, education at schools and continuous education as a part of the profession (the latter also includes training and practical 'on-the-job' knowledge acquisition). Research in these areas has examined **curricula**, practices in **distance learning, e-learning** and **professional updating**, **access to maps** and spatial data, **use of maps** to promote attitudes and behaviours (e.g. spatial thinking), and establishment of a profile for cartography which allows it to be applied and integrated with other subjects at school and in society.

University curricula have been changed during the past years: it is clear that GI systems and GI science have taken over a place in the classroom from cartography. The impact of new technologies and political pressures, such as the introduction of the Bologna pattern of study at European universities, has lessened the appeal of cartography. However, cartography is a subject which can and should play a larger role in curricula at many schools and universities. Curricula need continuous updating because of the rapidly developing technology and increasing methodology and theoretical knowledge. International cartographic association must follow the developments at universities and also try to influence the **development of educational programs.** Universities in less developed countries could enjoy **distance learning and virtual education,** as long as the methods and content match research findings in this general area.

Cartography and GI science as school subjects have taken some space in school teaching mainly in the geography and environmental programs. International cartographic association should also try to influence to this change, particularly in developing countries. Schools should be able to enjoy **Internet datasets and free software.** Especially in elementary school education, **spatial thinking and learning** enhanced by using maps are interesting topics. These topics are related with more general research into *pedagogic learning*, but could be recognized more in cartographic research as well.

Society

Society is one of the five main 'areas of operation' of ICA and it also offers many interesting research topics from **legal issues** (including copyright and privacy questions) to **ethics, democracy and equity**. However, accessibility to cartographic and geographic datasets and GI services is a global problem – not all members of society with an interest or need to access geospatial data are in front of a desktop computer. **Access problems** for many make it impossible to get information and participate in the developing digital society. **Gender problems** together with other problems of **under-represented groups and equity issues** are a continuous topic. Within ICA these topics have been long recognized and from the research point of view it could be interesting to analyse the effects of the development of virtual services in an e-government context on the equity of individuals. **Virtual geographies** might also develop people's ability in spatial thinking. Modelling the world, either in an individual or on a collective basis, is one example of **social impacts** that should be seriously studied.

The heading 'Society' covers the collection, handling and representation of many highly varied socio-economic spatial datasets which can be studied using cartography and GI methods. Particularly important areas which are subject to significant contemporary mapping and geospatial data handling activity and research include **health, unemployment, literacy, public services, cultures, age and human rights**.

As a globally visible and well represented organization, ICA can support and enhance the use of such geospatial datasets in the research of **social questions at a global scale**. Such approaches need the support and cooperation of national and international institutions and organizations, including national mapping agencies, global non-governmental organizations and world development bodies, including United Nations bureaux.

With the help of the Internet, maps are now distributed to users in very different ways than they were only a decade ago. This has introduced a host of research questions related to use of electronic networks for map distribution and **the influence of the medium on the message of maps**. In addition, the question arises as to which medium should properly be used in cartography to assure the distribution of maps to the broadest possible audience. Likewise, questions must be asked about **copyright and licensing of maps** that are distributed through the Internet and how sophisticated online map servers will be maintained. This question has links to SDI as well.

From the audience point of view it is most important that **the research results are delivered equally to the users,** whoever they may be or wherever they are.

THE COMMISSIONS/WORKING GROUPS AND THE RESEARCH AGENDA

The Terms of Reference of each Commission and Working Group have been analyzed to see which of their Terms is related to research. It should also be realized that the Commission and Working Group chair had the opportunity to indicate which of their terms of reference is research related. The interpretation of the meaning of research will no doubt vary among the chairs. Its outcome is also qualitative, it does not tell us about the amount of research. Publications of the Commission and Working Groups could quantify the result a bit more.

The result of his exercise is depicted in the schemes in Figures 2 and 3. It will be obvious that the result depends on different factors. Most important is the overall objective of the Commission or Working Group. Not all of them have been established to do research. Since the Terms of Reference are redefined every four years a Commission or Working Group might have decided for a period that concentrates on more pragmatic topics. The background of the chairpersons and changing composition of the Commissions/ Working Group will also influence its focus. Just as the research topics defined in the previous section represent a snapshot in time so do the schemes in Figures 3 and 4.

An on-line survey has been held among the chairs of the Commissions and Working Groups to see which of their Terms of Reference are research related (Figures 2 and 3). In addition they were asked to indicate which of the topics in the research agenda (Figure 1) had the interest of their Commission or Working Group. This is depicted in the diagrams in Figure 4. It depicts a qualitative interest, and does not tell us anything about the amount of activities related to a particular topic. Also not all Commissions and Working Groups have executed the online survey. Eighteen out 22 of the Commissions and one out of six Working Groups returned the questionnaire.

Figure 5 summarizes the relationship between the research topics and the Commissions and Working Groups in a slightly different way and allows us to see common interest between the Commissions and Working Groups that responded to the online survey. This could act as a guide for the chairs to see with whom to cooperate more intensively.

CONCLUDING REMARKS: HOW TO IMPLEMENT THE RESEARCH AGENDA?

The purpose of this research agenda has been to identify and briefly elucidate some current and potential research issues which fall under the terms of reference of ICA and individuals and groups who work under its remit. Primarily this includes the Commissions of ICA each of which is charged with undertaking research work in their area. This agenda is intended to encourage the Commissions to consider their research areas, and to examine possible overlaps and cooperation possibilities with other Commissions. Furthermore, it will assist in identifying those areas of cartographic research which are not currently covered by any Commission and which need further encouragement. Finally, this document should disseminate the agenda of ICA to other organizations, both those with which we can undertake research collaboratively and those for whom the results of ICA sponsored research will be of value.

Clearly, therefore, we believe that this research agenda should be reflected upon by the constituent Commissions of ICA. One of the major responsibilities of the elected chairs of the Commissions is to develop a 'Terms of Reference' document which should explicitly list the deliverables expected over the four-year period of the Commission's existence (the Commissions can be re-elected). Such deliverables should yield valid research results. A further duty of a Commission chair is to invite and manage a group of experts and interested individuals to achieve the deliverables. The work programme can be completed through focused research meetings and conferences (which can be during and around the time of biennial international cartographic conferences or at other times), through ongoing communications within the Commission, and through collaboration with Commissions in sister societies. Alternatively it is hoped that this agenda can be used in a positive way by those individuals who are submitting proposals for funding to regional, national and international organizations.

In all cases, ICA expects the results of research to be widely disseminated for the benefit of itself, the wider cartographic community and society in general. The presentation of a Commission report is required at each quadrennial ICA General Assembly of Delegates and the opportunities to present research findings in the conference arena exist. Publication of research work in academic and scientific journals would also be expected, along with more informal communication through Commission websites.

REFLECTION

Is the agenda as presented here complete? Can it be complete? The answer to both questions should be no for several reasons. First of all, creating the agenda has taken many years due to the organizational workflow with organizations like the ICA. Second, the technology push is stronger than ever and new hypes pass by every few months. However, some hypes prove to be of structural importance, so even when an hype some attention is required. An example is the Google Earth/Maps type of developments.

Another 'hype' not found in the agenda, but picked up by some Commission and Working Group activities is for instance related to Web 2.0. With Mash-ups one can create customized and privatized maps. In combination with other Web 2.0 facilities such as wiki's, blogs, photo sharing, podcasting, social software like facebook, folksonomy and (geo)tagging, as well as RSS feeds users contribute to the collection of georeferenced materials available via the web.

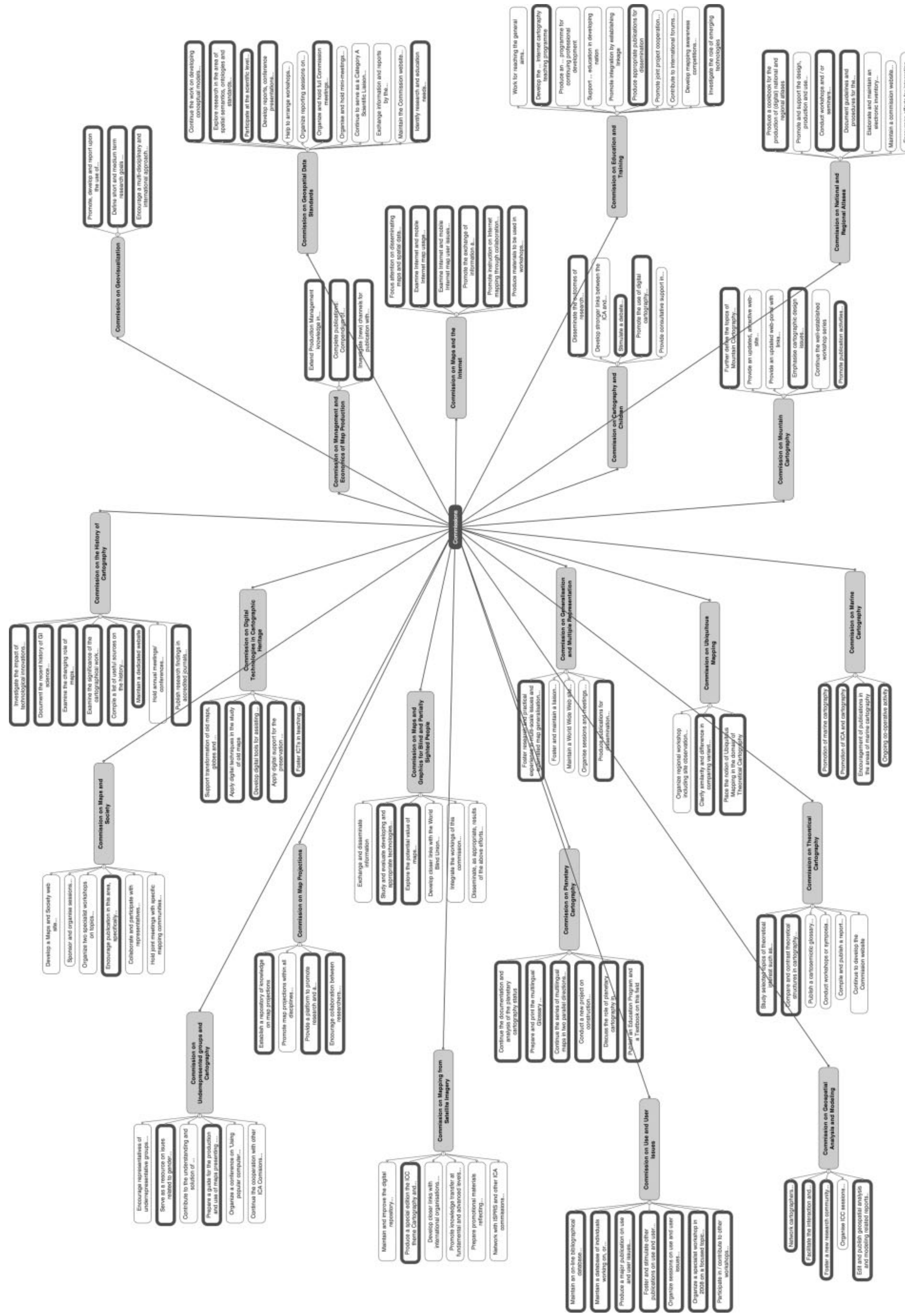

Figure 2. The ICA Commissions and their terms of reference. The research related terms have been highlighted. See http://www.icaci.org/ for details on the Commissions. There is a qualitative and quantitative difference among the Commissions and their Terms of Reference and of what is considered research

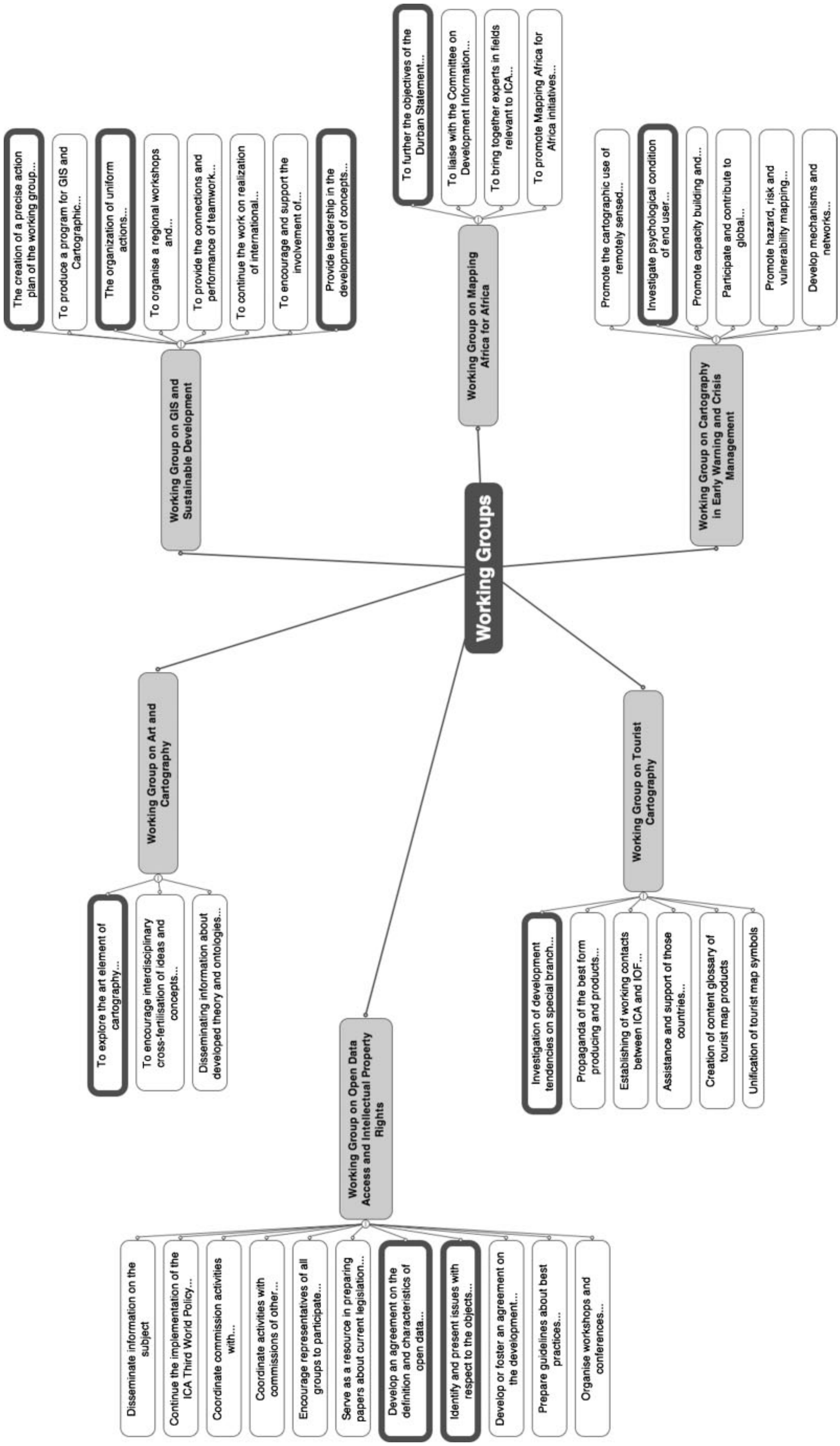

Figure 3. The ICA Working Groups and their terms of reference. The research related terms have been highlighted. See http://www.icaci.org/ for details. There is a qualitative and quantitative difference among the Working Groups and their Terms of Reference and of what is considered research

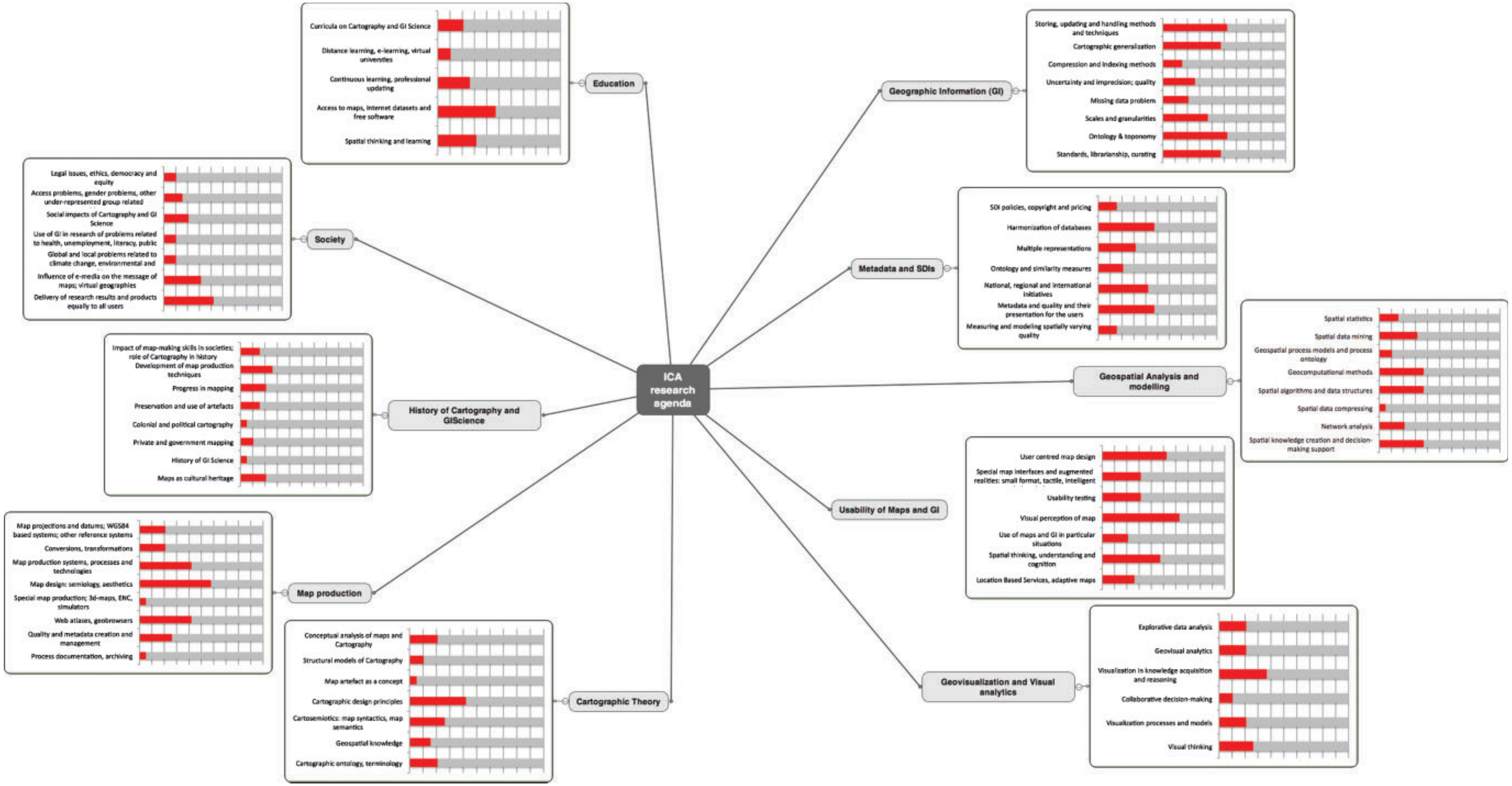

Figure 4. Focus on the agenda's individual research topics. The horizontal bars represent the percentage of Commissions and Working Groups 'interested' in that particular topic based on the data received from the on-line survey

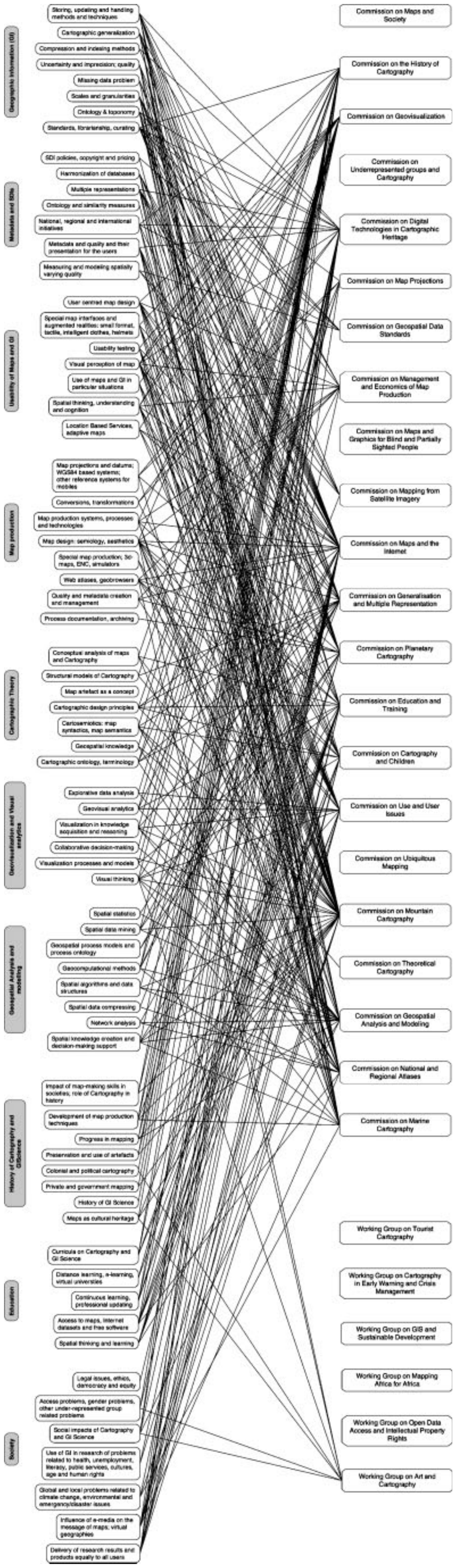

Figure 5. The relationship between the ICA research agenda's individual research topics and the Commissions and Working Groups. It shows common interests and gaps in the execution of the agenda. The diagram could be a guideline for chairs to find partners in tackling particular research problems. It shows that some have a limited interest while others have a very broad research scope. Commissions and Working Groups without links did not respond to the on-line survey

This trend has been 'classified' as neo-geography or when we relate it to the maps 'neo-cartography'. Would it be possible to bring these often informal data collection processes of Web 2.0 together with the formal world of for instance the National Atlas or Topographic Maps, such that both worlds could benefit and one might even think of update via the people?

Map design in a neogeography environment will require innovations of the traditional approaches. The strength of maps is their ability to select from reality and abstract the selection via a well designed symbolization. This results in maps that are characterized by their relative emptiness, by visual hierarchy and have a particular appealing style. Both selection and abstraction are challenged by the current Web2.0 products. This will require attention from many of ICA's Commissions and Working Groups. And these challenges will keep the research agenda alive.

BIOGRAPHICAL NOTES

Menno-Jan Kraak is professor in Geovisualization at ITC and head of ITC's Geo-Information Processing Department. He has written more than 200 publications on cartography and GIS. His most visible publications are three books on aspects of cartography: Cartography, visualization of geospatial data, (with Ormeling) published by Prentice Hall, (translated in 5 languages) and Webcartography, developments and prospects (edited with Brown) published by Taylor & Francis, and Exploring Geovisualization (edited with Dykes and MacEachren) published by Elseviers. Menno-Jan is a member of the editorial board of several international journals in the field of cartography and GIS, and is active in the International Cartographic Association as Vice-President. He is chair of the Foundation Scientific Atlas of the Netherlands.

FURTHER READING

'A Strategic Plan for the International Cartographic Association for 2003–2011 as Adopted by the ICA General Assembly, 2003-08-16' http://www.icaci.org/en/ICA_Strategic_Plan_2003-08-16.pdf).