From macrogeography to microgeography and back: Emerging issues for geographical information handling across scales

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SUMMARY

This paper considers selected current and emerging GIS developments at scales varying from macro to micro, global to local, from digital earth to digital dust. Beginning with a retrospective focus on Digital Earth, the essay addresses contributions to geographic information science at the global level, examines the social implications of GIS at the human scale, and converges on the micro scale to investigate several emergent and potentially revolutionary developments. Finally, by raising the expectation of ubiquitously distributed computing in conjunction with locationally-aware micro sensors, the theme brings us full circle, back to the vast volumes of data that are, and increasingly will be, generated globally and to Digital Earth, or rather, to new forms of digital earth.

KEYWORDS: *Digital Earth, scale, emerging challenges*

INTRODUCTION

Undaunted by its all-encompassing perspective, this paper leaps where angels fear to tread in presenting a cyclical approach to assessing the standing of a highly selective set of emerging geospatial technologies and practices. The objective is to consider current and emerging GIS developments at scales varying from macro to micro, global to local, from digital earth to digital dust. Beginning with a retrospective focus on Digital Earth senso stricto, the essay addresses contributions to geographic information science at the global level, examines the social implications of GIS at the human scale, and converges on the micro scale to investigate several emergent and potentially revolutionary developments. Finally, by raising the expectation of ubiquitously distributed computing in conjunction with locationally-aware micro sensors, the theme brings us full circle, back to data being generated globally and to Digital Earth, or rather, to new forms of digital earth.

The presentation begins at the macro level with a brief review and update on the status of Digital Earth as first envisioned. Next, two themes of considerable significance visualization and spatial analysis of global data (whether or not a Digital Earth is ever realized) are considered. A current initiative of the author and others studies the implications of Digital Earth from the perspective of the effect of universally available global data on human scale relationships and society at large. Primary among these human scale questions are issues relating to the ethics of surveillance, privacy, power, and consent. The imagination is simultaneously intrigued and repelled by the advent and very rapid adoption of wearable, locationally-aware technologies. Locational-awareness next takes the theme of essay to the scale of small and very small spaces. A perplexing problem in locational awareness is

the technological transition required for monitoring the everyday act of going indoors. Radio frequency identification (RFID) offers some potential here, but only to limited scales of resolution. The paper considers the use of locational tagging in small spaces such as rooms. What does GIS have to offer the forensic specialist, for example, at room-scales or at the microscopic level? At present the limits, conceptually speaking, are at the scale of smart dust and nanotechnology. And from this smallest of scales we return to the digital earth and a future that will inevitably embody ubiquitous computing. So from distributed micro sensors and ubiquitous GIS, we come full cycle, back to Digital Earth. Undoubtedly unprecedented volumes of data will flood from all imaginable objects and fields at all scales from macro to micro.

In order to bring a degree of synthesis to these sweeping themes, some critical issues are identified from the American geoinformation community. Drawing on research priorities and recent UCGIS presentations these are related to AGILE research challenges.

GEOGRAPHIC INFORMATION SCIENCE AND SCALE

It was David Gelernter in "Mirror Worlds" who appears to have been among the first to forward the analogy of the microscope and telescope with regard to massive information systems and software models of complex realities such as cities. Such models "are scientific viewing tools – microscopes, telescopes – focused not on the hugely large or small, but on the human-scale social world of organizations, institutions and machines; promising that same vast microscopic, telescopic increase in depth, sharpness and clarity of vision." (Gelernter, 1992 p.5.) Gelernter's vision of vast quantities of multiple scale, deep, real time information provides the necessary impudence for the organization of this talk.

MACRO SCALE

This section relates to the global scale and assesses the current state of the Digital Earth concept and its progeny. It pays particular attention to digital global grids and the need finally to move away from a flat-earth conception for small-scale, i.e. global GIS representation and processing. ERSI's ArcGlobe™ notwithstanding, there is a major gap between science, capability and practice in global representation. That gap is most rapidly being addressed in scientific visualization and multimedia, but is moving somewhat more slowly in spatial analysis.

Seven years ago here in Portugal, Professor Michael Goodchild addressed the GIS Planet conference on the prospects for a second age of geographical discovery using Digital Earth to rediscover the world through GIS (Goodchild, 1998). At that time there was a considerable buzz around Digital Earth; Vice-President Al Gore had raised the political awareness of an active area of research in geoinformation and communications technology by reviving the concept in a speech to the California Science Center (Gore, 1998). Seven years later, the promise does not seem quite so imminent or the progress so energetic (see Longley et al, 2005), but the vision of a Digital Earth, or several instances of it, still persists as a future, if more distant possibility. So what then are the active themes in geographic information science research at the macro level, the global scale? Visualizations of three and four dimensional Earth, digital global grids, and analysis methods for global data are three examples of a wide range of possible themes that have enormous potential in the near and short term.

Vice-President Gore described Digital Earth as a "multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of geo-referenced data." (Gore, 1998) At its core, the initial Digital Earth concept was an organizing structure using the Earth as a data model for access to, and exploration of, numerous types of data, information, and knowledge. As a form of digital library the model draws on that of a geographic footprint (Goodchild et al, 1997). Digital Earth was global in conception and implementation, but emphatically local in use.

The implementation of Digital Earth integrates digital spatial and statistical data, as in a conventional GIS, and scientific knowledge of human and physical systems with an unprecedented ability to simulate and analyze these processes in a publicly accessible and interactive interface. This

vision looks forward to future generations being able to explore features, events and process on the earth's surface by developing and integrating numerous distributed databases, visualization technologies, and analytical tools, especially for spatial-temporal analysis. Digital Earth researchers started developing and sharing digital spatial data, information, and knowledge towards "an immersive environment through which a user, particularly a child, could explore the planet, its environment, and its human societies" (Goodchild, 1998, p.4.). Motivated by a 'Big Science' analogy to the human genome project Digital Earth is a means to raise the perception of the important and value of geography and geographical information. It is worth asking whether Geographic information science needs a "Big Science" ticket. Two events in the past six months serve to highlight the need for a wider public appreciation that could stem from such a label. These events were the Indian Ocean Tsunami disaster of December 2004 and the announcement in March 2005 of the Millennium Ecosystem Assessment (Millennium Assessment Organization, 2005). Global scale geospatial information analysis and dissemination are at the heart of these events, one highly publicized, the other far less so. Although some recognition of the critical role of spatial information and knowledge was raised in each case, the financial commitment to global GIScience research remains relatively low.

What then is Digital Earth today? For political and economic reasons, the concept of Digital Earth has survived in different forms than originally proposed. What forms do these various interpretations of Digital Earth take? Are they operational applications or do they remain virtual; lingering as ambitions rather than specifications?

In one guise, the US federal government defines Digital Earth as "a virtual representation of our planet that enables a person to explore and interact with the vast amounts of natural and cultural information gathered about the Earth." (Consensus definition adopted at *2nd Interagency* Workshop, 1999 Sept 23.) Arguably the strongest research initiatives have been associated with distributed geolibraries (National Research Council, 1999), NASA's Land Processes Distributed Active Archive Center, which includes the Earth Observing System Data and Information System, (EOSDIS, http://edcdaac.usgs.gov/main.asp) and discrete global grid initiatives, such as the 2nd International Conference on Discrete Global Grids (http://www.discreteglobalgrids.org/). Other practical developments have been realized by the Federal Geographic Data Committee (FGDC) in the National Spatial Data Infrastructure (NSDI), and more explicitly, as the Geospatial Applications and Interoperability Working Group (GAI). The FGDC has pursued the Digital Earth Reference Model (DERM) and the Geospatial Interoperability Reference Model (GIRM) as templates for the standards and specifications to enable Digital Earth interoperability.

Additional Digital Earth projects have been maintained through international collaboration. For example, the International Symposium on Digital Earth (ISDE) has been hosted by China (1999), Canada (2001), the Czech Republic (2003) (http://digitalearth03.geogr.muni.cz/b), and convened recently in Japan (2005) (http://g-web.sfc.keio.ac.jp/nishiyama/isde/eng/home.html). In the private sector, SRI International's ARPA sponsored Digital Earth project incorporates Gore's vision of a connected suite of technologies with the vision of enabling a massive, scalable, and open model of the planet where millions of users can interact with vast quantities of geographically referenced data over the Web (SRI, 2005). SRI's ostensible goal is to create an open infrastructure that allows anyone around the globe to publish or to search for data based upon a specific location. However, SRI is a major military contractor so the real impetus for the effort may well be hidden.

MESO SCALE: A SOCIAL TURN.

It is audacious to assert that any of the myriad aspects of GIS at the human scale can be reasonably prioritized for scrutiny. Clearly such a selection is a highly personal choice and by necessity somewhat arbitrary. From the social context I have selected 'wearing location' as being particularly apposite to the rapid development of location based services, which is in turn linked to the section below on micro scale developments by virtue of the inexorable spread of locationally aware sensors.

Today, the availability of data on individual human beings raises serious ethical issues of consent and privacy and innovative and necessary research is related to identity masking (Rushton, 2005).

At the human scale, critical and contentious issues revolve around information communication and access rather than technological barriers. The social critique of GIS raises privacy militarization, and elitism as three major areas of concern. One such critique, the GIS and Society perspective on Digital Earth, is a project concerned with the rapid diffusion of sources and sinks of digital spatial information and how power relations at multiple scales mediate this information (Elmes et al, 2004). The project builds on previous research and conversations about Digital Earth, but does so from a GIS and Society conceptual framework. The GIS and Society perspective on Digital Earth suggests broad areas for research. Privacy, confidentiality, and power, appear to some scholars to be immediate impediments to much greater public-participation GIS usage and hence form priorities for research and development.

The core conceptual questions for this initiative are as follows:
One GIS and Society research perspective on Digital Earth establishes who controls digital spatial information. The project seeks to understand the political and institutional frameworks by which data is produced and distributed, including the origins and purposes of such data, and who has the ability to control its content and access to it. A second theme inquires how access to digital spatial information impacts power relations, and how power relations influence access at the multiple scales of analysis. There is often a distinction between the potential users (those that the producers imagine to use the information) and the actual users, who may be unexpected and not anticipated by the producers. Determining the characteristics of usage is a particularly difficult research question.

Advances in scientific visualization have a major role in the display of Digital Earth data. The visualization of Digital Earth privileges information that is easily rendered to resemble the Earth over information that can only be represented symbolically. What are the implications of this privileging for our understanding of the planet? In this context, the initiative explores the visualization of landscapes in Digital Earth and how such representation of places might impact, and be impacted by, local politics and environments.

A fourth subtopic investigates the politics of scale and asks how Digital Earth might scale, reproduce, reinforce and reflect power. Multiple scales are present, but are contributions of local data and applications prevalent, or even present? This focus concerns the incorporation of socially-differentiated local knowledge into geo-spatial databases and their eventual inclusion in Digital Earth. The diverse participatory geographic information systems in use today lead to the question, “Is this global technology creating powerful information locally and for whom?” Ethics is a fifth area of investigation. Who decides what is ethical and what information should be included, excluded and made available on Digital Earth? Aspects of an ethical perspective include investigations of digital imperialism, geoprivacy, and geoslavery (Dobson and Fisher, 2003).

MICRO SCALE: UBIQUITOUS LOCATABLITY?

One can effect a transition from meso scale to micro scale concepts by virtue of an everyday activity: going indoors. To go from a widely surveyed and locatable exterior space to a less well spatially-documented interior space engenders real challenges for integrated geo registration. For location based services to advance, GPS cannot stand alone. Radio frequency identification (RFID) and trilateration present some immediate solutions, but only to a given scale of resolution. Increasingly, the micro scale impinges on the human scale. Start from the problem of crossing the threshold - going indoors, and away from the ubiquitous location capabilities of GPS. Geographic information research then enters a realm of spatially-enabled data that is relevant to human-decision making, but which occur at scales from 0.1m to 10-9m. Digital dust and nanotechnology along with RFID are rapidly spatializing microspaces. This presentation briefly considers the spatial challenges posed by forensic science as one boundary of exploration, which raises the question of the need for,

and creation of, microscopic spatial information. Pandora's box of nanotechnology is opened. Locationally-aware smart dust experiments are underway and the consequences of micro surveillance should be considered from a social perspective.

AND SO BACK TO A DIGITAL EARTH

The existence of all-pervading dispersed sensors brings the topic to pervasive or ubiquitous computing and full circle to the global perspective. Eventually, the entire surface of the Earth will be spatially enabled at a very fine scale of resolution. The volumes of data that will be generated at every scale are imaginable, but unmanageable in the present state of IT and GIS. Some prophetic scientists are forecasting entirely new modes of computing (for example, Schneiderman Leonardo's Notebook, 2003). Whether Digital Earth is realized by intelligent design or by evolution the fact is that it is already here and will only become richer and deeper as Gelernter would describe it.

SUMMARY: SOME EMERGING PRIORITIES

In attempt to draw attention to the most pressing need for research, AGILE (2001) and UCGIS (2002) have both identified challenges. I have proposed a 'cross-walk' between the two most recent versions of the challenges, which is attached as Appendix 1. The table is only one of many ways in which the two visions of important research may be correlated. To be fair, the UCGIS priorities were specifically identified as short-term; it may be more reasonable to compare the major challenges as set out in McMaster and Usery (2004). Given the breadth of the material presented in this paper, it is hardly surprising that some of the themes that have been raised appear in both tabulations. But the statement, "The exploitation of digital information poses challenges and opportunities as yet not fully understood or tested" under AGILE's GI Policy and Society challenge, encompasses some themes that I would like to emphasize by way of conclusion. One theme is that Digital Earth will happen, and in some ways has already happened, whether it is intentionally designed by central authorities or not. The foundations by way of data generation, integration, and dissemination are in place, if only roughly crafted as yet. Additionally, there seems to be a powerful impetus driving distributed computation on ever smaller computers, which favors a different user interface than that held up by NASA. There indeed will be hologram displays of real-time earth processes, physical and eventually social, but the great majority will not need to see the whole in glorious 4D Technicolor motion. The dissemination of innovation in small displays will bring Digital Earth to a multitude of users in manageable chunks, many of whom will be totally unaware that they are accessing Digital Earth at all.

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