



Visualization of spatial data for field based GIS

Hardy Pundt*, Klaus Brinkkötter-Runde

Institute for Geoinformatics, University of Münster, Münster, Germany

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Abstract

Field based and GPS supported GIS are increasingly applied in various spatial disciplines. Such systems represent more sophisticated, time and cost effective tools than traditional field forms for data acquisition. Meanwhile, various systems are on the market. These mostly enable the user to define geo-objects by means of GPS information, supported by functionalities to collect and analyze geometric information. The digital acquisition of application specific attributes is often underrepresented within such systems. This is surprising because pen computer based GIS can be used to collect attributes in a profitable manner, thus adequately supporting the requirements of the user. Visualization and graphic displays of spatial data are helpful means to improve such a data collection process.

In section one and two basic aspects of visualization and current uses of visualization techniques for field based GIS are described. Section three mentions new developments within the framework of wearable computing and augmented reality. Section four describes current activities aimed at the realization of real time online field based GIS. This includes efforts to realize an online GIS data link to improve the efficiency and the quality of fieldwork. A brief discussion in section five leads to conclusions and some key issues for future research. © 2000 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The increased use of GIS creates an apparently insatiable demand for new, high resolution visual information and spatial databases. The technological developments, combined with this demand, are rapidly changing the way in which ground data are collected (Dangermond, 1997).

Field based GIS tools increasingly become the means for capturing and visualizing spatial data for

both environmental and socio-economic applications. They contribute to a completely digital data flow from data collection to analysis and visualization. The acquisition of spatial data with field based GIS — an often extremely expensive component of GIS — can be carried out in an effective manner in terms of time and costs. Services to support data acquisition outdoors are knowledge-based diagnostic tools, automatic plausibility controls and the provision of visual and textual add on information (Hitchcock et al., 1996; Pundt and Kuhn, 1998). The quality of captured spatial data can be improved if the user can link the attributes directly to visual objects on maps, orthophotos, satellite imagery, digital elevation models or other kinds of 2D or 3D displays. This refers to the basic

* Corresponding author. Fax: +49-251-83-39763.

E-mail addresses: pundt@ifgi.uni-muenster.de (H. Pundt), runde@ifgi.uni-muenster.de (K. Brinkkötter-Runde).

paradigm of visualization, that 'seeing' is a good way towards understanding, which finds support in the use of maps and other graphical displays (Hearnshaw and Unwin, 1994).

The efforts of the Working Group for Mobile Geo-computing at our Institute were focused on tools for field based GIS which enable the user to define spatial objects with DGPS support. A main task was to support the user during outdoor data capture as much as possible with tools that should help carry out work effectively. This goal requires tailored applications for users in special information communities, such as agriculture, forestry, ecology, etc.

This article will emphasize important issues related to visualization in field based GIS. In particular, the paper will point out that visualization can contribute to better quality and more effectiveness during data capture and other main tasks of field based GIS. The second section will discuss some basic points concerning visualization, whereas the third and fourth sections focus on specific issues. The key points of the second section are the graphic display of

- topographic data in raster and vector format,
- data from existing digital data sources,
- vector data from other GIS,
- visualization as a source of additional information ('add-on information') to support field assessments.

Section three will outline some issues related to wearable computing and augmented reality. The latter will have significant influence on field based GIS in the future. In the fourth section, the idea of online field GIS is discussed including the access to WWW based visual data to support fieldwork. At last, some conclusions and issues for future research are mentioned.

2. Visualization of spatial data to support field data acquisition

One reason for the quick adoption of visual GIS technology is that visualization comes naturally to users (Buttenfield, 1996). The procedure of digital outdoor data capture requires the application of visualization as a means to recognize and interpret visual patterns. Such patterns occur on maps and other images on the pen computer screen and can be compared straightway with the outdoor situation. In this sense, visualization serves the purpose of clarifying and enhancing the understanding of real world conditions (Beard et al., 1994). The user 'sees' the object of interest in both forms, naturally and symbolically on the digital graphic display. This contributes to an easier process of matching symbol dimensions (used in maps) directly with phenomenon dimensions (occurring in

nature) which is a basic requirement of cartographic languages (MacEachren, 1994). Examples that show the usefulness of such tools exist in various forms:

- Updating topographic maps
- Updating land use maps
- Comparison of historic photographs and maps with the current field situation
- Modification and improvement of various kinds of ecological maps (e.g. soil maps, geological maps, vegetation cover maps)
- Improvement and evaluation of thematic maps and other graphics.

Field based, mobile GIS can also be used for environmental characterization, modeling and decision support. Advantages lie in the interactive development of sampling strategies through visualization and on-the-spot environmental modeling and feedback through field-based verification (Carver et al., 1996).

Orientation and navigation in the field are additional issues that must be supported by mobile GIS. Maps are designed to communicate a special message to a user (Wood, 1994). This means that the use of topographic and thematic maps in the field can contribute to a more comprehensive understanding of the outdoor situation. To support such goals, field based GIS must provide georeferenced, topographic and cartographic information. An adequate support for the user is to provide raster maps on which the user can define new objects, select them and add attributive information. For the user, the digital raster maps, plus the GPS link, support orientation and navigation. The raster maps can be overlaid with various vector data, such as official topographical information (e.g. roads, streams, parcel boundaries; Fig. 1). These functionalities guarantee adequate support for data capture. Examples of projects at our Institute are

- river habitat surveying (where river sections are defined and detailed habitat data are added),
- collection of parcel-related information in agriculture (based on polygons for which land use information, size, etc. is captured),
- forest inventories (where polygons are defined and comprehensive data of each tree within this area are collected).

Such visual support is relatively simple to realize within a more or less closed system. However, in many cases, field workers want to use data from various sources. For example, they need data from the stationary GIS in an office (e.g. ArcView shape files), scanned raster maps, vector geometries from official topographic services and other information. The open flow of different raster and vector formats between GIS (i.e. interoperability) is an issue currently under intensive discussion and development

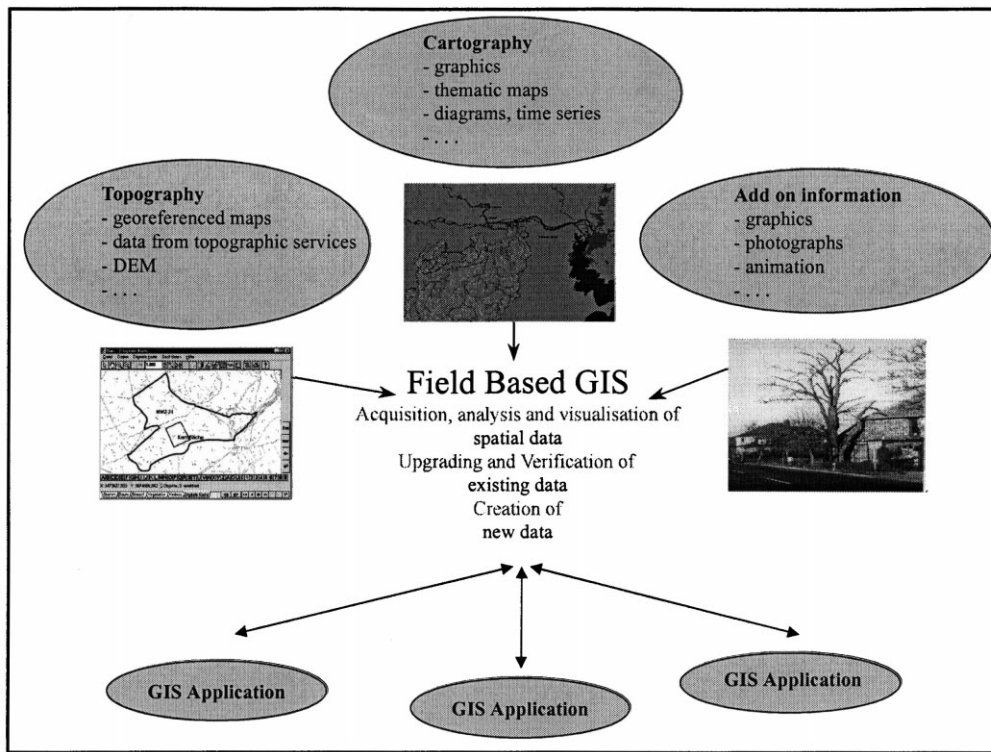


Fig. 1. Uses of visual information for field based GIS.

within the framework of the OpenGIS initiative (McKee and Kuhn, 1997; OpenGIS, 1998a). Field based GIS should support, therefore, the Simple Features Specification of the OpenGIS consortium (OpenGIS, 1998b). Apart from the topics discussed here, the specification of interoperable tools for field based GIS is becoming an important branch of research and development. Interoperability can also play a significant role for the provision of visual add-on information. For ecological purposes, for example, classifications and assessments have to be carried out. The field workers, especially persons who are not experienced in ecological mapping, often do not have the sophisticated knowledge required to adequately perform such complex tasks. Diagrams, images, photographs including 3D visualizations can represent support in such situations. Figure 1 shows different kinds of visual information used for field based GIS. This kind of add-on information becomes increasingly effective if it is organized using multimedia techniques. These approaches bridge the gap to current initiatives looking at the potential of multimedia technology for the visualization and display of spatial data (Masser and Salgé, 1997).

The visual capabilities mentioned, combined with knowledge based functions aimed at the achievement

of high data quality (Pundt and Kuhn, 1998), make field based GIS comprehensive and indispensable components of environmental information systems.

3. Wearable computing and augmented reality

The potential to use the technology of wearable computing and augmented reality for field based GIS is considered in this section. The Massachusetts Institute for Technology (MIT) suggests that a wearable computer is one that has many of the characteristics listed in Table 1.

Most of these characteristics are significant for field based GIS. Apart from these characteristics, visualization is one of the most useful techniques for field workers and should be added to the list for spatial applications. Today, many efforts in wearable computing utilize visual information presentation based on textual or graphical user interfaces. Two types of displays are currently competing to become the standard. One is the solid head-mounted display through which one cannot see. The other type of display offers what is termed 'augmented reality'. Such displays are transparent and project images onto the inside surface of the display. Augmented reality (AR) is a combination of

Table 1
Characteristics of wearable computers

Usability of equipment	Portable, while operational; hand-free use; always on
Sensors integration	availability of sensors (such as wireless communications, GPS, cameras, micro-phones); attention-getting

the real scene viewed by the user and a virtual scene generated by the computer. The computer augments the real scene with additional information that could provide visual support for special field based GIS applications (Vallino, 1998). Current examples for such applications are known from network control and pipeline supervision.

Head-mounted displays are criticized because in special situations they can be cumbersome and may cause unnatural interference with human vision. An 'eyes-free' approach, using audio-based augmentation of the physical environment, can be used to express peripheral information and provide passive interaction for specific tasks and usage scenarios (Sawhney and Schmandt, 1997). The addition of eyeglasses, for example, leads to the situation that the computer has the same perspective as the field worker. This allows the user to explore some of the more fundamental issues in computer-mediated reality (Mann, 1996).

Thus far, technical equipment such as that mentioned before has been used primarily by large companies that need to make massive amounts of highly technical data available to mobile workers (Nilsson, 1997). Projects in spatial disciplines are dealing increasingly with issues requiring augmented reality and the combination of wearable computers, sensors, eyeglasses and head-mounted displays. This may improve the procedure of data acquisition in the field and enable better assessments of natural situations through visualization support. An ultimate goal of using such techniques should be to improve the effectiveness of the data capture procedure and the quality of spatial data collected outside.

4. Online visualization of spatial data and data transfer

Advanced mapping systems integrate descriptive data, electronic sensors, photo/video and telecommunications to provide up-to-the-minute real world data for spatial management and analysis. The integration of real-time differential GPS into field GIS and the fast growing experience with various DGPS telecommunications services have led to new opportunities for mobile geocomputing. One of these is to use the existing wireless data communication unit, not only for accessing differential correction data, but also for bidirectional online GIS database access. By combining wireless and other advanced communications technol-

ogies, mobile computing gives immediate access to critical information wherever surveying takes place. The most convenient way to obtain this feature lies in the use of common standard communication protocols and techniques such as cellular phone, GSM (global system for mobile communications), Internet and WWW. These ideas were triggered by the desire and sometimes urgent need for additional information when out in the field. Frequently, critical field surveys, such as disaster relief applications are dependent on the direct transmission of collected data to a central office. Some portable GPS/GIS emergency mapping kits are already on the market for rapid response to emergencies and disasters (Fig. 2).

The most important advantages of using the WWW as user interface can be summarized into the following items: User input can be easily done and controlled by GUI's written in HTML, Java or Tcl/Tk. Multiple queries on theme, space and/or time can be done by simple mouse (pen) actions without demanding complex SQL statements. The WWW's hypermedia properties offer a possibility to generate dynamic quicklooks, particularly when performing spatial queries and visualizing their results. In addition, they are an essential requirement for accessing spatially distributed databases. The WWW's multimedia properties allow spatial data to be visualized and presented in a graphically attractive manner and, if possible, dynamically (e.g. by using VRML). Entrance and all accesses to such a data information and retrieval system are controllable by paying attention to the Internet security standards, such as firewalls. By means of a password query, user-specific write and read access, as well as encryption techniques, misuse or unauthorized access can be prevented extensively. The example of accessing the WWW during field surveys demonstrates the hardware independence resulting from the use of standards like HTML and Java.

5. Conclusions and research issues

The intensification of the use of visualization techniques is a crucial step to improve field based GIS. Visual communication is 'to make a point' (MacEachren, 1994). If maps and other graphic displays are used during fieldwork, we use tools to communicate a known situation. It is a different story, however, when we use such maps (the 'known situation') as a basis to

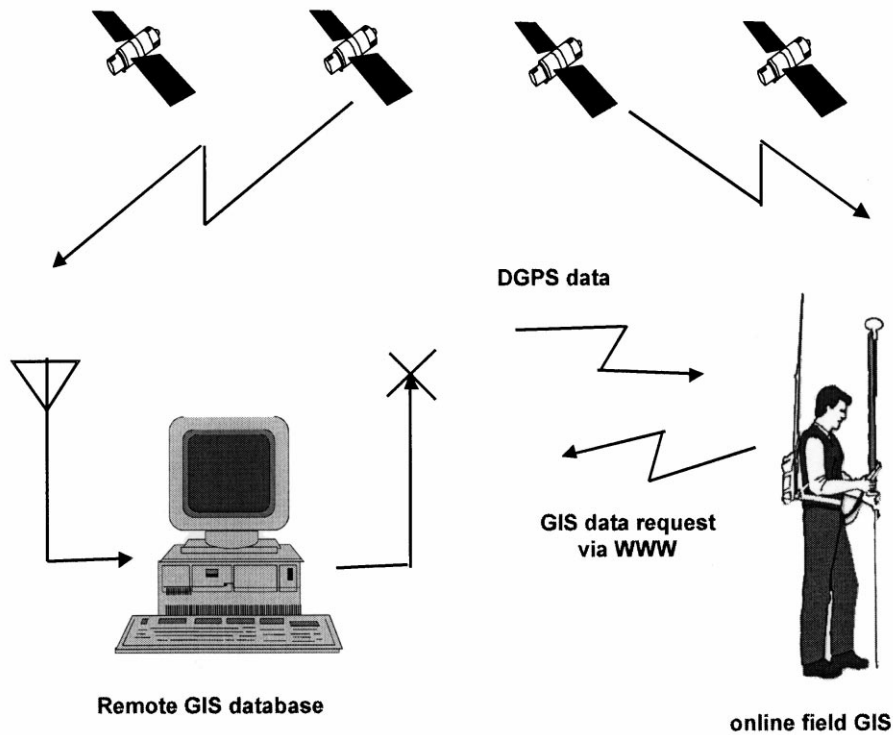


Fig. 2. Data flow to and from field based GIS.

modify and *enhance* 'what we think we know' (MacEachren, 1994). Considering the purposes of field work, such as

- upgrading and/or verifying existing data
- adding new information
- collecting data about unexpected phenomena

one can see clearly that visualization in all its facets described here can play a dominating role for field based GIS in future. Such information can be linked with existing knowledge of the outdoor situation and used as a basis for spatial analyses. The consequence should be that the results, mostly new visual displays and maps, have a higher level of quality than their predecessors.

In spite of the obvious advantages, visualization has to be regarded critically. It must be considered that one may be as easily informed as misled by graphical display and that poorly designed visual displays may convey or even reinforce false ideas (Buttenfield, 1996). Those involved in the use of field based GIS (including digital cartography) should always be aware of this fact.

Research and development in visualization will have impacts on GIS in general and on field based GIS specifically. Efforts in computer science on the other hand lead to new concepts and techniques to solve

problems related to visual information management (Jain, 1997). Some key approaches to remaining issues are, for example,

- closer cooperation between industry (hardware and software producers) and research departments at universities to guarantee a satisfactory usability of field based GIS
- focus on concrete workflows in field data acquisition for which tailored applications will be produced
- further research on different levels of abstraction (from abstract symbolic diagrams and maps to photorealistic representations)
- further research on feature space representations (comparison of different features e.g. temperature vs. elevation)
- further development of WWW based spatial databases for use in field based GIS
- provision of metadata (about features collected outdoors and about existing data used or accessed in the field)
- provision of navigation tools (orientation and navigation in time, space and thematic dimensions is often difficult and should be supported by a comprehensive visualization environment, Bernard et al., 1998).

Wearable computers are becoming comparable to

other personal computers in terms of processing times, storage capacities, etc. This will make techniques, such as higher dimensional visualization and augmented reality combined with means to directly transfer real time data from and to the field worker extremely valuable to develop powerful field based GIS. Other technologies will enable GIS users to work with information systems in completely new ways, by manipulating spatial objects or scenes with their bare hands and querying through gesture, voice, or a combination of the two (Florence et al., 1996).

The ongoing efforts to realize the interoperability of GIS data and services between different information communities will also contribute to a wider use of spatial data and tools to process such information. The progress in visualization techniques for spatial data and efforts to produce tiny wearable computers as well as usable add on equipment will help to make GIS a tool with which we can work whenever and wherever we want. This is not just a vision for geosciences anymore but a significant distance has yet to be covered on the road to true mobile geocomputing

References

- Beard, M.K., Buttenfield, B.P., Mackaness, W.A., 1994. Visualization of the quality of spatial information. Closing Report on Research Initiative 7. NCGIA, Research Initiative 7, Orono, ME, and Buffalo, NY.
- Bernard, L., Schmidt, B., Streit, U., Uhlenkücken, Chr., 1998. Managing, modeling and visualizing high-dimensional spatio-temporal data in an integrated system. *GeoInformatica* 2 (1), 59–77.
- Buttenfield, B., 1996. Scientific visualisation for environmental modeling. Interactive and proactive graphics. In: Goodchild, M., Steyaert, L.T., Parks, B.O. (Eds.), *GIS and Environmental Modeling*. GIS World Books, Fort Collins, Colorado, pp. 463–467.
- Carver, S., Heywood, I., Cornelius, S., Sear, D., 1996. Evaluating field-based GIS for environmental characterization, modeling and decision support. In: Goodchild, M., Steyaert, L.T., Parks, B.O. (Eds.), *GIS and Environmental Modeling*. GIS World Books, Fort Collins, Colorado, pp. 43–47.
- Dangermond, J., 1997. Synergy of photogrammetry, remote sensing and GIS. In: *Photogrammetric Week '97*. Wichmann Verlag, Heidelberg, pp. XI–XVI.
- Florence, J., Hornsby, K., Egenhofer, M.J., 1996. The GIS wallboard: interactions with spatial information on large-scale displays. In: Kraak, M.J., Molenaar, M. (Eds.), *Proceedings of the Seventh International Symposium on Spatial Data Handling*. Taylor and Francis, London, pp. 449–463.
- Hearnshaw, H.M., Unwin, D.J. (Eds.), 1994. *Visualization in Geographical Information Systems*. John Wiley & Sons, Chichester, 260 pp.
- Hitchcock, A., Pundt, H., Brinkkötter-Runde, K., Streit, U., 1996. Data acquisition tools for geographic information systems. In: *Geographical Information Systems International Group (GISIG) (Ed.), Proceedings of the 13th WELL-GIS Workshop on technologies for land management and data supply: RS and GPS Research and Education*, June 13, 1996, Budapest, Hungary. 3rd session: *GIS and Global Positioning Systems*, 8 pp.
- Jain, R., 1997. Visual information management. *Communications of the Association for Computing Machinery* 40 (2), 31–32.
- MacEachren, A., 1994. *Some Truth with Maps*. Association of American Geographers, Washington, 129 pp.
- Mann, S., 1996. 'Smart clothing': making multimedia computers and wireless communication more personal — a paradigm shift in wearable computing. <http://www.wearcam.org>.
- Masser, I., Salgé, F., 1997. The GISDATA programme: an overview. In: *Geographic Information Research at the Millennium. GISDATA Final Conference*. European Science Foundation (ESF), Le Bischenberg, France, pp. 5–10.
- McKee, L., Kuhn, W., 1997. The OpenGIS consortium's purpose and technical approach. In: *Photogrammetric Week '97*. Wichmann Verlag, Heidelberg, pp. 237–242.
- Nilsson, B.A., 1997. Ready to wear. Wearable computers: replacing interruption with integration. In: *Mobile Computing and Communications*, pp. 15–21.
- OpenGIS, 1998a. *OpenGIS Guide*. <http://opengis.org/techno/guide.htm>.
- OpenGIS, 1998b. *OpenGIS implementation specifications (simple features specification for OLE/COM, CORBA and SQL)*. <http://opengis.org/techno/specs.htm#implementation>.
- Pundt, H., Kuhn, W., 1998. Dependencies between semantics and data quality — examples from the field of mobile geocomputing. In: *1st AGILE Conference 1998 in Enschede*. International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands (<http://www.uniroma1.it/DICEA/AGILE.HTM>), 7 pp.
- Sawhney, N., Schmandt, Chr., 1997. Nomadic radio: a spatialized audio environment for wearable computing. *International Symposium on Wearable Computing*, Cambridge, MA, 1997. <http://nitin.www.media.mit.edu>.
- Vallino, J., 1998. *Introduction to augmented reality*. <http://www.cs.rochester.edu/u/www/vallino/research/AR/introduction.html>.
- Wood, M., 1994. The traditional map as a visualization technique. In: Hearnshaw, H.M., Unwin, D.J. (Eds.), *Visualization in Geographical Information Systems*. John Wiley & Sons, Chichester, pp. 9–17.