Beyond Desktop GIS

A Family of Portable Spatial Information Technologies

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Emerging technologies will change the future use of geographic information systems (GISs), moving GISs from the office desktops into the users' hands. Current GIS architectures focus on a static environment in which a user sits at a workstation to perform spatial analysis. With the advent of ubiquitous computing, this setting will change dramatically. Devices that combine a hand-held computer with a GPS receiver, a cellular phone, and a digital camera will enable users to integrate spatial analysis into their daily lives, opening GIS to the mass markets of day-to-day use. Mobile GISs will differ significantly from today's multi-purpose GISs and we envision a whole family of portable spatial information technologies that will be tailored to specific needs. Smart glasses, for instance, will allow people to augment reality by seeing additional thematic information or seeing through obstacles. Smart Compasses will be based on entry-level Personal Digital Assistants, giving directions in the field on such phenomena as weather-fronts, congestions, or geographic areas. Mobile GISs pose challenging new research questions about the spatial concepts people employ when they move through space, the interaction styles and modalities people use in the field, the particularities about processing spatial queries posed in the field, the efficient handling of massive amounts of spatio-temporal data, and the on-the-fly integration of new field observations with data warehouses across a distributed information network.

KEYWORDS: Next-generation GIS, Mobile GIS, portable spatial information technologies, Geo Sketch Pad, Smart Compass, Smart Horizon, Smart Glasses.

INTRODUCTION

Geographic information systems (GISs) as they are known in the late 1990s have reached a state of maturity and a level of saturation. They have seen unprecedented growth and popularity over the last 15 years, but to make the next quantum leap so that GISs become a true asset for new, broader user communities, significant design changes must occur. Pondering about "more of the same" use for GISs (e.g., as advanced map maintenance systems) will not generate challenging research questions, nor will "more of the same" research—more R-trees, more spatial SQL dialects, more formalisms of spatial relations—generate significant advancements. A fundamental assumption behind today's GIS architectures was that these systems are located on the desk tops of office users; therefore, the platforms—initially mainframe computers—are primarily workstations and Personal Computers (including laptops, their portable descendants aimed at office-like work). Considerations about what manifests a GIS, its data models, user interfaces, software architectures, and data storage do not scale to new use of GISs, such as in a wireless computing environment in the field or on the street. A similar dead-end is the concept of the generic GIS that is supposed to be applicable for the whole range of geospatial application domains. Such GIS platforms expose serious usability problems and build unnatural gaps between user tasks and platforms. Clutching at the top of the GISs does not work, because the underlying assumptions are not synchronized with the concepts needed.

The remainder of this paper presents the opportunities provided by new portable spatial information technologies, the personal spatial assistants of the future. Since they are only a concept at this time, not a product, we discuss technological assumptions and requirements for advancement of our knowledge to make them reality.

A FAMILY OF PORTABLE SPATIAL INFORMATION TECHNOLOGIES

We need new impulses from applications of innovative technologies, which enable new approaches to problem solving. The enabling technologies exist today—the world-wide web, the Global Positioning System (GPS), cellular phones, and virtual reality—but with a few exceptions they have not been tied into the concept of integrated information systems. Rather than having GIS boxes on our desk tops or laps, we envision future GISs to be nodes in global information networks. This next (or next-but-one) generation of GISs will appear to have little in common with today's GISs. Particularly, the one-size-fits-all approach will be replaced by a family of portable spatial information technologies, each of which tailored to particular tasks.

GEO SKETCH PADS

People take notes in all kinds of situations. The Geo Sketch Pad allows a user to capture geographic field notes through the annotation of digital pictures and videos taken in the field. It is supported by a GPS receiver and a gyroscope to record the location and direction of the note taking and a digital camera or a video camera capture the visual channel. The Geo Sketch Pad offers a multi-modal user interface on which a user may sketch with a pen over an image taken to highlight the features of interest, or annotate through spoken language the image recorded. The Geo Sketch Pad builds a bridge between the content captured by a recording device and the sensations a person feels in the field, thereby providing a better accounting for the context in which often abstract measurements are made.

SMART COMPASSES

The Smart Compass gives directions and helps users with orienteering in an unfamiliar environment, much like the magnetic compass, its analog counterpart. While the magnetic compass gives one fixed direction to which a user must align his or her own reference system or the orientation of a map, the Smart Compass points the user into the direction of a particular geographic object. Equipped with a GPS receiver to determine the observer's location, a gyroscope to measure the orientation of the display unit, the smart compass works with a simple gazetteer of geographic names and their locations. Given the location of the observer, it calculates the direction to the target and shows the user an arrow pointing in the direction of the target. As the user turns the display unit horizontally, the pointer's direction stays on the target, of course.

SMART HORIZONS

Smart Horizons allow a user to actually look beyond his or her field of view. Often people's decisions are hampered by a lack of knowledge of what is behind the horizon. Smart Horizons present the user with such information as topography, infrastructure, traffic, or weather conditions in a way that it generates an integrated world of the user's visible and invisible world. Smart Horizons consist of a GPS receiver to determine the observer's location, a gyroscope to determine the observer's direction, a bi-directional wireless link to a real-time information source that provides the thematic information beyond the visible horizon, and a hand-held computer that processes the incoming data and generates in real-time the appropriate views. A device may be a hand-held display on which, when pointed into a particular direction, presents an extended panorama. Users pan left and right by horizontally rotating the device, while they explore an area further remote by vertically tilting the device. An alternative would be electronic binoculars, which generate a 3-dimensional model for the area behind the horizon through which the observer may navigate. With Smart Horizons travelers will avoid to drive into the bad weather and sailors will find a landing with a road close by.

MAGIC WANDS

A Magic Wand is an intelligent geographic pointer, which allows users to identify remote geographic objects by pointing to them. It replaces the use of the traditional compass in combination with a topographic map to identify objects in the field, and enhances the concept by providing information that may be generally accessible through an information network. A magic wand is equipped with a GPS receiver to determine the location and a gyroscope to capture the direction in which the wand points. Position and direction are matched with a digital terrain model, which is part of the Wand's knowledge base, to determine the object to which the user pointed. Using a Magic Wand, a hiker in the field may point to a mountain top and get its name, altitude, and distance. With the availability of up-to-date and detailed DTMs derived from aerial photographs or 1-meter resolution remotely sensed imagery, details about individual buildings will be accessible. By connecting the Magic Wand through a cellular phone with an information network such as the world-wide web, the user may browse through any additional information available about the identified object.

SMART GLASSES

Smart Glasses allow a user to augment reality by superimposing into the visual field a digital image. This device resembles the eye goggles found with virtual reality, however, unlike VR, Smart Glasses display a virtual world in addition to what a user sees naturally. A geologist, for instance, may find new insights through the use of Smart Glasses in the field when a simulation model of the geological processes over the last 10 Million years is superimposed over today's terrain. Likewise, a fluvial geomorphologist may gain new insights from an augmentation of the flow in a ravine by displaying the flow vectors derived from a simulation model. Sometimes information from another domain may be the key for making the right inferences, as in the case of an archeologist who, while in the field, may observe from a historical flashback that a piece of pottery found at this particular location may have actually originated further upstream and was likely flushed through floods to the location where it was found.

CONCLUSIONS

The portable spatial information technologies sketched in this paper do not yet exist. While they may sound like fiction, they are pretty realistic goals for the next 5-10 years. In order to make them reality, however, two types of advancements are needed. First, technological advances. They include improved quality of displays of hand-held devices (e.g., larger screens, foldable screens, readability under sunlight), more stable and much higher-bandwidth wireless communication, and low-cost GPS and gyroscope cards. These hardware technologies are developing rapidly and we foresee little impediments for them to become available as the basis of our family of portable spatial information technologies. The second area in need of advancement is know-how. In order to design successfully portable spatial information technologies, we need better knowledge about human-computer interaction, including how people work in the field, how they perceive geographic space, and how the new technologies influence their working habits. These new devices will need to make predictions about human behavior and performance as their users perform spatial tasks. It is necessary to identify appropriate, human-centered models for a variety of spatial tasks, to formalize these models so that they can be implemented in an information system, and to test whether these implementations match with the expected human behavior. We will need more knowledge about the implications for ethics and privacy as this next generation of Mobile GISs will be able to track the devices (not necessarily their users') movements more than any other technology used today. Finally, to tailor portable spatial information technologies to user groups, a better understanding of cultural differences will be necessary as they may form the basis for adaptive user models.

In the same vein, we will need better computational models to deal with highly distributed GISs that are supposed to respond in almost real time. Such "zero-latency databases" are beyond the push-technology currently being discussed within the setting of today's World-Wide Web.

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