A2A01: Committee on Photogrammetry, Remote Sensing, Surveying, and Related Automated Systems
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Spatial Data Technologies

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The efficient planning, construction, and operation of transportation facilities depend on access to the right spatial data, in the right format, and at the right time. The provision of spatial data—traditionally the domain of surveyors; engineers; and various mapping specialists, such as photogrammetrists, geographers, and aerial photographic and remote sensing specialists—has undergone a series of profound technological changes.

The purpose of technology is to serve people. The evolution of methods for acquiring, processing, and distributing spatial information provides an excellent example of how technology can serve transportation professionals. The unprecedented explosion in use of the Global Positioning System (GPS) clearly demonstrates that the provision of accurate and reliable remotely sensed and acquired spatial information is one of the major innovations.

Already being used to precisely map facilities, count cars, or locate accidents, new spatial data technologies have become a fundamental component of the transportation information system. Such applications are enabling transportation professionals to function more effectively by allowing them to make decisions more quickly and with better data. Moreover, it can be anticipated that the most dramatic results of having inexpensive, accurate, and readily available spatial data are yet to be realized. Access to even better data will result in enhanced services to more people at less cost.

Changes in spatial data capabilities are continuing at a rapid pace. Methods for the collection and use of the data are being defined largely by the convergence of a number of widely used technologies that include the following:

- High-resolution commercial satellites capable of resolving features as small as 1 meter;
- High-altitude airborne sensors;
- Low-altitude airborne platforms, including helicopters;
- GPS for location;
- Economical and robust high-resolution digital cameras;
- Improved digital image processing, distribution procedures, and media;
- Widespread acceptance of geographic information systems (GIS) technologies;
- Increased sophistication of database management and information systems;
- Expansion of the Internet and the World Wide Web, and the globalization of information sources; and

- Increasing availability of large public information sources at little or no cost, at least in the United States.

The new millennium will herald an era of spatially referenced data that are not merely a *little* better than those presently available, but *much* better. These advances are coming at a very important time for many transportation agencies. This will be the era of multidisciplinary teams and integrated technologies. The anticipated advances offer the promise of enabling the transportation community to evolve into a cross-agency enterprise through the power of accurate, timely information.

THE FUTURE IS NOW

Regardless of how exciting one might find the technical details of the new remote sensing devices and information technologies, the real story revolves around their applications—and the applications involve people. The following are some existing advanced applications undertaken by forward-looking people and organizations.

Until GPS became available, a metropolitan planning organization (MPO) in Georgia had no detailed paper maps of its area other than the traditional U.S. Geological Survey topographic maps. The members of the MPO are now constructing accurate maps on their own. Agencies without the funds to obtain their own GPS equipment are trading the data they acquire for time with a GPS receiver. The MPO conducts a half-day training session in a town, and the town then gets to use the equipment for 3 days. The data are valuable because they are accurate, and they can be obtained at low cost.

In another example, about 70 people showed up for a recent workshop sponsored by Arizona State University concerning the use of GPS data for building a spatial referencing system, even though the workshop had had virtually no advance publicity. The attendees wanted to know how to do things themselves. One of the organizers commented that the experience was singular in that professionals from three or four levels of government, the private sector, and academia were collaborating for the good of the citizens of the state. The scope of the technological experiments is growing. A rural Arizona county is among the first to have a three-dimensional (3-D) referencing system generated entirely from GPS data. There have also been several statewide efforts to adopt a 3-D referencing system. Those involved are excited about creating something of value that is new.

Jefferson County, Colorado, includes much of the western portion of the Denver metropolitan area. The county extends into the Rocky Mountain foothills and is subject to considerable development pressure in complex terrain. The county has entered into a development agreement with one of the providers of the new 1-meter-resolution commercial satellite data and a software firm to obtain a capability for producing extremely rapid photorealistic 3-D renderings of any location in the county. Current tests are based on existing 10-meter U.S. Geological Survey Digital Elevation Model (DEM) data and scanned county-owned orthophoto maps (see Figure 1), which have a slightly lower resolution quality than desired and cannot show present conditions. Both of these constraints will be removed once the new data sources become operational. The county plans to use the new technology to support technical studies and to provide displays for county commissions and public hearings on site evaluations, site planning, zoning applications, transportation improvements, and viewshed analyses. More information on these applications can be obtained from the Jefferson County GIS Web site: http://co.jefferson.co.us/dpt/gis/gis.htm.

FIGURE 1. Jefferson County 3-D visualization model—view south along Dakota Hogback west of Denver. C-470 is left of and parallel to Hogback. Interchange C-470/US-285 lies just beyond lakes. Colorado Highway 8 connects US-285 with town of Morrison, a portion of which is visible in lower right.

An even more ambitious program is under way in Los Angeles. The Urban Simulation Team of the University of California at Los Angeles is creating a real-time virtual model of the entire Los Angeles Basin. Combining aerial and terrestrial digital images within 3-D computer-assisted design geometries creates accurate 3-D models of small areas. The results are photorealistic urban images, even down to the graffiti and signs (see Figure 2). These local models are then linked to create models of larger areas. The intent is to create a single unified virtual model that can be used to help solve a multitude of civil engineering, urban design, and planning-related problems. Similar experiments are under way in several other urban areas. All are pushing the current technological and economic envelope.

CURRENT TRENDS

The cost of spatial data is declining rapidly because there is competition in all aspects of the technology—data acquisition, processing, and distribution. This competition is spurred by increasing acceptance and use of spatial data, which causes unit costs to fall. These trends are evident today, and transportation practitioners are the beneficiaries.

New Satellite Data Sources

Several satellites and space missions scheduled prior to 2005 may be useful for transportation studies. The National Aeronautics and Space Administration (NASA) launched Landsat-7 on April 15, 1999, and several commercial firms are planning to

FIGURE 2. Virtual Los Angeles model—view of downtown.

deploy additional satellites. There is a great deal of such activity, and it appears likely that in the next few years many new data sources will emerge. Competition among the various purveyors of space-borne sensors will keep prices attractive.

An important trend is toward high spectral resolution, as well as high spatial resolution. When the electromagnetic spectrum is divided into a large number of segments, discrimination among materials becomes possible. In response to expressed needs, NASA has created a scientific payload that will be carried on a Space Shuttle mission in late 1999. ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is capable of collecting 14 bands of data at 15- to 90-meter resolutions. The scheduled launch of the Orbview4 satellite in 2000 will provide a 200-band hyperspectral capability with an 8-meter resolution. Not only will the resolution be even better than that of ASTER, but the capability will be operational for several years.

Improved Spatial Location Procedures

The GPS revolution is well under way. In the United States, federal and state agencies are cooperating in making differential GPS (DGPS) readily available to all users. DGPS allows locations to be determined with submeter accuracy—an essential requirement for many transportation applications.

New motion sensors that will further revolutionize the accurate identification of spatial positions are coming to the market. These new fiber-optic gyroscopes are so sensitive that if left on one's desk for a day, they would determine that the earth had made a full rotation and would read 360 degrees. The devices have no moving parts and will be much less costly than existing systems. They will increase by perhaps an order of magnitude the spatial accuracy achievable by moving data-collection platforms, such as logging vans, while driving the total price of the vans down by perhaps 30 to 50 percent. The low cost, light weight, and inherent accuracy of these devices will also result in their being incorporated into new forms of personal locator devices.

VISIONS FOR 2010

Advances already under way in information technology, communications infrastructure, microelectronics, and related technologies will provide unprecedented opportunities for information discovery and management, and new ways to conduct research. Following are some visions of how spatial information might be used by transportation professionals in the year 2010.

Recent rains have caused a small landslide on a new earthfill. A geotechnical engineer working for the New Mexico Department of Transportation dons a headset as she leaves the site office. The headset provides an enhanced reality system that combines glasses, earphones, and a tiny microphone, yet weighs little more than a pair of sunglasses. When the engineer reaches the site, she issues a simple voice command, and the microtopography of the earthfill slope is superimposed as a red wire-frame display on the landscape before her. Where there has been significant erosion, the designed surface appears like a net stretched above the ground. In areas where deposition has occurred, the original surface lies below the current one, so the planned surface is obscured. The engineer takes out a hand-held device and begins to point at the current surface in various places while clicking the pointing device. A green mesh appears as she quickly collects sufficient points to make the digitized data fit the current microtopography. Her new slope data appear simultaneously in the division office, allowing a colleague to undertake slope stability calculations. Using these results, the engineer is able to discuss with the earthfill contractor steps necessary to repair the slope erosion damage and prevent a recurrence.

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The Minneapolis Airport is experiencing a mid-December snowstorm. The snow is fairly light, but drifting to cause extensive visibility problems for ground crews. Modern air traffic control systems allow aircraft to land and depart on a nearly normal schedule, but the runways, taxiways, and ramps must be kept clear. The snowplow operators are able to continue by using the heads-up graphical displays in their vehicles, which project an image of the pavement edges onto the windshield. The system is based on a detailed 3-D model of the entire airport and on real-time GPS vehicle location technology. The central dispatch office and control tower are able to coordinate the snow clearing with aircraft arrivals and departures with perfect safety.

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In New York City, the emergency measures coordinator is overseeing a training drill of an evacuation of the RCA Building in downtown Manhattan. A simulated fire on the 44th floor requires coordination of several groups, including helicopter pilots from the Air National Guard, representatives of the City of New York, and the New York State Police.

The simulation is using the recently completed New York Virtual Reality Model, which allows multiple users to interact in real time. Pilots can operate their virtual helicopters in individual simulators while controllers monitor an overview of the operation. The photorealism of the simulation is uncanny. Flames and smoke from the fire can be seen, and the smoke plume can be adjusted to reflect different and changing weather conditions. The test is completed without disturbing the public and at a fraction of the cost of the old-style training.

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In the Denver suburb of Lakewood, a public hearing on a new transit stop on the proposed western light rail corridor is under way. The planners display photorealistic 3-D simulations of existing and proposed conditions on a large screen. Citizens protest the style and scope of the proposed parking structures. Several small-group discussions are organized around graphical workstations operated by facilitators. Alternatives are suggested and incorporated in rough form into the displays as the discussions progress. At the end of the meeting, two new alternatives are selected for further detailed analysis and presentation on the local Jefferson County website at the end of the following week. These alternatives will be the subject of an additional public hearing at the County Planning Commission in a month.

These scenarios may sound like science fiction, but much of the technology needed to support them—including high-speed wireless information links, real-time multimedia satellite transmission, high-performance computing, GPS chips, and methods for content-based retrieval from digital libraries—is already under development or available in prototype form.

CONCLUSION

As can be seen from the scenarios presented above, the impact of the new spatial data technologies will be profound. These technologies will change completely the way transportation professionals view their roles and responsibilities. The technologies will be not only inexpensive, but also easy to use and ubiquitous. Thus they will enable transportation analysts to manage change proactively and thereby better meet the needs of society.

Virtually all of these new technologies are inherently three-dimensional. No longer will transportation applications be isolated and limited by one- or two-dimensional modalities. The new 3-D information will support integration and interoperability in ways not envisioned by most current practitioners. Making such applications a reality, however, will require substantial advances in technical knowledge; in understanding of human–computer interactions; and in the development of appropriate models of environmental, physical, and social processes that shape our geographic world. Major investments in information infrastructure will be required. Yet these advances will influence the way people work, communicate, teach, and learn—perhaps even the way they think.