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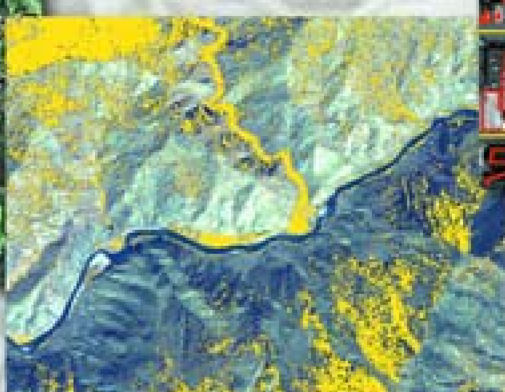
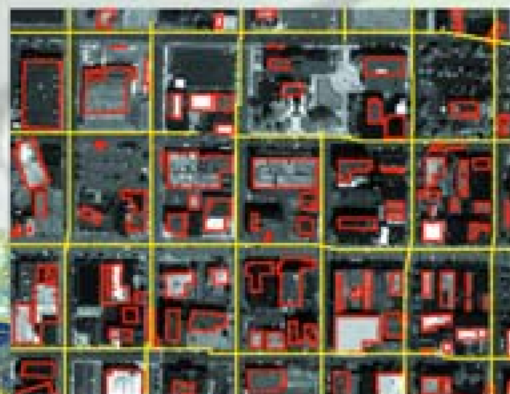
January 2005

EOM
Earth Observation Magazine

Geospatial Technologies in Your World

Feature Extraction: Getting the Most Out of Imagery





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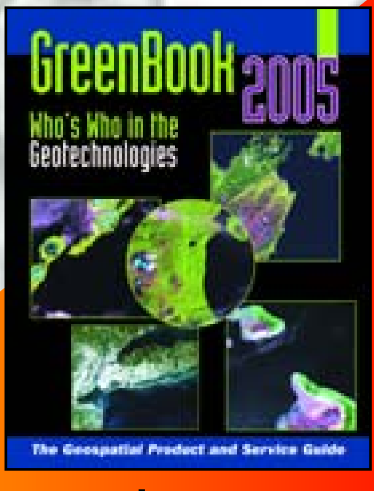

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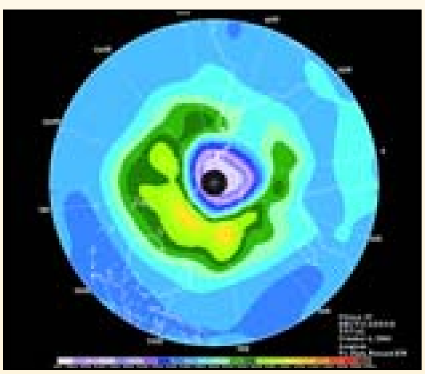
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On the Cover: *Sophisticated feature extraction helps count oranges, determine land cover, and draw building footprints. Techniques have come a long way in recent years.*

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Automation

I love automation. I think it's magical that the heat in my house turns on and off without any input from humans. (It's on a timer.) And, I love my bread machine that can, with some help from me at the outset, prepare hot bread that'll be ready at dinner time. (It's also got a timer, but also the smarts to turn raw ingredients into bread.) And, where would I be without my Norton Anti-Virus that automatically updates itself without my prompting?

One of the tasks assigned to specially trained analysts is exploring and analyzing imagery. The goal is to tease out of images areas of interest or things that are out of the ordinary. But with the vast quantity of imagery data pouring in from satellites and planes, many in the military and civilian areas are looking to technology to automate at least some of that work. Automated Feature Extraction, AFE, is the term for siccing computers and software on raw or enhanced imagery "to make sense of it" for us, and in turn, help support base mapping and decision support.

While not quite as far along as the "set it and forget it" of my bread machine, the technology has come quite a long way since its early days. It's one of those technologies that I put in the same category with voice recognition: you need to "check in with it" every year or so, to appreciate the improvements.

EOM Update

I want share some of the latest news about the magazine you are now holding (or reading online). First off, thanks very much to the many readers who participated in our survey this fall. You shared opinions, requests, and information about yourselves that are already helping further shape this magazine. Special congratulations to our raffle winners, Bill and Norma who have shiny new thumb drives, and Greg, who's grooving to a new MP3 player. Readers are welcome to send input anytime, not just when we have surveys.

I also want to take the opportunity with the new year at hand to formally introduce *EOM's* slate of columnists. Chris Andrews has been with *EOM* since June, and tackles the difficult task of making geotechnology make sense in his "Understanding Technology" column. Others are tapping Chris' knowledge; he'll be presenting a seminar at the upcoming GITA conference in March. Mark Eustis has contributed to *EOM* recently, sharing his views on the commercial viability of satellite remote sensing. Beginning this month he'll be sharing his thoughts on the industry regularly, in his "Another Perspective" column. Atanas Entchev will explore "Geotechnology and Society" in this issue and in the months to come. I'd like to extend my welcome to these writers and hope you will find their contributions educational, timely, provocative, and interesting. For those of you who have something to "get off your chest," the SoapBox column accepts submissions on any geo-related topic.

Adena Schutzberg, *Editor*

EOM Now an Electronic Monthly Magazine

Dear *EOM* readers,

In an effort to reach more readers worldwide, beginning in February *EOM* will be available only via our website *www.eomonline.com.* We will notify those of you who have provided us with email addresses of its availability so you may read it at your convenience. For those of you who have not provided us with an email address, we encourage you to do so at *www.eomonline.com.*

Neil Sandler, *Publisher*

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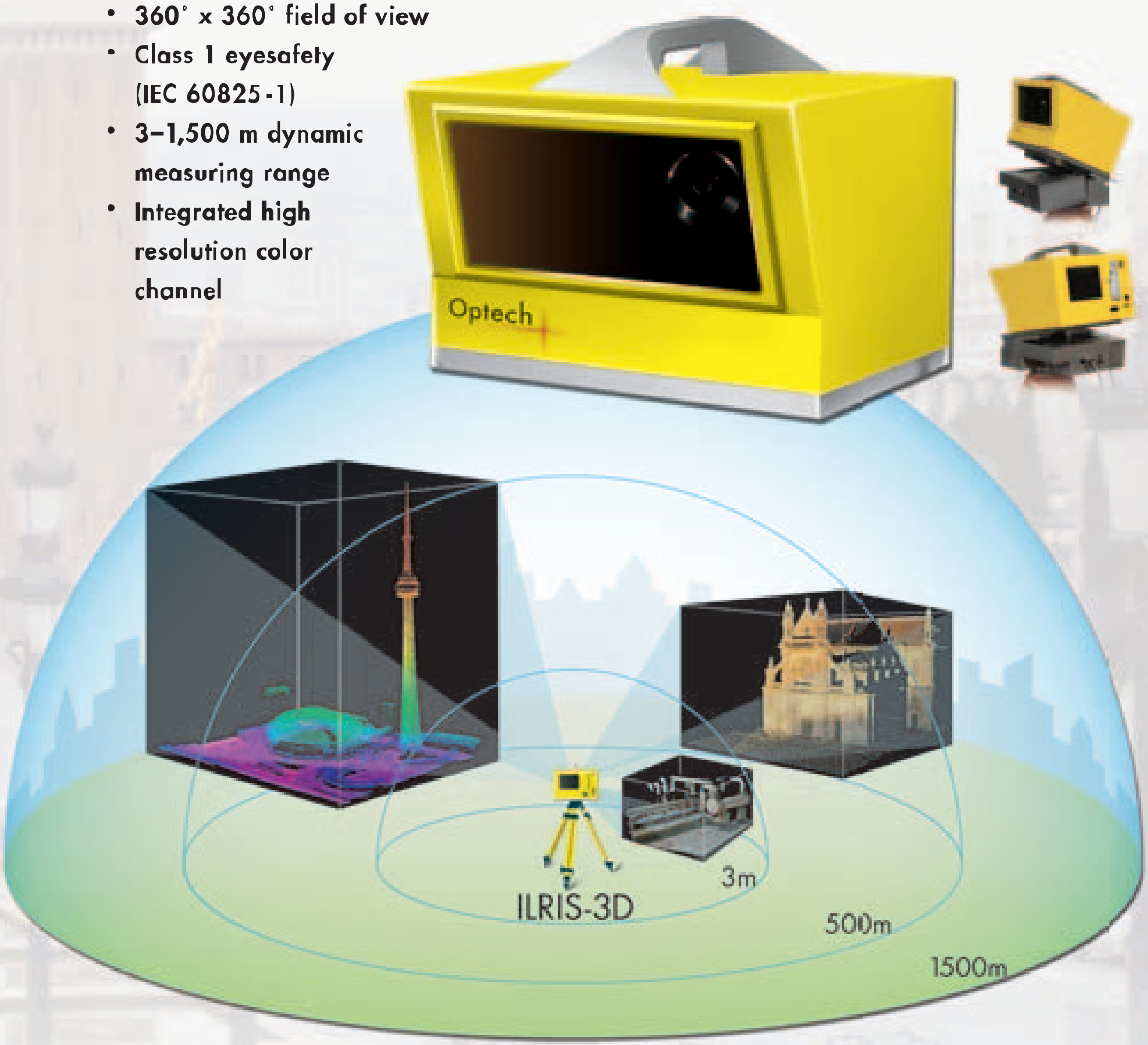

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Nancy Bohac

Earth's Flattest Place Measured by Satellite

Satellite imagery has allowed scientists from NASA and the Scripps Institution of Oceanography to survey the flattest place on earth. The Salar de Uyuni on the Altiplana of southwestern Bolivia is the world's largest salt flat. Measuring 3,800 square miles, it is about half the size of New Jersey. Scientists used images from NASA's Terra satellite's Multi-angle Imaging SpectroRadiometer (MISR) to observe the flat both when it was dry and when it was flooded with rainwater. Researchers studied the reflection of sunlight off the bright salt and determined small differences in water depth by levels of dimness. Using this method, they found that elevation varied by only about 16 inches over the vast salt surface.

A group of tourists explore the Uyuni salt plain. Image courtesy: NASA

Siemens Developing New Mobile Watchdog

A new, mobile communications device in development by Siemens may augment cell phones in the future by providing an alarm system. The Mobile Alarm System (MyAy), designed to alert users when something unforeseen happens, is equipped with a radio, microphone, speaker, keypad, and numerous sensors, including an infrared sensor to detect objects moving in the device's surroundings. An acceleration sensor can determine if the device is being moved, making it suitable for many uses, including a car alarm. MyAy's mobile radio module maintains contact with cell phones and is always on. The device runs Java allowing users to select from a wide variety of applications.

If certain criteria are met, such as a sound of a certain level or movement of an object in front of the device, MyAy can transmit a warning via SMS, or call a preselected cell phone number to alert its user. The device can be programmed via SMS, Java applications, a website, or a WAP-enabled cell phone. MyAy is expected to come in two versions, one that can be carried with a user and another that can transmit from home or other remote locations. The first version is scheduled for testing in spring of 2005.

Indian Ocean Warming May be Caused by Changing Winds and Currents

A recent NASA study suggests a link between changing winds, currents and the observed warming of the Indian Ocean during the 1990s. This research suggests the Indian Ocean is subject to the same type of long-term ocean-circulation oscillations that drive weather and climate patterns in the Pacific and Atlantic Oceans. By providing vital information about how currents and winds interact to drive climate change, this study reveals a missing link in the global ocean-warming puzzle. Findings were based on sea level measurements from NASA's Topex/Poseidon oceanographic satellite, sea-surface temperature data from the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) satellite, and wind data from the European Space Agency's European Remote Sensing satellites. Understanding the cause of this warming and predicting its future evolution are major challenges to the climate community, as the ocean's warming is tied into a much larger global cycle of events. Such findings demonstrate the importance of satellite data in understanding how complex planetary systems work.

Places like Chagos on Diego Garcia Island in the middle of the Indian Ocean may see the impacts of changing winds and currents in the form of ocean warming. Image courtesy: NOAA

Aerial Photography and Satellite Imagery Aid in Tracking Duck Migration

Hunters in Louisiana are wondering where the ducks have gone. After years of steadily decreasing populations, a cooperative effort between state, federal, and private waterfowl management agencies was launched to answer this question. The study will track the movement of mallards within the northeastern and southwestern areas of the state. Ducks with radio transmitters and bands will be tracked using both aircraft and ground crew teams within habitat areas identified and mapped from aerial photography, satellite imagery, and ground surveys. The half million dollar project is being funded by Ducks Unlimited, U.S. Fish and Wildlife Service, and the Louisiana Department of Wildlife. The project is scheduled to run through 2006.

Transmitters will help researchers find out where ducks are going. Image courtesy: Scott Bauer, USDA/FRS

NASA Grant Awarded to San Diego State Faculty Studying Global Change

Assistant Professor of Biology Matt Edwards has been awarded a $92,723 grant from NASA to collaborate with Ocean Imaging of Carlsbad, California, in studying global change and its effects on worldwide kelp distribution. Kelp populations offer a unique opportunity to map and monitor ocean changes, because they form extensive canopies. Using Earth Satellite Corporation's global database of Landsat satellite imagery, Edwards will produce the first global scale map of kelp communities and document the changes they have undergone during the past 25 years. One goal of Edwards' study is to determine the effects of climactic and human-induced changes on temperate reef communities.

Study Shows Glacial Melt Accelerating in Greenland

A NASA-funded study using satellite imagery and airborne lasers shows that Greenland's Jakobshavn Isbrae glacier doubled its speed of ice flow between 1997 and 2003. Satellite imagery and airborne lasers were used to track ice movements. Synthetic aperture radar from Canada's RADARSAT and data from the European Space Agency's European Remote Sensing Satellite was used to measure the glacier's velocity. Jakobshavn Isbrae is Greenland's largest outlet glacier and drains approximately 6.5 percent of the continent's ice sheet area. The accelerated rate at which this glacier is thinning provides evidence that glacial melt is accelerating due to warming.

TerraSAR-X To Launch in 2006

Germany plans to launch a new high resolution radar satellite in April of 2006. TerraSAR-X will provide up to 1-meter resolutions for both scientific and commercial use. Outfitted with Synthetic Aperture Radars, the satellite will provide detailed radar images around the clock in all weather conditions. A unique feature of this satellite is the active X-band antenna used to steer radar impulses in a desired direction or receive them from a certain direction without requiring rotation of the satellite. TerraSAR-X will operate in three different modes: a spotlight mode where the radar image covers an area of 5-10 x 10m at a resolution of up to one meter, a strip-map mode where corridors 30km in width and up to 1,500km in length are covered at 3m resolution, and in scan SAR mode, where corridors of a maximum of 100 km x 1,500 km are collected at 16m resolution. TerraSAR-X will be built through a public/private partnership between the German Aerospace Centre (DLR) and EADS Astrium (GmbH). Commercial imagery will be provided solely through Infoterra (GmbH).

NASA Ocean Data Program Ends

NASA has ended a program by which scientists had free access to ocean data collected by ORBIMAGE's OrbView-2 satellite. ORBIMAGE turned down a contract extension from the agency after seven years of successful contracts. More than 2,000 researchers have been receiving the ocean-color and temperature data collected by the satellite's Sea-viewing Wide-Field-of-view Sensor (SeaWiFS). NASA was the largest customer for the SeaWiFS data, according to ORBIMAGE. As of December 24 of last year, scientists have to arrange their own purchases through ORBIMAGE or use data from NASA's Aqua and Terra satellites.

ORBIMAGE's OrbView-2 "SeaWiFS" satellite captured this image of Hurricane Jeanne over Florida on Sunday, September 26, 2004. Image courtesy: ORBIMAGE

The State of Automated Feature Extraction:

A Conversation with Dr. David Opitz and Stuart Blundell

David Opitz

Stuart Blundell

Adena Schutzberg

Automated Feature Extraction (AFE) is a term I don't recall from my remote sensing class, but it's certainly one that today's remote sensing and GIS students know. More importantly, it's becoming a key part of getting the maximum value out of earth imagery to support and enhance GIS investments in local government, forestry, intelligence, or other areas. I recently spoke with Dr. David Opitz (CEO) and Stuart Blundell (COO) of Visual Learning Systems, Inc. (VLS), developer of the Feature Analyst software, to better understand how and why feature extraction tools came about.

History

How old is feature extraction? AFE has been the Holy Grail of the remote sensing industry, said Opitz. Remote sensing has a long history before the advent of digital cameras and multispectral sensors, so feature extraction likely did, too. The biggest demand for feature extraction has always been from military leaders: they wanted maps of battlefields. As the technology developed over time, airplanes carried photographers to capture imagery, and the disciplines of photogrammetry and image analysis matured. In World War II feature extraction from imagery was used to identify potential targets, and provided data for planning purposes. However, it was during the Cold War that serious interest and investments in automating the collection of information from satellite and airborne imagery became a major topic of research and investment by the government.

The challenge then, as it is now, says Blundell, was moving from a human powered feature extraction paradigm to one that depends mostly on a computer. Three related developments helped push AFE technology in that direction. First, there was the development of GIS which drove requirements for geospatial features to be stored in a computer database. Second, there were many more images to explore as governments started to launch satellite systems. With more planes and satellites in the skies, military and civilian users had far more data than they could interpret with limited staffs. Finally, computer technology grew powerful enough both in terms of speed and data storage to allow for advanced AFE to flourish in a larger audience of users.

As Opitz recalls, the 1970s and 1980s "were the years of military investment in the use of feature extraction." By the 1990s the technology was dormant with respect to the commercial GIS markets, but still very active in the defense and intelligence community. Most of the development of automated feature extraction tools was and is funded by the government; some hundreds of millions of dollars were spent during those decades. And, what did the government have to show for the investment in the early years? Opitz notes that while the goal was to be able to extract foundation features such as roads, buildings, drainage and vegetation, early systems using supervised classification could extract some types of vegetation, but that was all. Roads and buildings were typically extracted by hand (**Figure 1**).

Building a Better Mousetrap

The challenge of getting a computer to accurately recognize features in an image is a highly complex task. Early systems only considered spectral attributes as the basis of feature identification. "Consider roads for example," Optiz explains. "Some are gray, some are black, but all of them are weathered with varying textures. It's difficult to determine what is a road versus what is a parking lot, solely on the basis of color." Roads, he points out, have other properties than color. In fact, that's how people identify them, by combining many different feature-recognition properties. So, while a person walking down

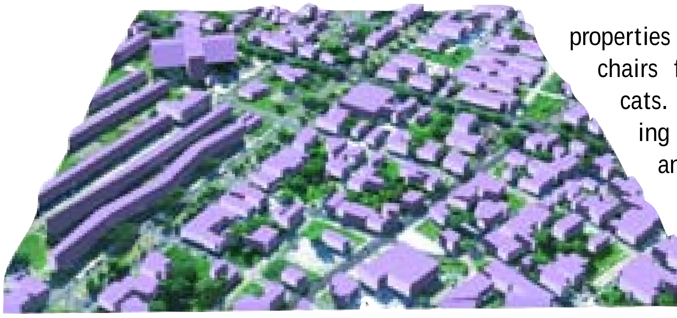

Figure 1 *Today, buildings can be extracted and converted to 3D.*

the street doesn't consciously think about it, determining if something is a road involves its texture, linearity, continuousness, and edge properties. "So, to be effective at extracting roads, you really need to look beyond spectral properties."

Opitz approached the problem from a machine-learning perspective, his area of expertise. He sought to "teach" software to look for seven key properties of features, specifically: color, size, shape, shadow, spatial association (what's nearby), texture, and pattern. Those are, whether each of us knows it or not, the properties our brains use to distinguish chairs from tables and dogs from cats. The hard part, really, is taking that logic out of the brains and putting it into the software, which is essentially what Opitz and Blundell did in their software.

VLS was founded in 1999 with money from a NASA Small Business Innovative Research grant and released its first product in 2001. Was there any technological reason for this level of feature extraction to appear on the market at that time and not before? Opitz feels that it would have been possible to create the software ten years earlier, but also notes, the processing would have been slow. "Instead of a one-minute extraction you'd see today, ten years ago you'd likely be waiting hours for your results." Blundell notes that ten years ago, high-resolution commercial satellite imagery was not available; hence, the software would have been less valuable outside of the defense and intelligence community. Today, he lists orbital platforms, such as IKONOS, QuickBird and OrbView-3, and the aerial photography industry as prime resources for high-value, temporally current, multi-band data (**Figure 2**). Add in the variety

Figure 2 *Road centerlines are extracted from QuickBird data in two steps: first by getting a polygon rendering, then converting the polygon to a centerline.*

Figure 3 *Shorelines can be extracted from multi-spectral (color) imagery as well as panchromatic (gray-scale) seen here.*

of new sensors—passive ones like digital cameras, and active ones, including LiDAR and radar, and there's plenty of data for all types of feature extraction uses (**Figure 3**).

Feature extraction from 3D and LiDAR, says Opitz, "is very accurate. Buildings have a consistent volumetric shape—consistent sizes, smooth planes, and sharp drop-offs at the edge. With monoscopic (one image) and 2D imagery, buildings are highly inconsistent in terms of color and texture, making it a difficult problem." Scanned maps are another popular data source which is easily exploited via AFE. Because they are already simplified, they are relatively "easy" to process. It's worth noting that in the 1990s there was lots of discussion

Figure 4 *Large land cover type features such as tree canopies, fields, and hydrology can be extracted from either high, or low resolution datasets.*

of raster-to-vector conversion. That, says Blundell "is simply capturing lines into spaghetti. Today, you can get real features that can flow directly into a GIS database."

Trends

The pair identified three trends they are seeing in feature extraction. First, the widespread availability of imagery including multi- and hyper-spectral data with hundreds of bands is making new kinds of collections possible. Blundell notes the use of Feature Analyst by researchers working with Mars data to extract geological features as an example. Back on earth, they point to the requirements of AFE for up-to-date maps as a second trend. "The biggest issue today in GIS work is keeping the data current. Once imagery is collected on a recurring timeframe, every year or two, for example, the goal is to ensure current maps." That's driving the use of feature extraction. The final trend, both feel, is the widespread and increasing use of 3D geospatial information to support a wide array of modeling and simulation requirements.

Opitz points to demands of homeland security for accurate 3D models of cities, not the "cartoons" of past years made from images draped over DEMs. It's possible now, he confirms, to use imagery data combined with DEMs to create realistic 3D features for simulation and modeling.

What are the limitations of the technology? Blundell notes that in the past, excluding the performance issues, the cost and access to imagery by the GIS community were the biggest limitations. Those cost issues have declined significantly over the past three years. What are not gone are some of the human factors. Opitz notes that there's still a need for education about the value of AFE in lowering the cost of geospatial production. Some are skeptical since the process is not 100% automated, and won't have a look. "They need to recognize that a 20-95% savings in labor costs is huge." But he is heartened; traditionally conservative agencies like the U.S. Forest Service are quickly coming around and becoming active users, helping to spread the word. The defense and intelligence communities are key users, as well (**Figure 4**).

Beyond Geospatial

While most of Visual Learning Systems software users extract features from geospatial data, the company has several interesting users from other fields, including the medical imaging industry. Users include dentists who rely on the technology to find cavities in teeth, and archeologists who match cracks in bones to help determine age ranges. Foresters use the software not just to identify tree species, but also to identify areas devastated by specific pests.

Both Opitz and Blundell are excited about the future role of AFE technology in the GIS industry. In fact, they feel it is something that will eventually be in nearly every GIS user's toolbox.

Vector-to-Raster Change Detection for Property Assessment

Bart Pouteau

Property assessment is an extremely time-consuming and expensive process that typically requires on-site visits by personnel from the local tax assessor's office. The City of Leduc, Alberta, Canada, has found a way to maximize the efficiency of its assessment personnel with assistance from an automated change detection technique applied to aerial photography and satellite imagery.

The application automatically compares remotely sensed imagery acquired in different years to find properties that have undergone structural changes that alter their values. The most common examples are construction of new buildings, room additions to existing houses, or demolitions of older structures (**Figure 1**). Local governments usually receive information about these projects through the building permit process, but when no permits are filed, property enhancements go unrecorded—and untaxed—unless field assessors happen to spot them.

Figure 1 *Construction in a farmer's field in 2003 (left) resulted in four new structures in 2004 (right).*

Computerized change detection techniques have traditionally provided little or no success in property assessment applications because new building additions, the most frequently unreported property enhancement, are usually too small to be accurately identified with standard raster-to-raster comparison techniques. In early 2004, however, Leduc learned that a new change detection service called HouseDiff, involving building footprint extraction and vector-to-raster comparison, had been developed by Hitachi Software Global Technology of Westminster, Colorado, specifically for tax assessment applications.

"Just in our pilot project, we found three or four house additions where no permits had been filed," said Ben Leung, Leduc City Assessor. More unreported enhancements may be discovered when Leduc completes its review of results for the entire change detection project.

"We plan to use it again next year," he added.

Assessing Leduc

Leduc is located 15 miles south of Edmonton, the capital of Alberta, with a population of 17,000 people. Through its Geomatics Services group, the city has developed customized GIS maps and applications used daily by multiple municipal departments. Digital GIS base maps are also available for public viewing on the Internet.

Figure 2 *A small shed was added in the back of a property during 2003. It's not visible in the 2003 image (left) but is in the 2004 image (right).*

Since 1998, the city's geospatial mapping efforts have included the acquisition of satellite imagery and aerial photography in alternate years. Leduc originally planned to collect new air photos every four years, but membership in a local consortium made aerial mapping affordable on a two-year cycle. The city orders high-resolution satellite coverage during interim years.

The consortium contracted for color aerial orthophotography at 10-centimeter (cm) spatial resolution in 2003, and Leduc obtained 0.61-meter QuickBird satellite imagery from DigitalGlobe of Longmont, Colorado, through Hitachi Software in 2004.

The city assessor has been a regular user of the imagery and other GIS data created by the Geomatics group. By law, the assessor must re-assess property values whenever the local market experiences a major change, either up or down. The Leduc assessor has typically sent field personnel to visit each parcel every two to three years. The crews carry print-outs of floor plans with them from the property records database and lists of approved construction from the permitting system.

"The crews drive down streets verifying that permitted work has been done," said Leung. "They also look at floor plans for all other houses and compare them with what they see from the street to determine if anything has been added."

Sometimes the addition of an unreported room or building is obvious, but at other times the assessors get a "gut feeling" that something has changed on a property, explained Leung. For example, the assessor may not have a clear street-side line of sight to a house addition or new building on a larger property (**Figure 2**). In these instances, the assessor personnel requested the Geomatics group to provide recent images spanning a few years to determine if undocumented enhancements had indeed been made to the property.

The drawback to this approach was that it required the field personnel to first observe something in person that warranted further investigation in the imagery, which wasn't always effective given the fact that many improvements can easily remain hidden from the assessor's view on the street. Undoubtedly, some property enhancements were being missed.

Leduc—and many other taxing districts—realized that a larger percentage of these improvements would be found and taxed if the procedure could be reversed so that imagery would be used first to spot evidence of property change. This information could then serve as guidance for field assessors who would know precisely where to look for the improvements.

City Geomatics personnel began considering options for applying change detection to the multi-year images and quickly concluded that an automated process was a necessity because manual comparison of raster imagery would consume too much staff time and too many hardware resources.

Comparing Vectors to Rasters

Traditional raster-to-raster change detection analysis involves the overlaying of two digital images acquired over the same area at different dates. The data sets must be perfectly registered during the overlay procedure so that like pixels match up. Some comparison methods simply allow the user to switch between the images. Other automated routines subtract one pixel value from that of its corresponding pixel, with a difference indicating some change has occurred.

While these processes work extremely well in locating large-area changes on the earth's surface, such as deforestation or regional development, they can't pinpoint feature variations like home additions that measure just a few meters. This is because the pixel-to-pixel registration process is never perfect, especially when corresponding pixels are different sizes as was the case with the Leduc aerial and satellite images. The resulting margin of error in raster-to-raster change detection exceeds the average size of the building features being sought, making it impractical for property assessment applications.

Hitachi's HouseDiff is an automated vector-to-raster analysis process that

Figure 3 *A gas station in the center of the image was demolished in 2003 (left), leaving an empty lot in 2004 (right).*

requires no overlaying or registration of pixels. Instead, it involves extraction of building vectors from the baseline, or earlier, image data. In the Leduc project, therefore, the vectors were created from the 2003 aerial orthophotos and then compared with the 2004 QuickBird satellite imagery. The system costs, on average, less than $0.50 per parcel.

In other methods of change detection, the two sets of imagery were required to have the same resolution. For HouseDiff, the difference in pixel size between the aerial photography and satellite imagery has no effect on processing results since pixels aren't compared.

Hitachi undertook the project in summer 2004. Once the building footprints were extracted, the automated routine began processing the raster satellite image, digitally examining each parcel in the search for geometric shapes that were probably buildings. To achieve the highest accuracy possible, Hitachi ran the raster identification routine several times on the multispectral QuickBird imagery, each time using different spectral filters. The near-infrared data, for instance, enabled the application to distinguish buildings from grass lawns or impervious driveway surfaces by their spectral signatures even though all might have similar geometric shapes.

When each property was analyzed, the system linked the parcel identification number to compare findings with the corresponding building vector and compared property information in the city's Computer Aided Mass Appraisal (CAMA) system. If a building was identified in the raster image, but there was no vector footprint from the aerial photo, HouseDiff tagged the parcel as "new" construction indicating that a house, barn, or garage had been built on the property between 2003 and 2004. Conversely, when no building was detected in the newer image, but a footprint vector existed for the older photo, the application labeled that parcel as "demolished," identifying

Figure 4 *This house was updated in the back, perhaps with an enclosed porch, between 2003 (left) and 2004 (right).*

that the structure present in 2003 had been torn down by 2004 (**Figure 3**).

In the Leduc project, there were 238 buildings tagged "new" and 71 labeled "demolished." These changes had been reported to the city and were recorded by the Assessor's Office.

For most parcels, however, the application found corresponding buildings in the raster and vector files, which were then subject to further automated analysis. The routine measured the borders, calculated the area, and determined the geographic orientation of the raster and vector building shapes and then compared them. A deviation in total square footage or structural shape indicated a probable building addition (**Figure 4**). A change in structure orientation may signal that the existing house had been replaced by a new one of similar size.

In all of these cases, the application flagged the parcels as "changed" and calculated the approximate square footage of the altered area. Properties were otherwise labeled "unchanged" if the geometry of the 2003 vector shape matched that of the 2004 raster. The process ultimately labeled 320 out of 9,419 homes and buildings in Leduc as "changed" between 2003 and 2004.

"Before delivering the results to Leduc, we performed a visual quality control check on images of the tagged properties just to make sure that a non-building feature, such as a recreational vehicle parked in the driveway, had not been misinterpreted as a shed or other permanent structure," said Bill Emison, Hitachi Project Implementation Engineer.

Maximizing Field Efficiency

Hitachi Software provided the results to Leduc in tabular and ESRI shape file formats. The Geomatics group loaded the shape files into its existing GIS and created a map with each parcel highlighted in a different color to represent "new," "changed," "demolished," and "unchanged" properties. This map and an address list were given to assessment personnel to guide them in determining which parcels required especially careful scrutiny during the field visits.

"We verified the results in person and were pleased with the accuracy," said Leung. He stressed that automatic change detection does not replace field assessment, but helps to improve its effectiveness by directing the field teams of where to look for unreported changes. This ultimately saves money for the city by helping the Assessor's Office make better use of limited personnel. Of the results reviewed to date, Leduc discovered several properties that had been improved without proper permits. These will be included on the city's tax rolls, helping to defray the cost of the change detection project.

About the Author

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Citrus Yield Mapping Machine Vision

Palani Annamalai and
Dr. Wonsuk Lee

***Figure 1** Experimental setup*

Introduction

This article describes the image processing module of a research project titled "Citrus Yield Mapping" that is being carried out in the Agricultural and Biological Engineering Deptartment, University of Florida, Gainesville, Florida. Precision farming, sometimes called site-specific farming, allows farmers to reduce costs through efficient and effective application of crop inputs tailored for within-field variability of factors such as soil fertility and weed populations. Global positioning system (GPS), GIS, remote sensing, variable rate technology (a technique that allows farmers to vary the application rates of production inputs such as fertilizers, pesticides and seeding rates based on spatial variability, VRT), yield mapping, and advances in sensor and information technology enable farmers to visualize the entire field to help manage the agricultural operations efficiently and improve overall productivity.

Among precision agriculture technologies, yield mapping is the first step in implementing site-specific crop management on a field. A yield mapping system measures and records the amount of crop harvested at any point in the field along with the position of the harvesting system. Yield maps are useful resources to identify yield variabilities within a field.

Currently, citrus groves are managed by blocks. A "block" is usually considered to be either a unit of land area separated by ditches or roads from adjacent planted area, or a group of trees of the same variety and original rootstock. There is no specific size for a block. They can range from 5 acres to 500 acres. The variability found within a block is not generally considered for grove management. Yield information is available only after the fruits are harvested, and then only as the sum from multiple trees. There is typically no data for an individual tree.

A yield mapping system using machine vision was developed as a means to identify citrus fruits and to estimate yield information of the citrus grove. The proposed system would provide single-tree yield and estimate citrus yield before the actual harvesting operation.

The Yield Mapping System

The yield mapping system was tested in a commercial grove located near Winter Garden, Florida. The system was mounted on a 4x4 truck which drove inside the grove during data capture. The system includes a desktop computer, a control box for an encoder and a color CCD (Charge-Coupled Device, an optical-electrical sensor) camera, and a DGPS receiver (Differential Global Positioning System, which provides enhanced position information) secured to the rear of the truck (**Figure 1**). A metal frame attached to the rear of the truck carries a generator, the source of power supply for the entire setup. The camera and a DGPS receiver are attached to a metal pole supported by the tailgate of the truck. The camera was 4.9m above the ground and pitched at a 45-degree angle relative to the ground, to cover a maximum section of the tree canopy. Video signals from the camera were fed to the computer through a frame grabber which provided real-time image transfer to system.

System Using

In order to develop the citrus fruit recognition algorithm, the project team shot 354 640 x 480 pixel images during the end of the citrus harvesting season, in the last week of December 2003 and the first week of January 2004. Each image was taken when the truck was stopped. It was moved to a new location and the next picture taken. Those images, shot across two days, were used to develop and test the algorithm. The images were taken in natural outdoor lighting condition.

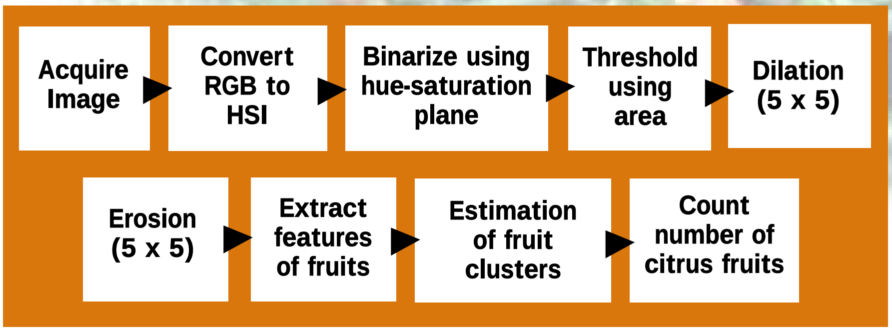

Figure 3 *Image processing steps of the fruit counting algorithm*

The Algorithm

The fruit recognition algorithm included three steps: (1) identify fruits from an image, (2) process the results to remove noise, and (3) improve precision in counting the number of fruits. The images were divided into calibration (25 images) and validation (329 images) data sets.

Pixels in the calibration images were classified into three classes: citrus fruits, leaf, and background. Pixel distribution graphs were plotted for various combinations of color components in the Red, Green, and Blue (RGB) and Hue, Saturation, and Intensity (HSI) color space. Using the hue-saturation information, it was possible to simplify the input images into just two colors—one for fruit, the other for leaf/background.

The condition for identifying the fruit was predicted by looking into the distribution of pixel values of fruit, leaf, and background classes in the calibration images in the hue-saturation graph (**Figure 2**). The luminance component of each pixel was added to make the value less dependent on the brightness level of the image. The algorithm classified a pixel as a citrus fruit class (white color) if it fell inside the thresholds; otherwise it was classified as a leaf or background class (black color). The binarized images contained noise mainly due to the little overlap of the leaf class with the citrus class in the hue-saturation color plane (the few "blue squares" in the threshold in Figure 2). By applying a threshold based on size of the extracted features, these noises were removed from the images.

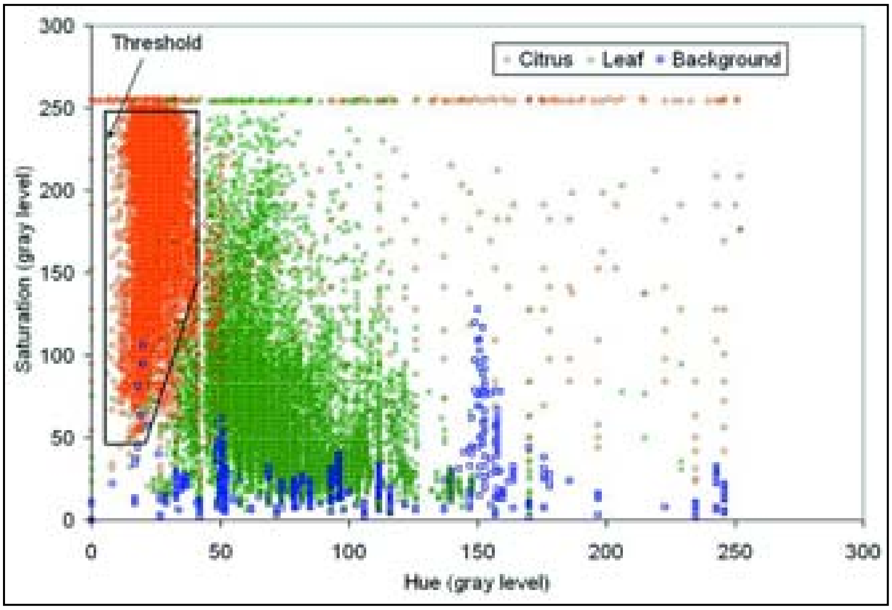

Figure 2 *Pixel color distribution for citrus, leaf/background in calibration images*

After binarization and noise removal, there were cases in which a single fruit, occluded by small leaves, was counted as more than one fruit. To overcome this problem, a set of dilation (grow objects to combine objects split by noise) and erosion (shrink objects to find and remove noise) with a suitable kernel size was applied to the images. Study revealed that the areas of the fruit clusters were relatively large in size, compared to other single fruits. A threshold was calculated based on the average area of fruit, and if the fruit area was more than the threshold, it was identified as a fruit cluster, and counted as two fruits instead of one. Fruit clusters were counted only as two instead of

Figure 4 *Input color image and final processed image*

many fruits because of the difficulty in defining a threshold in area for multiple fruits. The steps in the fruit counting algorithm are shown in **Figure 3**.

The fruit counting algorithm was applied to a validation set of 329 images. **Figure 4** shows a sample input color image and the final processed image. The percentage error per image was as low as 0% and as high as 100% in cases where there were 1 or 2 fruits and the algorithm identified none. The main reason for the high error rate was due to very small fruits. These were clear to the human eye, while the algorithm treated them as noise and failed to count them.

In order to evaluate the performance of the algorithm, fruits counted by the fruit counting algorithm should have been compared with the actual number of fruits in the region covered in the image. Since it was very difficult to define the boundary of each image and count the number of fruits in the grove, the images were shown to three observers and the average of these three readings was taken as reference for the fruit counting algorithm. A regression analysis was conducted between the number of fruits by manual counting and the number of fruits counted by the fruit counting algorithm. It was found that 79% of the fruits were correctly counted by the machine vision algorithm.

A yield prediction model was developed based on the collected data and it was tested with the hand-harvested yield data. Harvesting crews collected fruits from each tree, allowing for accurate counts per tree. For qualitative analysis, the yield data was arbitrarily classified into three classes based on the yield distribution. The yield prediction model predicted 15 plots correctly out of 22 plots (**Figure 5**). The reasons for the false predictions were mainly due to the fact that, using a single camera, it was not possible to cover the entire citrus tree. The results indicate that the yield prediction model could be enhanced by using multiple cameras for covering the majority of tree canopy. Highly non-uniform illumination in an image presented a problem for color vision based segmentation approach. The result of this research verifies the feasibility of developing a real-time machine vision system to estimate citrus yield on-the-go.

About the Authors

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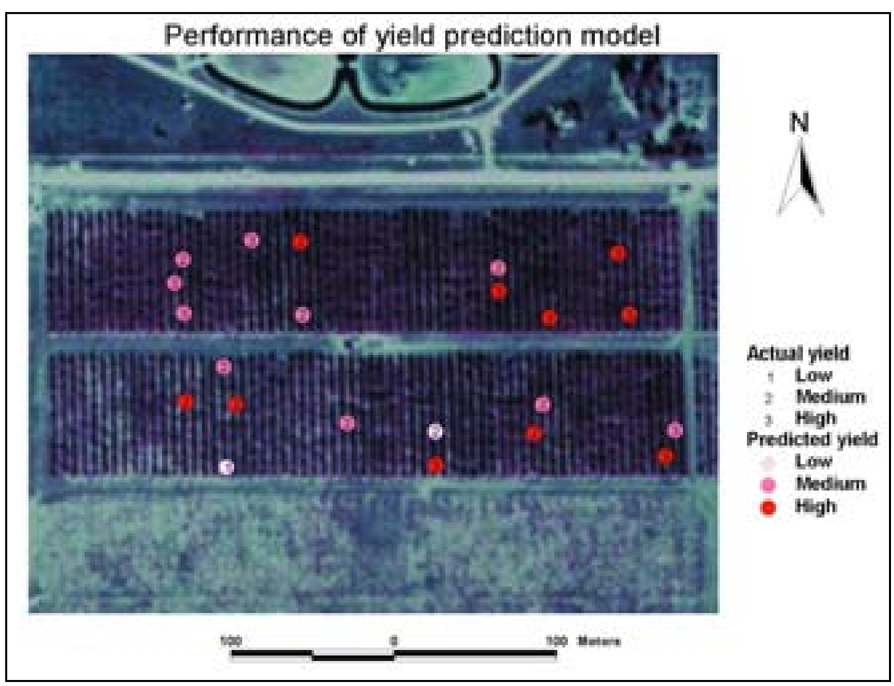


Figure 5 *Performance of yield prediction model. A Digital Orthophoto Quarter-Quad (DOQQ) 1-meter resolution photograph underlies the yield map.*

Automated Processing of High Resolution Satellite Imagery

for Feature Extraction and Mapping of Urban Areas

Aaron K. Shackelford
and Curt H. Davis

Introduction

High-resolution satellite imagery became commercially available in late 1999 with the launch of Space Imaging's IKONOS satellite. In subsequent years, several other high-resolution commercial satellites were launched (DigitalGlobe's QuickBird and ORBIMAGE's OrbView-3). The spatial resolution and spectral information provided by these sensors make them well-suited for urban area applications. The high spatial resolution (0.6-1m) allows the delineation of fine-scale features in the urban environment, such as individual roads and buildings.

Recently, the National Geospatial-Intelligence Agency (NGA) issued two separate $500M contracts to DigitalGlobe and ORBIMAGE for the development of next generation satellite sensors. These next generation sensors will have increased spatial resolution (~ 0.4 m) and additional spectral bands. Even with current imaging assets, the quantity of image data exceeds the human capacity of trained image specialists within the intelligence community to analyze. When data from the next generation sensors becomes available, the problem will get significantly worse. Automated upstream processing is needed to exploit the vast quantities of high-resolution commercial satellite data from current and next generation satellite sensors.

There are a number of commercial software packages, such as eCognition (Definiens Imaging) and Feature Analyst (Visual Learning Systems) that provide semi-automated processing capabilities. Semi-automated techniques require human interaction in the processing loop to input training data and/or control the operation of the software. Although semi-automated techniques can decrease the workload of image analysts, more automation in the processing chain is needed. Thus, the development of fully automated processing techniques, requiring no human interaction in the processing loop, is an active research area. This article summarizes several fully automated processing techniques developed for feature extraction and land cover classification over urban areas.

Urban Area Feature Extraction

The two most prominent features characterizing an urban environment are road networks and urban buildings. Both roads and buildings can exhibit a variety of spectral responses due to differences in age and/or material and vary widely in physical dimensions. Thus, these features are difficult to extract in an automated fashion due to their spatial and spectral variability within a scene and across multiple scenes.

In one approach we developed, road segments are extracted by first identifying groups of spectrally similar non-vegetation pixels oriented in a long narrow rectangular shape. An iterative algorithm then grows the ends of the line segments, extracting curved portions of roads (if present). As each road is extracted, it must fit a spatial model that enforces the road network topology. Vegetation is identified from the normalized difference vegetation index (NDVI) statistic calculated from the spectral image information and shape is quantified by a 2D spatial signature of the image pixels. The 2D spatial signature consists of the maximum and minimum length line segments of spectrally similar pixels passing through each non-vegetation pixel in the image. The process for computing the 2D spatial signature is illustrated in **Figure 1**. The output of the road extraction algorithm is a single pixel-wide piecewise linear response that estimates the location of the road centerline.

Although buildings vary significantly in size and spectral response, there are several characteristics common to most buildings that can be exploited for automated extraction. First, buildings cast shadows on the ground. Second, buildings in urban areas typically are quasi-rectangular in shape. Because there is significant variation in size, a multi-scale approach must be utilized. A multi-scale image decomposition technique can be used to identify bright and dark objects in an urban image. Bright and dark objects identified at one scale of a multi-scale decomposition are shown in **Figure 2**. Buildings with a bright spectral response as well as building shadows are easily visible in the decomposition. Two building detectors are utilized, direct detection of spectrally bright buildings through shape analysis, and indirect detection of buildings through identification of cast shadows.

The output of the fully automated road network and 2D building footprint extraction techniques for a dense urban area is

Figure 1 *2D spatial signature determination for a single road pixel. Left: line segments radiating out from central pixel are examined for spectral similarity. Right: maximum and minimum length line segments identified.*

shown in **Figure 3**. Accuracy measures for the extraction are reported in **Table 1**. The accuracy measures are calculated by comparing the automatically extracted features to ground truth reference features. Completeness is the percentage of the reference features that have been extracted by the automated processing, and Correctness is the percentage of the automatically extracted features that are not in error. It is important to report both statistics when analyzing feature extraction results. For example, if the entire image is identified as building, the extraction would be 100% complete but have a very low value of correctness. Conversely, if only a single road is extracted and it is correct, there will be 100% correctness but a very low completeness value.

Fully Automated Urban Land Cover Classification

Supervised classification techniques, such as maximum likelihood, are widely used for generation of land cover maps from remote sensing imagery. These classifiers require human generated training data and are thus only semi-automated. However, by automating the generation of training data, supervised classifiers can be used in an unsupervised, or self-supervised fashion, to perform urban land cover classification. Fully automated feature extraction techniques can be used to generate training data for input into supervised classification algorithms, thereby producing a self-supervised urban land cover classifier. Here, the feature extraction techniques do not seek to extract all features present in the imagery. Instead, they are used to identify very high confidence instances of the different urban land cover classes, so as to minimize the use of erroneous training data in the classifier.

Due to the complex nature of high-resolution urban area imagery, traditional classification techniques achieve only limited success in these areas. We previously developed a supervised fuzzy logic based classifier that was designed specifically for high-resolution urban imagery. In addition to spectral signature, the classifier makes use of a variety of spatial measures, selectively applying them only to the classes where they increase discrimination. The classifier operates at both the pixel and object levels, outputting a detailed urban land cover classification map. The identified urban land cover classes are: Road, Building, Impervious Surface, Grass, Tree, and Shadow.

Although our initial classifier was supervised, we can automatically generate the training data using feature extraction

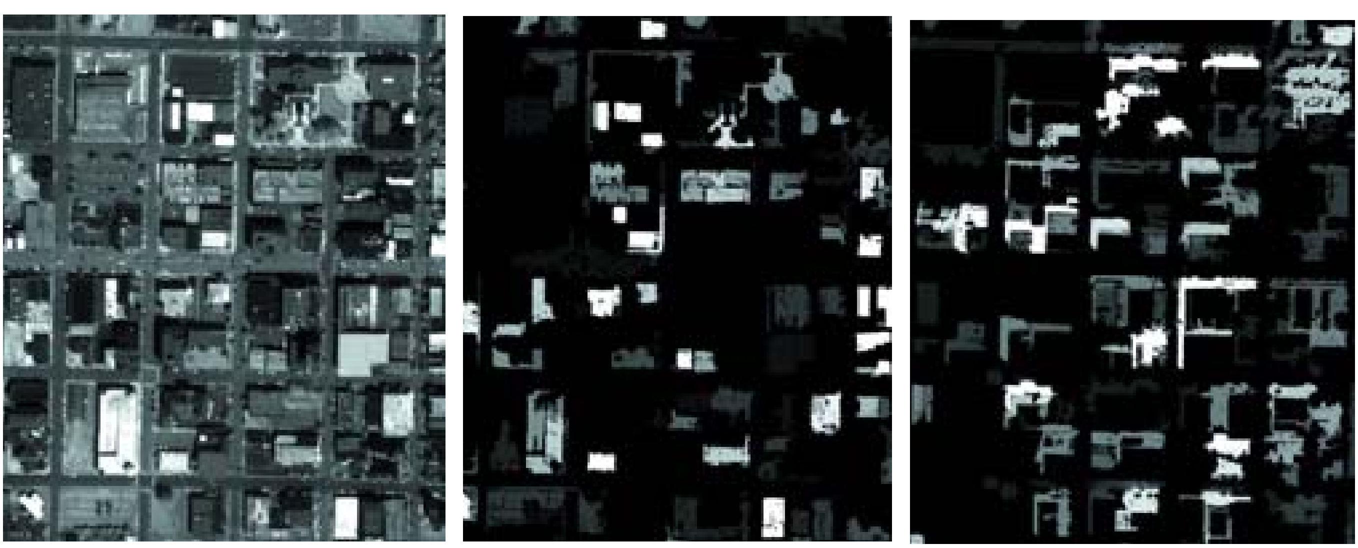


Figure 2 *Image decomposition. Left: panchromatic image; middle: bright objects; right: dark objects. Note: Only one scale of the multi-scale decomposition is shown here.*

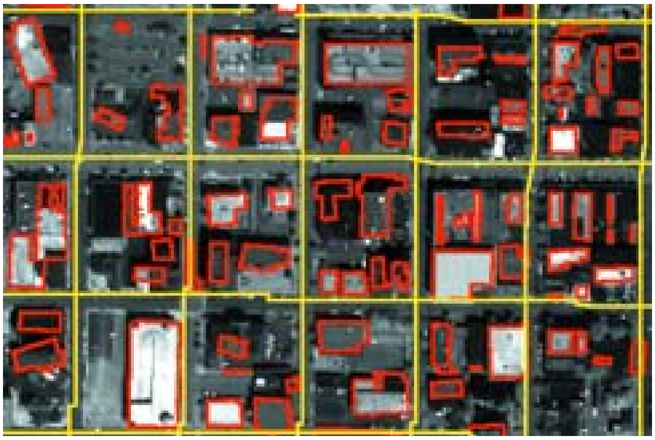


Figure 3 *Extracted road network and 2D building footprint features*

methods so that no human input is required. Because labeled training data is generated internally by the system, systems of this type can be referred to as self-supervised. Self-supervised classification systems differ from unsupervised classifiers in that unsupervised classifiers output an unlabeled classification, requiring further human analysis to determine the class labels, whereas self-supervised classifiers output a labeled classification.

Feature Extraction Statistics ***(Urban Image, Figure 3)***

	Completeness	***Correctness***
Road Network	**87.2%**	**70.4%**
2-D Building Footprint	**70.7%**	**87.4%**

Modified versions of the feature extraction algorithms described in the previous section are used to generate training data for the Road, Building, and Shadow classes. Training data for the vegetation classes are generated through analysis of the NDVI statistic and an entropy texture measure. No training data is required for the Impervious Surface class. The urban land cover map generated using this fully automated self-supervised classification approach is shown in **Figure 4**. The classification has an overall accuracy of 87%, extremely good for a fully automated technique. The individual class accuracies are reported in **Table 2**.

Urban Land Cover Classification Accuracies
(Land Cover Image, Figure 4)

Class	***Accuracy***
Road	**95%**
Building	**70%**
Impervious Surface	**72%**
Grass	**100%**
Tree	**99%**

Future Work

Although the results achieved thus far are promising, there remains much work to be done in the development of fully automated processing techniques for urban area mapping and feature extraction. Specifically, additional work must be done on the self-supervised classifier to increase the accuracy of the Building and Impervious Surface classes. In addition, when the next generation satellites from DigitalGlobe and ORBIMAGE become available, these techniques will need to be extended to take advantage of the increased spatial and spectral resolutions.

About the Authors

Mr. Aaron Shackelford is a Ph.D. student in the Department of Electrical and Computer Engineering at the University of Missouri-Columbia. His doctoral research is focused on the development of automated processing techniques for extraction of urban area geospatial information products from high-resolution satellite imagery.

Dr. Curt Davis is the Croft Distinguished Professor in the Department of Electrical and Computer Engineering at the University of Missouri-Columbia and the Director of the Center for Geospatial Intelligence *(geoint.missouri.edu).* He can be contacted at *DavisCH@missouri.edu.*

Figure 4 *Self-supervised urban land cover classification. Left: false color image; right: urban land cover map*

With New Central Database, GIS Data Flows Freely at Thames Water

Simon Timmis

RWE Thames Water, the world's third largest private water company serves 70 million customers in 20 countries, and has a myriad of responsibilities to its customers, investors, and local governments. Based in Reading, England and part of the German-based RWE Group, Thames Water is above all charged with providing efficient water services to the people it serves.

Thames Water must efficiently manage the data that it uses for everything from onsite maintenance and financial management to customer service. These "silos" of data work most intelligently when they're linked across departments, and are accessible to a wide range of employees, and sometimes, customers.

Until Thames Water brought in a group of technology partners to create an open database of GIS data, the vision of free-flowing access to mapping information was just a vision. After completing a pilot project with its partners Oracle, Autodesk, and Crowder & Co., Thames Water is now reaping the benefits of its first true shared GIS database.

GIS Datasets in Isolation

Thames Water used GIS datasets, of varying formats, which resided in various vendor solutions provided by Oracle, Autodesk, and ESRI, among others. The knowledge within these datasets could not be tapped to their full potential; the data could only be accessed by "those in the know"—that is, by a small number of users within each specific department.

The fragmented, department-based systems used aging software, which increased the chances of breakdowns. The systems were becoming increasingly expensive to maintain and run. In order to share information between departments, datasets had to be copied, translated, and loaded between many different file formats and databases. The fact that datasets existed in isolation meant that updates took as long as three weeks, which made it difficult to base any field or office decisions on the information.

Thames Water executives determined that a better system for updating and sharing GIS data would help the organization meet its goal of providing efficient and safe water service to its customers. The new vision included allowing customer service representatives to see GIS maps when customers phoned, speeding answers about service shutdowns or water main breaks. An easily updateable GIS database would increase the trust that Thames Water workers had in the data. For example, if mapping data could be updated in a timely manner, field workers and financial staff would feel more comfortable basing key decisions on the data at hand.

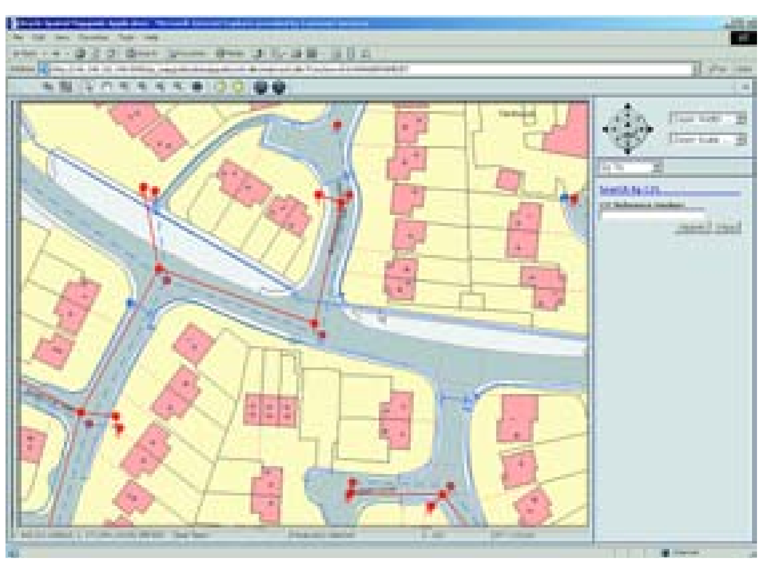


Figure 1 *Thames Water's intranet application powered by Autodesk MapGuide 6.5. Based on the Ordnance Survey map with the sanction of the controller of H.M. Stationary Office, license number WU298557.*

Call to Action: Creating Detailed Network Reports

Like all privatized water companies in the United Kingdom, Thames Water is regulated by the U.K.'s Office of Water Services (known colloquially as Ofwat), along with the Drinking Water Inspectorate, another regulatory body, and several others.

Figure 2 *Thames Water's data maintenance application using Autodesk Map 3D. Based on the Ordnance Survey map with the sanction of the controller of H.M. Stationary Office, license number WU298557.*

Each June, the water company must deliver reports about its network to the U.K.'s Director General of Water Services. These detailed reports indicate the length of new mains laid, relined or renewed each year. The compilation of these reports was a huge task involving many hours of staff time—and costing much more money than necessary. As soon as one report was completed, work began on the next, so some staffers were effectively employed full-time to produce this information.

In the end, it was the release of a new series of the definitive U.K. topographic mapping data that spurred Thames Water to create a central GIS database. Ordnance Survey, the UK government agency charged with mapping (akin to the U.S. Geological Survey), released its new MasterMap product, an entirely new, definitive, massive, digital map of Great Britain, for use within GIS systems. Thames Water needed a central geospatial database in order to make use of the MasterMap data.

Having identified the vision, it became clear that the company had to take an overview of the whole organization, and should tap into the expertise of its information technology partners Autodesk, Oracle, Crowder, along with Ordnance Survey.

Instead of using traditional GIS vendors, which use proprietary interfaces to provide data access, Thames Water looked to different providers, with open systems. That meant if the company was not happy with the technology for any reason it would be possible to put in a different system, provided it used the same open technology. The first step was to prove the validity of a central database vision by creating a pilot.

Pilot Project Proves Benefits

Thames Water officials decided to build the pilot project around a central Oracle Spatial database. On top of the database, Autodesk Consulting implemented its MapGuide 6.5 solution (Figure 1) which provided intranet access. Autodesk Consulting also added its Map (Figure 2) product to allow data updates to the network set data, and a series of Java Web Services so that Thames Water could generate network asset reports from the database.Crowder contributed its NETBASE integrated network management system, which brought together 18 corporate data sets from a variety of systems, including customer billing, customer contacts, regulatory reporting systems and flow/pressure telemetry. The NETBASE database and software suite helps major water utilities manage distribution and drainage systems.

With the technology in place, the testing began. The questions, beyond "Does it work?" included: How we could use the new system to solve business problems? How could it help the business become more flexible? The designers wanted to make sure if anyone had a problem with data it could be solved with the pilot; they did not want to have to create other applications.

The Thames Water teams continue to develop different scenarios to check that the technology could solve any business problem, or make a process more efficient. For example, they are examining what happens when a water main bursts—a routine event for a water company, but one where GIS information comes into play throughout the entire process.

The pilot database went live in summer 2004, and Thames Water executives are currently applying the data to many business needs. Asset strategy teams can now access geographic breakdowns of assets. Since data is updated immediately, reports to regulatory bodies are completed far more quickly. Customer service representatives can access maps that allow them to provide better answers to customer questions.

The Present and the Future

With a shared database, Thames Water can now realize its vision of making its maps available to many departments and many workers. And that easy access to GIS data is just the start. For instance, customers will be served faster and more efficiently. Expensive and unwieldy processes will be eliminated, freeing up funds for other vital projects, such as infrastructure upgrades.

And, because the technology is all based on a robust, open platform, it forms a solid bedrock for any possible future development, leaving the way open to realize even further potential in the years to come.

About the Author

Simon Timmis has been working for more than a year as a consultant in the IS team within the European division of RWE Thames Water. He focuses on the GIS Strategy with the UK business. Previously, Timmis developed a GIS/CCTV system, Pipesight, while working as a CAD Manager for a large UK construction contractor.

NPOESS and Climate

Part 2: Making the Measurements

George Ohring
Mitch Goldberg
Dave Jones

This is the second part of a two-part article on just how the National Polar-orbiting Operational Environmental Satellite System (NPOESS) will measure the Earth's climate. Multiple sensors on NPOESS will make the observations, which must be collected, processed, quality controlled, and used as input, into decision support systems, such as numerical weather prediction models and climate change assessments. Unfortunately, no single "environmental sensor" exists that can provide scientists with a critical single measurement of the Earth's long-term climate system. One of the challenges for NPOESS is to collect critical information for operational use while simultaneously collecting high quality observations for longer-term monitoring and research on the Earth's changing climate.

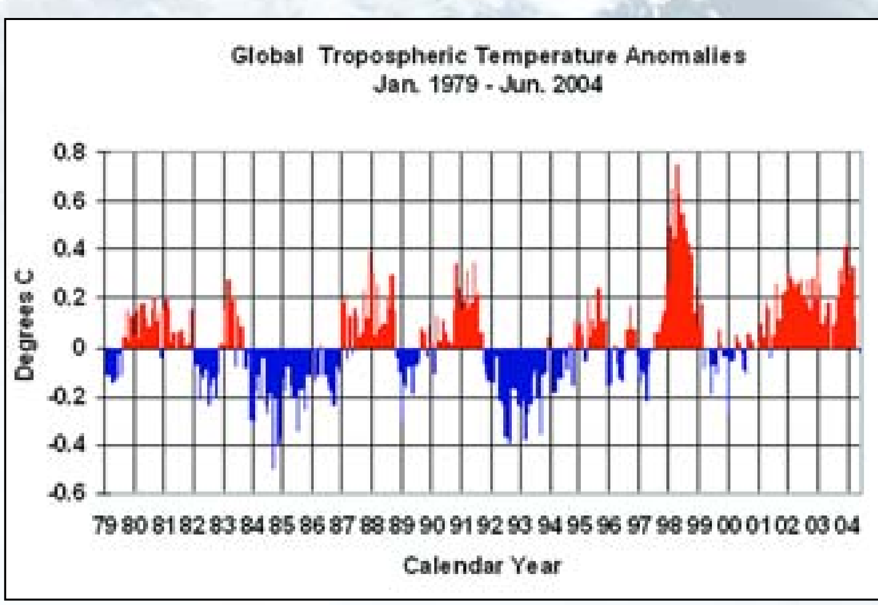
The NPOESS Climate Mission

Today, operational earth-observing satellites provide more than 99% of the observations used in computer-driven weather forecasts—the backbone of all weather predictions. The bulk of these observations come from polar-orbiting satellites. These systems also provide useful climate information, in particular on climate variations. Climate is of primary importance in the NPOESS program as shown by its plan to minimize measurement bias errors and to maintain the long-term stability of instruments, a critical requirement for constructing reliable long-term climate records. The design lifetimes of the NPOESS satellites are about twice those of the current operational

Meteorologist Andrew Shashy works on an extended weather forecast as a monitor above him displays a Global Forecast System model prediction for Hurricane Frances and other weather patterns on Saturday, September 4, 2004, at the National Weather Service facility at Jacksonville International Airport in Jacksonville, Florida.
Image courtesy: AP World Wide Photos

satellites, 5-6 years vs. 2-3 years. This is a significant advance for climate applications because it will reduce the uncertainty that results when records from successive satellite instruments are compiled to create a long-term climate data record. The NPOESS program will try to assure the continuity of observations from instruments on the National Oceanic and Atmospheric Administration's (NOAA) Polar-orbiting Operational Environmental Satellites (POES), the Department of Defense's (DoD) Defense Meteorological Satellite Program (DMSP) spacecraft, and the National Aeronautics and Space Administration's (NASA) Earth Observing System (EOS) satellites that are essential for the construction of long-term climate data records.

In comparison to their current operational counterparts, the NPOESS instruments will also have much better spatial and temporal resolution, as well as more spectral channels of observation. NPOESS will provide new observations, for example, the composition and size of atmospheric aerosol particles. The effect of these particles on climate forcing—through their influence on the Earth's radiation budget and on cloud and precipitation formation—is a major unknown. NPOESS will measure climate variables not currently observed by the operational satellites, providing sustained measurements of solar radiation, sea level, and the Earth's radiation budget. Such measurements have been made in a research mode with no commitment to a long-term continuity of observations.



Global atmospheric (lower troposphere) temperature trends from the NOAA POES Microwave Sounding Instrument. Red is an increase in the temperature from the average and blue is a decrease in temperature. The temperature in this region is strongly influenced by oceanic activity, particularly the "El Niño" and "La Niña" phenomena.
Image courtesy: University of Alabama, Huntsville

NPOESS Instruments and the Climate Mission

In this section, we review the planned NPOESS instruments, describe their contributions to the climate mission, and present some examples of the climate applications of current satellite instrumentation.

The Advanced Technology Microwave Sounder (ATMS)

The ATMS will continue and improve upon the measurements of NOAA's Microwave Sounding Unit (MSU) and Advanced Microwave Sounding Unit (AMSU) instruments. The MSU and AMSU have provided critical data on long-term changes in atmospheric temperatures. However, the trends from such observations are uncertain due to calibration problems and the drifting orbits of the NOAA POES spacecraft that cause the daily observing time to drift over the satellite's lifetime. As a result, different investigators have applied various schemes to account for these effects and have come up with differing temperature trends. Higher values agree with the average, *in situ* global warming rate at the Earth's surface and lower values suggest that the atmosphere is warming only at a negligible rate. NPOESS satellites will maintain constant equatorial crossing times and altitude throughout the mission lifetime. This capability to make measurements at "precisely" the same time each day is important to maintain consistency in the long-term data records required for climate change analysis and assessment.

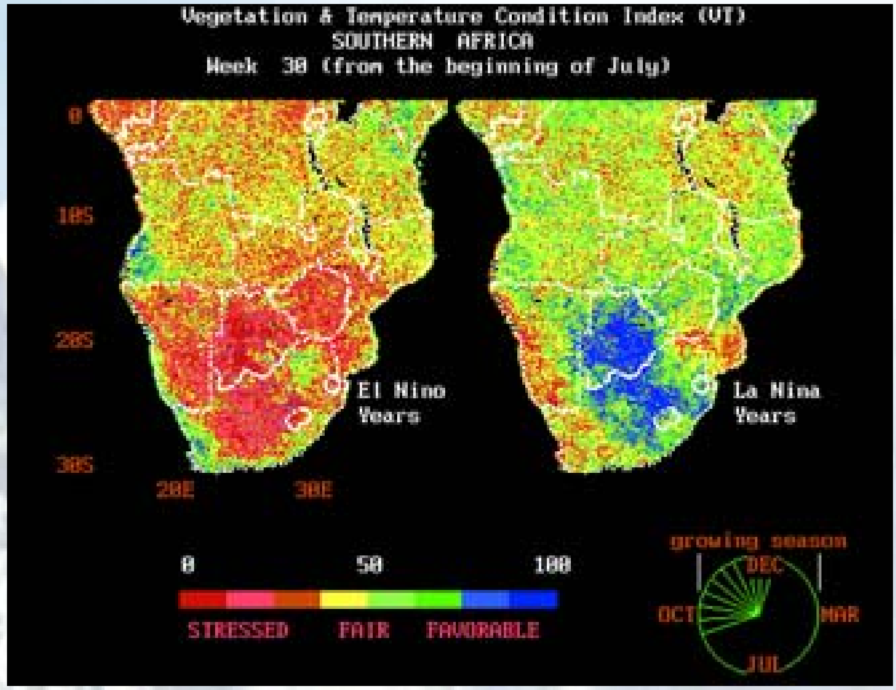
The Cross-track Infrared Sounder (CrIS)

The CrIS will provide substantially improved measurements of the temperature and moisture profiles in the atmosphere. The current High-resolution Infrared Radiation Sounder (HIRS) instrument on POES contains 20 infrared (IR) channels of information. CrIS will have more than one thousand spectral channels in the infrared. The large number of channels coupled with more refined spectral resolution will enable CrIS to measure temperature and moisture at better vertical resolution and with greater precision. CrIS will also have improved horizontal spatial resolution and provide unique information on clouds and greenhouse gases. CrIS will provide continuity with the NASA EOS Atmospheric Infrared Sounder (AIRS) instrument that is currently flying on the Aqua satellite.

The Ozone Mapping and Profiler Suite (OMPS)

The OMPS will measure the total amount and vertical profile of atmospheric ozone and continue the daily global data produced by the current ozone monitoring systems: the Solar Backscatter Ultraviolet spectral radiometer (SBUV)/2 and Total Ozone Mapping Spectrometer (TOMS), but with higher fidelity. The OMPS is comprised of two sensors—a nadir-viewing sensor and a limb-viewing sensor. Both sensors will maintain long-term data product stability through periodic solar irradiance measurements.

The SBUV/2 heritage instrument has been used to monitor the Antarctic ozone hole and the destruction of the ozone layer by industrial chlorofluorocarbons (CFCs). The NPOESS OMPS will monitor the recovery of the ozone layer with the phase out of CFCs and will do so with much improved measurements of ozone profiles in the stratosphere, where these changes are occurring.



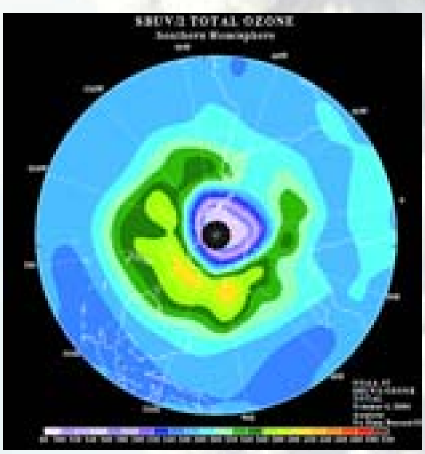
Typical patterns of vegetation conditions for El Niño and La Niña years in southern Africa from NOAA POES AVHRR observations. Red color represents stressed vegetation conditions (drought); blue portrays unstressed vegetation state. VIIRS, with its on-board visible calibration and finer scale horizontal detail, will permit more reliable quantification of El Niño effects on vegetation. Image courtesy: NOAA NESDIS

The Visible/Infrared Imager Radiometer Suite (VIIRS)

The VIIRS will combine the radiometric accuracy of the Advanced Very High Resolution Radiometer (AVHRR) currently flown on the NOAA POES spacecraft with the high (0.65 kilometer) spatial resolution of the Operational Linescan System (OLS) flown on DMSP. The VIIRS will have more than 20 spectral channels in the visible, near-infrared and infrared, and provide information on sea surface temperature, vegetation, clouds, aerosols, snow and ice cover, and, for the first time, operational measurements of ocean color. VIIRS will have on-board calibration of its visible channels, remedying a significant impediment to climate monitoring applications from its operational heritage instruments.

The Total Solar Irradiance Sensor (TSIS)

The TSIS will measure the total radiation from the Sun as well the spectral distribution of solar radiation from 0.2-2 micron. Instruments currently flying on NASA's Solar Radiation and Climate Experiment (SORCE) mission will provide historic data. The TSIS will supply measurements of total solar radiation with an absolute accuracy of 0.01%, and a long-term relative accuracy of 0.001% per year.



The purple areas over Antarctica in this color-coded image of Southern Hemisphere ozone amounts from SBUV/2 observations are the 2004 ozone hole. Highest ozone values are blue, lowest, pink. The black disk in the center is the region of winter darkness where the instrument, which measures solar ultraviolet radiation scattered back by the atmosphere, cannot obtain measurements. Image courtesy: NOAA Climate Prediction Center

The Earth Radiation Budget Sensor (ERBS)

The ERBS will be similar to its heritage instruments flown on NASA's Earth Radiation Budget Experiment (ERBE) and Clouds and the Earth's Radiant Energy System (CERES) missions. These sensors measure the total amount of solar radiation reflected and the total amount of long-wave radiation emitted to space by the Earth's surface, clouds, and atmosphere. NPOESS will ensure the sustained, continuous measurements of the Earth's radiation budget that are needed for climate studies.

The Conical-scanning Microwave Imager/Sounder (CMIS)

The CMIS will collect global microwave radiometry and sounding data to produce microwave imagery and other atmospheric and oceanic data. CMIS will observe at 77 microwave channels, covering the spectral range from 6.6 to 183 GHz, with a horizontal resolution from 15-50 km, depending on the data product. Data products will include atmospheric temperature and moisture profiles, precipitation rates, snow and ice cover, cloud water and ice content, sea surface winds (speed and direction), sea surface temperature, and soil moisture. Of particular importance to climate applications are the low frequency channels on CMIS at 6.6 and 10 GHz, which will enable the first operational measurements of soil moisture, a key variable about which very little is known for both interannual climate variations and long-term climate change. The low frequency channels will allow "all weather" determination of sea surface temperature (SST), another key climate variable. The capability of obtaining SST observations even under cloudy conditions overcomes a drawback of the traditional IR observations of SST.

The Aerosol Polarimetry Sensor (APS)

The primary mission of the APS is to provide high quality radiometric data as a function of polarization in the visible through short-wave infrared spectral regions in support of climate studies. APS will measure radiance in orthogonal polarizations at multiple wavelengths and viewing angles to produce data on aerosol total amount, particle size, shape, scattering albedo, and refractive index. These measurements will enable scientists to determine the absorption and scattering characteristics of aerosols that control the effects of aerosols on climate. These effects are of two types: the direct effect—the influence of the particles on the reflection or solar radiation or absorption of Earth's long wave radiation—and the indirect effect —the influence of aerosols on cloud and precipitation formation.

Summary

NPOESS will significantly advance the nation's ability to monitor global climate variations and change. NPOESS is the first operational environmental satellite system that has been designed from the outset with climate as one of its missions. Realizing the full benefits of NPOESS for climate will not be easy. Monitoring and early detection of climate change requires highly stable instruments, a major challenge for NPOESS. This challenge is also an opportunity—an opportunity to provide policy makers with the information they need to make informed decisions about adaptation, mitigation, and prevention strategies for climate variations, change, and their impacts.

The contents of this paper are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of the NOAA, NASA, or the U.S. Government.

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Mitch Goldberg is the Chief of the Satellite Meteorology and Climatology Division in the NESDIS Office of Research and Applications. He has been instrumental in preparing for NPOESS by ensuring that the advanced research instruments on NASA's EOS satellites are rapidly exploited for operational weather and climate prediction. Mitch can be reached at *mitch.goldberg@noaa.gov.*

Dave Jones is Founder, President, and CEO of StormCenter Communications, Inc. *(stormcenter.com)*. He is also President of the Foundation for Earth Science and sits on the Executive Committee of the Federation of Earth Science Information Partners (ESIP Federation) *esipfed.org.*

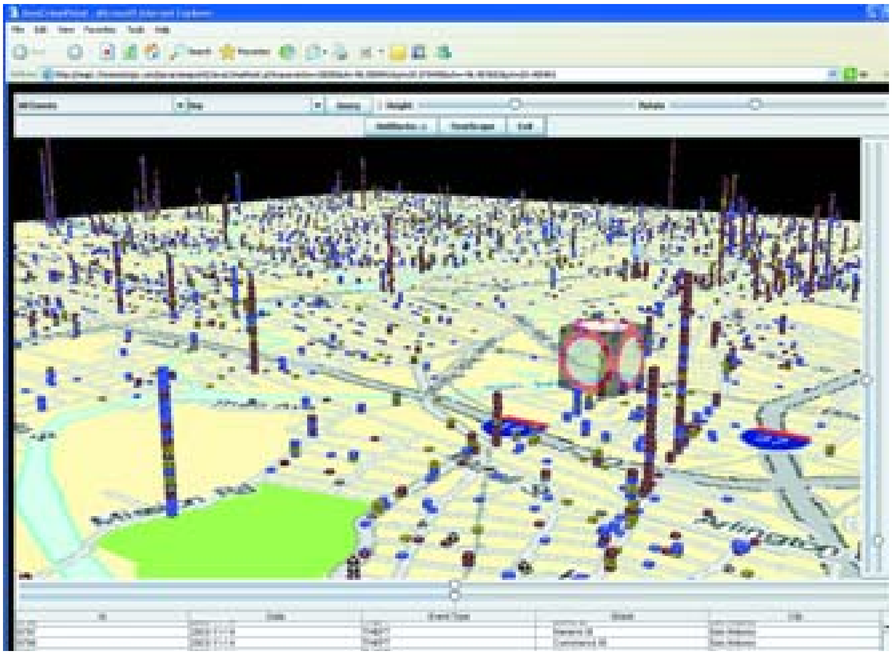
The ground is cracked from lack of rain between rows of corn in some fields on Jim Frauenberg's farm near La Moure, North Dakota in July 2002. La Moure had little rain during this growing season but enough to sustain plants. Frauenberg, whose corn yields have won awards, employs a no-till method to preserve soil moisture. NPOESS will be able to collect the first known operational measurements of soil moisture.

Services-Oriented Architectures: Goodbye Glue and Rubber Bands

Chris Andrews

The term "software architecture" describes the fluid infrastructure that merges hardware and function-specific software applications for the purpose of collecting, processing, and storing data. Historically, many companies started off with software applications for focused purposes, never imagining that employee payroll software could someday be connected to a satellite tasking application, for example. As companies grew and looked for new efficiencies, analysts saw that error and time intensive paper processes could be replaced by direct connections between applications. Unfortunately, many of these direct interfaces grew as custom, non-reusable solutions within software architectures that were never thought about as whole systems in themselves. In the last few years, technologists recognized that software architectures presented a prime place for optimizing software systems and so they began to design architectures before software interfaces were implemented. The Services-Oriented Architecture (SOA) developed as the leading contender for developing flexible, reusable software interfaces.

SOAs are made up of clients, that need to send or retrieve data, and services, that respond to client requests to store, process, and return data. However, an SOA is not a web of unrelated client-server interfaces. Participants in an SOA make use of a limited, standardized set of common protocols and languages that allow the decoupling of the implementation of clients and services. SOAs require that clients are isolated from the implementation of the service. Clients of an SOA-based order processing system, for example, should not have to adapt whether order information is stored in Java Message Service queues or in a relational database. The client may simply be able to send and receive ordinary XML over a common HTTP interface that is parsed and interpreted using a variety of software tools. SOAs' support interactions are asynchronous, where the service contacts the client with information when it is finished processing, and synchronous, where the client holds activity while it waits for the response. Combining all these components, many SOAs mask complex workflows that chain together complex services, but which ultimately may be called with seemingly simplistic requests.



Forensic Logic, Inc. of Walnut Creek, California, makes crime analysis software that uses XML Web services to communicate crime events between services and clients. Shown here is a Forensic Logic MapServer-based client application displaying crime locations in the City of San Antonio, Texas. Applications using standardized Web service interfaces integrate well into Services-Oriented Architecture-based systems.

Geospatial applications make perfect clients and services. Plus, when geospatial tools are coupled with a standardized interface protocol, they fit well into an SOA. An address geolocation service can be called with simple XML that describes a location and then return another simple XML document that contains hyperlinks to an image, route points, and a standardized address. Routing, map projection, map image generation, and metadata retrieval are some of the other geospatial applications that lend themselves well to being built as services.

MapInfo Corporation realized several years ago that Simple Object Access Protocol-based (SOAP) Web services were one technology that could standardize the interface between its software and other business applications. An early version of MapInfo's MapXtreme Java software came with instructions for making Web services out-of-the-box. Autodesk, Inc., Environmental Systems Research Institute, Inc. (ESRI), and other geospatial software vendors are changing their mapping tools to allow easier integration of their software within SOAs. The Open Geospatial Consortium, Inc. is probably doing the most for adapting GIS to SOA by developing well-publicized standard frameworks for integrating geospatial services and clients.

While the concept can no longer be called new, many organizations are only beginning to grasp the power and flexibility of an SOA. SOAs often chain together many different types of services and build a cumulative result that is returned to the client. The use of a standard interface framework allows SOAs to be adaptable and malleable so they can grow with an organization's changing needs. Much of the painful-to-build infrastructure software code becomes reuseable. SOAs are likely to promote the use of geospatial applications as it becomes easier to connect the intuitiveness of map interfaces and the power of back-end geospatial processing to diverse decision support and data processing applications.

Acknowledgments

The author would like to thank Ron Mayer of Forensic Logic, Inc. *(http://www.forensiclogic.com)* for information and graphics.

About the Author:

Chris Andrews has been an advocate for standardizing and expanding GIS technology in the past eight years, programming and listening to customers in a variety of environments from private industry to the Kennedy Space Center. Chris is currently employed as a GIS Solution Architect at Idea Integration in Denver, Colorado, and may be contacted at *chris.andrews@idea.com.*

LETTERS

I have enjoyed your publications for the past couple of years. I do, however, have a bone of contention with your article titled "3D GIS: A Technology Whose Time Has Come" by Gary Smith and Joshua Friedman. The article is not a survey of 3D GIS, but rather the two authors' experience with a particular set of software packages.

. . . [There is an *EOM*] article . . . written over seven years ago *[http://www.eomonline.com/Common/Archives/1997oct/97oct_lang.html]*, casting serious doubt on, if not refuting outright, Smith and Friedman's more recent claim that "[s]erious use of 3D in GIS started about five years ago." ...3D Nature [...a] pioneering firm released 3D Rendering software for the Amiga platform in 1994 and for the Intel and DEC platforms in 1995.

I feel that you are doing your readers a disservice by publishing what appears to be a survey article on 3D GIS when incomplete and even anecdotal information is presented instead. Perhaps a case study article would serve to better indicate a particular experience with the technology. The fact that 3D Nature, LLC, XFrog . . ., and the open source Virtual Terrain Project were not even mentioned is indicative of the problem a trade journal has in filling its pages: no responsibility to check submission completeness is undertaken by the editorial staff, even to the point where the publication contradicts what it wrote less than ten years ago.

James A. Zack, President
Xtra-Spatial Productions, LLC

The editor replies:

Thanks for your letter. Please do understand that the article in question was not intended to be a "survey of 3D GIS" as you suggest but rather, as stated in the article itself, "a basic primer to help one get started in the 3D arena." The authors wished to expose (and celebrate) the bi-directional integration of good 3D visualization with traditional 2D GIS and did so highlighting one software package. *EOM* is indeed a trade publication. We welcome submissions from all interested writers.

Author Gary Smith clarifies the authors' intent:

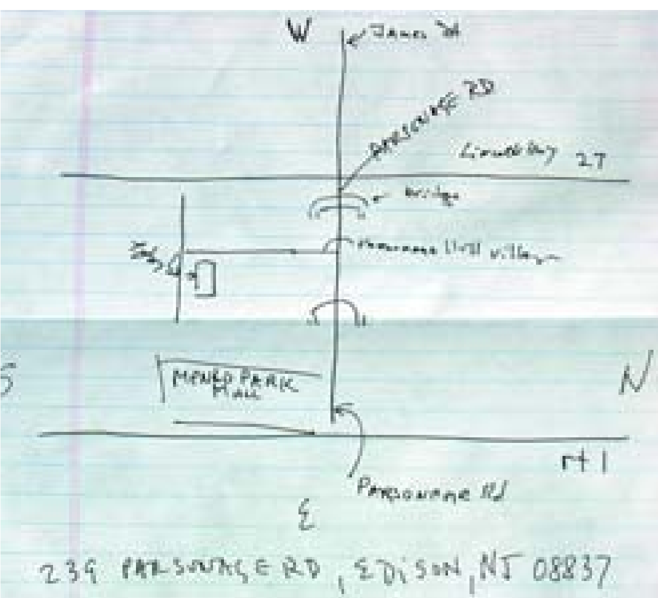
It is our contention that 3D models should be GIS features and have the ability to participate in geoprocessing tasks. There are many 3D rendering programs that can accept GIS data and produce beautiful renderings. This article was not intended to discuss 3D rendering outside of the GIS.

The reference to . . ."about 5 years ago" comes from our development work with MultiGen-Paradigm and The Orton Family Foundation for the Site-Builder 3D extension to ArcView 3.x. The big distinction we hoped to make was between the export of many sources to create a 3D scene, external to GIS and the import of materials into a GIS environment where 3D visualization and analysis can occur. Our experience with ArcGIS version 9 and the multipatch shapefile in the 3D environment is one solution.

The Battle for the Minds and Hearts

Atanas Entchev

The reasons for a technology's general acceptance or rejection have always intrigued me with their unpredictability. It is my theory that the informed skeptics are often the actors at the tipping point who ultimately lead one way or the other. But who are those informed skeptics?



Peter's electronic directions—a hand-drawn map which he then scanned and e-mailed to me.

My high school friend Peter is one of them. He was visiting relatives for Thanksgiving, just a short car ride from my house. So we decided to get together one evening, and that I would pick him up. He gave me directions to his relatives' house. Here they are, above.

You probably think that Peter is a technophobe, or worse—he didn't even know about the power of the Internet, and has never heard of Web mapping. He could have given me the street address, and anybody—not just a GIS expert—could have mapped the location in two minutes flat. Correct? Not quite.

Peter is not a technophobe. He is actually a self-described geek and gadget freak with an M.D. and a Ph.D. He has a mobile GPS in his car (in his home state), coupled with a laptop running a mapping application. Peter had every intention to go high-tech with his directions, but the mapping component failed him. So, Peter hand-drew a map for me, scanned it, and emailed me the image. Still very high-tech, but without GIS.

Peter described the online mapping system's shortfall: his relatives live in an apartment complex, and all available mapping applications map all of the 100+ addresses in it down to a single point. So the application cannot be used to find a particular building within the complex.

That evening Peter and I talked a lot about technology in general, and GIS in particular. The idea was born of an online collaborative repository of driving directions. We envisioned a human-based system to fill in where technology failed. ("If everybody who has successfully navigated a horrible route took some time to describe and post their experience…") Peter is an informed skeptic who taught me a lot that evening. (Another one of his questions: "Why is every on- and off-ramp listed as a separate trip leg on the computer-generated manifest?")

When I, as a GIS consultant, go to meet with a new prospect to extol the virtues of GIS, I usually encounter two kinds of reactions, which are almost always present: the reaction of the GIS "champion," who is all excited about the technology and wants to implement it immediately, and that of the skeptic, whose motto is: "This will never work…"

Many GIS practitioners tend to dismiss the skeptics as old-school technophobes (which sometimes they are). But quite often the skeptics are very knowledgeable, have done extensive research, and can support their skepticism with in-depth analyses of the state of the industry, current trends and the like. Those are the informed skeptics for whose hearts and minds we have to fight. We can't implement a successful system without their support. They may look like adversaries, but are indeed our allies, much more so than the GIS champions. They are like the friends who tell us when we are wrong.

No one would use an ATM card which worked only 93% of the time. Imagine if your anti-lock brakes only worked 97% of the time. Yet we continue to expect GIS users to "live with" GIS that only works about 90% of the time. We take offense when the informed skeptic asks a loaded question. We need, instead, to recognize that technology acceptance is a battle for the hearts and minds of the informed skeptics. They, not we, will take the technology mainstream.

About the Author

Atanas Entchev has worked in GIS for more than 13 years, 11 as a consultant. He is currently a senior client manager for Civil Solutions, a New Jersey GIS consulting firm. He can be reached at *atanas@entchev.com.*

EOM Now an Electronic Monthly Magazine

In an effort to reach more readers worldwide, beginning in February *EOM* will be available only via our website *www.eomonline.com.* We will notify those of you who have provided us with email addresses of its availability so you may read it at your convenience. For those of you who have not provided us with an email address, we encourage you to do so at *www.eomonline.com.*

Stuck in Our Own Mud

Image Courtesy: Iowa Department of Transportation

Mark Eustis

Enacting laws to force geospatial work into U.S.-domestic vendors ignores history and will stifle industry growth. GIS market velocity should increase, not stagnate behind protectionist barriers. In point of fact, the geospatial community has been offshoring services for decades. Well-managed international partnerships deliver the best value to the consumer, create mechanisms for scalable, rapid growth, and are the essential springboard for long term industry success.

The big GIS projects that drove double-digit market growth in the 80s and 90s would never have happened without offshoring. Vendors built offshore “click shops” because knowledgeable, trainable, eager, and honest people were (and still are) willing to work at a fraction of the on-shore cost. Mostly, such companies focus on work that can be mind-numbingly simple, but nevertheless requires major commitments in personnel and process controls to ensure reliable results.

“Ah-ha!” you say…”that’s the whole point: Since a distant vendor can be difficult to manage, how do we avoid sloppy services?” Well, just as in any other market, there are good firms and bad. Just as you would in any other business decision, you research the company’s track record, check its references, and conduct an evaluation using your own products, schema, and models. If the results look good, you set your acceptance criteria in stone, draw up a contract, and do some business. If the results are poor or you’re not comfortable, you find another vendor. Simple.

Nevertheless, if there are security concerns, complex requirements, or tight production timelines…then you’re not talking about basic services anymore. “Right!” you say…”that’s the whole point: it’s worth paying more for a domestic product, because the results are safer, faster, and better.” Well, maybe, maybe, and maybe. As for security, that’s a decision to be made by the owner of the data…although a recent Rand study *(http://www.rand.org/publications/RB/RB9045/)* found most geospatial content is of little use to a terrorist. As for faster and better, there can be real value in choosing a local vendor to work through complex problems, and iterating a solution through close collaboration and creative development. This is not to say an offshore vendor couldn’t have done an equally good job. But without a local presence, they are far less likely to succeed.

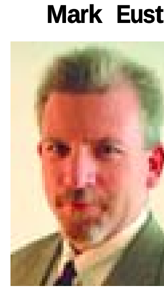
Although protectionism is a political silver bullet, it rarely succeeds beyond slowing the inevitable. That’s particularly true in a digital economy. Fundamentally, it’s a negative-sum game. When demand for services is high, the market will find alternatives; when demand is low, purchases occur less frequently. In a fixed universe like the U.S.-domestic GIS market, higher costs contribute to stagnation. There are only so many cities, counties, states, utilities, and federal programs that require the services under consideration. Forcing this market to “buy American” may well raise transaction prices, but it will also slow purchase cycles, negating or even reducing revenue gains. Rather than stifle growth and raise prices, we should lower the entry cost to produce geospatial content and manage more frequent and reliable transactions. Preserving five-year update cycles in a universe of fixed customers is niche-market thinking, not a vision for growth.

Instead of locking ourselves behind a false wall of economic insecurity, our clients and industry are better served to let the market decide. Vendors can easily offer two forms of service: one all domestic, and another a combination of domestic and offshore. Two packages, two prices, and let the customer decide.

The bottom line is every customer wants high quality for less money, the best value. It’s an age-old equation, and for the geospatial trades is one that compels us to build ever-closer relationships with offshore partners. The end result will be the best value for the customer, which at the end of the day is the best value for our industry.

About the Author

Mark Eustis is a marketing professional with almost twenty years of experience across the geospatial industry. Mr. Eustis resides in the Mid-Atlantic area and consults to various geospatial, natural resources, land engineering, and marine-market clients. He can be reached at *real_answers@comcast.net.*



Why Feature Extraction is Hard

Christian Heipke

"An image speaks more than 1,000 words." This well-known Chinese saying describes much of the fascination of photogrammetry and remote sensing, especially of the images involved. But is it really true? Imagine two persons looking at the same image, say an aerial image of a town. What do they see? The first one might recognize a building, perhaps a house in a residential area with a red roof and a green yard. The other person may instead call this same building his home, the place where he was raised, and immediately recognize the door handle, because he used to bump his head on the handle when he was a kid. In point of fact, neither the door nor the handle may actually be visible in the aerial image.

Why are these two descriptions of the same image so different? The reason is that when we look at an image, we do not only see what is presented to us, instead we relate the features in the image to our background knowledge, our memories, and our experience about the scene in general (a house) and special objects in particular (the former home). Based on such aspects, it is of course difficult, if not impossible, to arrive at general conclusions about anything. Thus, we need to find a sort of compromise between our internal, subjective view of the depicted scene and the image and a more external, objective view, shared by others. Moreover, both views must be represented in a suitable, computer-readable way. The latter task has proven to be a formidable challenge, indeed, and is far from being solved even after a few decades of research and development in computer vision and digital photogrammetry.

In addition, humans often construct missing parts, for instance the door handle mentioned above. Consider too that a sketch of a cube on a piece of paper is generally seen as a three-dimensional cube.

In order to carry out feature extraction, single objects depicted in the scene must be recognized and described. This recognition assumes prior knowledge of objects as models, which first of all should be made available to the computer. The production of the object models is a major challenge in itself. Research has shown that both geometric and radiometric information on the various objects is necessary. For aerial imagery, the larger the scale of the images to be analyzed and the more details are required, the more important is geometric information, as one enters closer to the domain of human activities, which can be characterized by linear borders, symmetries, right angles, and other geometric aspects. For smaller resolutions, however, radiometric and spectral attributes dominate, which explains the good results of multispectral classification for satellite images of coarser resolution as well as the inferior results of the same technique for high resolution satellite and aerial images.

While image analysis is a very challenging and inspiring field of research—an example of a tree extraction result is shown in **Figure 1**—fully automatic systems do not seem realistic in foreseeable future. Semi-automatic procedures, which integrate the human operator into the entire evaluating process however, are being used successfully. A person remains responsible for tasks which require major decisions (*e.g.,* selection of algorithms and parameter control), quality control, and—where required—the correction of intermediate and final results. Thus, the best of both worlds can be put together for the benefit of exploiting images faster, more objectively, and sometimes also more accurately.

About the Author

Christian Heipke is a professor for photogrammetry and remote sensing at the University of Hannover, Germany. His main research interests lie in the area of automatic image analysis and geometric aspects of photogrammetry. He can be reached at *heipke@ipi.uni-hannover.de.*

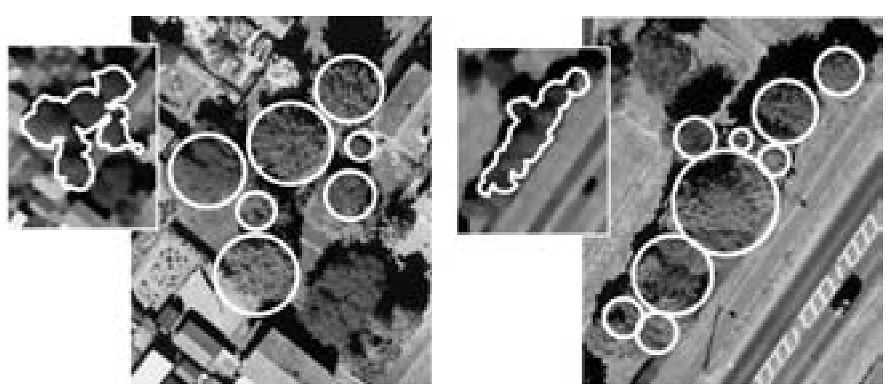


Figure 1 *Two results of an automatic tree extraction from multi-spectral images and a digital surface model in several stages of resolution*

Five Questions for . . . Mike Liebhold

Mike Liebhold is a Senior Researcher for the Institute for the Future, *(www.iftf.org)*. There, he focuses on geospatial infrastructure for pro-active and context-aware computing, as well as social implications of a geospatial Web for IFTF clients from top tier companies and public agencies. Previously, Liebhold was a Visiting Researcher, Intel Labs, working on a pattern language based on semantic Web frameworks for location-based computing, and co-author of *Proactive Computing through Patterns of Activity and Place,* publication pending. Liebhold publishes his occasional thoughts about microlocal and geospatial computing on his blog at *www.starhill.us* and can be reached at *mnl@starhill.us.*

Mike Liebhold

1

You speak of the Geoweb. What is that, exactly?

The newest wave of wireless notebooks, PDAs, and phones integrating GPS and WiFi positioning technologies offer the unprecedented possibility for general, day-to-day information to be spatially described and utilized. We are beginning to see physical objects and locations being digitally linked, annotated, bookmarked, and searched. In addition to URLs, geographic coordinates (latitude, longitude, elevation) may become a widely used type of network addresses for Web pages, media, and services.

A geoweb or geospatial web is a combination of this new geocoded hypermedia, and more traditional geodata: points vectors, polygons, rasters, and spectral data. Multiple terms have been used to describe what is evolving: geoweb, geospatial Web, Spatial Web, Locative Web, or the Digital Earth. We use the term geoweb because it best conveys the combination of geographically related information and the Web linked hypermedia.

Human beings are rather impoverished data sources. As we move about our environment, we register withour senses only a tiny portion of information and knowledge

2

Do you see a large gap between the ideas envisioned at say the Institute for the Future's New Geography Conference (annotating points of interest in the ether, for example) and what "mainstream" GIS/geospatial companies are doing? Is there overlap?

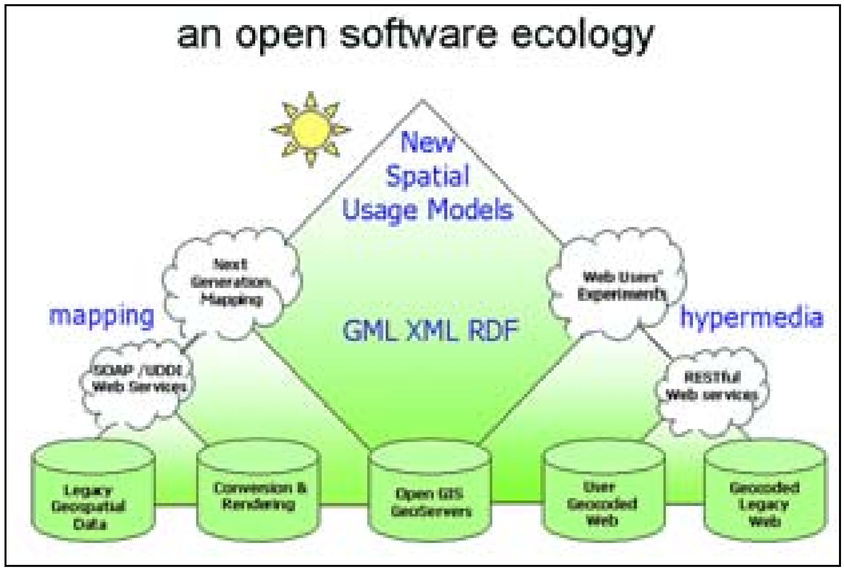
While most of the existing legacy geodata is encoded and used in proprietary formats and file systems in proprietary applications, from ESRI, and others, there is a growing global movement to render and process geospatial data and geocoded hypermedia using open formats and open source tools and applications, all built on best Semantic Web practices. All data properly encoded with XML, RDF, GML, and SVG should be self identifying, and self describing to standard client application. A prospective geoweb might more properly described as the "Geospatial Semantic Web."

3

What are the biggest challenges facing the new use of location in computing?

Aside from increasingly ubiquitous, low cost broadband wireless networks and devices, which we can assume, there are several elements of the ecology requiring considerable continuing development:

- *Location Sensing Techniques*—Ultimately, almost any digital device can know where it is by either calculating location from radio signals, or by querying a network.
- *Geocoded Data and Information*—In order to interact with hypermedia or digital that is directly relevant to a place or physical object, data has to be explicitly identified as relevant to that location. And, location coordinates have to be available.
- *Geospatial Information Integration Technologies*—There are many discrete data formats that are not interoperable, or at least not automatically interoperable. Geodata and hypermedia need three kinds of integration: file interoperability, rendering alignment, and semantic (metadata) interchange.
- *Comprehensive Geospatial Data Search*—We'll need the ability to search and retrieve all of the attributes of a place, collections of features, maps, and aerial and satellite images of a place. There is not one comprehensive clearing house on the Web where you can find all of the data you might want to use from all domains of knowledge-covering all geographies.
- *Location Aware Applications and Services*—Telecommunication companies, consumer electronic companies and automotive companies, and related .net and .com startups are experimenting with new location services, many of which could be described as "Walled Gardens"— services available to only their subscribers are [often] not even encoded in standard data formats. These are fundamentally different from open, Web-like services using standard data, over standard IP networks.
- *Geospatial Information Policies*—Geodata-related policies directly or indirectly address geodata access, protection, and use, including such issues as privacy, ownership, and access to public data. Why are they important? These policies will ultimately determine how widely accessible geodata will be to the public and the types of applications that will be created using that data.
- *Human Geospatial Competency and Literacy*—Geospatial literacy might be described as the ability to understand, create, and use spatial information and maps in navigating, in describing phenomena, in problem-solving, and in artistic expression—ultimately including the ability to create and utilize information, viewable in place, directly associated with physical reality.



There is a growing global movement to render and process geospatial data and geocoded hypermedia using open formats and open source tools and applications, all built on best Semantic Web practices. All data properly encoded with XML, RDF, GML, and SVG should be self identifying, and self describing to standard client application.

4

There seem to be many efforts almost at odds with one another to add geospatial smarts to the Web (.geo, GEOURL, even the Open Geospatial Consortium specifications to name three). Have any emerged as "leading" implementations?

A wide range of standards is required for humanity to enjoy the full benefits of a geospatial Web. Fortunately, many of the key standards are in place or in process:

- *Standard geocodes for hypermedia*—The W3C WGS84 proposal is in review. It will allow hypermedia to be tagged and viewed locally.
- *Standard location, presence, and privacy protocols*—The IETF GEOPRIV final draft provides rules for noting locations of users and documents.
- *Standard data basis for Wi-Fi base station locations*—A standard database of Wi-Fi beacons for geolocation is in the process of development.
- *Standard APIs for device location*—The standard location API for Java Mobile Edition (J2ME) is now complete enough for applications to run on many Java-equipped devices.
- *Standard carrier API for E911 location information*—OpenLS [an OpenGIS Specification] has been accepted and allows applications to access location information provided by carriers.
- *Standard Geography Markup Language*—GML/XML standards have been defined, providing uniform descriptions for maps and allowing digital map data to be exchanged easily.
- *Standard Web Feature Services*—OpenGIS WFS now provides the rules for servers to serve GML standard data.
- *Standard Web Map Services*—OpenGIS WMS now provides the rules for servers to serve standard raster maps of combined layers.

5

How might the U.S. look in five years in its use of location-smart tools? What are some of the wilder or most clever uses of location in computing that you've run into/imagined?

Leading-edge coders and bloggers, researchers, geographers, and artists worldwide are experimenting with new "locative-hypermedia" applications. These often use open source mapping programs, always running on standard Internet protocols.

Human beings are rather impoverished data source. As we move about our environment, we register with our senses only a tiny portion of information and knowledge contained in the place. Our eyes see what is observable, our brains recognize visual patterns and retrieve layers of associated information from our memories. The brain accesses only what we know, what we learned ourselves and from others, what we read on a page or learn from the screen. This information is limited by the very fact that each individual human being has limited capacity for observation, information storage, and retrieval.

Imagine, however, a world in which as you move about physical places, you can access not only what is stored in your brain but also multiple layers of previously invisible information—annotations left by friends, colleagues, and complete strangers; data on who lives in the place, their demographic characteristics and political affiliations; crime statistics for the area; traffic accidents that might have taken place; information about businesses in the area, their products, images of the place from long ago, and much, much more.

This is precisely the physical landscape in which we will be living in 5-10 years. Wireless location-aware devices, new geospatial software, new global location services, and online geodata repositories, are eroding limitations to human perception making accessible a rich spectrum of digital information in real-time and in real place. The physical landscape we move in will become "deep"—containing vast amounts of digital information and knowledge that was previously either unavailable or difficult to access in real-time and in real place. Several elements will become inherent in this landscape:

- *Invisible Layer of Information Will Become Explicit*—Relationship of physical and virtual objects will become visible as well. We'll be able to view and utilize tags, pages, or graphic data about places in real-time and context, environmental details, cultural information, history, mythology, social information about people nearby…
- *We Will Interact with Information Through Body Extensions*—In not too distant future, wearing unobtrusive, head-mounted displays or neural implants as we walk around, we'll be able to literally see the invisible layers, and selectively view or switch hyperlinks on and off, filter out spam and pop-ups and everything else. The world will become a hyper linked Web.
- *Landscape Itself Will be Sentient and Context Aware*—It's not just human beings that will interact with a Spatial Web; little sensors and nanobots embedded in our environment are going to be operating with spatial intelligence. The resulting systems will increasingly anticipate our context and task focus and limit the safely usable flow of precisely relevant information. The implication is that the physical environment can become programmatically responsive; spaces can become responsive to predictive needs of people or devices.

Glossary

XML:	eXtensible Markup Language
RDF:	Resource Description Framework
GML:	Geography Markup Language
SVG:	Scalable Vector Graphics
IP:	Internet Protocol
W3C:	World Wide Web Consortium
IETF GEOPRIV:	Internet Engineering Task Force, Geographic Location/Privacy Working Group
API:	Application Programming Interface

Announcements

The **Global Monitoring for the Environment and Security (GMES)** initiative is setting up a number of services including one called "Respond" to provide mapping to a variety of humanitarian aid organizations in a wide range of operational and management roles. Recently, "Respond" provided satellite-derived maps to those involved in the Sudan Darfur humanitarian crisis.

LandVoyage.com, an online mapping services company, announced an agreement allowing **TerraServer.com** to access maps and imagery hosted by LandVoyage.com. Under this license agreement, TerraServer.com will be able to distribute data from the LandVoyage.com mapping library.

Image courtesy: LandVoyage

GeoTango International Corporation has been taking the lead in a project that will enhance visualization of geospatial information over the Internet. The project, underway since April 2004, is supported by the **GeoInnovations** program of **GeoConnections, Defence Research and Development Canada (DRDC)** and **Natural Resources Canada (NRCan).** The objective of GeoTango's project is to implement a commercially viable 3D tool to access, visualize, and analyze GML data and integrate GML vector with raster and digital elevation model (DEM) data types via OGC/CGDI compatible Web service interfaces.

Intermap Technologies Corporation announced that it will not proceed with the previously announced intention to acquire Phoenix, AZ-based **AirPhotoUSA, LLC** due to the inability of the parties to negotiate mutually acceptable terms. The strategic relationship between the two companies remains unchanged and product deliveries and commitments to customers are unaffected.

LizardTech, Inc. announced the kick-off for its Educational Licensing Program. With the Educational Licensing program, students and faculty will be able to use GeoExpress with MrSID to produce high quality geospatial imagery for research and learning.

The sale of **Space Imaging's Federal Civil/Commercial Solutions Business** to **Geo360** will not go through. Space Imaging's Gary Napier explained, "We have not been able to close on the deal with Denver-based Geo360 for the sale of Space Imaging's Federal-Civil Solutions line of business. Discussions with Geo360 have been terminated. We are committed to fully support this line of business and will continue to meet all of our customer's requirements."

Contracts

DigitalGlobe announced that the **Department of Urban Services** in Canberra, Australia uses **QuickBird** satellite imagery in its Internet mapping service, called Australian Capital Territory (ACT) Locate. The tool is used by urban planners, developers, and resource managers for various mapping and spatial information applications pertaining to Canberra, Australia's capital. The Nature Conservancy is using QuickBird satellite imagery to assess biological diversity and conservation progress in several regions throughout the U.S. and worldwide.

Sanborn has been selected by the National Oceanic and Atmospheric Administration (NOAA) to demonstrate high spatial resolution landcover and landcover change products derived from aerial digital and satellite imagery acquisition in accordance with NOAA's Coastal Change Analysis Program (C-CAP), a current government-funded program.

Pictometry has secured a license agreement for Elmore County, AL for providing software and imagery.

Leica Geosystems GIS & Mapping, LLC announced the first sale of the recently available **DSW700 Digital Scanning Workstation** to **Cooper Aerial Surveys Company.** The **U.S. Forest Service** signed a blanket purchase agreement (BPA) for Leica Geosystems software. The Forest Service is standardizing on Leica Geosystems imaging processing and photogrammetry software.

Special Forces have chosen **Intelepix's Oblivision** to provide comprehensive on-demand, geo-referenced intelligence to assist in advanced target analysis. Oblivision incorporates large amounts of geospatial imagery, from multiple sources using ER Mapper's ECW JPEG 2000 technology.

WIRE Services, a division of **Manitoba Hydro,** has a contract to perform a LiDAR survey project for **Public Service Electric and Gas Co.** in New Jersey. Through the use of Aerial LiDAR data collection technology, WIRE Services will assess 189.6 miles (305 km) of single and double circuit transmission lines in the utility's service territory. The survey analysis will provide the utility with new plans and profiles in connection with its vintage circuit replacement program.

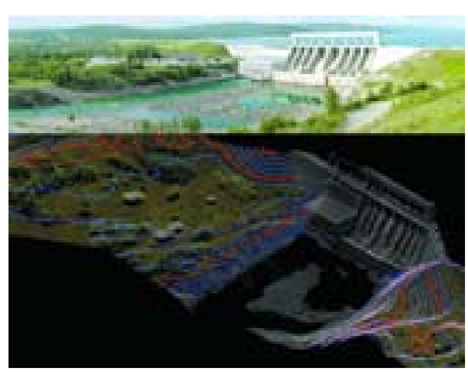


Image courtesy: WIRE Services

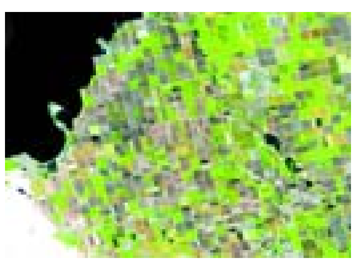
Merrick & Company received a new contract with the City of Casper, Wyoming to update its geographic information system basemap.

Space Imaging Middle East (SIME) signed a cooperation agreement with **Khatib & Alami (K&A),** a multidisciplinary architectural and engineering consulting company in the region. This agreement will enable SIME to provide specialized GIS solutions to the marketplace.

Mohammed El Kadi, SIME Managing Director with Faisal Al Alami from K&A. Image courtesy: Khatib & Alami

Products

The **U.S. Geological Survey (USGS)** has completed development of a major new product enhancement for Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data captured after the Scan Line Corrector (SLC) anomaly in May of 2003. Gap-filled product options will now allow the use of scenes from consecutive passes to fill the gaps of the target scene. Users may select from up to four SLC-off scenes, in addition to an optional SLC-on scene, to create a final data merged product.



Level 0Rp product, showing nominal image data at the scene center. Image courtesy: USGS

GlobeXplorer, a provider of online aerial and satellite imagery, and **Telemorphic Inc.,** maker of image manipulation tools for GIS, have announced the release of **MapImager** for **ImageConnect,** software that allows ArcGIS users to easily perform interactive image or map comparisons within the ArcMap environment.

Intergraph Mapping and Geospatial Solutions introduced the **Z/I Mouse,** a high-precision 3D mouse that enhances digitizing data and capture of stereo data for input into photogrammetric processes. The new mouse is now shipping with the

Image courtesy: Intergraph

company's redesigned Z/I Imaging ImageStation digital photogrammetric workstation and Z/I Imaging ImageStation Stereo Softcopy Kit (SSK).

People

ORBIMAGE Inc. announced that **William "Bill" Schuster** has joined the Company as Chief Operating Officer. He was most recently with BAE Systems, where he started a new operation as the President of Integrated Systems.

Bill Schuster. Image courtesy: ORBIMAGE

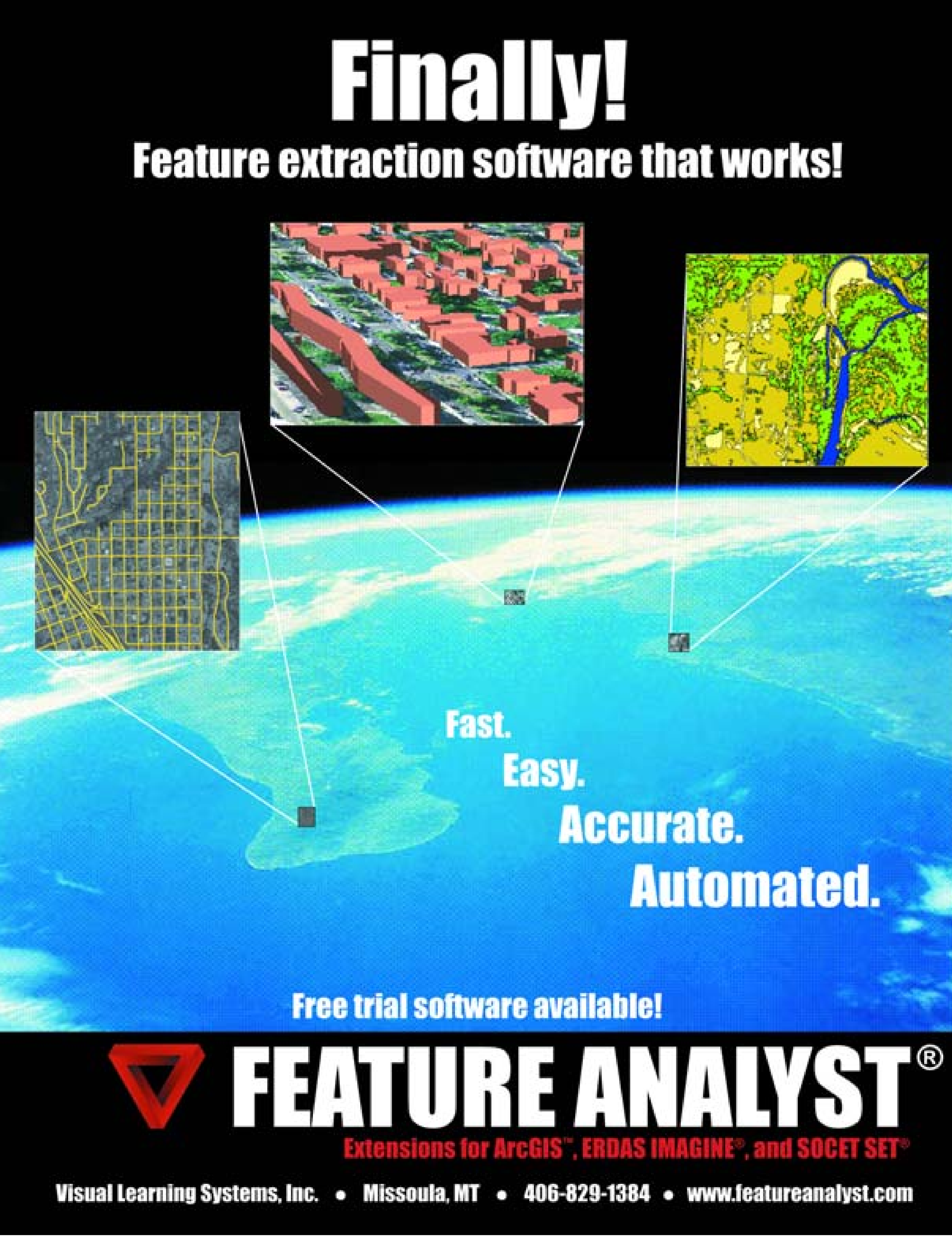
Michael Villarreal has joined **Sanborn** as senior product manager, and is responsible for product innovation and extension. **David Carter** joined the company as project manger; he will be responsible for the success of current and future GIS projects. **Bill Claveau** has joined the Sanborn team as senior program manager.

Dr. Manfred Krischke has been named **Intermap GmbH Managing Director.** He co-founded and managed RapidEye AG for nearly six years. His primary responsibilities will include the management and expansion of the Intermap GmbH Wessling office.

EarthData appointed **Martin Roche** to head the organization's GIS operations in Orlando, Florida, and New York, New York.

Litigation

ORBIMAGE Inc. received notice from the Government Accountability Office in November 2004 that the Office had dismissed the protest of the **NextView Second Vendor** contract awarded to ORBIMAGE from the National Geospatial-Intelligence Agency. The protest had been filed by New SI LLC, the competing bidder under the program.


Finally!
Feature extraction software that works!
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Accurate.
Automated.
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