Change Detection for More Actionable Intelligence

Quick detection of environmental changes is crucial for meeting geospatial intelligence demands that were barely comprehensible several years ago.

Jan 1, 2006
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GeoIntelligence

From the Persian Gulf in Iraq to the U.S. Gulf Coast, our collective feeling of security is shaken time and again by highly dynamic threats and events.Terrorist attacks in New York, Madrid, and London; tsunamis in the Indian Ocean; and hurricanes in the Gulf of Mexico are followed by widespread and massive disruption.

Our ability to predict, prepare for, respond to, and recover from such events is challenged by growing change in new or expanding locations. The challenges for security and intelligence organizations are aggravated by the increasing complexity and vast amount of information amid ever-present resource constraints.

The good news is that rapid change detection can facilitate actionable geospatial intelligence (GI) sooner, shortening the decision cycle of observing, knowing, and acting. However, change detection requires an increased level of automation of GI. To address these needs, industry, government, and academia have developed and continue to introduce a new generation of tools that increasingly automate the GI process. These tools facilitate an understanding not only of where, but also who, when, why, and how much.

New and emerging technical tools (such as georeferenced imagery) enable more efficient change detection, which is crucial for such military and civilian applications as tracking objects of interest and rapid damage assessment. But industry and government leaders must ensure that the technology, people, data, and processes are all in place and ready to take advantage of the opportunities these technologies afford.

Types of Change Detection

The following examples illustrate how change detection is critical in both military and civilian applications:

- **Tracking Objects of Interest**

In counter-insurgency and other military operations, decision makers require the rapid location, identification, and tracking of people, groups, and/or equipment that pose a threat. These people need timely and relevant information about where the potential target has been, where it is now, and where it may be headed.

In both military and civilian contexts, an object of interest may also include other types of natural or manmade threats (for example, the path of an impending storm, disease outbreak from natural or manmade causes, the source of a hazardous material spill). In any case, similar answers are needed. Where has the object of interest been? Where is it now? Where is it headed? Questions such as these require rapid orientation and identification of movement over time.

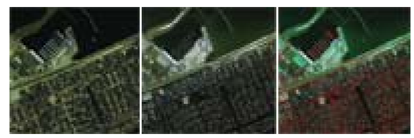
- **Rapid Damage Assessment**

This type of change detection involves quickly assessing the impact of or damage from an event or action. Key questions are: What was it like before? What is it like now? What is the difference? The need is to determine the scope and extent of an effect. What are the areas affected by the hurricane or terrorist event? How far has contamination spread? What infrastructure has been damaged, and how severely? What are the affected populations and where are they now? For the military planner, has the operation achieved its intended effect against a military target? How much and how many targets have been destroyed?

The ability to rapidly assess the current situation and compare it to the past is needed to take corrective action. Hurricane Katrina demonstrated the devastating effects of not having this type of rapid and comprehensive damage assessment.

Technological Trends

As stated earlier, technological innovations can improve the ability to perform rapid change detection. One of these innovations, georeferenced imagery, can provide a vast amount of understandable information. By overlaying or stacking two images and comparing the difference, analysts can determine what has changed at a pixel level.Traditional imagery has included panchromatic or RGB color imagery and stereo imagery, but additional sensors such as radar, LIDAR (light detection and ranging), multispectral, and hyperspectral are assuming ever-greater importance.



Using Feature Analyst for GeoMedia, users can detect changes to the New Orleans landscape after Hurricane Katrina. The image on the left shows New Orleans before the hurricane. The middle image depicts the same area after the storm. The image on the right reveals distinct differences between the before and after photos.

Ultimately, the challenge lies in reducing the amount of time it takes to collect, process, align, compare, analyze, and communicate results. This process can take months for large areas, but today that time must be shortened to hours or even minutes. More rapid change requires more frequent collection of such data as georeferenced imagery. This is why we're seeing an ever-increasing number of platforms and higher rates of collection for each platform. Aerial digital video is also assuming increasing importance because of its ability to shorten the interval between collections.

The revolution in small, cheap, remote mobile ground-based sensors can further contribute to rapid change detection by increasing the type and quality of information that is available about the environment. However, this information must be rapidly integrated with other information to be most useful. Work now under way on industry standards for interfaces to create a Sensor Web will greatly enhance the accessibility and usability of the growing sensor population (**see "Setting the Stage for Sensor Web Standards," July/August 2004, GeoIntelligence**).

Collection and Preprocessing. Automated imagery-collection and preprocessing practices facilitate a significant increase in productivity while reducing the time from pixel collection to intelligence analysis. Fully digital mapping cameras with sophisticated preprocessing can shorten the time between collection and analysis and exploitation.

Digital mapping cameras can also streamline aerial mapping operations. With a fully digital image environment and workflow, digital images can be generated more quickly and accurately, allowing analysts to carry out change detection sooner and integrate other information faster.

Imagery Management. Although the growing amounts of imagery and other location-based sensor data provide greater coverage and information, they also create data-handling challenges.Traditionally, analysts maintain data in a file-based format through CDs, tapes, and other electronic media. The data-management challenges that arise from this practice can easily overwhelm analysts.

Technology now exists to automate the management of very large amounts of image data. Commercial off-the-shelf solutions for enterprise image and elevation data management can provide multiple users with transparent access to large amounts of common imagery. This can greatly reduce the time from collection to exploitation while improving efficiency, collaboration, and quality.

Several elements are required for such an enterprise solution. These include a geospatial raster and elevation data/metadata architecture; geospatial raster and elevation data/metadata management capabilities; image and elevation processing procedures (by the specialist); and image and elevation distribution and exploitation (by the end user).As an open system, Intergraph's TerraShare does not require the image or elevation information to be converted into different formats, and metadata are stored in standard database tables. The physical geospatial image and elevation files can be located in a file system in any operating system as long as that file system is accessible to the TerraShare application through a network connection.

Automated Fusion and Search. Collecting and managing image information is only part of the technical challenge of change detection. That information must also be rapidly searched and analyzed for objects and conditions of interest. Multiple imagery sets for the same location must be compared with one another. The imagery must also be combined and compared with other types of geospatial information, including feature data and other types of sensors. This has led to a growing demand for fusing multiple data sources and integrating imagery and geospatial analysis workflows in a totally digital environment.

Fortunately, automated multi-intelligence fusion and broad-area search capabilities are now available commercially. For example, Intergraph's Image Scout facilitates data management, data fusion, and image exploitation in one commercial off-the-shelf product. The solution provides the means to ingest and manage terabytes of imagery and other collateral data. Users can configure, manage, and control searches through the imagery. All users can access files across distributed networks without greatly impacting network loading. Image Scout also allows users to browse image data within the Windows Explorer interface with basic view controls, as well as undertake initial imagery checks using geographic coverage searches and metadata with fast access to imagery.

Image Scout allows the fusion of several different geospatial data types, including U.S. Geological Survey DLG (digital line graph) raster maps; IKONOS imagery; ArcView vector data; and simulated collateral intelligence data (showing points of interest). The open architecture allows for on-the-fly fusion and access to multiple data and database sources. Geospatial data-search capabilities enable analysts to find, assess, and select imagery for virtual mosaic broad area searches. Users can control search patterns by using reference point searches, area searches with geographic constraints, or linear searches.

The image window supports electronic light table functionality, incorporating Paragon Imaging's ELT5500 software that allows analysts to maintain image quality. The images are georegistered to maps to permit change detection while using vertical or horizontal wipe, blend, or flicker modes.

Feature Extraction. The exploitation and fusion tools described earlier provide the foundation for adding other types of data and exploitation extensions, including automated or assisted feature extraction extensions. Tools like Visual Learning Systems' Feature Analyst for GeoMedia can help users more rapidly produce and maintain such features as roads, buildings, and streams while identifying and tracking changes in mobile objects of interest. The product also allows analysts to remove clutter that can make change detection difficult.

Benefits and Barriers

Rapid and effective change detection is essential for enhancing domestic and international security, but this capability has other societal benefits as well. Change detection can provide policymakers and business leaders with the ability to understand and react to complex changes in everything from environmental and land-use decisions to infrastructure development and resource management.

It's important to note that the barriers to realizing the benefits of these new tools are not necessarily technical; instead they include the many organizational and cultural challenges that always accompany change. Entrenched interests in old, proprietary paradigms often resist the move to open, interoperable, distributed data solutions. The organizational resistance to information sharing and interagency cooperation must be overcome.

Rapid change detection requires removing legacy boundaries, streamlining end-to-end processes, tightening system integration, and leveraging Web functionality to make information instantly available across an enterprise through Web and mobile computing technologies. Many tools are available to enable rapid change detection. Our challenge is to put these tools into the hands of those who need them and to provide the training, data, and work processes required to make them effective for enhancing our nation's security, prosperity, and social welfare.

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