Integrating Remote Sensing and GIS Technology

Using Image Processing and GIS Software in Tandem to Improve Analysis Capability
INTRODUCTION

Improvements in recent years to the spatial, spectral, and temporal resolution of geospatial data intrinsically create opportunities to conduct more detailed analysis. However, with higher volumes of complex data come new challenges for those charged to use them to make important decisions under urgent circumstances. Amidst an increasing abundance of geospatial information, one needs to be adept in the integration of available geomatics technology to effectively synthesize multiple data sources, and provide end users with comprehensive, multidimensional information that is timely, decisive, and meaningful. By effectively integrating earth remote sensing and Geographic Information System (GIS) technology, an organization can benefit from richer qualitative and quantitative analysis capabilities, and the ability to achieve greater productivity and efficiency from an investment in geomatics technology. This document summarizes the differentiating characteristics of remote sensing and GIS technology, illustrates the ways in which software tools are facilitating the convergence of these previously disparate technologies, and outlines the benefits provided by a combined remote sensing and GIS geospatial analysis capability.

BACKGROUND

Remote Sensing Technology

In a general sense, remote sensing entails the collection of measurements of an object from a distance. Humans have always employed remote sensing techniques to assess the environment in which we live from key vantage points. Information we gather about our surroundings such as the location of resources of value, threats to our security, and the lay of the land, is often critical to our survival and prosperity.

Technological advances have promoted our ability to collect data about our world from hilltops to airborne and spaceborne perspectives high above the earth’s surface. These platforms can be equipped with advanced imaging and ranging instruments that detect interactions between objects on the earth’s surface and the amount of reflected (or emitted) electromagnetic radiation originating from the sun, or emitted from onboard power sources. In addition to capturing visible light, these spectral data can include valuable information regarding targeted objects that are not discernible to the human eye, for instance the characteristics of vegetation and minerals present in an area.
Collecting information via modern remote sensing platforms entails some unique benefits: accessibility, persistence, and accuracy. An imaging platform circling above the planet allows us to capture information over areas that are dangerous, inaccessible, or otherwise too costly to access from the ground, such as war zones, or vast areas of ocean, desert, and jungle. As spaceborne imaging platforms orbit or hover above the earth, they provide data coverage over these inaccessible areas repeatedly, creating an information archive that provides the ability to perform temporal analysis. Finally, the precision of on-board ranging and positioning instruments allow for highly accurate measurements of objects below, and provides an authoritative source for locational data, particularly for landscapes that are often in flux. Recent disaster management situations following earthquakes in Haiti and Japan exemplified how the unique characteristics of remote sensing technology culminate to provide significant benefit to authorities making critical decisions. For example, remote imaging platforms persistently collecting data over an area affected by disaster provide: the ability to detect the extent of change or damage in a scene between pre- and post-event imagery; the determination of ideal routes for the transportation of relief efforts and materiel; topographic data that allow for the identification of subsequent risks posed by floods or earth slides; and the locations of human activity with which to prioritize response operations.

**GIS Technology**

Similar to remote sensing technology, GIS relates to the collection, management, and analysis of geospatial information to support decision making. In simplistic terms, GIS can be considered a combination of cartography and information technology; bringing cartographic, or spatial perspectives to data analysis and management. When designed and implemented as a system, GIS technology facilitates the integration of various data types from myriad sources and provides a user the ability to interact with these data to perform analyses, make edits to improve accuracy, and create visual representations of spatial analysis results in the context of a map to convey important information. The power of GIS technology is realized when relationships between available data sources are established in relation to space or time, and the relational attributes of complementary data sources are analyzed using database technology. GIS uses location as a spatial attribute to provide real-world positional context and clarity to complex data relationships and decision support systems.

Geographic data is the lifeblood of GIS technology, and a GIS can be populated with data from many sources. Traditionally, GIS analysts hand-digitized features from existing paper maps to capture electronic information relevant to their analysis goals. This relevant information may
include vectors representing elevation contours, road networks, or structures; point locations associated with specific objects, field data, or event occurrences; and polygons encompassing the areal extent of a large homogeneous features, such as cadastral boundaries or ecological zones. Once captured, these digitized data layers could then be overlain on each other to interpret data relationships. Additional processing steps could yield new data layers, for example, by interpolating point data to create rasterized surfaces that generalize data values over a broad area, such as the depth of a water table across a flood plain. The availability and adoption of Global Positioning Systems (GPS) improved the accuracy of locational data, and the efficiency by which a GIS user could integrate geographic data into their spatial analysis models.

**OPPORTUNITY**

**Persistent Traditions**

Traditionally, a gap has existed between users of GIS and remote sensing technology—a de facto cultural separation between geospatial professionals who worked with vector data and those who worked with raster data. Much of this vector-raster segregation is attributed to the method and scale of geographic data capture. Data acquired for GIS applications, with its strong cartographic heritage, often entails point and line locational information sourced from local or regional field collection methods, and is intended for spatial representation via map format. In contrast, remote sensing data capture and analysis technology developed around the characteristics of the electromagnetic radiation emitted by our sun and its interactions with broad areas of the earth, and catered to spectral science applications foremost. Depicting spatially oriented spectral data on maps was often relegated to basic graphics within esoteric publications. Despite sharing a common use as a tool to extract information from geospatial data, remote sensing and GIS technology developed relatively independent of each other for several decades. The extent of these tools working together has traditionally been limited to employing remotely sensed digital imagery in a GIS display tool as a contextual backdrop relative to other geographic data layers. Due to persistent traditions within respective vector and raster camps, and in large part the lack of interoperable tool technology, the promise of a unified remote sensing and GIS analysis platform remained unrealized for years.
A New Paradigm

Convergence points between remote sensing and GIS disciplines appeared in recent years along their independent tracks of technological progression. Most notably, the increasing availability, standardization, and improved resolution of remotely sensed imagery is creating new intersections along previously parallel trajectories—opportunities to accomplish geospatial analysis objectives by integrating remote sensing and GIS methods. For a GIS user, higher fidelity data (spatial and spectral) collected by remote sensing platforms promotes the utility of imagery from basic contextual backdrops to new sources of rich geographic information from which to create foundational data layers. At a fundamental level, high spatial resolution imagery allows a user to identify and trace features of interest with a mouse or other pointing device, commonly referred to as on-screen digitizing, for inclusion into spatial analysis models. Capturing geographic data in this fashion requires the imagery to be georeferenced to a common ground coordinate system, and can be very time consuming; hand-digitizing features like rivers and shorelines entails many mouse clicks and a skilled GIS user with a steady hand. Nevertheless, establishing the concept of using imagery as a GIS data source, rather than just an aesthetically pleasing contextual picture, is a pivotal way point in the progression of a new geospatial analysis paradigm.

In the remote sensing domain, extracting meaningful and accurate information from sources of remotely sensed data historically required an in-depth understanding of the data collection systems and advanced analytical techniques. Notable technological advancements to remote sensing software tools relate to the consolidation of spectral science and raster analysis methods into higher-level, solutions-based tools; the ability to use a single, unified platform to process complex data originating from many types of sensors, such as hyperspectral, Light Detection and Ranging (LiDAR), and Synthetic Aperture Radar (SAR); and visualization capabilities that enable users to create virtualized three-dimensional data representations. These tool-level capabilities -- particularly when presented in an intuitive step-by-step workflow manner--enable users of geospatial data to quickly extract meaningful information from imagery without the need to comprehensively understand specific remote sensing techniques and methods. Technological developments are bridging expertise gaps that exist between the remote sensing and GIS worlds, and enabling geospatial professionals to more readily consider additional sources of information to solve problems.
The Shrinking Remote Sensing - GIS Gap

Deriving the most comprehensive intelligence products from geospatial data often requires performing both image processing tasks and GIS analysis—informing decisions with perspectives gleaned from both vector and raster data sources. This dual-perspective approach may entail utilizing separate software applications to affect specific processing steps—a carry-over from the GIS-remote sensing divide. Historically, no single software includes the full capabilities of individual fully-featured raster and vector processing tools, and allows users to create their desired output product in one package; the breadth of functionality covering every method specific to image processing and GIS methods precludes the feasibility and efficiency of such a holistic tool.

However, incremental steps toward a unified tool are evidenced as software manufacturers develop tools and methods borrowed from outside their primary domain. For example, GIS-specific software, like the ArcGIS® tool from Esri, now includes image analysis capabilities such as classification, georeferencing, and mosaicking to facilitate the use of digital image data in conjunction with existing geographic data layers. A similar trend is evident with specialized image analysis and processing software, like ENVI from Exelis Visual Information Solutions (VIS), where GIS-related capabilities for creating, editing, and exporting vector files are added to a raster-specific suite of spectral analysis and feature extraction tools to minimize the need to use multiple software tools to complete a workflow. Each of these tools represent several decades worth of domain expertise and tool development in their respective, and historically separate, GIS and remote sensing industries, and these forays outside their core competencies represent important steps in the convergence of geospatial analysis technology. Since 2006, Exelis VIS and Esri have been working in partnership to leverage their combined expertise and facilitate this convergence by developing robust integration features between their respective industry-leading products, ENVI and ArcGIS. By improving the interoperability of their toolsets, and borrowing specific best-in-class processing and analysis capabilities from each other, together ArcGIS and ENVI are bridging the remote sensing - GIS gap, creating processing efficiencies, and allowing users to realize the power of a highly integrated vector and raster analysis capability. Now, more than ever, capabilities exist to use complementary software tools to extract meaningful information from complex geospatial data—regardless of whether it is GIS or remote sensing based.
Remote Sensing - GIS Technology Integration in Practice

In practice, integrating remote sensing and GIS tools to solve geospatial problems may occur in a variety of ways. The following are specifics exemplified by the implementation of integration features between the ArcGIS and ENVI software tools.

File Level

The foundation for interoperability is laid at the file level; a comprehensive geospatial system must be able to share data by interacting with a variety of specific file formats and conventions.

- Geodatabase read/write capabilities in ENVI
- ENVI file format read/write in ArcGIS (including JTC certified NITF)
- Esri file format read/write support in ENVI
- Online file services and connectivity standards
Interface Level

Interoperability at the interface level facilitates using remote sensing and GIS software packages side-by-side, typically using a multiple monitor configuration. This allows for an iterative and interactive analysis process whereby intermediate products resulting from workflows and processes are manually transferred from one application to another until a final analysis is reached. This type of integration also includes the deployment of specific workflows from one package into the toolbox of another, and the availability of specific processing and analysis functionality for inclusion in the construction of geoprocessing models.

- ENVI to ArcMap GeoLink facilitates synchronized display pan/zoom for areas sharing common geographic extents
- Drag-and-drop, or send-to functionality shares data layers between software programs
- ArcGIS Map Projection and Layout Engine utilized by ENVI for output map production
- ENVI tools for ArcGIS installs powerful image processing tools directly into the Arc Toolbox, which may include custom-developed ENVI tools, and may be included in an Arc ModelBuilder geoprocessing chain
Web and Enterprise Level

By deploying traditional file-based desktop tools in a server-based architecture, geoanalytical technologies are extended beyond an individual user to an entire organization—or beyond. This scalable type of deployment allows for the centralized management of tools, applications and data, leverages the power of distributed computing resources, and allows for the development and implementation of dynamic geoprocessing capabilities to meet specific user requirements. The integration of GIS and remote sensing technology in an enterprise framework involves making specific processing and analysis routines seamlessly available to users as services for access by a variety of client types, for example via a web page, mobile device, or desktop machine.

> ENVI Tools for ArcGIS integrated into the ArcGIS Server environment to support online, on-demand geospatial tools throughout enterprise environments

> ENVI image analysis and ArcGIS geoprocessing capabilities can be deployed as cloud-based services and via Esri’s GeoServices REST specification for consumption by HTTP interface.

> When published as image services through ArcGIS Server, remotely-sensed imagery and LiDAR-derived raster data products are available for geoprocessing and analysis via the web.

THE BENEFITS OF INTEGRATING GIS AND REMOTE SENSING CAPABILITIES

Current

For the variety of reasons discussed previously, the divide between GIS and remote sensing technology is effectively closing—yielding new technological linkages that create unprecedented opportunities to solve complex problems using geospatial data. The value inherent to the unique data collection characteristics of imagery has integrated into the GIS paradigm as a primary source of foundational data. For example, the acquisition of remotely sensed imagery from an orbiting platform provides information rapidly to decision makers determining routes for recovery and reconstruction efforts after a natural disaster. Remote sensing platforms providing data over broad inaccessible areas allow scientists to measure ice fields or extensive areas of deforestation in support of large climate models. The properties of spectral image data yield advanced geospatial analysis results that defense and intelligence officials use to identify targets beyond the range of human sight. And advanced classification routines applied to multispectral image data allow municipal planners to track urban growth and develop water runoff models to
The technological advancements that have enabled the integration of remote sensing and GIS practices also entail practical benefits for organizations in which the tools are used. Improved interoperability increases productivity, reduces the training, expertise, and management requirements of multiple software packages, and helps to justify the purchasing expense for compatible products. In addition, software development costs are reduced since custom software tools are developed once and then leveraged from both applications. In an era of tightened technology procurement expenditures, and a general need to do more with less, these ancillary benefits are welcome by many in the geospatial industry.

**Future**

The integration of remote sensing and GIS technology is symbolic of a larger movement toward the fusion of myriad geospatial data types and collection methods. In a relatively short time, the geospatial industry will see an explosion of available data produced by an increasing number of remote sensing platforms such as Unmanned Aerial Vehicles (UAV) and small scale satellites. The proliferation of complex data, in both time and space, will require a technological foundation on which storage, processing, analysis, and dissemination capabilities for future decision support systems will be built. Current developments in GIS and remote sensing desktop tool interoperability are the basis for this technological foundation. And, as these capabilities continue to transition away from the desktop towards scalable, more powerful, and efficient cloud-based deployments, a wider audience of users will realize the benefits inherent to integrating remote sensing and GIS technology: the ability to effectively synthesize multiple data sources and yield comprehensive, multidimensional information that is timely, decisive, and meaningful.