Synthetic Aperture Workhorse

Responding to government needs, industry develops a variety of tools to exploit and analyze SAR data and to integrate it into geospatial intelligence work flows.

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Synthetic aperture radar is becoming one of the workhorses of the U.S. military and intelligence communities, which in recent years have come to recognize the value of using SAR products for a variety of applications, including for tactical missions, mapping elevations, detecting terrain changes and a variety of other uses.

The myriad of potential uses for SAR is a testament to the technology's flexibility and utility. It can be mounted on satellites or on airborne platforms. It can concentrate on a narrow ribbon of territory or take in wide swaths. It can penetrate cloud cover and is not disturbed by most weather phenomena. It doesn't require daylight to generate useful images.

The U.S. government, since scrapping a radar satellite program a few years ago, has relied on commercial sources of data for its SAR needs. Industry has responded to this development with many recent innovations in this area, ranging from new hardware that is compatible with small UAVs to enhanced on-board processing capabilities and the development of a variety of tools designed to exploit and analyze SAR data and to integrate it into geospatial intelligence work flows.

Unlike air traffic control radar, for example, which sends out beams of energy and receives reflections of that energy that appear as blips on a screen, the antenna of an SAR system ranges for a period of time across a target area generating a two-dimensional image. "The image is derived from the long track along the flight path of a satellite to piece together points on the ground," explained Ian McLeod, director for defense and security at MDA Geospatial Services.

MDA operates two RADARSAT satellites that carry a SAR instrument capable of taking images at multiple resolutions ranging from one to 100 meters. The Canadian National Defense Department and the U.S. National Geospatial-Intelligence Agency, Navy and Coast Guard are among the major users of RADARSAT data.

The radar image differs markedly from the pictures generated by an electro-optical sensor, but contains much useful information that can be exploited in conjunction with optical images.


Kevin Jones

"Military users began taking interest in SAR two or three years ago," said Kevin Jones, director of marketing and product management at PCI Geomatics, a developer of geo-imaging software and systems. "They realized they could get more actionable intelligence with information from multiple sensors. SAR is particularly useful for change detection missions. It can detect very subtle changes on the ground."

That is because it is possible to extract measurements from SAR that are not possible from optical sensors, including ground deformation, human activity indicators and digital elevation models. "You can detect and measure phenomena in addition to typical image exploitation," said McLeod. "Many use SAR to complement optical assets. There are too many targets for the optical sensors and not enough capacity. When the SAR detects change or another item of interest, the user can then cue the higher resolution optical sensors to take a look."

Digital Models

SAR digital elevation models have garnered a good deal of interest recently. "They can be rapidly produced over any area," said McLeod. "Our wide swaths and cloud independent imaging mean we can very quickly cover large areas." The RADARSAT satellites are currently producing images for 50,000 square kilometers per week.

"RADARSAT is especially well-suited for maritime applications, with very large swath widths up to 500 kilometers wide," said McLeod. "Our wide-swath modes are preferred for maritime surveillance, and we offer products that combine the SAR results with other information from optical and automatic identification systems to provide a maritime picture where none may exist."

SAR also has a long history of being used for ice monitoring. "Organizations like the National Ice Center routinely use RADARSAT imagery operationally to create ice charts used to support U.S. Navy and Coast Guard operations in polar regions," said McLeod. "SAR is also very good at detecting oil on water. RADARSAT-1 and RADARSAT-2 were used heavily by BP and the Coast Guard during the Deep Water Horizon disaster to monitor the spill and direct cleanup activities."

The development of very small SAR units now allows the technology to be installed on small UAVs. The NanoSAR system developed by a company called ImSAR, for example, has reduced size, weight and power consumption as compared to typical SAR units, so that it can now be mounted on Insitu's ScanEagle UAV.

Charlie Guthrie

Trip Carter

"Our mission was to develop radar to go on small unmanned planes," said Adam Robertson, ImSAR's NanoSAR program manager. "NanoSAR is orders of magnitude smaller in size, cost and power consumption than other commercially available systems. NanoSAR weighs 2 pounds, consumes 15 watts, and measures 6 x 6 x 5 inches. Typical systems weigh 100 pounds, use hundreds of watts, and are the size of a small engine."

"We supported the development work enthusiastically," said Charlie Guthrie, Insitu's chief technology officer. "NanoSAR is the smallest SAR radar mounted on an airplane."

The ScanEagle was first developed in the mid-1990s by Insitu, which has been a Boeing subsidiary since 2008. It recently logged its 400,000th hour in the Southwest Asia theater.

"The ScanEagle was fundamentally an eye in the sky," Guthrie explained. "It always carried electro-optical and infrared sensors and video cameras. What SAR brings to the table is a completely different type of sensor. It can detect objects day or night. It can detect metallic objects better than video. Since it can operate in all kinds of weather it represents a new way to find things."

NanoSAR's range is narrower than those of larger systems, and it needs to be closer to its targets to produce valuable information. "But that happens to be where our system operates," said Guthrie. "We view it as an enhancement to our current capabilities."

ScanEagle is a 44-pound UAV with a 10-foot wingspan. Insitu has plans to integrate NanoSAR onto its larger, 135-pound platform called Integrator. The ScanEagle-mounted NanoSAR is currently being demonstrated for potential customers and is ready for market, said Guthrie.

Multi-Band SAR

Another innovation that reduces size, weight and power usage of SAR systems, albeit for use on a much larger platform, comes from Northrop Grumman. Multi-Band (MB) SAR is a software-defined radar and real-time on-board processing system developed by Northrop Grumman Intelligence Systems with support from the Air Force Aeronautical Systems Center. The radar's multiple bands support many missions, including locating IEDs, imaging under foliage and into buildings, and detecting changes over a wide area. The ability to survey very large areas in all weather conditions, day or night, and to cue other on-board sensors enables airborne assets to provide real-time, tactically relevant information directly to troops on the ground or for border surveillance.

"The reductions in size, power and weight allow MB SAR to be installed on platforms such as such as Beechcraft King Air class aircraft," said Trip Carter, director of the airborne ISR mission area for Northrop Grumman Intelligence Systems.

MB SAR was integrated aboard a Navy NP-3D Orion aircraft as part of a Naval Research Laboratory program called Project Perseus. The aircraft successfully performed missions as a part of Task Force Observe, Detect, Identify and Neutralize, an ISR group that has operated in both Iraq and Afghanistan. Because the system is software-defined and designed for flexibility, Northrop Grumman's team was able to rapidly adapt to mission requirements as well as integrating, testing and calibrating the system in less than five weeks.

"Simply put, it has been used as part of a change detection process," said Carter. "It involves looking at a new image, comparing it to a prior image as a baseline and identifying changes. MB SAR is used to cue the system to put an eyeball on the target from an aircraft in near real-time to confirm something is there."

The advantage of MB SAR is that it can cover very large areas and provide highly accurate and precise images. "Because we operate at the lower end of the frequency regime, we are able to see a lot of territory," said Carter. "X-band SAR systems have the scope of soda straws. The system then maps out the changes that occurred over the previous flight. The ability to cover large areas translates to other types of missions such as foliage penetration and littoral surveillance."

Another advantage of MB SAR is that it has been integrated on a single airborne platform with other sensors. "The sensors are able to work collaboratively," said Carter. "The on-board processing capability is able to cross-cue different sensors to collect different kinds of data, including LiDAR data, in a multi-intelligence approach."

Light detection and ranging (LiDAR) uses laser light pulses from an airborne platform to gauge distances by measuring the time delay between transmission of the pulse and detection of the reflected signal to develop elevation models of terrain.

With the success of MB SAR's deployment with the Navy, Northrop Grumman is currently investigating other opportunities to deploy MB SAR to support broader airborne missions.

Software Tools

The increased recognition of SAR is also manifested by the growth the number of software tools being developed to analyze and exploit SAR data. MDA is currently working with ERDAS and PCI Geomatics on projects in this area.

"One of the challenges in the world of SAR is that it takes some know-how and specialized software to read the images derived from it," said McLeod. "You need an educated user, and you need to have appropriate tools in order to exploit the data."

Much of MDA's business is in providing intelligence products to customers with the use of its in-house, proprietary tools as well as with COTS products. The company doesn't market "shrink-wrapped software" to the general user public.

On the other hand, McLeod considers it to be "in the best interest of MDA to help GIS vendors develop the tools needed to interpret and exploit SAR imagery. The purpose is to collaborate to develop new SAR exploitation capabilities that can be made available on a wide scale."


Brad Skelton

In the case of MDA's collaboration with ERDAS, the latter "contributes their platform and their expertise, while MDA contributes the data and our expertise," said McLeod. "The goal is to make the advantages of SAR data more easily accessible to users."

A recently announced agreement between MDA and ERDAS will have the two companies embark on a series of pilot projects designed to demonstrate the utility of exploiting SAR data with ERDAS tools.

ERDAS has a long history of working with radar, noted Chief Technology Officer Brad Skelton, and has developed the Imagine Radar Mapping Suite, a bundle of tools for ERDAS Imagine that enables users to analyze and exploit radar data, including SAR data. The Imagine Radar Mapping Suite does not need to be reconfigured to work with SAR, but has been tweaked in order to read and interpret the SAR data.

The Imagine Radar Mapping Suite includes Imagine Radar Interpreter, which provides fundamental tools to preprocess radar images or enhance them for visual interpretation. "The tool enables speckle removal and radiometric calibration and terrain correction for radar imagery, and the ability to fuse radar and optical images," said Skelton.

Imagine OrthoRadar performs georeferencing and orthorectification of SAR images, using SAR sensor models, satellite orbit models and digital elevation models (DEMs). The Imagine SAR Interferometry module includes Interferometric SAR, which creates accurate, high-resolution DEMs from SAR image pairs, Coherence Change Detection, which produces georeferenced raster and vector change maps, and Differential Interferometric SAR, which enables precise mapping of surface displacement. Imagine StereoSAR DEM enables users to extract terrain height information from stereo pairs of RADARSAT data to generate accurate DEMs.

"We intend to continue to support radar as an important part of ERDAS Imagine," said Skelton.

Although a specific list of pilot projects has yet to be developed, Skelton surmises they will include applications for ice detection, soil change detection and ship monitoring, as well as oil spills and dumping.

"We are working with ERDAS in a number of areas," said McLeod. "The goal is to bring products to market. The timeline will depend on the progress of the work."

PCI Geomatics, a developer of geoimaging software and systems, recently announced a collaboration with MDA to implement software tools for ArcGIS using RADARSAT-2 demonstration data. PCI Geomatics introduced GeoImaging Tools for ArcGIS in 2010, and is currently developing a radar module, which will allow ArcGIS users to perform change detection, time series analysis, image classification, and feature extraction using RADARSAT-2 data as well as other commercially available SAR imagery.

ArcGIS is a leading integrated geographic information system from Esri.

PCI Geomatics has had a long relationship with MDA, stretching back to the initial launch of RADARSAT-1 in 1995. The technology developed by PCI at that time made it possible to analyze the imagery and develop operational applications using RADARSAT-1 data. PCI Geomatics added support for the next-generation RADARSAT-2 satellite in 2005. The latest development will allow ArcGIS users to run PCI Geomatics analysis tools on RADARSAT-2 data within the ArcGIS environment.

"Our key objective is to develop powerful, simple-to-use tools that can be integrated into GIS work flows," said Jones. "RADARSAT-2 imagery will be used to develop compelling application examples for GIS users to adopt SAR imagery."

The companies are going about their collaboration by collecting RADARSAT-2 data over locations in Europe, the United States and Canada—including areas of the Netherlands and Portland, Ore.—that will be used to develop operational demonstrations of SAR data. PCI Geomatics, together with Esri, will then prepare a series of demonstrations to educate the international community through a series of webinars and live demonstrations at trade shows and events.

Incorporating SAR data into ArcGIS will allow analysts to more easily generate actionable intelligence on ground disturbances using data from multiple sources, according to Jones. "It will better allow defense personnel to incorporate and combine multi-sensor data to pinpoint disturbances or problem areas," he said. "Our tool is plugged directly into the GIS toolbox. Multiple images can be accessed and automatically aligned in order to perform change detection. Using spatial and image analysis tools, users can detect changes of interest and produce a map that contains useful information that has been derived from the imagery."

PCI's current focus is to develop customized work flows for multi-sensor scenarios based on the market feedback the company has received this far. Ultimately, Jones is convinced that the PCI-MDA collaboration will provide richer analyses and make analysts' jobs easier.

"Current and future users demand going beyond the generation of image products alone, as multi-source imagery and derived products are fused with other data sources and presented in a form that is easily integrated with established operations," he said. "By linking proven radar image analysis technology to universal GIS data exploitation and dissemination, a new level of utility will be established." ✶

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