3-D Mapping

ADDING DIMENSION TO A FLAT WORLD.

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Three-dimensional mapping technologies are understandably advancing in the tactical sphere. Three-D applications allow warfighters, commanders and analysts to develop a deeper understanding of environments such as urban areas that help them execute their missions better and more efficiently.

Three-dimensional visualizations use geospatial data and imagery to consolidate and present information in a fashion that is easily usable by those who need it. Three-D gives individual warfighters a better picture of the terrain and the environment they are operating in, particularly at close quarters in urban areas. With a 3-D representation, warfighters can better understand how the terrain and the man-made environment affects military operations.

"There is always a need for warfighters to have an appreciation of the terrain they will be operating in," said Mark Grablin, director of Airborne Reconnaissance Systems at Lockheed Martin Information Systems & Global Solutions. "The farther they can get away from two-dimensional maps, the more information they will have for operational planning and execution of different missions."

"Three-dimensional mapping is an important situational awareness tool for warfighters," said John Coots, director of business development at Hover Inc. "It is used for planning to gain a better understanding of missions. Three-D technologies can even pinpoint specific buildings so warfighters can plan how they are going to approach it."

"Three-D is important for mission planning, rehearsal and analytics," said Matt Morris, a director of product development at Overwatch, part of Textron Systems. "Advances in dissemination technologies, such as such 3-D PDF files, make it easier to distribute the 3-D maps. Before, you needed high-end software to be able to render the 3-D image on a screen."

"One thing that 3-D really brings out is a normal human sense of vision," said Rick Black, director for defense and intelligence programs at Zebra Imaging Inc. "A photograph will always look flat."

Geographical information systems form the core of 3-D mapping technologies, while light detection and ranging (LiDAR) provides the key elevation data used to generate the 3-D representation. "Three-D maps require a strong visualization capability," said Morris. "You take in imagery and elevation data and create a realistic terrain picture by draping imagery over the elevation data. What warfighters see when they are on the ground can't be represented in a two-dimensional map. Three-D maps can allow warfighters to acquaint themselves with a mission environment before they get there."

LiDAR technology has been around since the mid-1990s. But its application to military missions took off in the last decade thanks to the fact that United States armed forces found themselves fighting in theaters in which they owned the skies, allowing the aerial overflights that collect LiDAR data in Afghanistan and Iraq to proceed undeterred. From there, military and industry imaginations kept thinking up and developing new and better ways to collect, extract, analyze, exploit and apply LiDAR data.

Airborne LiDAR uses 1.064 nanometer wavelength laser light pulses to gauge distances by measuring the time delay between transmission of the pulse and detection of the reflected signal. A rangefinder mounted in an aircraft swings back and forth collecting data on up to 150,000 points per second, providing resolutions of one point per meter on the ground and one point per 15 centimeters vertically. The data returned by the LiDAR sensor provides location data on an x-y-z axis, referred to as a point cloud. Ground based LiDAR utilizes rotating rangefinders with up to 64 lasers channels, that can collect up to 1.3 million points per second.

The importance of LiDAR to 3-D mapping is that it provides accurate elevation data. LiDAR sensors and data pinpoint the location and elevation of surface elements such as buildings, trees and roads. Under the right circumstances, it can also detect hidden objects by, for example, penetrating forest or jungle canopies.

LiDAR really shines when it is used in conjunction with data from other sources such as electro-optical, infrared and hyperspectral sensors. U.S. forces in Afghanistan use the BuckEye system, which was developed under the auspices of the Defense Advanced Research Project Agency (DARPA), and which combines airborne LiDAR technology with digital color camera imagery. Fusing data from multiple sources increases the probability that features can be automatically extracted from the raw data and that an accurate situational picture will result. Some 3-D mapping applications also use BuckEye data.

"LiDAR adds a human dimension to situational awareness and mission planning," noted Morris. "You need to know the height of a building to know whether to bring a 6-foot ladder or a 12-foot ladder. LiDAR elevation data provides the information that can be included in 3-D representations."

Overwatch markets a series of products that first automatically extract features from LiDAR data, and

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then incorporate those into 3-D maps and visualizations. Its LiDAR Analyst software works as an extension for systems such as Esri ArcGIS and Overwatch's geospatial analysis software. The company's Remote-View and 3D Pro are the 3-D visualization tools.

Automated feature extraction, as exemplified in LiDAR Analyst, is a capability that allows software to recognize certain specific objects represented in LiDAR point clouds. Programming the software to be on the lookout for topographical features such as hills or man-made objects such as buildings, vehicles, or power transmission lines allows those features to be separately and distinctly portrayed.

"LiDAR Analyst uses advanced algorithms to detect, recognize and extract complex 3-D building shapes from point cloud data so that all the buildings across a city or area of interest can be inventoried," said Morris. "The buildings, trees and shrubbery can also be stripped away to reveal the true ground level for a detailed digital elevation model, which is especially useful for mountainous terrain."

Analysts use 3D Pro to generate detailed 3-D terrain and urban models that help decision makers and warfighters understand the real-world conditions they face. The solution provides interactive tools that allow users to perform line-of-sight analyses and to identify buffer zones and landing zones. Users can set conditions such as cloud cover, fog and night vision.

"The software brings realism to simulations and increases mission success," said Morris. "It can be challenging for analysts and warfighters to visualize territory or a target of interest based upon 2-D imagery. A rich 3-D scene provides better context and fills knowledge gaps."

Zebra Imaging Inc. takes 3-D to another level by producing holograms of terrain, particularly urban terrain, of interest. A hologram is a 3-D, 360-degree representation of an object or area that can be observed from all sides. The hologram is projected by illuminating Zebra's proprietary film. The company is in the process of introducing a new product that projects a hologram above the glass of a screen without the use of film.

"A hologram is virtually solid but not physically solid," explained Zebra's Black.

Zebra's holograms are can be created from a variety of data. They have utilized LiDAR data from the BuckEye program, as well as commercial satellite imagery and airborne imagery.

"We typically extract elevation data from LiDAR and generate 3-D models by overlaying imagery on top of that," said Black. "The holograms have been used to plan line-of-sight communications in urban areas. Line of sight is not easily discernible from a flat representation. The holograms have also been used for route planning, for mission pre-brief and debriefs, for flight rehearsals, and for virtual reconnaissance."

Unlike photographs or maps, hologram users don't need any special training to understand the terrain being represented, according to Black. "It makes it easier to understand where vehicles can transit and how much they can carry," said Black. "By walking around a hologram, warfighters may be able to identify a cave system on the side of the mountain that they never noticed before."

Zebra has placed over 12,000 of its hologram products in Afghanistan and Iraq since 2005. They are run by an Army program called Tactical Battlefield Visualization.

Facilitating advances in 3-D mapping are new high-definition LiDAR sensors that are able to gather much denser point clouds, which can then be transformed into more detailed and higher resolution 3-D maps. "Most LiDAR systems employ a single laser," said

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Wolfgang Juchmann, product marketing manager at Velodyne. "Our high-definition LiDAR sensor uses a rotating head featuring 64 semiconductor lasers, each firing up to 20,000 times per second, resulting in a total of 1.3 million data points per second. This allows the sensor to achieve data collection rates that are an order of magnitude higher than most conventional designs. The resulting point cloud is so dense that computer programs can identify objects such as street curbs and overhead wires at distances up to 100 meters."

The technology was originally designed to compete in DARPA's Grand Challenge, a competition designed to spur innovation in the field of unmanned ground vehicles. It has since been applied to mapping systems as well.

A somewhat different approach to 3-D mapping is taken by Hover Inc. and its Indigo product, in that it does not use LiDAR data to generate 3-D images. "LiDAR data is not available in every area of the world," noted Coots.

Instead, Indigo creates 3-D models from imagery. "We can take satellite images and ground photos in a variety of formats and combine all those to make a high-quality and high resolution 3-D model based on our patented algorithms," said Coots. "We only project into the 3-D model we can see. There are no fake facades or manipulation of photographs. If we don't know, we say we don't know. That way the warfighters don't plan for something that may not be there."

Hover plans on evolving Indigo into an enterprise solution that will allow dissemination over a variety of different handheld devices. Housing such an enterprise solution in a cloud computing environment, according to Coots, will enable the more rapid update of the 3-D models as new images are captured.

Lockheed Martin is investigating the possibility of adapting 3-D technologies developing in the commercial gaming industry to military applications. "We have been involved in the Distributed Common Ground System programs for decades," said Grablin. "We work on the principle of adding value. In this case, we are talking about adding value to sensor data and other information that will allow analysts, commanders and warfighters to make sense out of them for planning and targeting. The idea would be to take digital elevation maps and combine them with different tools and information that already exits to create knowledge within existing ground stations for warfighters in real time. The view would be updated as new information comes in to allow warfighters a view not only of their current environment but where they will be going on their missions."

Zebra Imaging has developed a 3-D hologram application that is not dependent on its proprietary film. The system is currently being studied by the Army and the Air Force and will soon be unveiled to the public.

"The biggest problem for 3-D," said Black, "is that there are not enough applications to bring all of the data to users. LiDAR data collection is expanding faster than the output uses for the data."

That doesn't worry Morris, who said that "the expansion of LiDAR collection will drive the use cases," which in turn, presumably, will stimulate the development of the required applications. ✴