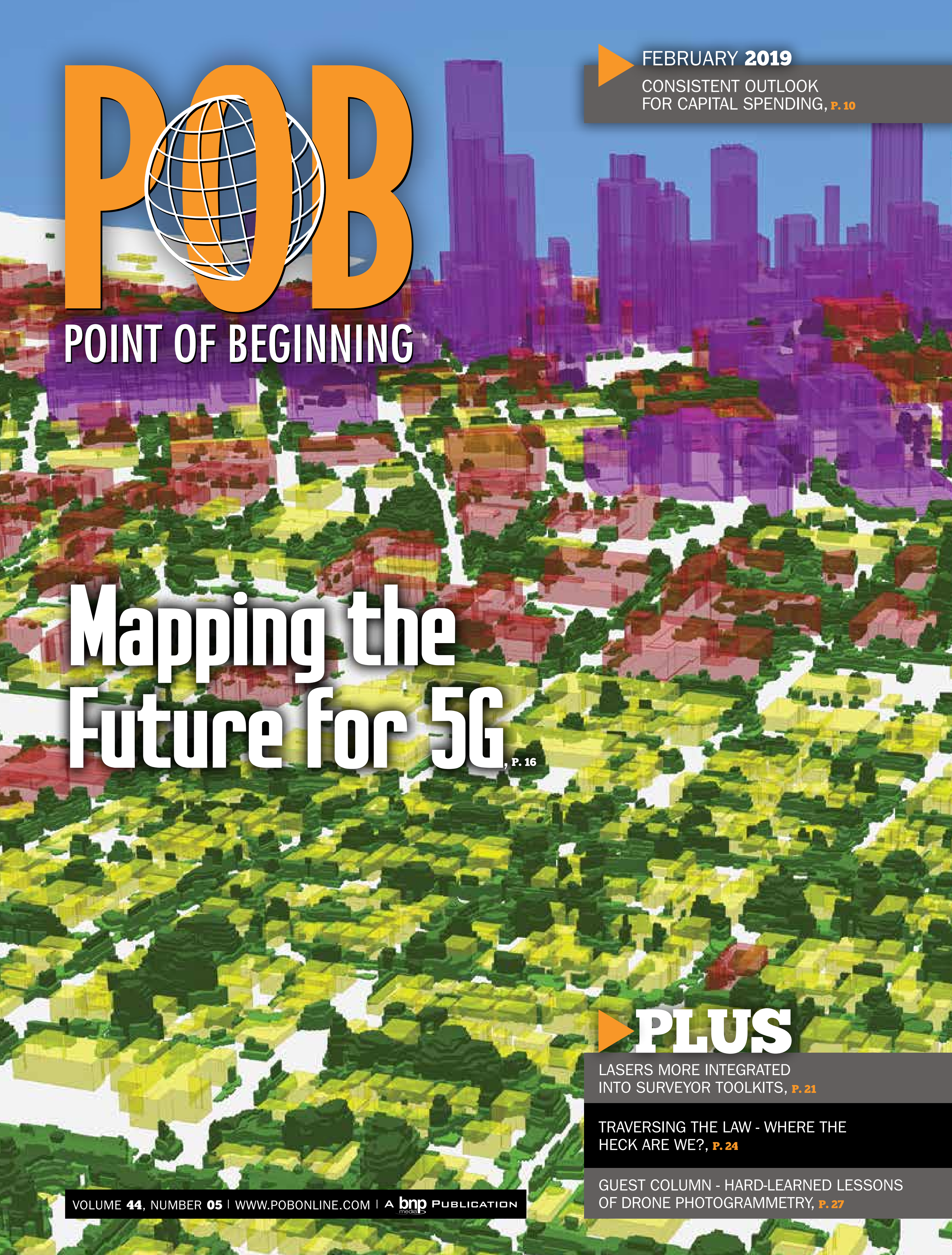

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Fast Forward to 5G

Three-dimensional city models are providing infrastructure intelligence in the race for network coverage.

Seattle's abundance of tall trees and its urban infrastructure mix made classifying the land cover particularly tricky.

By Mary Jo Wagner

Developments in commercial technology often trickle down and have a dramatic benefit to consumers — such as GNSS. Mobile communications technology is so deeply embedded in our working and personal lives that major developments can simultaneously affect both. In early 2017, at the Mobile World Conference in Barcelona, the usual topic about a new fancy phone was usurped by excited chatter centered around an invisible connection that didn't yet exist: 5G (fifth generation) wireless cellular technology. Despite not having any consensus on exactly what 5G would constitute, what spectrum would be needed, how the network would be distributed or if consumers would even want it, major telecom players were already starting to invest in the next generation of mobile networks — and surveyors and geospatial professionals are helping to get it started.

One year after the conference, that potential hype solidified into a serious business case — the Global System for Mobile Communications Association predicted 5G connections to reach 1.1 billion by 2025, boosting overall operator revenues to $1.3 trillion.

Tapping into that revenue stream, however, is requiring companies to commit significant spending to meet the demands of the new reality. Handset companies need to produce 5G devices — Samsung and Verizon jointly announced in early December 2018 that the companies would sell a 5G smartphone in the first half of 2019. Chip manufacturers like Qualcomm need to make compatible smartphone communications chips. And mobile operators need to upgrade their networks with 5G gear. The investments in 5G infrastructure, according to market research firm Moor Insights & Strategy, are estimated to exceed $325 billion by 2025.

"In the telco industry, network coverage is king," says Nick Hubing, president of Land Info Worldwide Mapping, an aerial and satellite data provider based in Colorado. "To ultimately rollout 5G, telco operators need to have accurate, detailed and up-to-date mapping of the markets they serve."

5G will require lots of small cells to be installed on city infrastructure like utility poles, lampposts and buildings to ensure line of sight is maintained.

For the past year, Land Info has been providing that essential market intelligence to help support telco companies in their preparation for emerging 5G rollouts across the U.S. Using aerial imagery, LiDAR, and object-based image analysis (OBIA) technology, Land Info has been producing both 3D building and tree vectors and 1-meter resolution land-cover classifications of metropolitan areas. With this telecom-tailored information, companies are able to analyze urban and residential areas to determine the optimal locations for 5G sensors so their signals reach the highest number of users, helping them remain strong contenders in the race for a future that is predicted to be lightning fast.

FAST FORWARD

Although 5G is still in its infancy, the expectation is that the next generation networks will offer data speeds up to 50 or 100 times faster than current 4G networks (depending on what part of the spectrum is used). It will also significantly reduce communication latency. That combination not only allows for a larger array of applications that 4G can't provide, but it also provides the critical infrastructure needed to enable the next wave of technological advancements in Internet of Things (IoT), smart cities, virtual reality and autonomous vehicles.

One of the keys to unlocking this fast future is the 5G network's use of millimeter wave technology, which uses shorter, higher frequency wavelengths in the 30 gigahertz (Ghz) to 300 Ghz range of the spectrum. The shorter transmission ranges and larger bandwidths can mean faster data transmissions.

The caveats to achieving the forecasted "Usain Bolt" wireless speeds are: 1) telecom companies will need a notably denser array of small antennas; and 2) millimeter waves tend to be susceptible to interference and generally need to maintain line-of-sight for transmission to work. Companies then have to figure out how to make sure the signal gets from the next generation of 5G base stations — their largest operational expense — to mobile devices.

To help resolve this critical challenge, multiple U.S. telecom companies have tasked Land Info with creating customized mapping of select areas of interest (AOIs). In particular, they requested 3D models of AOIs that would include layered views of 3D building footprints, classified land cover, and classified tree contours and their heights — critical information to analyze line-of-sight potential for 5G sensors and determine the best strategy to optimize their network.

"5G will require lots of small cells installed on city infrastructure like utility poles, lampposts and buildings to ensure line of sight is maintained," Hubing says. "The 3D mapping we are providing enables telco companies to readily identify the optimum locations for their infrastructure and accelerate their rollout."

JUST THE BUILDINGS AND TREES, PLEASE

Developing the 3D city models has been the responsibility of Chris Lowe, Land Info's director of imagery analysis, who was first introduced to cellular network design 20 years ago at Motorola.

"When I started with Motorola in 1998, we were doing heads-up digitizing of old Russian topo maps and then converted them to 30-meter and 90-meter digital elevation, land-cover data," he says. "Back then, the technology transmitted on such a low gigahertz that we didn't need really high-resolution data to produce maps for network design. But while the mapping quality was lower, we needed a team of 20 to digitize all the paper. Today, planning for 5G networks requires the accuracy and detail of 1-meter datasets. In sharp contrast to 20 years ago, however, our OBIA technology allows us to process, classify and map significant volumes of data with a small team."

Guided by the telecom companies' lists of AOIs nationwide and their mapping requirements, Lowe first acquired his needed imagery inputs. Serving as the raster foundation, he obtained 1-meter multispectral aerial imagery from the USDA's National Agriculture Imagery Program (NAIP) and aerial-derived DTM and DSM

Industry analysts proclaim that 5G will enable the next wave of technological advancements in Internet of Things (Iot), smart cities, virtual reality and autonomous vehicles.

data, sourced from either LiDAR or SGM (Semi-Global Matching.)

"The consistent leaf-on seasonality of NAIP imagery provides the best tree-extraction results, and aerial-derived DEM data gives the highest level of building detail, including the ability to model multiple building levels and roof-top obstructions," Lowe says.

For the vector datasets, Lowe sourced building footprints, water polygons and roads. He also used the DTM and DSM to create a normalized DSM (nDSM), which would provide key elevation data for classifying trees and buildings and calculating their heights.

Both the raster and vector datasets were then put into Trimble's eCognition software, an OBIA information extraction technology that employs user-defined processing workflows called rule sets, which automatically detect and classify specified objects and map them.

"eCognition was built to classify and map vegetation, so it's a given for this work," Lowe says. "OBIA can take in any spatial-based data and it uses my parameters to classify it. It automatically uses the traditional image-processing method of matching a pixel's spectral properties with its typical land class, and it considers an object's environmental surroundings to extract specific features for a more intelligent and meaningful classification."

With his image layers prepared, Lowe focused on developing the rule set workhorse to process and classify the data. For this particular work, he needed three rule sets — a main, comprehensive workflow and two smaller, more targeted workflows — which together required more than 100 individual processing steps.

The first rule set was designed to consider and analyze all the data inputs to delineate and classify building footprints and vegetation. Based on thresholds and parameters that Lowe established, eCognition methodically studied the data layers and grouped objects into basic classes including water, impervious, barren, vegetation and buildings. Using the nDSM, spectral properties, vegetation indices and a proprietary roughness layer, the software then focused specifically on the vegetation to delineate trees from other vegetation types. It looked at each vegetation object, and using the LiDAR or SGM height information and the spectral information from the NAIP imagery, would determine if an object is a tree and classify it as such. Based on its calculated height, eCognition would then move it into one of three predefined height categories.

Once the woody (tree) vegetation was classified, the rule set then called for the software to classify shadows. That was a notable challenge, especially for hilly, tree-heavy urban areas such as Seattle, Lowe says.

"With the multispectral imagery, we knew there would be shadows cast from trees and buildings, but we needed to classify what was obscured. Seattle, with its abundance of tall trees and its urban infrastructure mix, was particularly tricky to correctly classify the land cover. I had to develop a creative way for the software to analyze the shadow objects and their nearest neighbors to make accurate class decisions."

The hilly, tree-heavy urban area of Seattle made classifying shadows and land cover challenging.

Still focused on the trees, the final steps of the first eCognition rule set tasked the software to use both custom morphological operators on the nDSM and iterative segmentation to classify individual tree contours at 2- to 3-meter intervals. The contours represented varying levels of height above ground, from the top of the crown to the bottom branches.

Given the breadth and rigor of the first main rule set, Lowe used eCognition Server technology to run that workflow. The technology enables him to automatically process and analyze large areas and heavy volumes of data through batch processing.

"I could have a 400-square-kilometer project, create 3,000-meter-by-3,000-meter tiles, insert my rule set, click 'go' and it would be done in a few hours," Lowe says. "We couldn't have completed these projects without that."

Once the first workflow was complete, eCognition stitched all the raster tiles together and exported the raster land-cover classification into ArcGIS. It also exported the tree contours including their mean heights and the building footprints with a mean height.

A CROWN JEWEL

The second rule set targeted each AOIs building footprints. Unlike typical building footprints, which appear as simple squares or rectangles, these classifications needed to represent buildings like they are in the real world, with different levels and elevations. Lowe created a rule set that tasked eCognition to analyze each building footprint and use the nDSM to segment the building object based on defined height. It then classified each building into one of three types: central business district, mid-rise and residential.

The third, and final, rule set refined the vegetation and building height classifications to ensure building elevations weren't skewed by trees on rooftop gardens — trees can obscure smaller residential buildings or overhang roofs, making them taller than the main roof structure. Lowe designed an algorithm for the software to identify elevated vegetation within a building's footprint, "erase" the vegetation and then use the nDSM to attribute each building segment with a mean height.

The results of these additional rule sets were also exported into ArcGIS for further customization and quality-control checks. The final deliverables to the telecom companies were 3D city models complete with vegetation contours, building footprints and the raster classification.

With so many diverse AOIs, Lowe says the ability to easily tweak the master rule sets to accommodate for each area's unique topography, infrastructure, and unexpected challenges enabled him to consistently meet the customer's specifications and deadlines.

"One of the strengths of OBIA is that it doesn't deviate from user-specified parameters," Lowe says. "It doesn't guess. So I can adjust or create any rule, and the software will consistently and reliably follow it. That flexibility allows me to solve some really challenging issues like fixing the shadows

The hilly and tree-rich city of Seattle forced Chris Lowe to develop a creative way to analyze shadows and make accurate class decisions for the Seattle 3D city model.

To capitalize on the fast future of 5G, telecom companies will need a notably denser array of small antennas installed all over urban areas.

and classifying tree contours. I can't think of another way to accurately classify those objects without OBIA technology."

To date, Land Info has produced 5G customized 3D maps for more than 30 metro areas in the U.S., and they expect more demands for this information when 5G rollouts begin in earnest in 2019. Given the efficiency of their automated methodology, they are confident they can meet these expectations.

"I typically only had a few days to process each AOI, and often, I was processing more than one simultaneously," Lowe says. "The speed and automation of eCognition allowed me to process 100 square kilometers in about 35 minutes, but with the scalability of the software, I could process 10 times that just as quickly. What's really impressive is that the datasets come straight out of the software nearly customer ready."

To prepare for future work, Lowe is working on refining the three rule sets to incorporate them into one comprehensive workflow that would also include classifying individual tree crowns. They are also studying the possibility of isolating tree trunks. With the line-of-sight requirement of the 5G signal, knowing the location of tree trunks could benefit network design analysis. And classifying building material types such as glass or brick is also being considered because certain materials affect radio frequency propagation.

"Given the incredibly competitive telco sector, telco companies are heavily invested in securing dominance in the market," Hubing says. "With 5G, antenna placement will be key. Having detailed models to optimize network expansion is the type of infrastructure intelligence that can help them make those strategic business decisions to give them a competitive edge."

Indeed, if network coverage is king, telecom companies may consider the OBIA-based land-cover classifications and 3D models a jewel in their crown.