GIM INTERNATIONAL INTERVIEWS BENOÃ®T ST-ONGE

Lidar, Imagery and InSAR for Digital Forestry

Benoît St-Onge is a professor at the University of Quebec in Montreal, Canada. He works at the Department of Geography with a major research interest in 3D remote sensing for forest analysis. '*GIM International*' recently interviewed Professor St-Onge to gain a better understanding of the challenges and innovations in this field.

(By Martin Kodde, contributing editor, GIM International)

In your research work, you have a clear focus on the use of Lidar and photogrammetry for analysis of vegetation, forests, etc. How did your interest in vegetation develop?

When I chose to specialise in remote sensing at master level in the 1980s, eastern Canada was invaded by a plague of insects that depleted leaves from trees. I worked on mapping tree defoliation using images from the Landsat satellite, which had a spatial resolution of 30m, but I was frustrated by the fact that I couldn’t see the individual trees. That’s why I decided to work on high-resolution images for my PhD, at a time when commercial high-resolution imagery was not yet available. Since I wanted to study the link between forest structure and image texture, I ended up synthesising thousands of 50cm-resolution images of artificial canopies using simple 3D models of trees. A few years after completing my PhD, I discovered airborne Lidar, which provided me with the actual 3D representation of the forest directly. My use of photogrammetry came a few years later, initially to obtain better reference data for tree height. That’s how the idea of combining Lidar and photogrammetry emerged.

Lidar technology has been used for quite some time in forestry. How has this technology impacted on forest and vegetation management?

We’re starting to see an impact in several countries. In Norway, almost 100% of forest inventories have become based on Lidar. Other Scandinavian countries have followed a similar path and we’re seeing more and more countries adopting Lidar for forest mapping. Here, in the province of Quebec, forest inventory is rapidly evolving towards intensive use of Lidar and there will be Lidar coverage from the US border up to the 51st parallel by 2022.

After a slow start, adoption by the forest industry is quite rapid now. Lidar is used to optimise the layout of forest roads, to find small intermittent streams for protection, and to estimate timber volumes. Knowing exactly where to send the harvesting machinery optimises the value chain while improving habitat protection.

3D forest mapping only adds value if this process is repeated frequently. However, the current costs are prohibitive. Do you believe a higher temporal frequency can be achieved?

This is indeed a real issue. It’s quite clear that the impetus for large-area Lidar acquisition comes from the fact that a wide range of users want an excellent digital terrain model (DTM) for use in hydrology, civil engineering or risk assessment, while the forest community is looking for accurate forest information. The DTM is not expected to change rapidly, but of course the forest will evolve quickly. This leads to situations in which the forest users want updated coverage, while the DTM users are still satisfied with the old DTM.

Will we see enough demand from the forest community alone to warrant surveying large tracts of land on a regular basis? This is far from certain. Regular airborne Lidar surveys can be considered in small countries with limited forest cover. Spain, for example, where 36% of the country is covered by forest, has a programme for re-flying Lidar every six years. However, I don’t see this happening in Canada nor in the US, unless new technologies sharply bring down the cost of Lidar acquisition. This is why we’re increasingly hearing about combining photogrammetry with Lidar to update the forest height information.

You’re a strong advocate of the use of dense image matching as an alternative to Lidar. What are the benefits?

We’ve seen considerable progress in terms of image matching solutions in recent years. First, flight configurations are evolving towards a high forward overlap of 80%. It doesn’t cost much more than the standard 60%, but considerably helps the matching process by deploying multi-ray matching techniques. The algorithms are also more sophisticated and speed has increased. The results we’re seeing from the best software solutions are astonishing in terms of point density and accuracy. In our comparisons between photogrammetric point clouds and Lidar, we showed that even individual trees can be resolved in the photogrammetric surface models. By subtracting a Lidar DTM from the photogrammetric surface model, we get a very good canopy height model from which attributes such as height, timber volume and biomass can be extracted. Aerial photos can be acquired from a higher altitude, at a faster flying speed and at a lower cost than Lidar – plus you get information in full colour.

Do you believe both technologies will continue to co-exist or will we see one edging out the other

We will always need a technology to map the bare earth topography accurately and in great detail. Airborne imagery will never provide that information under closed canopies. This means that Lidar is here to stay, unless alternative technologies such as interferometric synthetic aperture radar (InSAR) take over laser scanning, which seems improbable in both the short and medium term. So it becomes a matter of whether dense matching could gradually disappear. That also seems quite unlikely as, at least for space-borne acquisition, optical imagery is hard to beat in terms of technical feasibility, resolution and ease of acquisition. My impression is that Lidar is becoming more and more spectrally oriented with developments such as multi-spectral Lidar. Meanwhile, imagery is moving towards better 3D extraction capabilities using multi-view oblique imagery. For these reasons, I see both Lidar and dense matching thriving side by side for at least another couple of decades.

Multi-spectral Lidar is a very recent development that may help with vegetation classification. What's your view on this development?

Tree species information is not only necessary for timber inventory but also for habitat studies and other analysis. While Lidar has been extremely useful for mapping forest structure, its use for species identification is still marginal. Although 3D data contains information for distinguishing species to some extent, a lot of discriminating power comes from the analysis of spectral signatures of colour imagery. Tree foliage colour in the visible and infrared band indeed differs between certain species. However, the radiometric corrections necessary to attenuate the variation in the sun-object-sensor geometry in airborne images are very complex. Multi-spectral Lidar provides a way to measure multi-channel intensities with a constant geometry, which make them easier to correct. At the SilviLaser 2015 conference we showed that Optech's Titan sensor with three channels considerably improves the identification of tree species compared to single-channel Lidar.

You've also investigated the use of InSAR for vegetation management. With the launch of new satellites, what kind of potential do you see?

Lidar and image matching are two widespread approaches, but they are not easily deployable to create a global canopy height model. InSAR is a promising technology because it provides large coverage, even in clouded areas. The challenge when applying InSAR to forest canopies is avoiding problems caused by temporal decorrelation due to the movement of canopy between data takes. So the only good InSAR solution for forests is single-pass interferometry where both of the images forming the interferometric pair are acquired at the same time. This is what DLR's TanDEM-X mission is providing. A global TanDEM-X DSM is already available, but what is still missing is a good global DTM. There's also hope that DLR's planned TanDEM-L will have a much better penetration within canopies, but that mission is still a long way off.

Food security is a major societal challenge in which improved agricultural efficiency could play a role. Could your research on forests be applicable in that field?

Food security depends on a wide array of factors, such as water availability, land preservation, use of fertilisers, stable climate and, in an overarching way, a good balance between production and consumption. Based on my understanding of the overall problem of food security, I don't believe that the use of 3D remote sensing to gain better estimates of yield per hectare is the most urgent issue. What I can say is that the pressure to expand agricultural lands is taking a toll on the world's forests. For example, some forests are being cleared in South America for soybean production. Remote sensing can be useful for monitoring these dynamics. The DSM from TanDEM-X, for instance, reflects the state of the forests in 2011-2013. Further mapping of clear cuts can reveal the amount of forest biomass removed for growing crops. After trees are felled, the InSAR surface will reflect the ground elevations, thus allowing us to calculate the height of the forest prior to being cleared. This does not improve food security, but it may further raise awareness of the lack of sustainability of our current level of consumption.

Rather than surveying forests from above, would there be potential for equipping forests with sensors – kind of like an Internet of Trees?

That's an intriguing possibility and one with some possible applications but also a large number of logistical constraints. Technologies for surveying from above, whether using low-altitude drones, standard aircraft or satellites, will certainly continue to evolve and satisfy more and more data needs. However, installing a network of on-site sensors will likely be suitable for only very small niches. One example could be as an early warning of insect infestation. Remote sensing still doesn't provide an efficient means to monitor this, so why not install a grid of cameras on selected trees to allow us to see the actual bugs? Nevertheless, that would involve a lot of effort to install and uninstall it so, apart from for scientific objectives, I don't see this becoming part of widespread operational solutions.

What other exciting developments do you foresee in the near future?

If you look at the history of airborne Lidar you can see that innovation is constant. We went from putting a laser on an aeroplane, to Lidar profiling of forests, scanning Lidars, full waveform Lidars, etc. We're now seeing expansion towards multi-spectral Lidar. Prototypes of hyperspectral Lidars are also being developed. These use white laser light generated using a supercontinuum principle. Like radar, Lidar can also be made polarimetric, which would certainly help in vegetation mapping. Moreover, we are also seeing photon-counting or Geiger-mode airborne Lidar including the promise of high point densities from 9km flying height. On another front, oblique multi-view aerial photography is emerging, thus increasing our capacity to extract 3D information about forest canopies. Who knows where groundbreaking research in physics will lead us? A recent development of a flat meta-lens at Harvard University could one day replace the heavy glass optics we're still using today. Far from having plateaued, I think that the evolution of 3D remote sensing will remain buoyant for a good while yet!

Biography

Benoît St-Onge is a professor in the Geography Department of Université du Québec à Montréal (UQAM). He obtained his PhD in geography at University of Montréal in 1994. He specialises in the use of 3D remote sensing for the analysis of forest environments. He develops image and Lidar data processing techniques as well as new digital photogrammetry and InSAR approaches for mapping of forest canopies in 3D. He is currently working on species identification using standard or multispectral Lidar data, and photogrammetric point clouds. Moreover, Professor St-Onge teaches various aspects of geomatics (geographical information systems, remote, etc.) and supervises several master and PhD students.