Using Mathematical Algorithms to Monitor Forest Health

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Addressing the destruction of forests is a global priority for science and policy. Complex mathematical image processing is extracting intricate detail from airborne images of forest canopies, providing conservation scientists with new insights into forest health.

THE CHALLENGE

Tropical rainforests are believed to be Earth's most complex and diverse land-based ecosystem. They regulate global climate, hold significant undiscovered potential for future medicines, and are home to an estimated 30 million species of animal and plant. Across the world, around one billion hectares of degraded tropical rainforest may have potential for restoration. But understanding and diagnosing the health of extensive areas of rainforest to inform their management is a complex task. Conditions can vary over just a few hundred square metres, and are continually changing through natural regeneration. Satellite imaging often doesn't provide a high enough resolution. And repeated imaging, to monitor changes over time, creates an enormous amount of data to manage and analyse.

THE SCIENCE

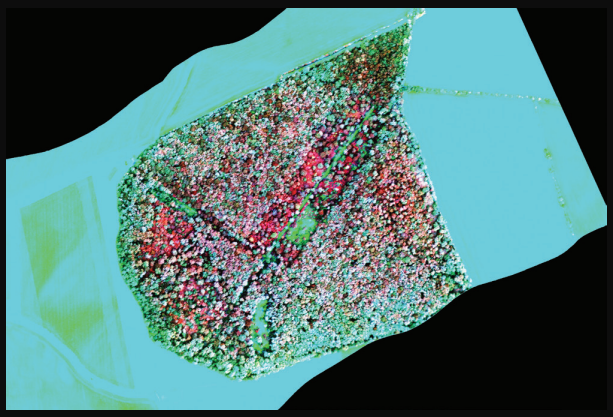
Dr Schönlieb has joined forces with a group of conservation scientists, led by Dr David Coomes in the University's Department of Plant Sciences, to bring her mathematical expertise to bear on the problem. Their approach is to develop algorithms to automatically combine and analyse three different types of imaging data - LiDAR (which records height), hyperspectral images (which give information about the material make-up of the trees), and ordinary photography - to produce highly detailed maps of the forest. The aim is to analyse airborne forest sensing data with such high accuracy that individual trees can be mapped in 3D, identified, and monitored over time.

"This sort of analysis hasn't been done before with this kind of accuracy. We're pushing boundaries, developing the algorithms that are needed to deal with huge amounts of different types of data."

Dr Carola Schönlieb

"Being able to bring these datasets together gives us a much fuller idea of the health of the forest than each of the datasets individually. With the addition of GPS too, we can map the forest tree by tree, over time, in three dimensions."

Dr David Coomes



Hyperspectral image of Hayley Wood in Cambridgeshire.
Photo courtesy of Juheon Lee, Forest Ecology and Conservation group, led by Dr David Coomes.

THE IMPACT

Test flights, using a small fleet of unmanned aerial vehicles, are now taking place over highly degraded rainforest in Indonesia and Ghana. Equipped with inexpensive remote sensors, these vehicles are gathering data on tree species, location and health to provide an astonishingly detailed picture of the health of the forest. The next challenge is to develop the mathematics to speed up this data-intense process, to create automated software that can run on any personal computer. By identifying and counting key indicator species of tree, Schönlieb's technique can spot areas of forest that have been damaged but are showing early signs of recovery.

The approach has applications far beyond conservation. Using similar techniques, Schönlieb's collaboration with Dr Stella Panayotova at Cambridge's Fitzwilliam Museum is helping with the virtual restoration of precious illuminated manuscripts. And through her involvement in VoxTox, a five year programme funded by Cancer Research UK, her research has the potential to guide the optimal radiation dose during radiotherapy treatment in order to prevent damage to patients' normal tissues.

Find out more:

Schönlieb's collaborations arose through the **IMAGES Network**, which brings together leading academics from across the University of Cambridge, international experts and research-led industries working on pioneering imaging technologies and analytical algorithms. The Network aims to stimulate new enquiry and dialogues between the sciences, arts and humanities by providing a platform for communication (**www.images.group.cam.ac.uk**).

Schönlieb leads the **Cambridge Image Analysis** group, which specialises in the mathematics of digital image and video processing using partial differential equations and variational methods. Their use of mathematical techniques to analyse and improve real-world images ranges in application from photographs made with consumer cameras, to images made using professional techniques such as Magnetic Resonance Imaging (MRI) (**www.damtp.cam.ac.uk/research/cia**).