02 SEEING THE UNSEEN

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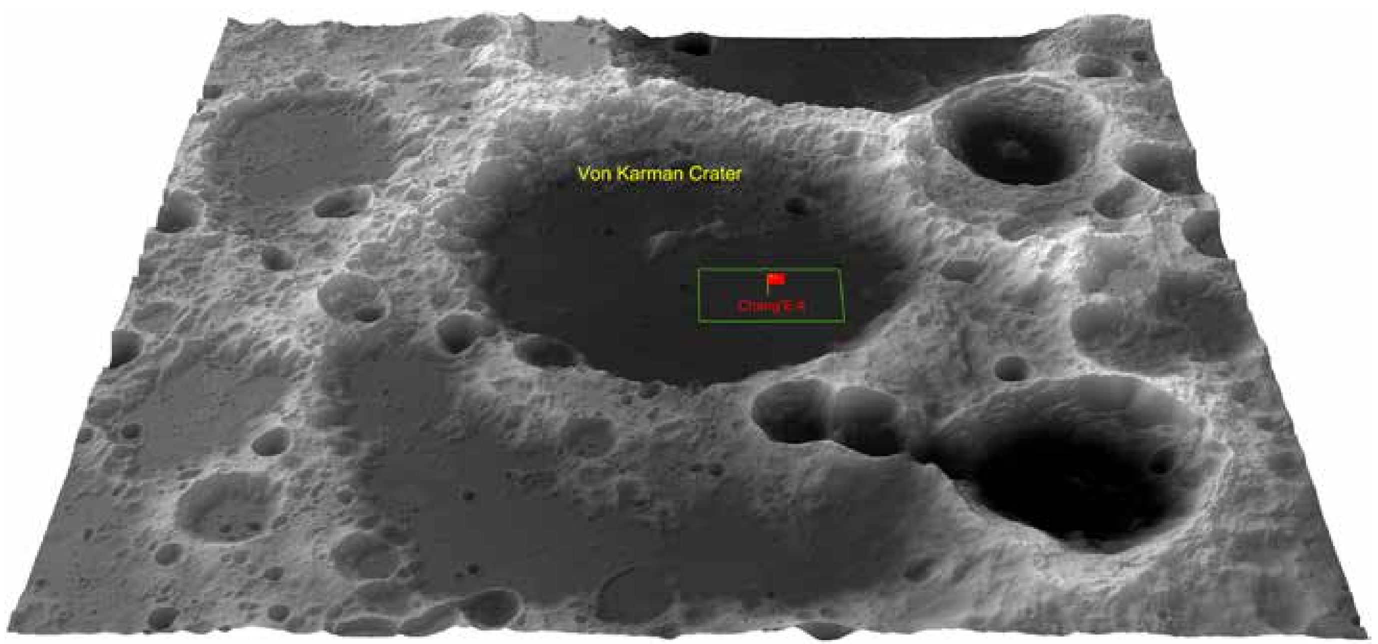
Remote sensing, multi-source data, computer vision and AI reveal surface details of the moon and Mars like never before

Jeff Bezos has been there. Richard Branson has been there. William Shatner, better known as Captain Kirk in the 60s sci-fi series Star Trek, has also been there. Humans are driven by our innate curiosity to explore the unknown. Seeing the Earth from space has proven to be a life-changing experience for astronauts. Scientists and scholars have been striving to see more of alien worlds not just to fulfil our curiosity, but also for the revolutionary scientific discoveries that our future generations can benefit from.

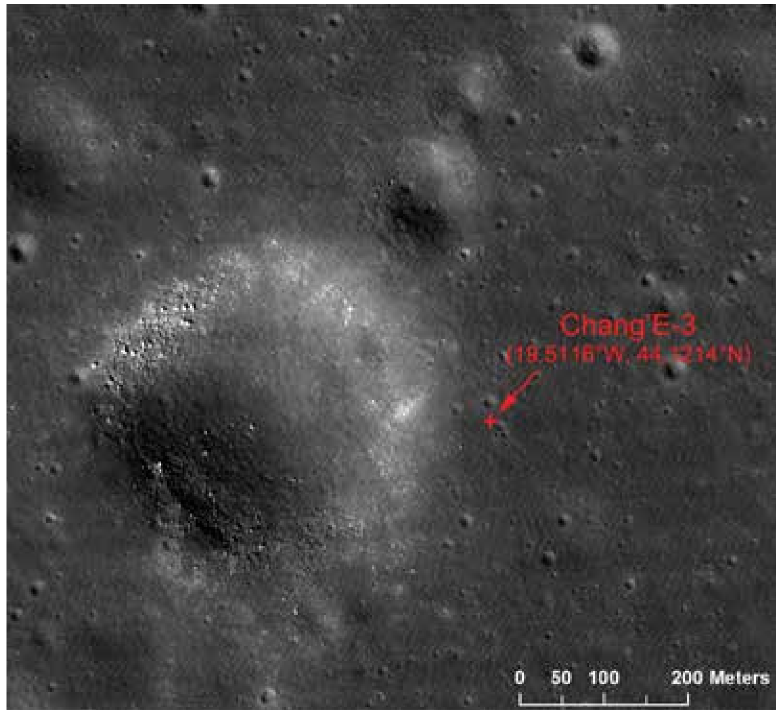
Spacecraft landing on planets and celestial bodies are especially important as they offer insights on how the universe works, the possibility of space colonisation, and space mining for minerals that the Earth is running out of. Just like any expedition on Earth, you need a good map for a landing mission. And for that matter, an accurate, detailed 3D map of the terrain is essential.



Trailblazing in the brave new worlds

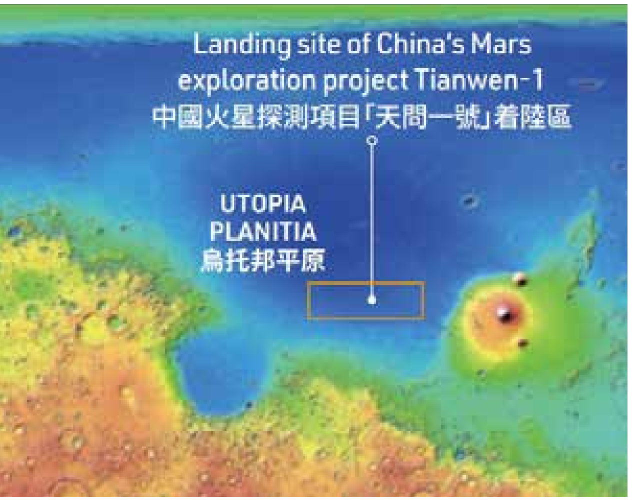
Any planetary surface sloping more than 15 degrees could be dangerous to land a spacecraft on. Craters are very common features on celestial bodies and can be thousands of metres deep. Even rocks can be a hazard for landers and rovers. A spacecraft that lands in the wrong spot could be seriously damaged and unable to carry on its mission to explore the planet.

"That's why it's extremely important to choose a landing site carefully. A bad choice could damage the mission," explains Prof. WU Bo of the Department of Land Surveying and Geo-Informatics, who spearheaded a novel system that combines satellite images with laser scanning data from multiple sources across different platforms to render the 3D topography of planetary surfaces down to several centimetres.



Prof. WU Bo
Fiona Cheung Professor in Spatial Science
Associate Head, Department of Land Surveying and Geo-Informatics
Associate Director, Research Centre for Deep Space Explorations

Prof. Wu's main research area is planetary mapping and remote sensing. He worked as a postdoctoral researcher at the Ohio State University in the US from 2006 to 2009, and participated in NASA-funded projects for exploration missions to Mars and the Moon. Since joining PolyU in 2009, he has developed innovative 3D topographic modelling and intelligent geomorphological mapping techniques, and contributed to mapping and selecting the landing site for China's Chang'e-3, Chang'e-4, Chang'e-5 lunar missions, and the Tianwen-1 mission to Mars.



The China Academy of Space Technology has used Prof. Wu's planetary remote sensing and mapping system to evaluate landing sites, optimise orbit design, and improve surface operation on the Chang'e-3, Chang'e-4 and Chang'e-5 lunar exploration missions, as well as China's first Mars mission Tianwen-1.

Best of all worlds

Existing 3D mapping technologies include stereo photogrammetry and laser altimetry. Stereo photogrammetry uses two or more images taken from different positions (such as satellites) to measure the 3D topography of a surface. However, due to orbital and mission design, high-resolution photos of the same spot from two or more different angles are not commonly available. On the other hand, laser altimetry measures topographic heights and depths by sending laser pulses to a surface and analysing the reflected laser energy. Yet laser altimetry usually samples a large area with sparse measurements, so the result is usually low in resolution.

For high-precision and high-resolution topographic mapping, Prof. Wu developed a new 3D mapping model that incorporates information from various sources using different remote sensors and cameras across different platforms, including both images and laser scanning.

"It's a challenging job because different sensors have different configurations and spatial-temporal attributes. Their results are often inconsistent if not downright contradictory," explains Prof. Wu. But he managed to adjust the results from each source and combine them to synergetic effect to achieve the best accuracy. In order to pick a landing site for the Chang'e-4 mission, he modelled the lunar topography using images and laser scanning data collected by different satellites that orbit the moon to achieve the best result.

God is in the details

Multiple high-resolution images and laser scanning data give rise to inconsistencies that need much time and energy to reconcile. But having too few images and too little information can also be a problem. For locations on a planet where only one image is available, Prof. Wu uses photoclinometry to recover topographical details.

One of the key components in computer vision, photoclinometry estimates the gradient and shape of a terrain by analysing the shading information in a 2D image in relation to light direction and the reflective behaviour of the surface among other factors. Prof. Wu wrote a powerful algorithm that successfully reconstructs and preserves small features not shown in low-resolution models, such as small boulders and craters, to generate 3D models with a resolution as high as 1 cm/pixel.

Last but not least, artificial intelligence, namely active machine learning and deep learning, is employed to automatically detect and analyse geomorphological hazards such as rocks, craters, cones and dunes on a planetary surface. This can achieve 85% accuracy and greatly reduces the labour burden. It helps a lander avoid potential hazards for safe landing, and helps a rover travel safely on the surface.

Prof. Wu's high-precision, high-resolution remote sensing and mapping system enables us to see planetary surfaces in much greater detail than ever before, fuelling future spacefaring adventures as we address the question of our place in the universe, and usher in groundbreaking discoveries in science and engineering.