Chromo-Stereoscopy: 3D Stereo with Orthoimages & DEM Data

Use the 3D ChromaDepth Viewing Spectacle Included in this Magazine

A very modern trend in photogrammetry is the automated production of DEM data from overlapping stereo-pairs of remotely sensed image data, followed by the generation of an orthoimage or an orthoimage mosaic. These operations may be carried out as a single integrated process using suitable imagery acquired from a spaceborne platform.

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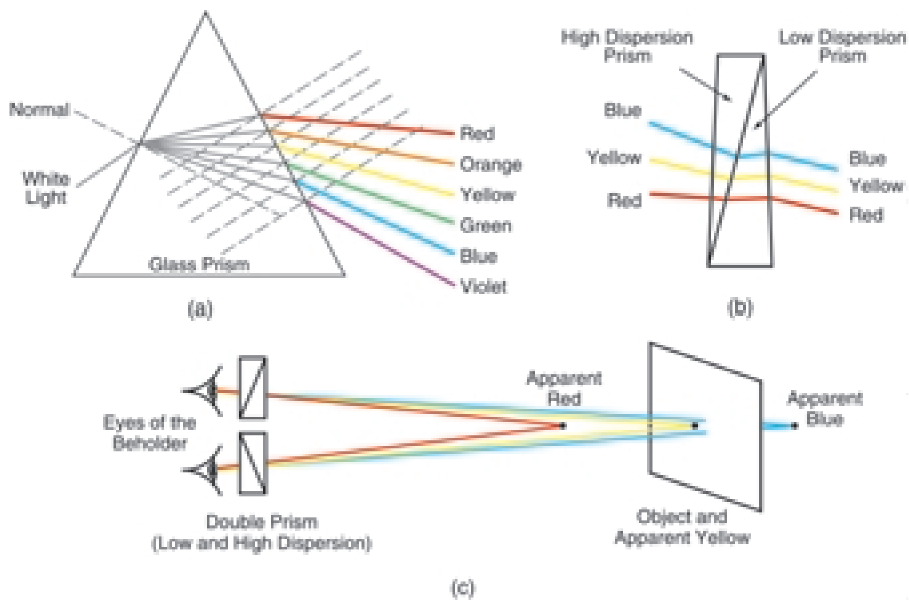
Examples are (i) the overlapping images acquired cross-track from the SPOT or IRS satellites on two different orbits; and (ii) those acquired along-track from a single pass of the MOMS, IKONOS or EROS-A1 satellites. (iii) A further possibility is to use either stereo- or interferometric radar (SAR) imagery to generate the DEM and orthoimage data. Even more common is the use of imagery taken from an airborne platform. Within this latter context, the process of DEM and orthoimage production is commonly carried out by mainstream photogrammetric service providers using stereo-pairs of aerial frame photographs, whether collected in analogue or digital form. Now the method is being implemented with the digital imagery acquired by the new generation of airborne pushbroom scanners, e.g. the DLR HRSC-A and LH Systems ADS40 imagers. The great attraction of the process from the photogrammetric production point of view is the highly automated procedure that can be implemented with a minimum of human input after the identification and measurement of the ground control points (GCPs). While this is extremely satisfactory from the point of view of the photogrammetric service providers, the situation may be viewed in a quite different way by the actual clients or end-users.

Need for 3D Stereo-Viewing

On the one hand, the client or end-user does receive an ortho-rectified image having a good map geometry, together with the corresponding DEM data. On the other hand, delivery of an orthoimage throws the task of carrying out the interpretation and extraction of the point, line and area data on to the end-user. Previously, when the traditional type of vector line map with contours was being supplied to the client, the detection, identification and extraction of the topographic features was carried out as a prior operation by the photogrammetrist and the specialist image-interpreter using 3D stereo-viewing. Nowadays the end-user may have to execute this task himself using the orthoimage without the benefits of having a 3D stereo-model available for the purpose. Besides which, 3D stereo-viewing is also essential for the execution of the quality control that is a necessity with DEMs produced using automated image matching methods. This quality control operation takes the form of editing and removing mismatches and ensuring that the DEM data and the lakes, rivers, mountain crests, passes and ridge lines occurring in the area of interest are all consistent with one another and make sense from the topographic point of view. Quite apart from feature extraction and DEM quality control, the simple stereo-viewing of an area in 3D is often highly beneficial to an understanding of the terrain and its landforms and hydrology by field scientists, engineers, planners and military personnel. However there is no possibility of them doing so using only the DEM and orthoimage data.



(a) The refraction of white light through a glass prism; (b) The superchromatic double prism; (c) ChromaDepth viewing spectacles using a pair of double prisms (drawn by Mike Shand)

3D Chromo-Stereoscopic Images

One solution to this particular problem is to generate a 3D chromo-stereoscopic image from the orthoimage and DEM data. This method of 3D stereo-viewing has been developed originally by Steenblink in the late 1980s. During the 1990s, it then became available from the Chromatek Technologies company in the U.S.A. as a commercial product, called ChromaDepth. This has been further developed and refined specifically for use with remote sensing data by Dr. Toutin of the Canada Centre for Remote Sensing (CCRS), which forms part of Natural Resources Canada (NRCan). Details of the underlying theory and the actual process of generating chromo-stereoscopic images are given in two of his papers (Toutin 1995, 1997).

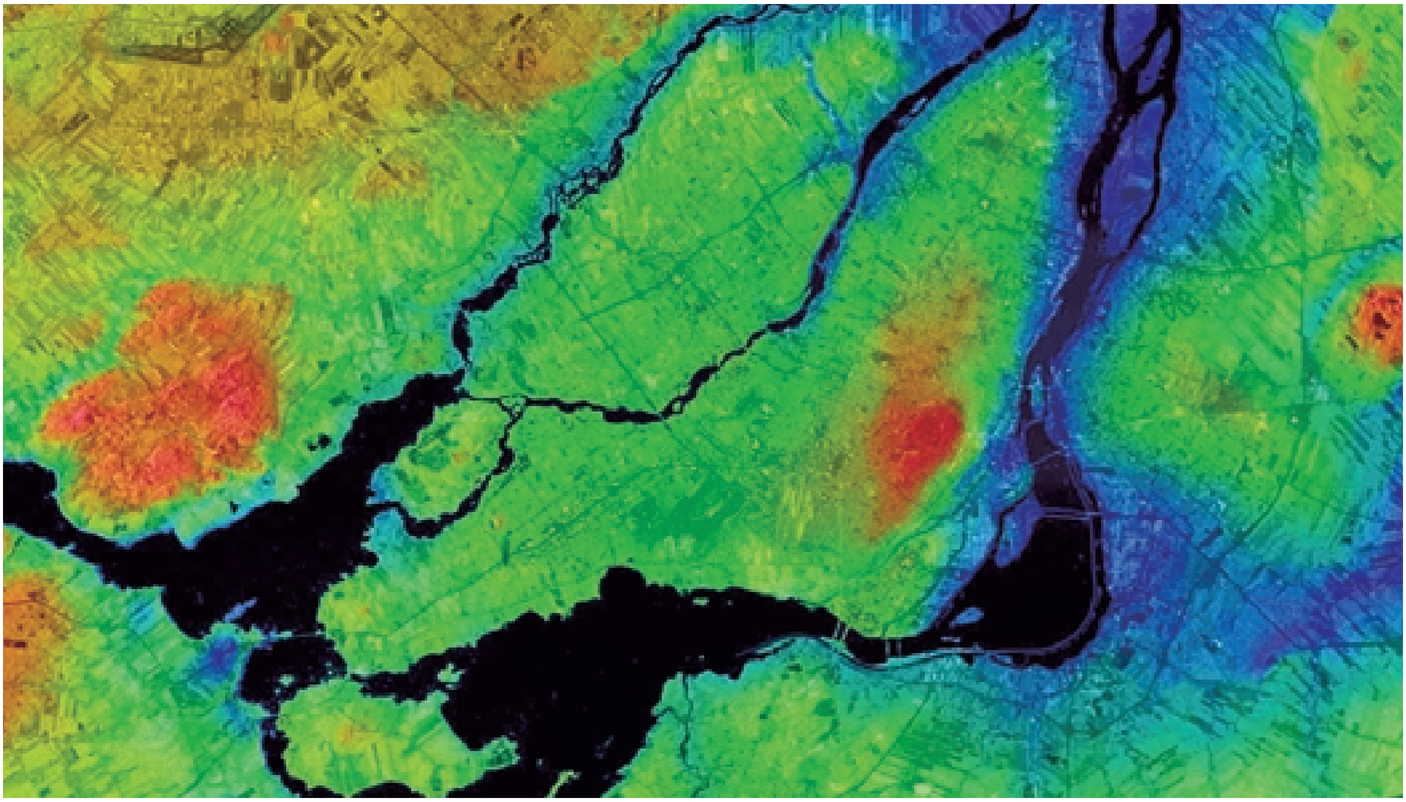


Figure 1: Montreal, Quebec Canada (copyright: Canadian space Agency)

The Basis of Chromo-Stereoscopy

The basic process is relatively straightforward - at least in principle! The individual elevation values from the DEM are encoded systematically into the orthoimage on a pixel-by-pixel basis in the form of different colours. This allows an observer to exploit the well-known phenomenon that objects lying in the same plane - e.g. on the screen of a display monitor or on a hard-copy print - but in a different colour, appear to an observer to lie at different depths. Thus a red object appears to the observer to lie above the level of a blue object. While a yellow object appears to lie at an intermediate level or depth between the red and blue objects. To further enhance this effect, use is made of suitably designed spectacles that utilize the differential refraction of light that is produced by prisms. These prisms cause differential refraction of the various components of white light. These spread out to produce the classic "rainbow" effect in which the light occurring at different wavelengths is spread out and seen as contiguous bands of different colours. Utilizing this effect, the ChromaDepth spectacles that are worn by the users are equipped with pairs of specially manufactured prisms. These are used to enhance the apparent depth of the differently coloured parts of the image for each eye and so produce a 3D stereoscopic image.

ChromaDepth 3D Stereo-Viewing

The ChromaDepth spectacles utilize a pair of very thin prisms made of a completely transparent plastic material. In practice, these act like thick glass prisms. To achieve this effect, each prism comprises two component thin prisms cemented together - the one using a low dispersion material, the other a high dispersion material. The combined effect of the pair of these double prisms when used in the spectacles is to decode the colour-encoded orthoimage as seen by each eye. This allows the observer to experience an increased perception of depth corresponding to the elevation values that are present in the DEM. Thus a strong stereoscopic impression of the terrain is obtained with those objects having the highest elevation values (encoded in red) appearing to lie nearer (i.e. higher) to the observer, while those encoded in blue (with the lowest elevation values) appear to lie further away. Terrain objects having intermediate elevation values between these two extremes (which have been encoded in orange, yellow, green, etc.) will appear at the appropriate intermediate depths or levels between these highest and lowest elevation values.

Examples

The chromo-stereoscopic technique can be used with a wide range of imagery acquired from a variety of spaceborne and airborne platforms; using different types of imaging sensors; and with images having widely differing ground resolution values. Three examples covering quite different types of terrain at a variety of image scales and ground resolutions are given below.

-Montreal, Quebec, Canada
This image is a space radar orthoimage mosaic covering the city of Montreal and

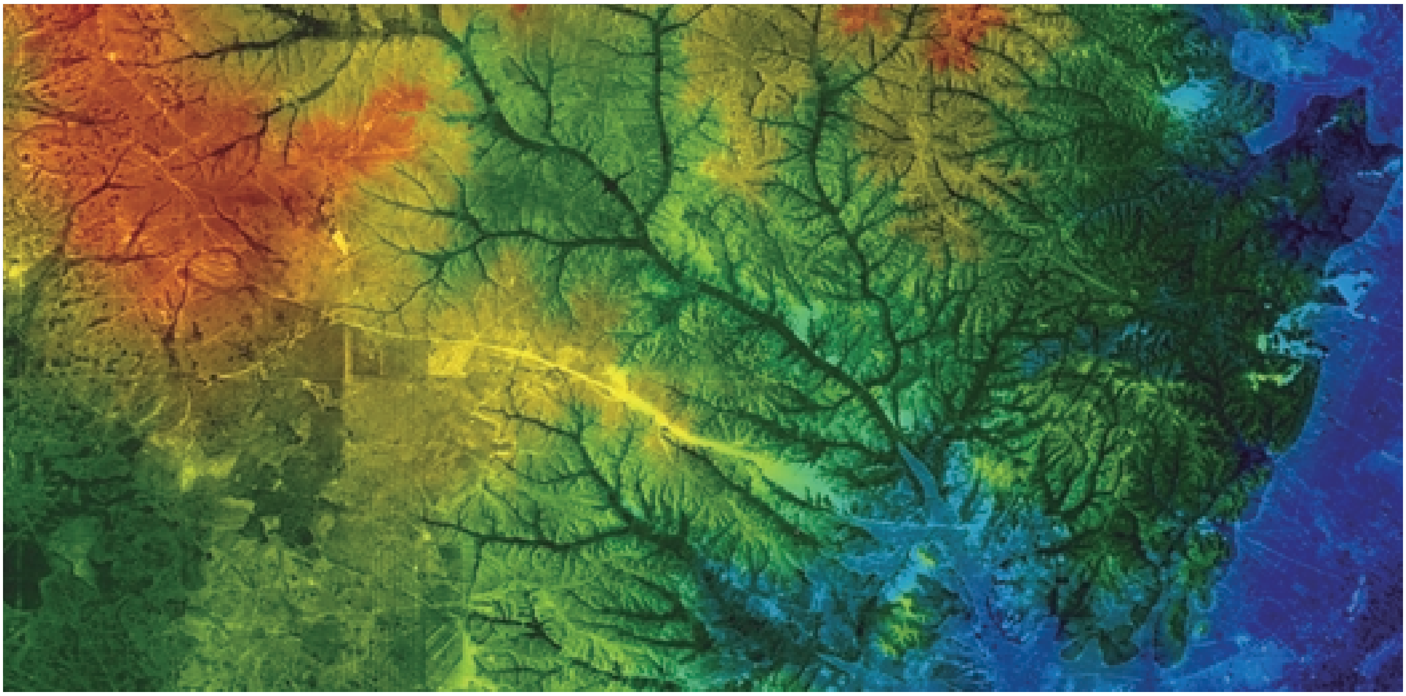


Figure 2: Misratah, Tripolitania, Libya (copyright: University of Glasgow)

its surroundings. It has been produced by CCRS/NRCan from two Radarsat-1 SAR fine mode images having a 6m ground pixel size. The chromo-stereoscopic mosaic has been generated using a two-stage process. (i) First of all, each of the radar images has been fitted to GCPs extracted from the standard 1:50,000 scale topographic maps of the area produced originally by the Canada Centre for Topographic Information (CCTI/NRCan). This was followed by the actual ortho-rectification process using the DEM data generated by CCRS/NRCan from the digitized 10m contour lines taken from the topographic maps. The merging of the two individual ortho-rectified images produced the required radar orthoimage mosaic. (ii) The second stage in the process was to integrate this radar orthoimage data with the DEM data to generate the final chromo-stereoscopic image. This was carried out via a radiometric process involving the use of the IHS (intensity-hue-saturation) transformation to define and generate the appropriate colours for each individual pixel in the radar orthoimage mosaic. This was done on the basis of the corresponding elevation values derived from the DEM. The final 3D chromo-stereoscopic mosaic was published originally by CCRS/NRCan in the form of a poster, with the actual image measuring 53 x 35cm. However it has of course been reduced greatly in size and resolution for inclusion in GeoInformatics. The image shows the St. Lawrence River crossing the area from the lower left corner to the top right corner of the image. The Ottawa River flows into it as a tributary starting midway up the left side of the image. The city of Montreal occupies the central part of the image with the Mont Royal featuring prominently above the St. Lawrence River.

-Misratah, Tripolitania, Libya

The second example forms part of the coastal area around the city of Misratah located 150km east of Tripoli, the capital of Libya. The area has been used for the production of a series of experimental space image maps intended to explore the cartographic design aspects of this type of map at 1:50,000 and 1:250,000 scales. The underlying objective behind this project was to see if this type of image map would be a suitable replacement for (i) the existing series of line maps @ 1:50,000 scale that had been produced for the more developed areas of Libya; and (ii) for the series of space image mosaics @ 1:250,000 scale that provide complete national coverage of the country. Both series are now completely out-of-date. As part of this experimental work carried out at the University of Glasgow, chromo-stereoscopic images of the test area were produced with the help of Dr. Toutin. On this occasion, the data that was used was SPOT Pan monoscopic imagery with a 10m ground pixel size. As with the previous Canadian example, the required DEM was formed from the digitized contours taken from the existing 1:50,000 scale topographic map. The procedure used for the generation of both the SPOT orthoimage and the final chromo-stereoscopic image was basically the same as that used with the Montreal example. The final image shows clearly the strongly incised wadis (valleys) cut into the semi-arid plateau and the slopes running down to the flat coastal plain where Misratah city and the developed areas of agricultural land are located.

-Sophia Antipolis, Southern France

The third example shows part of the "science city" of Sophia Antipolis which lies a short distance inland from the Cote D'Azur and just north-west of the coastal city of Nice in the south of France. This image has been generated by the ISTAR company, whose headquarters and main processing facilities are actually located in Sophia Antipolis. The 3D chromo-stereoscopic image has been produced from overlapping high-resolution images (with 0.25 ground pixel size) of the area acquired by DLR's HRSC-A airborne pushbroom scanner. This features a three-line pushbroom arrangement with the overlapping images generated from the forward, nadir and backward pointing linear arrays. This allows stereo-coverage to be collected along-track during a single flight. The HRSC-A imager has its own integrated DGPS/INS system which provides continuous positional and attitude information for each line of the image data. In this particular case, first of all, the elevation data was generated from the overlapping HRSC-A stereo-imagery using automatic image matching techniques in conjunction with the in-flight position and attitude data given by the DGPS/INS unit. This took the form of a digital surface model (DSM) including both building and tree canopy elevation data. Thereafter the orthoimage was produced using the DSM data as the basis for the ortho-rectification. This was followed by the production of the final chromo-stereoscopic image (called a "Hypsoimage" by ISTAR) using the same technique as described for the two previous examples. Once again, the pronounced depth of the 3D image at the large scale of the image shows clearly the rolling wooded character of the area and the heights of the many large buildings that have been constructed by the industrial, commercial and scientific organisations that have established themselves in Sophia Antipolis.

Conclusion

The combination of orthoimage and DEM data - when allied to the complementary chromo-stereoscopic image that can be derived from these two data sets - is well suited to a wide range of topographic mapping, GIS and thematic mapping applications where 3D stereo-viewing would be helpful, indeed often invaluable, to the users. As the examples show, the technique can be applied to a wide range of spaceborne and airborne imagery having quite different ground resolutions.

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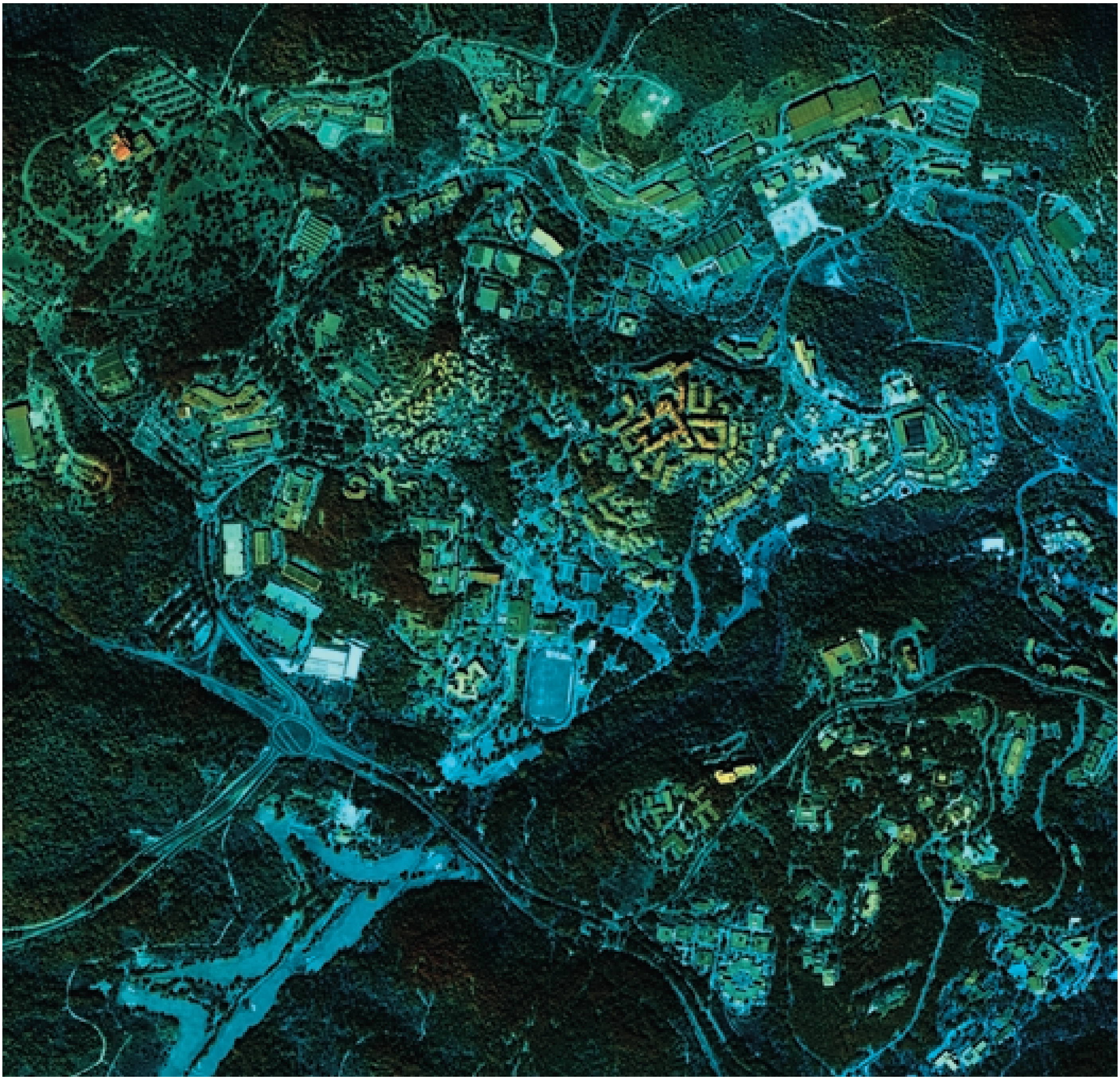

Figure 3: Sophia Antipolis, Southern France (copyright: ISTAR)