Remote Topographic Mapping for Geoscience

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Almost every geoscience project has a requirement for accurate topographic data. Whether the project involves geological mapping, mineral exploration, or study of the hazards posed by landslides, volcanoes, earthquakes or subsidence, topographic data is the foundation on which the science rests. Yet in the early 1990s, a United Nations Development Project suggested that reliable topographic maps were available for less than ten percent of the world’s surface. Even where they are available they are unlikely to be in digital format. Modern, GIS-based geoscience projects need digital data and so valuable project resources are often expended scanning and digitising paper maps. The need for fast, economic and reliable methods to generate accurate, digital topographic data is clear and remote sensing is the obvious tool to meet this need.

With this in mind, the Geological Remote Sensing Group (GRSG) of the Geological Society of London and the European Association of Remote Sensing Laboratories (EARSeL) organised a workshop on Remote Topographic Mapping for Geoscience at the Headquarters of the British Geological Survey (BGS) in Nottingham, U.K., during December 1996. Over one hundred people attended. Most were from the U.K., but there were also attendees from Belgium, France, Germany and Norway. A very broad audience included members of GRSG and EARSeL as well as the Photogrammetric Society and the Remote Sensing Society. They heard keynote presentations from two of the leading academics in this field, Professors Petrie and Dowman, as well as fourteen other talks given by scientists from academia, government and industry. There were also seven posters and presentations or displays from ten software companies working in this field.

Five different methods for remotely measuring topographic data were featured: digital photogrammetry; stereo space imagery; airborne laser scanning; SAR interferometry; and GPS. These techniques were applied to a wide range of geoscience problems, ranging from straightforward geological mapping to environmental applications and geohazard assessment. Four of the speakers have contributed papers to this volume: Al-Rousan et al. examine the accuracy of stereo space imagery for cartographic applications in arid and semi-arid regions; Lohr introduces the latest developments in laser scanning; Currie presents a paper on a new airborne interferometric SAR system capable of single-pass interferometry; and Ganas et al. describe the use of space-derived topography in seismicity studies in Greece. These four papers and all the other presentations are summarised below.
The conference opened with the first keynote address, in which Professor Gordon Petrie (University of Glasgow, U.K.) appraised the meeting of the latest developments in digital photogrammetric systems and of the various components including scanners, workstations and plotters. His presentation provided an overview of current methods used for precise topographic mapping. This set the scene for the session to follow, which featured four presentations describing the application of digital photogrammetry to a wide range of geoscientific studies.

Mark Stileman (Sir William Halcrow, UK) described a flood risk classification for England and Wales. The study, based on 1 km grid squares, used digital terrain models (DTMs) created from aerial photography. It examined the effect of different scales of photographs and sampling types on the resultant DTMs. From volumetric analysis of the DTMs it was found that the most important factor influencing the accuracy of the representation of the land surface was the scale of the photography, with larger scales giving better results. The use of digital photogrammetry to model coastal erosion in south-east Yorkshire was discussed by Douglas Tragheim (BGS). With an erosion rate of 2 m per year, this section of the British coastline is the fastest retreating in the country. Photogrammetry was used to obtain a three dimensional model of the coast from which an estimate of sediment type and yield could be determined. The use of aerial photography provided synoptic coverage of the area and also obviated the need for regular field measurements, although some ground control was still required. Steven Trew (Queen's University Belfast, U.K.) demonstrated that large scale photography (1:5 000 scale) could be used to map the surface of peat bogs rapidly and accurately. The digital photogrammetric methods were found to take less than half the time of the conventional ground survey over the same area. Keith Westhead (BGS) described how mapping of geological features in an area of chalk could be assisted by digital photogrammetry and terrain visualisation. The subtle topographic features detected in this way have been a key element in the development of a new stratigraphic framework now extended over several map sheets.

The guest speaker for the conference, Uwe Lohr (TopoSys, Germany), described an airborne laser scanning system which measures the height of the ground surface directly. The high quality and accuracy of the data were shown using examples of surveys over a variety of target areas, including urban and forested ground. Due to the design of the sensor it is possible to obtain surface measurements by penetration of the forest canopy. The presentation stimulated much discussion during the meeting.

Contrasting uses for satellite derived topography were described in two papers which concluded the first day of the conference. Dominic Kniveton (Bristol University, U.K.) described a European Union funded project to model landslide hazard at sites in the French Alps. The study found that a 10 m DTM calculated from SPOT imagery did not have the necessary resolution for this purpose. Andy Fraser (Integrated Statistical Solutions, U.K.) showed how a combination of Landsat TM and SPOT imagery could be used for hydrocarbon prospecting. He described a procedure for lithological classification using the TM data, followed by the calculation of structure contours for each stratigraphic horizon. This was achieved by associating the TM-derived lithologies with height information from the SPOT-derived DTM. The results compared well with information from conventional seismic interpretation of the area. This is a powerful technique for targeting expensive seismic surveys and is also an aid to surface fault mapping and the correlation of surface faults with the same faults at depth.
Day two began with the second keynote address, in which Professor Ian Dowman (University College London) discussed the automatic co-registration of images for data integration, one of the central issues of remote topographic mapping. He concluded that this was now an operational procedure for optical images of the same type, but remained difficult between images of different types such as SAR and optical images. It is possible to register images and maps automatically but further research is necessary to make the procedure flexible and fully operational for a variety of data types. Other examples of satellite based topographic mapping described in the session which followed included: the use of GPS for ground deformation studies on Mount Etna (Jane Moss, Cheltenham and Gloucester College); an assessment of the accuracy of DTMs in arid and semi-arid areas; and the use of SPOT data to characterise the seismogenic potential of active faults in central Greece. The last two studies are described in papers appearing later in this volume (Al-Rousan et al. and Ganas et al. respectively).

SAR interferometry is an emerging technology and a number of papers addressed the subject. Anthony Currie (Defence Evaluation Research Agency, U.K.) described airborne platforms which obtain interferometric information in a single pass. Using C band radar the typical RMS height error is 3 m with a total error of about 5 m across the image. Francois Archambault (ESGT/Aerospatiale, France) presented a quality assessment of SAR interferometric DTMs, using a phase oriented SAR simulator. Nicki Stephens (Reading University, U.K.) discussed topographic mapping of lava flows using ERS-1 and ERS-2 data. Ren Capes (Nigel Press Associates, U.K.) discussed earthquake hazard assessment using SAR interferometry in combination with other data. He described the utility of SAR interferometry as site specific. Although a promising technique for remote topographic mapping, SAR interferometry has a number of drawbacks: complex data processing; image distortion and data loss in mountainous regions; baseline restrictions; image decorrelation due to changes in time of vegetation and moisture; and stratospheric and ionospheric variations.

The conference brought together a broad mix of researchers, practitioners and vendors. It provided a balanced view of the theory, best practice and operational practicalities of remote topographic mapping. Users delivered a clear message about what has to be mapped and the operational and economic constraints on doing so successfully. The meeting provided an opportunity to review the strengths and weaknesses of the different methodologies. It concluded that none of the methods gives the complete solution, each has advantages and disadvantages. Digital photogrammetry generates considerable volumes of data, is computationally intensive and requires manual intervention. Stereoscopic space imagery is not yet accurate enough for many applications. SAR interferometry involves complex data processing and is subject to baseline restrictions, image decorrelation and phase ambiguity. GPS surveys are field based and perhaps more suited to monitoring than mapping. The laser scanning method may be the most promising because it measures height directly but, unfortunately, systems are not yet widely available.

The advent of high spatial resolution stereoscopic satellite data, with precise orbit parameters, may be a turning point for remote topographic mapping. The widespread availability of 1 m data from satellites is likely to challenge photogrammetry in the mass market for topographic information. The very near future should see some exciting developments and contributors to a similar meeting held in five years time may be in a position to describe the transition of these methodologies from the development to the fully operational stage.