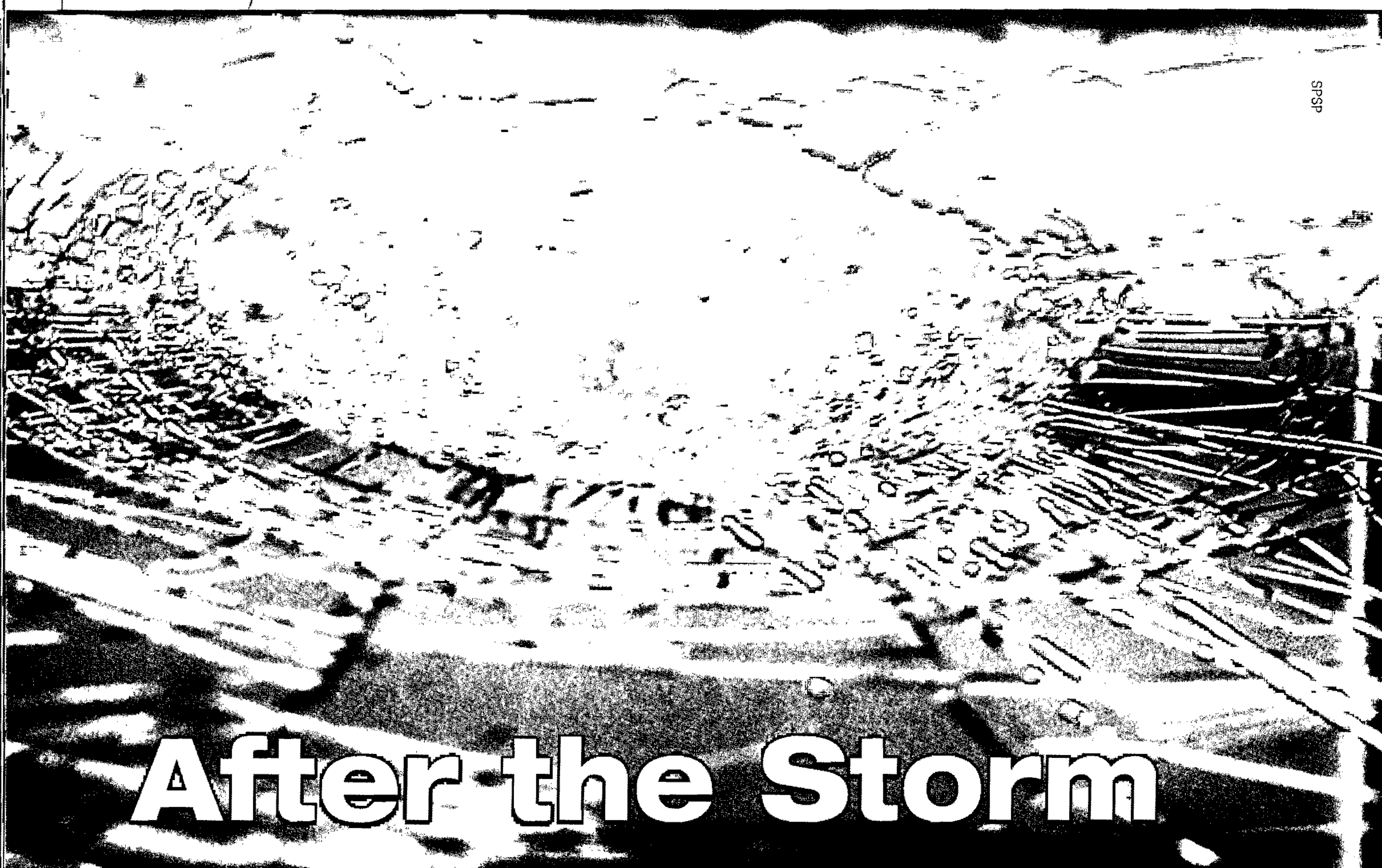


After the Storm

Even the most sophisticated technology will not predict some natural disasters, but it can help us to prepare, and to deal with the devastation that follows.

SUNIL BHASKARAN, TREVOR NEAL, BRUCE FORSTER and BISUN DATT

Hail stones can strike the earth with tremendous force. They can leave a trail of destruction in the form of damaged roofs, flooding, and power breakdowns. Sometimes these events are of such proportions that emergency services are hard pressed to simultaneously allocate dynamic resources (staff and equipment) to damaged areas and distribute resources to potentially susceptible areas.

Allocation of dynamic resources before, during and after hailstorms is an important issue that can be aided by prior knowledge of vulnerable areas. Emergency services have to make time-critical decisions, and these decisions are influenced by numerous factors, usually of a spatial or temporal nature.

For instance, resource allocation is influenced by the location of hazard-prone regions, existing land use, population density and socio-economic characteristics. Since dynamic resources have to be managed in an efficient way, the combined analyses of remote sensing data and GIS data can assist in the decision-making process.

One of the important indicators of vulnerability is the type of roofing material used for buildings – residential, commercial and industrial; another is demographic characteristics such as age, income and ethnic background. Our project used these two indicators in its testing of the integration of hyperspectral data and GIS.

Multispectral remote sensing data is inadequate for mapping the surface materials in urban areas ...

Data from satellites can provide details about terrestrial features in near real time, but the resolution of this imagery in terms of mapping urban features has been inadequate to date. Multispectral remote sensing data is not good enough for mapping the surface materials in urban areas: it is lacking in spectral resolution as well as in spatial resolution. Whether or not this is important will of course depend on the use to which the data is being put.

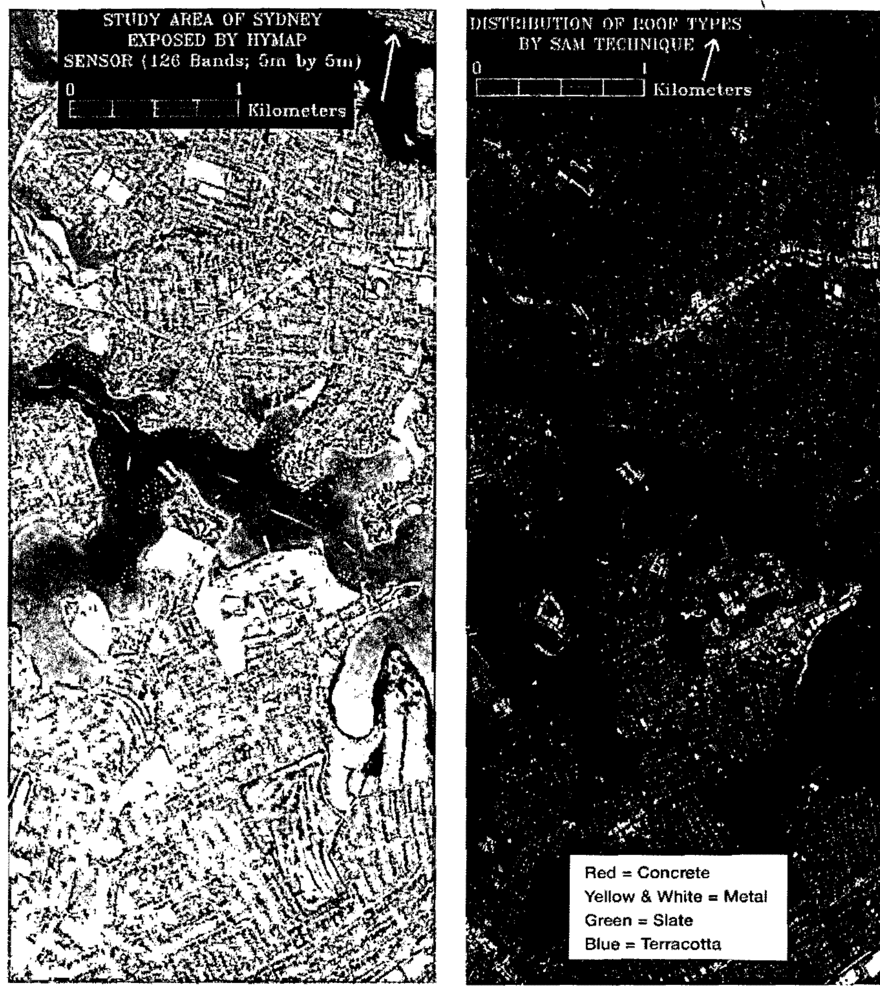
Very high-resolution aerial photo images are an option, but they cannot determine the type of material seen in the images, and they are an expensive source of data. Most natural earth surface materials have diagnostic absorption features in the 0.4–2.5 micrometer range of the electromagnetic spectrum. Since the diagnostic features for each material are apparent over very narrow spectral bands, differences between materials can only be identified if the spectrum is sampled at high spectral resolution – by a hyperspectral sensor, in other words.

Hyperspectral datasets generally contain at least 16 contiguous bands of high spectral resolution.

A joint project between the School of Surveying and Spatial Information Systems (known earlier as School of Geomatic Engineering), University of New South Wales and the NSW Fire Brigades (NSWFB) was initiated in August 1999. The main objectives were to test the potential of data from the HyMap hyperspectral sensor for detecting features in urban areas that would be useful for assessing relative vulnerability, and to develop decision support systems for emergency services such as NSWFB.

The Concord Bay region in Sydney was selected as the study area since it had a mix of different urban land uses, from residential to commercial and industrial. There are also some recreational areas. It also has a wide variety of roof types.

A combination of spectral analysis, contextual information and GIS data was used ...



HyVista Corporation

A combination of spectral analysis and contextual information and GIS data were used for determining the roof types and land use. The figure on the left shows the HyMap image strip; on the right is the classified image, which shows the distribution of roof types based on their material composition. The image shows the Parramatta River from Abbotsford to Mortlake Point. Note that East is to the left.

A narrow transect – 3 km by 19 km – covering the region from Concord, located to the south of the Parramatta River, to Forestville in Sydney's north, was exposed using the airborne HyMap sensor in early September 1999. The instrument manufacturer, Sydney-based Integrated Spectronics, flew the mission.

The instrument recorded 126 spectral bands, which spread from 0.4–2.5 µm in the electromagnetic spectrum. The HyMap sensor covers the reflective Visible (VIS) (0.4–0.7 µm), Near Infra Red (NIR) (0.7–1.1 µm) and Short Wave Infra Red (SWIR) (1.1–2.5 µm) wavelengths. A lot of time was spent on image processing in order to get the best quality images. In the end, only 115 out of 126 bands were used in the analysis.

A visit to the study site was carried out to gain first-hand knowledge about the area's land use and types of roofing materials. This was done using visual aids including aerial photo images, which were displayed on a laptop; a Garmin handheld GPS receiver was used to mark co-ordinates of locations during the field visit.

The survey revealed that most of the surface materials in the study area were roofs of either terracotta, concrete or slate tile, with some corrugated iron and metal roofs, as well as pavers and bitumen. Various samples of urban surface materials, mainly these roofing materials and pavers, were gathered. A database was created from the samples, and the typical use to which they belonged was added. The age, location and land use of the area they were in were also recorded.

A spectral library of reflectance was made of the surface materials, using a full-range spectrometer developed by Analytical Spectral Devices in the US.

After calibrating the image spectra with laboratory spectra, a supervised classification technique called Spectral Angle Mapper (SAM) was used to classify the HyMap image data.

Endmember spectra from metal, slate, concrete tile, terracotta tiles and numerous other surface materials were used as input classes for the SAM classification. A classified image was produced in which each pixel was assigned to a class (Figure 1B).

A combination of spectral analysis, contextual information and GIS data was used to determine the roof types and the land use. Figures 1A and 1B show the HyMap image strip as well as the classified image, which shows the distribution of roof types based on their material composition.

Classification results were highly accurate except for a few instances where some practically non-absorbent materials could not be detected clearly. The accuracy of image classification was checked in the field and later by confusion matrix. The types of roofing materials were converted to vector from raster format and analysed with other surface data from the Australian Bureau of Statistics.

Demographics were combined with the base image to create a map showing degrees of vulnerability to hailstorms and to thus determine which areas require more attention in terms of resource allocation and planning. We used different GIS software and programming languages to perform spatial analyses, and had to deal with some issues related to GIS software formats.

The study demonstrated the potential of airborne hyperspectral analysis: it can be integrated with surface data and it can be used to help assess risk and vulnerability in urban areas. This methodology can be applied to any type of resource management problem – and it need not be restricted to urban areas. The research was carried out in heterogeneous urban areas, which means that the hyperspectral data was tested to the maximum.

The spatial resolution of current airborne hyperspectral sensors does not enable spectral unmixing; this was especially apparent in this study, where different types of roofing materials were found in close proximity to each other.

As a result, a single five metre pixel results in spectral confusion in heterogeneous urban areas. However, there is scope to use the ground-based spectra as endmembers. In this case it might be necessary to normalise the ground-based and image data to avoid scaling issues.

Nevertheless, airborne hyperspectral sensor data has a definite edge over space-borne hyperspectral sensors: the airborne data is scale independent and can be exposed over any region to the required resolution. This is important for the study of urban areas, particularly given the irregularity of urban features.

The integration of HyMap and GIS data provides valuable information that will assist in carrying out emergency operations and allocating dynamic resources. For instance, an area that is dominated by terracotta tile roofs and that has a high population of elderly folk has a significantly higher overall vulnerability than an area dominated by terracotta tile roofs and a population of young singles.

Demographics were combined with the base image to create a map showing degrees of vulnerability ...

In reality, much more data will be needed before people can comprehensively assess risk from hailstorms. Roofing materials and demographics are only two important variables in vulnerability; there are others that may have to be considered.

It may be argued that the variables chosen in this study were inadequate in terms of total risk, but the study's objective was to develop a methodology which would demonstrate the potential of hyperspectral data in quantifying risk in urban areas.

The advantage of the methodology is that it enables the input and integration of additional data to develop a composite risk assessment model in near real time. Methodology that allows the integration of hyperspectral data and GIS has huge implications for organisations that deal with city planning, transport and emergency services; it can be done now, and it can be developed further, into custom-made applications.

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