PROCESSING AIRBORNE , SPACEBORNE HYPERSPECTRAL AND GIS DATA IN URBAN AREAS.

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Paper describes a methodology to process, analyse and compare hyperspectral remote sensing data for mapping vulnerability in urban areas. Spaceborne and airborne imaging spectrometers are used to develop this model. A high precision spectral library of pure materials over an urban scene in Sydney was created by using a spectroradiometer. Hyperspectral images were corrected for radiometric and atmospheric disturbances and calibrated before classification by a supervised method. Results include the creation of a detailed high precision spectral library of urban surface materials. Other results include an integrated model which was developed by combining with other GIS data for providing decision support systems.

1. INTRODUCTION

Urban areas are dominated by features which have different shapes, sizes, materials and composition. These characteristics present numerous challenges for mapping, planning and management of resources in urban areas. Urban areas present numerous challenges for the development of a knowledge base, since the materials in these regions are characterised by subtle changes in their physical and chemical properties, colour, age and a dense use of land [1]. Mapping these regions will provide decision support tools to many organizations such as emergency services, local councils, planning agencies. Planning for urban areas demand accurate and current geo-spatial information about the various features and objects that are found in urban areas.

RS of urban areas have been attempted in the past, mainly with broad band multi-spectral sensors. However these attempts which used classification of multi-spectral data materials [2],[3],[4],[5] have also exposed some limitations of using broad-band remote sensing data for analysing urban areas. For instance, [2] found that the heterogeneity of urban surface materials added to spectral confusion, and [6] found that the limitations of few spectral bands makes most of the available broad-band sensors such as Landsat and SPOT incapable of detecting urban surface features. Unlike broad band sensors, hyperspectral sensors have narrow band widths, which enable them to identify and extract features that may not be identified by broad band sensors [7]. Due to their narrow bandwidths hyperspectral sensors have a great potential in mapping features in urban areas [8]; [9]. However, the analysis of spectroscopic data from the laboratory, from aircraft, and from spacecraft requires a knowledge base. A spectral database of surface materials is essential to identify the component of the unknown spectra. It is a vital component for performing detection and identification, because it is the reference to which the actual RS data are compared with. Identification of materials from such data requires a knowledge base: a comprehensive spectral database of surface materials, vegetation, man-made materials, and other subjects in the scene. Detailed spectral libraries have been prepared for many materials and minerals [10], but a detailed and elaborate spectral library of urban surface materials has not yet been developed. The spectral database will be used to detect, extract pure spectral reflectance values of materials found in a given pixel, and assists in the identification and estimation of materials from an image. The principal advantage of unmixing an image using endmembers is that it offers the reduction of the complexity of the data set based on a physical set of component spectra [11]. The resulting images will form the abundance of the corresponding substance for that pixel. There are two methods to derive spectral libraries. One is through the information in the imagery itself. When a hyperspectral image is acquired of a ground scene but there is insufficient "ground truth" data or it is known that there are no "pure" pixels, then the purest pixels can be identified through various spectral tools such as those in the ENVI software from Research Systems, Inc. Pure pixels are those that represent a single material and are not a mix of various elements, such as soil and plant. However, in urban areas due to the presence of various materials in close proximity, there is considerable spectral mixing. The approach followed in this project will be to build spectral libraries to measure the important features within an image using ground based reflectance data and applying this to the hyperspectral imagery to unmix it.

2. PROJECT AIMS AND OBJECTIVES

a) To develop a dedicated high precision spectral library consisting of pure samples, covering a wide range of materials spread over a large wavelength by using the full range field spectroradiometer. b) To classify the image data by using spectra from library of pure endmembers.

3. STUDY SITE

The choice of Concord Bay in Sydney as the study area was made since it had a mixed type of land-use where all types of attributes such as different urban materials, infrastructure facilities, vacant spaces, trees, vegetation belts, were found. The study site has been registering steady growth (population and infrastructure). Selection of Concord as study site therefore will provide multiple benefits that will not be restricted to emergency services but also to planning department and local councils. The Concord Bay site had a mixed type of land use and with a wide variety of roofing materials were found to be in close proximity.

4. DATA AND EQUIPMENT

The study area was exposed by HyMap remote sensor data. HyMap is an airborne hyperspectral sensor and has been developed in Australia. It provides contiguous spectral coverage across the wavelength interval 450-2500 nanometres (nm). HyMap has a higher spatial resolution and has 128 bands and therefore renders higher spatial resolution. Hyperion sensor has 220 bands that provides higher spectral resolution at a spectral bandwidth of 10nm. The Hyperion image was provided by CSIRO (Land and Water Group) and was used to map urban features by using a spectral library created over Concord Bay, Sydney. This task is currently in progress and will be completed before July, 2003.

5. METHODOLOGY

The methodology was carried out in three phases which focused on a) Image pre-processing b) Creation of a Spectral Library and c) Image calibration and classification.

A minimum noise fraction (MNF) transformation was used to determine the inherent dimensionality of Hyperion and HyMap images, to segregate noise in the data and to reduce computational requirements for faster computer processing. The HyMap and Hyperion image data was first be normalized to surface reflectance images and then georeferenced to a map base. Normalization to surface reflectance included pre-processing of the data, atmospheric corrections, and post processing/smoothing operations. The HyMap data provided as at sensor radiance images was atmospherically corrected using ACORN (Aigllc) and FLAASH software packages. The Hyperion data was pre-processed using methods developed in Datt et al. [12] prior to atmospheric correction. Image processing and enhancement techniques were used on all remote sensing data. Filtering the image data for obtaining the best data from the image was followed by removing multi-band data correlation. The image was calibrated using the empirical line method and classification was done by the spectral angle mapper method. The samples were named and their physical and chemical compositions were recorded separately. In the second phase, the hyperspectral image was pre-processed for radiometric and atmospheric correction. Samples of surface materials were collected from different sources and labelled respectively according to their material composition. Documentation of each spectra were mainly consisting of sample naming, which included mineral and material name, its composition and colour. A full range field spectroradiometer, which operates in the 350–2400nm wavelength will be used to extract spectral reflectance values from samples of materials. Strict sampling protocols were followed when acquiring sampling targets for bright and dark spectra and the time of the acquisition will be maintained to the time of the image exposure. The average of many spectra of a certain type of material, were measured under different conditions (sun angle, background etc.). The standard deviation of all these measurements was calculated to create the ideal also part of the exemplar spectra. Exemplar spectra has the advantage that makes the identification process not very sensitive to the noise in the data, which is always present in remote sensing. It does not require a perfect match, as long as the RS data is similar to the averaged spectra and falls within the standard deviation, the material is identified. The reflectance of these dark and light targets, and their known spectral response, was used to calibrate the hyperspectral imagery and to correct for atmospheric influences. A supervised classification was performed on both the radiance and reflectance data. An empirical line (EL) technique was employed on the radiance data in order to force the spectra from the image and library. A know dark and bright object (metal and bitumen) was used for the EL method. The classified image data was georeferenced to the GIS data bases such as population density, demographic characteristics. Spatial analyses were performed to determine the most vulnerable regions. Vulnerability was calculated by indices such as landuse classes, population, age of people, location of hazardous sites, access to fire stations, streets etc.

6. RESULTS

Using RS images for mapping, analysis and other terrestrial applications have been carried out for many years. A major outcome of this project was the creation of a detailed spectral database of urban surface materials, that can be used to identify features on a remotely sensed image. The database consists of pure samples, covering a very wide range of materials, a large wavelength range with very high precision will be created in both softcopy as well as hard copy formats. Sampling procedures were documented, which will enable a wide range of users to access and use this database. Sample analysis and documentation to establish the quality of the spectra will be created. The other important result was to study the ability of the Hyperion sensor to classify urban features. The classified image was spatially analysed with other GIS data for providing decision support tools.

7. FUTURE WORK AND RESEARCH

Future research will focus on comparing results from classification by both broad band remote sensing data and narrow band remote sensing data. This will have substantial implications for users of remotely sensed data, particularly hyperspectral data for urban area analysis and mapping. Hyperspectral data acquired from satellites and airplanes will also be compared for urban area analysis which will indicate the usefulness of such data for mapping urban areas.

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