CAPABILITY FOR DATA FUSION BY AIRBORNE SENSING

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ABSTRACT:

The recent advances of GPS/IMU have made it possible to perform the multisensor, multi-resolution and multi-spectral data fusion utilizing GIS technique. In the present study we utilized the Airborne Digital Sensor (ADS40) image and Digital Surface Model (DSM) by pixel matching techniques and studied the data fusion capability with LIDAR data from Airborne Laser Scanner (ALS40) and filtered Digital Terrain Model (DTM), Hyperspectral data from the Airborne Imaging Spectroradiometer for Applications (AISA) in the visible and thermal information by Thermal Airborne Broadband Imager (TABI). The study compared pixel matching of DSM by LIDAR data and reported the compiled applications. On the other hand we observed the multispectral characteristics of the features by multi-sensing approach. The capability to extract features and automation in 3D Modelling has been reported.

1. INTRODUCTION

Integration of remote sensing and GIS is increasing. Given the ongoing trends of increasing spatial and spectral resolution of remotely sensed imagery and of the increased uptake of GIS by a diverse range of users, some degree of Integration of high-resolution image data and GIS is desirable because of the potential to facilitate the flow of information from imagery into GIS and also the image processing systems available for quick processing of the data.

The fusion of multi-sensor, multi-resolution, and multi-date high-resolution images is an effective means of exploiting the complimentary nature of different data types for change-detection studies. The *Multi-aspect-data* fusion helps to generate an interpretation of the scene not obtainable with data from a single sensor and it diminish the uncertainty associated with the data from individual sensor.

Data from sensors such as TM, MSS, SAR, LIDAR, HRV, and LISS data have been integrated for different environmental applications. Some of the information extracted from them also integrated with GIS data. However, there are not many research reported on the fusion of information from high-resolution DSM, visible band, Infrared band, thermal and hyperspectral together with GIS map data such as road, building and NDVI for efficient change-detection studies. Fused information from the most recent scientific and technologically developed high-resolution sensors such as Airborne Digital Sensor (ADS40), Airborne Imaging Spectroradiometer for Applications (AISA), and Thermal Airborne Broadband Imager (TABI) sensors through GPS/IMU was used in this study. An additional GIS analysis with other map data allowed the development of applications for environmental planning and land management.

The aim of present study is to combine automatically various subtle information derived from multiple airborne sensors' data fusion. Our data-fusion and change-detection research work utilised remote sensing and GIS data. Remote sensing data involves high-resolution DSM data generated from ADS40 stereo matching, Thermal data and hyperspectral data where as the GIS data includes road network and building plans. A number of separate avenues of research have been suggested as future work. Examples given will include the detection of building (removed/newly constructed/under construction) in airborne imagery of urban and sub-urban regions, and use of GIS data such as road map for moving vehicles/objects elimination as well as the location of buildings regions for an autonomous land tax assessment.

PASCO Corporation of Japan owns several latest technologies based high-resolution remote sensing sensors such as Airborne Digital Sensor (ADS40), Airborne Laser Scanner (ALS40), Large Format Digital Aerial Camera (UltraCam-D), Airborne Imaging Spectroradiometer for Applications (AISA), and Thermal Airborne Broadband Imager (TABI). For registering data, the key technology utilized has been GPS/IMU systems. The use of high precision GPS/IMU data combined with traditional triangulation techniques expedient the integration of all the sensors in a robust and very flexible mode. The navigation systems used for all the flight, APPLANIX POS, are integrated GPS/IMU systems, designed for direct determination of position and attitude of airborne sensors. They efficiently combine inertial sensors and GPS technology.

2. DATA FUSION

It is only recently that papers are appearing which consider the questions of combining images from disparate remote sensing sensors to improve their use and reliability on a wider variety of applications. Data fusion techniques combine data from multiple sensors, and related information from associated databases, to achieve improved accuracy and more specific inferences that could be achieved by the use of single sensor alone (Hall and Llinas, 1997). Integration of disparate data sources is a problem that is being investigated for several years. Methodologies for integrating different data sources can be divided into two major categories, viz., sensor dependent and those that are sensor independent (KrishnaMohan et al., 2000). In the former, specific image formation models are incorporated into the analysis process. Solberg et al. (1994) attempted to fuse LANDSAT-TM and SAR images using SAR specific image formation model. This has the advantage of using most appropriate features for analysing the image data. Sensor independent approaches are based mainly on integrating segmentation maps produced by analysing data sets individually. Our study belongs to the second category.

Sensor independent approaches are based mainly on integrating segmentation maps produced by analysing data sets individually. For instance, region boundaries produced by textural segmentation of SAR images can be merged with intensity edges produced from visible/infrared images. Here it is assumed that the segmentation procedures applied to individual data sets are responsible for accounting for all the sensor related issues and the integration module is independent of the origin of various segmentation maps input to it. Image fusion can be performed at three different processing levels such as pixel or data level fusion, feature level fusion, and decision or interpretation level fusion (Varshney, 1997; Pohl and Genderen, 1998). Le Moigne and Tilton (1995) integrated edge and region data for refined image segmentation and applied it to segmenting LANDSAT TM data. KrishnaMohan et al. (2000) suggested IRS image classification by fuzzy k-means clustering and fuzzy set theoretic integration of landuse /landcover data of two dates.

The studies on change detection based on differencing radiometrically-normalized images have been performed (Fung, 1990; Heo and Fitzhugh, 1999; Itthi and Wallapa, 2002). For change-detection studies multitemporal data was used (Smara et al., 1998; Bruzzone et al., 1999; Saraf, 1999). Remote sensing data have also been integrated with GIS data for environmental studies (Fegan, 2000; Rocha and Tenedorio, 2001; Xie et al., 2002.). Urban activities were estimated by using thermal and large-scale vector maps (Michaelsen and Stilla, 2001). Chu and Agarwal (1993) developed a system to integrate edge and region maps to produce accurate segmentation from multisensor data consisting of laser range, velocity, intensity and thermal infrared images.

3. UTILIZED DATA

High-resolution remote sensing data over some Japanese cities such as Tokyo (TABI, AISA) and Yokohama areas (ADS40) were acquired incorporating GPS/IMU for geometric positional accuracy preservation. ADS40 has the ground spatial distance (GSD) of 20 cm for the multispectral and 10 cm for the panchromatic range. Data of AISA (VNIR-Eagle) and TABI sensors have 1.5m GSDs for this study (table.1). The images used in this work currently mainly cover the DSM of two dates generated from pixel matching of stereo pairs of ADS 40 digital airphotos, thermal data from TABI sensor and hyper-spectral data from AISA sensor. The main applications of this work will be in the area of image databases for property evaluation and other government controlled applications. The LIDAR data acquired was tested for change detection studies and the results were not presented here due to lack of space.

4. PRESENT AND FURTHER APPROACH

From a data fusion perspective, an automated integration of Remote Sensing and GIS was suggested. Data from several sources (image and non-image) was used and fused in combination with the goal of producing output information of higher quality than obtainable from a single source. We aimed to automate the data fusion and GIS analysis for application of change detection study for property tax evaluation and others.
Our study encompasses:

- Capability of two date DSM data obtained from a pixel to pixel matching was examined for broad as well as subtle change-detection application.
- Integration of thermal images from TABI sensor and hyperspectral images from AISA to best differentiate man-made structures from vegetated features was attempted.
- NDVI extracted from AISA and thermal image fusion results evaluated for the extraction of subtle man-made structures.
- Finally, GIS data such as road network to remove mobile objects and building plan will be used to extract very subtle changes in man-made structures.
- Importance of colour information other than geometric characteristics of roofs was elucidated.
- To justify the present fusion analysis for property tax application, the importance of extracted data from DSM change-detection was shown.
- As a future study broad-change-detection results will be fused with NDVI and thermal images.

Multi-temporal, multi-resolution and multi-sensor data were fused to make thematic maps. We aimed to develop a novel technology to integrate multi-date, multi-resolution, and multi-sensor data for the purpose of subtle change detection. We used DSM data obtained from LIDAR and ADS40 stereo images, NDVI derived from hyperspectral sensor, road network map along with other derived information.

Figure 1 shows the flow of our present and future methodology involved. The figure 1 explains the idea about our fusion for the automated mapping and GIS resources purposes. First DSM data of two dates obtained from pixel-matching was used to identify broad as well as subtle changes in man-made and vegetated objects. Surface temperature from TABI images and NDVI from AISA images were integrated. It is also planned to use Road network area maps, roof parameters and colour information of roof to detect subtle changes in features.

Ultimately we are interested in combining image and textual database concepts into a single system in which both can be used to reinforce the confidence in results of changes and subsequent GIS queries. We initially considered the questions of combining several feature detectors to improve their performance and reliability on a wider variety of images.

Moving on from the idea of actually combining individual detectors we are now experimenting with the use of ADS40 image based DSM, TABI sensor data Hyperspectral and infrared colour images through some efficient image processing algorithm and secondly through a GIS.

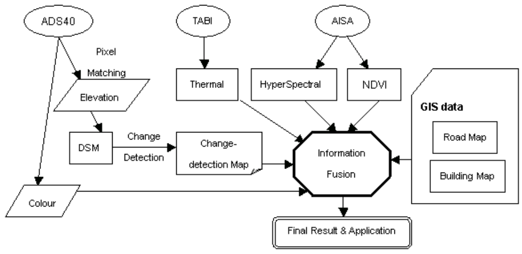


Figure 1. Disparate high-resolution sensor data and GIS data automatic fusion for change-detection analysis.

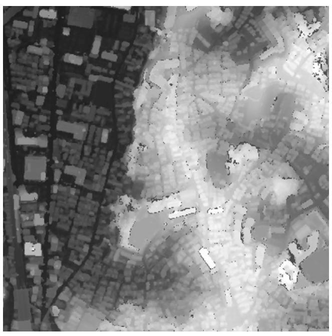
To refine the change-detection to fine level (subtle) other parameters such as NDVI obtained from hyperspectral images, Road data for moving objects location extraction and building data information were also used. After obtaining the final change-detection image a GIS analysis of attribute data was carried out. Later a pixel-by-pixel matching was carried out with TABI, and hyper-spectral images to know the landuse/landcover features.

5. RESULTS

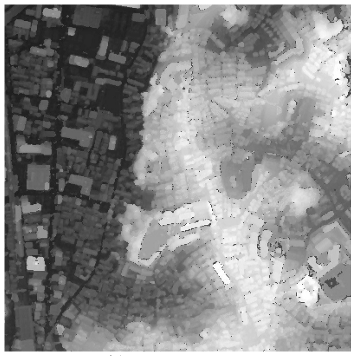
5.1 Change-Detection by DSM Analysis

Since DSM data plays a vital role in detecting subtle changes in landuse/landcover features, the obtained DSM data were matched for change detection purpose. DSM from stereo matching of ADS40 images of two dates was used at present. A broad change-detection image was generated first. By using DSM data obtained by pixel-pixel matching we tried to extract subtle changes in landcover for various applications such as automatic mapping and house taxing purpose.

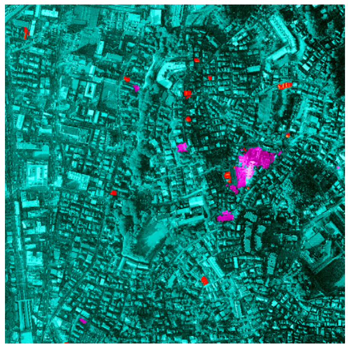
For the purpose of DSM extraction six stereo pairs of ADS 40 images were used and DSM at 50 cm was obtained (figure 2. a, b) for two dates. Then by simple pixel difference estimation, changed areas were extracted (figure 2. c). The cyan colour shows areas where there is increase in elevation (structures demolished or no vegetation) and orange colour areas correspond to new structures or land cover features. Information, which can be read in change-difference, are the existence of the leaf, new-buildings, a removed building, and plant, a growth situation (after /before 2003 shedding leaves /2002 shedding leaves) and a moving objects.



a). Year: 2002



b). Year: 2003



c). Detected changes

Cyan: Change but no features; Orange: New construction

Figure 2. DSM obtained from pixel matching

5.2 Thermal and Hyperspectral Fusion

Figure 3 shows AISA and TABI data fused image. The AISA captured 66 ranges of bands and the PCA was fused with TABI thermal pixels. The temperature ranges from 33 deg. Cel (in orange) to 43 deg. C. (in Red). It can be observed from figure 3 that the vegetated and cooler areas have lesser thermal values than the residential and industrial rooftops.

The AISA sensor hyperspectral data was used to estimate the NDVI values (figure 4). Because of its dimensionality, hyperspectral data potentially provides the capability to discriminate between nearly any set of classes.

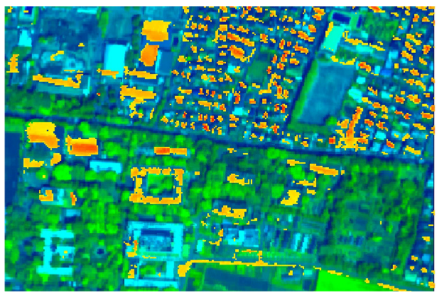


Figure 3. Hyperspectral (PCA) and thermal data fusion result. Man -made structures show higher temperature values.

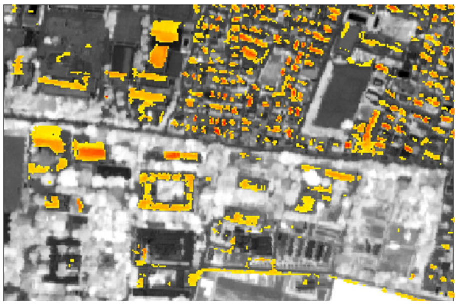


Figure 4. NDVI and thermal data fusion result. Lower NDVI values correspond to higher temperature regions (man-made features and moving objects).

Though the remote sensing data covers different areas, for the purpose of describing the capability of sensors, we integrated thermal and hyperspectral images (AISA) as well as thermal (TABI) and NDVI obtained from AISA for Tokyo region. Where as to show the advantage of using multidate DSM exclusively extracted from high-resolution ADS40 stereoimages for subtle change-detection study, data of Yokohama was utilized. A GIS analysis for the change-detected areas was carried out manually as well as automatically by remote sensing and GIS data fusion for fixed property tax division of Yokohama city. The accuracy of the results for various building nature is summarized in Table 2.

A. Situation	B. Extracted Manually	C. Extracted Automatically (against A)	Ratio %
New construction	151	151	100
Re-built	32	31	97
Non-existence	101	100	99
Expansion	35	22	51
Under construction	47	46	98
Unknown	98	76	78
Total	465	417	90

Table 2. Information from remote sensing and GIS fusion

5.3 Colour information for Building roof identification

Figure 5 shows the importance of roof colour information in a high-resolution image. From the DSM roof geometries such as shape, size and orientation can be obtained. But a close observation of roof features in figure 5. (a) to (c) revealed that the geometry of the roof structures is similar but the spectral signature (colour) is different. Therefore, the roof geometry information could not be used in certain case. For the change-detection purpose existing building data will be used to find the difference along with an analysis of the colour images will also reveal the difference.

6. SUMMARY AND FUTURE WORK

In this study, first an attempt was made to use DSM derived from pixel-pixel matching of ADS40 images for broad change-detection. Secondly, to develop a novel technology to integrate multi-date, multi-resolution, and multi-sensor data for the purpose of subtle change-detection analysis.

Further work in this subtle-change-detection with the aid of parameters such as NDVI from hyperspectral sensors, colour information from RGB, NIR sensors (ADS40), road network map along with the geometries of roof. The obtained GIS information was used for an application in the area of property tax office.

(a) Colour information Date: 2002

b) Colour information Date: 2003

c) Colour information Date: 2002

(d) Colour information Date: 2003

Figure 5. Importance of Colour information of Roof

Our automating the processing of images for importing to GIS has the advantageous such as that it is possible to enter remotely sensed data into GIS in a routine economical fashion, and then frequent updating of GIS data by fused remote sensing imagery would improve the accuracy of applications. Automatic image processing of data fusion will provide a rapid and application specific reconnaissance of high-resolution images from visible, IR, and thermal. A degree of automation through high-resolution and new remote sensing data and GIS integration will facilitate the demand of government and public agency adoption of DSM, ADS40, TABI and AISA data.

Our study presented a method of automating the processing of high-resolution imagery into a suitable form for import into GIS. In addition, the information (such as road and building) contained within the GIS can be used. The results obtained from NDVI difference, Road data, roof geometry and colour image analysis will be combined with the DSM-difference data and final change-detection map could be achieved. We also planned to improve in the rate of extraction, and reduction of the rate of misreading. Adoption of vector type system for extraction of roof break line and other geometry is also underway.

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