

BUILDING FOOTPRINT EXTRACTION FROM IKONOS IMAGERY BASED ON MULTI-SCALE OBJECT ORIENTED FUZZY CLASSIFICATION FOR URBAN DISASTER MANAGEMENT

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ABSTRACT

The study deals with semi automatic extraction of urban risk related base data and their different generic aspects. Emphasis is given to the building footprint map which is a major base data. The main objective of the study is to extract Building Footprints from High Resolution Imagery using a semi automated approach. In this context the research mainly focuses on developing an integrated extraction to generate the risk related base data in an urban area from high resolution remote sensing images. A multi scale object oriented fuzzy classification of various urban settings was carried out. The method was applied in Dehradun, Uttaranchal, India. The city lies in the high seismic risk zone, also experiencing rapid urbanization due to its newly attained status of a state capital. The extracted base data maps were empirically evaluated by comparing them with visually interpreted reference maps. The evaluation of the extracted base data was carried out by both the quantitative and quality assessment techniques. It was observed that the building footprints extracted from fused Ikonos (PAN+XS) image gave acceptable accuracy for providing better management and better preparedness for any future disasters. Though there are compound problems associated with extraction of information from high resolution images, it is demonstrated from the study that such extraction techniques can be used and improved upon.

1. INTRODUCTION

Natural disasters always leave a devastating impact on human life especially in the developing countries, where its effect coupled with existing problems of poverty, lack of infrastructures and communication hinders the overall growth and development process. Although it is almost impossible to control the occurrence of natural disaster but its prediction and preparedness together with an effective post disaster management programme can definitely minimize risk.

Airborne and satellite imaging of the earth provide disaster and emergency services managers with an "eye in the sky" view for rapid assessment of infrastructure damages caused by catastrophic events such as wild fires, earthquakes, floods or terrorism. Extracting information from images to support geographic information systems (GIS) represents a major bottleneck in the race against time in the eventuality of disaster.

The non-availability of necessary data for disaster management in urban areas is a common problem in most of the developing countries. Also the data that are available may not be accurate and consistent enough for a reliable analysis and decision. In such a scenario the technologies of geographic information sciences coupled with the remotely sensed data can be of immense utility to address the elements of risk faced by an urban area. Infrastructural elements would face high risk of damage in the event of a disaster. There are many other factors that are directly or indirectly associated with risk. For example, in urban areas in the event of a disaster, what is the number of buildings lost and how important are they? In the economical context if structures are lost then how much financial loss can they incur?

The technological advancement in the field of Geoinformatics and increased availability of remotely sensed satellite imagery has ensured that the problem of disaster and emergency services is addressed more effectively than in the past. Remotely sensed satellite imagery can be especially useful in the extraction of information necessary for providing better management and better preparedness for any future disasters that might occur. In this regard, it is essential to have an effective mechanism that ensures quality data acquisition and their quick dissemination for the purpose of analysis, mainly, after or before occurrences of any disaster. The utility of remote sensing imageries to map anthropogenic and natural objects before and after the disaster has been demonstrated (Mueller and Kaufmann, 2001).

Operations in urban areas often require very detailed and high-fidelity models of the real environment. However, the generation of such information is not straightforward. Common obstacles are the availability of data describing the area and the vast amount of details to be handled. For applications supporting ongoing operations, e.g. crisis management, decision support, mission planning, etc., additional requirements such as time frame and accessibility to the area of interest must also be taken into account. Thus, some kind of automatic modelling tool is needed (McKeown, 1996). The long term objective of our work is the development of automatic methods for rapid construction of high-fidelity natural environment models from sensor data (Ahlberg & Söderman 2002).

This task is difficult because of the complexity, number and diversity of objects of the urban environment. Most of the extraction is currently done manually. The cost and time involved in manual reconstruction is high and has motivated

much active research on automatic detection and reconstruction of buildings.

Numerous efforts have been made in the past few years to automate building extraction from digital images (Gulch, 2000, Baltsavias et al, 2002, and Haverkamp, 2003). Fully automatic feature extraction systems until now are limited to specific applications and are not yet operational (Rottensteriner, 2001). In the absence of fully automatic systems, semi-automatic systems seem to be an alternative solution (Gruen and Wang, 1998, Rottensteriner, 2000). However, in recent years, we have experienced the emergence of high-resolution space borne images, which have shown potential for medium and large-scale topographic mapping (Toutin, 2002). In order to effectively utilize the potential of satellite image for building extraction, new methods and tools are urgently required.

Brunn and Weidner (1997) distinguished two main tasks for building extraction from digital images: building detection and building reconstruction. These tasks are inter-related and cannot clearly be separated because the tasks involved in building detection can also be implemented in building reconstruction. Building extraction processes differ based on the model and prior information used.

One first difficulty for automated techniques is caused by image variation in terms of type, scale, and required level of detail (Wang and Tseng, 2003). Secondly, automatic recognition of semantic information of an object using computers is very difficult; existing algorithms tend to fail whenever a new situation in image space is encountered or where objects are very close to each other (Gruen, 2000, Ruther et al., 2002). A well-extracted building requires good interpretation of imagery to recognize its location and extent, and then automated processes are employed.

In general, most of the existing building extraction methods are based on generic models where buildings are assumed to follow a certain code. However, using generic models in areas where buildings does not follow any particular code such as those found in informal settlements areas, cannot provide realistic results (Ruther et al., 2002). In informal settlements areas are made of diverse materials, very close to each other and have no proper orientation which making the extraction process very difficult. For the technology to be effective in an informal settlements environment, it must be flexible to cater both for structured and unstructured buildings (Ruther et al., 2002). The object-oriented information extraction provides a new tool for automated image analysis. Object-based classification attempts to describe relationships in terms of several categories of characteristics, each of which may be assigned weighting factors. Fuzzy logic functions permit complex, adjustable-detail classifications.

2. STUDY AREA

- The study area is located in Dehradun, a city situated in the recently formed state of Uttaranchal, India. It lies in the central part of Dehradun city between Longitude: 78 02 20.54 E to 78 03 04.70 E and Latitude: 30 20 19.81 N to 30 20 46.60 N. It is situated amidst the Siwalik range, the flat floored structural valley of Dehradun has long acted as the break-of-bulk town between the Himalayan region in the north and Ganga plains in the south.
- Dehradun is located in the eastern part of Doon valley, at the foot of the Himalayas, in the northern state of Uttaranchal, in India. Dehradun has a total

population of about 600,000. The city has recently become the capital of the state of Uttaranchal and is experiencing a rapid increase in population. Dehradun is located near the main active thrustzone in the Himalayas, such as the Main Boundary Thrust (MBT) and Main Central Thrust (MCT). The city is located within one of the highest seismic hazard zones of the country, but has not experienced a major earthquake in recent times

2.1 Data Preparation and Method Applied

The overall approach for this study purpose is mainly based on object oriented classification. The main advantage of using the object oriented image analysis technique is to find out the object of interest step by step. Another reason for using this object based method is that it not only incorporates the spectral properties but also the spatial variations into the classification. Buildings may appear very different spectrally, as there are many different compositional materials used for constructing roofs around the world. Allowing the use of spectral content when roof composition is unknown could lead to an unsatisfactory result that would require extensive editing by a user. Starting with shape allows the extraction algorithms to quickly narrow in on objects which are very likely to be buildings.

Recent research has focused on object-based methods for classification and different segmentation techniques key to this approach. Software packages such as eCognition have shown encouraging results in assessing spatial and spectral patterns at varied scales in intelligent classification of aerial and satellite imagery

3. OBJECT-BASED CLASSIFICATION

Object-based classification attempts to describe relationships in terms of several categories of characteristics, each of which may be assigned weighting factors. Object features include properties such as color, texture, shape, area, and scale. Class-related features involve a connection to nearby objects, e.g. super- and sub-objects in a hierarchy. Other relationships include spatial terms such as "nearest neighbor" or statistical similarities. Panchromatic aerial photographs for instance might be classified with additional information concerning texture and relational descriptions. In order to classify objects, the source image must be partitioned in some respect. Image segmentation seeks to classify objects by partitioning or grouping related regions based on shared attributes (Asano et al., 1996). Groups of pixels within each region can be viewed as a statistical sampling of collected multispectral or feature values, or alternately as derived information including as band ratios, textural features, or a region's shape. Derived data can provide further cues for labeling regions. Standard segmentation can be further augmented by knowledge-based partitioning and the construction of sub-objects for special classification tasks. Knowledge-based partitioning utilizes previously created classifications as additional cues for the merging of objects. Segmented sets of one class can be merged at the same level or grouped beneath a new, higher level. Relationship-based classification is possible as each object is aware of its neighbor, sub- and super-objects. Ensuring a consistent hierarchical structure requires that:

1) object borders of higher levels are inherited by the sub-levels, and 2) the segmentation process is bounded by super-object borders (Willhauck, 2000). As the segmentation process is comparable to the construction of a database with information of each image object, the classification process can be viewed as a form of database query (Tilton, 1997). Partitioning is done via image segmentation techniques such as clustering, boundary detection and region-growing. Fuzzy logic functions permit complex, adjustable-detail classifications. A continuous range of values [0...1] represents degree of certainty, as opposed to binary (0/1) decision. Membership functions or a nearest neighborhood classifier are used to translate the range of most feature types into adaptable fuzzy logic expressions such as AND (max), AND (mean), OR, IF and ELSE. All expressions that form part of one class are combined to reach the final result (Mayer et al., 1993).

Fuzzy Expert system:

Human knowledge about prediction and classification can often be expressed as "rules-of-thumb." An expert system involves the collection and encoding of these rules, together with an engine for evaluating the rules for a given set of inputs.

The Expert Classifier interface is designed to capture the process that an expert in a particular field of expertise would use to sift through, process and analyze geographic data, then compare and combine results, to infer information about a geographic location. The captured process can then be repeated by someone who may not be an expert in either the application field or in the use of software tools. But by recording the expert's inference process, Expert Classifier can repeat it with new data, consistently producing reliable and repeatable analysis results.

The ability to handle uncertainty is of vital importance to the knowledge base. The expert places confidence in each rule and as multiple rules are triggered within a tree, the Knowledge Classifier combines the confidences. Several rules could be true at a particular location – the one with the highest confidence is most likely to be the class for that pixel.

The foremost reason for using knowledge based (expert system) approach is the increasing availability of high-resolution imagery. Per-pixel classifiers (such as Maximum Likelihood supervised classification or ISODATA unsupervised classification) are of limited use when using the higher-resolution imagery being produced by data vendors today.

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These high-resolution images are difficult to classify because a single feature may consist of many pixels with several differing spectral characteristics. Therefore, instead of relying on per-pixel spectral characteristics alone, expert systems can be built which incorporate rules looking at spatial relationships and other contextual information (proximity to other classes or features, altitude, aspect, shape, etc.).

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This ability to use spatial operators then enables the operator to determine land use, rather than the traditional land cover produced by per-pixel classifiers.

The Knowledge Engineer can also be used to build expert systems looking at fuzzy classifications and combining

GIS and image processing techniques into complex expert systems. These systems then become decision-support tools, rather than traditional “classifiers” of imagery and data.

Another advantage of the knowledge based approach is that, once a knowledge base has been built, it can be applied to new data or locations without re-training. Consequently, the results of using a knowledge base are both reliable and repeatable. If you have passed a knowledge base to a colleague in a different office or country, you know that the results they are gaining with their own data are directly comparable to your own because the exact same methodology is encoded into the knowledge base. Equally important is the fact that the results are justifiable.

Data Preprocessing:

The first section deals with the basic image processing and the second pertains to building extraction. IKONOS MSS layers were stacked, Panchromatic and MSS images were registered and fused using the PCA technique.

Building Extraction:

The first step to towards Building footprint extraction is image segmentation. The basic element of an object oriented approach is the image object. This image objects are segmented into separated homogeneous region based on certain threshold value that is a fusion of both spectral and shape heterogeneity.

This is the first step to towards further analysis of objects. Another reason for doing segmentation is to extract the object of interest for the study purpose. The second step is to give the scale parameters which are basically a measure for maximum change in heterogeneity that may occur when merging two image objects. This scale parameter value is squared and served as threshold, which terminates the segmentation algorithm.

Colour Heterogeneity:

It is the sum of the standard deviation of spectral values in each level weighted with the weights for each layer WC are used

Shape Heterogeneity

It can be defined by two parameters: Smoothness and Compactness

Smoothness: It is described by the ratio of border length l and the square root of number of pixels (n) forming the image objects. This is used to optimize the image object with regard to smooth borders.

Compactness: This can be described as the ratio of border length l and the shortest possible border length b given by the bounding box of an image object parallel to the raster. This is used to optimize the image objects with regard to compactness.

Values for the scale and homogeneity criterion were set keeping in mind the building shape, type and size and also the kind of urban setting in which it was situated.

Knowledgebase Generation

The structured objects (prototypes) are organized as hierarchical taxonomies (underlying knowledge). These allow the description of both the objects and their relationships. The class hierarchy is known as the knowledge base in image object classification. This class hierarchy contains the number of classes that are meant for classification with specific class description. In this study only single class is taken in to consideration i.e. building. The class is described on the basis of its specific characteristics like mean values, their relation to neighbours, density, their ratio to scene, length and length /width ratio, texture, shape and grey level co-occurrence matrix (GLCM) etc. The membership function shows the relationship between feature values and the degree of membership to a class.

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4. RESULTS AND DISCUSSION

Extracted Base Data and their Associated Accuracy:

The research attempted to extract building footprint map which can be used as base dataset for disaster management. The extraction method has been applied to three different types of urban settings like planned, unplanned and mixed (both planned and unplanned) areas. In order to carry out accuracy assessment, visual interpretation (manual digitization at a fixed scale of 1:2000) was initially carried out on IKONOS 1m panchromatic imagery, which was considered as a reference map. The evaluation of the extracted base data maps was carried out by comparing the automatically extracted maps with manually prepared reference maps. The evaluation of the extracted base data was carried out by both the quantitative and quality assessment techniques. The qualitative assessment technique involved the computation of two parameters, i.e the completeness and correctness, which were used to assess the quality measurement. These parameters were calculated based on the following formula:

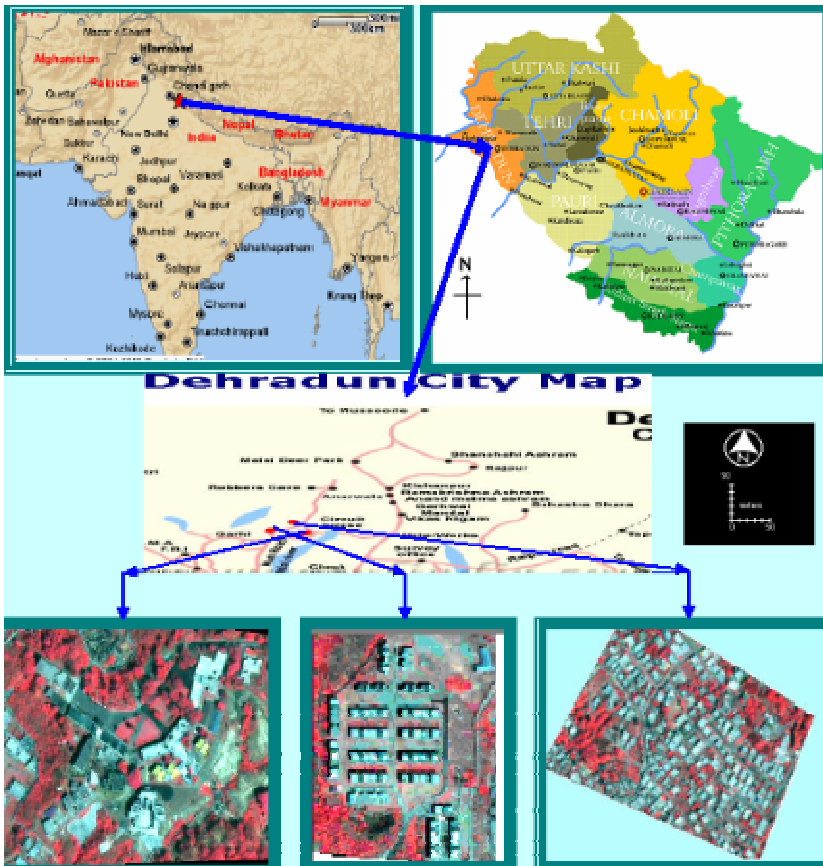
The accuracy of the extracted objects was calculated based on the above described parameters.

The variation in the result may be due to several reasons which play important role in accuracy assessment. The two factors that are important for the accuracy assessment i.e. completeness and correctness mainly depend upon the number of building extracted. It is also seen that some other features which are not of interest are also extracted. It may be due to the confusion between buildings and other features having same reflectance values. But it was observed that overall accuracy of the extraction is satisfactory in all the urban settings and such an approach may be useful for semi automated GIS database creation and updation.

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Remote Sensing Data

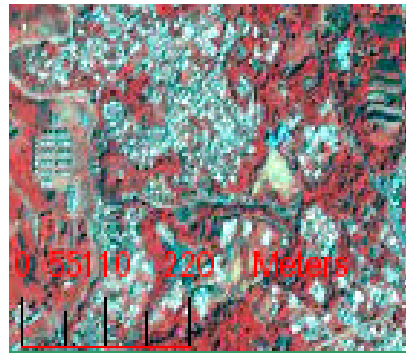
IKONOS 1m Panchromatic

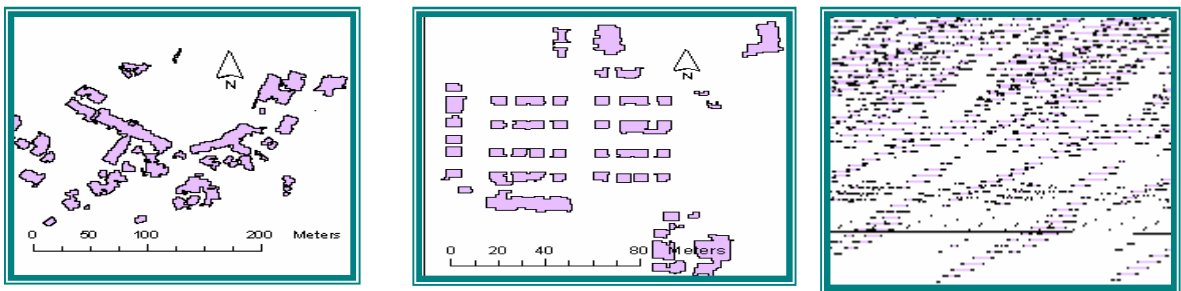
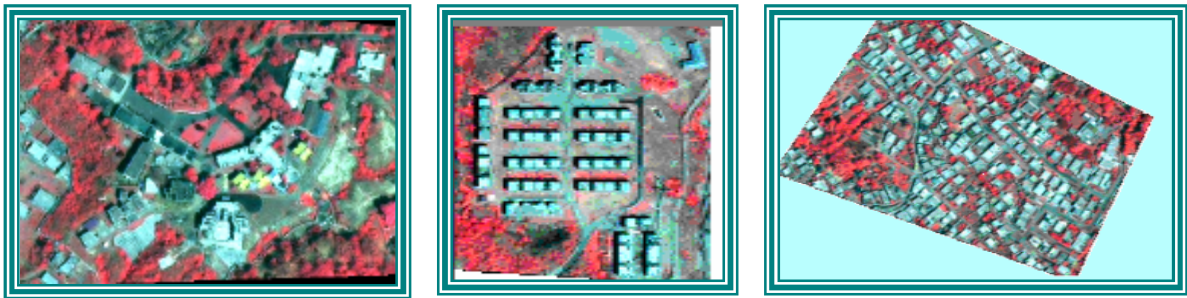
Spectral range: 0.45 - 0.9 micrometers.

Data: 11 bits per pixel (2048 grey tones)

IKONOS 4m Multispectral

Band 1: 0.45 - 0.53 (Blue), Band 2: 0.52 - 0.61 (Green), Band 3: 0.64 - 0.72 (Red), Band 4: 0.77 - 0.88 (Near Infrared)





| Image | IKONOS Fused | | | |
|------------|--------------|-------------|---------|-----------------|
| Study Area | Completeness | Correctness | Quality | Building Area % |
| Mixed area | 0.86 | 0.44 | 0.5 | 115 |
| Planned | 0.69 | 0.76 | 1 | 104 |
| Unplanned | 0.64 | 0.78 | 1 | 92 |

