ISSN: 2151-1950 (Print), 2151-1969 (Online)   Vol. 2, No. 2, April 2010

Journal of Geographic Information System

Editor in Chief: Prof. Xincai Wu

www.scirp.org/journal/jgis

RCGIS

Scientific Research

Journal Editorial Board

ISSN: 2151-1950 (Print) ISSN: 2151-1969 (Online)

http://www.scirp.org/journal/jgis

Journal of Geographic Information System(JGIS) is a comprehensive international journal published by Research Center for GIS Software and Application Engineering, Ministry of Education, Zondy Cyber and SRP(Scientific Research publishing).

Journal of Geographic Information System, **2010, 2, 55-128**
Published Online April 2010 in SciRes (http://www.SciRP.org/journal/ijcns/)

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Volume 2 Number 2 April 2010

Journal of Geographic Information System

Journal Information

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Journal of Geographic Information System, **2010, 2, 55-62**
doi:10.4236/jgis.2010.22011 Published Online April 2010 (http://www.SciRP.org/journal/jgis)

Semi-Automatic Objects Recognition in Urban Areas Based on Fuzzy Logic

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Abstract

Three dimensional object extraction and recognition (OER) from geographic data has been definitely one of more important topic in photogrammetry for quite a long time. Today, the capability of rapid generating high-density DSM increases the supply of geographic information but the discrete nature of the measuring makes more difficult to recognize correctly and to extract 3D objects from these surface. The proposed methodology wants to semi-automate some geographic objects clustering operations, in order to perform the recognition process. The clustering is a subjective process; the same set of data items often needs to be partitioned differently based on the application. Fuzzy logic gives the possibility to use in a mathematical process the uncertain information typical of human reasoning. The concept at the base of our proposal is to use the information contained in Image Matching or LiDAR DSM, and typically understood by the human operator, in a fuzzy recognition process able to combine the different input in order to perform the classification. So the object recognition approach proposed in our workflow integrates 3D structural descriptive components of objects, extracted from DSM, into a fuzzy reasoning process in order to exploit more fully all available information, which can contribute to the extraction and recognition process and, to handling the object's vagueness. The recognition algorithm has been tested with to different data set and different objectives. An important issue is to apply the typical human process which allows to recognize objects in a range image in a fuzzy reasoning process. The investigations presented here have given a first demonstration of the capability of this approach.

Keywords: Objects Recognition, DSM, Fuzzy Logic

1. Introduction

1.1. Motivations

Estimating the research fields involved in the 3D topographic objects generation for 3D GIS are very huge.

3D GIS require 3D representations of objects and 3D object reconstruction of real world is a relatively new issue in photogrammetry.

Progress in the field of digital image matching for DSM generation and growth of airborne laser scanning technologies have improved the derivation of digital surface models.

The basic idea of this work is to use the 3D information contained in these DSM in order to aid the 3D identification and extraction of features. Using the DSM we would to overcome some typical difficulties in image interpretation.

Then this work focuses on the automation and acceleration of the recognition of 3D topographic objects for 3D GIS. The purpose is to use the 3D information contained in the DSM in order to automatic detect and recognize topographic objects in complex scenes. Furthermore, it is tried to use only LiDAR or Image Matching DSM. Due to this limitation our goal becomes even more challenging.

Experience and daily practice allow us to have our brain automatically interpreting what we see. Human recognition takes advantage of a variety of acquired information rather than relying on, say, a single descriptor of the objects. Further, human perception possesses a tremendous potential for learning and deals perfectly with the fuzziness of the real world. In the case of objects in geographic data an interpretation by human operator may be easier but, if these processes are replaced by a computer, it is more than probable that none of the objects will be identified.

Fuzzy set theory, introduced by L. Zadeh in the 1960s, resembles human reasoning in its use of approximate information and uncertainty to generate decisions.

This work contains possible methods that aim at an automated object recognition based on fuzzy logic. An important aspect of fuzzy reasoning is that the rule base should include observations of the important object's descriptors. Moreover, it reflects the fact that people may formulate similar "fuzzy statements" to characterize how they perceive object in range images. Formulating the rules is more a question of the expertise of an operator than of a detailed technical modelling approach. This aspect is very important because we are aware of the fact that an operator will never be completely replaced.

1.2. Related Works

Three dimensional object extraction and recognition (O ER) from geographic data has been definitely one of more important topic in photogrammetry for quite a long time. However, most of the existing methods for automatic object extraction and recognition from data are just based on the range information and employ parametric methods while object's vagueness behaviour is basically neglected [1].

The main task in automatic DTM generation from data is the separation of terrain points from non-terrain points; further classification of non-terrain points in buildings, vegetation and other objects (e.g. bridges) may be necessary, depending on the application.

Since long years automatic approaches to DTM generation and building reconstruction based on radiometric images have long been a research topic. It is shown that the segmentation and classification problem is not only an interesting research topic, but also very important in practice. Multiple, largely complementary, sensor data such as colour or multi-spectral aerial images and range data from laser scanners or SAR have been used to achieve robustness and better performance in 3D ORR. For example, colour infrared (CIR) aerial images in combination with laser scanner data DTMs can be used for feature extraction [2].

If multispectral imagery is available the classification approach is the most convenient way for detecting building areas or urban regions [3]. Everything that exceeds a certain threshold in the nDSM will be included, and vegetation will be afterwards excluded by interpreting the NDVI [4].

In many case however the multispectral information are absent and techniques in order to segment the DSM are carried out. Different filtering strategies have been proposed, based on deviations from a parametric surface, slope threshold, clustering, *etc*.

A slope based filtering using mathematical morphology has been developed defining a slope threshold as the maximum allowed height difference between two points as a function of their spatial distance [5].

A complex iterative procedure, based on the analysis of gradient, surface orientation and residuals from successive spline interpolations has been implemented in order filtered out non-terrain points [6].

Another interesting approach [7] has been discussed: the segmentation is carried out by combining region growing with a principal component analysis (PCA).

A three-stage framework has been implemented for a complete, robust and automatic classification of LiDAR data and is composed by: a region-growing technique to obtain regions with a step edge along their border, a grouping of connected sets of pixels on the basis of an 8-classes partition of the height gradient orientation and a rule based scheme applied to the classification of the regions [8].

Study focuses on the automatic extraction of a DTM from a high-resolution DEM produced by image correlation in urban or rural areas based on a hybrid approach has been designed and combines complementary aspects of both TIN-based and segmentation-based techniques [9].

This review outlines the considerable efforts which have been undertaken to deal with the complex problems of segmentation Computational theories on human perception and artificial intelligence are partially included in these developments.

2. Classification Based on Fuzzy Logic

2.1. Fuzzy Logic and Application in Feature Extraction

By recognition we refer to the process that assigns a label (e.g. "building" or "tree") to a segmentation result, in particular a region, based on properties (descriptors) of the region. Segmentation is the process that partitions the spatial domain of an image or other raster datasets like digital elevation models into mutually exclusive parts, called regions.

The major challenge of this work is to develop a segmentation procedure in connection with an inference process for object recognition where computational theories on human perception and artificial intelligence are partially included.

The bridge to connect the computational theories specified above with the human perception can be given by the Fuzzy Logic.

Fuzzy logic provides a simple way to arrive at a definite conclusion based upon imprecise, uncertain, ambiguous, vague or missing input information. Over the past few decades, fuzzy logic has been used in a wide range of problem domains. Although the fuzzy logic is relatively young theory, the areas of applications are very wide: process control, management and decision making, operations research, economies. Dealing with simple 'black' and 'white' answers is no longer satisfactory enough; a *degree of membership* (suggested by Prof. Zadeh in 1965) became a new way of solving the problems. The natural description of problems, in linguistic terms, rather than in terms of relationships between precise numerical values, is the another advantage of this theory.

Fuzzy Logic introduces *linguistic variables* for the object characteristic descriptors and *linguistic labels* to describe the fuzzy sets on the range of all possible values of the linguistic variables.

The basic idea of the recognition approach presented in this work is to resemble human reasoning in its use of imprecise, vague or missing information. This involves formulating rules with imprecise knowledge and providing a simple way of arriving at a definite conclusion, *i.e.* the recognized objects. The recognition approach based on fuzzy reasoning and a concept for introducing learning into fuzzy recognition is in the focus of this work.

2.2. Application in Feature Extraction

Many methods in pattern recognition and feature extraction have been proposed, based on various approaches, such as Bayesian inference, neural networks, linear methods, nearest prototypes, *etc*. Fuzzy set theory and related domains have brought new tools for pattern recognition, either based on the concept of fuzzy sets as a fundamental concept for modelling classes, or based on non classical representations of uncertainty.

These approaches can often be viewed as a generalization of some classical method, these generalizations introducing either some fuzziness in the modelling or some uncertainty measure more general than probability measures. In other cases, they follow the same kind of philosophy, but with different tools. Typical examples in the first category are: the fuzzy *k*-nearest neighbours and the fuzzy *c*-means. In the second one, the fuzzy pattern matching approach, in the framework of possibility theory, can be viewed as the possible counterpart of the Bayesian approach to classification.

Applied to raster image, fuzzy classification estimates the contribution of each class in the pixel. It assumes that a pixel is not an indecomposable unit in the image analysis and, consequently, works on a new principle: "one pixel-several classes" to provide more information about the pixel unlike the hard classification methods which are poor in information extraction. For instance a fuzzy c-means clustering algorithm has been developed and implemented in unsupervised classification of remote sensing data [10].

In the proposed fuzzy process (**Figure 1**), each pixel is transformed into a matrix of membership degrees representing the fuzzy inputs. A minimum-reasoning rule is, then, applied to infer the fuzzy outputs. Finally, a defuzzification step is applied to extract features [11].

The main components of the fuzzy recognition process are as follows:

- a database, which defines the membership functions of the fuzzy sets,
- a rule base, which contains fuzzy if-then rules,
- a fuzzy reasoning procedure, which performs inference operations on the rules.

This should consider 1) all available descriptors of an object (such as: 3D structure, textural information and spectral responses), 2) a fuzzy description of object properties and a fuzzy inference strategy for object recognition, 3) learning capabilities to modify imprecise model descriptions and increase the potential of recognition in particular if new and unrecognized objects are encountered.

The fuzzy AND or OR operators combine the membership values of the inputs in each rule for the antecedent of that rule. The MIN reasoning rule, applied on the matrix of produced fuzzy, inputs will consider, for each class, the membership degrees provided by the different fuzzy sets and pick out the minimal membership degree to represent the class extent in the pixel. Then a MAX operation will be performed, on the consequent of each rule, to obtain the element with the highest value (fuzzy output) and the corresponding class of that feature willbe considered as associated fuzzy class to that pixel (**Figure 2**).

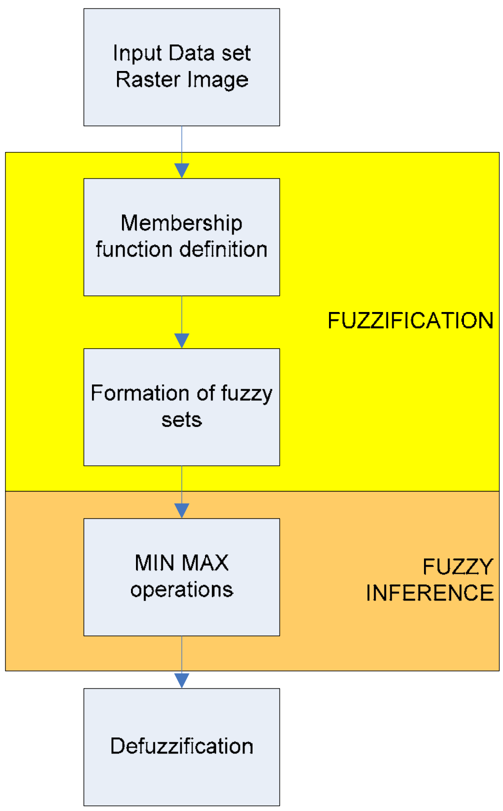

Figure 1. Implementation flowchart in fuzzy step.

Rule base should include observations of the important descriptors. Moreover, it reflects the fact that people may formulate similar "fuzzy statements" to characterize how they perceive objects in, for instance, aerial colour images.

The investigations of the works involved in classification and feature extraction [12-14] have given a demonstration of the capability of these fuzzy approaches.

2.3. Proposed Workflow

The proposed methodology wants to semi-automate some geographic objects clustering operations, in order to perform the recognition process.

The clustering is a subjective process; the same set of data items often needs to be partitioned differently based on the application. There is no general algorithm or approach that solves every clustering problem. In order to overcome this problem is important to have simple and semi-automated tools with the possibility to change the classification based on different situations and different data.

As seen in the previous, fuzzy logic gives the possibility to use in a mathematical process the uncertain information typical of human reasoning. The concept at the base of our proposal is to use the information contained in Image Matching or LiDAR DSM, and typically understood by the human operator, in a fuzzy recognition process able to combine the different input in order to perform the classification.

So the object recognition approach proposed in our workflow integrates 3D structural descriptive components of objects, extracted from DSM, into a fuzzy reasoning process in order to exploit more fully all available information, which can contribute to the extraction and recognition process and, to handling the object's vagueness.

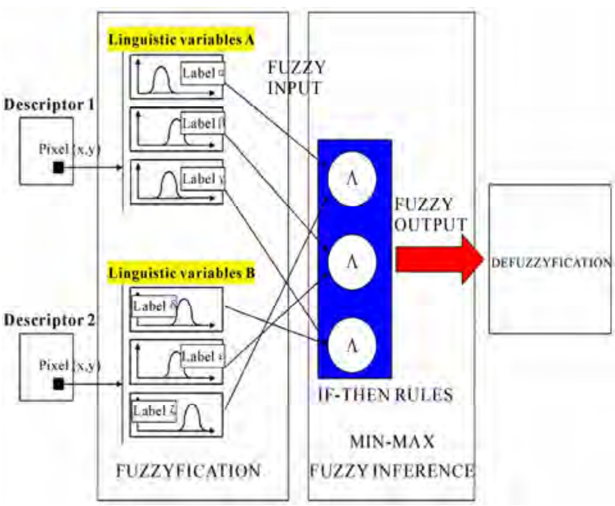

Figure 2. Architecture of the explicit fuzzy method illustrated for two descriptor, two variables with three classes.

The proposed objects extraction method requires some preliminary step that consists in 1) to locate and separate all 3D objects from the terrain and 2) to considerate and generate all the geometric properties that can describe the objects. Then the challenge is to develop a segmentation procedure in connection with an inference process for object recognition.

Basic idea was to perform the classification procedure using a priori human knowledge about the objects and then in fuzzy logic manner. Some information, needed for membership function definition, was taken from human heuristic knowledge.

More specifically the steps of fuzzy recognition process will be:

- input raster data and structural descriptor variables are introduced;
- membership functions are defined using results from human heuristic knowledge;
- definition of fuzzy logic inference rules;
- performing Raster data classification.

The OER process starts with the extraction of the Structural Descriptor (SD). Then the descriptors are analyzed to derive the SD membership functions. In the next stage, the recognition operation is performed with the application of the sample if-then fuzzy rules and the MIN-MAX inference process (**Figure 3**).

Prior to fuzzy recognition the membership functions of the structural descriptors have to be specified but, before the system operation is started, it is always necessary to set up the fuzzy reasoning parameters. For the object classes, the preliminary Structural descriptor's membership functions components are defined based on the knowledge of an experienced photogrammetric operator.

The formulation of the fuzzy rules requires a profound observation of the integrative impact of the descriptors on the recognition of an object. This again depends on the experience of an operator but also on the complexity of an object. In the experiments we observed that for partition walls a comparatively small number of fuzzy rules are sufficient, whereas trees require more rules probably due to their more complex shapes and variety of appearances.

2.4. Recognition of Little Objects in Urban Areas: The Partition Walls

In the data-test we investigated the possibility to recognize large scale objects in urban areas. In these areas large amount of objects are constituted by building and road feature classes but, there are also many little objects which are important *i.e.* for construction of 3D city models. In many cases these features are difficult to single out into images by an expert photogrammetric operator too. The partition wall is a typical example of this kind of feature class. In fact due to their geometry is difficult

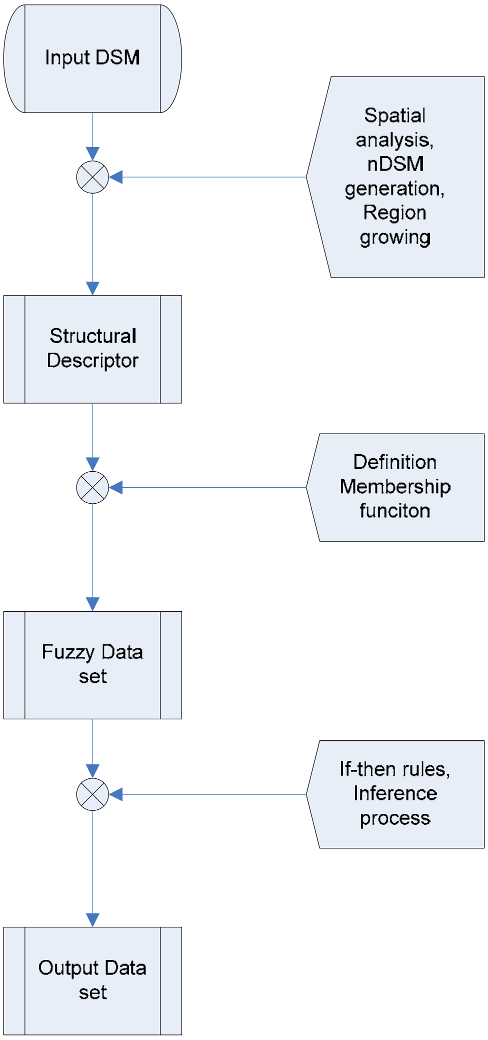

Figure 3. OER (Object Extraction and Recognition) fuzzy process work-flow.

to detect them into image, beside they may have parts occluded by the buildings or trees, or may be confused by the shadow of the walls themselves. Human recognition takes advantage of a variety of acquired information and the walls are identifiable on the aerial images more like as a separation between to different areas then like as single geometry. In this situation human perception possesses a tremendous potential for learning and deals perfectly with the fuzziness of the real world. For these reasons the recognition of these particular features may take advantage from a fuzzy logic approach, which is able to capture the "fuzziness" or "imprecision" of the real world.

Beside in this particular context use of Structural descriptor are fundamental because the spectral information is very poor due to shadows, noise and similarity to other objects such as road, buildings *etc*. So this is a very important challenge for our approach which starts only from 3D Structural Descriptors.

The data test is an urban area of Milan, there are many partition walls which divide road and railways and like as boundary of big factory (**Figure 4**). The input DSM is obtained trough Image matching technique and has 1 × 1 meter resolution.

The surface model generated by image matching is shown in (**Figure 5**). Appling segmentation of the surface model based on morphological filtering in order to the detected 3D regions, we can obtain the nDSM.

After refinement of the extracted regions the next step is to derive the structural descriptors: gradient edge detector and others. The membership functions are defined and applied to these features and the results are shown in **Figure 6**.

The trapezoidal membership function, with maximum equal to 1 and minimum equal to 0, is used in this work. Special cases like symmetrical trapezoids and triangles reduce the number of parameters to three. The trapezoidal function are modelled with four parameters (α, β, γ, δ).

$$\mu_A(x,\alpha,\beta,\gamma,\delta)=\begin{cases} 0 & if\ x<\alpha \\ \dfrac{x-\alpha}{\beta-\alpha} & if\ \alpha\le x<\beta \\ 1 & if\ \beta\le x<\gamma \\ \dfrac{\delta-x}{\delta-\gamma} & if\ \gamma\le x<\delta \\ 0 & if\ x<\delta \end{cases}$$

Figure 4. Sample data-set, the more important partition walls are highlighted. It is possible to see like as the object identification into the image is problematic.

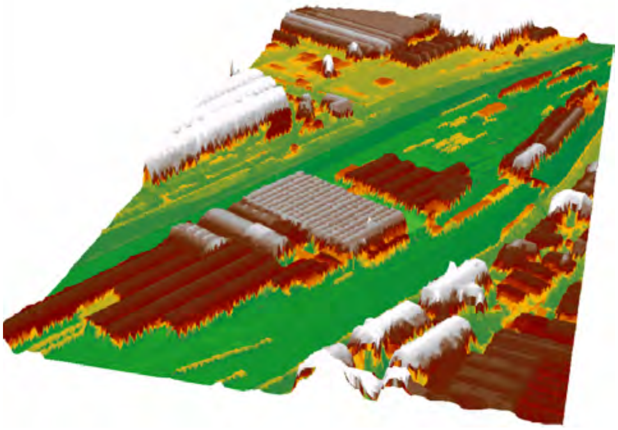

Figure 5. Digital surface model generated by image matching. 1 × 1 meter resolution.

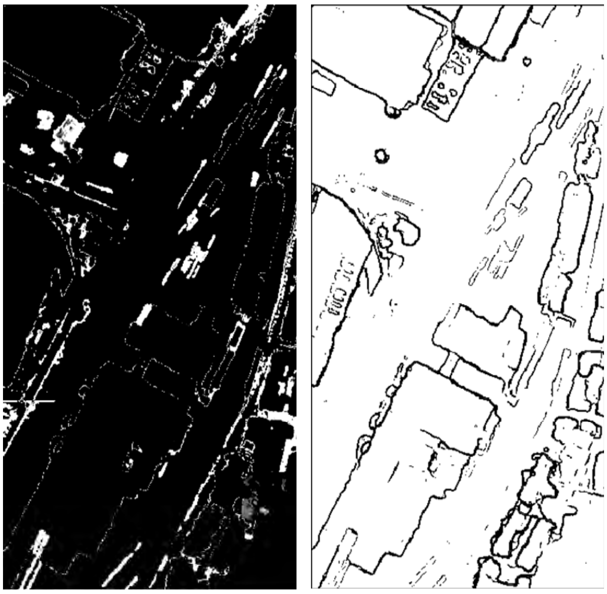

Figure 6. Application of the membership function to the structural descriptors (Height range, edge) generation of the fuzzy Data Set.

The linguistic variables, which are variables that assume linguistic terms values, of the object's structural descriptors have to be defined in fuzzy logic. Linguistic variables are associated to each input structural descriptor and for each linguistic variables some linguistic labels has been assigned. This assignment is mostly a mixture of expert knowledge and examination of the desired input-output data.

Through definition of linguistic variables and membership function parameters calculation of the input to the fuzzy recognition process is given.

In a second step the determined membership values have to be combined to get a final decision (inference process). This component of the fuzzy recognition process consists in the definition of a set of rule base, which contains fuzzy *if-then* rules.

Once defined the sample *if-then* rules we can start the inference process. The results of classification are shown in **Figure 7**.

This methodology returns as output a very thigh recognition objects set, due to use of *min* implication, which consist in low pass filter. In this situation is enough a wrong value in an input data set to get worse in the objects extraction. For instance, inaccurate DTM extraction may cause the elimination of some objects part from nDSM. This is all the more probable in case of little objects such as walls. The result is a chopped classification set where the objects classified as walls are correctly understood and the false positive are limited but, we have many not recognized objects and the geometry results fragmented.

The second method we have tested a weighted sum approach [15] and this has shown better results.

The resulting output value (**Figure 8** left) is calculated by the sum of the membership values for each rules concerning an individual weight factor W_i. The weights for parameters *height*, *edge* and *height range* depend on the experience and data input/output

$$m_i = \mu_{A_i}(x_1) \cdot W_{A_i} + \mu_{B_i}(x_2) \cdot W_{B_i} +, \ldots\ldots, + \mu_{N_i}(x_n) \cdot W_{N_i}$$

with $\sum_{i=1}^{n} W_i = 1$

Our investigations have shown that the classified objects are better defined than in *fuzzy-min* approach and we may recognize more features than previously.

Finally an accuracy investigation is carried out to evaluate the recognition results. For this purpose the ex-

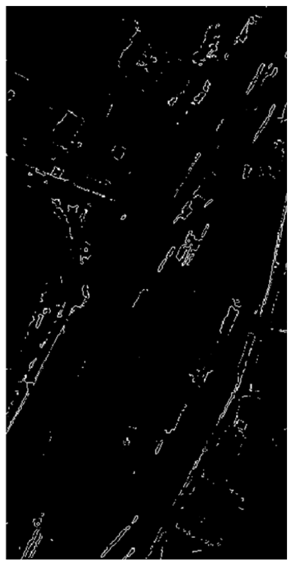

Figure 7. Results of fuzzy walls recognition process.

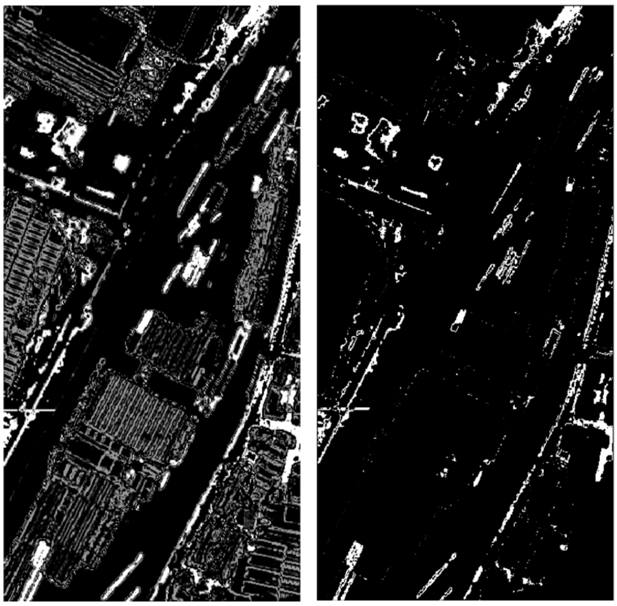

Figure 8. Results of fuzzy walls recognition process using the weighted sum approach. At left is shown the results of fuzzy inference process and at right the final cluster once applied a threshold (value 0.6) to the weighted fuzzy output.

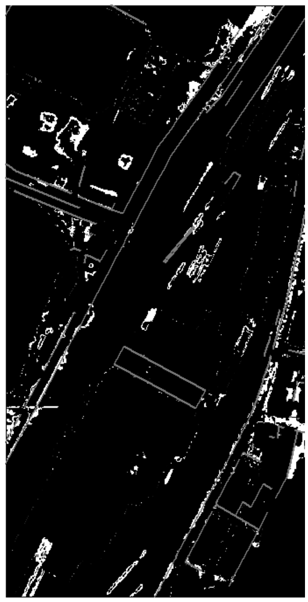

Figure 9. Comparison between the extracted features and 1:1000 digital maps of Milan. In red the wall features manually extracted. We can observe a good result for 50% of elements, while some walls are not recognized and we have many false-positive due to the presence of many objects which have wall's similar characteristics.

tracted objects are compared to the object manually measured and contained in the 1:1000 digital maps of Milan.

Due to the particular wall's geometry (very thigh in one direction), the classification is influenced by the quality of input DSM. Where DSM is well defined (**Figure 9**) we have a good result.

3. Conclusions and Future Works

In object recognition, human interaction remains an important part of the work flow even though the amount of work to be done by the human operator can be reduced considerably in the global extraction process. Many of automated and semi-automated methods proposed in literature focus their efforts on the reconstruction process or on the feature extraction once recognized the objects by the operator.

The core of the system is an approach for recognition of object's primitives based on fuzzy logic theory which analyzes the data in order to extract a maximal amount of information, through an explicit process that uses structural information of objects and integrates them in a fuzzy reasoning process.

The methods presented in this work integrate some typical heuristic human concept and is adaptive to operate with different data sets and in different applications. Despite that further investigation and developments might be carried out. In relation to data input different descriptor of objects, such as textural or multispectral properties, can be considered in recognition process. Moreover the generation of structural descriptor have to be improved considering the sensitivity of the algorithms to the coarse input.

Another important improvement is neural-network learning. The learning capability of neural networks can be introduced to the fuzzy recognition process by taking adaptable parameter sets into account which leads to the neuro-fuzzy approach.

Finally data acquired from different sensor (such as High density Airborne Laser Scanning) or new systems (UAV) can be used in recognition process and their potentiality can be evaluated.

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Journal of Geographic Information System, **2010, 2, 63-84**
doi:10.4236/jgis.2010.22012 Published Online April 2010 (http://www.SciRP.org/journal/jgis)

Urban Vulnerabilities in the Kathmandu Valley, Nepal: Visualizations of Human/Hazard Interactions

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Abstract

Excessive unplanned urban growth leads to many vulnerabilities and impacts on urban environments to varying degrees. However, the majority of the extant literature focuses on the problems related to location and socioeconomic conditions, rather than vulnerability processes and related environmental degradation. This paper analyzes the scope of urban vulnerabilities for five rapidly urbanizing and highly-congested cities in the Kathmandu Valley, Nepal. First, the historic context of the Valley's uncontrolled urbanization sets the scene. Second, the optic is narrowed to focus upon the geographical features of the resultant urbanized Valley landscape that includes spatial arrangements and of houses, population densities, road networks, vehicular densities, garbage problems, and available open spaces. Additionally, seismic vulnerabilities in the urban areas are also considering in this examination. Third, three-dimensional visualizations of selected urban locations are presented to differentiate between vulnerable and relatively safe locations. The intent of this research is to contribute to the methodological understanding of human/hazards interactions in rapidly urbanizing cities of the Third World, which share similar socioeconomic conditions and environmental contexts.

Keywords: Urban Vulnerability, Planning, Kathmandu Valley, Two Dimensional (2D) Maps, Three Dimensional (3D) Visualization

1. Introduction

Urban vulnerability analysis using spatio-temporal information is increasingly used by urban planners and policy makers to anticipate and prevent catastrophic human disasters. Throughout the world, urban centers are becoming environmentally complex; home to over half of the world's population, these centers provide employment and commerce opportunities as well as administrative services to residents. Even in smaller urban centers many complex infrastructures have been developed to provide essential amenities to their overcrowded urban populations. At the same time, organic (haphazard/unplanned) developments often lead to increased vulnerability, and in many cases a variety of urban vulnerabilities, that taken together, make public solutions difficult if not impossible to anticipate, ameliorate or address adequately. The identification of such "mixes of vulnerabilities" requires sophisticated spatial analysis to understand the interactions among biophysical and economic factors that bring about such heightened vulnerabilities.

Over the past two and half decades, the integrated use of geographic information systems (GIS), global positioning systems (GPS), and remote sensing has become instrumental in addressing urban vulnerabilities at the local, national, and international levels [1-4]. Using these tools to analyze the landscape, researchers have identified numerous urban vulnerabilities resulting from a lack of emergency vehicular accesses and open spaces, uncontrolled solid waste management, and related unhygienic conditions, to name a few. To date, methodological approaches to identify and monitor urban vulnerabilities are limited and inconsistent due to an absence of uniform concepts, rules, and principles among academics and practitioners. To help remedy this situation, this paper analyzes spatial arrangements and housing types, population densities, road networks, vehicular densities, garbage problems, available open spaces and possible seismic vulnerabilities using 3D visualization techniques for the Kathmandu Valley of Nepal. One goal is to identify gaps within the extant of urban literature. A secondary goal is to explain how urban density-intensification not only results in declining rates of economic returns per land area unit [3,5], but also how such density-intensification hinders accessibility in cases of natural disasters such as Haiti's 2010 earthquakes, negatively impacts hygienic conditions, and threatens the public's health.

Urban vulnerabilities are the result of the complex interaction of biophysical and economic factors. The identification of such intertwined complex interactions requires three-dimensional (3D) x, y, and z information, due to the fact that two-dimensional (2D), x and y, information produces incomplete and therefore, inadequate scenarios for analyzing future urban landscape trajectories. We take a 3D visualization approach and use combinations of different datasets, such as GIS layers of multi-layer building morphologies, satellite images, and high resolution digital elevation data models (DEM) to assess vulnerabilities. More specifically, these visualizations evaluate: a) man-made hazards in congested urban areas; b) access to roads and bridges by emergency vehicles; and c) highlight the importance of such infrastructure patterns in politics, culture, economy and finance. Similar purposeful, three-dimensional visualizations will make it easier to implement settlement planning in locations such as the Kathmandu Valley, considering the challenges routinely faced by national and regional planners in Third World urban centers. In addition to regularly addressing the problems of slums, squatters, inadequate low-income housing and overburdened infrastructure systems, urban planners of the Third World may also have to work within a corrupt political system and with an equally inefficient governmental bureaucracy [5]. Planners and policy makers should find 3D data valuable not only to present long-term urban trajectories, but also to overcome undue pressures from politicians who routinely get their votes from the slums and squatter dwellers and who generally look for immediate problem-solving approaches in an organic fashion [5]. Instead, 3D presentations can illuminate planned outlays to promote sustainable solutions based on scientific, methodological analysis.

Using spatial information within an urban theoretical framework, we analyze urban vulnerabilities of the Kathmandu Valley (**Figure 1**). To address urban vulnerability issues, this paper is structured as follows: 1) research questions; 2) literature review; 3) brief description of the study area; 4) data and methodology; 5) causes of urban vulnerabilities; 6) remediation procedures to alleviate congestion problems, and 7) conclusion.

2. Research Questions

1) What determines urban vulnerabilities, and what factors make some urban areas more vulnerable than others? 2) Is it possible to identify repeated patterns of urban vulnerabilities and if so, how might such vulnerabilities be ameliorated?

3. Review of Literature

Research has identified a mix of urban vulnerabilities [6-9]. As a spatial science, geography concerns itself with the behavior and distribution of: 1) urban objects, such as residential and commercial buildings, pedestrians, and vehicles; 2) urban features, such as land parcels, shops, roads, sidewalks; and 3) natural features, such as green/open spaces, rivers, and the seismic vulnerability of places. Spatial science considers these dynamic factors as "urban ensembles," which vary at different locations and scales [10]. Some researchers have used simulation methods to view the roles of these ensembles in urban amenities Torrens [11] while Blaikie *et al*. [12] have taken a theoretical approach and defined vulnerability as being prone to, or susceptible to, damage or injury due to biophysical factors. Rasheed and Week [13] relate urban vulnerabilities to natural hazards such as earthquakes, and to human behavioral adaptations; and argue that urban vulnerabilities become intertwined with socioeconomic systems. The World Vulnerability Report (2003) presented 50 different indicators of urban vulnerabilities by analyzing "urban ensembles" at various scales.

Urban ensembles such as buildings, streets, bridges, public and industrial areas, roofs, facades, open and green spaces, are obviously highly interrelated, but they can be visualized using design plans, drawings, and video data records [14]. Various layers such as houses, critical facilities, industrial sectors, and others can be overlaid together for visualization and subsequent spatial analysis. Researchers often apply spatial, multi-criteria approaches using spatial objects to examine the quality of life, urban conditions and aesthetic structures, because these "urban ensembles" represent dynamic phenomena involving people not only as users but also as victims, contributors, and modifiers [15-21]. Remote sensing and GIS technologies have proved to be especially-helpful tools to identify vulnerable and/or non-vulnerable ensembles across urban landscapes.

Alexander [6] used GIS to locate areas within seismic zones and analyzed the degrees of urban vulnerability they posed. Webster [22] used GIS at three levels of analysis: describing, predicting, and prescribing the growth and associated problems within an urban area. Cutter [23] used GIS to develop weighted social and biophysical indicators associated with urban vulnerability. Wu and Webster [3] hypothesized an artificial city and created a multi-dimensional matrix model as P grids each consisting of $n \times n$ cells to demonstrate the power of GIS as an integrative exploratory tool within the geographical, complex systems and economic theories. They argued that a city constantly shifts spatially achieving fraction of the cells, starting with pre-existing residential and industrial uses, initializing the majority of cells as vacant and then presented several possible scenarios of urban morphologies.

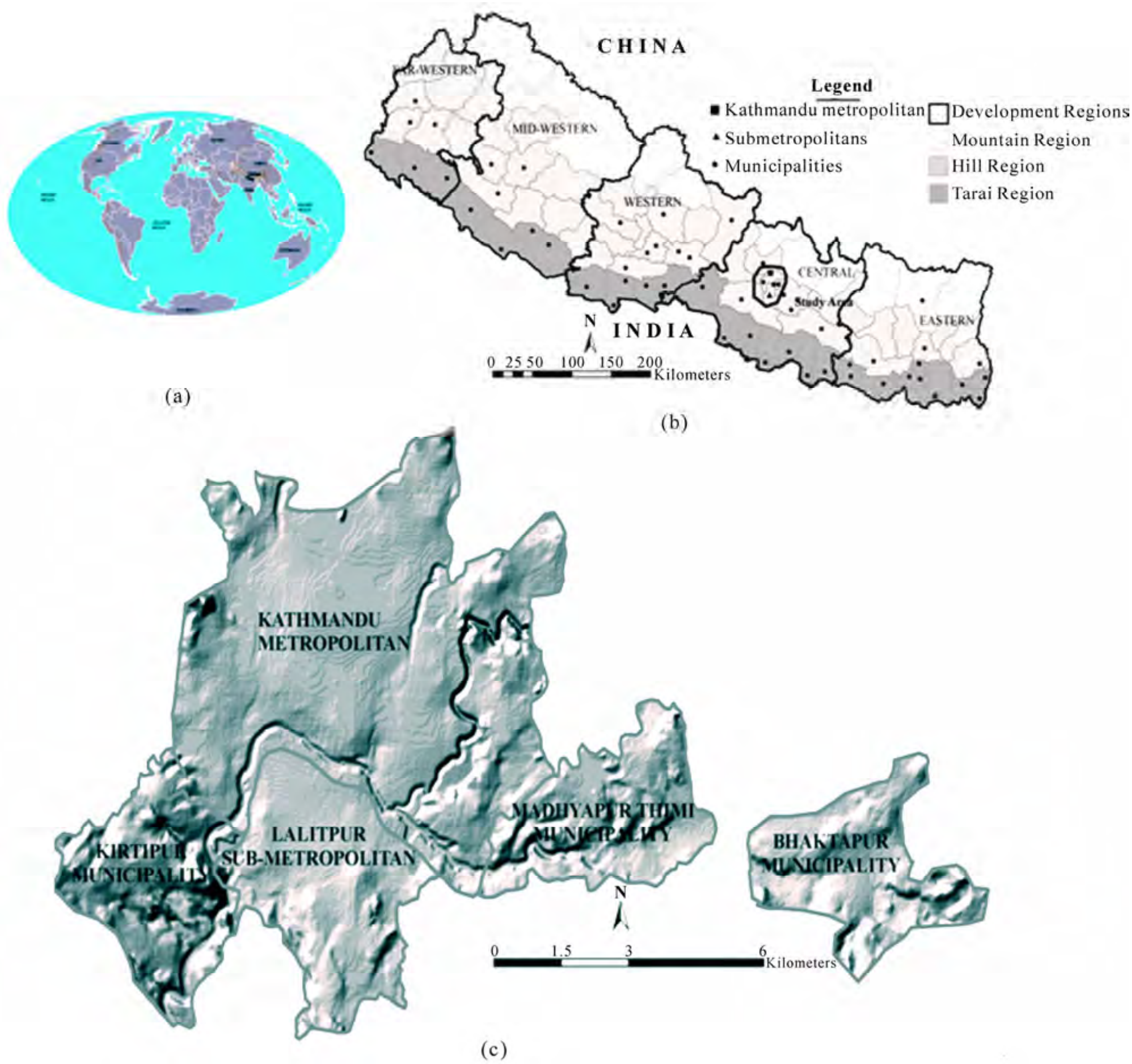


Figure 1. Map of the (a) world, (b) Nepal, and (c) Kathmandu Valley showing five urban centers.

Further, they analyzed the agglomeration effect in a city through a moving kernel, which returns a parameter that is a function of the number of built-up activities in the immediate neighborhood. They argue households in a community are assumed to place a measurable value on such development, which may add to both urban amenities and vulnerabilities due to their causal linkages. Madhavan *et al*. [24] used remote sensing to explain how land use and land cover changes are associated with urban vulnerabilities in the Metropolitan area of Bangkok, Thailand. Rashed and Weeks [2] explained how a society might be subjected to various hazards because of its own actions, such as construction of unaesthetic and congested structures such as substandard buildings and narrow roads.

Bhaskaran *et al*. [25] analyzed vulnerability due to hail damage in urban areas of Sydney, Australia, using remote sensing techniques. They determined the need for a higher concentration of post-disaster emergency operations in areas with less resistant roofing materials. Bottari *et al*. [26] identified seismic urban vulnerabilities citing examples from Sicily using GIS techniques. Li *et al*. (2006) used quantitative models using GIS and remote sensing and analyzed urban vulnerabilities associated with environment conditions in the upper reaches of the Minjiang River, China. Zamoranoa *et al*. [27] used GIS techniques to develop indices to determine appropriate locations for waste disposal. Kamozawa *et al*. [28] studied vulnerabilities associated with bed rock movements during earthquakes using 3D features.

Researchers have found the 3D visualization technique useful in examining the effects of adjacency (what is next to what), containment (what is enclosed by what), proximity (how close one geographic object is to another), accessibility (how an object can be reached from a certain road), and visibility (how far certain objects are visible from certain locations) [29]. However, as in simple two-dimensional features, it is essential in 3D features to either associate the distance and direction with the object as an attribute to the housing unit, or to compute the distance and direction between the roads and houses along with the height or depth of individual objects. This requires the storage of extra attribute information, *i.e.* latitude, longitude, height or depth, (and/or time). In earlier times, 3D visualizations were possible only in computer-aided design (CAD) [30,31] and cadastral mapping [32]. Today, ArcGIS 9.4 beta version incorporates 3D functions in its Network Analyst [33], making it accessible and functionally more useful to planners and researchers alike in the accessibility analyses [34].

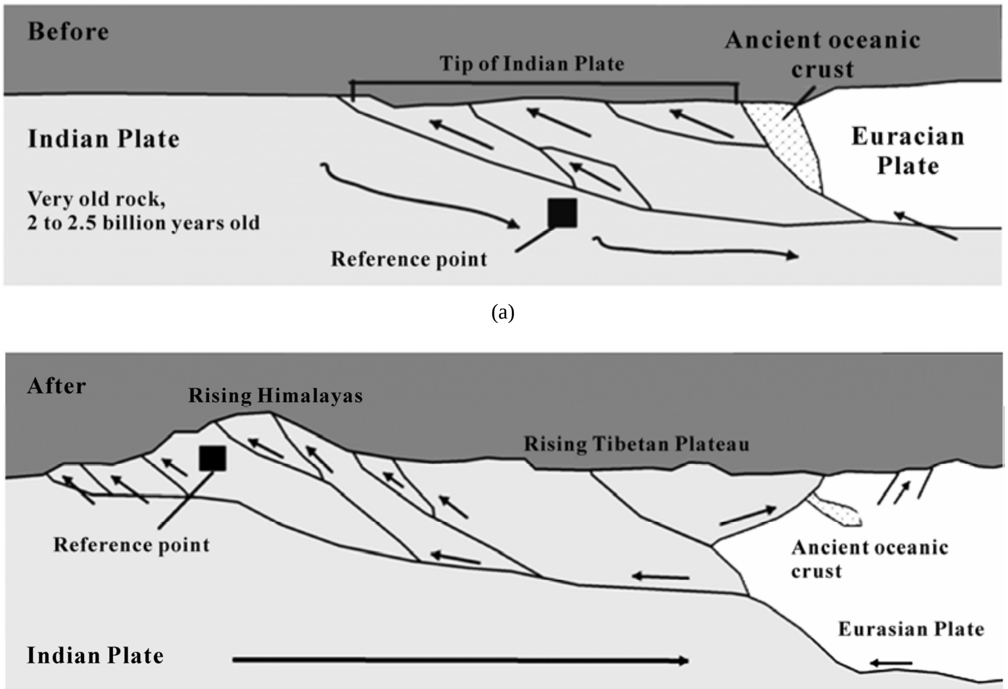
Urban vulnerability analysts have found 3D models very efficient for correlating societal and biophysical factors while working in unfamiliar locations [2,35]. Others have used 3D visualization to display remotely sensed images and to analyze ozone and nitrous oxide concentration and dispersal patterns [36]. The use of 3D is also increasing in transportation planning with the use of a lane-oriented, 3D road-network model [37], though very little research has been done in this area to date. Since 2D road network data does not have sufficient accuracy for lane-oriented micro-scale, the recent development of sensor technology has been recommended for the development of road layers with higher positional accuracy that use differential GPS, often termed as DGPS receivers. Moreover, the rapid development of digital photogrammetric cameras to capture lane oriented data has improved the quality of 3D data [38]. These 3D road lane data are useful to predict both upward and downward (flyovers, tunnels, over/underpass) movements of vehicles [39], which is not possible with 2D data. The 3D model maintains the integrity of the network data and provides better compatibility with the general hierarchical view of roads. Its dynamic segmentation outperforms traditional 2D dynamic segmentation in accuracy and flexibility. Companies like Vexcel Corporation based in Boulder, Colorado, are producing 3D models of the world from custom satellite data with high accuracy. However, these images are currently cost prohibitive.

The above account highlights the methodological advancements using spatially referenced data, beginning with a simple 2D version and progressing to a much more complex 3D methodological framework. Though many studies have analyzed the Kathmandu Valley's urbanization patterns, to date nobody has used 3D visualization to analyze possible urban vulnerabilities in a Valley wherein the urban areas have expanded 450% between 1950 and 2000 [40]. Past research on Kathmandu urbanization includes cartographic visualization and historical descriptions [41] and analyses of urban sprawl using remote sensing and GIS techniques [42-46]. We intend to conduct research and present evidence that reveals the usefulness and value of 3D visualization techniques by examining adjacency, proximity, accessibility, and environmental conditions within the uncontrolled and unevenly patterned conurbation of Nepal's Kathmandu Valley.

4. Study Area

The Kathmandu Valley is facing potentially insurmountable challenges due to overpopulation by immigration and natural growth. Traffic jams, a polluted environment, and rapid changes in the socio-cultural diversity are common features of this valley. Unplanned urban development fostered by weak institutional arrangements has encouraged rapid and uncontrolled urban sprawls which have contributed to dramatic changes in the urbanized landscape. Road blockages and the incessant shutting down of educational institutions, government offices, factories and shops due to political agitations have become common occurrences. Garbage disposal has become a political issue as well as a health hazard. As vulnerable as this city is to political unrest and garbage pollutants, the possibility of a high intensity earthquake (**Figures 2(a)** and **(b)**) is perhaps the greatest threat to the city and its inhabitants [47].

Geologically, the Kathmandu Valley is as vulnerable as Haiti, which experienced a devastating 7.0 earthquake on January 13, 2010 that resulted in the loss of over 200,000 lives, and left half a million people (a third of the nation) homeless [48]. Seismic geologists attribute the huge loss of life and property to the location of the quake's epicenter, near the capital in Port-au-Prince, and the construction of substandard buildings that commonly are not build according to seismic codes. Even the Presidential Palace of Haiti was damaged. Seismic geologists in Asia fear that the Kathmandu Valley might face a similar situation due to four reasons: 1) the Kathmandu Valley lies between the two young and active Eurasian and Indian Plates, similar to Haiti's location between Caribbean and North American plates; 2) many fault lines crisscrossing the Valley; 3) the soft floor of a prehistoric lake; and 4) the occurrence of many violent earthquakes in the past.



(a)

(b)

Source: Digitized from the base map of: *http://pubs.usgs.gov/gip/dynamic/understanding.htm* and **Figures 2(a)** and **(b)**. The meeting of the Indian and Tibetan Plates is influencing the Himalayan arc. The Himalayan mountain range dramatically demonstrates one of the most visible and spectacular consequences of plate tectonics. When two continents meet neither is subducted, because the continental rocks are relatively light and, like two colliding icebergs, resist downward motion. Instead, the crust tends to buckle and is pushed upward or sideways.

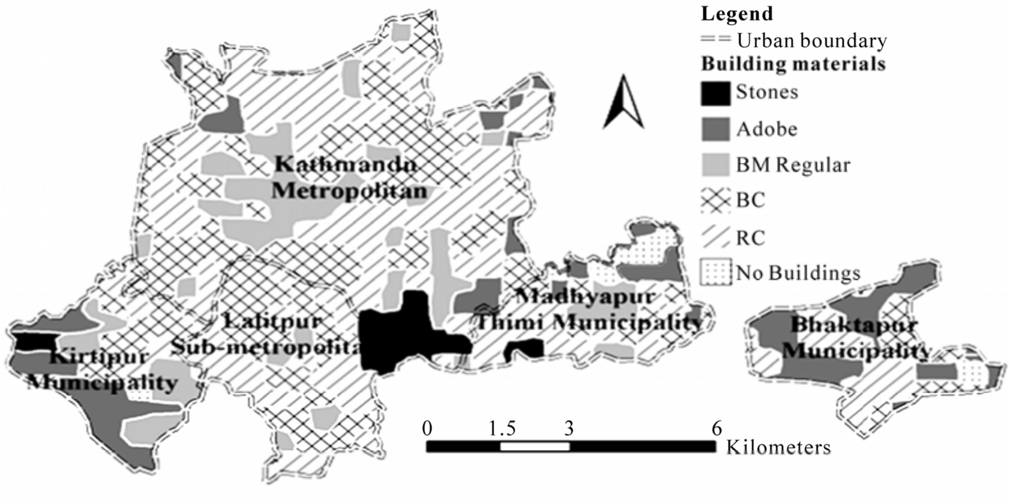
Figure 2. (a) and (b) Location of Nepal with reference to Indian and Eurasian plates.

The great 8.4 earthquake of 1934 hit Nepal on January 16, 1934, and killed 16,775 people, damaged 318,000 houses, and left thousands homeless. A recent report by the Japan International Cooperation Agency (JICA) estimates that if an earthquake of the same intensity were to hit the Kathmandu Valley, 50 percent of the buildings would be damaged while 10-15% percent of Kathmandu's 750,000 populations would likely be killed within the building rubbles because many of the areas are inaccessible by emergency vehicles.

Another recent study on the movement of tectonic plates and history of Himalayan earthquakes has predicted that the next great earthquake may hit the "central gap" of the Himalayas of Nepal at any time [47,49,50].

If an earthquake measuring greater than 5 M_w occurs in the Kathmandu Valley, many large structures, such as temples and monasteries constructed of heavy rocks, bricks, mud-mortar, masonry, and timber, as well as individual houses built with adobe, stone, mud-mortar, brick-cement, and masonry (**Figure 3**), having low tensile strengths, are likely to be destroyed. Dixit [47] argues that if an earthquake of similar magnitude to that of 1934 occurs, over 60 percent of the houses and over 50 percent of bridges will collapse, and the city would likely lose telephonic connections. An earthquake of similar (6 M_w) magnitude in Eastern Turkey on March 8, 2010 leveled off all the mud-mortar buildings of a village trapping people under the rubble of collapsed buildings [51]. However, there were minimal damages in cement concrete buildings. Most of the old mud-mortar and stone buildings of the Kathmandu Valley are similar to those of Turkey's rural areas. Dixit [47] argues that aid from foreign countries may get stuck at the airport, which is likely to be cut off or suffer from transportation bottlenecks (like the airport in Haiti). The resultant difficulties in rescuing the injured and distributing aid to the impacted population will inevitably result in more fatalities [47].

Over the years, the trends of rapid urbanization and haphazard (re)development activities in the core historical areas and peripheral agricultural lands, have exposed an increasing percentage of the population to seismic hazards, and have decreased the capacity of emergency services to cope with challenges associated with disasters. Many private schools, colleges, other educational institutions and private nursing homes, which should serve as "evacuation shelters" and "treatment centers" in the event of an earthquake striking the Valley, are currently operating in ordinary, residential substandard buildings. The



(a)

(b)

(c)

(d)

(e)

(f)

(g)

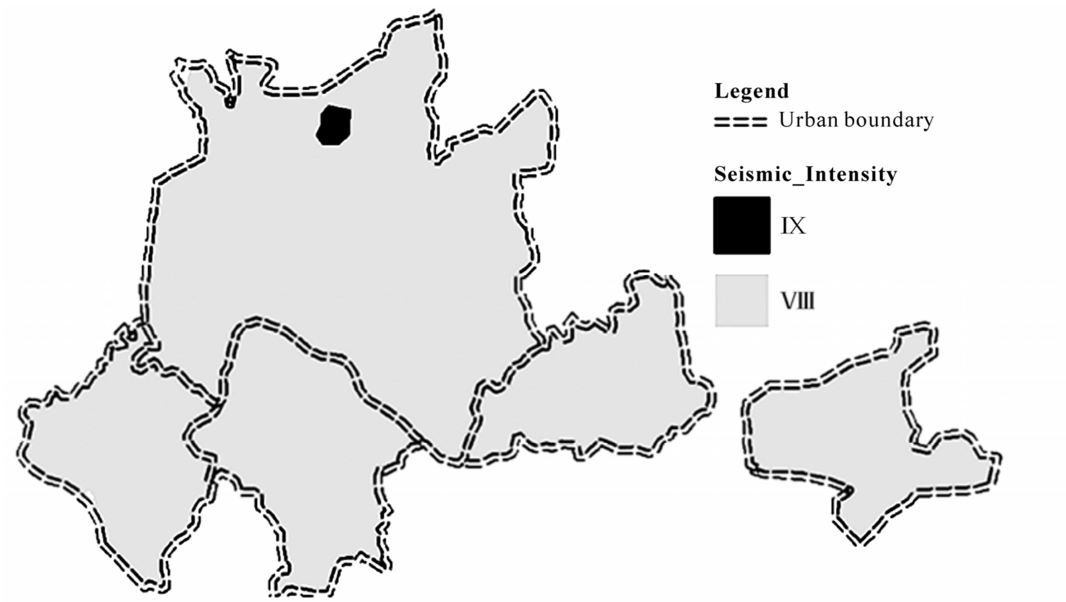
(h)

Figure 3. (a) Building types in five urban areas; (b) Adobe built; (c) Stone built; (d) Adobe well-built; (e) BM well-built; (f) Brick Cement; (g) RCC Pillar; (h) Temples and residential buildings.

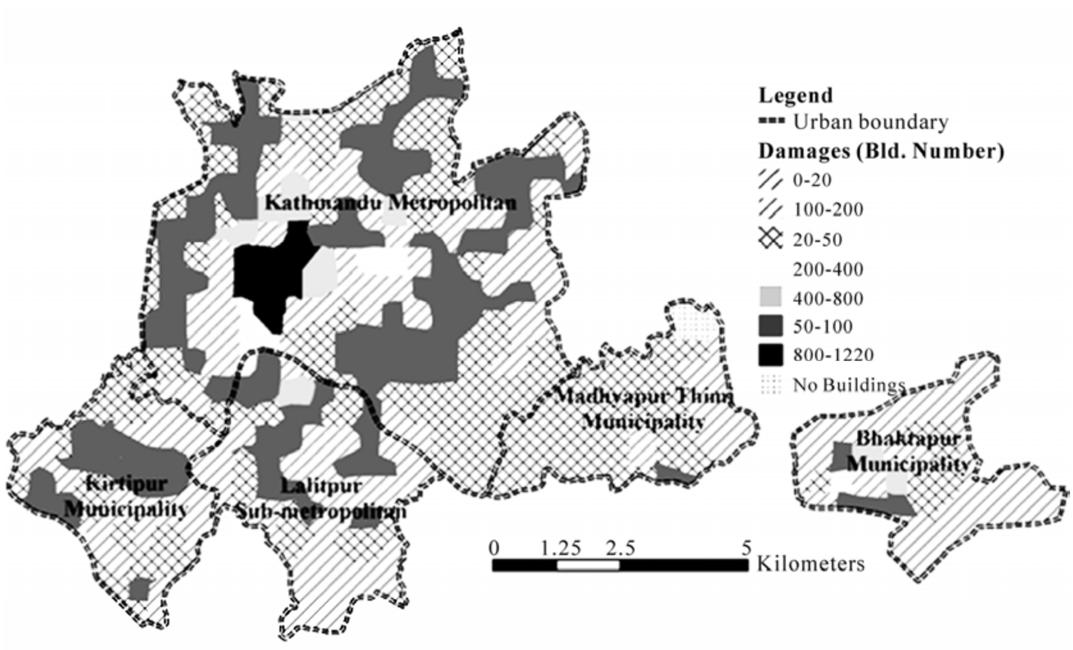
replacement of old three- and four-story residential houses with eight- to ten-story commercial office complexes in the urban centers has transformed narrow pedestrian lanes, street squares and courtyards into parking lots, garbage dumping sites, and "death traps". The riverfronts, prone to flooding in the event of an earthquake, are filled with slum and squatter settlements [50,52].

Geologists argue that conditions have ripened for a mega earthquake to strike Nepal [47,53] suspecting major devastation like that of Haiti in 2010. A simulation conducted by the National Society of Earthquake Technology Nepal, suggests that stone-built and adobe buildings sustain heavy damages even in the normal peak ground acceleration (PGA) of earthquakes. Studies of the 1934 earthquake damage reveals that houses with: few stories, few widows, large open spaces between them, wedge-walls (joists and walls interlocked with each other) with two bricks of adjacent layers put perpendicular to each other, light upper stories, made of good quality lime mortar with thick walls and deep foundations, more wooden structures than brick pillars, are more durable than houses without these attributes [54]. Since the houses of the Valley's city core areas are built in a more compact environment (**Figures 4(a)** and **(b)**), they are likely to sustain more casualties in the event of a high intensity earthquake.

Joshi [54,55] studied the damages that occurred in brick and stone masonry structures during the 1934 earthquakes and discovered that structures built by intermediate tech-



(a)

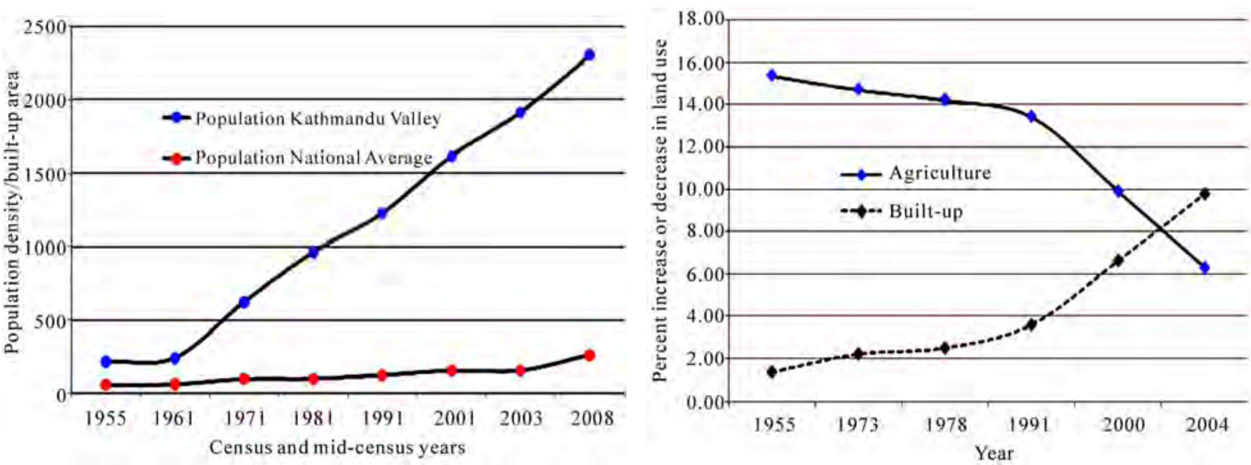


(b)

Figure 4. (a) and (b) Earthquake intensity and building damages.

nology suffer the most damage because of their low tensile and shear strength when the ground shakes at a higher scale. Because of the low tensile strength of materials used to build temples and monasteries, if an earthquake occurs, people living close to these structures would be more vulnerable than individuals were during the 1934 earthquake due to overcrowding and increased population densities. Today, a growing number of people are living close to low tensile structures, which were previously only located in tranquil and contemplative environments away from settlements. Successive waves of economic restructuring and population growth are reflected in the on-going development patterns of the Kathmandu Valley (**Figure 5**) resulting in rising land prices and sub-standard housing structures in the Valley [56] and urban sprawl into the hinterlands (**Figure 6**).

(a)



(b)

Figure 5. Kathmandu Valley: Once a fertile rice field (Aerial photo, (a)) has been turned into a concrete jungle (IKONOS image (a) as the Valley's population density is increasing at a much faster rate than the national average; (b) increasing the built-up area at the cost of agricultural land (b).

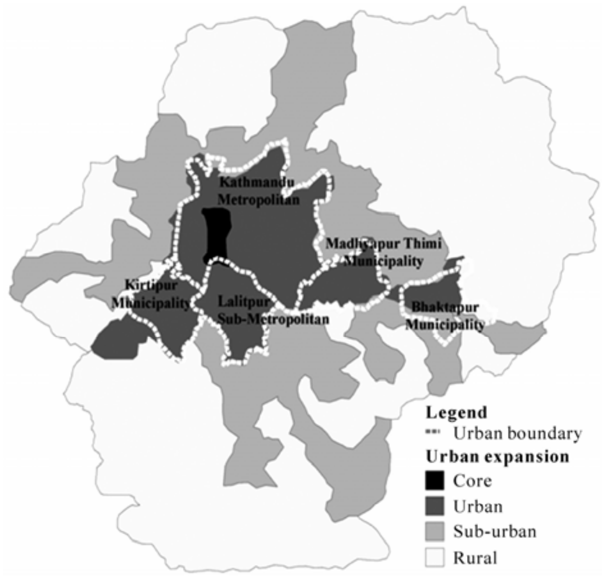


Figure 6. Urban sprawl into the hinterlands.

In the 1900s, Kathmandu was a small town with a little over 5,000 people [55]. In 1955, it comprised 100% of the total urban population of the country [57], and in the 1970s, Kathmandu had slightly more than 50% of the total urban population [58] as one of 33 urban centers in Nepal. In 2008, with over 58 urban centers, the Kathmandu Valley supports over 40% of the total urban population [59]. From 1955 to 2008, the Valley's population grew over 499% [40]. Currently, it accommodates over 750,000 people [59] and has become a macrocosm of South Asia comprised of many diverse socio-economic and ethnic groups. Due to the unplanned urban growth similar to many other developing countries of the global South, where "86% of the households face more than one threat" [60], contemporary Kathmandu dwellers face many risks due to unplanned structural construction practices, inadequate planning for road accesses, high population density [59,61], weak institutional capacities [62] and inadequate solid waste disposal facilities (**Figure 7**).

Figure 7. Problems of waste disposal (Source: http://www.kantipuronline.com).

5. Data

Our data utilizes the smallest geographical units for measurement, such as the housing patterns by dwelling types, vacant land, parcel lot and home sizes, and roads. These features are digitized from IKONOS (2004), WorldView (2008), Google and ArcGlobe images of 2008 and 2010. Multicolor IKONOS 2004 images were used to digitize structures from compact urban areas, while other images were used to capture structures of newly developed and in-filled areas. Demographic data, such as the average number of households and total number of people living in urban areas was obtained from the Census Bureau of Statistics (CBS) of Nepal. Administrative boundaries of metropolitan, sub-metropolitan and municipal areas are digitized from the 1:24,000 topographic maps obtained from the Department of Survey of Nepal's Government. Due to high costs, it was not possible to purchase 3D features from Voxel Corp. For example, a scene of 100 square miles that details road network costs over $ 50,000 to purchase, and $ 100,000 for a scene that captures detailed urban ensembles. Alternatively, we use 1 m × 1 m elevation data purchased from LandInfo (http://www.landinfo.com/) to build 3D structures of urban features. Using this data we examine population growth rates, housing densities, building plot sizes, hygienic conditions, and road accessibility to individual houses.

6. Methods

Urban vulnerabilities are assessed using: 1) population growth and urban density-intensification; 2) plot sizes and building structural compactness; 3) housing patterns and hygienic conditions; 4) available open spaces; and 5) emergency vehicle accessibility to residential houses.

7. Population Growth and Urban Density-Intensification

Population Population density of the Kathmandu Valley is increasing at a much faster rate than the overall growth rate of the country **(Figures 5(a)** and **(b))**. This growth is mostly concentrated in the urban centers (**Figure 8**). By 2008, the Valley's residential density grew more than 1,000 persons/ha and many new three- and four- story buildings are constructed on farmlands (**Figure 5(b)**) and on smaller open spaces to accommodate the increasing populations in densely built structures.

Although residential density in Kathmandu is lower than in Hong Kong (> 4,800 persons/ha) and Thailand (≈ 2,950 persons/ha), it is much higher than in the US suburbs (< 10 persons/ha), and is similar to Malaysia (1, 100 persons/ha). This increase in population has in-filled many open areas in the already-emerging "concrete jungle" of the Kathmandu Valley increasing the vulnerabilities of many urban areas (**Figuses 9(a)** and **(b)**). To make matters worse, new houses are continued to be built on any available space (**Figure 10**).

8. Plot Size and Structural Compactness

Although the recommended official plot sizes in the Kathmandu Valley are similar to those in Latin American Cities (plot size ≈ 100 m^2) which also have spontaneous settlements, such as *favelas*, *barrios*, and *colonias miserias*; observations from WorldView I, Google, and ArcGlobe images of 2008 reveal that many houses in the Khatmandu Valley are built on plots as small as 15 to 45 m^2. Adhikari [56] observed similar conditions, and following an analysis of housing density rates and housing costs, he concluded that accommodating over 600 persons/ha in compactly built structures is not economically beneficial (**Figure 11**).

Despite this significant relationship between housing densities and costs, smaller plots of land are often sold by private land brokers to meet individual buyer's economic (use-value) interests, and in many cases new houses are built at substandard levels, sometimes without the basic necessities [63]. For example, many reinforced concrete (RCC) houses are constructed on smaller plots ranging from 2-4 *anas* ≈ 63 to 127 m^2:1 *ropani* ≈ 16 *anas* ≈ 509 m^2; often without proper sewage outlets [56].

9. Housing Standard and Hygienic Conditions

The American Public Health Association (APHA) defines housing as a "safe dwelling unit with sanitary facilities fit for human habitation by governing the condition and maintenance (1971)." Mood [64] defines housing

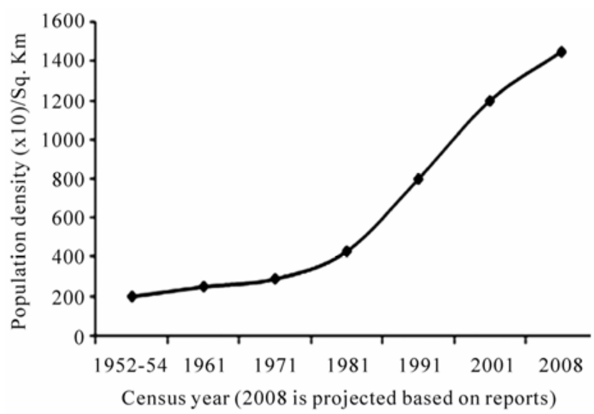
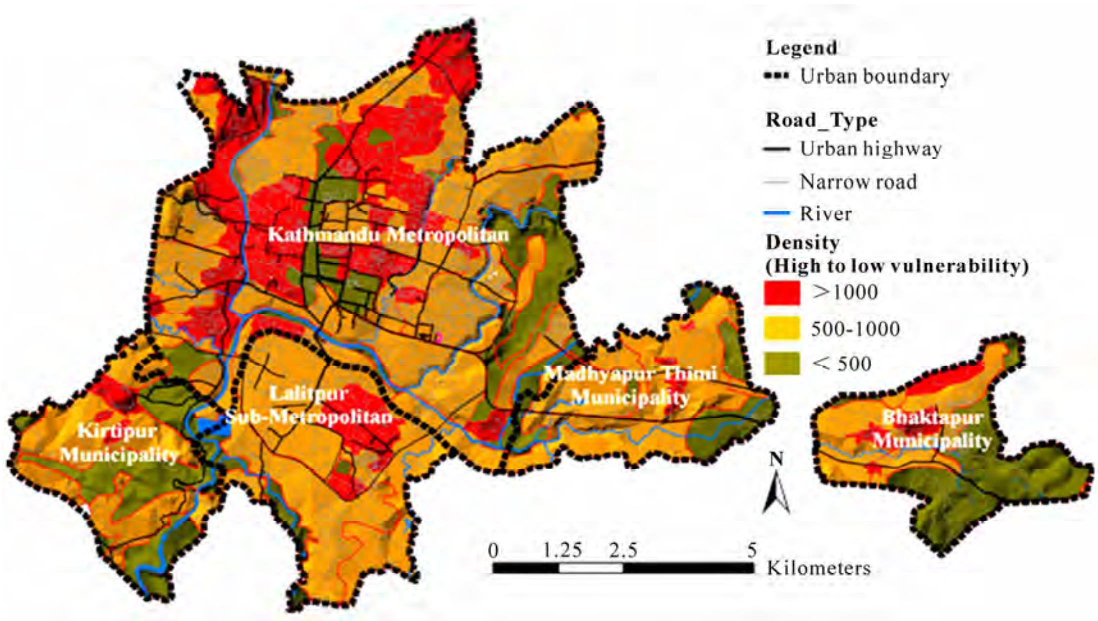


Figure 8. Urban population density.

(a)



(b)

Figure 9. Visualizing (a) low and high risk housing areas, and (b) housing population densities. All compact areas are extruded in ArcScene to reveal their vulnerabilities, in the event of an earthquake.

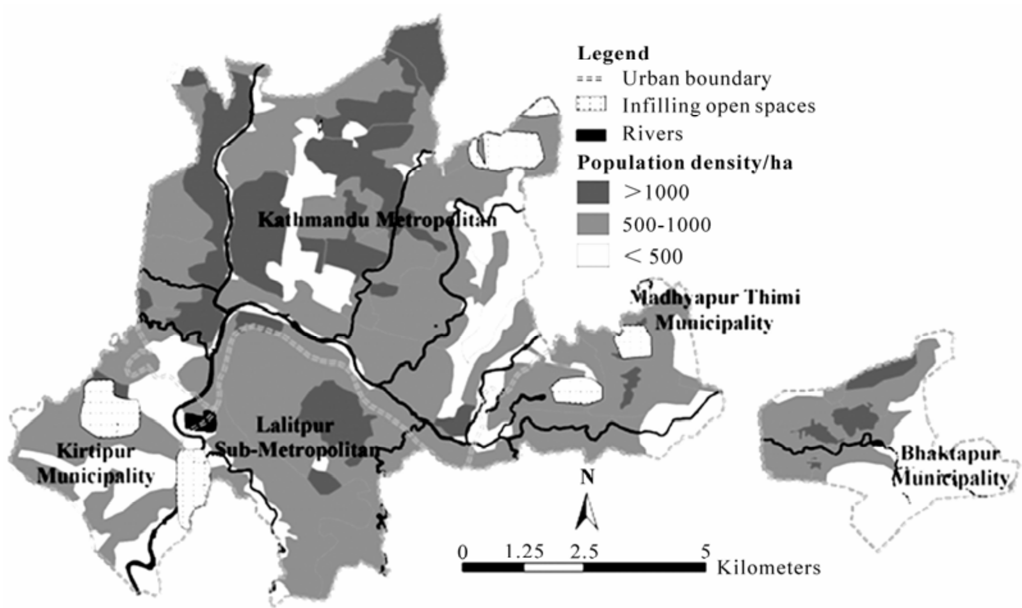


Figure 10. Infilling of built structures in the Kathmandu Valley.

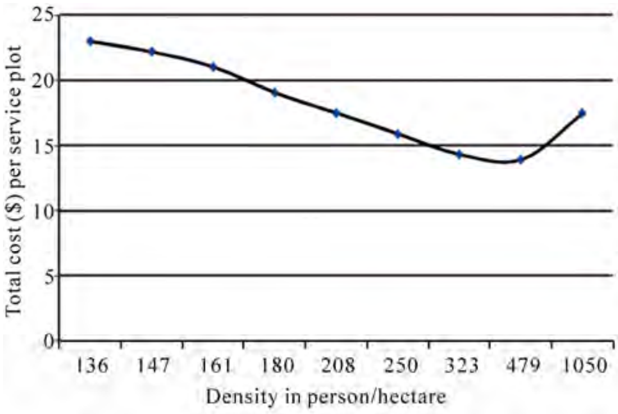


Figure 11. Plot size and cost of land (Modified from Adhikari [56] including land prices of obtained from the Land Reform Office, Kathmandu).

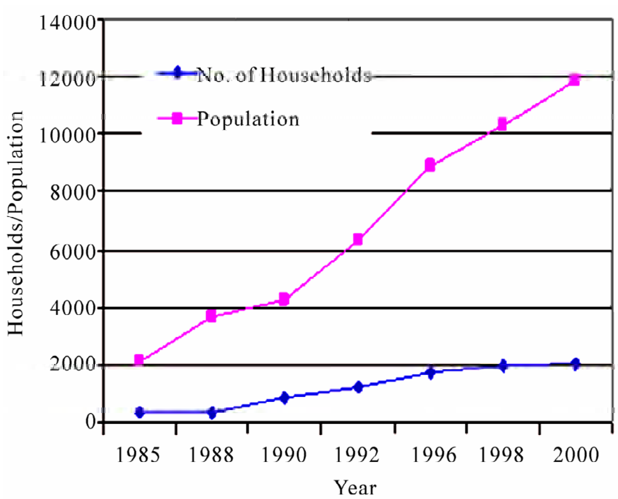
as "necessary to safeguard the health and welfare of the occupants of the dwelling and the persons residing in the vicinity of the dwelling." Most of the spontaneous and institutional types of houses built with local materials (**Figure 3**) in the Kathmandu Valley do not meet "the required health, safety, seismic scales and external environment" [56]. Many buildings are built with scant regard for regulations, such as building codes and municipal regulatory controls. Some residential buildings are constructed on 400 m^2 land, occupying up to 51% of the plot with < 4 m from the front and back boundaries of the plot, and < 3 m from the sides of the plot boundary. Other buildings are constructed on plots of 200 m^2 with a maximum permitted built-up area of 55% leaving at least 3 m in the back and 2.5 m in the front. Also, within this spontaneous typology are government institutional buildings constructed on plots > 900 m^2 with at least 5 m distance between the houses and with 7 m at the front and back boundaries, and 5 m from either side. Such modern expensive buildings with hyperbolic parabolic roofs, large concrete cantilevered beams and slabs, and concrete steel structures designed with modern engineering methods are very common on smaller plots [56]. A newly emerging architectural trend of decorating building façades with numerous "false" elements such as double columns, bay windows, and sloped roofs, often makes buildings vulnerable to earthquakes due to the lack of structural connection with the building framework. The differences in the building (and floor) heights, materials and construction technology in new constructions, are likely to produce a "pounding effect" vis-à-vis adjacent houses in the event of an earthquake [50].

Housing standards are not strictly followed, as the existing legislation is simply inadequate and ineffective to curb such practices. A house with a 30 m^2 floor-space needs at least a 40 m^2 plot to accommodate a family of six. The majority of the houses in the Kathmandu Valley do not adhere to these requirements. As a result, people live in overcrowded and often dangerous conditions. An analysis of residential housing units from WorldView I images of 2008, following Lo [65] model, reveals that on average, three-to-four people share a room of 12-15 m^2. Small, irregular-sized houses within sturdy "housing compounds", designed for security reasons, commonly serve as garbage sites and dust bowls in the dry season and filthy-water ponds during the rainy seasons. This problem is further exacerbated when seepage from individual septic tanks leaks through the residential compound walls that interface with and front adjacent narrow roads [56]. Additionally, drinking water pipes often follow the narrow winding streets and run parallel to sewage pipes making service maintenance difficult [63].

Sub-standard, yet often exorbitantly-priced housing has increased property and land prices, making most housing unaffordable to the common Nepalese and leaving them with no other alternative but to squat on open lands. A comparative assessment of the IKONOS 2000, Quickbird 2003, WorldView I, Google and ArcGlobe images of the Valley taken in 2008 reveal the mushrooming of spontaneous slum settlements along the riverbanks and open spaces (**Figure 12**), [52]. These houses are constructed along the ecologically sensitive and marginal areas, such as riverbeds and lowlands, and along dangerous or untenable flooding areas without proper access to clean water. In most instances, these houses are not accessible by motor vehicle. Furthermore, squatters often occupy national heritage sites such as temples and monasteries [66,67], or live near waste-dump sites, making them extremely vulnerable to life-threatening events and conditions.

Many houses in the Kathmandu Valley store garbage in large polythene bags, which are then thrown outside to lie uncollected for long periods of time in the adjacent open areas. This practice of open dumping is not only unsightly, but also serves as a breeding ground for diseases, posing a constant health hazard for the surrounding population. Many dumpsters or garbage collection sites are close to sensitive ecological areas, such as drinking water sources. Thus, these effluent discharges pose health challenges [68] from the daily discharged waste (1091-1155 m^3/day or 245-260 tons/day in the valley). Waste is not collected from dumping sites on a regular basis due to opposition from landfill sites. Similar to the case in Mexico City where garbage disposal has become an effective political tool [69], garbage disposal in the Kathmandu Valley is not only a political tool, but has also made living conditions more difficult by creating new health hazards. The situation becomes much worse as new consumer products-many with unnecessary packaging, plastics and styrofoam-enter into Kathmandu's "modernizing" market every day. The protestors of the landfill sites often agitate against the municipal authorities like those that occurred in Philadelphia (1986), New York City (1990), Toronto, Ontario

(a)



(b)

Figure 12. (a) Locations of squatter settlements along the low level river banks (Pradhan & Perera) [52]; and (b) number of households in different years (http://emi.pdc.org/cities/CP-Kathmandu-08-05.pdf).

(2002), Chicago (2003), Vancouver, British Columbia (2007), Athens, Greece (2006), Alumfiecer, Spain (2007), Naples, Italy (2008), and Oaxaca, Mexico (2009) (Moore, [69]. In the Kathmandu Valley, the more unorganized the garbage management becomes, the more it becomes a political act. Similar to Castro-Gomez's [71] call for an "ideal of synthesis" between science, economic growth, and aesthetic development (p. 139), some local Valley political parties consider debates related to garbage disposal as a Marxist "dialectic discourse." As the dialogue goes, dumping garbage on the available open areas has become a practice of Kathmandu's dwellers.

10. Open Spaces

Each household needs some open space for a healthy environment and an escape-route to safety in the event of a disaster. An open space is defined as the ratio of circulation area divided by the total area that is specific to cultures and places. Parks and playgrounds, schools and colleges, hospitals, public transportation, telephone lines, sewers and discharge pipes are considered open spaces. Caminos and Goehert [72] recommended an open area of 150 m^2 per 10,000 m^2 of built-up area, while the World Bank housing project recommends 20 to 25% open space for a built-up area. For the safety of an individual, a 2 m^2 space is needed. In general, 5-10% open space is needed for housing purposes; however, the unplanned housing schemes in the Kathmandu urban areas leave few open spaces producing conditions far below any Western standards. Even in Manhattan, New York, an average of 19.2 m^2 of natural area is available for each skyscraper; in London, the number is 30.4 m^2 for each building accounting for the city's surrounding Green-belt spaces; in Paris, it is 12.2 m^2; and in Tokyo, it is 2.1 m^2 [70].

These aforementioned numerical values of "open space", however, may not be the best measures when evaluating "accessibility" and its efficiency and cost- effectiveness as it pertains to a metropolitan area's housing growth and development. For example, only 12-16% open spaces are maintained in Singapore, but all houses are accessible by emergency vehicles. Nonetheless, for cities like Kathmandu to serve 2- to 4-story spontaneous and institutional housing styles, sufficient open spaces are needed to rescue people from possible seismic vulnerabilities. Given the seismic vulnerability of the Valley, contemporary planners in the Valley suggest a 40:60 ratio, for built-up and non-built-up land, by 2021, which will be higher than the 32:68 ratio that planners envisioned in 2001. A detailed analysis of the Kathmandu Metropolitan area from the WorldView I, Google, and ArcGlobe images of 2008 reveal that it is almost impossible to meet this goal given the diminishing number of open spaces resulting from the infilling of housing in small open spaces (**Figures 5(b)** and **10**). Additionally, the loss of open spaces and vegetation (**Figure 5(b)**) due to conversions into sub-standard buildings, has not only hindered vehicular accessibility to houses, but also has made the bowl-like geography and generally low wind- speed valley, become a sink for pollutants during the winter seasons [42].

11. Road Accessibilities

The The UN has long defined a housing standard as a "measure of accessibility, at a given time and place and in a given set of cultural and economic conditions" (73: p9). For good connectivity and the movement of people and goods, both within urban areas and between urban centers and hinterlands, effective transportation networks are essential. However, narrow streets and cul-de-sacs limit vehicular accessibility to individual houses. A classic example of the "Tragedy of the Commons" is evident in Kathmandu, due to individual households' thoughtless efforts to maximize the private use of their entire property, at the expense of the common good [56]. In the inner areas of the Valley's city centers, the narrow streets (≤ 2.5 meters) and sturdy wall fences erected for security reasons are posing problems of accessibility (**Figure 13**). In the absence of sufficient rules and/or the lack of implementation, inner-city land plots have been subdivided to maximize profits, and such action has further narrowed the width of roads.

Western-style suburbs with large open spaces are unavailable in the Kathmandu Valley due to high population to land ratios, and the preponderance of low income conditions among a majority of residents. In western countries, roads are categorized by their widths and services they provide; for example, collectors (8 m width, serving over 150 houses with 10.5 right-of-way), secondary (6 m width, serving at least 15 houses with 10.5 right-of-way), and local (4 m width, serving 25 houses with 5 m right occur.

12. Patterns of Vulnerability and Resilience across Urban Areas

In Nepal, urban vulnerabilities are the result of poor planning. Local planners routinely deal with issues of slums, squatters and low-income housing, and overburdened infrastructure issues, not to mention the problems of working within a corrupt political and inefficient bureaucratic environment. Politicians routinely get their votes from the slum and squatter dwellers and keep planners and bureaucrats engaged with immediate problems rather than having them find long-term solutions [5]. Many planning decisions are made administratively, which are often influenced by backroom political pressures. Even when a physical plan is finally approved, individual builders often build their own projects in an organic fashion (unplanned) that routinely result in haphazard growth [5]. Because of such unregulated urban planning, quality of life issues such as the environment and social sustainability, rarely make it on to the agendas of the Valley's urban planners.

Planners have been dealing with the complexities created by the ever-changing societal needs, market and economic forces, and conflicting interests among various stakeholders. Mitigating urban vulnerability in such environments is difficult, and planners routinely experience a "planner's fatigue and burn out" from their work [5]. Though planners may attempt to achieve their goals with highly engineered processes, engineering alone will not solve problems such as jammed road networks (**Figure 13**) and poor accessibility (**Figure 14**).

Accessibility needs to be given the highest priority, because it is not only important for business but also to evacuate people in cases of emergency. Unfortunately, the occurrences of accidents, vehicle breakdowns, road closures due to road works and political agitations are

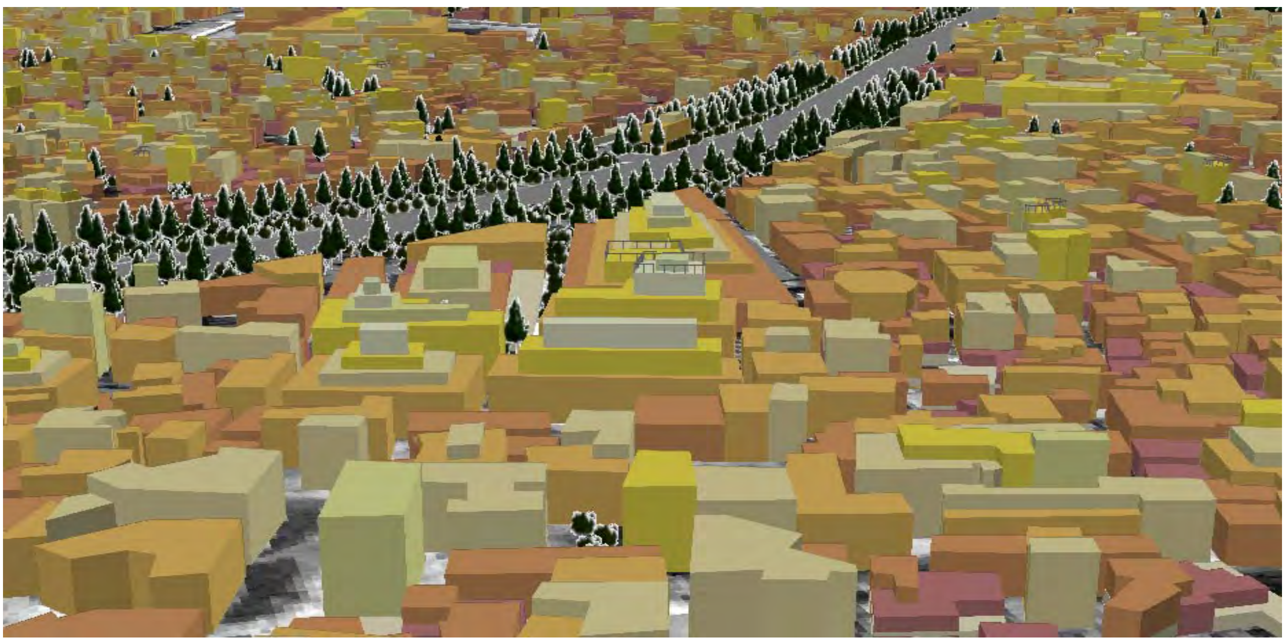


Figure 13. 3D visualization of housing typology without proper accesses by emergency vehicles (New Baneshwar area of Kathmandu digitized and converted into 3D).

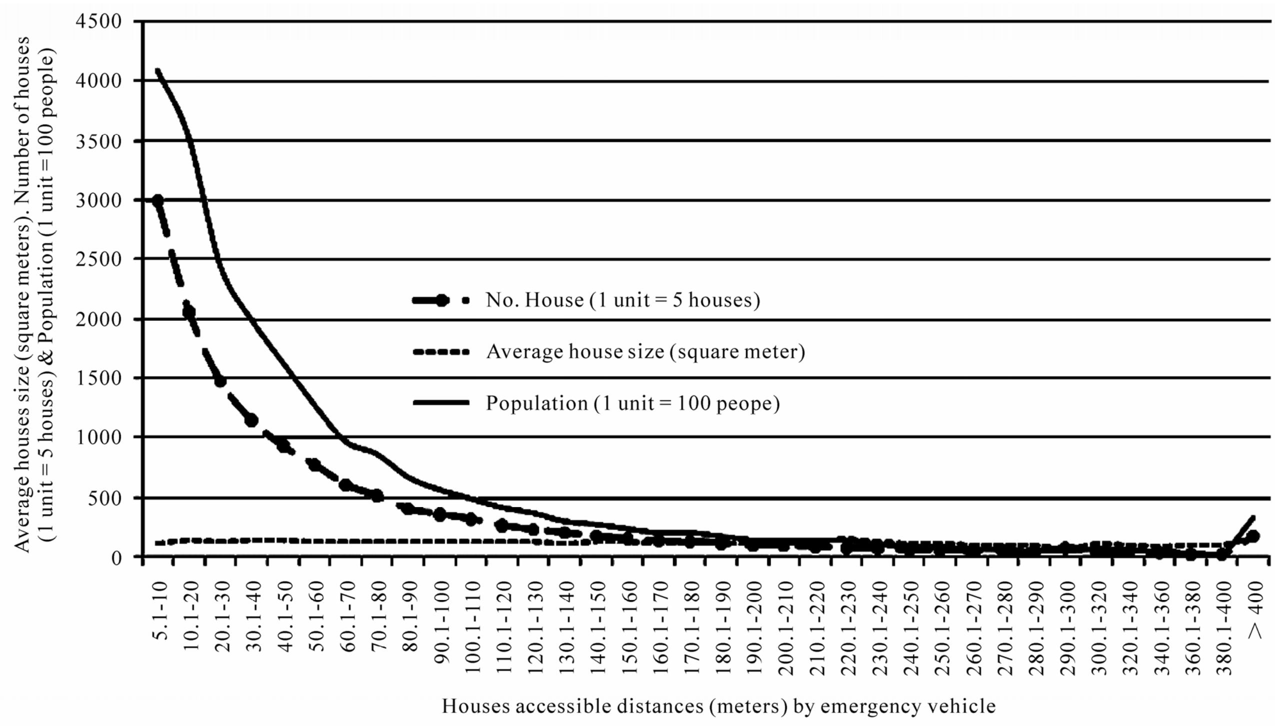


Figure 14. Distances to individual housing units from serviceable roads. Average plinth areas of houses were estimated from WorldView I and Google images of 2008, population for each housing dwelling unit was estimated following Lo (2006) "Dwelling Unit-related Demographic Models" (p. 351).

common problems on narrow roads. Despite traffic jams on narrow roads, more vehicles are registered than the transportation network can accommodate. For example, over 181,000 new vehicles were registered during 2005-2008 [74], but only a very small increase in road length was added to the existing 1,319 kilometers of road length over the same period. Each year, many houses are added by filling-in open spaces (**Figures 5(b)** and **10**). Politicians often favor their constituencies and pressure bureaucrats and planners to add more urban ensembles, in order to demonstrate their short-sighted promises made during the election periods. Political leaders often make false promises while campaigning when the mass gatherings of their supporters prompt such political pandering. Planners then bow to the pressures of these politicians, letting building code standards and their general plans go by the way side.

The 3D visualization techniques we use and advocate therefore may help planners to effectively visualize the cities (**Figure 13**) they are responsible for; and ultimately, convince them to implement more eco-friendly and sustainable policies [75]. Currently, these 3D data models are being developed on smaller scales, which are helpful when dealing with boundaries, neighborhoods, and co-boundary cells [30]. In order to display the topological relationships for large-scale areas, Chalmet *et al.* [76] developed a 3D graph model. Instead of representing the topological relationships between node, arc, face, and body, these graph models present the topological relationships among 3D objects [77] and 2D objects. These models represent the adjacency, connectivity, and hierarchical relationships among buildings and street networks to provide navigation guidance for an escape. Acquiring accurate location information is challenging as many buildings block GPS signals, however, geocoded addresses may help to accurately locate spatial objects.

In such a 3D model, geocoding converts descriptive location information into geometric coordinates. The geometric coordinate information can be applied in the 3D for route finding problems by identifying the shortest path from a single source to all other nodes in a network. It utilizes multi-layer building morphology data, shapefiles, digital elevation models (DEM) data, and remote sensing data to develop a complex 3D city model. Such 3D city models can be utilized to analyze a variety of parameters including building occupancy, frequency values and socio-demographic patterns that highlight areas and objects exposed to various levels of threat. By combining function-specific grids with 3D exposure levels, we map potential threat areas. These specific threat levels can be combined with additional socio-demographic or infrastructure data to further geo-visualize risk prone and safer areas to alleviate urban congestion.

13. Alleviating Urban Congestion to Minimize Vulnerability

We identify urban vulnerabilities in the Kathmandu Valley resulting from unplanned developments with irregular, substandard, and inaccessible (by emergency vehicles) housing patterns, coupled with waste disposal problems. Approaches taken by the past governments to alleviate urban congestions outside the Kathmandu Valley, such as, "Creation of Five Regional Divisions and Decentralization of Power," and "Relocating Educational Institutions" have unfortunately failed. None of them have successfully relocated any of the burgeoning urban population away from the urban concentrations in the Valley and none have reduced, or even satisfactorily addressed the unpredictable urban sprawl and growth.

Urban sprawl (unplanned growth) and growth (planned growth) often happen during economic booms, but in the Kathmandu Valley, rapid urban sprawl and growth occurred as the Maoist insurgency escalated in the countryside beginning in 1996. The threatened rural people responded by migrating into the Valley for safety. As a result, the lack of any planning is exaggerated, leading to inappropriate land-use, increased traffic congestion, persistent and increasing emissions of green house gases, longer commute times for shorter distances, increased dependence on imported goods and fossil fuels, worsening water pollution, loss of open space, unmanaged waste disposal, political upheavals, road network overloads and institutional "grid-lock".

There are cities such as Las Vegas, where a 238% urban growth occurred between 1990 and 1996 [78]. However, Las Vegas is comparatively "well planned", whereas Kathmandu Valley is growing organically despite experiencing a slower growth rate than Las Vegas. Long overdue in Valley planning logistics is a need to not only reduce traffic jams and to conserve open spaces, but also contingency plans and infrastructural re-alignments that will enable the authorities to evacuate people in the event of a high intensity earthquake like that of 1934 in Kathmandu and of January 13, 2010 in Haiti. Kathmandu's seismic condition is as vulnerable as that of Haiti. While earlier it was firmly believed that rapid urbanization would bring increased development, now, it is time to weigh the values of safer and healthier communities and green space against the consequences of unbridled, development. There is an urgent need to reverse the process of urban congestion through counter migration by decentralizing many power centers from Kathmandu to elsewhere. Limited open spaces of the Kathmandu Valley are today occupied with in-filled infrastructures with inadequate, poorly-constructed housing, and deteriorating local environmental conditions. In the foll population might be resettled and moved owing paragraphs we present various options on how the Valley to other areas.

14. Strict Imposition of Building Codes

Urban vulnerability in the Kathmandu Valley is due to physical events (seismic hazards) and societal conditions (substandard house and unplanned layouts). Though seismic hazards are very dangerous, socioeconomic and political systems play even a larger role in creating vulnerabilities for the population. As these natural processes cannot be changed, the practical solution is to address the hazards resulting from socioeconomic and political systems. In most parts of the Kathmandu Valley, buildings stand side-by-side on narrow alleys. Fire brigades and ambulances are unable to provide services (**Figure 14**) [79] and in the aftermath of a big earthquake, it will be difficult to provide emergency services due to the accumulation of debris on narrow roads. Even hospitals, schools and public offices are not earthquake-resistant [47]. Public awareness about earthquake safety, enforcement of building codes, and proper training of masons to build standard houses is essential. In the Kathmandu Valley over 90% of the houses are built by masons, however, only 10% are supervised by trained engineers [47]. Many engineers are needed to ensure an effective implementation of building codes for the safety and security of the Valley residents.

Nepal has acknowledged the need for earthquake safety measures-especially after the International Decade for Natural Disaster Reduction (1990-2000) and has initiated various strategies at the national level including retrofitting of schools, preparation of emergency hospital plans, and conducting training sessions to address the challenges faced in the aftermath of an earthquake. However, these plans have become paper tigers. For example, the 1995 Kobe earthquake in Japan, has clearly demonstrated that preparedness and emergency plans in hospitals alone are insufficient if it is not possible to keep equipments, staff and electricity running during an emergency. Learning lessons from the recent Haitian disaster is essential. Additionally, strict quality control on construction work and building materials including bars in slabs and columns is essential [50].

On the development front, a combination of disaster-relief programs and responsible (re)development techniques need to be introduced and implemented through flexible means of incentives, consensus, and awareness programs, rather than by rigid laws. On the legal and institutional front, an independent disaster management institute managed at the federal level and backed by legislation to formulate earthquake mitigation techniques, emergency response plans, and post-reconstruction programs to coordinate various concerned agencies is essential. The community's preparedness could be improved by retrofitting the existing buildings, developing rescue and response plans, and educating and training those involved in the building industry. Such efforts, together with increased public awareness at the household level could help develop a culture of building earthquake-resistant cities and disaster-responsive societies. Once individual households are made aware, it will be possible to develop model houses (*Namuna Gharharu*) that preserve the traditional architectural styles recognized by UNESCO.

15. Conserving Urban Spaces

In many developed economies, a number of communities are now purchasing environmentally sensitive land or farmland to prevent uncontrolled development. However, such an approach is not feasible for the Kathmandu Valley due to the high cost of land. Also, unstable political conditions do not support such moves. Nonetheless, the government can enforce laws to prevent the building of substandard houses on open spaces.

While such a law has been passed recently, the outcome of this rule is yet to be seen. Another example Nepal can learn from is the Communist government of Vietnam's decision in the 1970s to ban rural-to-urban migration. In 1949, the Chinese government strictly enforced and restricted in-migration by implementing stringent residency permits to control rural in-migration to the biggest cities. Limiting the number of citizens who could be registered as urban dwellers restricted the number of individuals moving to cities to find better jobs. The registration program was supported by the rationing of food only to those in possession of urban household registration documents. In the absence of any significant black market, these measures proved highly effective in slowing the rate of rural emigration [80]. Such approaches could be implemented in the Valley to stop further overcrowding and minimizing urban vulnerability and even improving city efficiencies and aesthetic conditions.

16. Improving Urban Efficiency

Kathmandu's urban patterns, its socioeconomic status, and demographics are a challenge to the successful implementations of innovative (re)development plans. However, some experiences from other countries could be helpful in improving the cities' efficiencies. One such approach—Haussmannization (named after Baron Haussmann, a Paris-based urban planner of the 1940's)—was followed by the French government to improve the cleanliness and appearance of Paris streets. Roads were widened roads and proper buildings were realigned. The US government in the 1950s and 1960s, implemented urban renewal plans backed by billions of dollars to dismantle old buildings and properly realign them along improved roads and housing patterns [81]. Likewise, in the 20th century, a social equity plan was implemented in New York City, USA. This plan allowed only a certain percentage of any given lot to be occupied by tenement buildings and strict building codes were followed. Such buildings provided much needed facilities to renters [81]. The Chinese government took a different approach to control urban congestion. When the Communist Party assumed power in 1949, many people were living in terrible slums. Cities were filthy with inadequate sewage facilities, water supplies, and garbage collection. The Communist government dramatically altered the Chinese cities by cleaning them up and providing standard housing for everyone. Rural-to-urban migration was strictly regulated. While the Chinese approach *per se* might not work for Nepal due to a different government system, cleaning the cities as was done in China, and regulating rural-to-urban migration would help to improve the city's efficiency, and control urban over congestion. A zoning method practiced in Frankfort, Germany in the late 19th century was used to control land use based on land suitability classes [81]. In capitalist economies these programs are self-sustaining financially, where the governments first purchase the lands and do planning to improve efficiencies, and then resell the lands at higher costs. Though some of these approaches may be possible for the Kathmandu Valley, substantial foreign aid is required. While it may sound unrealistic to look for foreign aid to dedicate to internal city planning, significant improvements could be made with foreign aid to prevent potentially disastrous conditions such as those in Haiti following the 2010 earthquakes. Nepal will need foreign aid to improve city efficiency. It is a matter of time- now or later after the destruction. Along with the improvement of city efficiencies, shifting Kathmandu's over crowded population elsewhere by creating new cities and shifting the country's only international airport to other location and/or creating new international airports in other parts of the country could be some of the options to alleviate Kathmandu's urban vulnerability.

17. Creating New Satellite Cities

Like the cities in the Kathmandu Valley, Cairo, Egypt became overpopulated, woefully deficient in urban services, and had a high unemployment rate beginning in the late 1960s. In an attempt to improve conditions in the city center, the Egyptian government began creating new towns and jobs outside Cairo [81]. Implementing a similar plan, the Nepalese government developed Five Development Centers, namely Eastern, Central, Western, Midwestern, and Far Western in the late 1970s. Unfortunately, these centers did not attract citizens due to the highly centralized power structure of the Nepalese government. The 1970s approaches failed to attract people away from Kathmandu due to a lack of planning and organization. Following the formation of the multi-party democracy in Nepal in 1990, several universities, technical institutions, and medical facilities were opened outside the Kathmandu Valley with the hope that new cities would be created and the Valley's population pressures would decrease. To some extent this approach has been successful in attracting businesses due to the low cost of land and proximity to several Indian cities near the southern border. However, these cities have failed to attract a higher number of residents due to a lack of job opportunities and inadequate access to international markets. To make matters worse, beginning in the late 1990s, security in virtually all of the cities outside Kathmandu was compromised as a result of the Maoist insurgency. Improving transportation to create increase connections between these outer cities and Kathmandu may help to improve security and ultimately facilitate out-migration from Kathmandu or even to daily commute to Kathmandu for official work. Several European countries have successfully reduced the overcrowding and traffic jams in urban cores by implementing various transportation policies and facilitating people to commute by public transportation services.

18. The Western European Transportation Model

Several transportation models adopted in European countries have been successful in alleviating traffic jams in the main urban areas. For example, the cities of Bergen in Norway have successfully decreased traffic by 7% with the introduction of a Kr. 5 ($ 0.80) toll per vehicle, per day, for entering the city center. A similar approach in Oslo minimally reduced traffic by 3% despite a higher Kr. 10 ($ 1.60) per day, per car [82]. In Singapore, a similar approach successfully reduced traffic congestion. The low rate of success in Oslo may be attributable to lower price elasticities, due to the lack of transportation alternatives available to the motorists for long-distance trips.

In Central London, a charge of $ 1.00 per day reduced automobile traffic by 45% and increased speeds by 40%, and the benefits were estimated at $ 50 million per year. Approximately, 15% of the revenues were used to pay for the enforcement and administration of the plan. This improvement in traffic reduction was possible with the reinforcement of other policy improvements such as rail infrastructure, bus service, park and ride provisions, and environmental traffic management [82]. The 40% decrease in car traffic has resulted in reduced fuel consumption and a 15% reduction in carbon dioxide emissions. However, the introduction of such a system raises the question of how to equip vehicles with a levy system to ensure payment [83], as well as issues of privacy and freedom of travel [84]. Low income travelers supported the idea of charging taxes to private vehicle owners [85].

Other measures that can be applied to control traffic include: 1) parking control, 2) physical reallocation of road space, and 3) regulatory controls using permits or other restrictions on car use. The practice of reallocating road space to other users, such as buses, failed in Nottingham, UK, in 1975 due in part to an increase in the cost of bus travel [86]. Yet in several Italian cities, grant permits were needed to enter certain zones, and in Athens, Greece, an "odds and evens" scheme was implemented in which odd-numbered cars were allowed into the city center on alternate days of the week and even-numbered cars on the others. Such schemes can, in principle, achieve any pre-specified reduction in car use. However, there are possibilities of producing fraudulent permits, and a simple scheme such as "odds and evens" is not guaranteed to allocate road space to those who most need it. In Nepal, when government car plates are converted into private plates and vice versa, such an "even and odd" number approach could fail easily. Athens also adopted a complex traffic checking process using electronic barriers in which a machine would detect a certain vehicle and would raise a barrier to stop a car from crossing into a certain area without paying a levy [87].

Given the unruly state of the Kathmandu Valley, where almost every day roads are jammed as the result of a minor car accident or political demonstrations, the models discussed above may not work without maintaining strict law and order. In the late 1970s, a ring road was built in the core peripheral areas, which at first reduced core area traffic. Currently, almost all of the areas of the old ring road are filled with new structures. The opening of a new ring road in the hinterlands of the Kathmandu Valley (**Figure 15**) may help to alleviate the Valley's core congestion problems for now, but the situation may very well repeat itself unless other regulatory measures are implemented. Significant changes in regulatory power, including 3D methodological assessment and enforcing building codes to ensure optimal road development is a recommended forward-looking policy. Such an approach would create the opportunity for the gentrification of neighborhoods, urban renewal, mixed land use development, and restoration of heritage sites.

19. Conclusions

In this paper, we have: 1) analyzed the spatial arrangements of houses in the Kathmandu Valley and identified areas with high, medium and low risks, based on the spatial arrangements of houses; 2) visualized urban ensembles in 3D views for some selected urban areas and explained how these crowded cities with sub-standard houses may prove fatal, if there is a disaster similar to the earthquake of 1934 and/or similar to that of Haiti in January, 2010; 3) analyzed the accessibility scenarios to different locations and found that many of the housing units are not accessible by emergency vehicles; and d)

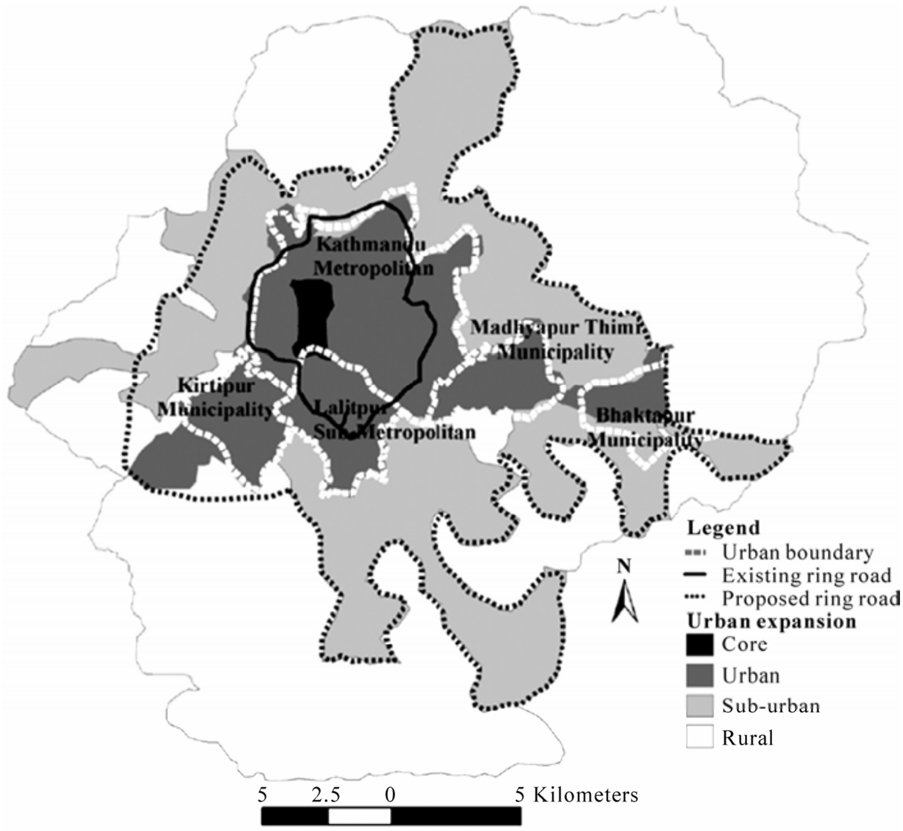


Figure 15. Proposed ring road in the Kathmandu Valley to depopulate urban core.

explained the merits and demerits of 2D and 3D data models to visualize transportation networks and a 3D road network to undertake vulnerability analysis. We conclude that without improving housing spatial distribution and the transportation network, urban vulnerabilities are likely to increase. In summary, we have identified vulnerabilities; second, we have analyzed divergent perspectives on urban vulnerability in order to test related theories and hypotheses to improve our understanding of the linkage among various urban ensembles and vulnerabilities; third, we have explained how important it is to work for integrated solutions to alleviate urban congestion; and fourth, our approach of 3D visualization of urban ensembles should help to accurately evaluate and quickly implement emergency response plans to reduce the risks to the affected urban populations following a natural disaster. Developing geospatial data in 3D will help to analyze emergency situations, and also offers spatial analytical and modeling capabilities to facilitate better planning and decision-making. We believe our paper's approach will lead to a better understanding of the dynamic nature of urban ensembles in such overcrowded urban core areas like the Kathmandu Valley, and will add to the spatial-scientific evidence that is necessary to improve planning and the implementation of solutions. One methodological limitation of this research, discovered while conducting our 3D data analyses, is that we were unable to accurately locate all objects/evacuees at certain specific locations, because GPS does not work efficiently within multi-level structures due to degradation or loss of signal in certain areas/parts of such buildings and locations. In our future research we will attempt to address this methodological conundrum.

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20. Acknowledgements

This research was supported by the University Research Grant from the Office of Sponsored Programs and the College of Arts, Humanities, and Social Sciences at the University of Central Missouri (19-SU003). Special thanks go to Prof. Nanda R. Shrestha for his insightful guidance during the formative phases of this research. Dr. Darlene Budd deserves special thanks for her initial comments on sociopolitical and demographic aspects that helped to shape this research. We want to thank to Prof. David Rice of the Center for Teaching and Learning, University of Central Missouri for his encouragement and support in software and data acquisition.

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Journal of Geographic Information System, **2010, 2, 85-92**
doi:10.4236/jgis.2010.22013 Published Online April 2010 (http://www.SciRP.org/journal/jgis)

Orthorectification and Digital Elevation Model (DEM) Generation Using Cartosat-1 Satellite Stereo Pair in Himalayan Terrain

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Abstract

High resolution data have high relief displacement in hilly terrains. Development of Digital Elevation model helps to assess bio resources more accurately in such terrains. While estimating bio resources in the Himalayan hilly terrain using multispectral LISS-III data of 23 m spatial resolution, the need for orthorectifcation of satellite data was necessary to correct for spatial distances due to high undulating slopes. Therefore, Cartosat stereo pair based Digital Elevation Model (DEM) was generated using the Rational Polynomial Coefficients (RPC) supplied along with the data products. By using the DEM orthorectification of LISS-III was created. In order to evaluate the positional accuracy of ortho rectified LISS-III Ground control points were selected using the Global Positioning System in differential GPS mode. As there is variation in the spatial distances and height over few points, the GCP corrected DEM was used for ortho rectifcation of Cartosat PAN and LISS-III data. This paper presents the procedure followed for ortho rectification and digital elevation model generation using Cartosat stereo pair data. The result of the study indicated high spatial resolution stereo images helped generation of three dimensional mountainous regions more accurately which helps in estimating the bio resources using multispectral LISS III data.

Keywords: DEM, Cartosat, Stereo Pair, Orthorectification, Himalaya

1. Introduction

Stereo imaging from space-borne platforms offers information about terrain elevation besides supplying spectral reflectance of the scene. This greatly assists the analysis and interpretation of images in terms of identifying slopes, surface material, waterways, vegetation growth *etc*. Applications like urban planning, agriculture, defence *etc*., need to use Digital Elevation Model (DEM) derived from stereo images, which is an important component of geo-spatial data. With the launch of Cartosat-1, ISRO's first satellite with along track stereo capability in May 2005 by PSLV-C6 vehicle, a new possibility has emerged for remote sensing and Mapping communities. The high-resolution stereo data beamed from twin cameras onboard Cartosat-1 mission facilitates topographic mapping up to 1:25,000 scale [1]. The primary advantage of Cartosat-1 mission is seen as generation of Digital Elevation Model (DEM) for production of Orthoimage and 3D terrain visualization of large tracts of landmass at fairly large scale. The 10 bits per pixel radiometric resolution of Cartosat-1 sensors allows for improved discrimination of objects, which enhances the cartographic potential of the sensor. The satellite has shown a very stable attitude behavior, which in turn helps in realizing data products with low internal distortion.

Cartosat-1 is the first operational remote sensing satellite capable of providing in-orbit stereo images with 2.5 m nadir resolution and 27 km swath. The two payloads viz. PAN-Fore and PAN-Aft are designed with state-of-the-art technologies in order to provide images of high quality [1,2]. They are mounted in along track direction with fixed tilts of +26 deg (Fore) and –5 deg (Aft) respecttively to provide along track stereo, each with approximately 2.5 m ground resolutions.

Satellite Photogrammetry techniques have been extensively used by the scientific community in deriving high resolution DEM, Ortho image and terrain parameters such as slope, aspect, contours, drainage *etc*. Digital Elevation Model (DEM) has become an inevitable component in most of the remote sensing applications viz. infrastructure development, watershed management and development, hydro-geomorphology, urban morphology, disaster management *etc*. Keeping these applications in view, the current study aimed at exploitation of Cartosat-1 stereo data for various applications.

Rational functions models (RFMs) have gained popularity, with the recent advent of high resolution data supplying Rational Polynomial Coefficients (RPCs) along with stereo/mono data. Providing these coefficients along with stereo data, instead of delivering the interior and exterior orientation parameters and other properties related to physical Sensor, one can proceed to satellite photogram metric processes which approximate the sensor model itself. A detailed study of the RFMs for photogrammetric processing has been carried out by Tao and Hu [3]. Di [4] demonstrated different ways to improve the geo-positioning accuracy of Ikonos stereo imagery by either refining the vendor provided RF (Rational Function) coefficients, or refining the RF derived ground coordinates. Poon [5] focuses on Digital Surface Model (DSM) generation from high resolution satellite imagery (HRSI) using different commercial of the shelf (COTS) packages. They validated the stereo DEM with InSAR DEM for different land forms. Nadeem [6] validated DEM generated from Cartosat-1 stereo data.

Crespi [7] evaluated the DSM by comparing the heights of several buildings and points on the road axis derived from a large scale (1:2000) 3D map. Fracer and Hanley [8] demonstrated the wide applicability of bias compensated RPCs for high accuracy geo-positioning from stereo HRSI for a mountainous terrain. Chen [9] compared geometrical performance between rigorous sensor model (RSM) and RFM in the sensor modeling of FORMOSAT-2 satellite image. Dabrowski [10] evaluated DEMs generated with different numbers of GCPs from Cartosat-1 stereo data at large number of evenly distributed check points. Similar attempts to evaluate the accuracy of the DEM using different number of GCPs have been made by Michalis and Dowman [11] and Rao [12].

2. Study Area

The study area in Chamoli district lies in the northeastern part of Uttarakhand state (**Figure 1**). It is bounded by North Latitude 29º55’00” & 31º03’45” and East Longitude 79º02’39” & 80º03’29” and falls in Survey of India toposheet nos. 53 O, M and N. The geographical area of the district is 7820 km^2. Chamoli district the sec- ond largest district of Uttarakhand, is also important from strategic point of view as it shares its northern boundary with Tibet (China). Geologically the area be- long to the Lesser Himalayas and lies in a tectonic fore deep. The Lesser Himalayas are comprised of fanglomerates followed by bedded quartzites, slates, phyllites and low-grade schists. The rock types are ranging from green schist to lower amphibolite facies. The main rock types are schists, phyllites and quartzites.

Agriculture is the main occupation of the people. The agricultural activities are restricted to river terraces, gentle hill slopes and intermontane valleys. The major crops are rice, wheat, potato, pulses, millets and seasonal vegetables. Forest cover (58.38%) is the main landuse. Alaknanda river, Ramganga River and their tributaries drain the district. Prominent of the tributaries are Dhauli ganga, Birhi ganga, Nandakini, Pindar *etc*. The main drainage patterns are dendritic, sub-dendritic, trellis, sub-rectangular and rectangular. The major rivers are Alaknanda, Dhauli ganga, Pindar are of antecedent type, where the drainage in the structurally disturbed area of subsequent type.

The climate varies from Sub-tropical monsoon type (mild winter, hot summer) to tropical upland type (mild winter, dry winter, short warm summer). The northern, northwestern, northeastern and western part of the district is perennially under snow cover, here the climate is sub-arctic type as the area is represented by lofty Himalayan Range. Severe winter and comparatively higher rainfall are the characteristic features of the northern part.

Larger part of the district is situated on the southern slopes of the outer Himalayas, monsoon currents can penetrate through trenched valleys, the rainfall reaches its maximal in the monsoon season that spans betweens June to September. Rainfall, spatially, is highly variable depending upon the altitude. In the Lesser Himalayan Zone (1000-3000 m) maximum rainfall occurs about 70 to 80% in southern half. August is the rainiest month. Rainfall rapidly decreases after September and it is the least in November. About 55 to 65% rainfall occurs in the northern half in Central Himalayan Zone. About 17% of the annual precipitation occurs in winter season.

Chamoli district comprises of high hills and mountains with very narrow valleys, deep gorges having very high gradient. The northern, northwestern, eastern and northeastern part of the district comprises Tethyan Himalaya with snow covered throughout the year. Physiographically the catchment of Alaknanda River comes under Gangotri-Badrinath-Kedarnath Complex (*i.e.* Himadri, Greater Himalaya zone) shows Radial Drainage pattern.

The soils are natural, dynamic, heterogeneous, nonrenewable resource, which support plant and animal life. The tract of Chamoli district consists of outward successsion of ridges viz; Greater Himalaya and Lesser Himalaya of decreasing height. These hills posse very little level land. The soils have developed from rocks like granite, schist, gneiss, phyllites, shales, slate *etc*. under cool and moist climate. Very steep to steep hills and Glacio-fluvial

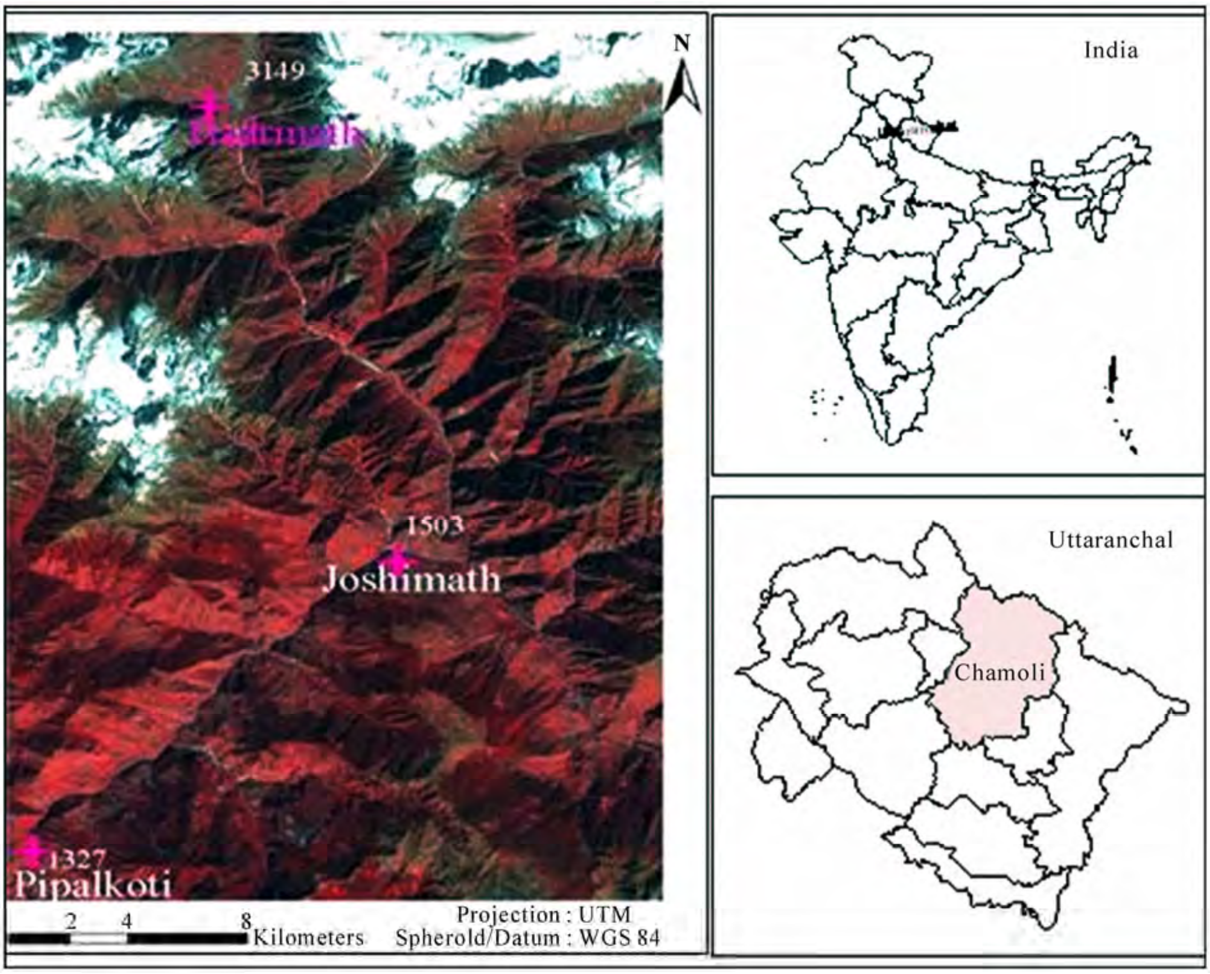

Figure 1. Satellite image showing study area.

valleys are dominantly occupied with very shallow to moderately shallow excessively drained, sandy-skeletal to loamy-skeletal, neutral to slightly acidic with low available water capacity soils. They have been classified as Lithic/Typic Cryorthents. These soils are in general under sparse vegetation. The Lesser Himalayan range is mainly composed of highly compressed and altered rocks like granite, phyllites, quartzite *etc*. and a major part of it is under forest. Intermittent sparse patchy terraced cultivation is also practiced on fairly steep hill slopes whereas dry and wet cultivation are prevalent on the uplands and low-lying valleys respectively. The broader valley slopes dominantly have deep, well drained, fine-loamy, moderately acidic and slightly stony.

3. Data Used

For Digital Elevation Model and ortho image generation from Cartosat-1 satellite data following data sets were used. The details of the Cartosat-1 data are given in **Table 1**.

4. Data Processing and Methodology

A standard methodology has been adopted for the generation of DEM and ortho Image as is shown in **Figure 2**. It comprises of reconnaissance survey and DGPS survey, establishment of reference station by network adjustment with IGS stations, establishment of a sub reference station with respect to reference station, establishment of GCPs with respect to sub-reference station, stereo data analysis using RPCs and updation of RPCs using GCPs, generation of DEM and Ortho image generation from DEM, accuracy assessment of DEM and ortho image, generation of DEM by refining Rational Polynomial Coefficients (RPCs) with different number and distribution of GCPs, validating the DEM, generating the DEM, Ortho images at the best check point RMSE.

The field data of base and rover stations were processed in DGPS mode using Leica's Ski-Pro. The field recordings were first transferred to the system and the points were assigned as reference and rover accordingly. Single point processing (SPP) was first done for the base points and

Table 1. Details of cartosat stereo pair used for DEM generation and orthorectification.

S. No.	Aft Scenes	Fore Scenes
1.	Satellite ID = CARTOSAT-1	Satellite ID = CARTOSAT-1
2.	Date of Pass = 09NOV2005	Date of Pass = 09NOV2005
3.	Sensor = PAN_AFT	Sensor = PAN_FORE
4.	Path = 0534	Path = 0534
5.	Row = 0258	Row = 0258
6.	Resolution along = 2.5 m	Resolution along = 2.5 m
7.	Resolution across = 2.5 m	Resolution across = 2.5 m
8.	No. of scans = 12000	No. of scans = 12000
9.	No. of Pixels = 12000	No. of Pixels = 12000

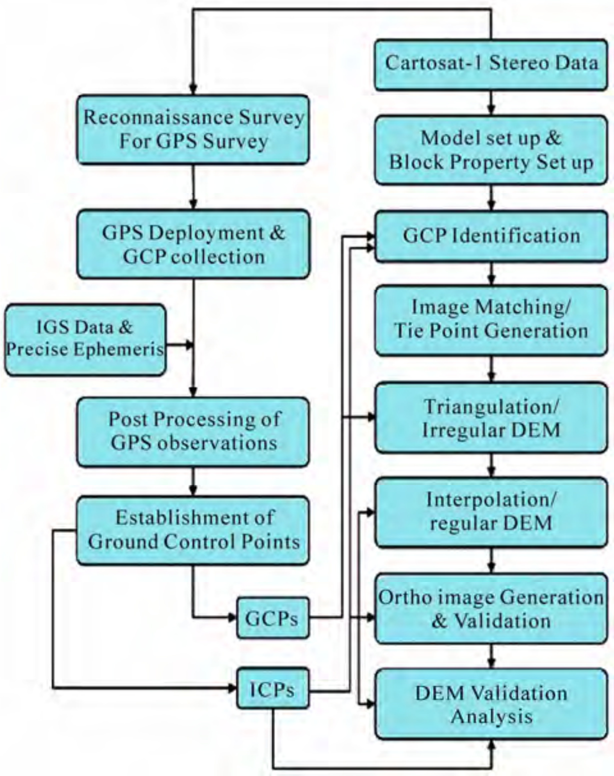

Figure 2. Flow chart methodology showing the detail procedure for DEM generation from Cartosat-1 stereo pair and orthorectification.

then the rover points were processed with respect to the base. The points which could not be accurately resolved were post-processed to remove ambiguities. However, only seventeen points could be determined precisely.

The fore and aft scenes of Cartosat-1 data were used to generate the Digital Elevation Model in Leica's Photogrammetry Suite with OrthoBase Pro. The scenes were provided with Rational Functions Coefficients (RPC). These coefficients are used to specify the geometric model, which defines the internal characteristics (*i.e.* internal geometry of the camera or sensor while capturing the imagery) and external parameters (*i.e.* original position and orientation of the camera or sensor).

The reference coordinate system is assigned a projection in UTM with spheroid and datum as WGS84. A block file is created in LPS and the two scenes added to the frame (**Figure 3**). The chipping coefficients are directly taken from the RPC text files provided with Cartosat-1 data.

Pyramid layers, based on a binomial interpolation algorithm and a Gaussian filter, were generated to preserve image contents and save computation time. Internal orientation is done to define the pixel coordinate positions of the calibrated fiducial marks within each image of the block. External orientation is done to define the position and orientation of the perspective centre. If very precise values (*i.e.* less than a meter) of exterior orientation are imported, the aerial triangulation process can even assigned a horizontal control as they were located beside cliff.

5. Results and Discussions

It was observed that while using only RPC information for Cartosat-1 stereo data, the error in height was in the range 124 to 286m**.** However, after use of GPS points and triangulation adjustment, the Cartosat DEM (**Figure 4**) becomes smooth and the error in height was reduced to 3 to 18m (**Figure 5**). It was found that accuracy of contours generated from Cartosat-1 stereo data was very accurate and close to ground height. Accuracy of DEM and ortho image was improved by triangulation iteration convergence option with less RMSE as shown in **Table 2**. The ortho image of Cartosat aft and fore image by DEM is shown in **Figure 6**. This Cartosat-1 stereo data can be used for height information generation at 4 m contour interval. The DEM generated from Cartosat-1 stereo data will be very much useful for topographic analysis in the field of water recourses, Landslide study, agriculture *etc*.

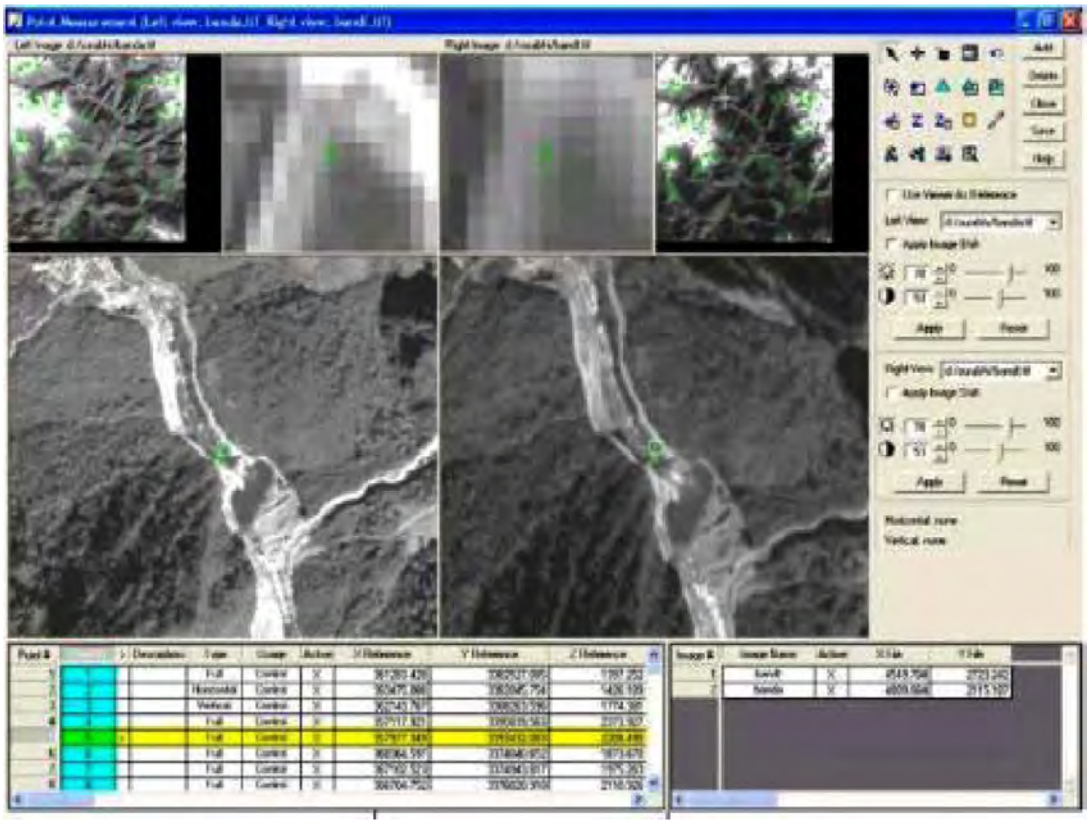

Figure 3. Generation of DEM and Ortho image generation in LPS.

Table 2. Details of triangulation summary showing RMSE error.

Triangulation Summary			
Triangulation Iteration Convergence:	Yes		
Total Image Unit-Weight RMSE:	0.2721570		
Control Point RMSE		Check Point RMSE	
Ground X	0.0711773 (10)	Ground X	7.4913788 (3)
Ground Y	0.3628044 (10)	Ground Y	7.3844452 (3)
Ground Z	0.0930104 (10)	Ground Z	6.8060341 (3)
Image X	4.6107092 (20)	Image X	0.4999596 (3)
Image Y	8.0061207 (20)	Image Y	2.8900647 (3)

The use of coarse resolution multispectral data of LISS-III (23.5 m) in the hilly terrain may not give accurate estimate of bio resource assessment due to high relief displacement. Therefore, the integration of the coarse resolution satellite data that of high-resolution satellite data (Cartosat PAN) after orthorectified helped in improving the accuracy of bio-resource assessment (**Figure 7**). The quality of orthorectification depends upon the quality of DEM. Therefore, high-resolution DEM needs to be used wherever possible. It is suggested that the loss of information in stretched areas could be supplemented with ground truth.

Digital Elevation Model generated from Cartosat-1 Stereo data could be improved with using more accurate and well-distributed GCP's for refining the rational function coefficients. Millimeter accuracy GCP's can be collected while using Geodetic Dual Frequency GPS in relative mode, which can improve accuracy of stereo model. It had also been observed that there was hardly any effect of small cloud covers present on the images,

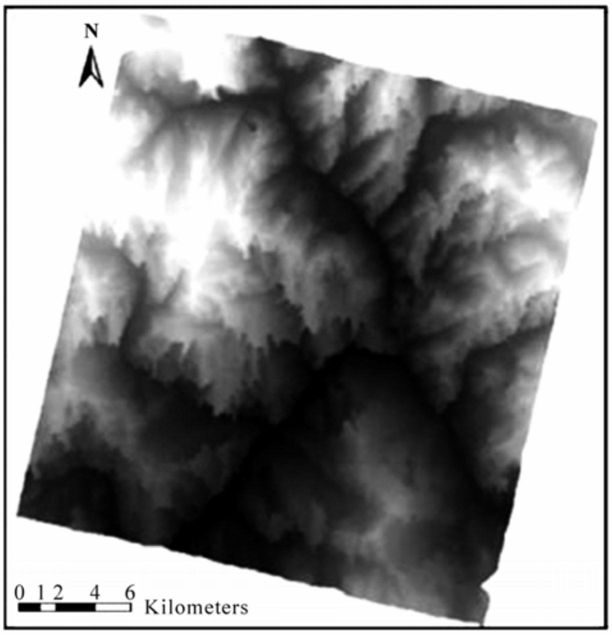

Figure 4. Digital elevation model generated from Cartosat-1 satellite stereo pair.

during automatic conjugate point matching. Generally speaking, we can affirm that the Cartosat-1 DSM's accuracy decreases as the number of GCPs used decreases, with increasing ground sampling distance and with increasing terrain slope. Moreover, the use of high quality GCPs is fundamental to obtain good DSMs, filtering may help to enhance the elevation accuracy and the generation method used is fundamental for determining the final quality of products.

6. Conclusions

The reason for the accuracy difference obtained using only one against four (or more) GCPs is due to the use of RPCs for image orientation. Data processed without any GCPs mainly show linear systematic errors and few GCPs can be used to improve the positioning accuracy by fitting the RFM calculated coordinates to the coordi- nates of the additional GCPs; with one GCP is possible only to correct for shifts while using more GCPs an addi- tional transformation in the image space can be applied.

More in general, Cartosat-1 stereo images have proven to be an excellent source of data for the production of DSMs with a ground resolution of about 10 m. Even if within the range of available high resolution optical remote sensing satellites there are several units with a higher geometric resolution than Cartosat-1, Cartosat-1 DSMs can nevertheless be compared to similar models produced from higher resolution input imagery.

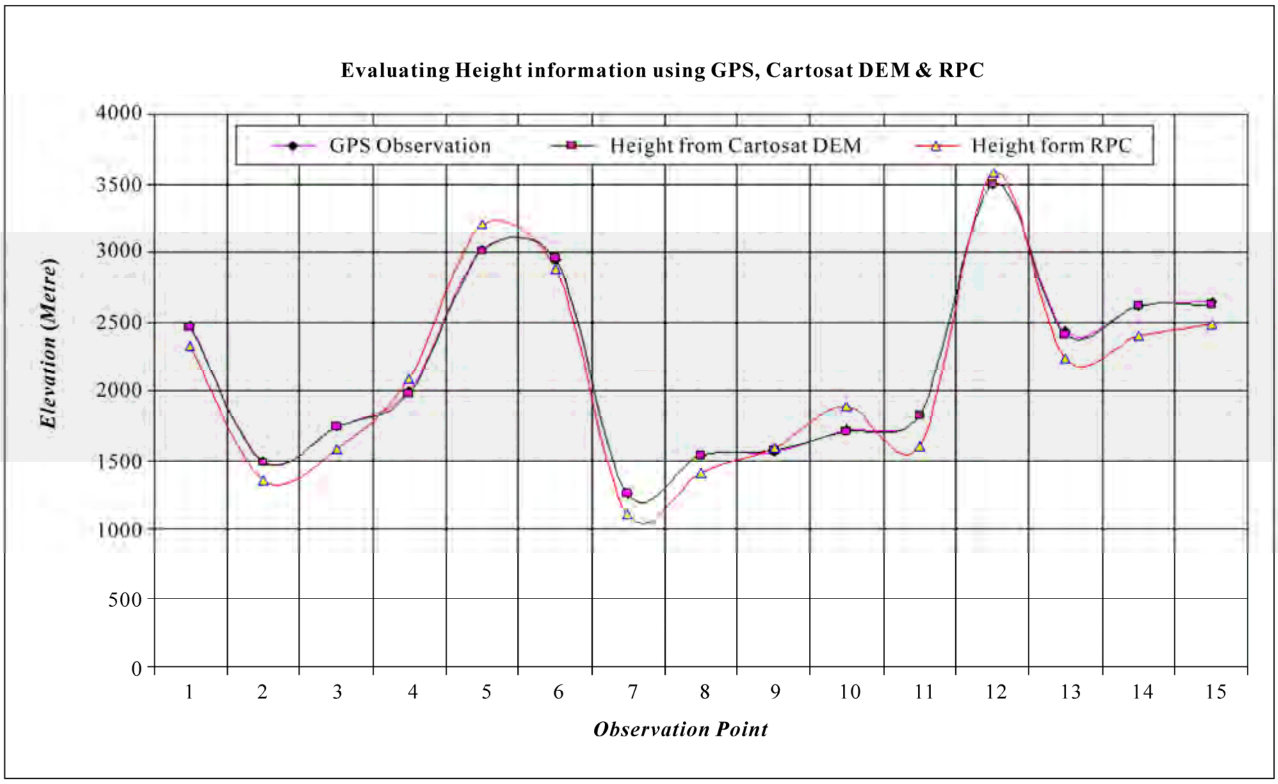

Figure 5. Graph showing comparison in height from GPS, Cartosat-1 derived DEM using GPS observation and Cartosat-1 derived DEM using RPC.

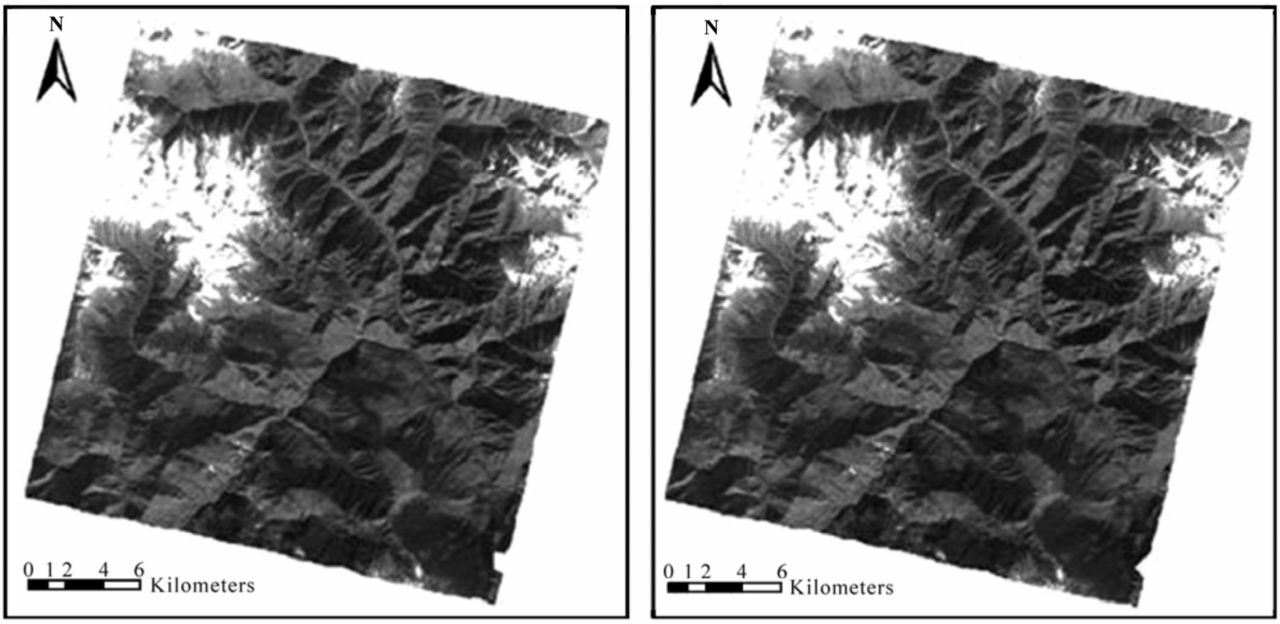

Figure 6. Ortho image generated (Fore & Aft) from Cartosat-1 satellite Stereo pair.

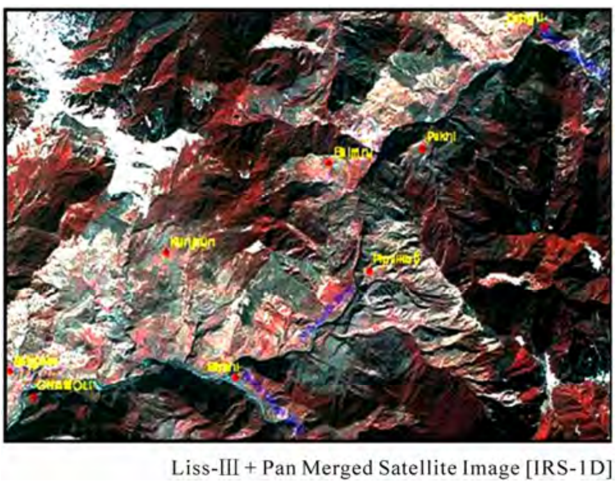

Figure 7. Liss-III + pan merged orthorectifed data showing sharp ridge and valley profiles.

7. Acknowledgements

Authors thankfully acknowledge the constant encouragement and support received from Mrs. Shefali Aggarwal, Head PRSD, IIRS & Prof. R. C. Lakhera, Head Geosciences Division, IIRS. Thanks are also due to Dr. R. D. Garg, Department of Civil Engineering, IIT Roorkee for his valuable suggestion and guidance.

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Journal of Geographic Information System, **2010, 2, 93-99**
doi:10.4236/jgis.2010.22014 Published Online April 2010 (http://www.SciRP.org/journal/jgis)

Remote Sensing and GIS as an Advance Space Technologies for Rare Vegetation Monitoring in Gobustan State National Park, Azerbaijan

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Abstract

This paper describes remote sensing methodologies for monitoring rare vegetation with special emphasis on the Image Statistic Analysis for set of training samples and classification. At first 5 types of Rare Vegetation communities were defined and the Initial classification scheme was designed on that base. After preliminary Statistic Analysis for training samples, a modification algorithm of the classification scheme was defined: one led us to creating a 4 class's scheme (Final classification scheme). The different methods analysis such as signature statistics, signature separability and scatter plots are used. According to the results, the average separability (Transformed Divergence) is 1951.14, minimum is 1732.44 and maximum is 2000 which shows an acceptable level of accuracy. Contingency Matrix computed on the results of the training on Final classification scheme achieves better results, in terms of overall accuracy, than the training on Initial classification scheme.

Keywords: Remote Sensing, GIS, Seperability, Classification

1. Introduction

The vegetation is one of the key and best instrument and indicator for monitoring of identification of impacts of the natural processes, environmental and ecological issues. As changes in vegetation are rapid and serious due to various human activities, it is urgent to monitor vegetation and their surrounding environment from physical, biological or social viewpoints. Remote sensing is expected to provide us an efficient tool for monitoring vegetation environment. In particular, as considering vegetation is often characterized by a mixture of different vegetations, soil and water, remote sensing is expected to delineate the relation between them.

This paper describes Remote Sensing and GIS as an advance Space Technology for Rare Vegetation monitoring in Gobustan State National Park with special emphasis on Image Statistic Analysis for set of training samples and classification.

Determination of the 'best' bands combinations in the context of Image statistical analysis is very important. The best band combinations will be used in accurate classification. Methods used to select the optimum bands combination are known as *feature selection techniques*.

A number of criteria can be used to categorize feature selection techniques. As they can be classified on the basis of whether they are graphical or statistical in nature [1], they can also be classified into two categories based on whether or not they use classification algorithms to evaluate the performance of subsets. Techniques that use the former approach are called 'wrapper techniques'; techniques using the latter approach are known as 'filter techniques' [2].

A filter is defined as a feature selection algorithm using a performance metric based entirely on the training data, without reference to the classifier for which the features are to be selected. The most widely used filter methods are based on class separability indices. Use of this approach in the context of Image statistical analysis was investigated in this study. Class Separability indices were employed to determine the best band combination of SPOT 5 image datasets.

These indices have been extensively used by researchers in remote sensing for many years [3-5].

Some researchers sought to test whether some bands had more discriminating power than others by using the Jeffries-Matusita distance analysis technique only [3], [5] and [6]. Other researchers, for this purpose, Divergence Distance or Battacharrya Distance were used to measure the separability [4], [5] and [7].

In our case, of the four separability indices compared, the use of transformed measures (Transformed Divergence and the Jeffries-Matusita distance) in the Class Separability appeared to be more powerful than other methods. Transformed divergence and the Jeffries-Matusita distance both found the best solution with the highest classification accuracy.

2. Study Area

This study was carried out in Gobustan, located between the southern outcrops of the Caucasus Mountain range and the Caspian Sea, some 60 km south of the capital Baku as in presented in the **Figure 1**.

The Study Area at Gobustan (covering the area of 282 km^2) contains a wealth of historical and archaeological sites and is also known for its rare vegetation.

The vegetation communities in the study area repressent the most ecologically important habitat. Some of Rare Vegetation communities within the expected for investigation area presently classified as either rare or threatened and recommended for inclusion into the National Red Book. The importance of this habitat type is one of the reasons why the Gobustan State National Park has been proposed, so that some level of protection is offered to this desert.

3. Data Used and Methodology

Four SPOT5 images in 2.5 m and 5 m resolutions, acquired between 2004 and 2007 were used for the delineation and classification of Rare Vegetation communities.

Figure 1. Study area.

The sampling scheme was designed to collect the rare vegetation communities in Gobustan National Park study site for combined ecological and remote sensing studies. The Field surveys were hold in accordance with preliminary data on the spreading of rare plants in the study area. Quadrates and plots assisted by satellite SPOT 5 imagery have provided information on habitat types and status. Because GPS devices provided the coordinates for ground-reference data during fieldwork, the sample plots were accurately linked to SPOT imagery. Every plot was registered with GPS Garmin device to allow further integration with spatial data in GIS and image processing systems (**Figure 2**).

4. Definition of the Initial Classification Scheme

Classification process involves three steps: 1) training, 2) classification and 3) output and validation.

In the training stage Initially 5 types of Rare Vegetation communities were defined that—according to ecologists' opinion—are indicators of climate and ecosystem properties in the region being studied. Below the Latin names of them are presented (**Table 1**). At first, these sites were geolocated, then using GIS procedures the areas of location of these vegetation communities were determined for extraction of samples for the classifier training and testing.

The set of training samples was tested for Representativeness and Separability based on their calculated statistical parameters. There are the tests to perform that can help determine whether the set of training samples are a true representation of the pixels to be classified for each class.

It is important that the training areas be representative of the full variability of spectral response in that class. Author [8] recommends that a minimum of 10 n to 100 n pixels be part of training areas, where *n* is the number of spectral bands. Hence, in our case, with SPOT data, the requirement is for roughly 30 to 300 pixels per class.

4.1. Image Statistical Analysis: The Initial Classification Scheme

Once the training areas are selected, different methods are used for testing purposes such as histograms, separability, signature statistics and scatter plots.

The visualization technique in feature space allows estimating range of the correlation of training samples: thereto, for each of the class from the training data was estimated of Minimum and Maximum values on each band used and created three-dimensional parallelepiped in the feature space. Or, another way is to define a three-dimensional ellipsoid, estimated of Mean ± Standard deviations values on each band used.

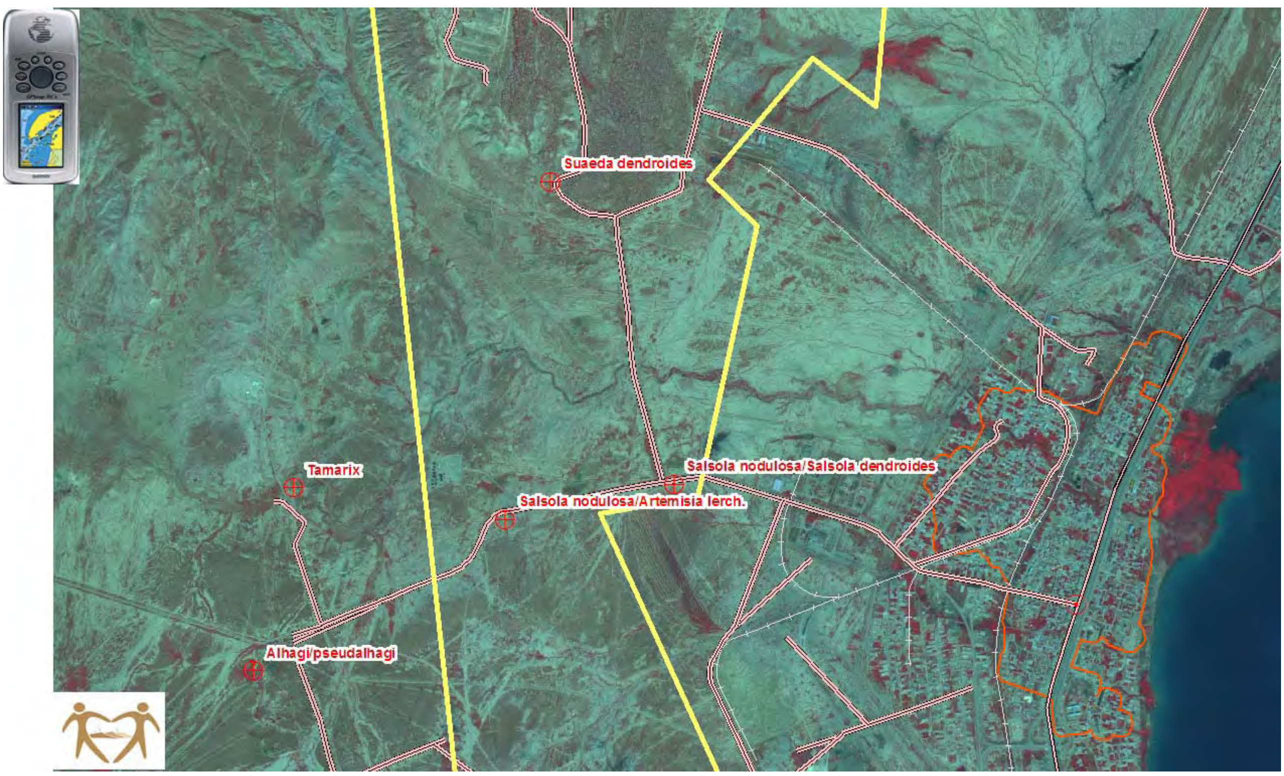

Figure 2. Interpretation of SPOT image and field survey.

Table 1. Rare vegetation communities. Initial classification scheme.

Class	The name of vegetation communities
Class 1	Alhagi pseudoalhagi
Class 2	Salsola Nodulosa/Artemisia Lerchiana
Class 3	Salsola Nodulosa/Salsola Dendroides
Class 4	Tamarix
Class 5	Suaeda Dendroides

4.2. Compare Ellipses

We can view graphs of these statistics for compare classes. The graphs display as sets of ellipses in a Feature Space image. Each ellipse is based on the mean and standard deviation of one class. The color is used as the color for the class in the visualization functions, ellipses, etc. The ellipses are presented with the color regarding each class as is shown in table below.

Class Number	The name of vegetation communities	Color
Class 1	Alhagi pseudoalhagi	
Class 2	Salsola Nodulosa/Artemisia Lerchiana	
Class 3	Salsola Nodulosa/Salsola Dendroides	
Class 4	Tamarix	
Class 5	Suaeda Dendroides	

By comparing the ellipses for different classes for a one band pair, it is easy to see if the training set represents similar groups of pixels by seeing where the ellipses overlap on the Feature Space image (**Figure 3**). As shown in **Figure 3**, the ellipses are overlapped, that means the set of training samples (excepting class Alhagi pseudoalhagi) represent similar pixels, which is not desirable for classification.

4.3. Class Separability: Initial Classification Scheme

Separability can be evaluated for any combination of bands that is used in the classification, enabling you to rule out any bands that are not useful in the results of the classification. These distances used to determine the best results to use in the classification. If the spectral distance between two samples is not significant for any pair of bands, then signatures may not be distinct enough to produce a successful classification. We evaluated the Average and Minimum Separability on all formulas for the band set. The Best Minimum and Best Average Separability values present in **Table 2**.

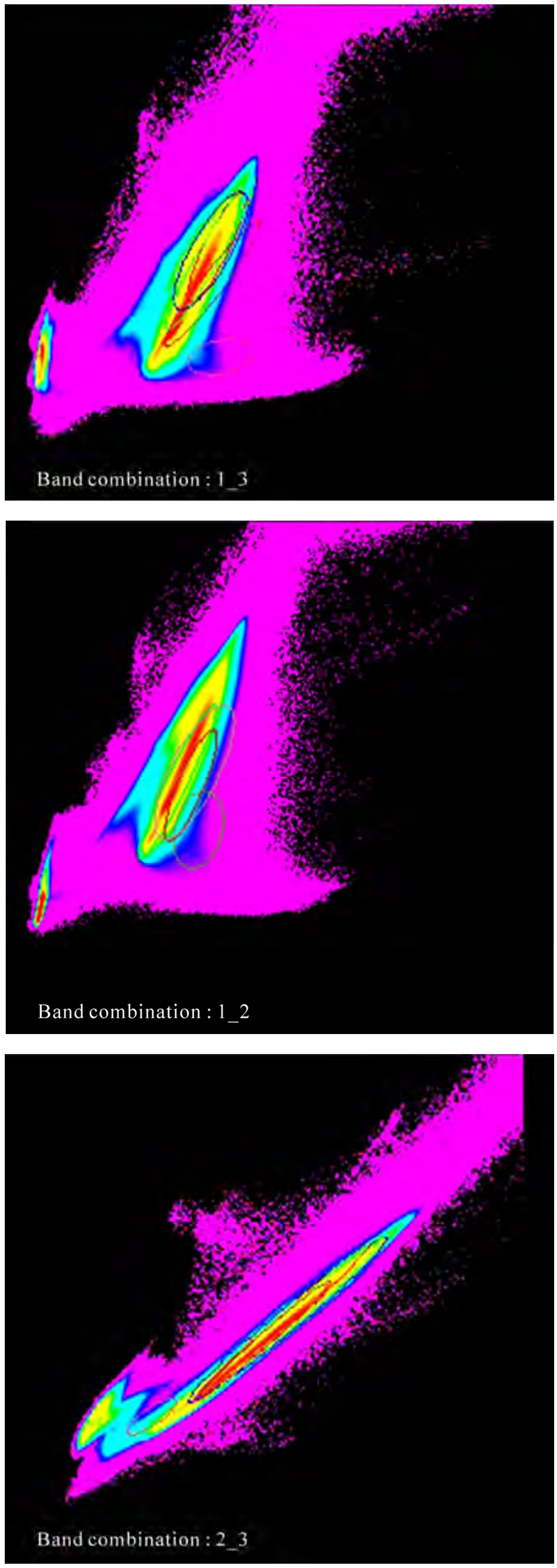

Figure 3. Band combination. Sets of ellipses in the feature space image.

Although for completeness we presented all four methods for calculating separability (**Table 3**), generally two different formulas were used: *Transformed Divergence* (*TD*) and *Jeffries-Matusita distance* (*JM*).

Transformed Divergence and the Jefferies-Matusita distance both found the best solution with the highest classification accuracy.

According [1] both *TD* and *JM* have upper and lower bounds:

Transformed Divergence is between 0 and 2000

Jefferies-Matusita Distance is between 0 and 1414

As a general rule, if the result is greater than 1900, then classes can be separated. Between 1700 and 1900 the separation is fairly good. Below 1700, the separation is poor [1].

Analyzing the results shown in **Table 2** we can unambiguously concluded that the classes are poor separable (Class separability values greatly lower bounds) and these training samples could not used for accuracy classification. For confirmation this conclusion a Contingency Matrix was calculated (**Table 3**).

4.4. Contingency Matrix: Initial Classification Scheme

Contingency Matrix do a quick classification of the pixels in a set of training samples to see what percentage of the sample pixels are actually classified as expected [9].

In theory, each training sample would be composed primarily of pixels that belong to its corresponding class. Practically, as are shown in **Table 4**, only all pixels from Class 1—*Alhagi pseudoalhag*—classified correctly (assigned to its class). The overall accuracy was calculated by summing the main diagonal elements of the Contingency matrix and dividing by the total number of samples.

These tests have shown that: Class 3 has completely contained Class 2; Class 4 and Class 5 have heavily overlapped each other. These undesirable results of Statistical tests and Class Separability generated the need to perform any operations to improve (qualify) of Initial classification scheme. These tests pointed out to a direction of possible modification of "Initial classification scheme", for that an additional set of training samples was required.

5. Definition of the Final Classification Scheme

In the during field surveys a new sites for collection training samples was defined.

After analyzing the results it would be beneficial to merge Class 2 (*Salsola Nodulosa/Artemisia Lerchiana* and Class 3 (*Salsola Nodulosa/Salsola Dendroides*) into one class:

Table 2. Best minimum and best average separability (Initial classification scheme).

Band Combination	Euclidean Distance		Divergence		Transformed Divergence		Jefferies-Matusita Distance	
	MIN	AVE	MIN	AVE	MIN	AVE	MIN	AVE
1 2 3	3	36	1	99	286	1414	525	1088
1 2	3	29	2	463	527	1730	436	1043
1 3			4	425	787	1699	408	1052
2 3	3	35						
2	2	29	4	472	747	1736	123	741

Table 3. Contingency matrix. Initial classification scheme.

Class Number	Class 1	Class 2	Class 3	Class 4	Class 5	Row Total
Class 1	226	0	0	0	0	226
Class 2	0	775	212	205	11	1203
Class 3	0	88	644	126	2	860
Class 4	0	352	378	471	0	1201
Class 5	0	169	115	24	176	484
Column Total	226	1384	1349	826	189	3974
Overall Accuracy = 57.6%						

(*SalsolaNodulosa/ArtemisiaLerchiana_SalsolaNodulosa/ SalsolaDendroides*).

The algorithm of this modification is presented (**Table 4**). There was received the Final classification scheme consisted of four classes:

Having received the new set, we performed the same statistical tests of representativeness and separability which show the advances have come using new Final classification scheme.

5.1. Class Separability: Final Classification Scheme

The Class Separability on Final classification scheme was arranged in matrix form.

We evaluated *Transformed Divergence* (*TD*) and *Jefferies-Matusita Distance* (*JM*) for every class pair and one band combination. Then we compared these num- bers (values) to other separability listings for other band combinations to determine which set of bands is the most useful for classification.

The **Table 5** and **Table 6** present the *Transformed Divergence* matrix and the *Jefferies-Matusita Distance* separability matrix on the best band combinations.

Analyzing the numerical *TD* values (**Table 5**) we can conclude that the separability results for training samples on final classification scheme are good enough with the exception of class pair 2:4. The Best Average Separability is 1951.14, Minimum Separability is 1732.44 and Maximum Separability is **2000**. That is to say Class Separability values greater than 1900 where obtained for most classes, besides for Class 1 the *TD* value is **2000 –** upper bound.

Also the values of the *JM* distance for the data set (**Table 6**) are greater than the values obtained from Initial scheme data (**Table 2**). Having acceptable levels for the separability of the training areas, the next step is to conduct the classification process.

Overall, Class Separability is adequate and would provide a fairly accurate classification.

Table 4. Final classification scheme.

Class	Classified Data
Class 1	Alhagi pseudoalhagi
Class 2	Salsola Nodulosa/Artemisia Lerchiana_Salsola Nodulosa/Salsola Dendroides
Class 3	Tamarix
Class 4	Suaeda Dendroides

Table 5. Transformed divergence separability matrix for training classes.

Distance Measure: *Transformed Divergence*
Best Average Separability: 1951.14
Band Combination: 1_2

Signature Name	Class	1	2	3	4
Alhagi pseudoalhagi	1	0	2000	2000	2000
Tamarix	2	2000	0	1975.13	1732.44
Suaeda Dendroides	3	2000	1975.13	0	1999.25
Salsola Nodulosa/Artemisia Lerchiana_Salsola Nodulosa/Salsola Dendroides	4	2000	1732.44	1999.25	0

Table 6. Jefferies-matusita distance separability matrix for training classes.

Distance Measure: *Jefferies-Matusita*
Best Average Separability: 1208.63
Band Combination: 1_2_3

Signature Name	Class	1	2	3	4
Alhagi pseudoalhagi	1	0	1411.5	1402.88	1367.45
Tamarix	2	1411.5	0	1255.07	1010.43
Suaeda Dendroides	3	1402.88	1255.07	0	904.43
Salsola Nodulosa/Artemisia Lerchiana_ Salsola Nodulosa/Salsola Dendroides	4	1367.45	1010.43	904.43	0

Table 7. Contingency matrix. Final classification scheme.

Classified Data	Alhagi pseudoalhagi	Tamarix	Suaeda Dendroides	SalsolaNodulosa/Artemisia Lerchiana/SalsolaNodulosa/Salsola Dendroides
Alhagi pseudoalhagi	151	0	0	28
Tamarix	0	342	0	151
Suaeda Dendroides	1	11	65	128
SalsolaNodulosa/Artemisia Lerchiana_SalsolaNodulosa/Salsola Dendroides	5	20	11	462
Column Total	157	373	76	769
Overall Accuracy = 74.2%				

5.2. Contingency Matrix: Final Classification Scheme

A common method for classification accuracy assessment is through the use of the Contingency Matrix. The Overall Accuracy is 74.2% (**Table 7**).

It has been found that the Contingency Matrix computed on the results of the training on Final classification scheme achieves better results, in terms of overall accuracy (overall accuracy = 74.2%) than the training on Initial classification scheme (overall accuracy = 57.6%).

6. Conclusions

The aim of this study was to perform the Image Statistical analysis in the training stage. The number of multivariate statistical techniques was employed to estimate the degree of discrimination between the classes. At every step of the training process, values of Class Separability as represented by Transformed Divergence and Jefferies-Matusita Distance where evaluated as a measure of the quality of training areas. Training areas for first dataset (Initial classification scheme) that produced *TD* coefficients lower than 1700 for either measure where rejected (**Table 2** and **Table 3**).

The Image Statistical analysis of Final classification scheme (modified scheme) have shown the advances of new Final classification scheme and determined the best combinations of bands for separating the classes from each other (**Table 6** and **Table 7**).

The accuracy in this classification suggested that this strategy for the selection of training samples, modification of classification scheme used were importance to perform better classification result.

7. Acknowledgements

This work was supported by the Planet Action and the Idea Wild non-profit organizations for their support by donating satellite images, GIS software and equipment, which provided recourses for the research that led to this paper.

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Journal of Geographic Information System, 2010, 2, 100-105
doi:10.4236/jgis.2010.22015 Published Online April 2010 (http://www.SciRP.org/journal/jgis)

Design and Key Technology of Gardening Information Management System Based on Data Center

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Abstract

To provide scientific management basis for the garden planning, project construction, maintenance, social service, this paper prompted that the urban gardening administration sectors need to construct gardening information management system. On the basis of fully requirements analysis of gardening sectors, this paper discussed the key technology for system construction. It also proposed to flexibly and smartly build up the system by using the secondary development design environment and running environment based on data center integration development platform. This system greatly helps the daily management and plays very important role in improving urban ecological environment and investment environment.

Keywords: Geographic Information System (GIS), Data Center Integrated Development Platform, Gardening, Workflow

1. Introduction

With economy rapidly development, gardening has been one of the most important parts of urban infrastructure construction which decorate the city more and more beautiful. More attention is paid to urban construction rather than urban management, which results in low informationized development. This problem has impacted the gardening construction and development. It mainly reflects in the following aspects:

1) Landscaping classification complexity result in difficult management, 2) due to the rapid development of urban construction, information is very difficult to update, 3) traditional management methods can't accurately statistic various landscaping, such as, old trees, parks, scenic spots, etc, 4) planning and evaluation are mainly based on practical experience.

Based on the above reasons, the key technology and construction methods of urban gardening need to be studied and gardening information management system will be studied. By operating this system, the operational level and management efficiency will be improved. Carry out comprehensive evaluation of urban gardening and set urban development strategies for gardening development.

2. Objective of Urban Gardening Information Management System

Urban gardening information management system is to study gardening classification encoding and management, data source sharing, data status, gardening 3D modeling, etc. All the landscapes, parks and scenic spots will be expressed in data and the urban basic spatial database, RS image data and gardening information base will be integrated. It will greatly help daily management, improve urban ecological environment, and play an important role in improving the investment environment.

1) Establish an integrated geographic information platform to achieve urban gardening and related data sharing, permanent preservation, real-time queries and dynamic management.

2) Establish administrative license handling platform. Integrate administrative licensing approval process and GIS to achieve digital approval process.

3) Establish decision-making support platform to help planning and designing, data query, simulated demolition, program optimization, etc.

4) Establish social service platform to release public urban gardening information.

3. System Structure Design

Gardening information management system is based on MapGIS data center integrated development platform (data center for short) [1] to build and design on three-layer architecture, (shown in **Figure 1**). The first layer is hardware and software-based layer, which is base for management operation platform. Hardware part includes network equipment, servers, storage, backup devices, network including government special network, Internet, GPRS network, etc. Software part includes operating systems, database management systems, mirror and backup tools, GIS platforms and security software. The second layer is an integrated development platform for data center which is the running environment for gardening information system building and configuration. The third layer is the applications and services layer which provides business applications and service to users.

Integrated development platform for data center is based on the gardening information management requirements, which provides common needs and capabilities. It adopts service-oriented architecture conceptions. It designs and develops corresponding abstraction function module which constituted by several basic function composition. It can be divided into three layers, (shown in **Figure 1**). The first layer is to provide basic and common features, such as basic heterogeneous data view, GIS capabilities, remote sensing capabilities, 3D functions, data processing work space, data security rights management module, etc. The second layer is to provide basic and general landscape features, such as data models management, basic function management, gardening basic method management functions, etc. The third layer is to provide gardening professional functions, such as landscaping assisted analysis, removal and analysis, etc.

In addition, as for specific business needs, it provides a standard function module expansion interface, which supports particular business logic integration, specific business function development completion. It can also be incorporated into functional warehouse to be an integral part of a functional warehouse. In addition, data center integrated development module and function module adopts "Loosely coupled" connection approach. This approach which is flexible in structure and powerful expansibility is the best connection method which has minimal environmental impact. Operation adopts "service" approach which converts "data access operation" to "data access service request service". "Data access service" is an example, which fully embodies the latest "service-oriented" design ideas.

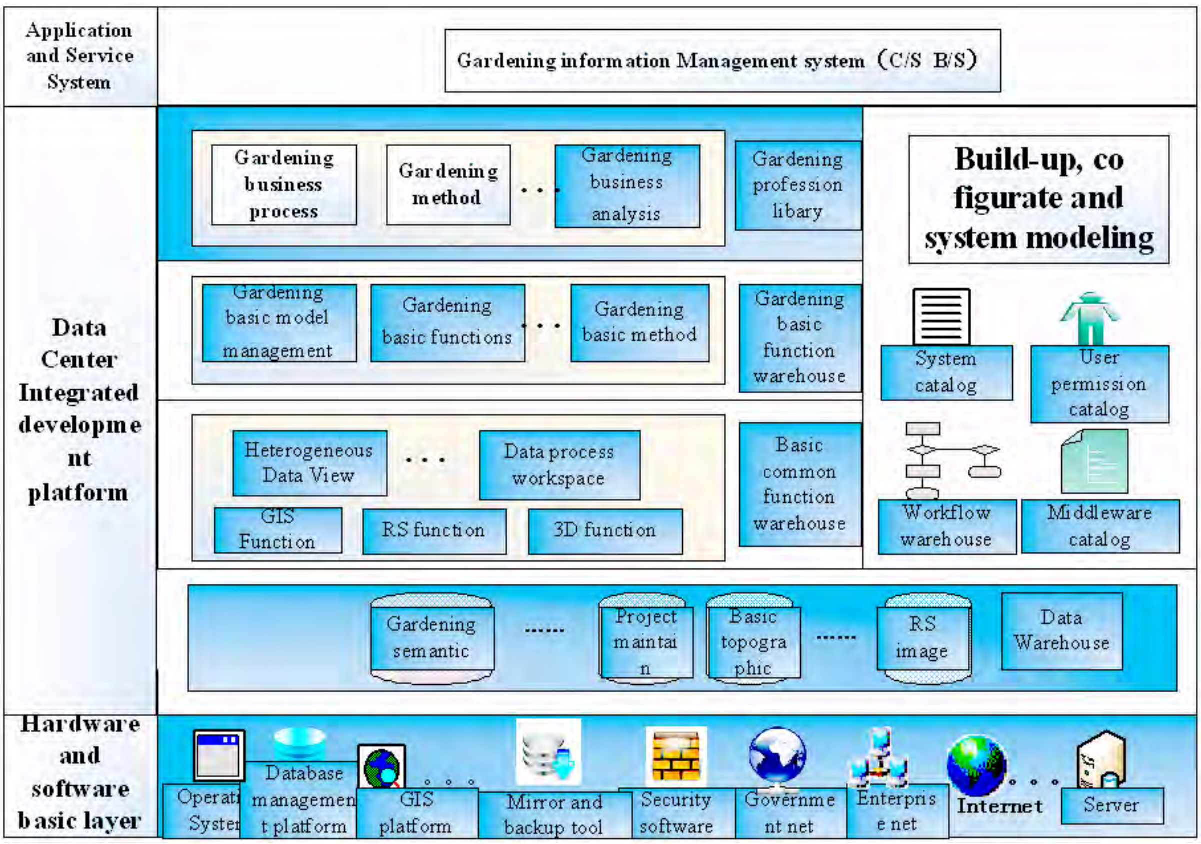


Figure 1. Gardening information management system layer structure.

4. System Function Design

Urban gardening information management system mainly includes the following aspects:

4.1. Establish Gardening Data Classification Dictionary

Green classification corresponds to urban land can be divided into three layers, which has 29 categories, including parks green, production green, protection green land, subsidiary green land and other green space, trees, old trees, plant resource protection base, etc. According to urban greening classification standards, establishing data dictionary is the basis for gardening effective management, data sharing and dynamic updating. The classification coding should have the following characteristics, scientific, systematic, stable, integral, compatible, scalable, adaptable and flexible [2].

4.2. Unified to Manage Various Data and Materials

Gardening includes all kinds of thematic data. Business layer includes community green space, trees, old and valuable trees, etc. Engineering class includes green space system planning, detailed planning, project planning and design programs, urban gardening, long-term development plans and annual plans and other documents. In addition to basic spatial data and urban RS image information, there are lots of other spatial data, such as, water resources, meteorology, ecology, pests and diseases.

Figure 2. Gardening data center manager.

The data manager provided by data center can classify, store, manage, query, index and statistic the heterogeneous spatial data and non-spatial data by different region, different time era and different category.

4.3. Gardening Plan Assisted Analysis

By spatial overlay analysis of landscape planning and residents feature, the gardening green engineer involved in demolition and resident resettlement assignments will be obtained. Then according to the cost checking database attribute, the related fees can be got. Comprehensively analyze gardening planning of landscaping construction costs and adjust the green structure and layout in order to minimize risk and maximize efficiency.

4.4. Establish Gardening 3D View

By using 3D view model evaluation to display gardening design planning aesthetics. Dynamically generate 3D modeling by the combination of DEM, RS image, texture, planning graphs and digital topographic graph. User can observe different perspectives and gardening design effects which will help them to make appropriate adjustment.

4.5. Dynamic Approval Process Update

Through workflow, the administrative approval licensing process and GIS are closely integrated, which achieves seamless integration of GIS, MIS (Management Information System) and OA (Office Automation). According to approval licensing information, user can dynamically modify gardening information in related areas to ensure real time data [3].

4.6. WEB Publishing Gardening Information and Public Services

It provides information publishing and query of parks, green area, place of interest, etc. All the parks distribution and park activities are published on the internet. Citizen can plant and safeguard the greening by the published information.

5. System Key Technology

5.1. Data Center

Data center architecture is based on a new generation of GIS technology and new development model, which integrates “basic” and “application”.

Data center is both a “resource manager” and also a "system developer". "Resource manager" manages data resource and function resource. Data resource is managed by data warehouse and function resource is managed by function warehouse [4,5]. "System developer" adopts flexible design concept which can build up the function very fast and adjust the function module according to the requirements. It has realized "zero-programming, smart combination and easy building-up" visual development.

5.2. Landscaping Modeling

Digital Elevation Model (DEM for short) is an entity ground model which uses an array of values to describe ground elevation. It's one of branches of Digital Terrain Model (DTM for short). The other digital model uses matrix form to express various non-terrain features, including the natural and geographical factors as well as the ground-related socio-economic and cultural factors, such as soil type, land use types, rock depth, land, commercial advantages district, etc. By using DEM, 3D visual reality technology, establish 3D view model of gardening planning area, such as urban green space system planning models, landscaping professional planning and green space system detailed planning model, landscape greening proportion and distribution models, urban green space and scenic spots of the planning model.

5.3. Spatial Data Management

Base state with amendments is one of spatial data management method which doesn't store all the status of researched area, but only the state of some point and also change to relative basic state. Base state with amendments can greatly reduce temporal data amount.

Gardening historical data management is based on tuple level which is based on base state with amendments. Generally, the status after construction of urban gardening is taken as "base state". User most concerned "current state" is the latest update data state. All the "current state" gardening information will be effectively managed which can fully reflect the change and development of gardening, and reduce historical data of the redundant and facilitate historical data management.

5.4. Workflow Technology

The workflow model based on network control realizes flexible operation adjustment and customization, which achieves seamless integration of GIS and office automation. The topological relations can realize automatically conditional judgment, loop, and countersigned, etc.

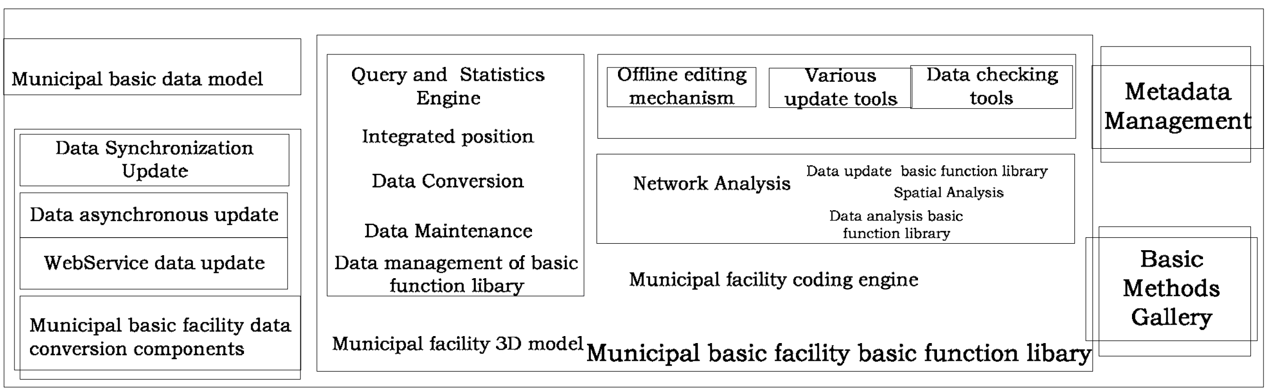
In this model, the "node" represents the workflow unit of the landscaping business departments. "Net line" represents the workflow between different departments, such as, the connection between Secretary's Office and Comprehensive Sectors, that is, the workflow transformation has converted to network resource flow. Workflow control also becomes a network control which makes the business logic of different sectors visualized, the logic control easier, faster and more accurate.

6. System Building-up Process

6.1. Professional Base and Industry Professional Function Building

Urban gardening information management system professional basic function includes, greening data model, metadata management, gardening basic function warehouse, gardening basic method warehouse, data exchange components, etc. (Shown in **Figure 3**). The basic function library includes data management basic function library, data update basic function library, data analysis basic function library, 3D model, encoding engine, etc.

System application function construction includes application function library, business process library, etc. The application function library includes analysis function library, business function library, thematic map



Fiugre 3. Professional basic function components.

function, etc. Analysis function libraries includes landscaping demolition cost accounting, green analysis, greening comparative analysis, index analysis, etc. Gardening business functions includes gardening project management, landscape planning and management, garden maintenance, etc.

Both professional basic and industry function support Visual Studio2005. All the plug-ins development is according to the relative interface standards. After completing plug-in functions, find appropriate registration documents (*. rgs) and start editing plug-ins register in accordance with registration standards.

6.2. Application System Building

6.2.1. System Building Process

Building and configuration development model uses flexible design concept, which provides fast building-up and adjustment according to requirements. First all the configuration tools should in accordance with gardening business requirements, such as, data center designer, workflow designer and the user permissions designer, then design the system and form system solution in XML file format. When the system is running, the solution will be loaded in the scalable framework by the running environment, and thus to building up the gardening information management system, as shown in **Figure 4**.

6.2.2. System Function Building

Using integrated designer to complete system interface design (such as, system's right-click menu, system menu, tool bar, status bar, hot key, interactivity, etc) and hierarchical data catalog configuration. Workflow designer supports flexible administrative examination and approval process customization. User permission configuration tools can define system user, user role, user permission, user department, region, facility type. Add related permission menu and toolbar according to role, thus to provide permission distribution for user building system and realize combination of permission and business. Finally building up system main interface through data center, as shown in **Figure 5**.

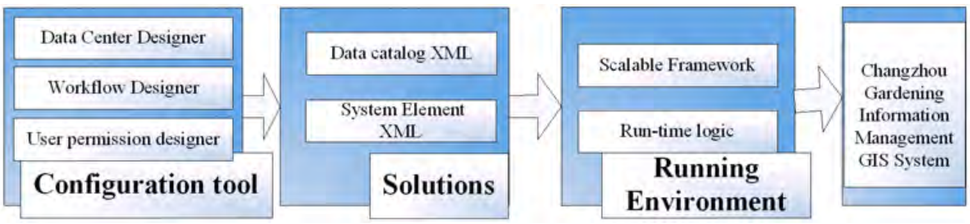


Figure 4. Urban gardening information system construction process.

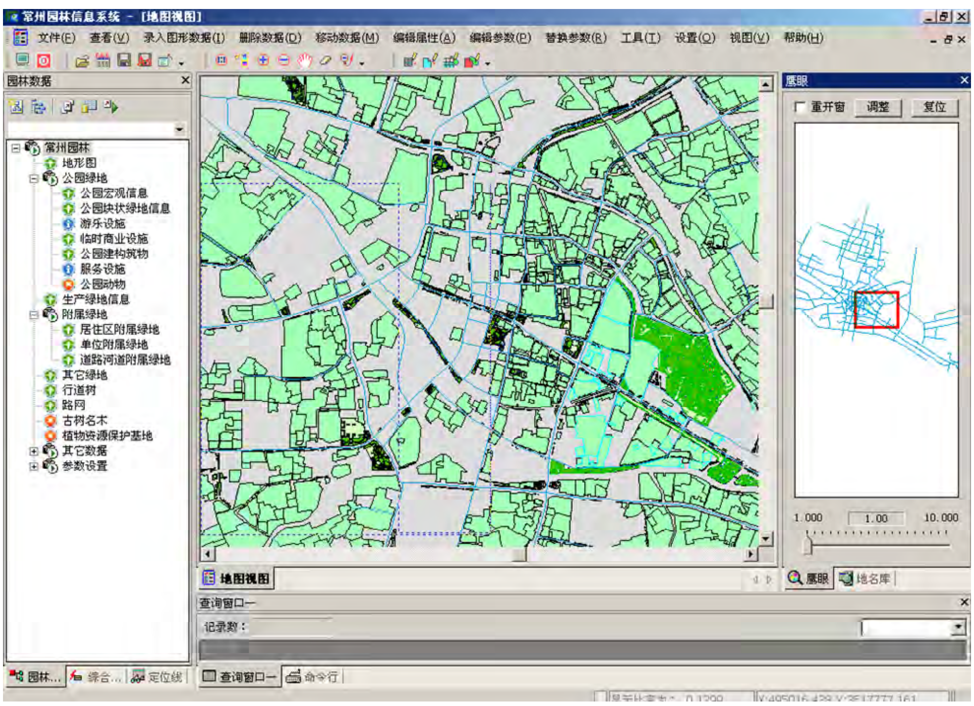


Figure 5. Gardening information management system main interface.

7. Conclusions

Gardening information management system integrates urban basic spatial databases, gardening professional database and non-spatial database which help to fully grasp urban gardening status, and monitor and evaluate urban greening information. By integration of administrative examination and approval process and GIS, and in support of network technology, the gardening unit can carry out administrative and operational work in unified workflow framework. It improves information management level and realizes “digital gardening”.

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Journal of Geographic Information System, **2010, 2, 106-112**
doi:10.4236/jgis.2010.22016 Published Online April 2010 (http://www.SciRP.org/journal/jgis)

Design of Data Model for Urban Transport GIS

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Abstract

Constructing the data model for public transportation by integrating the spatial and the non-spatial information, is the basis of reasonable plan and effective management of urban public transport. This paper presents a transit data model based on geographic information systems (GIS) technology, which utilizes arc-node networks, and manages the foundational bus data with point, link, polygon and record features. In this model, a transport network is generated and maintained in a dynamic manner, and hence supports planning, construction, management, operation and optimization functions for transit facilities and routes, as well as day-to-day transactions. Public transportation GIS established on this model foundation will remarkably upgrade the construction level and the urban service ability.

Keywords: Geographic Information System (GIS), Transit GIS, Transit Route Network, Data Mode

1. Introduction

With the rapid urban development, the population and vehicles increase faster and faster which bring more and more pressure for urban traffic. Improving public transportation is the key to solve this problem. To improve service quality and efficiency of bus, subway and other public transportation, it's urgent to promote pubic transportation informationization. From the national application trend, GIS has been the most effective method to foster public transportation informationization development. [1,2].

Transportation GIS which integrates spatial and non-spatial information, integrates computer network, spatial database technologies which supports map surveying, data surveying, real-time acquisition, spatial analysis and expert knowledge base. It can manage and assess the urban roads, public transportation network, the station facilities, basic data and the bus operator information which realizes various business functions.

Urban public transport system based on GIS will display the overall distribution of urban public transportation which achieves basic GIS functions, such as, add, modify, delete, query and browse related attribute of basic topographic graphics, road, station grounds, bus lines and operation data. What's more, it can conduct analyze and assess public transport facilities and routes reasonable layout based on the evaluation system and the knowledge base. GIS data model organizes data in different basic operation unit (such as point, line, surface, net, *etc*.), according to spatial entities and non-spatial information characteristics and describes entities relations by defining topology, relationships and constraints [3,4]. Public transport information is various which needs to be appropriate organized. Data model design is the basis for Public transportation research and development.

This paper presents public transport data model which can establish and create routes in real time, separate road layer and route layer, and separately manage route layer. The generation of route is based on site data and site routes. Public transport route generation has the several steps, such as, generating route site by site mapping the centerline and seeking the shortest path by centerline adjacent sites. It will improve the route accuracy and facilitate route analysis.

2. Management Object Analysis

Urban public transport managed objects, includes physical entities and data entities. Physical entities refer to the road network, public transport facilities, routes, vehicles, passenger traffic distribution and other objective object.

Fund Project: Research and demonstration of key technology of urban municipal infrastructure management and operation, Key projects of science and technology subjects, National Eleventh Five-Year Plan, (No.2006BAJ15B03).

Data entities are mainly public transport daily operation and management data, such as travel schedule, IC card credit card data, traffic statistics, sales data, and personnel management data.

Road network is the basis for all traffic information system and road network modeling is widely discussed. The actual model includes the arc-node data model (plane or non-flat), along the driving direction model, along driveway model, *etc*. Data entities are generally in the form of database table and every table are correlated by keyword. This paper mainly studies the public transportation facilities, lines, modeling, and operation data such as, operations and evaluation data.

2.1. Public Transport Facilities

1) Platform: Bus station is set on both sides in pairs. According to actual passenger traffic and geological location, it can be divided into three types, hub, the starting and ending, and common site. The hub is usually in a downtown with heavy traffic and large population which has great impact on urban management and operation.
2) Station: Mainly refers to parking lot and maintenance place. Parking lot is used to park buses which need to manage and dispatch buses according to the number of vehicles and starting-ending time.

2.2. Routes

Urban public transport bus route is the most important part of urban transportation which refers to the directed physical path [5,6] of every bus route. Bus lines are divided into one-way line and ring lines. One-way line contains uplink and downlink lines. The round-trip journey can be regarded as different paths. According to fixed order and the passed sites, determine the spatial location and morphology of bus route [5,6].

In data model, one line is alternatively connected by site and road section.

1) Site: Site is location for passengers getting on and off the bus. Actually, site is the "projection" of platform on one specific line and its location is according to the corresponding site. In fact, different buses lines may overlap and multi-lines may pass the same site. In other words, the platform and site has one-to-many relation.

2) Road sections: Section is a line segment between adjacent sites which is the basic building blocks unit of bus routes. Specifically, section is the connection of two adjacent sites along the road centerline.

The following diagram visually reflects the relationship between buses related objects:

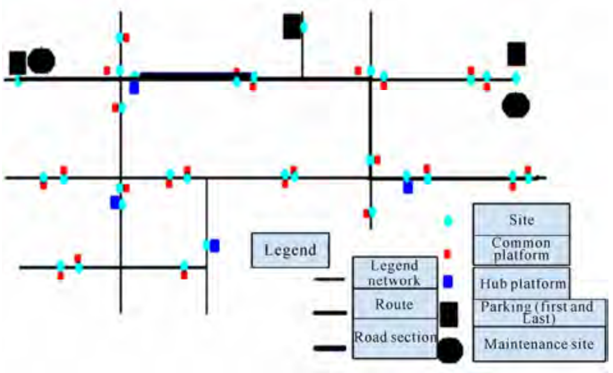

Figure 1. Objects relations of public transportation.

2.3. Operation Information

Public transport operation information is bus GIS information which is closely connected with the application business data including the frequency plan, passenger traffic and passenger revenue and other data. It organizes public transportation information.

The actual performance of public transport operations is reflected in many aspects, such as vehicle storage and organization, each line transceiver classes, schedules, operating interval, operation mileage management, lines traffic, operation income, *etc*. Related information and route will change accordingly.

2.4. Evaluation Index

Urban bus routes operation should be standardized by general regulations and supports. The macro index of public transportation is main involved in seven factors, the whole length of operation network, vehicle admission rates, bus travel proportion, bus site coverage rate, transfer coefficient, line density and line repeat coefficient. These factors change with time periods which reflect the overall condition of urban public transportation distribution density, service area, public travel convenience, *etc*.

3. Data Model Design

3.1. Overall Model

Public transport Information lies in urban infrastructure and urban road network data. You can see the organization correlations public transportation models in **Figure 2**.

In the model, the site data are abstracted from the actual platform which is taken as node in lines. Each site has one unique platform which recorded by its spatial geological location and expressed by point feature. Hub

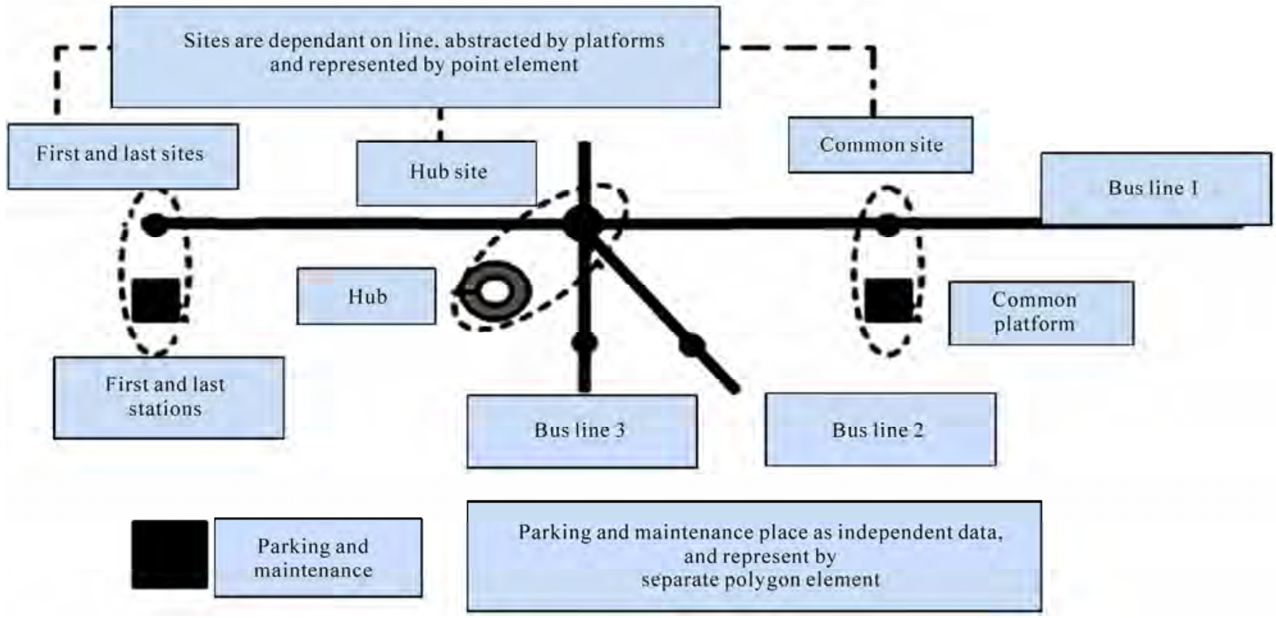

Figure 2. Data model of urban transportation.

site corresponding station is the platform data which has relatively complex attribute information. It's usually expressed in polygon element. All the sites corresponding to the platform passed by bus is closely related to site location. Parking and maintenance field is relatively independent which can be individually expressed.

3.2. Data Representation of Public Transportation Management Object

Data contents in public transportation management consists four parts, public transportation station, lines, line network and subsidiary business data. Station and line data in bus actual application has two major categories, the current data and planning data.

3.2.1. Public Transportation Station Data

Bus station data contains site and station two parts. The subsidiary attributes information of station and bus hub site are relatively complex which record the number of vehicles and their location and covered area. It will help vehicles management and bus operation analysis and represented in polygon features. The first, last station and the halfway stops are relatively simple which is the connection of every routes. It only relates to the passed lines and represented in points feature. It helps recording the spatial location of entities.

3.2.2. Public Transportation Route Data

Every bus route data not only record all the passed sites and relations, it also records large number of public transportation professional data. It will directly affect the operation analysis and comprehensive evaluation of public transportation system. Therefore, this model uses database table to store data. Actually, public transportation has uplink and downlink lines. The passed sites are not completely the same, and some lines are even single line (loop). This model takes every line as one closed loop, and records every passed site number of the uplink and downlink lines.

3.2.3. Public Transportation Line Network Data

Public transportation network does not exist in practice. It's only the correlation record of point entity coordinates of current site data and current site and lines. Then generate route network information, which record the topological relations of site and routes. Therefore, it's stored in network element structure.

Single-line network generation diagram is as follows. The virtual circuit displays the passed platforms of lines vividly. The uplink and downlink line form a closed circuit, which doesn't exist in practice. Actually, the bus routes are overlapped by the road centerline. Therefore, in order to clearly display the uplink and downlink lines, migration processing has been done. In the process of line generation, the platform is mapped to the centerline sequentially. Then seeks the shortest path of the adjacent sites, such as add control point at the corner (Shown in Figure midpoint bc1 and bc2), connect the generated site, thus finally get the route.

3.2.4. Public Transportation Subsidiary Data

Subsidiary data main contains operation information and macro information. Operational data includes public transportation IC credit card data, distribution data of bus traffic, distribution data of bus traffic, and the existing public transportation network data. Macro data, includes bus number, the proportion of bus travel, public transportation network density, public transportation non-linear coefficient, bus lines coverage, transfer coefficient, *etc*. A large number of attribute information can be stored in operation information and macro information database table.

3.3. Correlation

As for public bus transportation data, site and route are closely related, which is also the base for bus network. Other data are relatively independent. This data model proposes the following correlations to ensure the rationality and integrity of line network data.

1) Route and site, in one route there are many sites, the current bus lines and current site form one-to- many relations.

2) Routs and line network, site route table records all the site information of every passed bus, and thus generate a bus route which is the base for the urban bus network. The bus route and line network form many-to-one relationship.

3) Route and single-line, urban bus routes constitute bus line network. Each bus route is corresponds to one line in the network.

4) Site and platform, there are many lines in each platform which corresponds to site of each line. Platform and site has form one-to-many relationship.

5) Operation information and routes: Operation information bases on specific routes. The operation line mileage, passenger traffic, passenger data and traffic income are different for the same destination in different time periods.

3.4. Line Network Generation Process

From **Figure 3** we can see the single line network generation process. **Figure 4** flow chart describes the specific concepts and algorithms of line network generation. (The following are the description of the chart)

4. Data Model Realization

4.1. Database Organization

Based on data model design, bus related basic data, site field data of parking, maintenance field and hub station information, planning site and line data, and independent macro information need to record the information separately. Operation information is separately stored while it connected with lines. Current site and line data are correlated. All the above data form a transportation network.

1) Current site data: Record site number, name, location, type, and their respective sections and site. It also records the area, parking area and construction area.

2) Current line data: It records route designation, dock site in turn, first and last bus time and bus intervals. It also records various attribute information, such as, line length, total number of line vehicles, ticketing form and full line rate, average transport distance and non-linear coefficient.

3) Current site lines information: It records the correlation of each line and its corresponding site. One line record relates to multi site record. In addition, it contains the route length and non-linear coefficient. This table records and stores the correlation of sites and routes.

4) Public transportation network: It records designation of each route and all sites number and geometric information on this route. The network file is formed by the relations of site and route of site data and site line table. It records the geospatial location and topological relations of all the bus routes.

5) Station data: Data of parking and maintenance field and repair shop is relatively independent. It records spatial and attribute in polygon file.

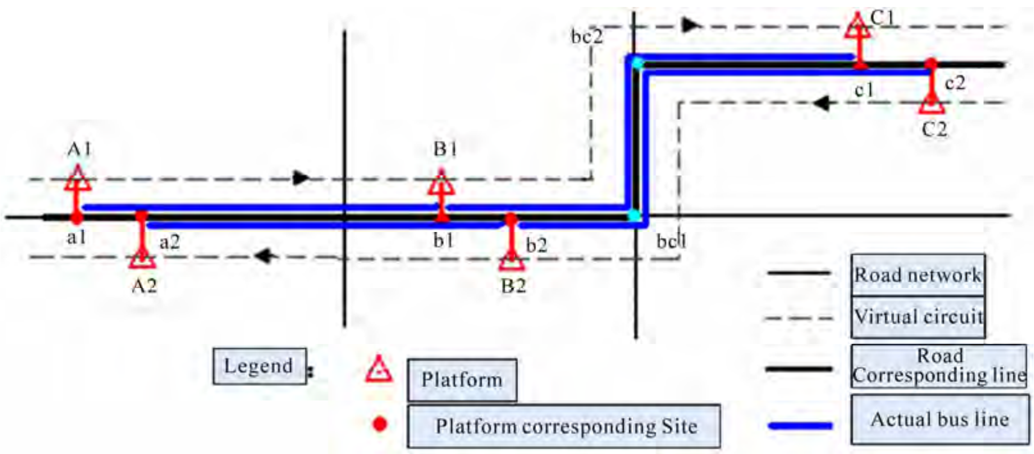

Figure 3. Single-line network generation diagram.

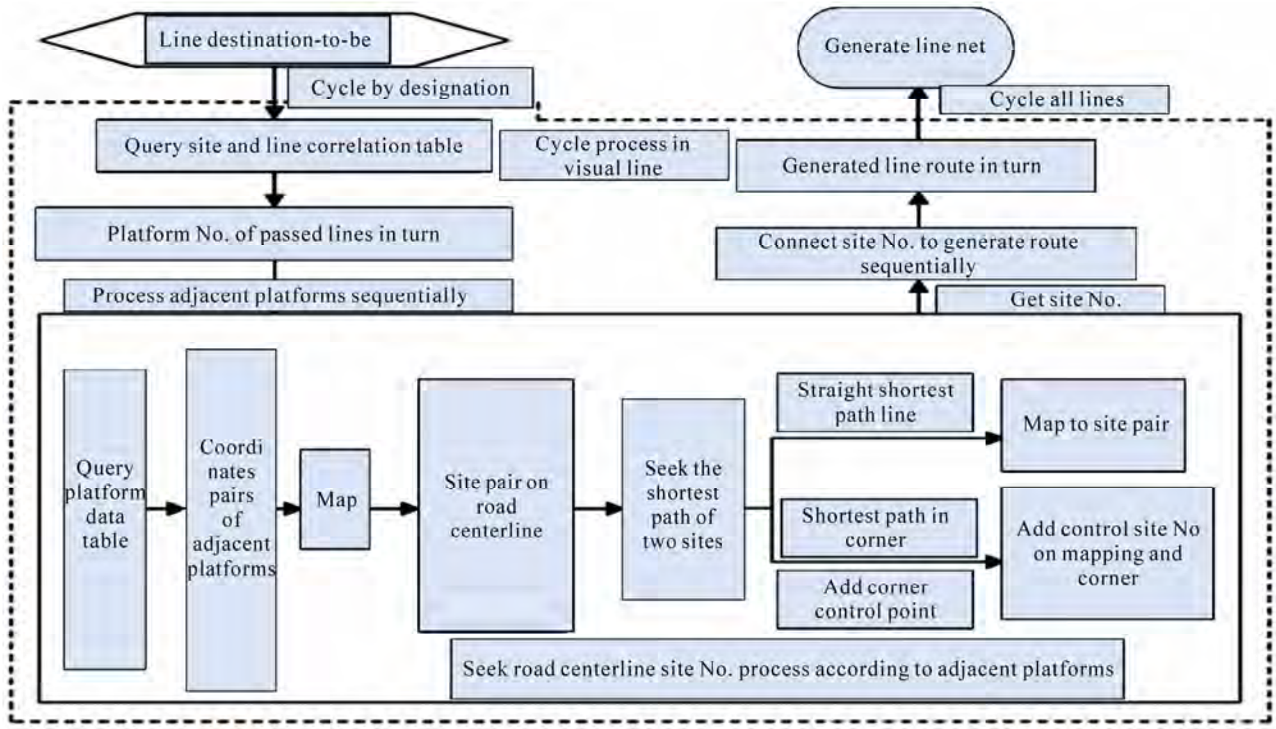

Figure 4. Flow chart of arithmetic.

6) Subsidiary data: Bus operational information and macro information store the bus operation related attributes. Operational information associates with the route and time. The file records the lien destination and date.

4.2. Correlation Realization

In accordance with the database organization, some of bus data are independent and some are interrelated. You can see vividly about the correlation of data from **Figure 5**. In **Figure 5**, current bus sites and current lines are correlated through site number and ID. The current site file and bus line file are connected by site number field. Current bus line file and current site file are connected by line designation field. Bus line net file and site line file are correlated through destination field. Bus operation

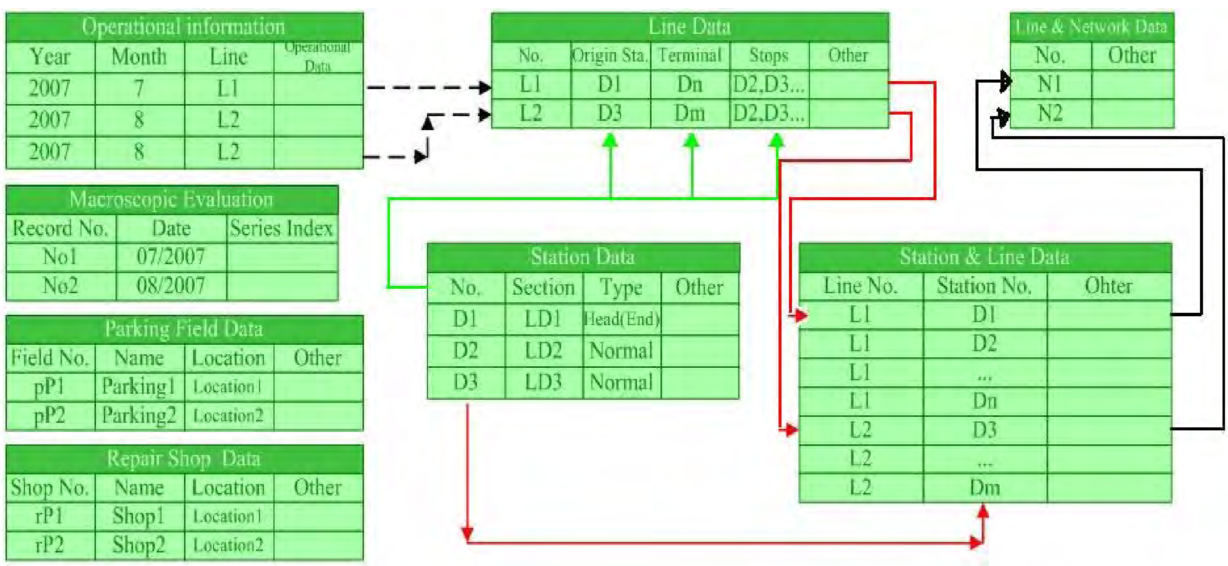

Figure 5. Correlations among the data tables in data model.

information and lines are connected by line destination. The macro-evaluation data are independent from site field data.

4.3. Database Realization

4.3.1. Data Entry

Bus station site data and route data are the basis of bus model and the system. The station site, line and data of every site will be input in database provided by user. Passenger traffic distribution data and site information can be input in table file in establishing lib, or by system. The historical data of operational information and macro-evaluation information can be directly manually input to the database and the new records can be added through the system functions.

4.3.2. Real Time Generation

Bus lines are the most important data and the lines aregenerated on the site route record. Site route file sequentially records corresponding relationship of one line and the sites that it passed which is generated by the line sequentially passed site information record. One line relates to multi-records. According to the line record, the bus transport number and passed site number, and search relative site spatial information according to site number in site files, record site location, and connect all the records sequentially to generate a route. At the same time, every single line is saved in bus line net file and all the single line constitutes the whole bus network.

The following diagram shows the final outcome of generation one single line net. The site name is marked on the line in turn, and the uplink and downlink line is marked in different color.

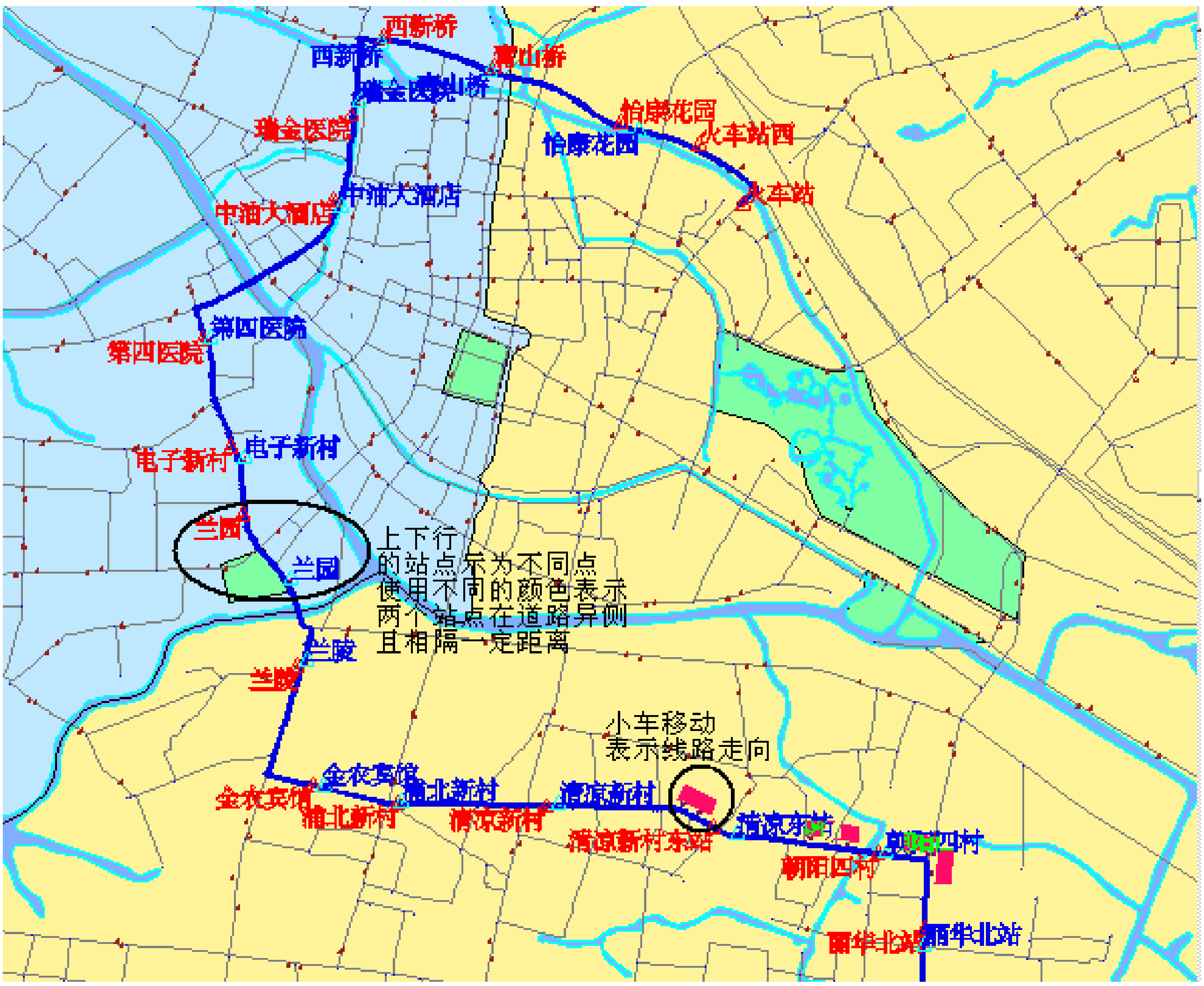

Figure 6. Result generation of single linear network.

5. Conclusions

Urban public transport is the public welfare undertakings for urban economic development and people's life. It also represents the degree of municipal construction modernization. This paper introduced a new transportation data model which can establish and maintain route network in real time. The main features are embodied as follows, separation of road layer and route layer separation, and route display doesn't rely on road net, route site generated by the mapping of station site to centerline, the geological location of route are more accurate, line generation algorithm is independent of any line, only related to site location and road conditions, so user can add, delete, and modify the route. In addition to basic GIS data processing function, the system store and manage public transport site data, operation and macro-information which can effectively organize urban public transportation planning and information management. The system has good expansibility, which will better serve urban public transportation GIS and foster urban development.

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Journal of Geographic Information System, **2010, 2, 113-119**
doi:10.4236/jgis.2010.22017 Published Online April 2010 (http://www.SciRP.org/journal/jgis)

Double Polarization SAR Image Classification Based on Object-Oriented Technology

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Abstract

This paper proposed to use double polarization synthetic aperture radar (SAR) image to classify surface feature, based on DEM. It takes fully use of the polarization information and external information. This paper utilizes ENVISAT ASAR APP double-polarization data of Poyang lake area in Jiangxi Province. Compared with traditional pixel-based classification, this paper fully uses object features (color, shape, hierarchy) and accessorial DEM information. The classification accuracy improves from the original 73.7% to 91.84%. The result shows that object-oriented classification technology is suitable for double polarization SAR's high precision classification.

Keywords: Synthetic Aperture Radar, Image Classification, Object-Oriented, Pixel-Based, DEM

1. Introduction

SAR has great significance because of its imaging capability in all day and all weather which could make up for the weakness of optical remote sensing in the application of land use and dynamic monitoring in cloudy and rainy areas. Electromagnetic waves are sensitive to the shape, size, texture, surface roughness, the complex permittivity of ground objects. Compared with single-Polarization, dual polarization is more sensitive to the properties of the ground objects and it's more suitable for ground objects' recognition and land use classification.

Traditional information extraction technology with single a pixel as a unit emphasizes too much on part (color and texture of a single pixel), while ignores the geometric structure of whole map spot nearby.

Pixel-oriented solution model analyze pixel separately which has low interpretation accuracy.

Pixel-based classification methods, such as maximum likelihood and ISODATA, only use the backscatter coefficient of SAR images, and the rich texture, roughness and other information in images are not applied. The result of classification is not satisfactory. The smallest processing unit of object-oriented classification method in information extraction is no longer the pixel, but the object with more semantic information of adjacent pixels. It classifies the remote sensing images in a higher level in order to reduce the semantic information loss rate as in the traditional pixel-based classification; so that the classification results semantic information will be richer [1].

A lot of scholars from home and abroad have studied the land use and land-cover classification using optical images based on object-oriented technology. The results show the accuracy of classification improves significantly compared with the traditional classification methods [2,3]. There are also many scholars who have studied the object-oriented classification using SAR images. [4,5]. However, the theoretical foundation, model building and other aspects in this field are less advanced than optical images obviously. This paper tries to conduct the double-polarized SAR image classification based on object-oriented technology, and confirms that the method is also suitable for the high-precision classification of dual-polarized SAR images.

2. Object-Oriented

The object-oriented classification idea is to simulate human cognitive processes. The human brains always put things in a specific environment when analyzing and identifying the things. Environment is vital important for identifying things. Human's perception of external things is unified, including the color, external contour, spacing and other properties of things. Similarly, in making visual interpretation of remote sensing images, besides the differences between the colors, it can identify the ground objects by texture, shape, adjacency relationships etc. The object-oriented classification method extracts the homogeneous regions before classifying. The specific two-step process is multi-scale segmentation and classification.

2.1. Multi-Scale Segmentation of Image

The multi-scale Segmentation of SAR image aims to cut the image into multiple small areas. Each small area has the same attributes and these regions can be taken as the ground objects in reality. Image segmentation shows that each pixel is an object at the beginning. The process is to combine the similar and nearby objects into a large new object. Compared with the pixels, image object has multi-characters, such as color, size, shape, uniformity and so on. Generally, SAR images have macroscopic and microscopic characteristics. If cut the region with single-scale, it will result in lots of broken areas. It is not conducive to information interpretation. The information of different ground objects need to be analyzed in different space sub-scales.

In the multi-scale segmentation process, each object layer has a scale. The remote sensing images can be described by a variety of the same phase and appropriate scales that caused by several object layers, rather than a single scale. The larger the segmentation scale, the larger the region area in the generated object layers and vice versa. It will form a multi-scale layers diagram of objects after several times' segmentation. The diagram is showed as **Figure 1**.

By using multi-scale segmentation technique, form image objects at different scales, at the same time generate the adjacent relation and level inheritance relation which have impacts on the objects. Different scales of image segmentation reduce data unit number to be addressed in the classification, and speed up the classification.

Choose appropriate level to extract information between multiple layers scales after the multi-scale segmentation. The larger spatial scale surface features can be extracted by the large split-scale layer, such as rivers, forests, etc. Similarly, proposing to select the smaller-scale layers for small split-scale or areas with complex feature.

2.2. Object-Oriented Classification

Object-oriented classification have two mainly methods, including nearest neighbor distance method and member

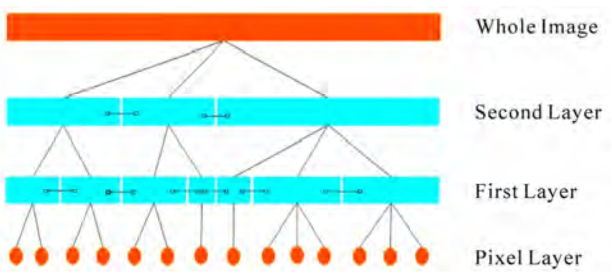


Figure 1. Hierarchy network graph of image object.

function method. The nearest distance classification is similar to supervised classification, which needs to select the sample. The member function method is based on the object characteristics with fuzzy logic, which is an uncertain method of the analysis of things. The polygon objects after being split do not rigidly belong to a certain ground object type, but describing the similar degree of object types and a certain ground object. Fuzzy logic is a kind of mathematical methods to quantify uncertainty. Using the member function method requires only a small amount of feature information to identify the types of ground objects. The member function method is a regulate classification method by imaging the object spectrum, shape, texture features and other information.

At the same time, the object-oriented classification can also use other ancillary information, such as DEM, statistical information of ground object area, as well as the known maps of ground object classification. Using DEM can separate mountains, hills, and plains based on the terrain trend. Using the statistical information of ground object area can make supplementary classification according to the area.

3. Experiment Result

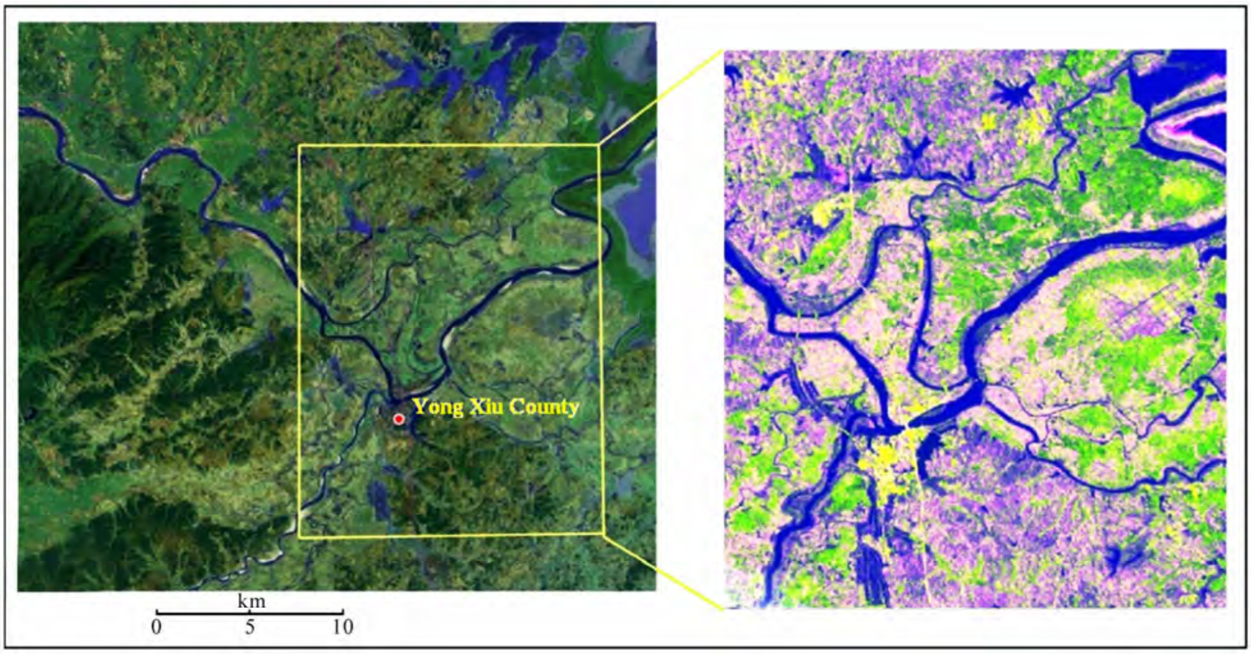
3.1. Experiment Area Survey

This paper selects a nearby typical area from the Poyang Lake region, Jiangxi Yongxiu County as an experiment area. This region is located in northern part of Jiangxi Province, Poyang Lake, west (longitude 115°45'-115°55', north latitude 28°59'-29°10'). It is subtropical monsoon climate zone, four distinctive seasons and sufficient sunlight, abundant rainfall, and is very suitable for the development of grain, cotton, oil and aquaculture. Land-use types mainly include hills, rivers, towns, grasslands, farmlands, as well as floodplain and other unused land. (as shown in **Figure 2(a)**)

3.2. Data Processing

Choose SAR data in the Poyang Lake region, Jiangxi Yongxiu County ENVISAT APP dual-polarized data which acquired on July 28, 2004 as the experimental data in this paper. Its polarization is HH, VV and resolution is 12.5 meters (**Figure 2(b)**). Before the classification of SAR images, it needs to do pre-processing, including image calibration, geometric correction and filtering. In order to increase the amount of information in dual-polarized images, it increases a band HH-VV based on the original two polarizations. The results showed that the differences between surface features are more clearly.

At the same time, this paper uses DEM as an auxiliary parameter to extract the hilly regions. DEM layer is set



(a) (b)

Figure 2. The local of experiment area (a) optical image, (b) ENVISAT false colour synthetical image red: HH Green: VV Blue: HH-VV.

as Layer 4 and the elevation of hills in the region is above 50 meters. It is shown in **Figure 3**.

3.3. The Traditional Classification Method

The traditional method is based on the pixel. It only takes advantage of the pixel values of the backward scattering. Specific classification methods include unsupervised classification and supervised classification. The traditional method completes classification based on ZONDY_SAR radar remote sensing image processing platform.

Non-supervised classification conduct "blind" classification under the condition that people do not have any prior knowledge before the classification process, according to the statistical characteristics and natural clustering features of the images. Its classification is only distinguishing different categories, but does not determine the types of property. Supervised classification is the method of pattern recognition, by selecting the characteristic parameters to find the characteristic parameters as the decision-making rules before the choice of representative or typical features in the training area and establishing discriminate function classification of individual images.

Non-supervised classification adopts ISODATA method. As shown in **Figure 4**. Unsupervised classification only recognizes 4 features, while the hills and bare land have not been correctly identified. Supervised classification sampling method is BP neural network. As shown in **Figure 5**. Supervised classification can identify most of the surface features, but the results have a serious error, that is hills are assigned to farmland category.

Because the overall scattering characteristics in the image of the fields and hills are similar, the supervised classification methods cannot separate the two kinds of surface features. The external solution is to use DEM, which will be specifically introduced in the following description. At the same time, supervised classification and unsupervised classification has serious "salt and pepper" noise to some extent, which is the inherent limitation of traditional classification methods.

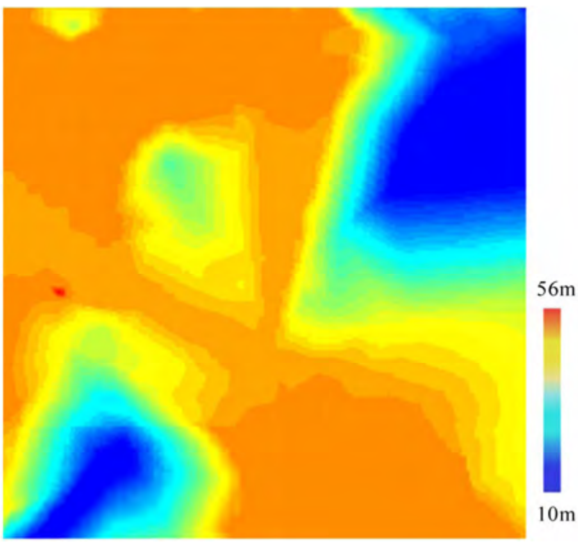


Figure 3. Auxiliary DEM image.

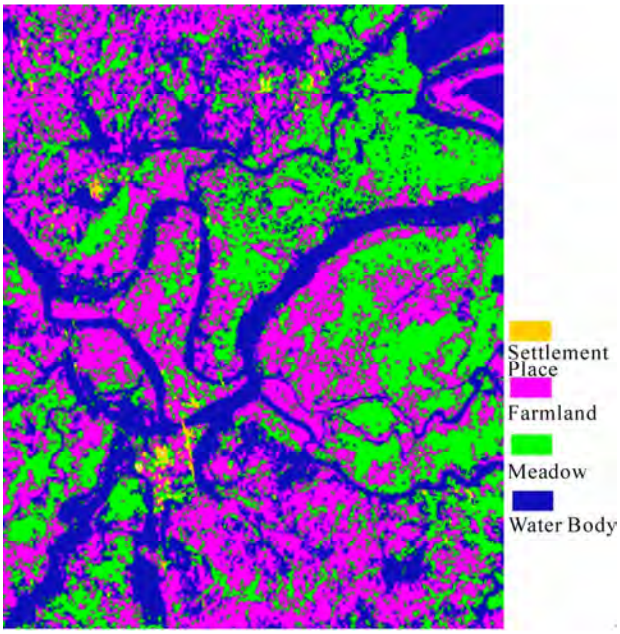


Figure 4. Unsupervised classification result (ISODATA).

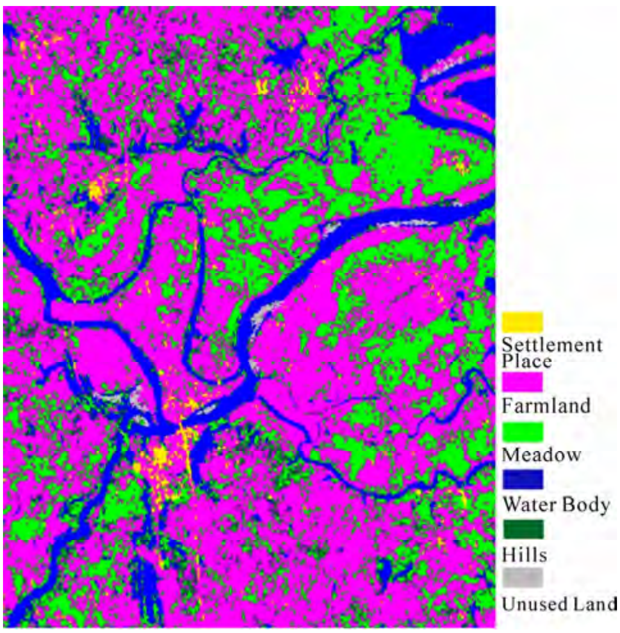


Figure 5. Supervised classification result (BP neural network).

3.4. Object-Oriented Classification

The basic entity of object-oriented classification of is a meaningful image objects, rather than single pixel. Image object not only contains scattering information, but also contextual information, object texture information and some auxiliary information. The following experiment is completed based on the Definiens 7.0 object-oriented information extraction system software.

3.4.1. Multi-Scale Segmentation

The scales of multi-scale segmentation of images are 30 and 60. There is a big difference between objects that obtained by different scales. There are a larger number of objects in images when the scale is 30 (**Figure 6(a)**). Small area such as residents can be separated from surface features such as energy and the surrounding grasslands, farmlands, etc, while large-scale surface features such as water bodies in the segmentation results have been divided into a number of small objects. It is not conducive to water extraction.

Large area water can be extracted when the scale is 60 (**Figure 6(b)**). It can be expressed with a small amount of polygonal objects and the effect is good. But small object like residents is merged into the category of grass which results in a mixed object. This is not beneficial to the extraction of the residents. Therefore, these features need to use smaller-scale segmentation.

3.4.2. Classification

According to the characteristics of experiment area features and the relationship between information and objects, this paper uses hierarchical classification structure. It is built on two levels. The divided scale of the first layer Level1 is 30. It is used for the unused land such as residents and exposed areas. The divided scale of the second layer Level2 is 60, and is used for the hills, water, farmland, grasslands and other regions. The specific processes are shown in **Figure 7**.

The first is the extraction of water. The water color in the image is a little bit dark. The water body is extracted by setting the rules. Due to the fact that there are a small number of residents in some parts of hills, residents are extracted first. Then hills in the remaining land are extracted second. This step needs the help of an external DEM. Lastly, extract residential areas, grasslands and farmlands in the remaining plain areas. Specific rules are as follows,

Water: Mean Layer1 < –17

Residents: Standard deviation Layer1 > = 41.5

Hill: Mean Layer4 > 49.5 (DEM)

Farmland: Mean of Inner border Layer2 > 170

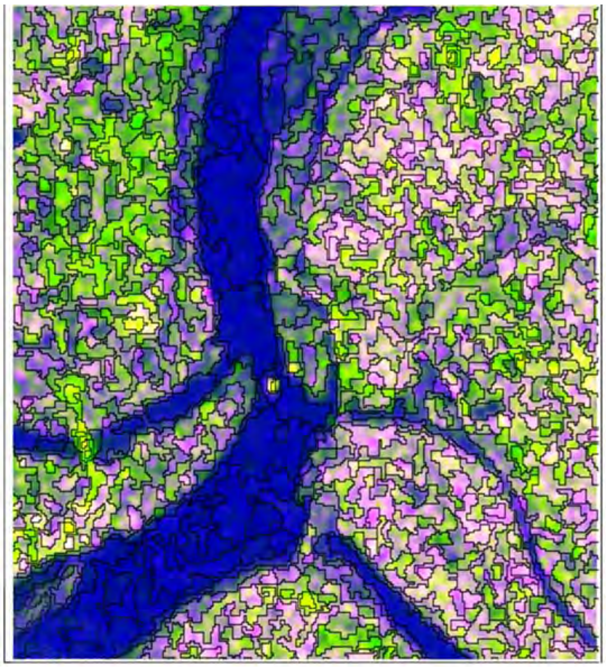
Grassland: Ratio Layer 1> = 0.57.

After the above steps, most of the features have been extracted. The features without division should be categorized into unused land. Through the cell processing and cartographic generalization, the classification results are shown in **Figure 8**.

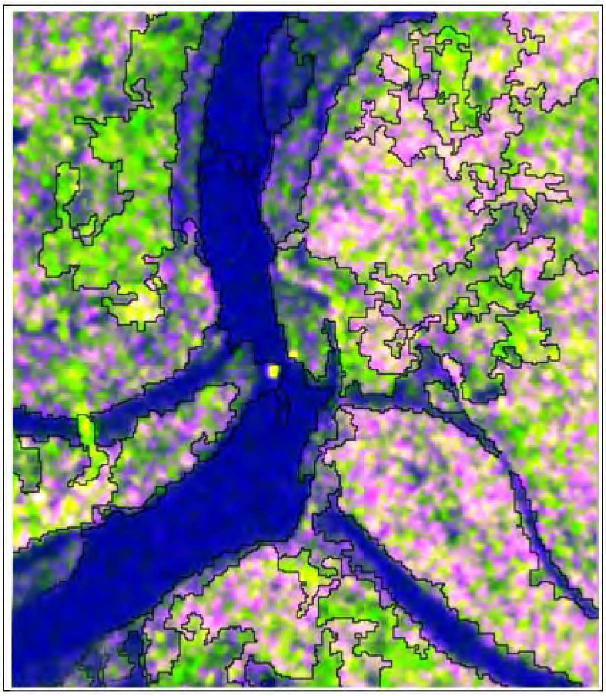
As can be seen from **Figure 8**, the object-oriented classification eliminates the “salt and pepper” noise which exists in the traditional classification and smooth the results in detail. The category of features is also more abundant. With the help of DEM, object-oriented classification can accurately extract the hills, which cannot be achieved by traditional classification methods.

3.5. Accuracy Evaluation

Choose the results of supervised classification and object-oriented classification to do accuracy evaluation comparison. The two methods are both based on samples.



(a)



(b)

Figure 6. Result of Different-Scale Segmentation. (a) scale 30; (b) scale 60.

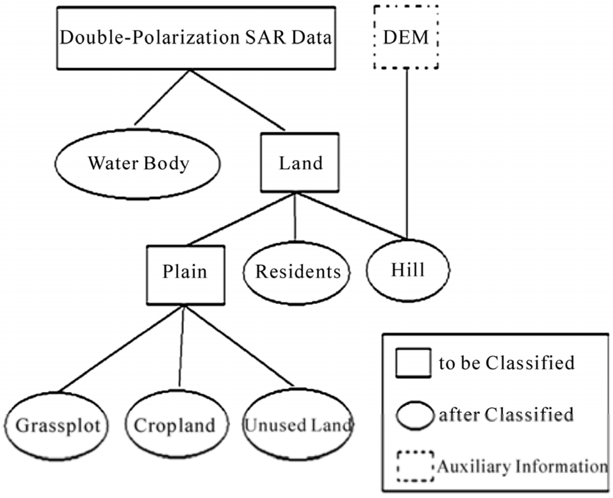


Figure 7. Processing flow chart of object-oriented classification.

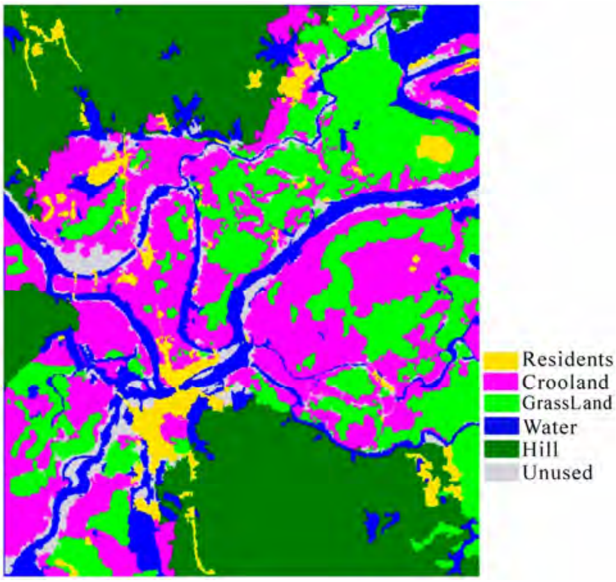


Figure 8. Result of object-oriented classification.

Supervised classification is based on a sample of pixel, while when it comes to object-oriented methods; the sample is based on image objects shown in **Table 1** and **Table 2**.

As shown in the **Table 1** and **Table 2** which record the classification accuracy of evaluation results, the overall classification accuracy and Kappa coefficient of the traditional supervised classification is 73.7% and 0.654. While the overall object-oriented classification accuracy and Kappa coefficient is 91.84% and 0.895, respectively. This shows that the object-oriented technology improves the accuracy of SAR image classification significantly. The traditional method is very easy to mislead hill to farmland because of the similar scattering characteristics. By using the external DEM, the object-oriented approach

Table 1. Precision of evaluate supervised classification.

	Water	Residents	Hill	GrassPlot	Cropland	Unused land	Samples sum	User precision %
Water	6465	0	11	0	0	550	7026	92.02
Residents	0	1243	0	54	0	0	1297	95.84
Hill	0	0	1375	0	0	0	1375	100.00
Grassplot	0	0	922	14989	0	251	15911	94.19
Cropland	0	119	7286	1614	5389	0	14659	36.76
Unused land	37	0	0	0	22	935	994	94.16
Samples sum	6502	1362	9594	16657	5411	1736	41262	
procretor %	99.43	91.26	14.33	89.99	99.59	53.86		
Precision sum = 73.7%		kappa = 0.654						

Table 2. Precision of object-oriented classification.

	Water	Residents	Hill	Grassland	Cropland	Unused land	Samples sum	User precision %
Water	81	0	0	0	0	2	83	97.59
Residents	0	25	1	4	0	0	30	83.33
Hill	0	1	17	0	2	0	20	85.00
Grassland	0	1	1	59	3	0	64	92.29
Cropland	0	0	0	3	28	1	15	87.50
Unused land	0	0	0	0	1	15	16	93.75
Samples sum	81	27	19	66	34	18	245	
procretor %	100	92.59	89.47	89.39	82.35	83.33		
Precision sum = 91.84%		kappa = 0.895						

separate farmland and hills through the elevation information. This increases the classification accuracy of the hills greatly, and this method cannot be achieved by traditional classification methods. As is shown from the accuracy of evaluation results, the producer accuracy of the hills in supervised classification is only 14.33%. The accuracy of supervised classification results is not high mainly due to the inaccuracy of this indicator.

Although the classification accuracy of some indicators of the object-oriented technology is lower than the supervised classification, this does not affect the overall classification accuracy.

4. Result and Argumentation

This paper uses external DEM, and classifies dual-polarization SAR images by using object-oriented technology. The classification accuracy is 91.84%, while the traditional pixel-based classification accuracy is only 73.7%.

1) The traditional classification can only make use of image pixel gray values, rather than other ancillary information, such as external DEM elevation in this paper, except its own image pixel gray value. The object-oriented classification not only takes the multiple features into account, but also can judge by making use of external auxiliary information. The results showed that object-oriented classification method can estimate the type of ground object effectively.

2) The results of object-oriented classification eliminate the inherent “salt and pepper” noise of pixel-based classification. What’s more, the classification of object-oriented technology not only make use of the scattering information of image, but also takes advantage of the shape, texture information, and external auxiliary information of the object. The experimental results adequately depict that the object-oriented technology is also suitable for high-precision SAR image classification.

With the development of SAR technology, full-polarization and high-resolution SAR images can provide more detailed features. Future research direction is applying object-oriented technology in the full-polarization SAR or high-resolution SAR image classification.

5. Acknowledgements

Thanks for providing experimental data by Envisat satellite radar data-sharing project of Center for Earth Observation and Digital Earth Chinese Academy of Sciences to this paper.

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Journal of Geographic Information System, 2010, 2, 120-123
doi:10.4236/jgis.2010.22018 Published Online April 2010 (http://www.SciRP.org/journal/jgis)

Study on Provincial Land Use Database Remittance Standard Establishment

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Abstract

In order to realize county-level land use database remittance, establish the provincial land use database and realize annual change statistics, this paper analyzed the requirements for establishing the provincial land use database remittance standards. It proposed the principle of establish the standard compile, introduced the standard establishment process, described the standard main content, and demonstrated technical reasons for standard topologic relationship, expression method for land use data time dimension, data file naming rule, land use element classification, land use database digital dictionary file composition, land use spatial objects, etc. It provides reference for the standard establishment of provincial land use database remittance.

Keywords: Land Use, Database, Remittance, Standard

1. Introduction

At present, China is building county-level land use database. The database construction for the national level should adopt software recommended by Ministry of Land and Resources. There are several database construction scales, 1:2000, 1:5000, 1:10000, etc. As database building uses various platforms and various scales, provincial land use database needs to be established to achieve county-level land use database remittance, build provincial land use database and realize annual change statistics. This database should be flexible to change in different software. The standard provincial land use database should set uniform data use feature classification code, layer division, data file naming rule, unified spatial data, attribute data and data dictionary structure, unified conversion format and metadata formats, etc [1].

2. The Standard Establishment Principle

Standard building must follow certain principles. Provincial land use database remittance standard establishment principle mainly includes the following.

2.1. Standard Should Orient to Requirement and Data Result

The standard orients to data classification, storage, sharing and transfer in routine land use basic data management. It sets common contents, formats and takes the requirements and result data as the description object. This standard doesn't involve in process data and processing method.

2.2. Standard Independence

From the data standardization aspect, the standard compile takes data analysis as the core. It starts from management requirement and doesn't base on any current GIS software platform or application software.

2.3. Standard Sharing

Standard basic characteristic is sharing, therefore in standard establishment process, the national and provincial norm and stipulation should be taken as the base. As for data expression model, Literature [2] is the reference. As for data expression, literature [1] and provincial related stipulation is taken as base.

2.4. Scientific and Open Standard Classification

Data classification changes with data change and the demand development. It requests standard classification has to reflect current situation and meet the requirements.

3. Standard Establishment Process

Provincial land use database remittance standard establishment generally has the following process.

3.1. Requirements Analysis

Firstly, analyze the county-level land use database remittance requirement, and fully understand data source complexity. Secondly, fully understand the multiplicity of county land use database that involved the software and hardware platforms, that is, the smallest set can not be used as standard. While it's difficult to achieve can not be divorced from the actual development of the standard, Thirdly, carefully investigate and analyze existing data resources and systems platforms, ensure the standard has nothing to do with software and the connected resource are not affected.

3.2. Standard Compilation

According to the standard guidance, set clear stand quotation standard and the integrant part, then divide standard layer, compile the format, and compile the standard (draft).

3.3. Ask for Standard Comments and Test

Ask for opinions of standard related department and sectors extensively, then carry out remitted test of different county-level land use database, after continuous revision, and get the final standard.

3.4. Standard Expert Argumentation

Standard expert panel discussion was held and will give lots of valuable suggestions for the final revision.

3.5. Standard Publishing

Standard publishing is a process for publish, receive and accept. When the Standard has established, the publishing department can hold a release conference, or in website forms. Related department should prepare to explain any related questions to the public.

4. The Standard Main Content

The main content of provincial land use database remittance standard includes the following aspects.

4.1. Scope

It sets standard main content and applicable scope.

4.2. Quotation Standard

Lists the reference and quotation norm and stipulation of national and provincial related standard.

4.3. Terminology

Define Standard related special terms and terminology to guide.

4.4. Land Use Database Remittance Content

It contains land use features, such as landownership, parcels, line features, and sporadic parcels. It also includes other relevant features such as, land use data processing, management and analysis which mainly include the fundamental geographic features, the administrative region features and the raster features, etc [1].

4.5. Land Use Database Remittance Form

Vector data is remitted in standard map sheet or a county-level administrative region form. Raster data is remitted in standard map sheet form. Land use database data dictionary and metadata is remitted in county-level administrative region form.

4.6. Land Use Database Remittance Scope

All features remittance in administrative region. Other features outside the administrative region are not remitted. For initial data remittance, all features will be remitted. When remitted data changes, all the involved features need to change (including additional and unused features).

4.7. Data Features Classification, Coding and Characterization in Land Use Database

Because different features have different purposes and usage methods, the land use database data features should be classified management. The larger class is classified in face method, while smaller ones use line classification method [1]. According to different feature characteristics, the land use database data feature are divided into basic geographic information, land use, raster, basic farmland, land ownership and other features [1].

4.8. Land Use Data File Naming Rule

Land use data in data use database remittance and data conversion will follow the following naming rules in describing other files, including land use standard map sheet data file name rule, and land use data file naming rule based on administrative region [1].

4.9. Land Use Database Structure

Give detailed description for the land use database spatial data structure, the attribute structure, the dictionary structure and an attribute code, etc [1].

4.10. Land Use Database Metadata

Lists land use database metadata form, define a two-dimensional data table for the land use database metadata which contains, data item, data type, value field definition, etc [1,3,4].

4.11. Land Use spatial Data Conversion Format

Describe data format content and grammar rule for various data conversion, such as vector data, the raster data, the metadata and the data dictionary [1,2].

4.12. Appendix

It includes land use terminology, spatial objects definition, land use vector data transfer format sample, land use database data dictionary transfer format samples and land use database metadata samples, etc.

5. Technical Description

Technical description for standard establishment of provincial land use database remittance.

5.1. Topologic Relationship

In standard, the description of the topologic relationship, should not only ensure data completeness and consistency, it also should reflect the principle that the standard has nothing to do with platform software. Topologic relationship allows a certain data capacity and requires fully expression of spatial objects. In other words, any face-shaped geometric object should ensure that the coordinate's connection strings are closed. The boundary of different spatial geometric objects is overlapped in spatial position, which needs separate description [2].

5.2. Land Use Data Time Dimension Representation

Fully express the historical condition of land use another request for land use data expression. The specific expression form is as follows, firstly, different periods land use data should be completely recorded. This method is intuitive but data is redundancy which is suitable for non-GIS platform management system. Secondly, establish base year background data and record changed data in different time period. In this situation, data redundancy is much smaller and easier to manage. While it needs spatial analysis to completely express land use information which is suitable for GIS platform. As the provincial land use database is based on the GIS platform management system, land use database remittance generally adopts the second method.

5.3. Data File Naming Rule

Data file in Standard only refers to remitted and transferred data file. In the process of data collection, processing and management, software usage, application, and management should be consistent with the naming rules. It has to establish conversion rules or procedures with standard naming rules.

5.4. Land Use Features Classification

In land use data management, features classification code can use the user-defined code, provided that it has to establish correspondence rule with standard classification code system. It has automated transformation program. What's more, the feature classification should be in accord with the standard.

5.5. Land Use Database Data Dictionary File Composition

Land use database data dictionary file usually consists of three parts: the first part is the file header, the second part is the data dictionary structure, and the third one is the data dictionary data.

5.6. Land Use Spatial Objects

Land use vector data constitutes by the spatial geometry data and attribute data. The two are connected by specific identification code. Identification codes with the same geometry data and attribute data describes the same space objects. The spatial objects in land use data generally refers to its specific features. Space objects expressed by land use spatial geometry data can be divided into zero-dimensional object, one-dimensional objects and two-dimensional objects [1,2] according to their geometry.

6. Conclusions

According to the above principle, process, content and method, "Guangdong Province Land Use Database Remittance Standard" has been formulated and published. This system has also been successfully in Guangdong Province's county level land use database remittance and provincial land use database construction. This system has played important role in administrative land use data management.

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Journal of Geographic Information System (JGIS)

ISSN 2151-1950 (print) ISSN 2151-1969 (online)

http://www.scirp.org/journal/jgis/

Journal of Geographic Information System (JGIS) is a comprehensive international academic theory journal associated published by Zondy Cyber Group and SRP (Scientific Research Publishing) Inc.
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Journal of Geographic Information System, **2010**
Published Online April 2010 in SciRes (http://www.scirp.org/journal/jgis).

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ISSN: 2151-1950
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