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Research Article

EXAMINATION ON EXTRACTION OF ROAD NETWORKS FROM VHR REMOTE SENSING IMAGES

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A R T I C L E I N F O

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A B S T R A C T

Road detection from remote sensing images, being a fundamental but challenging problem in the field of aerial and satellite image analysis, plays an important role for a wide range of applications and is receiving considerable attention in these recent years. While huge methods exist, a deep review of the literature concerning basic object detection is still lacking. This paper aims to provide a review of the recent progress in this field. Different from several previously published surveys that focus on a specific object class such as building and road, we concentrate on more generic object categories including, but are not limited to, road, building, tree, vehicle, ship, airport, urban-area. Covering many publications, we survey various road extraction techniques and compare different methods and results used to detect road network. The existing methods are compared and contrasted based on qualitative and qualitative parameters viz., purpose of the work, algorithms adopted and results obtained.

INTRODUCTION

Extraction of man made objects from remote sensing images plays a fundamental role in a variety of applications in recent years, such as map localization, urban planning, resource management, natural disaster analysis and transportation system modeling. Extraction of man made objects (road and building) in urban areas from remotely sensed imagery plays an important role in many urban applications (e.g. road navigation, geometric correction of urban remote sensing images (RSI), updating geographic information systems, etc.). It is normally difficult to accurately differentiate road from its background due to the complex geometry of the buildings and the acquisition geometry of the sensor. Accurate and up-to-date road information is essential for many urban applications, such as automated road navigation. Rapidly changing urban environments need frequent updates of road database. Roads can be defined as long narrow regions with various orientations, lengths, and widths. Usually, the width of a road is several pixels in high-resolution satellite images. Road extraction methodologies can be mainly classified based on two taxonomies. First, they can be divided into either road area extraction or road-centerline extraction. Road-area extraction mainly depends on image classification and segmentation. Man Made object detection in optical RSIs often suffers from several increasing challenges including the large variations in the visual appearance of objects caused by viewpoint variation, occlusion, background clutter, illumination, shadow, etc., the explosive growth of RSIs in quantity and quality, and the various requirements of new application areas. To address these challenges, the topic of geospatial object detection has been extensively studied since the 1980s. The low spatial resolution of earlier satellite images (such as Landsat) would not allow the detection of separate man-made or natural objects. Therefore, researchers mostly focused on extracting the region properties from these images. With the advances of remote sensing technology, the very high resolution (VHR) satellite. Many approaches have been developed to extract roads from remotely sensed images for urban areas. Recently, there is a great interest in including spatial information e.g., morphological filtering

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LITERATURE REVIEW

In this section, some promising approaches for extracting roads and buildings from a remote sensing imagery are discussed, highlighting their main contributions.

Rasha Alshehhi *et al*, 2017 Simultaneous extraction of roads and buildings in remote sensing imagery with convolutional neural networks Convolutional Neural Network (CNN) architecture for extraction of roads and buildings from high-resolution remote sensing data. Low-level features of roads and buildings (e.g., asymmetry and compactness) of adjacent regions are integrated with Convolutional Neural Network (CNN) features during the post-processing stage to improve the performance.

The framework for extracting roads and buildings in the high-resolution imagery of urban areas is illustrated. The method does not require any pre-processing stage. First, Convolutional Neural Network (CNN) architecture and learning framework are discussed. Second, some spatial features of adjacent SLIC regions, which are used to enhance CNN outputs

Alshehhi *et al*, 2017 Hierarchical graph based segmentation for extracting road networks from high-resolution satellite images

Extraction of road networks in urban areas from remotely sensed imagery plays an important role in many urban applications (e.g. road navigation, geometric correction of urban remote sensing images, updating geographic information systems, etc.). It is normally difficult to accurately differentiate road from its background due to the complex geometry of the buildings and the acquisition geometry of the sensor. In this paper, we present a new method for extracting roads from high-resolution imagery based on hierarchical graph-based image segmentation. The proposed method consists of: 1. Extracting features (e.g., using Gabor and morphological filtering) to enhance the contrast between road and non-road pixels, 2. Graph-based segmentation consisting of (i) Constructing a graph representation of the image based on initial segmentation and (ii) Hierarchical merging and splitting of image segments based on color and shape features, and 3. Post-processing to remove irregularities in the extracted road segments.

Pre-processing

Pre-processing is used to filter the effect of background variations and produce more effective feature image which shows a high contrast between road and non-road pixels to facilitate the segmentation process. Here, we consider two well known filtering methods: (i) Gabor filtering to discriminate road texture from non road texture and (ii) Morphological texture and (ii) Morphological filtering to eliminate the background.

Gabor filtering

Gabor filtering is one of the well-known methods for texture analysis and edge detection (Jain and Farrokhnia, 1990; Idrissa and Acheroy, 2002; Jirik *et al*., 2011). It has the ability to perform multi-resolution decomposition with various spatial-frequencies and orientations (multi-channel Gabor filtering). A two dimensional (2D) Gabor filter is obtained by modulating a sinusoidal plane wave of various frequencies and orientations with a 2D Gaussian (Idrissa and Acheroy, 2002; Daugman, 1985). and directionality by its orientation

Morphological filtering

Mathematical morphology (MM) is a non-linear approach which uses the concepts of set, topology and geometry to analyze geometrical structures (e.g., shape and form). It examines the geometric structure of an image by probing with desired structuring elements (B) (Soille, 2003; Soille, 2006). In this work, morphological closing with an oriented linear B is applied to filter three image bands (Red, Green, and Blue). Morphological closing is used to fill structures that contain oriented linear Bs. Oriented linear is selected because roads are oriented linear structures.

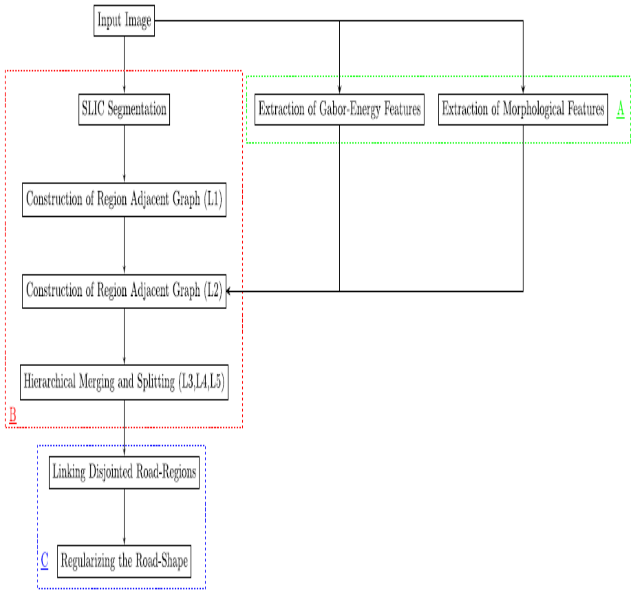

Fig1 flowchart it consist of Pre-processing, graph based segmentation, post processing

Graph-based segmentation

Segmentation in this work consists of three stages: initial segmentation using simple linear iterative clustering (SLIC) algorithm (Achanta *et al*., 2012), Region Adjacency Graph (RAG) representation (Tremeau and Colantoni, 2000) and hierarchical merging and splitting of segments. SLIC is used to construct an initial segmentation based on spectral-spatial distance. RAG is the graph representation of an input image, where superpixels are vertices and they are connected by edges whose values denote the similarity or dissimilarity between adjacent superpixels (Peng *et al*., 2011; Tremeau and Colantoni, 2000; Felzenszwalb and Huttenlocher, 2004). Merging is used to hierarchically group adjacent segments (superpixels in the first step) based on merging functions, which are mainly based on similarity of road spectral and spatial features. The merged segments are also split into smaller segments to remove artifacts from road segments based on dissimilarity in road properties.

Cheng *et al*, 2016 A survey on object detection in optical remote sensing images

Taxonomy of methods for object detection

In the last decades, a large number of methods have been developed for object detection from aerial and satellite images. We can generally divide them into four main categories: template matching-based methods, knowledge-based methods, OBIA-based methods, and machine learning-based methods. These four categories are not necessarily independent and sometimes the same method exists with different categories. Fig. 2 shows a taxonomy of geospatial object detection studies, in which rounded rectangles with solid borders illustrate our scope in this paper.

OBIA-based object detection

Recently, with the increasing availability and wide utilization of sub-meter imagery, object-based image analysis (OBIA or GEOBIA for geospatial object based image analysis) (Blaschke, 2010; Blaschke *et al*., 2008) has become a new methodology or paradigm (Blaschke *et al*., 2014) to classify or map VHR imagery into meaningful objects (or rather, grouping of relatively local homogeneous pixels). Fig. 4 gives the flowchart of OBIA-based object detection.As shown in Fig. 4, OBIA involves two steps: image segmentation and object classification. Firstly, imagery is first segmented into homogeneous regions (segments also called objects) representing a relatively homogeneous group of pixels by selecting desired scale, shape, and compactness criteria. And in a second step, a classification process is applied to these objects. Since OBIA offers the potential to exploit geographical information system (GIS) functionality, such as the incorporation of the spatial context or object shape in the classification, it provides a framework for overcoming the limitations of conventional pixel-based image classification methods and has been successfully applied to landslide mapping. Fig. 1 shows a taxonomy of geospatial object detection studies, in which rounded rectangles with solid borders illustrate our scope in this paper.

Template matching-based object detection

Template matching-based methods are one category of the simplest and earliest approaches for object detection.There are two main steps in template matching-based object detection framework. (1) Template generation: a template T for each to-be-detected object class should be firstly generated by hand-crafting or learning from the training set. (2) Similarity measure: given a source image, the stored template T is used to match the image at each possible position to find the best matches, According to the template type selected by a user, the template matching-based object detection approaches are generally categorized into two groups: rigid template matching and deformable template matching

Knowledge-based object detection

Knowledge based object detection methods are another type of popular approach of object Detection in optical RSIs. A review of knowledge-based object extraction in RSIs is also given. This type of approaches generally translates object detection problem into hypotheses testing problem by establishing various knowledge and rules. As shown in Fig. 2, the establishment of knowledge and rules is the most important step

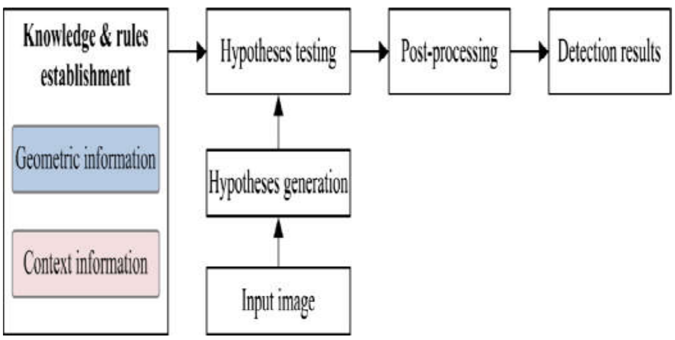

Fig 2 The flowchart of knowledge-based object detection

Machine learning-based object detection

With the advance of machine learning techniques, especially the powerful feature representations and classifiers, many recent approaches regarded object detection as a classification problem and have achieved significant improvements. Machine learning-based object detection, in which object detection can be performed by learning a classifier that captures the variation in object appearances and views from a set of training data in a supervised or semi-supervised or weakly supervised framework. The input of the classifier is a set of regions (sliding windows or object proposals) with their corresponding feature representations and the output is their corresponding predicted labels, i.e., object or not. As can been seen from Fig. 5, feature extraction, feature fusion and dimension reduction (optional), and classifier training play the most important roles in the performance of object detection. 4 Zhan et. al 2016 Urban land use extraction from Very High Resolution remote sensing imagery using a Bayesian network,Urban land use extraction from Very High Resolution (VHR) remote sensing images is important in many applications. This study explores a novel way to characterize the spatial arrangement of land cover features, and to integrate it with commonly used land use indicators. Characterization is done based upon building objects, taking their functional properties into account. We categorize the objects to a set of building types according to their geometrical, morphological, and contextual attributes. The workflow of the proposed urban land use extraction from VHR imagery consists of (1) urban land cover classification, (2) urban building types and land use definition, (3) urban building types classification, (4) spatial arrangement characterization, and (5) urban land use extraction by Bayesian network,

5.Song et .al 2016 Improved road centerlines extraction in high-resolution remote sensing images using shear transform, directional morphological filtering and enhanced broken lines connection

Directional segmentation based on spectral information and shear transform

Shear transform

Roads are mostly elongated segments with locally linear properties in the image. Road segments have definite directions, but the directions of elongated regions are difficult to estimate. Road segments are lost to some degree in the process of segmentation due to the direction constraint that only a small set of directions are considered, so it is difficult to extract the whole complete road regions. However, looking for pixels in all directions can be computationally complex. Therefore, in order to deal with it, the shear transform is introduced here. Shear transform is an affine transform which is similar to the rotation transform. The rotation transform is a very convenient tool to provide directionality and preserve important geometric information such as length, angles, and parallelism. However, this operator does not preserve the integer lattice, which causes severe problems for digitization. In contrast to this, shear transform with a shear matrix does not only provide directionality, but also preserves the integer lattice when the shear parameter is an integer. Thus, it is conceivable to assume that directionality can be naturally discretized by a shear matrix. If the shear transform is applied on an image, the line segments keep the characteristic of linear features, and the directional information of the line segments would be more.

Directional segmentation based on spectral information

The algorithm to efficiently isolate road segments in the sheared images is based on directional homogeneity using a modified metric. Two 5 _ 5 road seed templates from the sheared images are chosen as the representatives. Directional segmentation method depends on the homogeneity with respect to the two road seed templates in different directions.

To extract roads from multispectral images, we exploit the spectral information. Considering only eight directions provides a good balance between computational efficiency and accurate extraction of road pixels, so we consider eight directions in every sheared image. The central idea of directional segmentation is to compare the image parts with the templates. Given two n-dimensional points,

Zhang et .al 2016 Learning selfhood scales for urban land cover mapping with very-high-resolution satellite images. To map urban land covers with VHR satellite images and resolve the issues in existing methods, this study first presents three novel mechanisms: selfhood scale learning, self-adaptive segmentation and multilevel classification. First, the selfhood scales are learned from multiple scales which are ranked by reference to their feature importance. Second, the self-adaptive segmentation (zipper merging) using selfhood scales can reduce under- and over-segmentations and produce accurate segmented objects for object-based classification. Third, a multi-level classifier (the restricted forest) is proposed for per-pixel classification, which aims to resolve the scale variety of local contexts and considers the hierarchical relationships between local contexts and pixel features.

Learning mechanism of selfhood scales

To learn the selfhood scale of a pixel from multiple scales, the scale information should be measured and scored by feature importance first, and then the scale with the largest score is chosen as the selfhood scale. Feature importance refers to the contribution degree of a feature to classifying pixels. To evaluate feature importance, a random forest is employed, which is an assembled classifier based on decision trees (Friedl & Brodley, 1997) and skilled at accurate classification and measuring feature importance (Breiman, 2001). However, the feature importance varies from pixel to pixel.

Zipper merging for self-adaptive segmentation

Zipper in this study refers to the common boundary between two neighboring objects and contains the sudden change information between the two objects. All segmentation methods essentially aim to make the decisions whether sudden change boundaries should be kept or ignored. Such decisions should depend on global category System and local contexts, as the category system defines the geographic entities of interest, while the local contexts determine the intrinsic scales of geographic entities. As demonstrated in the last section, the learned selfhood scales can provide both information, thus they contribute to self-adaptive segmentation.

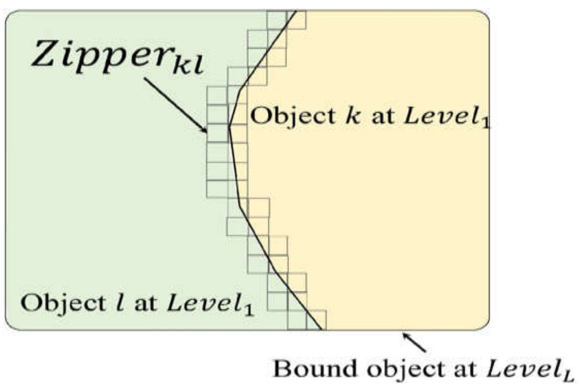

Fig 4 Zipperkl, the zipper of objects k and l, refers to their sharing boundary

The well-, under- and over-segmented image objects can coexist at diverse scales using multiresolution segmentation. The under- and oversegmented objects should be ignored, while the well-segmented ones should be kept.Namely, we aim to reorganize thewell-segmented objects at multiple scales into one level: the objects at the coarsest level LevelL are used as the bound, while the objects at the finest level Level1 are merged with considering their common boundaries and selfhood scales.Some methods also consider contextual feature descriptors based on neighborhood, but the window-size of feature descriptors is defined subjectively.

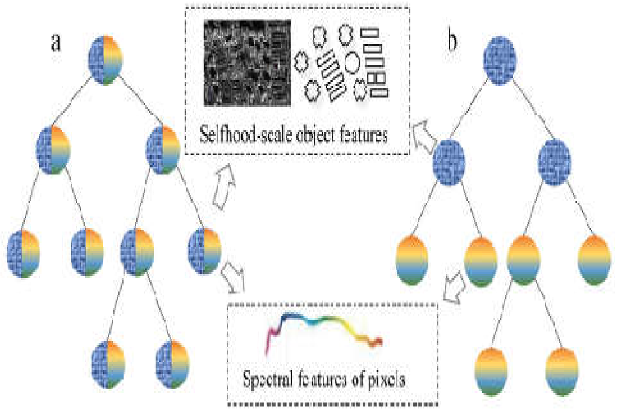

Fig 4 Comparison of the feature selection strategies used in (a) the original decision tree and (b) the restricted decision tree.

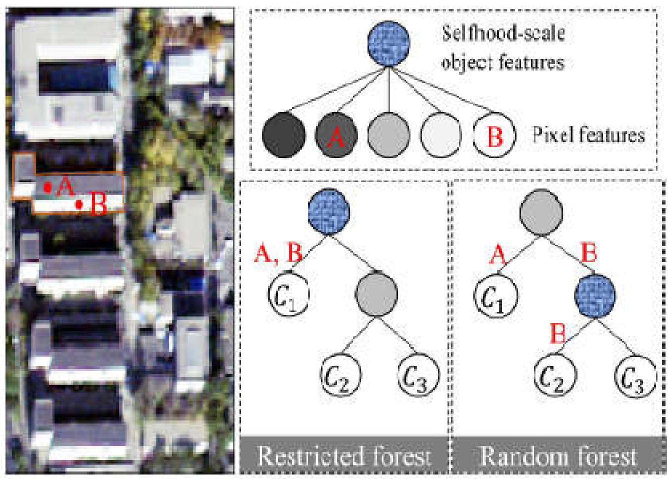

Fig 5 Comparison of restricted and random forests for classifying two pixel A and B belonging to the same category C1

Present day for finding road network use the above mentioned algorithms. Future technique for road extraction from remote sensing images with reasonably good accuracy.This review, therefore, is an attempt to critically explore the literature in the area of different methods and techniques in Road network analysis.

Author (Year)	Title	Methodology/Techniques	Benefits/features	Dataset	Results	Limitation/Gaps
Rasha Alshehhi 2017	Hierarchical graph based segmentation for extracting road networks from high-resolution satellite images	Graph based Segmentation, Gabour Filtering, Morphological Filtering ,Hierarchical merging and splitting,	1.Automatic method introduces the concept of hierarchical merging and then splitting in a multilevel graph-based framework. 2.The proposed method was evaluated using different datasets. The results demonstrate that the proposed method is able to extract complete road-map and eliminate noise due to parking lots, buildings, tree, partial shadow over the road.	Massachusetts Road dataset, Zurich Road dataset, Zurich Road dataset	Average performance factor=91.0%	1. Difficult to extract man made objects(eg , roads and buildings) due to complex data set in the form of heterogeneous appearance with large intra-class and lower inter-class variations
Gong Cheng 2016	A survey on object detection in optical remote sensing images	Object detection, Optical remote sensing images, Template matching, Object-based image analysis (OBIA), Machine learning, Deep learning, Weakly supervised learning	1.More detailed spatial and textural information. 2. Aside from region properties, a greater range of man-made objects become recognizable and even can be separately identified than ever before because of the increased submeter resolution.	NWPU VHR-10 dataset	1.Provides high reliability. 2.lack in Accuracy	Need a lot of training samples of objects and non-objects to learn classifiers; Detection accuracy depends on the training samples
Qingming Zhan 2016	Urban land use extraction from Very High Resolution remote sensing imagery using a Bayesian network	Urban land use, Very High Resolution, Spatial arrangement characterization, Building types Bayesian, network	1. integrating the spatial arrangement significantly improved the accuracy of urban land use extraction 2. spatial arrangement and Bayesian network integration was effective for urban land use extraction from VHR images	Training and Testing Dataset	Accuracy of land cover classification, the testing dataset was used to calculate a confusion matrix,an overall accuracy of 90.10%,	1. The high-density residential land use was extracted with the lowest accuracy. Because of the small coverage of this class in our study area 2. The poor extraction of highdensity residential might be caused by the imbalance of land use samples in both training and testing datasets
Huang , Jianfeng Song 2016	Improved road centerlines extraction in high-resolution remote sensing images using shear transform, directional morphological filtering and enhanced broken lines connection	Road centerlines extraction, Shear transform, Multivariate adaptive regression splines (MARS), Directional segmentation, Tensor voting,	1.enhanced broken lines connection algorithm to generate a complete road network	Aerial images, QuickBird Dataset	Average accuracy=89.53%	relatively longer execution time
Xiuyuan Zhang 2016	Learning selfhood scales for urban land cover mapping with very-high-resolution satellite images	Selfhood scales,Self-adaptive segmentation, Per-pixel classification, Object-based classification, Urban land cover mapping	1. Improving perpixel and object-based urban land cover mapping 2.Selfhood scales, the per-pixel classification has the potential to extract land cover in city with higher accuracy	WorldView-2 image	Overall accuracy=92.4%	1.Many pixel or object based environment are conducted at fixed scale that making the investigation results unreliable.
Zelang Miao 2015	An Object-Based Method for Road Network Extraction in VHR Satellite Images	Active contour, object-based filters, tensor voting (TV).	It is able to extract road networks with a completeness and quality values comparable to those by state-of-the-art techniques	Ground reference dataset, QuickBird	Lack in accuracy	Result are not accurate for large road segments with large road gaps.
Libao Zhang 2015	Residential area extraction based on saliency analysis for high spatial resolution remote sensing images	Remote sensing image processing, Residential area extraction, Saliency analysis, Lifting wavelet transform Logarithm co-occurrence histogram, Color opponency Feature competition, Threshold	1.An adaptive directional prediction 2. The color feature map is obtained using color opponency in the multi-spectral images 3. The orientation, intensity and color features are used to get the saliency map in remote sensing images.	Ground reference dataset	This method is inaccurate method	Results are not well presented in terms of accuracy evaluation.
Jerome 2015	Wide-area mapping of small-scale features in agricultural landscapes using airborne remote sensing	Random forest, Object orientated, Agriculture, Aerial photography, Spatial analysis, Classification	1. High resolution imagery is available 2. In this study high spatial resolution colour infrared aerial photography was used in object based image analysis	Auxiliary datasets,	Accuracy=79.4%	Computational efficiency is poor
Seyed Ahad Beykaei 2014	A hierarchical rule-based land use extraction system using geographic and remotely sensed data: A case study for residential uses	Land use extraction, Morphological analysis, Spatial arrangement analysis, Remote sensing	1.Spatial arrangement analysis further enhances the residential LU classification accuracy 2. Reliably and precisely represent economic interactions, activity locations.	The Digital Property Map (DPM) dataset,	Overall accuracy=93.5%	Cannot handle areas/zones with a mixture of several different land use types situated nearby each other
ImageryBardia Yousefi 2014	Hierarchical segmentation of urban satellite	Very high resolution, satellite imagery,Gabor wavelet Bayesian ,classifier Relaxation,labeling	1.Integrated method for automatically classifying urban-area objects in very high-resolution satellite imagery.	urban area images, Training map dataset	High geometric accuracy	Pre-processing of data is not efficient

Ngoc-Hoa Nguyen and Dong-Min Woo 2014	Terrain Segmentation of High Resolution Satellite Images Using Multi-Class AdaBoost Algorithm	Terrain; segmentation; satellite image; classification	The method begins with extraction of 2D and 3D co-occurrence features of high resolution satellite image from a (Digital Elevation Map)DEM image.	Training and Testing Dataset	Low accurate on detection of targets on large scaled images	Results are not well presented in terms of accuracy evaluation.
K. Maithili 2014	Probability based Road Network Detection in Satellite Images	Satellite images and Aerial images, road network detection, road center pixel detection, road shape extraction, kernel-based density estimation.	1. Extract linear as well as curvilinear roads. 2. Road centre pixels, orientation of roads, and width of the road can calculated automatically.	Quickbird input image, Ikonos input image	Overall accuracy=94%	Performance of results totally dependent on the intensity of the input images
Ali Ozgun Ok 2013	Automated detection of buildings from single VHR multispectral images using shadow information and graph cuts	Building detection Shadow evidence Graph cuts Satellite imagery	1.Detection of buildings using shadow information 2. shadow areas are extracted using the multi-spectral information widely accessible in most VHR satellite images.	VHR image datasets, aerial satellite image datasets	Overall performance=84%	1.Difficult to extract relevant data due to complex data set.
M Revathi 2013	Automatic Road Extraction using High Resolution Satellite Images based on Level Set and Mean Shift Methods	Road extraction; Level Set; Mean Shift method; Median filtering Performance evaluation	1. Removing unexpected road lines generated and extracting unidentified road regions	IKONOS high resolution satellite image	Accuracy=86.3%	1. Mean shift is fixed kernel bandwidth. The change in the road width requires an adjustment of the kernel bandwidth to consistently track the road.
Kadim Tas_demir 2012	A hybrid method combining SOM-based clustering and object-based analysis for identifying land in good agricultural condition	Land cover identification Unsupervised clustering Self-organizing maps CONN linkage Object based image analysis Good agricultural condition	1.Accurate quantification and fast identification of agricultural land cover areas from the imagery, a hybrid method, which combines automated clustering of self-organizing maps with object based image analysis	Spatial Datasets, LPIS (Land Parcel Identification System) datasets	High accuracy levels (more than 90% of overall accuracy, and kappa statistics close to 0:9)	1.Difficult to handle large data set of images, when entire country is considered.

Gaps in Literature

1. Need a lot of Training samples of objects and non objects to learn classifiers
2. Difficult to extract roads and buildings due to complex data set in the form of heterogeneous appearance with large intra-class and lower inter-class variations.
3. The high-density residential land use was extracted with the lowest accuracy. Because of the small coverage of this class in our study area.
4. Poor extraction of high density residential might be caused by the imbalance of land use.
5. Many pixel or object based environment are conducted at fixed scale that making the investigation results unreliable.
6. Difficult to handle large data set images, when entire country is considered.

CONCLUSION

In this paper, a road extraction methodology has been presented for very high-resolution imagery of remote sensing images, a new method for extracting road networks in high-resolution remote sensing imagery acquired over urban areas as well as rural has been proposed in future. Man made Object detection in RSIs has always been a fundamental but challenging issue in the field of aerial and satellite image analysis.During the last decades, considerable efforts have been made to develop various methods for the detection of different types of objects. In this paper, a review of the recent progress in this field was presented.

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