Automatic Extraction of Buildings and Roads using Combination of Airborne High resolution Laser Scanner and Multispectral Data

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Abstract
High-resolution airborne Laser scanner (Light Detection And Ranging) data in conjunction with high resolution airborne multispectral optical data have been used to extract buildings and roads in urban area. The geometric characteristics like shape of buildings and roads have been used in the feature extraction process. The height of buildings and length of the roads have been estimated using Laser scanner data. The paper discusses about the automatic extraction of shape, height and length using geometric properties of buildings and roads for their recognition and reconstruction. The new approach followed here was the use of Laser scanner and multispectral data in combination rather than independently. Data filtering techniques were applied to segment the buildings. For extraction of roads, Gaussian pyramid and edge detection algorithm were applied to extract centre line and roadside parallels of roads. The accuracy of building extraction was about 94%. The approach presented here has advantage over manual interpretation of buildings as because 220 buildings out of 231 were detected through automatic approach whereas through visual interpretation only 201 could be detected. Road length estimated through the analysis is 10.166 km. The study indicates high potential for extraction of complex buildings and road network in an urban environment with high accuracy in cost effective manner.

1. Introduction

The airborne remotely sensed high-resolution products like aerial photos and multispectral data have been widely used to map and identify earth surface features in rural, forested and urban areas for management and development planning. Automation is important to generate and update information in a cost effective manner especially mapping for large landscapes such as urban. The latest information on the urban features is required for a variety of reasons and applications and most of the urban ecosystem are dynamic (Oliver et al., 2003). Airborne Laser scanner data has been used in modeling for the reconstruction of man-made objects, which may be further used in various application areas such as virtual reality, tele-presence, and power line distribution planning, urban planning, etc. (Stamos and Allen, 2000) and enhancement of urban environs through urban forestry planning as well (Singh, 2001). Hence there is great a potential to develop and use automatic methodologies to extract features from remotely sensed images.

The automatic extraction of buildings and roads has been attempted either on multispectral data or on Laser scanner data. Efforts have been made to automate some of these processes, including reconstruction of coarse 3D geometric models, mainly at the level of buildings (Collins et al., 1998, Coorg and Teller, 1999, Mass and Vosselman, 1999, Morgan and Tempfli, 2000, Steinle and Voegtle, 2001 and Dash et al., 2004). Building extraction techniques using rectilinear hypothesis have been developed (Shufelt, 1999, Noronha and Nevatia, 2001 and Peng and Liu, 2005) using monocular aerial images. Zhou et al., (2004) have used Laser scanner data to generate true orthoimages in urban area with tall buildings. However, due to density and complexity, the automatic or semi-automatic recognition of complex buildings in urban areas is still difficult and is the subject of current research (Peng and Liu, 2005). The shapes of rooftops vary from simple rectangles to unrestricted polygons; however, as the complexity of rooftops increases, the computation required for rooftop hypotheses generation may grows exponentially. Hence, rectilinear rooftops have been modeled by a collection of rectangular components (Noronha and Nevatia, 2001) or by simple blocks with gable rooftops (Noronha, 1998) as these simpler models can be derived with a reasonable amount of computation. It is based on the assumption that if the extraction of the main ridge were not possible using Laser scanner data then it would also not be possible to extract the finer elements of the roof structure. However, for the extraction of break-lines from laser altimetry data edge detection filters like, Deriche and Laplace have been tested by Lohmann (2002) and Singh (2003). Aerial imagery in conjunction with Laser scanner data results in better complete surface reconstruction because the two data provide complete surface information ((Lemmens et al., 1997, Steel and Barr, 2001, Schenk and Csathó, 2002 and Singh, 2003). Moreover, the disadvantages of one data are partially compensated by the advantages of another. (Ameri, 2000) propagates segmentation in image space to object space using LASER SCANNER data, and matches the resulting object edges with image edges to improve their geometric quality. Road network planning in urban development is an important activity. During the testing of different approaches like road sharpening, road finding, road tracking, and road linking (Gruen and Li, 1995), LINE algorithm extraction, based on differential geometry (Heipke et al., 1997), extraction of roads 1m-resolution satellite images by varying the scale space and applying a watershed algorithm (Lee et al., 2000), data fusion techniques have proven to be of great significance. The fusion of different data is helpful to eliminate noise on the road while the fundamental structures are emphasized (Mayer and Steger, 1998 and Singh, 2003). Steger et al., (1996) emphasized to develop approach of lines extraction in an aerial image of reduced resolution and the extraction of edges in a higher resolution image. In present method is proposed on fusion of multi-spectral and laser data fallowed by the line extraction on reduced resolution and extraction of edge was merged develop to extract the road using data fusion techniques fallowed by the road extraction on low resolution and edge from high resolution image. The separation of objects using colour infra-red image simplifies the detection and separation of man-made objects from vegetation (Haala and Walter, 1999). Steel and Barr (2001) have used the combination of Laser scanner and multispectral data for extracting building-sets. In the present study multispectral data based Normalised Difference Vegetation Index (NDVI) has been used for separation of vegetated and non vegetated object after thresholds (Singh et al., 2006). The combination of multispectral and Laser scanner data have been used to separate buildings and roads. The study was undertaken as a part of NATSCAN project, which is part of European Highscan project.

2. Study Area

Study area is part of Engen city/ Lake Constance situated in southern part of Germany. This is one of three sites chosen in NATSACN project to extract man-made objects. The other two sites have natural systems like forests and mountains. The most of the area is plane and some area is mountainous. It has about 50,000 inhabitants and is located between 8°45'31" to 8°54'23" E longitudes and 47°50'55 to 48°03'10" N latitude. Town is in middle of the volcanic landscape called Hegau, famous for unique cone-mountain. City spreads mostly over plains with some hilly areas.

3. Material and Method

Laser scanner and multispectral optical dataset were recorded in May 2002 by TopoSys Company with their FALCON system. The used laser scanner device is a discrete return Laser scanner system. It records the first and the last pulse of each laser beam simultaneously. The data were available after gridding from the company. The Laser scanner sensor consists of 127 fan-formed glass fiber cells at the input and at the output side. Another cell is used for the calibration. The angle between the cells amounts 2mrad. The laser light is sent off with an angle of 1mrad. This means, that the footprint has a diameter of 1m at a flight height of 1000m. The sensor device consists not only of the laser scanner, but contains a digital line scanner. It is able to record Red, Green, Blue and Near Infra Red data. Each scan line has 682 pixel at a resolution of 0.55m at 1000m survey height. The wave lengths of the channels are 440 – 490nm in channel 1, 500 – 580nm in channel 2, 580 – 660nm in channel 3 and 770 – 890nm in channel 4 (Oliver et al., 2003). Total study area comes under 492 rows and 3016 column of laser scanner and multi-spectral data.

3.1 Data Filtering

The filtering process to segment the buildings from other undesired objects has two steps. First step is to make normalised Digital Surface Model (nDSM) using Laser scanner data and the second step is to prepare vegetated and non-vegetated map based the Normalised Difference Vegetation Index (NDVI) image from a multispectral data. Digital Surface Model (DSM) and Digital Terrain Model (DTM) were procured from TopoSys Company. The segmentation of laser point clouds is done in order to use them in extraction of man-made and natural objects. The segmentation is mandatory to differentiate between diverse objects in a scene. Extraneous objects such as trees or any other object above the ground that does not belong to the category –'building' is detected and removed from the scene.

3.1.1 Step 1: Normalised Digital Surface Model (nDSM)

In Laser scanner data acquisition, first and last pulse of each laser beam is recorded simultaneously. The first return pulses are the one which contains reflectance from objects such as trees, cars and buildings and thus have more noise (Figure 1), while the last return pulses are from non-penetrable objects like ground (earth surface) (Figure 2). Therefore, each laser vector will have two recorded heights: the first return pulse and last return pulse. The two different heights for a laser vector indicate the presence of a penetrable object such as a tree. In contrast, if the data point has the same height for first and last return then this point belongs to a non-penetrable object. The first step is to compute normalised Digital Surface Model (nDSM) based on the difference of first return pulse Digital Surface Model (DSM) and last return pulse Digital Terrain Model (DTM). The difference DSM and DTM is the height of the objects i.e. nDSM (Weidner, 1997, Ameri, 2000, and Oliver et al., 2003) (Figure 3).

Figure 1: Digital Surface Model (DSM) of Engen town based on Laser scanner data with first return heights

Figure 2: Digital Terrain Model of Engen town based on Laser scanner data with last return heights

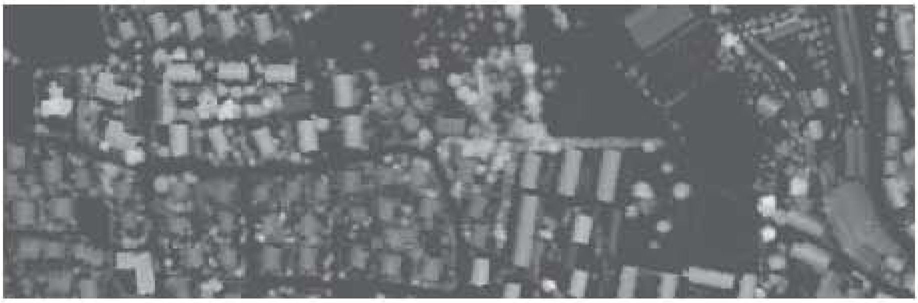

Figure 3: Normalized Differential Surface Model of Engen town based on Laser scanner data with normal heights of the objects

3.1.2 Step 2: Normalised Difference Vegetation Index (NDVI) Image

Standard NDVI algorithms and binary threshold histogram were used for separation of man-made objects and vegetated objects. Red and near infra-red channels were used to create NDVI image (NDVI=NIR–R/NIR+R). First, the relative histogram of the NDVI image was determined. Then, relevant minima were extracted from the histogram, which were used as parameters for a thresholding operation. In order to reduce the number of minima, the histogram was smoothed with a Gaussian, The mask size was enlarged until there is only one minimum in the smoothed histogram. Threshold limits 0.51 were automatically extracted from the histogram of image.

3.2 Building Extraction

In urban environment buildings are intermixed with trees, water-bodies and other features, which may be separated by roads, lanes, blanks or may not be. The extraction procedure involves detection and exclusion of natural features such as trees. The type and quality of object description depend on the objectives. Here, the basic objective was to detect and 'reconstruct' buildings in an urban area. While doing so, filtering is the first step to identify candidate-buildings from other urban features using algorithm provided in HALCON software. Candidate-buildings are those buildings, which are likely to be detected and subsequently extracted. The procedure basically uses laser scanning height image and spectral information of the multispectral image. During pre-processing, step-wise elimination of objects other than buildings, is carried out. Vegetation area was extracted in the multispectral image by applying thresholds on NDVI. The algorithm reduced domain, which is reduce the definition domain of the laser image to the indicated region. The new definition domain was calculated as the intersection of the old definition domain with the region. The new definition domain can be a subset of the region. In this processes the size of the matrix was not changed. This algorithm was applied on the laser image to enable elimination of vegetation. Some of the segmentation techniques such as threshold determined by histogram analysis and the use of multispectral inference have been tested (Brunn and Weidner, 1997; Mass, 1999). This was followed by a refinement procedure by applying morphological filters to get the desired result. Rectangles are created around each building, which were extracted in first step. The obtained roof plane is used further for building reconstruction. Figure 4 shows the flow diagram of the building extraction process. HALCON and HDevelop algorithms were used for the satisfactory results. Three steps: (a) bin threshold, (b) morphological filter and (c) rectangle generation are involved in building extraction, and are discussed below.

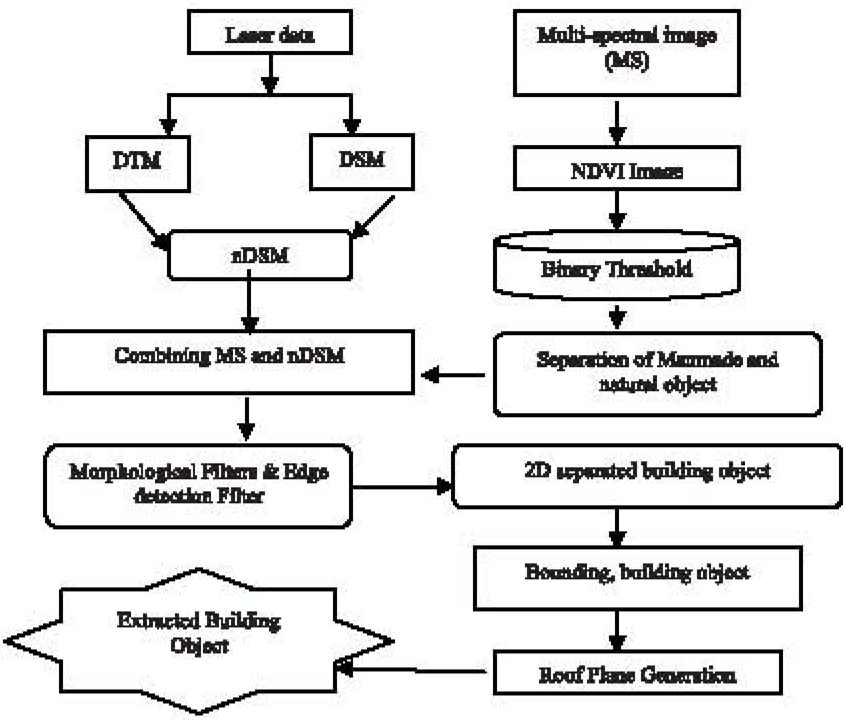

Figure 4: Flow diagramme for building extraction using Laser and Multispectral dataset

3.2.1 Bin-threshold

The process of binary threshold (*Bin-threshold*) segments a single-channel grey value image using an automatically determined threshold value. At first the relative histogram of the grey values is determined. Then relevant minima are extracted from the histogram, which are used as parameter for a threshold operation. In order to reduce the number of minima, the histogram is smoothed with a Gaussian filter (Mvtec, 2002). The mask size of filter is enlarged until there is only one minimum in the smoothed histogram. The selected region contains the pixels with grey values from 0 to the minimum.

3.2.2 Morphological filter operation

Two fundamental operations, dilation and erosion are commonly employed to enlarge or reduce the size of a feature. In the continuous case Minkowaki addition can be thought of a way to grow the members of source set by a method of psuedo-convolution. Minkowaki Subtraction, also known as Erosion, consists of applying the structuring element and sliding it about the source image just as in Dilation.

If A, B sets (of vectors):

a, b vectors (which indicate the interior of image objects)

$Ab = \{a+b \mid a \in A\}$ **translation of** A **by** b

$Ac = \{a \mid a \notin A\}$ **complement of** A

Then $A \oplus B = \{a+b \mid a \in A, b \in B\} = \bigcup_{b \in B} Ab$
Minkowski set addition of A **and** B **sets**

$$A \ominus B = \{x \mid x - b \in A, b \in B\} = \bigcap_{b \in B} Ab$$

Minkowski set subtraction of B **from** A

A *closing and opening* operation has performed after Minkowaki subtraction.

$A_B \equiv (A \ominus B^S) \oplus B$ **Opening** of A by B
$A^B = (A \oplus B^S) \ominus B$ **Closing** of A by B

Opening and closing are also dual: i.e. $A^B = [(A^C)_B]^C$

In the above discussion, both the sets A and B are equivalent. However, in many cases, A indicates a target image and B indicates a small figure that does the role of filter window. In this case B is called a structuring element. Erosion rectangle applies erosion to a rectangular structuring element to the input regions or image. The regions containing small connecting strips between large areas are separated and logically these remain as one region. Erosion is defined as A⊖B {p | B + p⊆ A} (Gonzalez and Woods, 1992, Dougherty, 1992 and Haralick, 1987). Erosion results in a shrinking of the image. *Dilation* rectangle algorithm applies dilation to rectangular structuring elements of the input regions or image. Dilation rectangle is also a very fast operation because the height of the rectangle enters only logarithmically into the runtime complexity, while the width does not enter at all. This leads to excellent runtime efficiency, even in the case of very large rectangles (edge length > 100m). Let B be a set in E^n Then $A \oplus B$ = {∪(A+b) | b∈} or A⊕ B = {∪(a+B)| a ∈ A} (Gonzalez and Woods, 1992 and Dougherty, 1992). Here B is the structuring element. The symbol ⊕ indicates dilation of A by B. Dilation expands the object if the origin is in B.

3.2.3 Rectangle generation

For generating a rectangle around an object first of all algorithms '*smallest rectangle*' 0.5 meter is applied. This algorithm generated the position of objects, which helped to generate the rectangle around that object. The operator determines the smallest surrounding rectangle of a region, i.e. the rectangle with the smallest area of all rectangles contained in the region. To determine the centre of the rectangle, inclination and two radii are calculated. Obtained parameters from the smallest rectangle are used to generate rectangle around the region. The operator *rectangle* generates one or more rectangle with the centre (row, column), the orientation Phi and the half edge lengths - Length1 and Length2. The orientation is given in arc measure and indicates the angle between the horizontal axis and Length1 (mathematically positive). The co-ordinate system runs from (0,0) (upper left corner) to (Width-1, Height-1) (lower right). Area of each rectangle and each region is calculated for obtaining maximum fit rectangle to the area.

3.3 Road Extraction

The approach for automated road extraction has three main assumptions. Earlier studies have shown that robust detection of roads in a variety of environments requires multiple detectors to be used for extracting road *primitives*. Roads are linear with parallel edges and to a large extent homogeneous. This means that if road in the image corresponds to an axis of the data then both roadsides will be approximately parallel to the axis.

Furthermore, roadside is assumed to have strong edges in the image and the grey values along a road axis can be expected to be more or less constant. The fundamental idea of this approach is that both roadsides are expected to be near the axis if the data correspond to a road in the image. Thus, the first step consists of searching of two strongest edges on both sides of the axis (Steger et al., 1996). Following steps are followed for road extraction (Figure 5).

3.3.1 Extraction of road in low-resolution using high-resolution image

At low-resolution roads can be modelled as a line that is brighter or darker than their surroundings due to high contrast. Hence first step to extract road automatically is to extract a line. The Gauss pyramid algorithm is applied to the original aerial image and/ or nDSM image to reduce the image by a factor chosen such that roads in reduced image become five to six pixels wide. The scale by which the next image will be reduced is determined by the parameter called 'Scale'. On this image, a line Gauss algorithm is used for the line extraction.

3.3.2 Extraction of road in high resolution data

At high resolution roads are assumed to be relatively homogeneous regions in the image that have significantly different brightness values than their surroundings areas. Hence it assumes that roadside can be detected by '*edge extraction*' algorithms. Following algorithms from HALCON were used for the road extraction.

3.3.3 Edge detection

In order to find out the two strongest edges algorithm begins by computing a gradient image on multi-spectral data using modified '*Deriche edge*' operator. The output from '*Deriche edge*' operator is used to filter out high frequency noise and pixelization from the image by linking adjacent edges into long, smooth and continuous contours. This image has two edges reflecting the dominant structure. '*Edges image*' algorithm optionally offers to apply a non-maximum-suppression (NMS = 'nms'/'inms'/'hvnms'; 'none' if not desired) and '*hysteresis threshold*' operation to the resulting edge image. Use of the edge amplitudes (gradient magnitude) and directions algorithms on image were returned in Amplitude image and Direction image respectively. To reduce the amount of data that has to be handled and to facilitate the perceptual grouping of parallel lines, a polygonal approximation of each contour is computed by the algorithm '*generate polygon*' (Mvtec, 2002). This algorithm splits contours into polygon segment, which have a limited distance to the approximated contour.

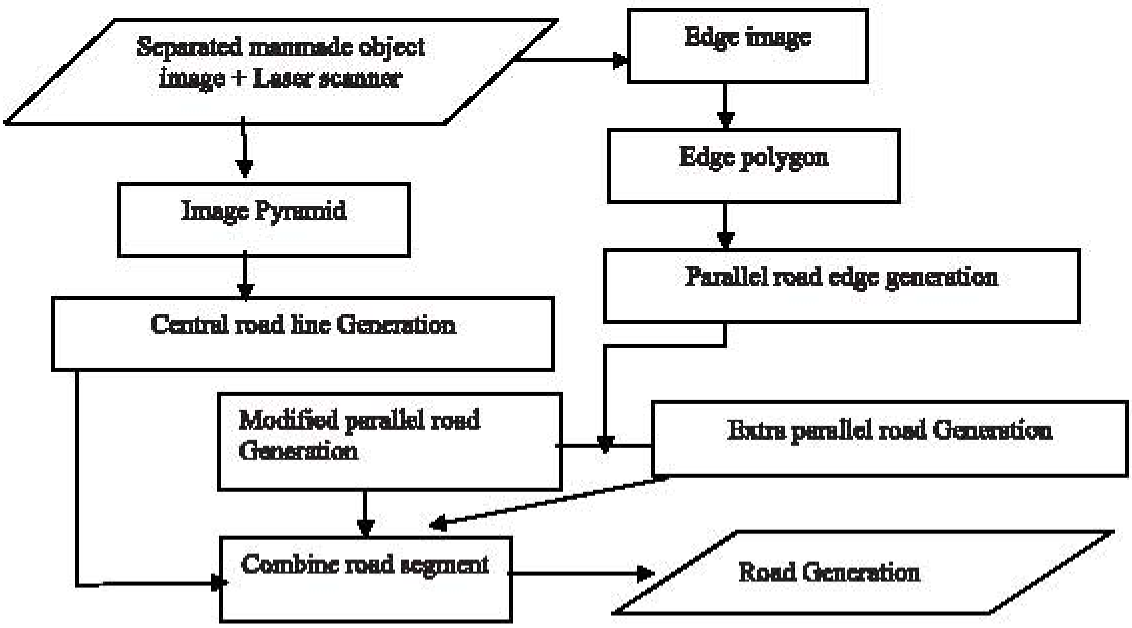

Figure 5: Flow diagramme of Road extraction using LASER and Multispectral data

3.3.4 Perceptual Grouping of Parallel edges

One feature, which is characteristic of roads, is the parallelism of opposite roadsides. Therefore, the next step in the road extraction process is to construct relationship of parallel polygon. To be considered into this relation, line segments have to fulfill several criteria. Road *'parallel_xld'* algorithms from HALCON software is used for examining polygons passed in above operation. The resulting parallel polygons are returned as Parallels. If the parameter 'Merge' is set to 'true', the adjacent parallel polygons are returned in a single parallel relation, otherwise, one parallel relation is returned for each pair of parallel line segments. Whether two polygon segments are parallel depends on their distance, a maximum allowed angle difference (Alpha, in radians) and a minimum length of the two polygon segments. Furthermore, the two segments have to overlap. As a *'side effect'*, a quality factor is calculated for each pair of parallels. It is based on the normalized angular difference and normalized length of the overlapping area:

3.3.5 Selection of homogeneous area between parallels

The next step is to examine whether the area between the parallel line segments is homogeneous in the direction of the centre line between them. Only parallels having a quality factor larger than specified are examined. The *'mod_parallel_'* algorithm performs parallel cross sections one pixel apart, and parallel to the line segments in the area of overlap between two parallel line segments. In the first iteration, the mean grey value for each of the lines in the cross section is calculated. In the second iteration, the standard deviation of the grey values along each line is computed. If the mean grey value of an area between parallels lies in the interval of minimum and maximum grey and if the mean of all standard deviations is smaller than the upper threshold, the corresponding parallels are returned as modified parallels. In a second step, all polygon segments adjacent to parallels bordering homogeneous areas are checked for homogeneity. To do so a rectangle having the width of the last area enclosed by a modified parallel is constructed and checked for homogeneity using the algorithm described above. This process is continued as long as there are adjacent polygon segments. The polygons thus found are returned as extended parallels in Extra parallels.

3.3.6 Combining road segments

Combine road' algorithm combines roads obtained from two different resolution levels. The algorithm selects only those outputs, which mutually supports each other in both resolutions. The basic strategy in this step is to take the result of both levels to start the processes, parallel lines that enclose a homogeneous area of the high-resolution level will be selected if a centerline of reduced resolution level will occur between these two parallels.

4. Result and Discussion

4.1 Building recognition and extraction

Various algorithms were tested for the building extraction in urban areas using Laser scanner data. However, it is observed that for extracting buildings both Laser scanner as well as multispectral images may be used. The binary threshold of the NDVI image was very useful in removing vegetation from the multispectral image. The separated man-made objects were combined with Laser scanner image to eliminate all unnecessary objects, which are not fulfilling the criteria of minimum building objects. Values are chosen based on prior knowledge of height and size of buildings. Man-made objects could be detected by removing extraneous objects. The stepwise processes solved the problem of detecting complex buildings by using morphological filters/operators. The disadvantage of this process is that the buildings with very complex structure/geometry were not detected. Using a square structural element equal or smaller than the spacing between objects solved this problem and regions just connected by small bridges were separated. An erosion operation removes building objects of size smaller than the structural element, while the dilation restores the shape of large building objects. The resulting binary image is analysed by a connected component analysis, which results in a greater number of regions and is evaluated again. Pixels in regions now classified as containing vegetation were erased in the initial image. The resulting image contained only building objects. Rectilinear line segments connect building objects bound by these shapes. Bounding rectangle was found pretty good option to separate and classify buildings. In first step sixty-four buildings were extracted which is equal and more than eighty per cent of the buildings. In second step eighty-four building were extracted, which fitted within rectangle. In third step eighty-three buildings were separated. Out of total 231 building objects, 220 buildings are with more than 2 m^2 of minimum area. Eleven objects which had less than or equal to 2 m^2 were excluded because of the assumption of minimum building area. In final image 220 buildings were extracted (Figure 6a) (Table 1).

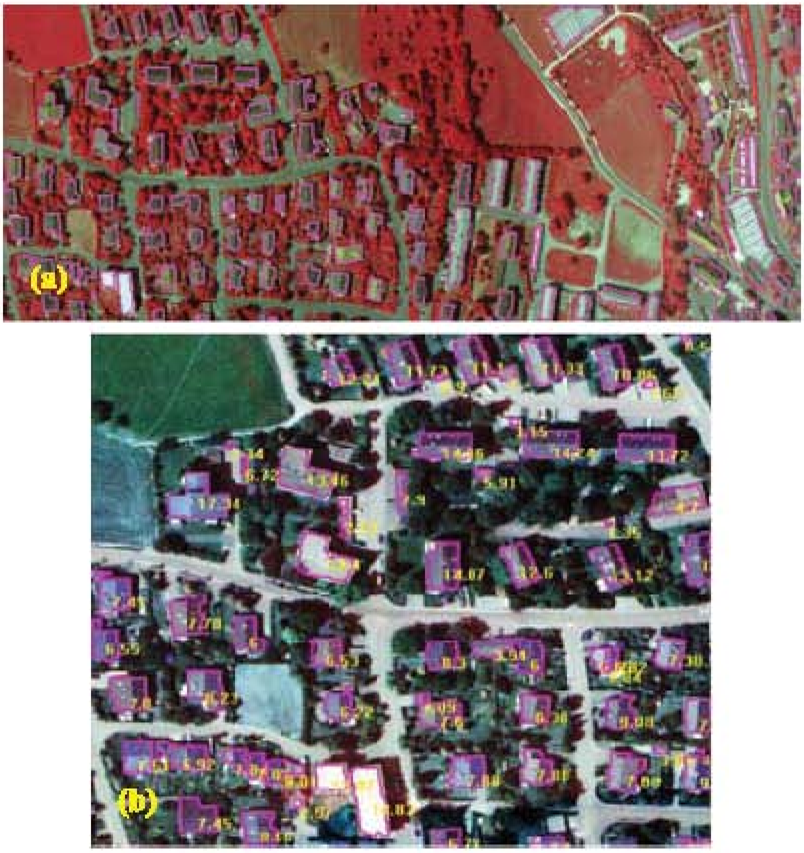

Figure 6: (a) Segmented buildings objects on False Colour Composite (FCC) of multispectral (RGB, 432) data, (b) enlarged view of buildings objects to show height (m) estimated on combined Laser scanner and multispectral data

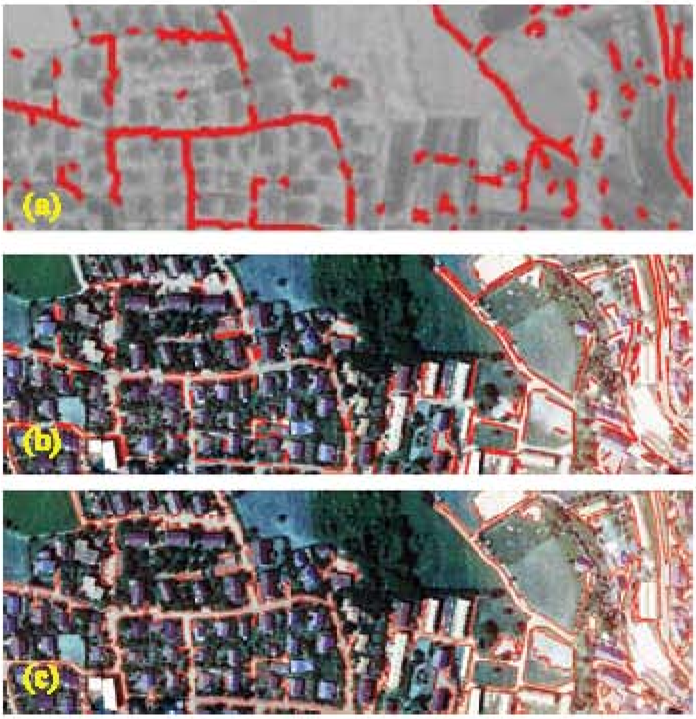

Figure 7: (a) Extracted central line in low resolution image draped on Laser scanner data, (b) extracting roadside line in high resolution draped on image, (c) completed missing road segment draped on image

Table 1: Showing area and height of buildings

Number of buildings	Maximum area (m^2)	Minimum area (m^2)	Maximum height (m)	Minimum height (m)	Mean height (m)	Total area (km^2)
220	4080	5.25	25.32	2.33	8.43	4.57

Table 2: Accuracy assessment of object extraction

	Completeness	Correctness
Building	100%	91.36
Road	100%	91.87

Area estimated for building cover is about 4.573 km^2. Maximum height of building is 25.32 m with mean height of 8.33 m. (Figure 6b) (Table 1). It was found that by manual observation only 201 building could be detected, which is however quite close to automatic extraction. The difference is due to mixing of spectral signature of buildings, suggesting that human eye was not capable to detect these. In order to generate the rectangle around the extracted roof border, for generation of roof plane, it was found that 75% of the buildings with simple shapes were found to fit exactly within rectangle and 25% of the buildings, which have very complex shape, were unable to fit within rectangles.

4.2 Road Extraction

As is obvious, road extraction is easier on high-resolution data and at the same time finding center-line on low resolution is difficult. Therefore, finding center-road-line from high-resolution image using pyramid algorithms is much more economical as compared to acquiring low-resolution image to find out central-lines. It was observed that the local Gaussian mean of the image helps to connect successfully the contours of the area. The algorithm was tested with 0.5m resolution Laser scanner and multispectral images. Figure 7a shows the image and the results of road extraction. Among various types of roads within the image, all major roads, whose centerlines were visible, were successfully extracted. In the high-resolution image (0.5 m), the edges were extracted and approximated by polygons. From these candidates, roadsides were computed using the knowledge given by the model that roads have parallel sides and that the region between two roadsides is homogeneous in the direction of the road. In high resolution image the main concern was to find out the extent of road width, which was however carefully identified, due to change of spectral response at the edge of image and frequency. It was observed that some roadsides were missing (Figure 7b). It is because algorithms described so far fail in region of the road where no parallelism existed. The missing road parallels were obtained using extra parallel algorithms. Splitting parallel roadsides into non-overlapping quadrilaterals helped in solving the problem. Adjacent road-parts are chained to road-segments and small gaps were filled. The results of combination of both resolutions provide roadside in urban area (Figure 7c). Total road length in the study area is about 9.34 km whereas total road length obtained through analysis is 10.166 km. Basically difference is to the fact that the algorithm failed to differentiate between road and railway lines. Fly over bridges were ignored due to their height matching with the surrounding buildings.

5. Accuracy Assessment

Results vindicated the potential of automatic extraction algorithms on LiDAR data. However, a quantitative accuracy assessment is required to identify how good these results are. Heipke et al., (1997) suggested several measures to assess the quality of road extraction. The completeness and correctness measures can be used to assess building extraction too. Completeness represents the percentage of reference data being extracted. Correctness indicates the percentage of correctly extraction accuracy .The accuracy analysis shows 91.36% of building pixels are correctly classified while 91.87/5 of road correctly extracted. (Table 2)

6. Conclusion

Present study had aimed to design and test a simple and fast method to automatically extract man-made objects such as buildings, roads etc. in urban area using Laser scanner and multispectral data. Since most of the studies using Laser scanner have reported high accuracy, therefore, emphasis has been to improve the processing speed. Single Laser scanner data is not able to capture feature like straight broken lines and ridges directly. The combination of Laser scanner and multispectral data is more efficient for extracting objects, spectral resolution of multispectral data provide horizontal accuracy while it is observed that high density of Laser point data might improve the extraction procedure, especially the roof details and help to reconstruct the buildings better. This method could be very useful and effective for extracting building in large area with acceptable accuracy in lesser time. In our approach 94% building region/objects were detected. The building models generated by the proposed method have the merit of high horizontal accuracy from multi-spectral images and high vertical accuracy from Laser scanner data. But it was observed during the experiment that many times edge detection algorithm did not work, generally in the areas where the tree canopy is adjacent or over to building and houses joined with each other. Future research will not only include the improvements in the modules for building reconstruction, but also the assessment of quality parameters for better results, with respect to the building outlines, which can be accomplished by integrating it with GIS data. The findings of road extraction algorithms presented here are fast and useful in implementing a system to automatically updating roads in GIS or any other existing database. However, there are some limitations with edge based detectors which are not able to differentiate between rail, road and highway and algorithm may not work on the road cast by shadow and therefore, pixels of roads in image must be selected carefully since algorithm cannot judge the validity of input seeds. The roads that will not give edges in edge detector cannot be extracted. The algorithm requires input roads of significant width. Further analysis to combine other filters to help separate road vs. rail and bridges vs. surrounding buildings may focus on integrating these algorithms more tightly.

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