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Hybrid comprehensive edge detection algorithm for LIDAR images

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ABSTRACT

Edge detection is a prominent feature in image processing used to detect edges and their analysis and detection are an essential goal in computer vision and image processing. Indeed, in a variety of applications such as 3-D reconstruction, shape recognition, image compression, enhancement, and restoration, identifying and localizing edges are a low level task. This paper presents a hybrid approach to LiDAR image edge detection which becomes a vital point in extracting features in images. In this, edge detection is considered as one of the technique and the evaluation metrics such as SSIM (Structural Similarity Index) and VIF(Visual Information Fidelity) has been applied to the images to measure the image quality. Light Distance and Ranging (LiDAR) is a technology which measures positions of physical ob¬jects, rapidly. In the urban case, the scanner measures the posi¬tions of most of the features along the street and it is also used to assess forests, rivers, mining, coastal areas, etc. In the present work evaluation metrics are applied to the original image and edge detected image, thus from experimental results it is observed that the proposed algorithm works well for measuring the quality of spatial resolution enhanced hyper spectral images.

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INTRODUCTION

The important image processing tool that is used as a fundamental pre-processing step in many image processing applications is edge detection. Edges map have a significant role in application such as image categorization, image registration, feature extraction, and pattern recognition. An edge detector can be defined as a mathematical operator that responds to the spatial change and discontinuities in gray levels of pixels set in an image (Zhongshui QU *et al*., 2010).

LiDAR images have extensive application in mapping the rivers, transportation, city modeling, mining, coastal areas, forest and vegetation terrains (Kenji Omasa *et al*., 2007). Thus in this paper we apply edge detection techniques to a LiDAR image. The RGB image is transformed to various color models such as YUV, YCbCr and XYZ. The metrics such as SSIM and VIF have been applied to the above models for assessment of quality of images and out of these XYZ color model is providing more detailed edge information than the other color models (S K Naik *et al*., 2006, R Lukac *et al*., 2007).

Different color spaces:

YUV and YCbCr Color Models:

The YCbCr color space is used for component digital video is a scaled and offset version of the YUV color space. The YUV color model is the basic color model used in analogue color TV broadcasting. Initially YUV is the re-coding of RGB for transmission efficiency (minimizing bandwidth) and for downward compatibility with black-and white television. The YUV color space is “derived” from the RGB color space .It comprises of the *luminance* (Y) and two color difference (U,V) components .The luminance can be computed as the weighted sum of the Red ,Green and Blue components, the color difference ,or *chrominance* ,components are formed by subtracting luminance from blue and from red. The principal advantage of the YUV model in image processing is decoupling of luminance and color information .The importance of this decoupling is that the luminance component of an image can be processed without affecting its color component . For example the histogram equalization of the color image in the YUV format may be performed simply by applying histogram equalization to its Y component .There are many combinations of YUV values from normal range that result in invalid RGB

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values, because the possible RGB colors occupy only part of the YUV space limited by these ranges. Figure 2 shows the valid color block in the YUV space that corresponds to the RGB color cube RGB values are normalized to [0..1] (Abhishek Gudipalli *et al*., 2012).

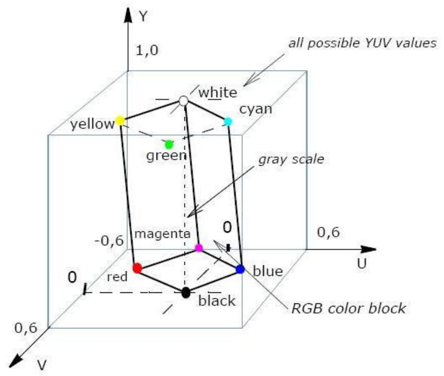

Fig.1: YUV Color model.

The Y'U'V' notion means that the components are derived from the gamma corrected R'G'B'. Weighted sum of these non linear components forms a signal representative of the luminance called *luma* Y'(*luma* is often loosely referred to as *luminance* so you need to be careful to determine whether a particular author assigns a linear or a non-linear interpretation to the term *luminance*).The YCbCr color model is a scaled and offset version of the YUV color space and is used for component digital video . The position of the block of RGB-representable colors in the YCbCr space is shown in Figure2 RGB Colors Cube in the YCbCr Color Model (Abhishek Gudipalli, *et al*., 2012).

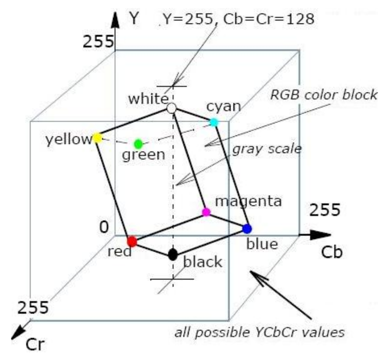

Fig. 2: YCbCr Color model.

Conversion between RGB and YUV models:

Y'= 0.299*R' + 0.587*G' + 0.114*B'
U'= -0.147*R' - 0.289*G' + 0.436*B' = 0.492*(B'- Y')
V'= 0.615*R' - 0.515*G' - 0.100*B' = 0.877*(R'- Y')

Conversion between RGB and YCbCr models:

Y' = 0.257*R' + 0.504*G' + 0.098*B' + 16
CB' = -0.148*R' - 0.291*G' + 0.439*B' + 128 s
CR' = 0.439*R' - 0.368*G' - 0.071*B' + 128

CIE XYZ Color Model:

The XYZ color space is an international standard developed by the CIE (Commission Internationale de l'Eclairage) . This model is based on three hypothetical primaries, XYZ, and all visible colors can be represented by using only positive values of X, Y, and Z. The CIE XYZ primaries are hypothetical because they do not correspond to any real light wavelengths. The Y primary is intentionally defined to match closely to luminance, while X and Z primaries give color information. The main advantage of the CIE XYZ space (and any color space based on it) is that this space is completely device-independent. The position of the block of RGB-representable colors in the XYZ space is shown in Figure3 RGB Colors Cube in the XYZ color space.(Abhishek Gudipalli *et al*., 2012).

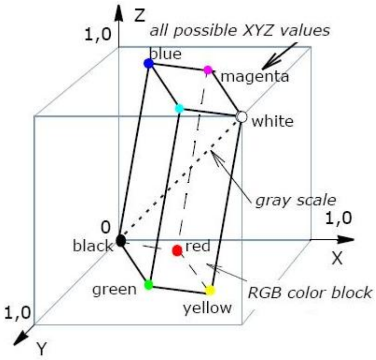

Fig. 3: XYZ Color model.

Conversion between RGB and XYZ models:
X = 0.412453*R + 0.35758 *G + 0.180423*B
Y = 0.212671*R + 0.71516 *G + 0.072169*B
Z = 0.019334*R + 0.119193*G + 0.950227*B

Lidar:

Lidar or Laser Altimetry is an acronym for light detection and ranging. It is similar to radar (radio detection and ranging), except that it is based on discrete light pulses and measured travel times. The location and elevation of the reflecting surface are evaluated from the time difference between the laser pulse being emitted and returned, the angle that the pulse was 'fired' at, and the location and height of the aircraft in which sensor is placed. The lidar has active sensor (Laser) which generates energy for measurement. This allows lidar to collect information at night when the air is clear and contains less air traffic than the daytime. Lidar cannot penetrate through clouds, rain, or dense haze and must be flown during fair weather. Lidar instruments can rapidly measure the Earth's surface, at sampling rates greater than 150 kilohertz. The resulting product is a densely spaced network of highly accurate georeferenced elevation points that can be used to generate three-dimensional representations of the Earth's surface and its features. Typically, lidar measures elevations at accuracy of about 6 to 12 inches (15 to 30 centimeters) (Aerometric: Geospatial Solutions, *et al*.).

Evaluation metrics:

In image processing applications, the measurement of image quality plays main role. Image quality assessment algorithms are classified into three categories: Full Reference (FR), Reduced-Reference (RR), and No-Reference (NR) algorithms (S Qian *et al.*, 2010). True No Reference algorithms are difficult to design and little progress has been made (Sheikh *et al*, 2005). Full Reference algorithms are easier to design and The SSIM index is a full reference metric. In this, the measurement of image quality is based on reference image of perfect quality. SSIM is designed to improve Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE), which is proved to be inconsistent with human eye perception(S Qian *et al*., 2010). However, in RR or NR quality assessment, partial or no reference information is available. The SSIM index is defined as (Chen G. Y *et al*., 2008):

$$\mathrm{SSIM(x,y)} = \frac{\sigma_{xy} + C_1}{\sigma_x \sigma_y + C_1} \cdot \frac{2\mu_x\mu_y + C_2}{\mu_x{}^2\mu_y{}^2 + C_2} \cdot \frac{2\sigma_x\sigma_y + C_3}{\sigma_x{}^2\sigma_y{}^2 + C_3} \tag{1}$$

Negative signals extracted from the same spatial location from two images being compared, respectively μ_x,σ_x^2 and σ_{xy} be the mean of x ,the variance of x and the covariance of x and y, respectively. $\mu_x$and σ_x gives the information on luminance and contrast of x. σ_{xy} measures the structural similarity.

where C_1, C_2 and C_3 are small constants given by $C_1 = (K_1\ L)^2$; $C2 = (K_2\ L)^2$ and $C_3 = C_2 / 2$; respectively. L is the dynamic range of the pixel values (L = 255 for 8 bits/pixel gray scale images), and $K_1 < 1$ and $K_2 < 1$ are two scalar constants (S Qian *et al*.,2010, Abhishek Gudipalli *et al*., 2012).

(Sheikh and Bovik *et al*., 2005), developed a visual information fidelity (VIF) index for Full Reference measurement of quality of image. VIF is calculated between the reference image and its copy (S Qian *et al*., 2010). For ideal image, VIF is *exactly* unity. For distorted image types, VIF lies in between interval (0, 1). Let $e=c+n$ be the reference image, and n zero-mean normal distribution N (0, $\sigma_n^2 I$) noise. Also, let $f=d+n'= gc+v'+ n'$ be the test image, where g represents the blur, v' the additive zero-mean Gaussian white noise with covariance $\sigma_v^2\ I$, and n' the zero mean normal distribution N(0,σ $n2I$) noise (Sheikh H. R *et al*.,2005, Abhishek Gudipalli *et al*., 2012). Then, VIF can be computed as the ratio of the mutual information between c and f, and the mutual information between c and e for all wavelet sub bands except the lowest approximation sub band

(Sheikh, H. R *et al*., 2005, Abhishek Gudipalli *et al*., 2012).

$$VIF = \frac{\sum |(c; f \mid z)}{\sum |(c; e \mid z)} \qquad (2)$$

Proposed edge detection algorithm:

The proposed algorithm can be explained in nine steps:

Step 1: The RGB image is sub divided into R, G and B layers of the image.

Step 2: A 3X3 Laplacian mask is convolved with the R component of the image.

Step 3: The edge detected R and the G, B layers of the image are concatenated to obtain edge detected image

Step 4: SSIM and VIF values are calculated between the R edge detected image and RGB image.

Step 5: Repeat steps 2 to 4 to calculate the SSIM and VIF values between G edge detected image and RGB image

Step 6: Repeat steps 2 to 4 to calculate the SSIM and VIF values between B edge detected image and RGB image

Step 7: The SSIM and VIF values of individual components are averaged.

Step 8: R, G and B values of the image are transformed into its YCbCr, YUV and XYZ Intensity values using the conversion formulas.

Step 9: Repeat steps 1 to 8 to calculate SSIM and VIF values for YCbCr, YUV and XYZ images.

Experimental results:

The Proposed algorithm has been applied to LiDAR images of different color models and SSIM &VIF values are computed for a set of edge detected images and dataset is formed and tabulated in Table 1. The Natural color image of river along with forest area was captured by LiDAR can be used as best mapping tool to provide information on river basin with flooding area, forests along the river basin. Floods in the river occur when the flow rate exceeds the capacity of the river channel, particularly at bends in the waterway. Floods count among the most frequent natural hazards in this world. Floods often cause damage to homes and forestry if they are in the natural flood plains of rivers. The image courtesy of river is provided by Valtus imagery and data store, canada. For RGB color model, The SSIM value range is around 0.2456 and VIF value range is around 0.0722. For YUV color model, The SSIM value range is around 0.1156 and VIF value range is around 0.0264. For YCbCr color model, The SSIM value range is around 0.3834 and VIF value range is around 0.0474. For XYZ color model, The SSIM value range is around 0.4179 and VIF value range is around 0.3187. From the dataset, XYZ model shows better quality of edge detection than the other color models. The original and edge detected RGB, YCbCr, YUV and XYZ images are shown below.

Table 1: SIM and VIF Values for RGB, YUV, YCbCr and XYZ images.

COLOR MODEL	SSIM	VIF
RGB	0.2456	0.0722
YUV	0.1156	0.0264
YCbCr	0.3834	0.0474
XYZ	0.4179	0.3187

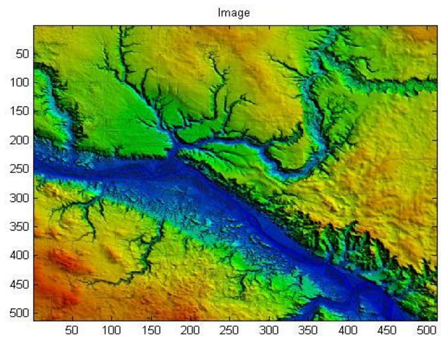

Fig.4: RGB image

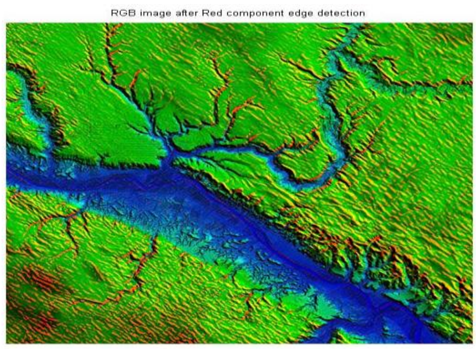

Fig. 5: RGB edge detected image.

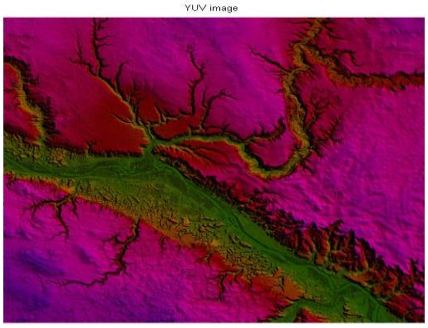

Fig. 6: YUV image.

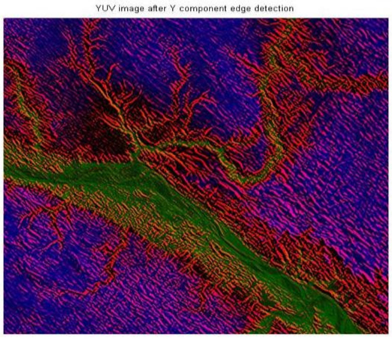

Fig. 7: YUV edge detected image

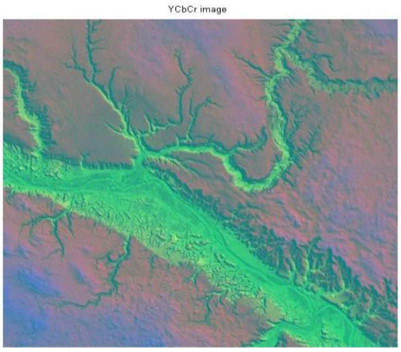

Fig. 8: YCbCr image.

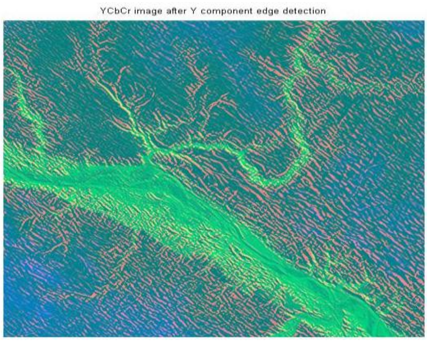

Fig. 9: YCbCr edge detected image.

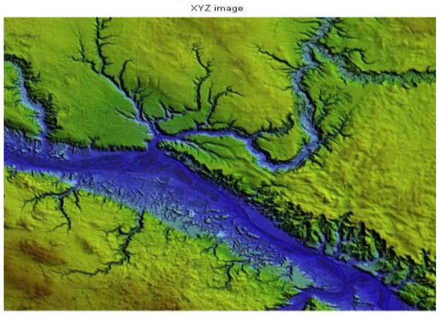

Fig. 10: XYZ image.

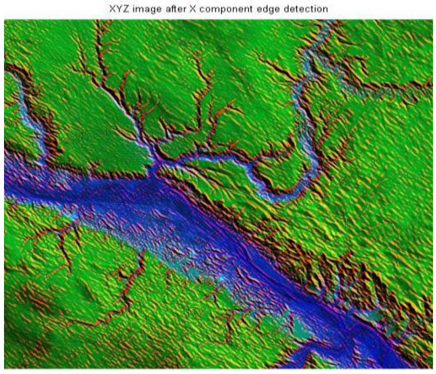

Fig. 11: XYZ edge detected image.

Conclusion:

The proposed algorithm has a variety of applications especially in Bio-medical field. Sobel operator and Laplacian operators are used to detect edges on different application specific satellite, Biomedical and general color images. Also by changing RGB image to XYZ and YUV color space we ensure a better quality LIDAR images with minimal data loss .LIDAR is regarded as the key technique in mapping terrains, forests and river basins to investigate the floods, density of trees and buildings in terrain areas. The computer modelling of the data captured by the LiDAR can be used to control the damage caused by the floods in the river basins. Therefore the concept of conversion of image from one color space to another extends hope to new horizons. The algorithm was developed based on RGB color space and the significant features extracted by converting it into YUV, YCbCr and XYZ models. Among these XYZ model shows better quality of edge detection.

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