Identification of Power Poles Based on Satellite Stereo Images Using Graph-Cut Algorithm

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***Abstract*— Monitoring vegetation encroachment for high voltage transmission lines is a challenging job for electrical distribution companies. The encroachment interrupts electrical supply to industrial sectors and residential areas. It also endures a great cost to the authorities for maintenance and damage compensation. This brings a necessity for companies to monitor the vegetation near power lines. To solve these issues, existing monitoring methods are time consuming and expensive. In this paper, we proposed a new method to detect the vegetation using satellite stereo imagery. The method is based on Graph-Cut algorithm which applied on satellite stereo images. We incorporated the ordering constrain with Graph-Cut on stereo images to detect occlusion on stereo matching algorithm. This will increase the accuracy of the disparity map which is required task for identification of power poles near vegetation based on satellite stereo images. In conclusion, based on the results, Our proposed Graph-Cut algorithm produces more accurate disparity maps than the existing matching algorithm used for disparity calculation.**

Keywords— Pleiades satellite stereo Images; Graph-Cut algorithm; Power poles detection; Stereo matching; LIDAR.

I. INTRODUCTION

Vegetation or trees may pose a major risk to the reliability of transmission power lines. Overgrown trees within the vicinity or in the 'danger zone' of transmission power lines can lead to short circuits, which consequently interrupts the continuous power supply, hence instigating blackouts. Danger zone refers to the area around the vegetation growth, which may cause flashover and subsequent power failures. The electric power utility companies monitor the vegetation growth regularly along the danger zone and eliminate them to avoid blackouts and economic loses. Many methods can be deployed to monitor the vegetation growth, and more importantly to estimate the height of the vegetation within the danger zone. Traditional method of manual line patrol or inspection on foot lack accuracy primarily due to human judgmental errors. Moreover, this traditional method consumes a long time, and can be dangerous; essentially due to bad weather, or sometime exposes human to wild and vicious animal. Aerial inspection of power lines using a helicopter, or airborne imaging sensors are very expensive and trivially feasible in a non-uniform terrain [1]. In comparison with the manual visual inspection method, the aerial inspection can cover a larger area in a lesser time but incorporates excessive costs. The latter method is also prone to error introduced by camera shaking, and target location ambiguity, especially for non-uniform terrain.

Videography, or aerial multispectral imaging utilizing computer vision techniques are better than the previous two methods. This method also uses the helicopter or balloon or airborne vehicle to capture the aerial images of vegetation. This method has a better accuracy as compared to visual or video surveillance, but more time consuming due to the low altitude of the airborne vehicle and its accuracy is dependent upon the multispectral resolution.

The method of satellite stereo imaging can provide a cost effective solution, with lesser involvement of human resources and manual judgment. The time required to monitor a particular danger zone is less, since the images are captured using satellite. The use of satellite stereo images has many advantages over visual inspection on foot and airplane based technique [2]. The satellite images cover a wide area; have cost effective and easier access to restricted areas [3].

This paper presents algorithms to process the stereo images obtained via Pleiades satellite sensor, and carry out the required calculation to monitor the vegetation, followed by performance comparison with Graph-cut algorithm for disparity calculation, in terms of accuracy.

The background or related work of stereo matching algorithms are discussed in Section II. The proposed technique is explained in Section III. Section 1V presents the simulation results. The conclusion and future research directions are presented in Section V.

II. RELATED WORK

There are many stereo vision algorithms available to calculate the stereo map and depth map. The stereo vision system is used to determine the depth of the scene with the help of two images, which are captured from the same or vantage points [4]. The stereo matching is the process of matching the pixel of left image to corresponding right image.

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The depth of the scene depends upon the disparity map/stereo matching. A good stereo matching calls for an accurate depth map; however, this task is very difficult and time consuming. The disparity assignment in stereo matching is difficult due to occlusion and existence of texture-less region [5]. Sun et al. [6] presented the fast cross correlation technique, and applied box filtering to measure the stereo matching.

Stereo matching methods are generally categorized into two classes: local and global. The local methods are very fast and efficient in computation based on area/windows. On the other hand, global methods based on some energy function are computational expensive [6-8]. When we use smaller window in area based method, stereo matching method demonstrates more noise. When we increase the window size, the noise is less affected, but the computational complexity increases with the increasing in the window size. For the good construction of 3D, the surface should be continuous and full textured.

The variation in intensity is not covered for small window size, and if we increase the size, then occlusion and discontinuities in disparity occur. Area based methods are used to measure the similarity between two blocks using different types of window for measuring the disparity map from stereo images. The maximum similarity between two stereo images in stereo matching depends upon the cost/similarity function. The efficient designing of the cost/similarity function produces fast and robust stereo matching.

Global optimization algorithms like Graph-Cut and Belief propagation sometimes require extra parameters which cause the computationally more expensive [11]. These algorithms are not suitable for real time processing due to higher running time. These algorithms can be used for non-real time processing of data where higher accuracy is required.The Graph-Cut produced new energy minimization algorithm and give good architecture for stereo matching problems.Boykov and Kolmogorov show graph-cut based energy minimization algorithms which are faster by 2 or 5 times as compared to traditional push-reliable approaches. Graph-Cut for energy minimization using the Potts model are used in segmentation, Stereo, Object recognition, shape reconstruction and augmented reality. The Boykov produces excellent algorithms are expansion move and swap-move. These algorithms are based on pixel labeling for large pixel sets. Stereo matching based on multi-labeling problems and these labels are called disparities. Graph-Cut Algorithm provide accurate result as compared to Belief Propagation and Dynamic Programming [11-13]. Therefore, it is a suitable candidate for stereo matching for estimation of disparity maps or depth maps.

III. Methodology

A. *Proposed framework*

The proposed depth measurement method was applied to stereo imagery of Pleiades satellite. The Pleaides has GSD 0.7 m for panchromatic images and 2.25 m for multispectral images. The images of Pleiades were cropped due to memory constraints of the processing system.

The Pleiades satellite was successfully launched two sensors Pleiades-1A and Pleiades-1B on 16 december 2011 and 1 December 2012. Pleiades-1(A&B) has the capability to acquire stereo imagery in one pass with the few second differences. It has also ability to provide stereo-pairs colour images of 20 km swath and 70cm resolution obtained with base-to height ratio from 0.15 to 2.The Pleiades has been placed on the same sun-synchronous orbit at 694 km .It has been acquiring the panchromatic stereo images with resolution of 50 cm and multispectral images with resolution 200cm and also in bundle form 50cm black and white and 200cm multispectral. The Pleiades satellite has high resolution and low weight and also low cost for acquiring the images of small area.

The acquired data is first preprocessed and cropped. After cropping, we performed orthorectification on the desired area of interest images.The two stereo images are then used to calculate the disparity maps. The disparity maps are calculated using Graph-Cut algorithm. The depth maps are then can be compared with the previously recorded satellite data to find the area where vegetation strikes the power transmission poles. Fig. 1 shows the block diagram of framework that how we can get the desired information by using disparity maps and depth estimation technique.

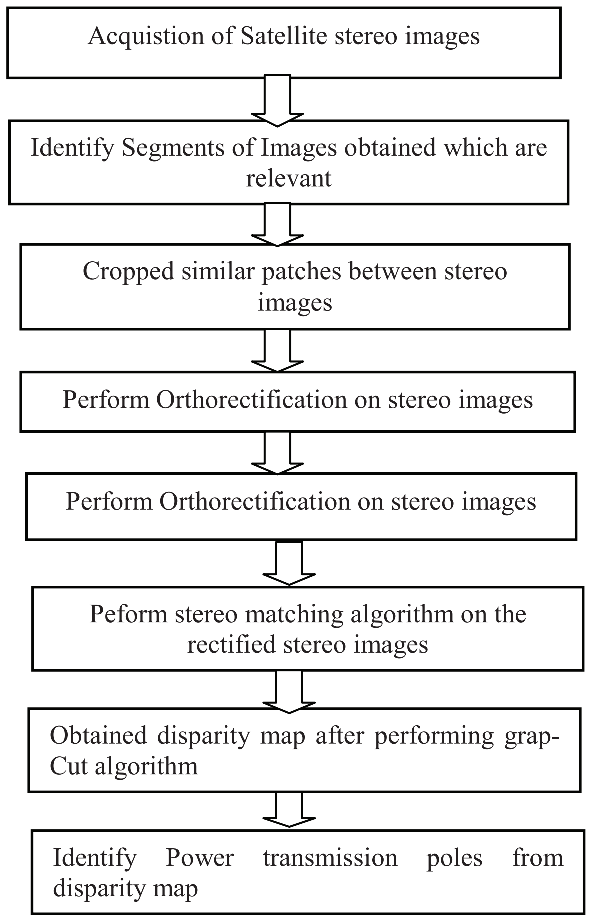

Figure 1. Proposed framework for Identification of poles using satellite stereo images based on Graph-Cut Algorithms

B. Disparity Map Generation

Depth information is computed from a pair of stereo images by computing the pixel wise distance between the location of a feature in one image and its location in the second image, hence generating a disparity map. Consequently, it gives a depth map because the pixels with larger disparities are closer to the camera, and pixels with smaller disparities are farther from the camera.

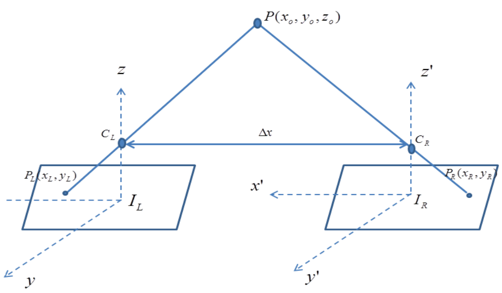

Figure 2. Stereo camera model [9]

In the Figure. 1, we have left and right camera images, where the left image have a center at 0 and right has a center at 0'. Therefore, we can calculate the 3D depth point at coordinates (X_0,Y_0,Z_0). We have the following relation from the above diagram [9]. Solving equation (4) and equation (5), we have the value of Z_o.This value of z depends upon the value of the denominator factor which is called disparity value.

$$\frac{x_0}{x_L} = \frac{y_0}{y_L} = \frac{\lambda - Z_0}{\lambda} \tag{1}$$

$$\frac{x_0 + \Delta x}{x_R + \Delta x} = \frac{y_0}{y_R} = \frac{\lambda - Z_0}{\lambda} \tag{2}$$

Solving equation (1) and equation (2),we obtain equation (3).

$$Z_0 = \frac{\lambda + \lambda \Delta x}{x_L - (x_R + \Delta x)} \tag{3}$$

The distance in pixels between the first and second image of the stereo pair is used to estimate the depth information and this information is called a disparity map. Pixels have smaller disparity are far from the camera and the pixels have larger disparities are near to the camera.in other words depth is inversely proportional to the disparity map as shown in the equation (3).We discussed Graph-Cut algorithms incorporated ordering constraint for stereo matching on plaids satellite stereo images.

C. Graph-Cut Algorithm for stereo matching

The stereo is a classical vision problem ,where graph based energy minimization method has been successfully applied. The three basic graph-based methods are used to solve stereo crosseponding problems are pixel labeling with the Potts model, stereo with occlusion and multicamera scene reconstruction[11]. The multicamera scene reconstruction method is used for more than three stereo cameras. We are interested to handle the stereo with occlusion and also detect object in stereo vision have textureless region. We used satellite stereo images which have low texture in some regions. In this paper, our work is closest to the formulation based on graph-Cut introduced by Kolmogorov & Zabih[14].They were used symmetrically images in both stereo pair and used binary labels to pixel from each pair instead of assigning labels to individual pixel. If the pixel pair has the same correspondence in stereo pair, it assign label 1 in the final disparity map, otherwise it is assigned 0 label. They further create a disparity map that imposes the uniqueness constraint.The Boykov [10] introduced similar work based on energy minimization using expansion move algorithm.This algorithm minimise the energy function in iterative manner.It minimize energy function by transforming into minimimum cut problem on the graph and cut the Graph at each iteration to sovle such problem at each iteration. The algorithm is run until convergence, and the result is a pretty strong local minimum of the energy function. The stereo correspondence algorithms based on graph cuts debated here practice the base from which innovative algorithms have arosed.the expansion-move algorithm has the following chracartestics.

- Large number of pixels can change their labels simultantaneously.
- Finding an optimal move is computationally interactive.
- It takes almost less than one minute for complete execution as compared to other energy minimization algorithm like simulated anneling and iterated-conditional model they take 19 hours to complete execution in early days.
- Finds local minimum of energy with respect to small “one-pixel ” moves.
- Initialization is important practice
- Theoretically,solution reaches the global minimum.

Kolmogorov & Zabih [14] introduced the energy function which comprises three terms: a data term,an occlusion term magnificent a penalty for making a pixel occluded, and a smoothness term penalising neighbouring pixels pairs for having different labels.

Baesd on energy function f of Kolmogorov and zabih,different energy function can be defined as

$$E(f) = E_{data}(f) + E_{occ}(f) + E_{smooth}(f) + E_{unique}(f) \tag{4}$$

We can define these energy termsone by one as the following

$E_{data}(f)$ define the matching cost of corresponding pixel and this matching cost can be calculated using four matching cost function given as

- Sum of absolute difference (SAD)
- Sum of Squared difference (SSD)
- Normalized cross-correlation (NCC)

- Zero-mean normalized cross-correlation (ZNCC)

The kolmogrov and zabih discussed squared difference of intensity values.We used Sum of absolute difference which is easy and cost effective.the formula of the data cost function is given below.

$$E_{data}(f) = \sum_{\langle p,q \in B(f)\rangle} \left| I_{LeftInteni\,ty}(p) - I_{rightInten\,sity}(q) \right|^{a} \quad (5)$$

Where a is may be 1 for SAD and 2 for SSD.

$E_{occ}(f)$ adds a constant value to total energy function for each occluded pixel in the stereo crossponding of the stereo pair.

$$E_{occ}(f) = \sum_{p \in P} K_p . F(\left| U_p(f) = 0 \right|) \quad (6)$$

Where F evaluates 1 if its argument is true otherwise zero.

$E_{smooth}(f)$ if the neighbouring pixels have different disparity this smooth energy function imposes the penalty and can be diffined as

$$E_{smooth}(f) = \sum_{\{b_1, b_2 \in N1\}} U_{b_1,b_2} . F(f(b_1) \neq f(b_2)) \quad (7)$$

The smoothness term will be zero if the assigmnet b_1 and b_1 have the same disparity in the $N1$ neighbouhood system for 4-neighbours in the input images otherwise it imposes penalty for different disparity of the neighbouring pixels.

$E_{unique}(f)$ confines the possible solutions of the optimisation problem to unique solutions. If pixel is containing more than one value in the crossponding image in stereo pair then it assign penalty for infinite value otherwise null value assign.

This can be defined as

$$E_{Unique}(f) = \sum_{P \in p} F(\left| N_p(f) \rangle 1 \right|).\infty. \quad (8)$$

We introduced the ordering term in the above total energy function for calculating stereo matching.

$E_{order}(f)$ can be wriiten as

$$E_{order}(f) = \sum_{\{b_1, b_2\} \in N_2} F(f(b_1) = f(b_2) = 1).\infty. \quad (9)$$

Where N_2 is a neighbourhood system and can be explain as in such a way that $b_1 = \langle p, q \rangle$ and $b_2 = \langle p', q' \rangle$ are neighbours pixels.They must fillfull the order as if $\langle p_x \rangle p'_x \rangle$ and $\langle q_x \langle q'_x \rangle$ is true.

The final energy function can be written as

$$E(f) = E_{data}(f) + E_{occ}(f) + E_{smooth}(f) + E_{unique}(f) + E_{order}(f) \quad (10)$$

The energy function can be minimized using Graph-cut algorithm is the overall solution of the crosspondence between stereo images.

IV. EXPERIMENTAL RESULTS

We selected area of 10X10 km square in Sabah in east Malaysia, so therefore we selected high resolution, small satellite sensor like Pleiades. This satellite has varieties probable various acquisition plans, such as a monoscopic cover up to 100x100 km or a stereoscopic instantaneous cover up to 60x60 km. The stereoscopic coverage is comprehended by only a single fly by of the area, which allows collection of a homogeneous product quickly. A classical forward and backward looking stereo pair provides the highest accuracy, but this combination is limited to areas with moderate terrain. A nadir and forward/backward looking stereo pair can be used in most kinds of terrain.The depth estimation was calculated on selected patches of imagery by employing the proposed Graph-Cut Algorithm.

We selected two cases when we have small occlusion in satellite stereo images as shown in Figure.7 and 8 and when large occlusion as shown in Figure. 3 and 4. we considered three problems in stereo matching. These three are textureless areas,occluded areas and nosiy area.The satellite images have low texure and more noise due to sensor orietenatation and very low resolution and very high altitude as compared to camera images. It is difficult to match prominenet feature or are similar patches or area in satellite stereo images,so we need to strong stereo matching algorithms to measure the disparity map or height of vegetation or trees near power transmission poles based on satellite stereo images. we proposed Graph-Cut algorithm and incorporate ordering constraint in this algorithm to detect object in texturless areas and occluded region and also we need smooth area which has low noise for propoer monitoring of vegetation or trees near power poles are lines.We processed panchromatic Pleiades satellite images of two different areas. The depth estimation was calculated on selected patches of imagery due to large size of images by employing our proposed Graph-Cut algorithm incorporated with ordering constraint.We need another solution for textueless region particular very important in satellite images.

A. Case I

The first case we selected contains four power poles having vegetation near power poles and some roads as it is clear from Figure 3 and Figure 4. Case I also contains some large occlusions. First we computed disparity maps using the existing graph cut algorithm. Figure 5 shows the obtained result which have some noise on textureless region as well as it is not so smooth. Now we applied our proposed Graph-Cut algorithm with incorporated ordering constraint on the same images. Disparity maps results are shown in Figure 6 and we obtained results with less noise and smooth image as compared to the existing graph cut algorithm. We are also able to detect 4 power poles out of 4 as marked in cicles.

B. Case II

We selected case II with less occulison as compared to the case I. It contains Pleiades Satellite stereo image with four power power poles and some vegetation also present near power poles. First we applied existing graph cut algorithm and results are shown in Figure 9. Results of disparity map to dectect power pole and vegetation shows a lot of noise and some streaking effect. Now again , we applied our proposed algorithm on these images and less noisy image was obtained and also we are able to detect the power poles 4 out of 4 which give us the higher detection accuracy.

Figure 11 shows the comparison between existing graph cut algorithm and our proposed Grah-Cut algorithm with ordering constraints. We obtained 80% accuracy as compared to the existing graph cut algorithm which is 72 %. This shows a significant improvement in the results with our proposed method.

Based on the these presented results here the use of the ordering constraint in a global method looks encouraging. Although the results are not amazing but it show that the significance of the ordering constraint will increase with images taking larger disparity ranges and more noise.

Figure 3. Reference Pleiades Satellite stereo image contains four power poles and vegetation near power pole and some roads having cars.

Figure 4. 2nd Pleiades satellite stereo image of the same area.this image contains power poles and vegetation and also roads but did not have vehicles.this is occlusion occur in this image when acqurired from satellite.

Figure 5. The disparity map obtained using existing Graph-Cut Algorithm on Pleiades satellite stereo image has some noise in textureless areas and not smooth. Red circles show that the power poles in white-colour.

Figure 6. The disparity map obtained using proposed Graph-Cut algorithm incorporated ordering constraint.Red circles show that the power poles in white-colour.

Figure 7. Reference Pleiades Satellite stereo image contains four power power poles and vegetation near power pole.

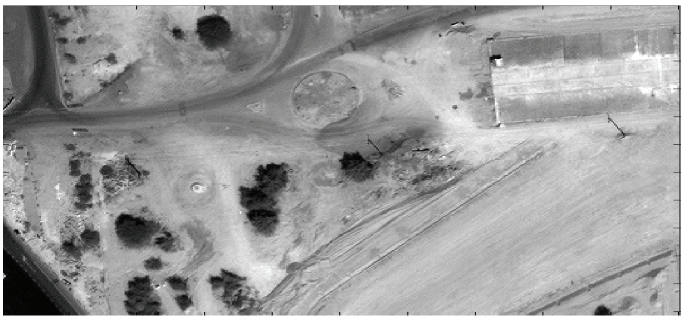

Figure 8. 2nd Pleiades satellite stereo image of the same area and have some displaced values.

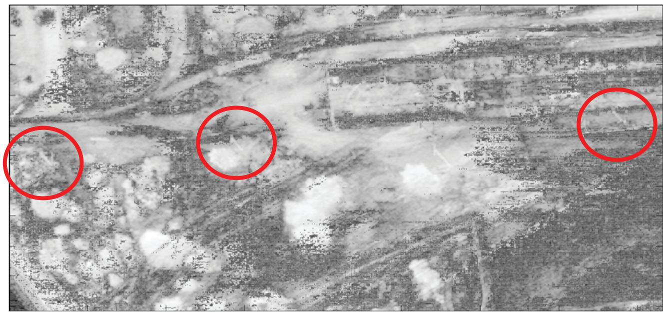

Figure 9. Disparity map using existing Graph-Cut algorithm to dectect power pole and vegetation.this image has a lot of noise and some streaking effect. Red circles show that the power poles in white-colour.

Figure 10. Disparity map using proposed Graph-Cut algorithm incorporated with ordering constraint has less noise and detect power poles to some extent. Red circles show that the power poles in white-colour.

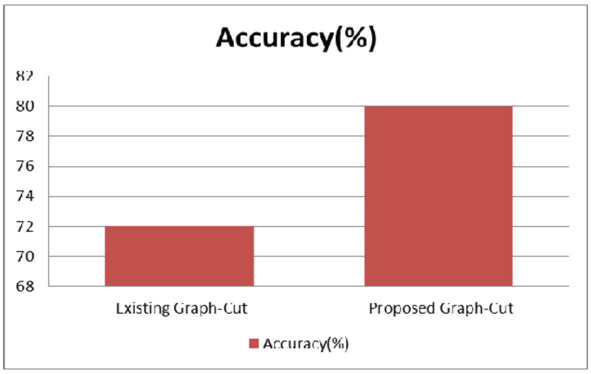

Figure 11. Accuracy of existing and proposed graph-Cut Algorithm.

V. CONCLUSION AND FUTURE DIRECTION

In this paper, a novel technique is proposed to monitor vegetation/trees near or under the power lines using satellite stereo images. The proposed method employs Graph-Cut to detect power poles near vegetation using Pleaides satellite stereo images.The proposed technique was employed imagery from Pleiades satellite.The experimental results exhibit that Graph-Cut based detection technique outperformed terms of accuracy. We investigate two cases of different area images of satellite stereo and shows that monitoring of vegetation near power poles is possible using Graph-Cut algorithm for future measuring the height of vegetation near power poles.

In future we can compare dynamic programming algorithm with graph cut to estimate the disparity map for this application. We can also apply two-way dynamic programming to compute the best optimal cost in inter-scan line between left and right stereo images.

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