ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A Multi-Decision Area Based Approach for Solving Correspondence Problem in Stereo Images with High Accuracy

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Abstract

In computer vision and digital photogrammetry solving the correspondence problem is one of the most important field of research. Conventional methods used to generate dense density maps for stereo image pairs is classified as either area based or feature based methods. In this paper a multi decision area based approach has been proposed that performs pixel matching in stereo-pairs. The approach makes use of various matching methods at different stages depending upon the value of parameter that has been used as Decision Factor. Normalized Cross Correlation which is a measure of similarity between windows has been used as decision factor, if maximum Normalized Cross Correlation calculated exceeds a certain upper threshold it is considered as If Normalized Cross Correlation value lies in midrange, 2nd stage analysis is performed that makes use of Edge Analysis and Euclidian distance while spline fitting is employed for lower values of decision factor, if NCC obtained falls below lower limit, no match is obtained. With the multistage approach & parallel processing speed of dense disparity map generation will improve along with improved accuracy. The method is tolerant to geometric distortions. The percentage of accurately matched pixels in stereo pairs was found to be 94.15% in one of the test data set, which was very high compared to standard Normalized Cross Correlation based approach (72%).

Index Terms—Multi Decision, Decision Factor in Stereo Matches, Area based matching, stereo-matching, correspondence problem, disparity map generation, template matching, Normalized Cross Correlation, Euclidian distance, RANSAC in image matching , Spline fitting.

INTRODUCTION

Stereo image matching is one of the core research areas in computer vision and digital photogrammetry. Stereo matching is the correspondence problem that is for any pixel in reference image of stereo pair finding corresponding point in target image. A multi decision algorithm based on NCC as parameter to select approach for determining the coordinate of matching pixel in reference image. Technological advancements have led to use of more precise feature based matching techniques. Disparity maps generated by stereo-matching techniques performed on stereo-pairs allow us to recover information that does not exist in any single image. The primary aim of stereo image matching is to recover elevation parameter from the given set of stereo images (Zitova and Flusser, 2003).

In order to recovering information related to elevation/depth, point to point correspondence or matching of stereo images is needed to be calculated. Correspondence points are the projections of a single point in to the three dimensional scene. The shift in the positions of two correspondence points is known as

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parallax or disparity that depends on position of the point in the scene, orientation and physical characteristics of the camera. The feature based approaches for stereo-matching are more accurate, but major disadvantage is that disparity maps obtained are sparse (not dense). We are proposing a multi decision area based image matching approach that is capable of producing dense disparity maps at a faster rate that can be utilized for generating Digital Elevation Model and reconstruction of 3D models and scenes.

In our approach, we utilize three different methods of image matching use of which totally depends upon calculated Decision Factor, The use of Decision Factor helps us to select the best suited technique for the image matching in the given region. Here, we are using Normalized Cross Correlation as Decision Factor. If the normalized cross correlation value obtained is fairly high, then we can consider geometric centers of two windows to be match and the matching to be complete. If normalized cross correlation is just optimum than further analysis using Edge Map Analysis and Euclidian distance calculation is done on 5 sub search windows showing best Normalized Cross Correlation values and the least Euclidian distance obtained is considered as match, the geometric centers are determined and stored as match points. For lower values of normalized cross correlation spline fitting has been performed, which requires minimum of seven control points' pair to find location of matching pixels accurately.

Certain applications such as Digital Elevation Modelling, terrain mapping, teleconferencing, robot navigation & control requires dense depth map. Stereo algorithm that produces dense depth maps are classified as global and local algorithms, as per the taxonomy given in (Peleg, and Weiser, 1996), Global algorithms (Fusiello, Roberto, and Trucco, 2000) involves usage of iterative schemes that carry out disparity assignments on the basis of the minimization of a global cost function. Local algorithms (Muhlmann, Maier, Hesser and Manner, 2002; Fusiello, Trucco and Verri, 2000; Trucco and Verri, 1998) also referred as area-based algorithms evaluate the correspondence at each pixel based on photometric properties of the neighboring pixels; local algorithms yield significantly less accurate disparity maps. So to improve the accuracy multiple methods have been proposed but which method has to be used that totally depends upon the decision factor presented in the paper. Search area in sensed image can be limited by visual inspection of stereo image pair, thus, improving computational speed that can be used in real time applications

In traditional Area based algorithms such as NCC based matching uses pixel intensity to compute similarity measure between small template and a large search window by using statistical correlation; however no attempts are made to detect salient objects. There is a high probability that a window having smooth area without any prominent details is matched incorrectly with other smooth areas in the reference image due to its saliency. Consequently they are sensitive to the intensity changes, introduced by noise, varying illumination and/or by using different sensor types

In the proposed approach, we are limiting the search window by visually determining the disparity which results in lower computation complexity. Further structural analysis of the probable matches is done with Euclidian distance criteria improve accuracy of the match. Even structural analysis fails to get correct matches in case of incomplete windows; to overcome this limitation spline fitting is used. The use of Normalized Cross Correlation as decision factor to decide which method needs to be employed at what point makes the approach highly accurate and less complex without compromising on density of disparity maps.

The Section 2 explains the use of decision factor and various techniques utilized in our approaches. Section 3 explains the proposed algorithm, which is a multi-decision area based technique that utilizes normal cross correlation as decision factor and Direct Selection, Edge Map Analysis and Euclidian distance and spline fitting as per obtained value of Decision factor. In section 4, results are presented for a sample stereo image pair and

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finally result analysis and an outlook to future research activities

THEORETICAL BASIS

Normalized cross correlation algorithm

Problem addressed in this paper is to calculate dense and highly accuracy disparity maps which selective approach to achieve comparatively lower computational complexity. Let f(x, y) denote the intensity value of the image f of size M x N at the point (x,y), x _ { 0, 1, ……, M-1}, y _ {0,1, ……,N-1}.

The pattern is represented by a given template t of size (p x q). A common way to calculate the position (mpos, npos) of the pattern in the image f is to compute normal cross correlation value ρ, at each position (m, n) for f and template t which has been shifted m steps in x direction and n steps in y direction.

The size of search window which is larger than template window is determined by inspecting stereo-pair visually.

$$\rho = \frac{\Sigma_{x,y}\left(f(x,y)-f'_{m,n}\right)\left(t(x-m,(y-n)-t'\right)}{\sqrt{\Sigma_{x,y}\left(f(x,y)-f'_{m,n}\right)^2 \cdot \Sigma_{x,y}(t(x-m,(y-n)-t')^2}} \quad (1)$$

In Equation (1) mean value of *f(x, y)* within the area of the template t shifted to (m, n) is denoted by f (m, n). Similarly t is the mean value of the template *t*. The denominator in equation (1) is the variance of the zero mean image function *f (x, y) – f(m, n)* and the zero mean template function *t*(*x* − *m*, *y*-*n*) − *t* . Due to this, the parameter normalized cross correlation coefficient at (m, n) is independent to change in brightness or contrast of the image. The method is more robust than other similarity measures like sum of absolute difference.

Edge Map generation & Euclidian Distance Calculation

Euclidian distance gives measure of similarity of model set lies near some point of image set that is used to find degree of resemblance in two superimposed objects. Edge map analysis combined with Euclidian Distance is utilized for template matching that can be viewed as a way of determining distance between shapes. Given two finite point sets in edge map generated using Canny Edge Detector.

A= {a_1, a_2... a_n} and B= {b_1, b_2… b_n}, the Euclidian distance is defined as

$$E.D = \sqrt{(a1-b1)^2 + (a2-b2)^2 + .. + (an-bn)^2}$$

ED = d, then each point of A must be within distance d of some point of B and there is some point of A that is exactly distance d from nearest point of B (the most mismatched point). It measures the degree of mismatch between two sets by measuring the distance of the point A that is farthest from any point of B. In this method of comparing shapes there is no explicit pairing of points of A with points of B.

Spline Fitting

Due to low Normalized Cross Correlation, the main causes of which are occlusions, border pixels geometric distortions conventional methods are not that useful. For that case, spline fitting is used. It mainly comprise of two stages:-

Generation of Control Points

NCC based image matching is applied on the two sets of stereo image and the points that are matched with high cross correlation are used as control points. There may be cases when for particular template desired number of windows may not be present and hence, method cannot be implemented. For solving this, adaptive window approach is used, that is, size of window is increased dynamically till at least 7 control points are not obtained.

Determination of coefficients

$$X = a_0 + a_1x + a_2y + \Sigma_{i=1}^{7} F_i r_i^2(\ln(r_i^2))$$

$$Y = b_0 + b_1x + b_2y + \Sigma_{i=1}^{7} F_i r_i^2(\ln(r_i^2))$$

For evaluating 14 coefficients at least 7 pair of control points is required. If number of control points obtained is greater than 7, than 7 control points are selected using RANSAC (Random Sample Consensus), using these control points, coefficients are calculated, the coefficients for which Sum of Squared Error is least

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among the set are used for calculating match points in sensed image. Once the coefficients gives calculated match for given pixel of reference image can be obtained in sensed image.

PROPOSED METHODOLOGY

A multi-decision area based method image matching is proposed below:

- Normalized cross correlation coefficient which acts as Decision Factor for selecting the approach used for finding matching pixel, NCC between template window and search sub windows is computed. If maximum Normalized Cross Correlation exceeds DS-NCC (Direct Selection Normalized Cross Correlation), than geometric centers of both the windows are considered match to each other.
- If NCC lies in range of DS-NCC(Direct Select) and O-NCC (optimum NCC) than five windows with best NCC is selected and further analysis using Canny Edge Map and Euclidian distance is done that filters out best templates, geometric centers of which is considered as match points.
- In case NCC values are greater than O-NCC (optimum) but exceeds T-NCC (Threshold NCC), approach used is spline fitting for image matching.
- In the NCC obtained is below T-NCC (threshold), it is considered that there is no match for that window.

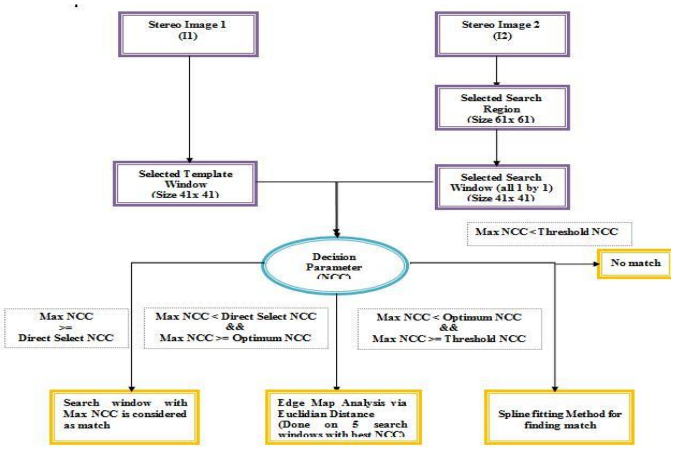
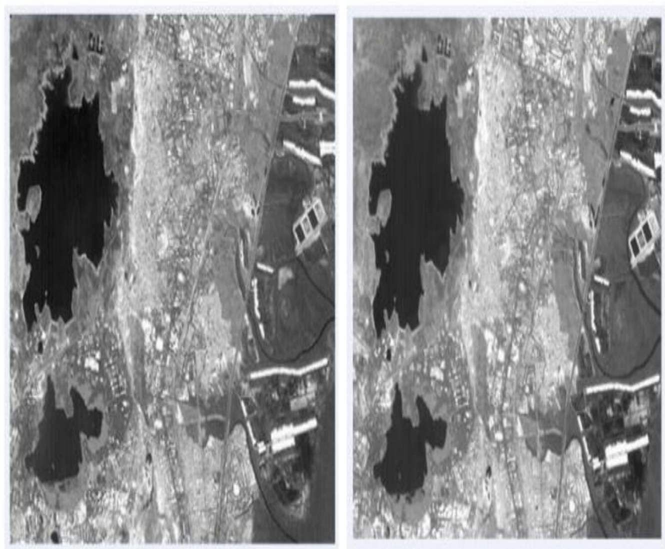


Figure 3: Flowchart showing multi-decision area based approach.

EXPERIMENTAL RESULTS

Proposed algorithm is performed on test pair of stereo images as shown in figure 4. As shown in the figure the left image shows the template window and the right image shows the larger search window. The size of the search window is decided by considering horizontal and vertical disparity measured by visually inspecting stereo pair in figure 4.1.



As shown in figure 3, the block diagram for the multi-decision algorithm, normalized cross correlation are used as decision factor, to decide what mode needs to be employed Direct Match or Edge Analysis + Euclidian Distance or Spline fitting. In order to improve speed further parallel processing can be done. The Decision Factor's value is decisive that which stage should be used to find match accurately. DS-NCC Value is selected as the mean value of all pixels where Normalized Cross Correlation is greater than 0.85, and was found to be 0.884. Further it was observed that windows having cross correlation less than 0.85 failed to give correct match by NCC alone so 2nd method is applied in range below DS-NCC and above O-NCC (0.712). Below O-NCC and above T-NCC Spline fitting was used.

Whenever NCC was obtained below 0.451, none of the stages gave accurate results so below these value, we can assume no match exists.

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Case 1 Result: When max NCC exceeds DS-NCC.

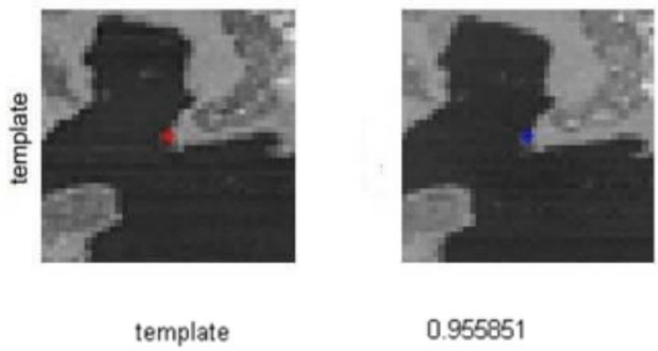

Figure 4.2: Selected Match

Stage 2 Result: When max NCC is in between DS-NCC & O-NCC-optimum.

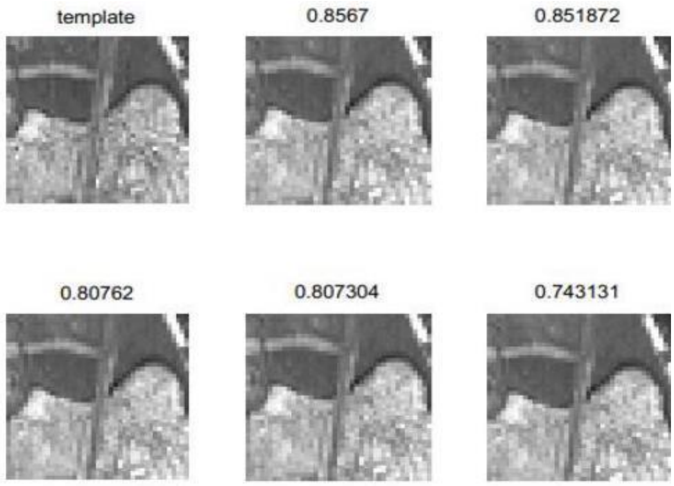

Figure 4.3(a): Selected sub widows as probable matches

Figure 4.3(b) Edge Map + Euclidian Distance Analysis

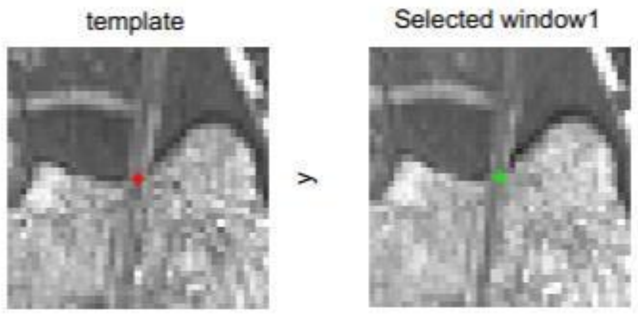

Figure 4.3(c) Selected Matches

Case 3 Result: When max NCC is in between O-NCC & T-NCC-optimum

Figure 4.4: Matched Pixel via Spline Fit

	Matched Pixel (%)
NCC only	64.71
Feature Extraction	72.56
Spline Fitting Only	84.36
Multi Decision Approach	87.67

Table: Accuracy Comparison of Approaches

CONCLUSIONS

Conventional area based image matching techniques produces dense disparity map that can be utilized for 3-D construction of a scene or generation of Digital Elevation Model from pair of stereo images. In proposed multi-decision area based matching technique different methodologies are incorporated that are best suited for the situation and hence, not only used to improve accuracy and lower computational complexities. The normalized cross correlation coefficient is used as Decision Factor, which is used for deciding which stage of analysis is further needed, if value obtained is fairly high than we can directly select window with maximum value as match. This value of Normalized Cross Correlation is referred as Direct Select NCC. Another technique select's best five matches which are further analyzed and filtered using Edge Map Analysis and Euclidian distance technique and best match is selected. One more spline fitting uses 7 control point pairs, control points pairs are points that are matched with very high cross correlation improves the accuracy of the match producing dense disparity map increased from 65% to 88%. It is useful in real time application as the size of search windows increases dynamically, as and when number of control points is not optimum.

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