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SURFACE FITTING BASED APPROACH FOR ACCURATE STEREO IMAGE MATCHING

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ABSTRACT

Traditional methods used to produce dense disparity maps for given stereo image pairs is classified as either area based or feature based methods. In this paper a we make use of area based approach for selection of control points which are further used in order to calculate matching pixel using surface fitting approach that performs pixel matching in stereo-pairs. The approach performs pixel matching in conjugate pairs in two stages. The 1st stage of similarity between windows is measured using Normalized Cross Correlation, if maximum Normalized Cross Correlation calculated exceeds a certain upper threshold it is considered as match and the corresponding pixels are selected as control points and are stored in database. In 2nd stage of algorithm, surface fitting is performed in this a window is selected such that at least 7 control points are obtained in case number of control points obtained are less window size increases dynamically so that more control points can be incorporated. With the multistage approach & parallel processing speed of dense disparity map generation will improve along with improved accuracy. The method is tolerant to radiometric distortions and occlusions.

***INDEX TERMS*—Area based matching, stereo-matching, correspondence problem, disparity map generation, template matching, Normalized Cross Correlation, control points, surface fitting.**

INTRODUCTION

Stereo Image matching is one of the core research areas in field of computer vision and digital photogrammetry. With advances in technology the use of more precise feature based matching techniques has become the necessity. The main motto of disparity maps produced by stereo-matching techniques performed on stereo-pairs allow us to recover information that is not present in any single image. The main goal of stereo image matching is to recover depth information from the given two or multiple images (Zitova and Flusser, 2003).

In order to recover information related to elevation/depth, point to point correspondence of stereo images is needed. Correspondence points may be considered as the projections of a single point in to the three dimensional scene. The shift in the positions of two correspondence points is referred as parallax or disparity which completely depends on position of the point in the scene, orientation and physical characteristics of the camera and due to which epipolar line and disparity can be used as constraints for matching. However, feature based methods for stereo-matching are comparatively more accurate, however, major limitation is that disparity maps obtained are sparse (not dense). We are proposing a surface fitting approach that is not only capable of producing highly accurate dense disparity maps used in 3D scene reconstruction.

Our approach can be divided into 2 stages of matching; the aim of the first stage is selection of control point which utilizes Normalized cross correlation based pixel matching. The value of Normalized cross Correlation obtained between reference and template window is utilized to find out whether the point selected can be used as control points or not. If the normalized cross correlation value obtained is fairly high then we can consider it as control point for performing surface fitting. In this method the basic units that are used for matching is regularly sized neighborhood of a pixel. The position of the given pattern is determined by a pixel wise comparison of the image with a given template that contains the desired pattern. For this the template is shifted m discrete steps in x direction and n discrete steps in the y direction of the image and the comparison is calculated over the template area for each position (m, n). The 2nd stage makes use of surface fitting, which requires minimum of 7 control points' pair to find location of matching pixels accurately.

Various applications such as elevation mapping and surface modeling, construction & landscape requires highly accurate and dense disparity maps. As the taxonomy given in (Peleg, and Weiser, 1996), stereo algorithms that produce dense depth measurements are classified as global and local algorithms. 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 calculate the disparity at each pixel based on photometric properties of the neighboring pixels compared to global algorithm; local algorithms yield significantly less accurate disparity maps. So to improve the accuracy the composite approach is presented in the paper. By visual inspection of stereo image pair approximate disparity range can be computed and the search area can be limited, thus, improving computational speed that can be used in real time applications

Area based algorithms 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

Even structural analysis fails to get correct matches in case of incomplete windows, occlusions and distortions; to overcome this limitation surface fitting is used.

The Section 2 explains various techniques used in the proposed surface fitting approach. Section 3 explains the proposed algorithm, which is a multi stage composite technique that utilizes normal cross correlation in stage 1 and surface fitting at stage 2. In section 4, results are presented for a sample stereo image pair and finally result analysis and an outlook to future research activities

THEORETICAL BASIS

Zero mean normalized cross correlation algorithm

The problem treated in this paper is to find out the position of a given pixel in a two dimensional image f. 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.

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

(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*) − *fm*, *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 desired position (mpos, npos) of the pattern which is represented by t is equivalent to the position (mmax, nmax) at maximum value _max of (m, n). The method is more robust than other similarity measures like sum of absolute difference.

Surface Fitting

Due to occlusions, border pixels or low values of NCC correct match is not obtained by using 3 stage algorithm. For that case, polynomial fitting is used. It mainly comprise of two stages:-

Determination 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 in that case polynomial fitting cannot be implemented. To overcome this limitation adaptive window approach is used, that is, size of window is increased unless minimum number of control points required is obtained

Determination of coefficients

$$X = a_0 + a_1 x + a_2 y + \sum_{i=1}^{7} F_i r_i^2(\ln(r_i^2))$$

$$Y = b_0 + b_1 x + b_2 y + \sum_{i=1}^{7} F_i r_i^2(\ln(r_i^2))$$

In order to calculate the 14 coefficients minimum of 7 control points are required. In case number of control points obtained is greater than 7, than 7 control points are selected randomly for given number of iterations and using these control points, coefficients are calculated, the coefficients for which Sum of Squared Error is least 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 2 staged surface fitting based method for high accuracy image matching is proposed below:

- Normalized cross correlation coefficient between template window and search sub window is computed. If maximum Normalized Cross Correlation exceeds NCC-DSV (Direct Selection Value), no further analysis in required and the window is considered to be the match, the central pixel of both the windows are selected as control points and stored in the database.
- In order to find match for given pixel the template window corresponding to it in reference image is selected and using the 7 control points selected randomly at once calculation of coefficient is performed, the process is continued all possible set of control point has been selected, the result is compared using Sum of squared error means, the set of coefficient is selected that provides least of Sum of squared error.
- Once the coefficients are calculated the pixel values of point on reference image for which match is needed to be calculated is substituted and match is obtained.

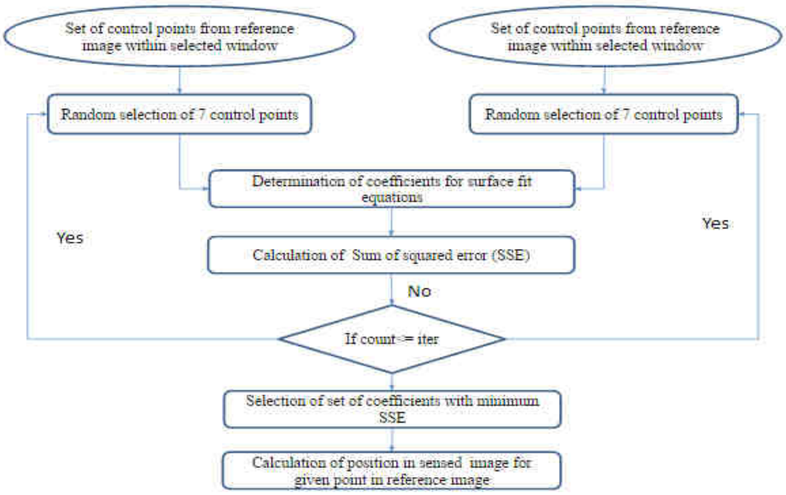

Figure 1: Proposed Algorithm for high accuracy pixel matching

EXPERIMENTAL RESULTS

The proposed method is executed on test stereo image pair shown in figure 1. 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 1.

Figure 2: Stereo image pair with left image with template window and right image with search window

As shown in figure 3, the block diagram for the proposed algorithm, the two stages are selection of control points via normalized cross correlation and calculation of matching pixel position using surface fitting is shown. In order to improve speed further parallel processing can be done. Using normal cross correlation is decisive that which stage should be used to find match accurately. The method is very useful even in case of incomplete windows and border pixel NCC was further low and for such cases

In case the value of position of matching pixel obtained is beyond the boundaries of image it can be assumed that no match is found.

RESULTS OF SURFACE FITTING

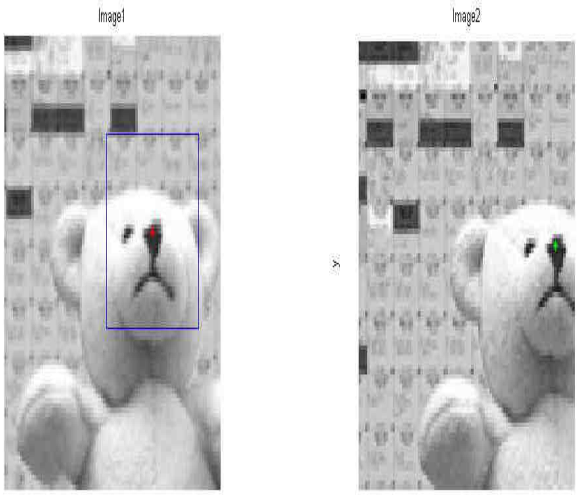

Figure 3: Matched Pixel in stage 3 using surface fitting.

Parameters	
Percentage of Correctly Matched Pixel	97.66%
Percentage of Mismatched Pixels	1.25%
Percentage of No matches	1.09%
Time taken in seconds	9946.032

CONCLUSIONS

Conventional area based image matching algorithm produces dense disparity map needed for 3-D construction of a scene from stereo pairs. In the proposed multistage surface fitting based technique two stages incorporating different methodologies are used to improve accuracy of the match. The normalized cross correlation coefficient is used in initial stage to decide which stage of analysis is further needed, if value obtained is fairly high than the points can be considered and regarded as control points. This value of Normalized Cross Correlation is referred as Direct Selection Value (NCC-DSV). In next stage surface fitting is implemented that uses 7 control points pairs, control points pairs are points that are matched with very high cross correlation. This method of area based image matching improves the accuracy of the match producing dense disparity map. It is useful in real time application as the size of search window can be reduced by visually finding disparity ranges in stereo image pair reducing the computational cost.

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