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Depth and Disparity Extraction Structure for Multi View Images-Video Frame- A Review

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Abstract: the stereo matching algorithms for binocular vision are very popular and widely used. Still, the algorithms may have lower matching quality or higher time complexity. Matching can be viewed as a process of finding the degree of correlation between two groups of data. This area belongs to the one of the most explored topics in stereo vision. The depth value can be found by the disparity estimation by taking advantage of the similarity in these two views, which can be captured at the same time in a depth generation algorithm. It is not easy to find the accurate depth value if there is high similarity in color spaces around the area. Stereo matching is a fundamental problem in computer vision that estimates depth of a 3D scene with a pair of images. This paper presents the fundamental steps for finding depth extraction and related terms.

Keywords: Depth, Disparity, Stereo vision, 3D, Stereo matching, Epipolar, Rectification, 2D.

1. Introduction

Difference between the horizontal coordinates of two corresponding points from the image pairs is called disparity or parallax in an image. An image that contains information relating to the distance between surfaces of picture objects and a position is called depth of that image. Disparity however is one and the same as inverse depth. Though, commercial three dimensional (3D) markets have grown incredibly, due to a limited number of available 3D contents, (two dimensions) 2D-to-3D conversion has been proposed as an alternative, to meet growing consumer demand of 3D contents. Most of the 2D-to-3D conversion techniques are time-consuming processes which require a lot of human intervention. There are some automatic methods however that need some improvement. Therefore, the need of the hour is a 2D-to-3D conversion with less human intervention.

Binocular right and left views of stereoscopic vision provide information about the distance to objects in the view field. The disparity observed between the right and left images is generally the inverse function of the distance to the object. The 3D structure of the object can be determined as a 2.5D solution of the structure from stereo vision problem, if the correspondence of all points in the right and left image pair and also camera pose parameters are provided. Stereo matching is to search for a point in an image that corresponds to that specified in the other image in terms of associated features.

Nowadays 3-D video (3DV) technology is based on stereo vision. Which use stereo video for pictures sent by two input cameras. Such stereo systems regenerate two camera views at the receiver and stereo vision display for multiple viewers, that require wearing special 3-D lenses. Another auto stereoscopic display emits a large number of views to enable 3-D viewing for multiple users without use of 3-D lenses. Usually multiview of stereo video coding is used, to represent a large number of views [1].

1.1 Fundamental Classification

Over the years numerous algorithms for passive stereo have been proposed, which can be roughly classified in categories given below.

1.1.1 Feature Based

Feature based stereo is defined as algorithms which perform stereo matching with high level parameterization called image features. Such feature based algorithms extract features of interest from the images, like edge, contours, segmentation and match them in two or more views. Feature based stereo is faster because only a small subset of the image pixels is used, But they may fail if the chosen primitives cannot be reliably found in the images; furthermore they usually only yield very sparse depth maps [2].

1.1.2 Area Based

In these approaches, the system attempts to correlate the gray levels of image patches in views being considered, assuming

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that they present some similarity. The resulting depth map can then be interpolated. The underlying assumption appears to be a valid one for relatively textured areas. It may prove wrong at occlusion boundaries and within featureless regions.

In area based techniques, usually a dense disparity map would be produced. According to Pascal [3], stereo algorithms that generate dense depth measurements can be divided into global and local algorithms. Global algorithms rely on the iterative schemes that carry out disparity assignments on the basis of the minimization of a global cost function. These algorithms yield accurate and dense disparity measurements but exhibit a very high computational cost that renders them not suitable for real time applications. Local algorithms are also called as area based methods. To calculate the disparity at each pixel on the basis of the photo metric properties of the neighborhood pixels. In area based method the elements to be matched are image windows of fixed or variable sizes. Similar criteria can be correlated between the windows in two images. Area based methods can run fast enough to be deployed in many real time applications. In Area based stereo matching, more accurate results can be obtain than that of feature based .

1.1.3 Pixel Based

In pixel based techniques, each pixel in each epipolar line in the left image would be compared to every pixel on the same epipolar line in right image and that with minimum matching cost will be picked. The correspondence search in stereo images is commonly reduced to important features as computing time, is still an important factor in stereo vision.

2. Obligatory for best Match & Challenges

There are common assumptions to construct smoother works. There are epipolar, continuity, smoothness, and Maximum disparity constraints as well as Lambertian surface assumption.

Epipolar constraint: To find the matching points between the image pairs and epipolar line.

Lambertian surface assumption: Here apparent intensities of such surfaces do not vary with view.

Continuity constraint: Disparity tends to vary slowly and smoothness across a surface, hence when we get two points on the left image which are located close to each other, their corresponding point pairs on the right image should be also close to each other.

Smoothness constraint: The adjacent pixel has the same (or similar) disparity spatially.

Maximum disparity constraint: Every image has a probable maximum disparity and this disparity value could be computed by getting the depth and geometry of a stereo system. There are number of challenges in this area

Occlusion is an usual problem in stereo matching and ignoring occlusion problems may guide disparity artifacts close to object borders.

Assumption of Lambertian surface in the real world, that a 3D point in space has the same appearance under projection from different geometries, is not always true even if image conditions are ideal. Some reasons may be : 1. A change of viewing angle causes a shift in apparent reflection and color of the surface if the illumination source is not at infinity or if the surface does not exhibit Lambertian reflectance. 2. Focus and defocus may occur in different planes at different viewing angles if depth of field (DOF) is limited. However change of viewing angle may cause geometric image distortion. 3. Large depth variations of one point relative to its surrounding points may break the ordering constraint or produce occlusions; a change of viewing angle or temporal change may also change geometry and reflectance of the surfaces if the images are not obtained all together.

Problems also exist in region with constant color. The matching may fail in those areas. The lack of texture information makes it impossible to uniquely identify and match the pixels within the reference image.

For these reasons we can see that it is still a challenge and difficulty to get an accurate depth map from image pairs in a practical situation. Hence, the question as to solving a such problems and production of an accurate depth map will always remain an important work in the field of stereo matching[4][5].

3. Related work

Fan et al [6] proposed depth map measurement and generation for multi-view video systems. In this architecture video segmentation and disparity estimation technique to generate depth map, object-based disparity estimation, luminance compensation and triangulation algorithms are performed to estimate depth information. Hardware architecture of depth map measurement and generation is achieved using structure of multiple processor elements.
An object region determination based on watershed segmentation algorithm to generate a matching window for stereo matching. This paper uses the motion vector information to compensate depth value for the successive depth video was proposed by Lee et al [7], to decrease the depth discontinuity and the computation time for disparity estimation on all pictures. This proposed algorithm can produce depth map which is more suitable for stereo images.
Stereo videos are mapped to the rank space from the gray-level space that eliminates the interference of the environment variations and varied cameras using a rank transform. The disparity is estimated by a multi- window algorithm with fast searching policy, which improves the accuracy of the depth map and the matching speed as sound. After that, a disparity compensation step is done by smooth area based algorithm to get a smoother depth map and clear region of substance. The experimental results show the efficiency and the robustness of the proposed method [8].
Kang et al. [9] proposed an efficient disparity map generation method for multi-view video sequences which can be captured by a forward moving multi camera scheme. It Increases the minimum and maximum disparity values of each frame with time due to forward moving multi camera. Thus, computational complexity can be increased and the quality of generated disparity can be degraded since the stereo matching operation has to deal with a wide range of the disparity candidates. Time-of-flight (TOF) depth sensor is used to find the minimum and maximum disparity values for each frame. Then, the stereo matching process for video

sequences are captured by the moving multi-camera system which becomes simple without quality degradation. They used three color video cameras and one TOF depth sensor.

An experimental model was proposed to improve stereo matching accuracy and lower error rate with low- cost IR-sensor such as Kinect by Chan et al. [10]. In this system, a disparity-adjustable hardware is constructed to achieve occlusion reduction as well as improving visual comfort. Depth maps offered by the Kinect IR-projector do not have enough resolution, thereby filtering stabilization and the appropriated de- noising are first performed for retrieving useful depths. By way of referable disparity resources from refined Kinect depth map, stereo matching strategies like Mini-Census transform, Absolute Difference Variable- cross based cost aggregation are adapted to produce accurate and lower error rate disparity maps.

Yang et al.[11] showed that an interactive method of depth map generation from a single image for 2D-to- 3D conversion where an image is input into similar regions to preserve details, that segments the image into salient regions with user interaction. Then, local depth hypothesis using structural information of the input image and salient regions is generated. The proposed method gives more natural depth map in terms of human perception as shown in paper.

4. Basic flow for estimation of depth map

The basic steps in extraction of a depth map to make stereo or multiview images for which we must either calibrate the camera or estimate the epipolar line (image rectification) is shown in Figure 1. For stereometric processing of optical image pairs, the concept of epipolar geometry is widely used. It helps to reduce the complexity of image matching, which can be seen as the most crucial step within a workflow to generate digital elevation models. The epipolar geometry is the intrinsic projective geometry linking two views which is independent of scene construction but dependent on the camera parameters and relative pose.

4.1 Epipolar Geometry and Rectification

The epipolar geometry depends on the internal parameters of the cameras and the relative pose. If we identify the viewing geometry (extrinsic parameters) and the intrinsic parameters and then get correspondences by exploiting epipolar geometry and reconstruction of stereo. The term ‘epipoles’ means intersection of baseline with image plane, projection of projection center in other image and vanishing point of camera

motion direction. An epipolar plane is a plane containing baseline (1-D family) wherein the camera centers, corresponding points and scene point lie in a common plane. An epipolar line is intersection of epipolar plane with image(always come in corresponding pairs). Epipolar geometry is an outcome of the co-planarity of the camera centers and scene point. As the position of the 3D point X varies, the epipolar planes “rotate” about the baseline known epipolar pencil. All epipolar lines intersect at the epipole. Epipolar geometry depends only on the relative pose (position and orientation) and internal parameters of the two cameras, like the location of the camera centers and image planes shown in Figure 2. It does not depend on the view formation (3D points external to the camera).

Figure 1: Basic steps for extraction of depth map

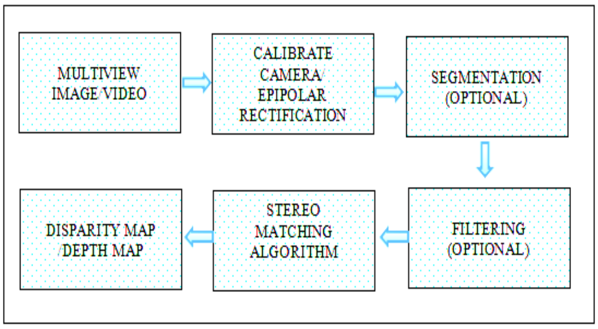

Figure 2: Epipolar geometry

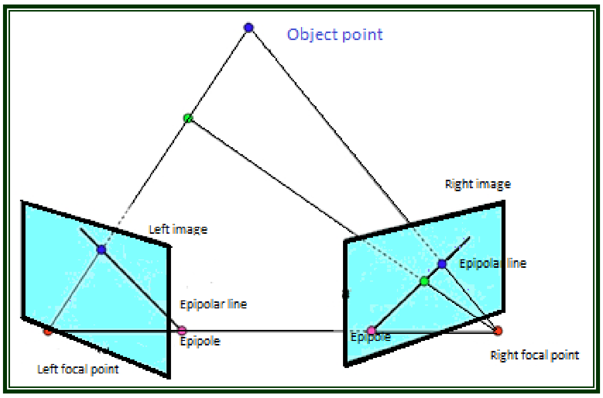

Image rectification is a transformation of each image such that pairs of conjugate epipolar lines become co-linear and parallel to the horizontal axis. Hence searching for corresponding points becomes simpler after rectified images.

4.2 Segmentation

Stereo segmentation is important in three-dimensional (3D) vision interpretations with many applications such as object tracking, object recognition and surveillance. Stereo video which captures the same scene from different perspectives is superior to the traditional two-dimensional (2D) ones in terms of visual experience. It seems easy for human beings to separate objects from the background; the computer still remains a long way to go. The research in stereo segmentation resulting in lots of commercial products, such as Magic wand™and Video snap cut™ in Adobe Photo-shop™ and Lazy snapping in Microsoft [12].

Stereo segmentation can be classified as region based and object-based segmentation. The former aims to cluster the similar pixels into homogeneous regions, while the latter tries to extract the meaningful objects and distinguish foreground from the background. In region based algorithm, the most important step is performing the stereo matching. Filtering processes can be used to remove noise [Figure 1].

4.3 Categorization of stereo vision algorithms

Stereo matching algorithms are divided into two main categories as shown in Figure 3. While one is software implementation (SI) and other Hardware implementation (HI). The SI can be subdivided into dense output and sparse output. HI can be categorized into FPGA (Field Programmable Gate Array) and ASICs (Application Specific Integrated Circuits). The use of FPGAs is now the most convenient, reasonable choice for hardware development and is also cheap. The available resources of the devices are constantly growing and have implemented more complex algorithms. The range of available electronic design automation (EDA) tools and the absence of fabrication stage makes the time very short. The main advantage is that the resulting HI is open for further upgrades and hence, FPGA implementations are very flexible and error liberal. There are three FPGA implemented methods SAD (Sum of Absolute Difference), DP (Dynamic Programme) and Local Weighted Phase-Correlation (LWPC).

FPGA implementations based on SAD methods are the most used. SAD calculation requires simple computational modules, as it involves only summations and calculations of absolute values. The implementation presented by Jeong and Park [13] uses the DP search method on a trellis solution space. FPGA phase-based techniques can be implemented on hardware as fine. The algorithm implemented by Darabiha et al. is Local Weighted Phase-Correlation (LWPC). HI of the algorithm turns out to be more than 300 times faster than the software one [14].

ASIC implementation is more expensive, except during cases of huge production. The prototyping times are considerably longer and the result is highly process-dependent. Any further changes are difficult and additionally time and money consuming. In most cases their performance supremacy does not justify choosing ASICs. These are the main reasons that make recent ASIC implementation publications rare in contrast to the FPGA-based ones. Published works concerning ASIC implementations (Hariyama et al.) of stereo matching algorithms are restricted to the use of SAD. The reported architectures make wide use of parallelism and seem to be promising. However, they require undisputed experimental results [15-16].

Dense disparity stereo matching algorithms can be divided in two classes, according to the way they assign disparities to pixels. Local method decides the disparity of each pixel according to the information provides by local neighboring pixels. Global methods assign disparity values to each pixel depending on information derived from the whole image. Local methods are usually fast and can at the same time produce descent results. SAD are example of a local method. Global methods produce accurate results but are more time consuming and computation. Dynamic programming is the example of a global method [17].

Sparse output or semi-dense, disparity maps tend to be less attractive as most of the present-day applications require dense disparity information. Although, they are very useful when fast depth estimation is required at the same time, the details in the whole picture, is not however so important. This type of algorithm tends to focus on the main features of the images leaving occluded and poorly textured areas unmatched. Therefore high processing speeds, accurate results, with limited density are achieved.

4.4 Disparity/Depth map

For a stereo matching process, we can consider estimating the three dimensional position of a point 'P' shown in figure 4.This has image 'O' as viewed from camera 1 and image 'O|' when viewed from camera 2. Relative shift or displacement of the point can be used, for matching 'P' point accurately between these two images and calculate the disparity of the point. From eq. 1 the depth (Z) of the point can be calculated.

$$\text{Disparity}(x-y) = (B\ f)/z \qquad (1)$$

where 'B' is the baseline distance between two cameras and 'f' is the distance of the image plane behind the principal point.

Figure 5 shows the stereo datasets of original image and its ground truth image which is compared with resultant image [18].

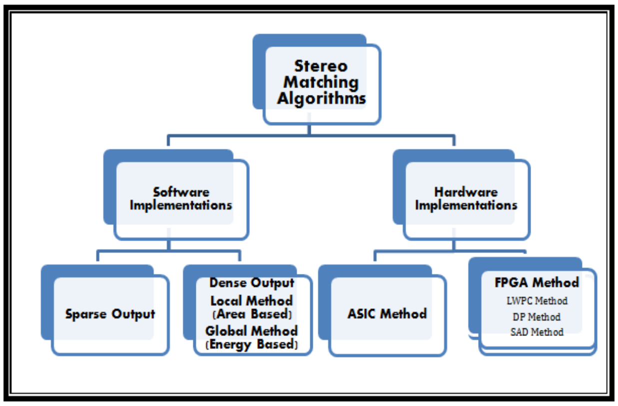

Figure 3: Classification of stereo matching algorithm

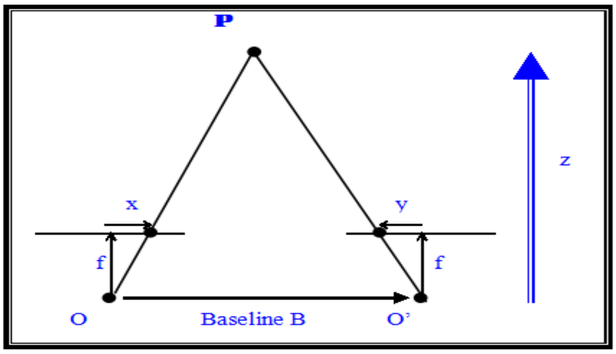

Figure 4: Basic camera setup for depth/disparity map

Figure 5: Middlebury stereo datasets: Left image of the stereo pair and ground truth [18]

5. Basic Stereo Matching Algorithm

The stereo matching algorithms reproduce the process of human stereopsis for a machine which can perceive the depth of each point in the observed scene, so that we can operate objects, re-establish 3D models or avoid them. The primary aim of such algorithms is found for each pixel in the corresponding image and the other matching image in order to get a disparity map containing the differences for each pixel position, between the two images that is proportional to the depth. There are mainly two types of stereoscopic matching algorithm:- (A) Based on characteristics, they find only matching of the main features in the image such as edges of objects. They require much less processing time as they only use certain features of the input image information. They have the disadvantage that they cannot find depths which change smoothly and produce scattered do disparity maps. (B) By correlation, dense disparity maps occur in which the disparity is for each pixel in the image, as a single pixel pair is more or less not possible. Each pixel is represented by a small region that contains a correlation window which performs the correlation between the image display and the other uses the value of the pixels within them. The most common area or region matching measures directly on pixels. Sum of absolute differences (SAD) is a broadly used and particularly simple algorithm for measuring the similarity between image blocks [19].

SAD works by taking the absolute difference between each pixel in the original block and the corresponding pixel in that being used for evaluation. These differences are summed up to make an easy metric of block similarity of the difference image. SAD is a correlation algorithm, as the matching steps can be calculated all in parallel. In addition, regular structures and linear data flow make the SAD algorithm a good candidate for hardware implementations. The SAD function can be defined as:-

$$\mathrm{C}(\mathrm{x}, \mathrm{y}, \delta) = \sum_{\mathrm{y}=0}^{\mathrm{wh}-1} \sum_{\mathrm{x}=0}^{\mathrm{ww}-1} \mathrm{I}_r(x, y) - \mathrm{I}_1(x+\delta, y) \quad (2)$$

where Ir(x,y) and Il(x+δ,y) represent coordinates in pixel on the right image and the left image, respectively. The 'δ' represents disparity number ranging between 0(zero) and the maximum disparity value Δ. The "ww" and "wh" represent the window width and height respectively. The SAD function C(x,y,δ) is evaluated for all possible values of the disparity, δ, and the minimum is chosen. That is, the criterion for the best match in the SAD algorithm is minimization of the sum of the absolute differences of corresponding windows. We implement a SAD correlator to find the best match among image windows. The SAD correlator consists of three modules: pixel shift register (PSR), disparity calculator (DC), and minimum calculator (MC) modules. Other methods are sub pixel-accuracy disparity and uncertainty estimators that are based on the sum of squared differences (SSD) method, frequently used in stereo and motion analysis.

SSD leaves enough time for performing other machine vision applications in real time. SSD performance is much faster than real time. Many embedded applications of vision system, such as mobile robots and humanoids require a super computing capability for various complex image processing tasks while being severely limited by the power consumption and size of the computing architecture. SSD may be given by eq. (3).

$$S(i, j, k) = \sum_{l=i-\frac{w-1}{2}}^{i+\frac{w-1}{2}} \sum_{m=j-\frac{w-1}{2}}^{j+\frac{w-1}{2}} [I_r(l, m) - I_l(l, m+k)]^2 \quad (3)$$

The pixel which minimizes so S (i, j, k) is the best match. Therefore eq. (3) can be given by eq. (4)

$$k^* = \arg\min_{j \le k \le j+\beta} S(i, j, k), \quad (4)$$

WHERE, $d(i, j) = k^*$

Briefly, the SSD algorithm consists of the following three steps: 1. Calculating the squared differences of intensity values in a given disparity. 2. Summing up the squared differences over square windows. 3. Finding two matching pixels by minimizing the sum of squared differences.

In eq. 4 Ir(i, j) and Il(i, j) are the intensities of pixels located at row i and column j in the right and left image, correspondingly. The input parameters of the SSD are β and w, maximum disparity and window size respectively. Assuming right image as the reference, the disparity for each pixel (i, j) in the right image is calculated as by this way:

Consider a window centered at (i, j) in the right image

Consider a window centered at (i, j+k) in the left image where j ≤ k < j+β

Calculate convolution function of the windows in the left and right image.

6. Application

Stereo vision technology is used in object detection and segmentation, public tracking, mobile robotics map-reading, and mining. It is also used in industrial automation and 3D machine vision applications to perform tasks such as: volume measurement, automotive part measurement, motion gaming, bin picking and 3D object place and recognition, travel aids for the blind and aerial photography.

7. Discussion and Summary

Each eye must present a picture to cover a common area and that parallax with respect to observing the other eye which necessary organs for stereoscopic vision. Visual rays must intersect at homologous points in the space of two by two, means that the observation should be made according to epipolar planes, i.e. the epipolar counterparts which of the rays are on the same line. The most distant points of both images should not have a separation greater than the papillary distance of the observer, or any vision based device used.

For the depth generation, there are following possible available ways:

1) Stereoscopic videos are generated using stereo or multi-camera system such as dual camera system. However care should be taken with regards to: Geometrical distortion & depth plane curvature, director and one camera operator should be highly skilled in stereoscopic geometry and camera calibration.

2) By introducing an IR range camera, depth information can

be captured:

However care should be taken with regards to: How to recover occluded region or correct holes and misaligned data in depth maps in synthesizing left-eye & right eye views.

3) Depth camera is replaced by 2D-to-3D video converter where depth information is extracted from monoscopic image sequence using computer vision technology. Extraction of depth information from single sequence is a problem in computer domains usually.

Recently used 2D-to-3D video conversion systems have two drawbacks i.e. inconsistent estimation depth & recovery of depth ordinal. This will result in an uncomfortable feeling due to motion, sickness. To the best of our understanding, depth cues i.e. photometric, appearance or geometry cues are not combinable and hence analysed for 2-D to 3-D video conversion. No method or algorithm is present for estimation of low quality video and this is the major requirement of 2D-to-3D video conversion.

To substantiate evidence for this review ,the following are utmost necessary:

- ❖ Investigation into monocular depth cues for 2D-to-3D conversion.
- ❖ Comparative study of various methods for extracting information from various depth cues in single view video.
- ❖ Device efficient system for extraction of scene depth information for 2D-to-3D Video Conversion.
- ❖ Application of proposed method for 2D-3D Conversion.
- ❖ Performance analysis investigation into objective quality evaluation methods such that Mean Squared Error (MSE) metric, Blind Image Quality Index (BIQI) metric, RMSE (Root means square error), Percentage Bad Matching Pixel (BMD) etc.

All the above have been defined in this review.

8. Implications

In this research, we can develop efficient methods for extraction of scene depth information for 2D-to-3D conversion to improve the conversion productivity, computation and interaction in the conversion system. In order to generate better depth maps, we can use more than one depth cue i.e. Photo metric, geometry, motion and appearance cues and analyses the effect of all depth cues for 2D-to-3D video conversion.

9. Conclusion

In this paper we have presented an extensive review of how depth for multi view images & video streaming can be obtained. We have outlined the basic steps for disparity maps and each have been briefly introduced. The stereo correspondence problem remains an active area for research. More and more modern applications demand not only accuracy but real-time operation as well. Software as well as hardware implementations have been considered and presented. There are many remarkable methods, like area, pixel and feature based methods. When it comes to hardware implementation, there are two available options, ASICs and FPGAs.

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