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Depth Map Estimation Using SIMULINK Tool

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***Abstract*—Stereo vision has usefulness in many applications like 3D scene reconstruction, robot navigation, etc. The disparity between two original stereo images and depth maps are calculated to find the depth levels. An algorithm to generate disparity maps using SIMULINK tool is presented in this paper. The disparity map was first obtained by using MATLAB tool. The objective of the present work is to generate depth map using SIMULINK tool. The SIMULINK model used to obtain depth map dataset images is presented.**

***Keywords* — Depth Map; SIMULINK; SAD; SSD; NCC**

I. INTRODUCTION

In computer vision stereo image matching is one of the main research area. Stereo Helps us to collect the information from the given two images about a three dimensional location of objects, which is not given by any single image. The similarity of image locations have been measured by all stereo correspondence algorithm. A matching cost is computed at each pixel for all disparities under consideration. The simplest matching costs assume constant intensities at matching image locations, but more robust costs model requires certain radiometric changes in the presence of noise[1]. Common pixel-based matching costs include absolute differences, squared differences, both on gray and color images. Common window-based matching costs include the sum of absolute or squared differences (SAD / SSD), normalized cross-correlation (NCC)[2]. Depth information from the given two or multiple images is the main goal of stereo image matching. The best depth information is given by point-point correspondence of stereo images. The location difference between two correspondence points is known as disparity. Disparity refers to the distance between two corresponding points in the left and right image of stereo pair. Disparity is also used as constraint for matching[1]. To extract depth information from images, stereo matching is used. Depth level estimation can be used to control the movement of ROBOT that can be used in robotic vision applications[3]. To inspect new approach for depth and depth level estimation and converting stereo code into small chip, SIMULINK tool is used.

The paper is organized as follows : Section I gives brief introduction to stereo. Section II gives cost functions Section. III deals with depth map estimation using SIMULINK tool. Section IV gives results and conclusions are presented in section V.

II. COST FUNCTIONS USED IN STEREO SYSTEM

Stereo vision systems basically consists of three processes. The first is of the cost computation which finds out the required features between two images which may be intensity based features or color based or other structural features like the edges and gradient across the image. The first step may vary according to various algorithms as distinct algorithms may use different approach to find correspondence between two images. Most of the algorithms use the same second step of cost matching function which may be pixel based or window based. Usually the cost is aggregated over a window. This aggregation of cost is the most important part of any stereo vision algorithm. The final step is of proper disparity selection based on the cost aggregated over the entire image. The output of this step is the disparity map which gives us the depth information of the two input images[2].

Figure 1. Steps in a stereo vision algorithm

For the present work , cost function comparison is carried out on MATLAB and the images used are the standard set of images provided by the Middlebury Data set.

A. Sum of Absolute Differences (SAD)

The sum of absolute differences (SAD) is a measure of the similarity between image blocks. It is calculated by taking the absolute difference between each pixel in the original block and the corresponding pixel in the block being used for comparison.

In SAD method, the correspondence is achieved by selecting a window of required dimension within the two images or the cost matrix and adding the difference between the elements over the entire window.

The SAD adds up the absolute differences between corresponding elements in the candidate and reference image.

$$W_c(x, y, d) = \sum_{i=1}^{w_x}\sum_{j=1}^{w_y} |f_L(x+i, y+j) - f_R(x+i+d, y+j)|$$

where ,
f_L - left image intensity
f_R - right image intensity

B. Sum of Squared Differences (SSD)

In sum of squared differences , the differences are squared and aggregated within a square window. This measure has a higher computational complexity compared to SAD algorithm as it involves numerous multiplication operations[2].

$$W_c(x, y, d) = \sum_{i=1}^{w_x}\sum_{j=1}^{w_y} [f_L(x+i, y+j) - f_R(x+i+d, +j)]^2$$

where ,
f_L - left image intensity
f_R - right image intensity

C. Normalized Cross-correlation (NCC)

Normalized cross-correlation is a metric to evaluate the degree of similarity (or dissimilarity) between two compared images. In NCC, a window of suitable size is determined and moved over the entire image or the cost matrix. The correspondence is thus obtained by dividing the normalized summation of the product of intensities over the entire window by the standard deviation of the intensities of the images over the entire window.

NCC is even more complex to both SAD and SSD algorithms as it involves numerous multiplication, division and square root operations[4].

$$W_c(x, y, d) = \frac{\sum_{i=1}^{w_x}\sum_{j=1}^{w_y} f_L(x+i, y+j) f_R(x+i+d, y+j)}{\sqrt{\sum_{i=1}^{w_x}\sum_{j=1}^{w_y} f_L^2(x+i, y+j) \sum_{i=1}^{w_x}\sum_{j=1}^{w_y} f_R^2(x+i+d, y+j)}}$$

where ,
f_L - left image intensity
f_R - right image intensity

III. DEPTH ESTIMATION OF IMAGES USING SIMULINK TOOL

SIMULINK , developed by Math Works, is a data flow graphical programming language tool for modelling, simulating and analyzing multi-domain dynamic systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. SIMULINK is widely used in control theory and digital signal processing for multi-domain simulation and model-based design.

An algorithm used here, uses an image pair with ground truth image as input. The proposed step by step SIMULINK model for depth estimation is shown in figures 2, 3, 4, 5.

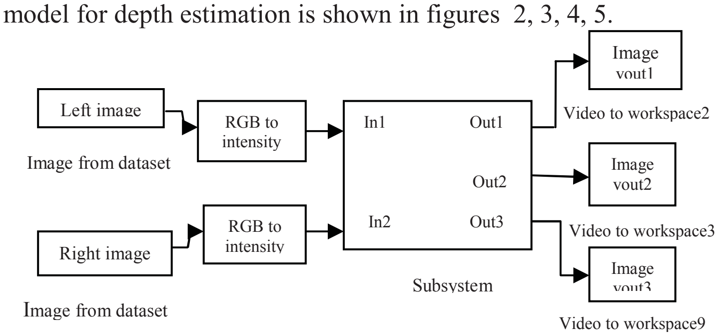

Figure 2. Simulink model for input as original pair

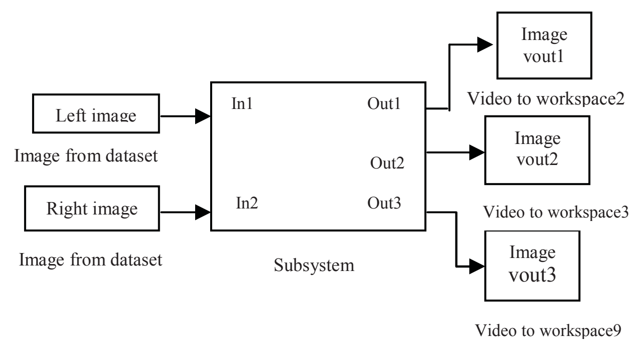

Figure 3. Simulink model for input as ground truth pair

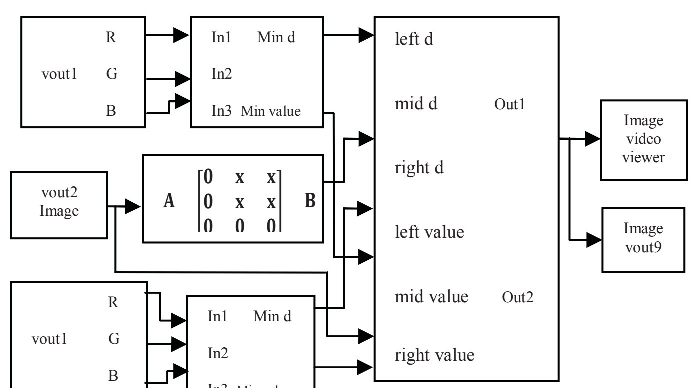

Figure 4. Simulink model to generate map

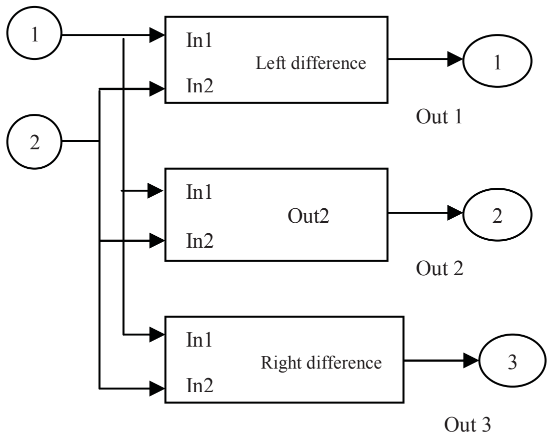

Figure 5. Simulink model for minimum disparity calculation

1)Input images which are taken from Middlebury dataset given to rgb2intensity block as shown in the figure 2 and input images which are taken from Middlebury dataset given to subsystem block as shown in figure 3. And the inputs are saved to workspace.

2)Original image with left shifted are compared, original image with right shifted are compared and original image with no shift image is compared in subsystem shown in figures 2 and 3 which is explained in figure 5. This gives minimum disparity among the disparity calculated with the left shift, right shift and no shift.

3)Cost function of all shifts are compared to find minimum cost function. Hence disparity map is calculated as shown in figure 4.

4)From minimum cost function, minimum disparity is found out.

5)Minimum disparity calculated from left shifted, right shifted and no shift image. i.e. the output of disparity is displayed with the help of video viewer[5].

IV. RESULT

Disparity is calculated with error pixel using SAD, SSD and NCC for the images taken from the Middlebury dataset[6].

Figure 6(a). Left Image

Figure 6(b). Right Image

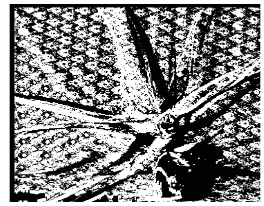

Figure 6(c).Disparity using SAD

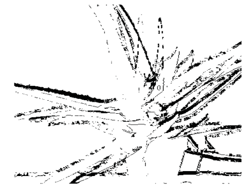

Figure 6(d).Error Pixel using SAD

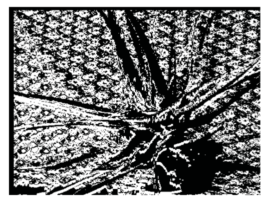

Figure 6(e).Disparity using SSD

Figure 6(f).Error Pixel using SSD

Figure 6(g).Disparity using NCC

Figure 6(h).Error Pixel using NCC

Figure 6. Implementation Results on Aloe Image

Figure 6(a). shows left image and figure 6(b). right image, figure 6(c) gives disparity calculated using SAD algorithm and figure 6(d) gives error pixel using SAD algorithm, figure 6(e) gives disparity calculated using SSD algorithm and figure 6(f) gives error pixel using SSD algorithm, figure 6(g) gives disparity calculated using NCC algorithm and figure 6(h) gives error pixel using NCC algorithm.

Several images from Middlebury dataset which has ground truth images also were tested using SIMULINK model developed. With the help of SIMULINK model, the disparity and depth maps are calculated.

Table 1.Disparity and Depth maps

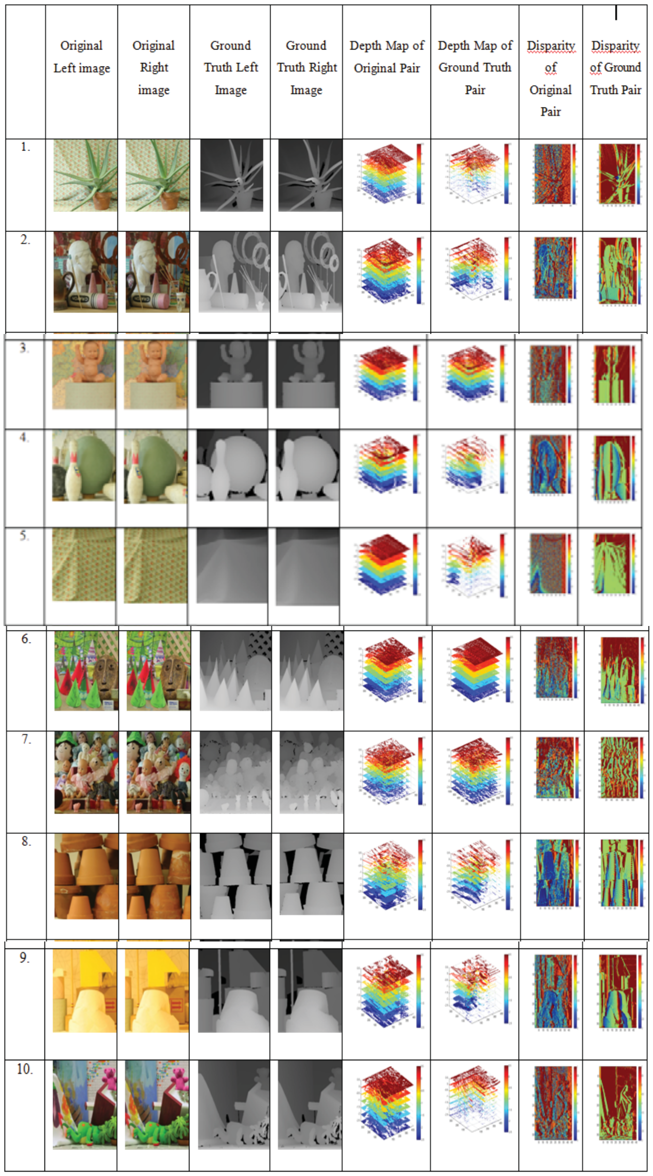

Table 2: Comparison of SAD, SSD, and NCC on the basis of Elapsed time in sec

Views	Elapsed time using Cross Correlation	Elapsed time using SAD	Elapsed time using SSD
Aloe	41.527340	6.804814	7.318734
Art	52.593749	47.475700	48.341166
Baby1	43.523019	39.767364	41.136384
Bowling2	40.652825	40.295296	40.216336
Cloth1	45.797540	40.125294	40.342312
Cones	43.067900	40.251364	40.336778
Flowerpot	41.393852	38.873364	38.707368
Lampshade1	43.025509	40.352116	40.444578
Teddy	43.996527	40.735356	43.499471
Wood2	43.705326	41.841025	42.628981

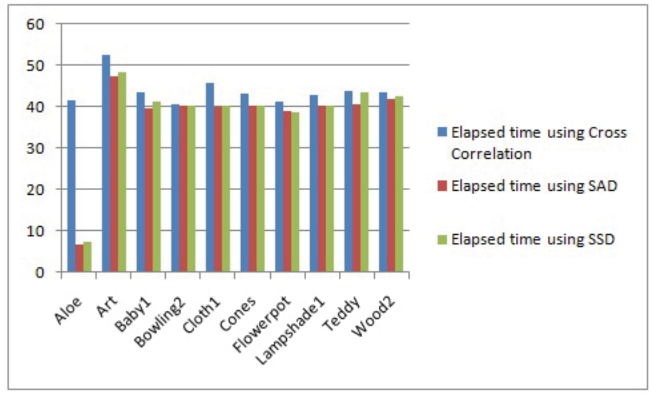

Figure 7: Plot of Comparison of SAD, SSD, and NCC on the basis of Elapsed time in seconds

Figure 7 shows that elapsed time in seconds for SAD is less than SSD and NCC. This shows that complexity of SAD is less than SSD and NCC.SAD is an ideal choice for real time systems.

All the methods have been implemented on MATLAB and the images used are the standard images which are provided by Middlebury standard dataset. The codes for the methods were run on a machine with Intel Core i5 processor with inbuilt graphics. The codes for the listed methods were optimized to run efficiently in MATLAB environment.

V. Conclusion and Future Scope

The SIMULINK model based depth map estimation is a new application in stereo vision and offers a model based design for processing. Proposed system used SIMULINK model for stereo matching. Proposed system compared disparity and depth map of stereo images from Middlebury dataset with original image pair and ground truth pair. In the future, the algorithm can be implemented on hardware i.e. the hardware implementation gets easier. NCC has higher accuracy as correlation is used but has limitation of high demand on computation time. SIMULINK model can be converted into VHDL code for hardware implementation.

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