SUSAN Window Based Cost Calculation for Fast Stereo Matching*

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Abstract. This paper presents a fast stereo matching algorithm using SUSAN window. The response of SUSAN window is used to calculate the dissimilarity cost. From this dissimilarity cost, an initial match can be found. Then, with this initial match, a dynamic programming algorithm searches for the best path of two scan lines. Since the proposed dissimilarity cost calculation method is very simple, and does not make use of any complicated mathematic formula, its running time is almost as same as SAD in the fixed window. In addition, the proposed matching algorithm only has two control parameters, bright threshold and occlusion penalty, which make it to be easily optimized.

1 Introduction

The stereo vision, which uses the image captured by two different cameras, has been strongly influenced by the rapid performance improvements of computer technology and of embedded systems, thus resulting in the invention of various real-time stereo vision systems[5][6][8] . Many of these systems employ a window-based correlation method. The matching cost calculation is one of the major factors that affect quality of resulting disparity map. Most of real time stereo vision systems use similarity or dissimilarity measurement method in fixed length window[3]. the use of a fixed-length window is due to its simplicity and speed. But in case that disparity jumps are placed in fixed window, the reliability of matching cost becomes poor. To overcome this drawback, many researchers proposed adaptive window method and multiple window method to improve matching cost. Recently, two proposals of window-based stereo cost calculation method (shown in 'variable window'[4], 'Adaptive weight'[7]) have reported successful results.

These two methods employ 'local support information' to find more exact matching cost. However, a decrease in speed from a complex formula and the use of many control parameters make them difficult to be directly adapted to a real-time system. Moreover, the use of optimization process 'winner take all'

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method makes it impossible to find an exact matching in any flat area that is greater than the maximum size of matching window. In order to solve this problem, many global optimization algorithms[2] such as 'dynamic programming', 'maximum flow', and 'graph cut' have been proposed. However, 'maximum flow' and 'graph cut' are inadequate for a fast system due to their immense calculation tasks. consequently, among global optimization algorithms, only 'dynamic programming' is used for the fast stereo vision system.

As a result, in this paper, a fast stereo matching window using SUSAN window[1] is proposed. The size of USAN within the SUSAN window allows the edge detection and feature detection. Similarly, we use the SUSAN window to find the Local Support Area within the window, then, with this result used as a weight, the matching cost of left and right windows can be found. Then, with the method of "Winner takes all," the initial match is found. After performing the reliability check on the initial match, global optimization is done by using a simple dynamic programming. The proposed method only uses two control parameters, which drives the optimization of the proposed algorithm easily. The following sections, from 2 to 5, demonstrate more detailed explanation about the proposed algorithm.

2 SUSAN Operator

SMITH[1] proposed an algorithm that can find the Edge and Feature from the size and weight of Univalue Segment Assimilating Nucleus (USAN) Area within the window. The pixels in the window, which have same or similar brightness, are defined as USAN. The area of USAN delivers the important information about the structure of the window. In the paper[1], USAN is defined by Eq. 1, 3 and the response of SUSAN window is calculated from Eq. 2

$$c(\boldsymbol{r}, \boldsymbol{r}_0) = \begin{cases} 1 & \text{if } |I(\boldsymbol{r}) - I(\boldsymbol{r}_0)| \leq t \\ 0 & \text{if } |I(\boldsymbol{r}) - I(\boldsymbol{r}_0)| > t \end{cases} \tag{1}$$

where $\boldsymbol{r}_0$ is the position of the nucleus in the 2D image, $\boldsymbol{r}$ is the position of any other point within the window,I($\boldsymbol{r}$) is the brightness of pixel, t is the brightness threshold. The output of SUSAN operator n is made ;

$$n(\boldsymbol{r}_0) = \sum_{\boldsymbol{r}} c(\boldsymbol{r}, \boldsymbol{r}_0) \tag{2}$$

$n(\boldsymbol{r}_0)$ is total size of USAN.

$$c(\boldsymbol{r}, \boldsymbol{r}_0) = e^{-(\frac{|I(\boldsymbol{r}) - I(\boldsymbol{r}_0)|}{t})^6} \tag{3}$$

If the similarity function in Eq. 3 is used instead of Eq. 1, a more stable and better result can be obtained. Moreover, if the output of n is less than the pre-computed geometric threshold, it is first defined as an edge or a corner. The geometric threshold of Edge is $\frac{3}{4}n_{max}$ while the corner is defined to be $\frac{1}{2}n_{max}$. The n_{max} is the maximum n value. Since the SUSAN operator does not possess