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# STEREOSCOPIC FOCUS MISMATCH MONITORING

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Fig 1: From left to right: 1. Output for left image. Red zebra area (e.g. the fountain) is less focused than in the other image. 2. Output for right image. 3. Left-Right disparity map. 4. Optimized focus difference curve. 5. Left image detail: flowers in focus, fountain out of focus. 6. Right image detail: flowers out of focus, fountain in focus.

**Keywords:** focus, defocus, stereoscopy, SML.

## Abstract

We detect focus mismatch between views of a stereoscopic pair. First, we compute a dense disparity map. Then, we use a measure to compare focus in both images. Finally we use robust statistics to find which images zones have different focus. We show the results on the original images.

## 1 Introduction

Live-action stereoscopic content production requires a stereo rig with two cameras precisely matched and aligned. While most deviations from this perfect setup can be corrected either live or in post-production, a difference in the focus distance or focus range between the two cameras will lead to unrecoverable degradations of the stereoscopic footage.

## 2 Disparity map computation

We first compute a dense disparity map. Since images may differ in focus, we use a real-time multi-scale method [1] which finds good disparity values even between focused and not focused textures. We also compute semi-occluded areas by left-right consistency check, and ignore them in the following computation. Let  $d(i)$  be the disparity of pixel  $i$ .

## 3 Blur Difference Measurement and Curve Best Fit

Measuring the focus at a point in an image is an ill-posed problem, since it may be the in-focus image of a non-textured point in the scene. However, it is possible to compare the focus of corresponding points from the left and right images: We use the SML operator proposed by Nayar and Nakagawa [2] which was primarily designed for depth-from-focus applications. For a pixel  $i$  in the left image,  $SML_l(i)$  is the SML operator computed at this pixel, and  $SML_r(i)$  is computed at the corresponding pixel in the right image. The max of  $SML_l(i)$  and  $SML_r(i)$  is high if one image is textured

and in focus. This tells us where important information is. The sign of the difference of SML between two pixels is positive if left is more focused than right, and negative if right is more focused than left. For each pixel, we have:

$$M(i) = \text{Sign} ( SML_l(i) - SML_r(i) ) \quad (1)$$

$$w(i) = \text{Max} ( |SML_l(i)|, |SML_r(i)| ) \quad (2)$$

For each disparity value of the scene,  $M(d)$  is the weighted mean of those differences at a given disparity and  $w(d)$  is the corresponding sum of weights. This gives us an estimate of which image is more focused at a given disparity.

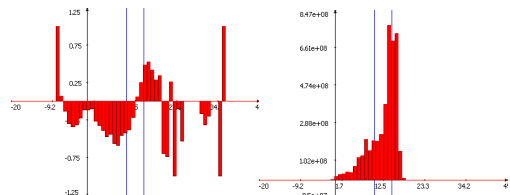


Fig 2: (Left) The measures  $M(d)$  (Right) The weights  $w(d)$

To extract robust information from the measures we fit a curve  $C(d)$  minimising the energy of Equation (3).

$$E(d) = w(d) \cdot E_{\text{Data}}(d) + E_{\text{Smooth}}(d) \quad (3)$$

$$E_{\text{Data}}(d) = M(d) - C(d) \quad (4)$$

$$E_{\text{Smooth}}(d) = |C(d-1) - C(d)| \cdot \text{DiscPenalty} \quad (5)$$

This can be solved in linear time using dynamic programming. The result is a curve telling for each disparity if: left is more focused than right, both focus are the same, or right is more focused than left. (Fig. 1.4).

We draw zebra strokes on each image (Fig. 1.1 and 1.2) in the areas where this image is less focused than the other.

## References

- [1] M. Sizintsev, S. Kuthirummal, H. Sawhney, A. Chaudhry, S. Samarasekera and R. Kumar, "GPU Accelerated Realtime Stereo for Augmented Reality", In Proceedings Intl. Symp. 3D Data Processing, Visualization and Transmission (3DPVT), 2010.
- [2] Wei Huang and Zhongliang Jing, "Evaluation of focus measures in multi-focus image fusion", Pattern Recognition Letters 28, pages 493-500. (2007)