Focus Mismatch Detection in stereoscopic content

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Motivation: stereoscopic visual quality

For best **visual quality** and **visual comfort** stereoscopic image pairs should:
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1. be geometrically aligned
Motivation: stereoscopic visual quality

For best visual quality and visual comfort stereoscopic image pairs should:

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2. be color-balanced
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For best **visual quality** and **visual comfort** stereoscopic image pairs should:

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2. be color-balanced

3. have same depth of field and focus distance
Motivation: stereoscopic visual quality

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**solved by** post-processing
Motivation: stereoscopic visual quality

For best **visual quality** and **visual comfort**, stereoscopic image pairs should:

1. be geometrically aligned

   *solved by post-processing*

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   *post-processing would degrade image quality*
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**Solved by post-processing**

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**Post-processing would degrade image quality**

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**Avoid it: detect while shooting**
Our goal

Given a stereoscopic pair of images, we want to answer:
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• Are focal distances and depth of field the same?
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Method outline

1. Detecting per-pixel focus mismatch.
2. Give feedback to operator
Detecting per-pixel focus mismatch
Focal Blur Model

Assuming parallel (or near parallel) cameras, optics imply:

• Stereo disparity depends on depth.
• Focal blur size is linear with the stereo disparity.

(Rajagopalan et al. 2004, Schechner et al. 1988)
Focal Blur Model

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(Rajagopalan et al. 2004, Schechner et al. 1988)
Measuring focal blur size is ill-posed

All-in-focus image

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Focal Blur Size

= Observed image

We would like to measure focal blur size
We only have access to the observed images
Measuring focal blur size is ill-posed

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All-in-focus image

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Problem: non-textured scene

We would like to measure focal blur size
We only have access to the observed images
Measuring focal blur *difference* is possible

- More focal blur causes more image blur
- Less focal blur causes less image blur
Measuring focal blur difference is possible

- More focal blur causes more image blur
- Less focal blur causes less image blur

The sign of focal blur difference is the same as the sign of image blur difference.
Focal Blur Difference

Right Focus Model

Left Focus Model

Difference

\( d \)

\( \sigma \)
Sign of Focal and Image Blur Difference

- Right Focus Model
- Left Focus Model
- Sign of Difference
- Difference

\[ \sigma \]
Sign of Focal and Image Blur Difference

Reminder:
Sign of focal blur size difference = Sign of image blur difference.
**All Configurations:**

**Focal Blur Size Difference**

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**Legend:**
- Left focal blur
- Right focal blur
- Focal blur difference
- Sign of Focal blur difference

Figure 2. Graphs of the focal blur size and the difference of left and right focal blur. Each cell contains the graph of the left and right focal blur functions, in red and blue respectively, corresponding to the given parameters. The difference of both functions is shown in green.

Figure 3. Sign of the difference between left and right focal blur (in orange), and left and right focal blur functions (dashed red and blue lines). The sign of the difference between the left and right image blur should give the same result. For each shape, we also give the list of signs used in the classification stage (see Sec. 3.5).
All Configurations: Sign of Focal/Image Blur Difference

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All Configurations: Sign of Focal/Image Blur Difference
Algorithm Outline

From two images:
Compute sign of image blur difference

The curve shape gives the focus configuration.
Image blur measurement: state of the art

Depth from focus:
“Given $N$ images of one object with known different focus distances, compute depth.”
For each pixel decide which image is more in focus.

Depth from defocus:
“Given two images of one object with known different apertures, compute depth.”
For each pixel quantify the focus difference.

In our case:
Focus mismatch detection: detect a difference.

Photostereosynthesis
Lumière, 1920.
Image blur measurement: state of the art

**Depth from focus:**

“*Given N images of one object with known different focus distances, compute depth.*”

For each pixel decide **which** image is more in focus.

**Depth from defocus:**

“*Given two images of one object with known different apertures, compute depth.*”

For each pixel **quantify** the focus difference.

**In our case:**

Focus mismatch detection: **detect** a difference.

⇒ use **Depth from focus** tools

Photostereosynthesis

Lumière, 1920.
Image blur measurement:
Sum of Modified Laplacian

From Nayar & Nakagawa, 1994 “Depth from focus”

Modified Laplacian at a pixel: captures “textureness”

\[ \nabla^2_{ML} I(x, y) = |2I(x, y) - I(x - 1, y) - I(x + 1, y)| + |2I(x, y) - I(x - 1, y) - I(x + 1, y)| \]

Sum of Modified Laplacian

\[ SML(i) = \sum_{i=x-1}^{x+1} \sum_{j=y-1}^{y+1} \nabla^2_{ML} I(i, j), \text{ for } \nabla^2_{ML} I(i, j) \geq T \]

Threshold discards sensor noise:

\[ T = 5 \text{ (for 8-bits images).} \]
We want to be able to answer the following questions, sorted by order of decision all possible combinations of the five images for each view. The 25 obtained results are presented in Fig. 13.

In order to validate our approach we first tested our algorithm using the ground-truth disparity map of the scene the Near and Far sample images.

In Fig. 10 we can see the computed disparity map, the computed Sign of the SML difference:

\[ M(i) = \text{sign} \left( \text{SML}_l(i) - \text{SML}_r(i) \right) \]

Mapping from left to right:
Dense disparity map.

Example: Left Far - Right Near
Mean Sign of SML difference wrt. disparity

wrt: with respect to
Finding a simple blur model

From the Mean sign curve we find simple blur model

details in the paper
Section 1 summary

From two images:
Compute sign of image blur difference

The **curve shape** gives the focus configuration.
2

Give feedback to operator
Zebras on images

Mean Sign

Disparity

+1

0

-1

⨁

→
Zebras on images

Mean Sign

-1

0

+1

Disparity

⨁
Manual adjustment hints

• Answers to the questions:
  • Are both focal distances and depth of field perfectly matched?
  • Are both focal distances equal? Which one is bigger?
  • Are both depths-of-field equal? Which one is bigger?
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  • Sometimes, some questions cannot be answered
  • details in the paper
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CONCLUSION
Conclusion and Future Work

Conclusion

• We presented a novel method to detect focus mismatch
• Evaluation on synthetic data is very promising: *(details in the paper)*
  • “Are both focus distances and depth of field perfectly matched?”
    • 100% accuracy
  • Always capable of accurately telling at least which camera is less in focus.
• All steps run in real-time

Future Work

• Validate proposed method with real footage from actual cameras.
• Quantification of the differences.
• Detect astigmatism? A non-flat mirror in a mirror rig?
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Thank you.

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http://3dlive-project.com/