Focus Mismatch Detection in stereoscopic content

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Stereoscopic Displays and Applications 2012

Motivation: stereoscopic visual quality

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

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→ solved by post-processing

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2. be color-balanced

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3. have same depth of field and focus distance

→ post-processing would degrade image quality

→ avoid it: detect while shooting

Our goal

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Method outline

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

1

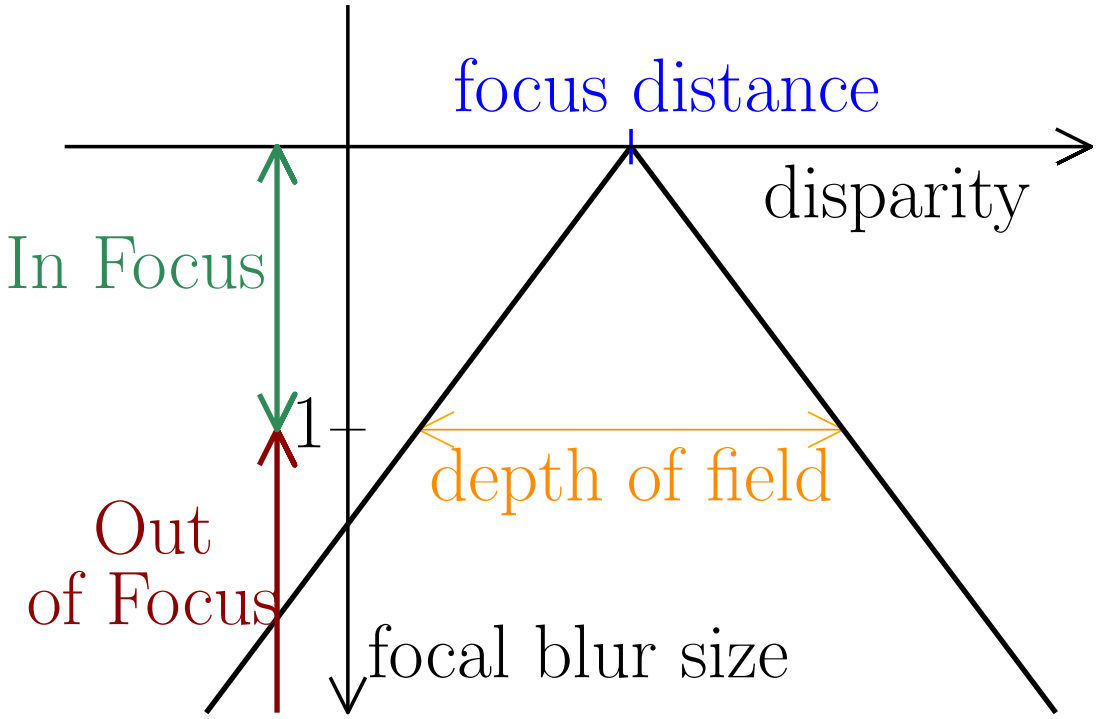
Detecting per-pixel focus mismatch

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)



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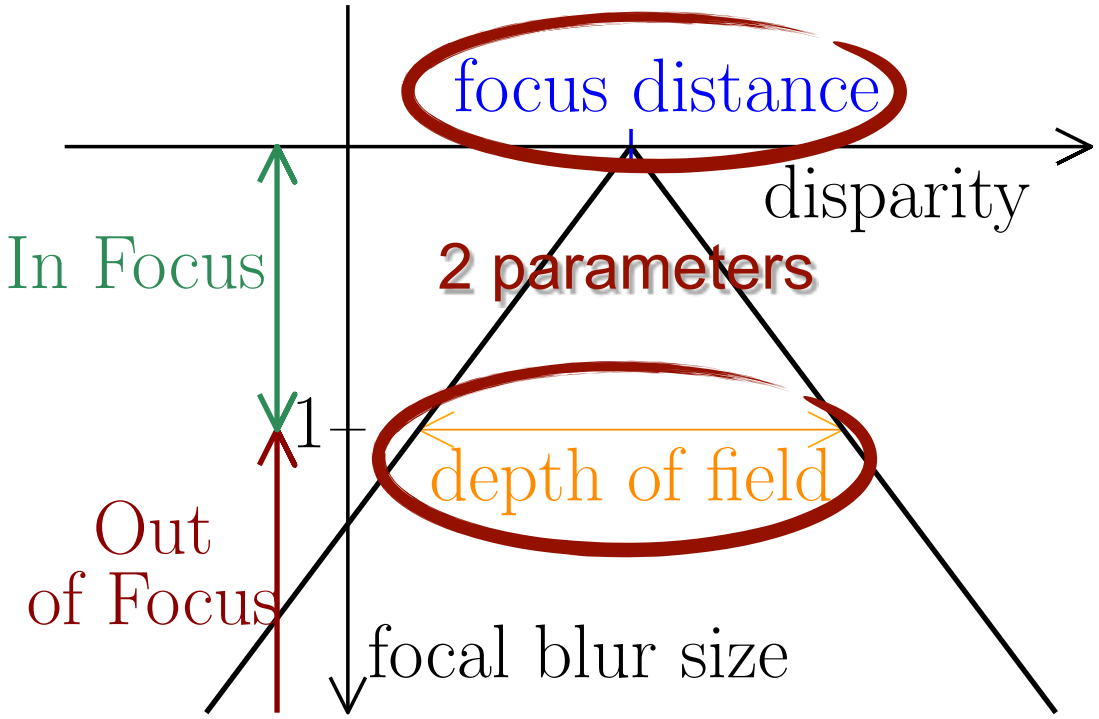

Measuring focal blur size is ill-posed

All-in-focus image

$\otimes$ Focal Blur Size $=$

Observed image

We would like to measure focal blur size

We only have access to the observed images

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Problem: non-textured scene

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Measuring focal blur *difference* is possible

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

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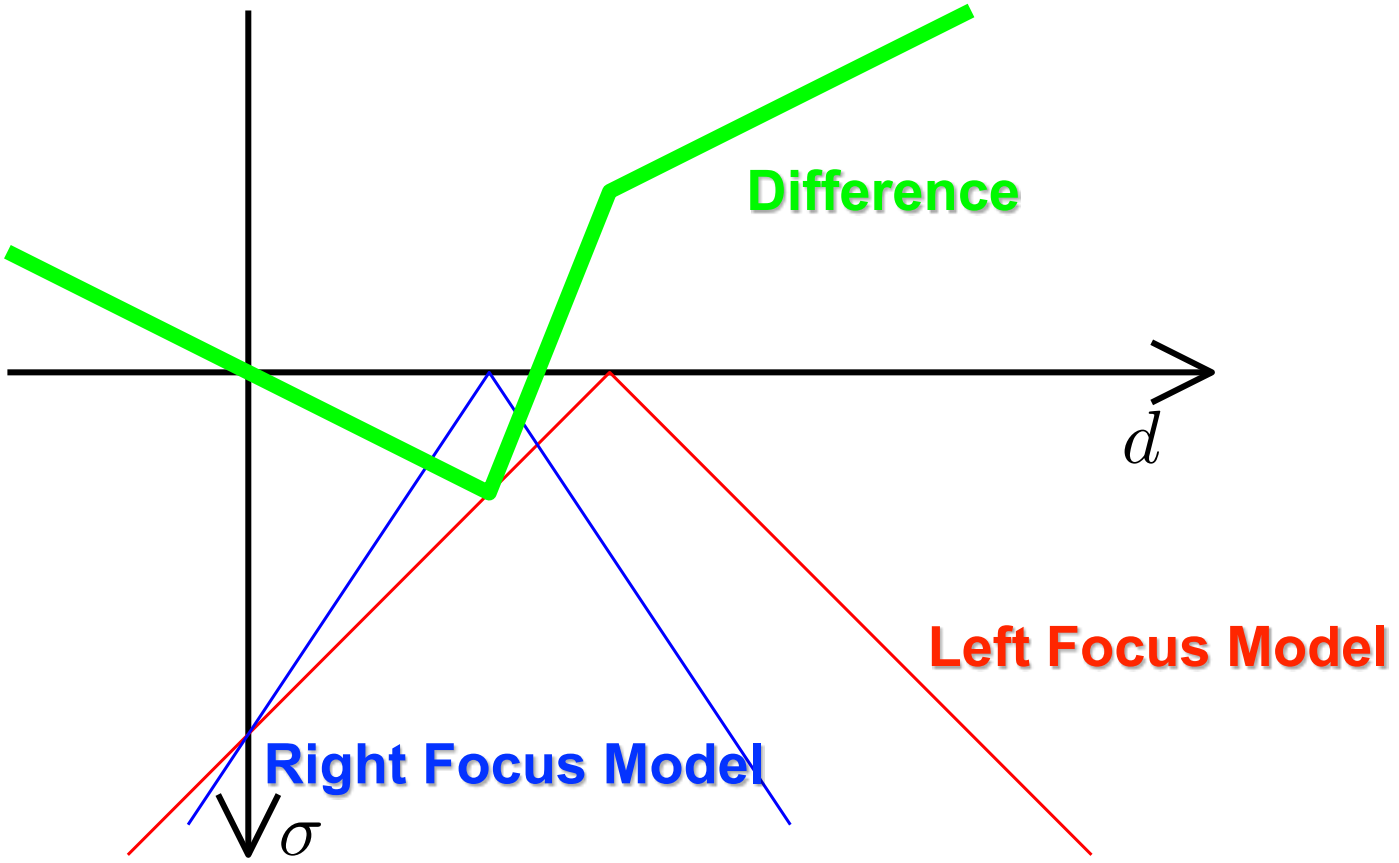
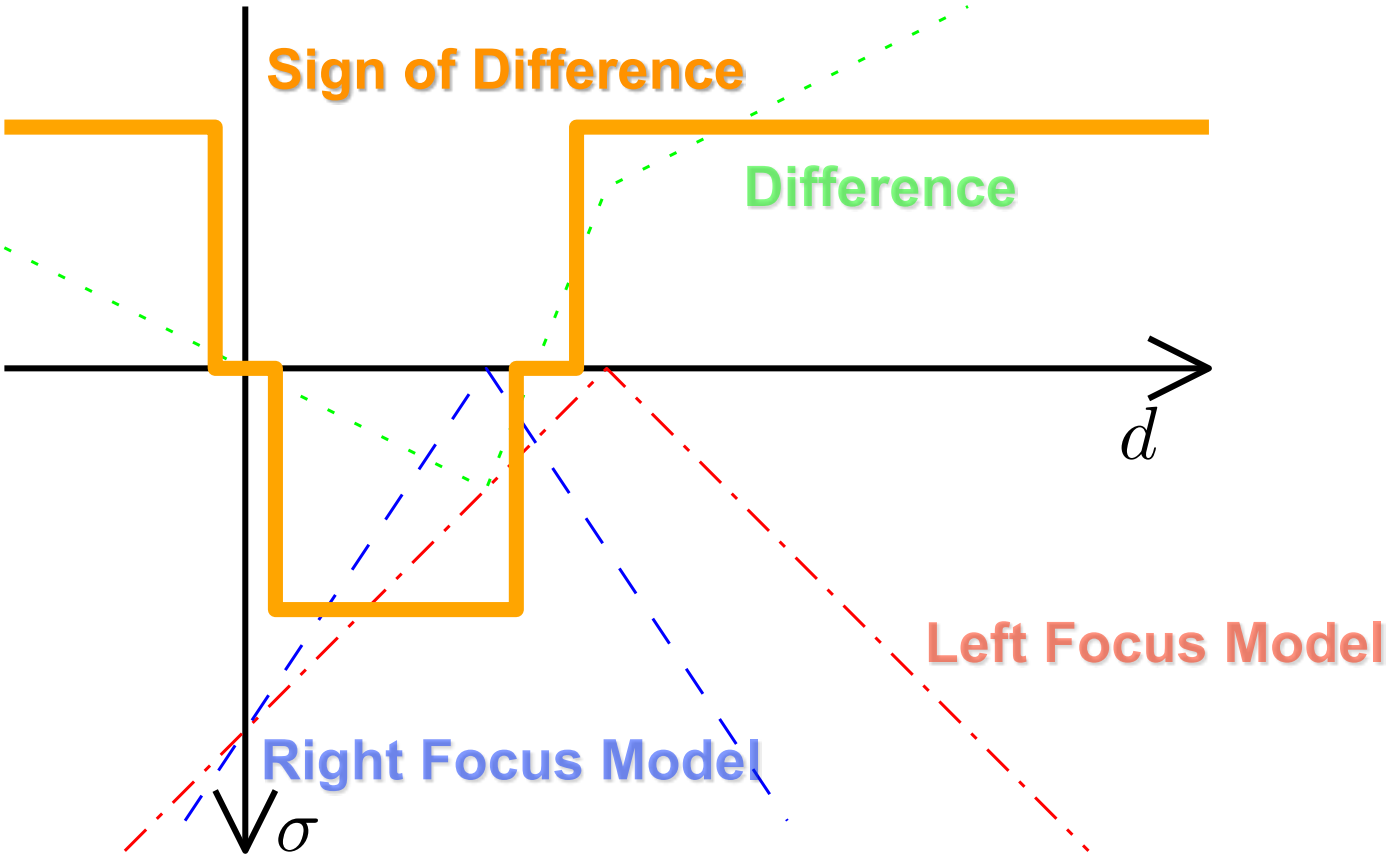
The **sign** of *focal blur difference* is the same as the **sign** of *image blur difference*.

Focal Blur Difference



Sign of Focal and Image Blur Difference



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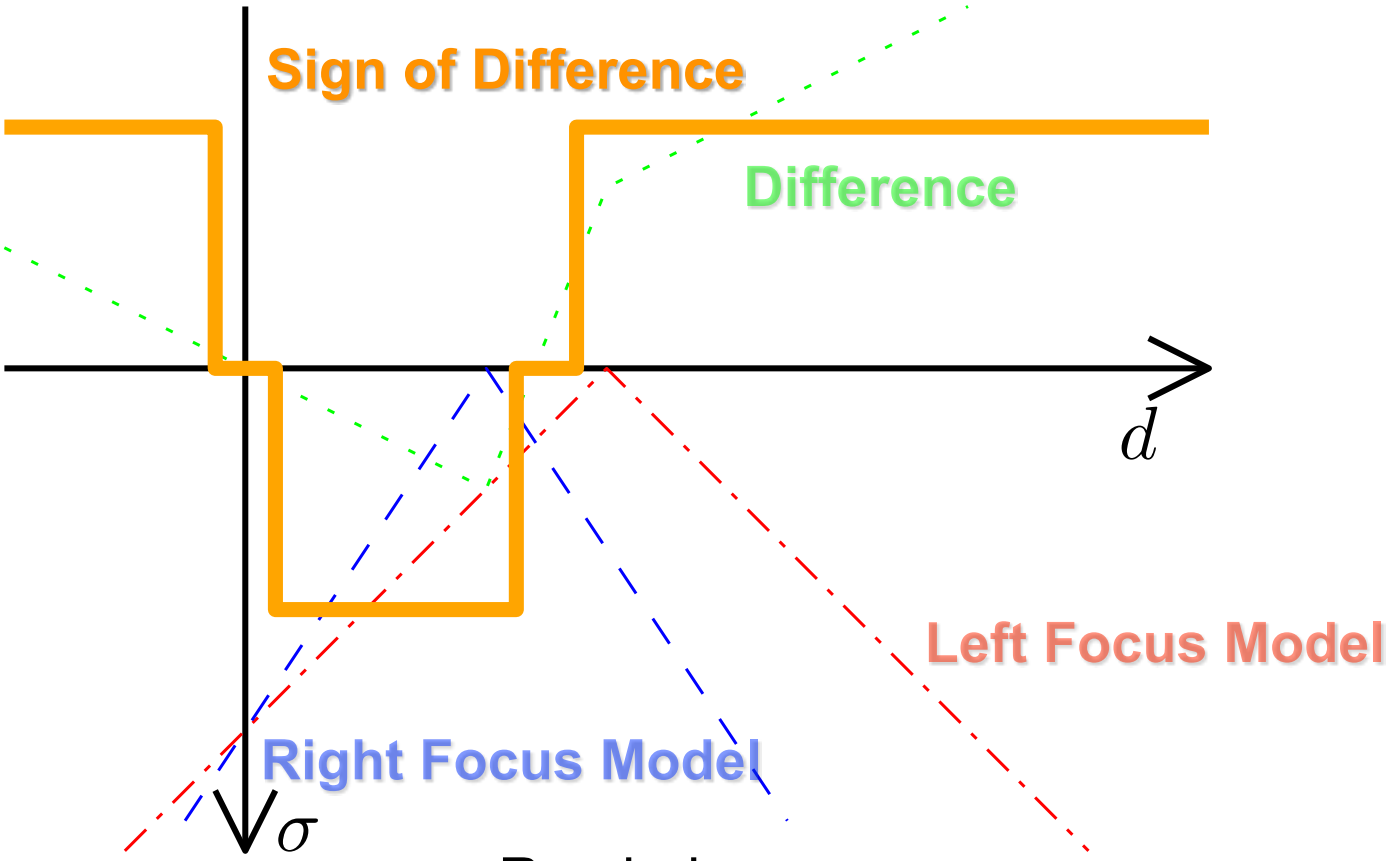
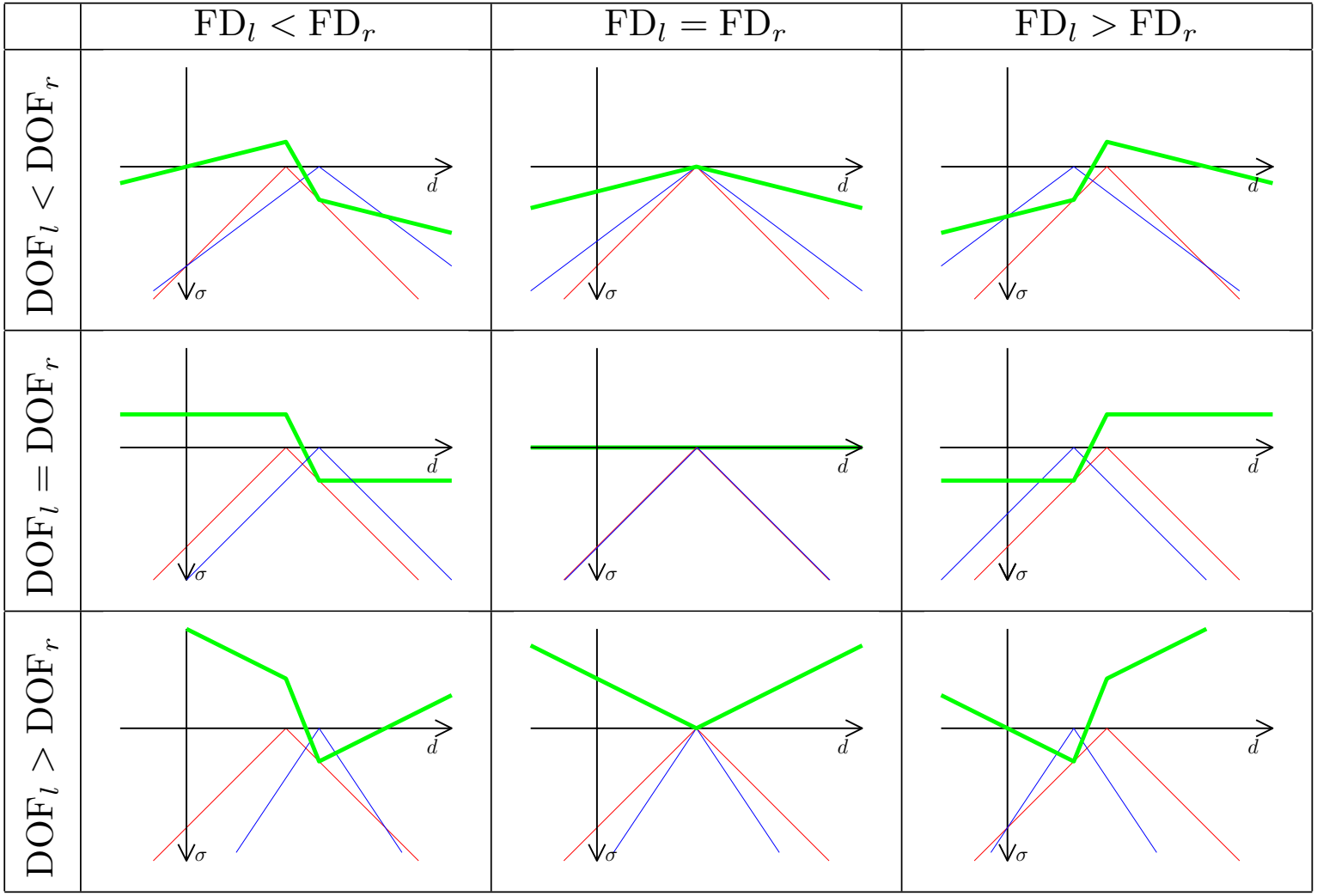


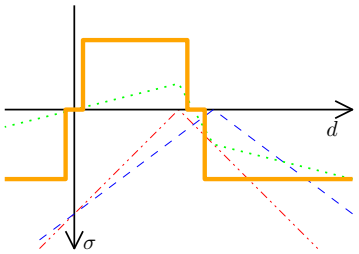
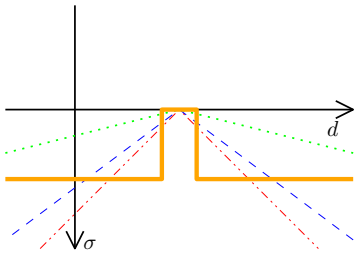
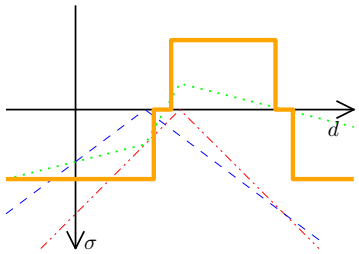
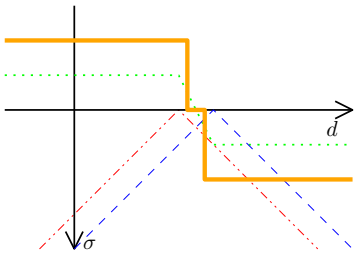
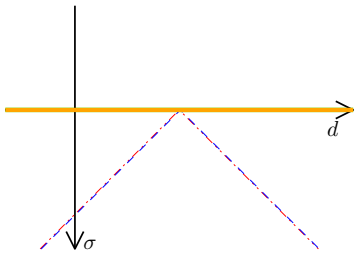
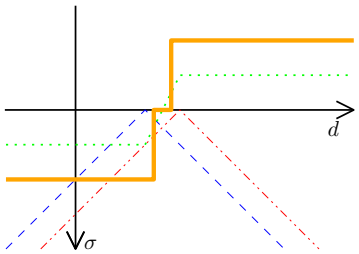
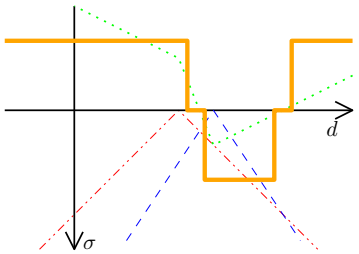
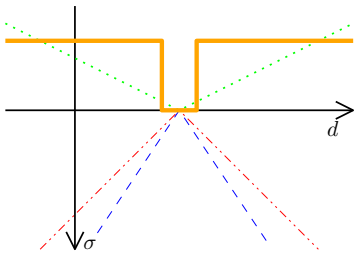
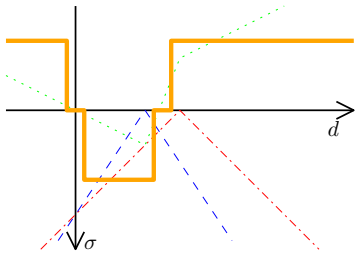
Reminder:

Sign of *focal blur size difference* = Sign of *image blur difference*.

All Configurations: Focal Blur Size Difference



All Configurations: Sign of Focal/Image Blur Difference

	$\mathrm{FD}_l < \mathrm{FD}_r$	$\mathrm{FD}_l = \mathrm{FD}_r$	$\mathrm{FD}_l > \mathrm{FD}_r$
$\mathrm{DOF}_l < \mathrm{DOF}_r$	 $L = (-,+,-)$	 $L = (-,-)$	 $L = (-,+,-)$
$\mathrm{DOF}_l = \mathrm{DOF}_r$	 $L = (+,-)$	 $L = ()$	 $L = (-,+)$
$\mathrm{DOF}_l > \mathrm{DOF}_r$	 $L = (+,-,+)$	 $L = (+,+)$	 $L = (+,-,+)$

Algorithm Outline

From two images:
Compute sign of image blur difference

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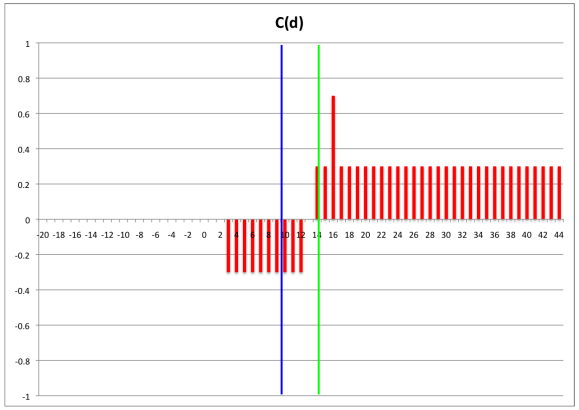

The **curve shape** gives the focus configuration.

Image blur measurement: state of the art

Photostereosynthesis
Lumière, 1920.

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.

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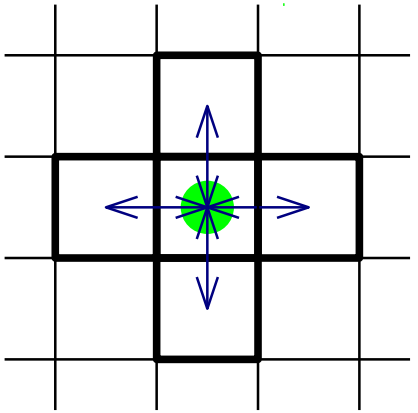
⇒ use **Depth from focus** tools

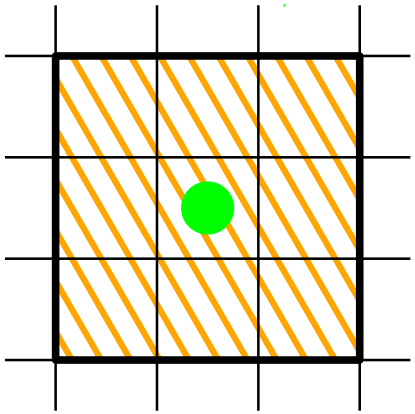
Image blur measurement : Sum of Modified Laplacian

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

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

Threshold discards sensor noise:

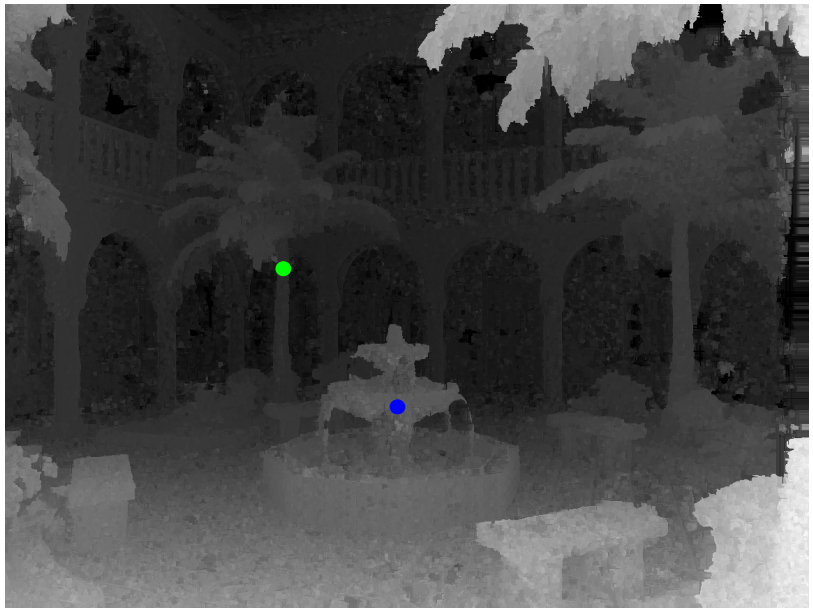
$$T = 5 \text{ (for 8-bits images)}$$

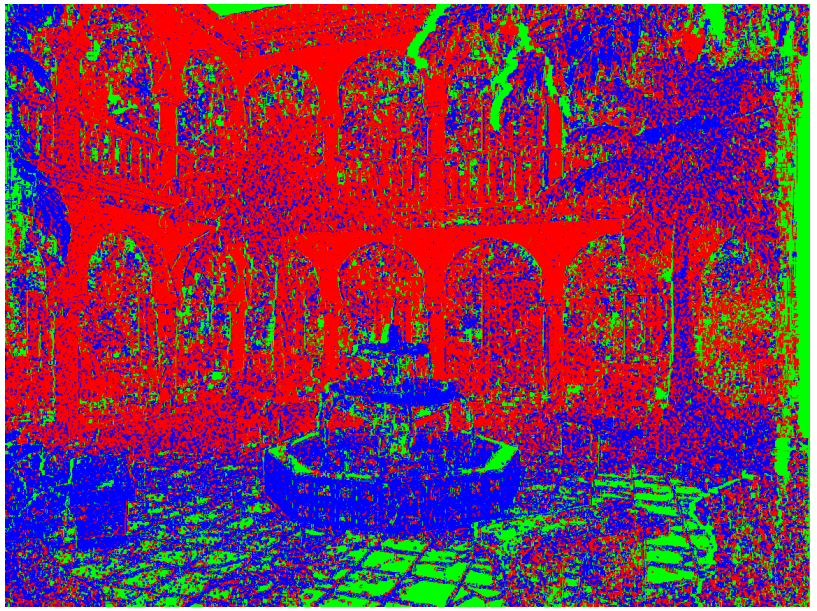
Image blur difference measurement: Sign of left and right SML image difference

Mapping from left to right:

Dense disparity map.

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



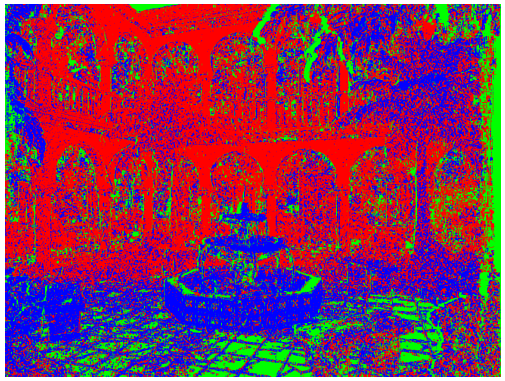


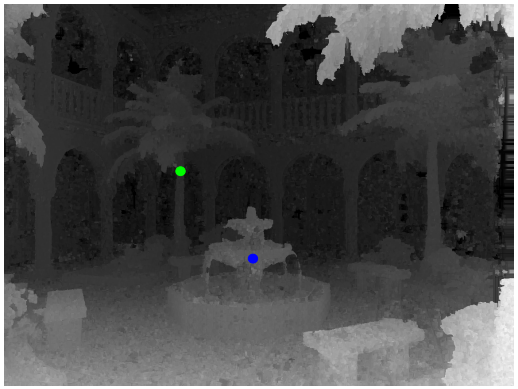
$M(\mathbf{i}) < \mathbf{0}$ $M(\mathbf{i}) = \mathbf{0}$ $M(\mathbf{i}) > \mathbf{0}$

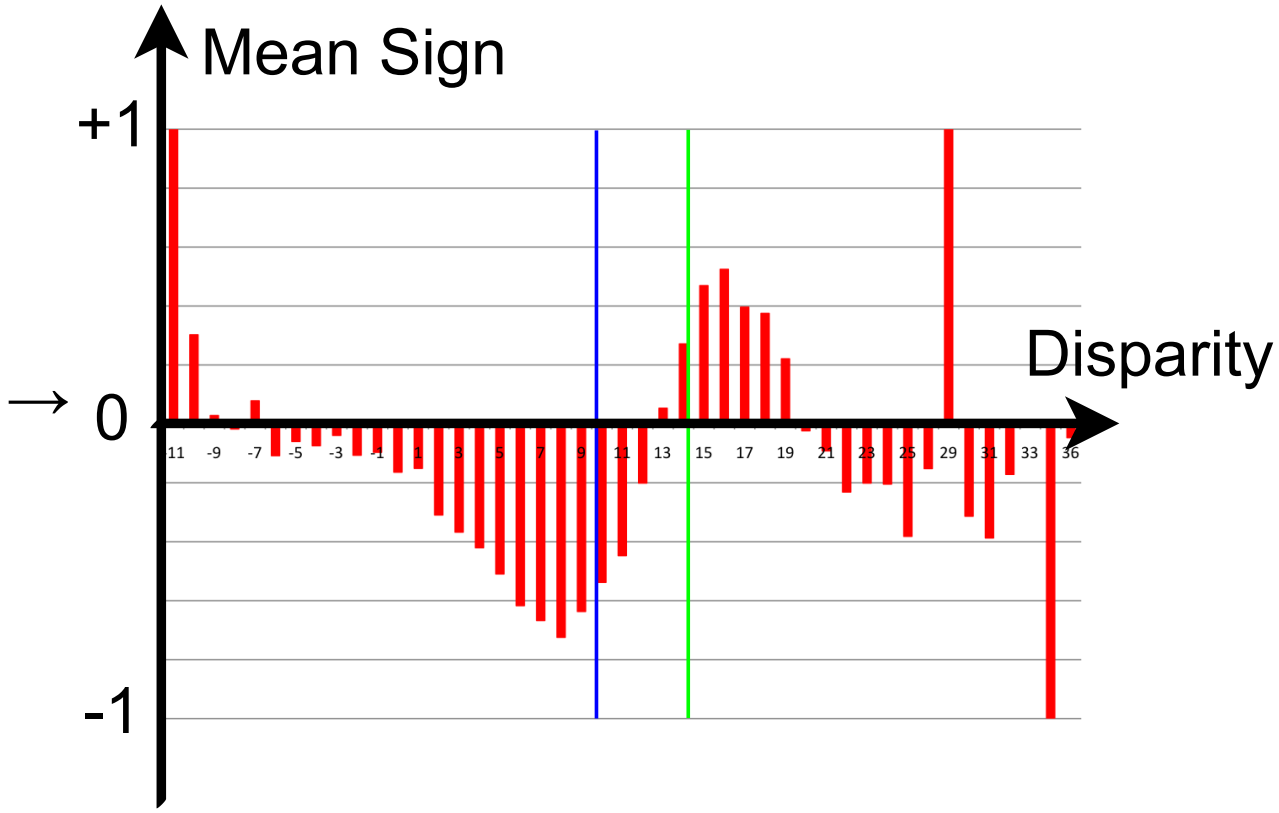
Example: Left Far - Right Near

Mean Sign of SML difference wrt. disparity

wrt: with respect to

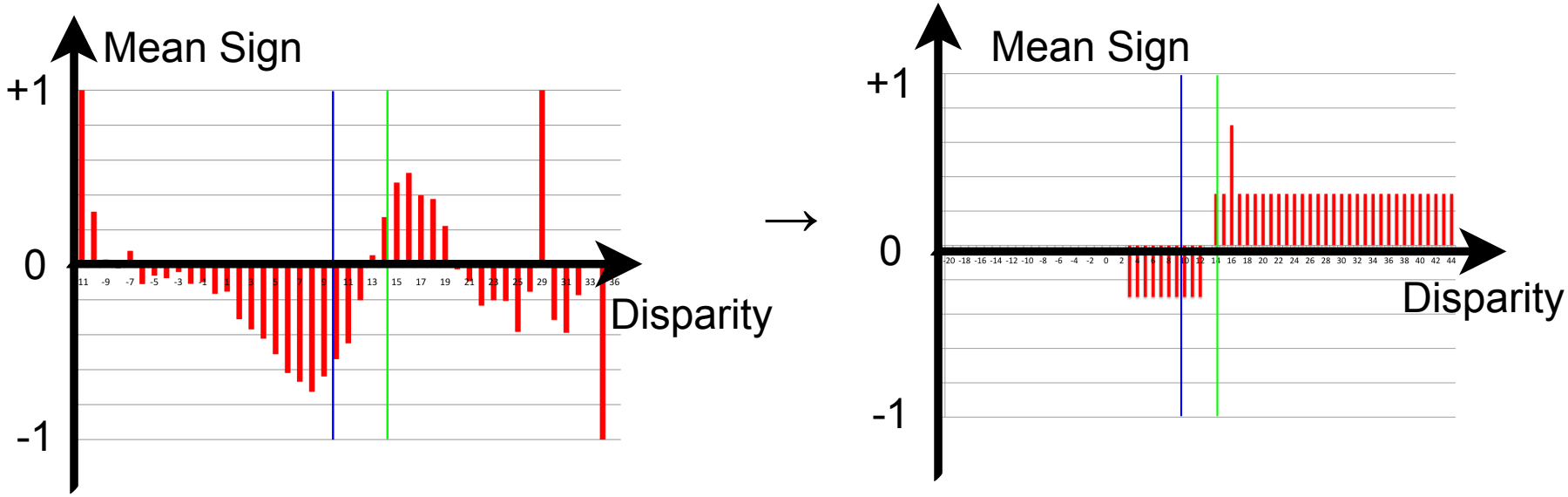






Finding a simple blur model

From the Mean sign curve we find simple blur model



details in the paper

Section 1 summary

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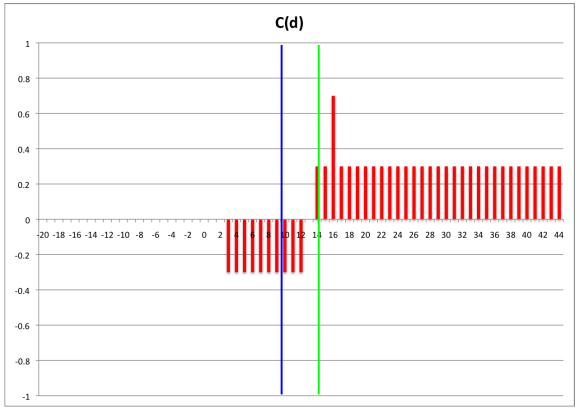

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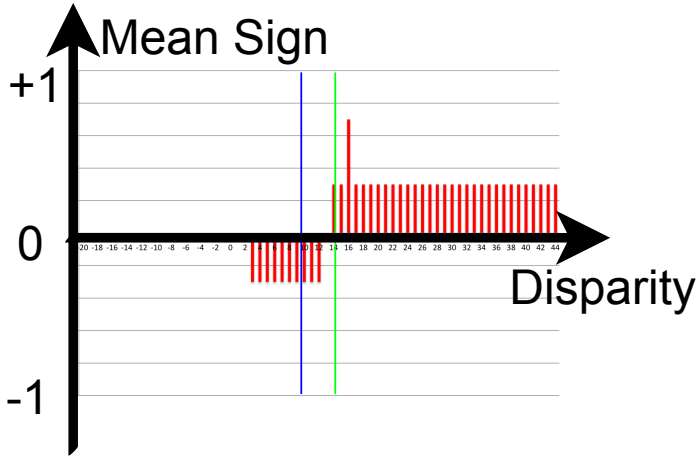
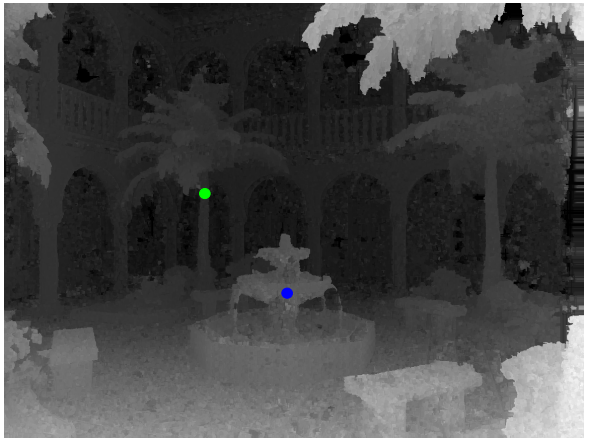
2

Give feedback to operator

Zebras on images





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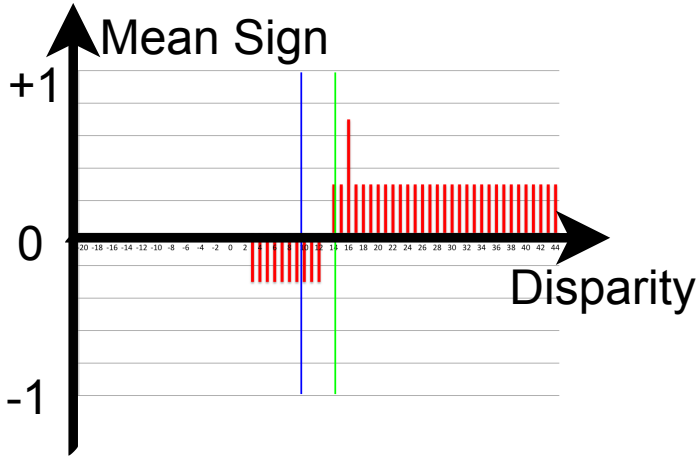

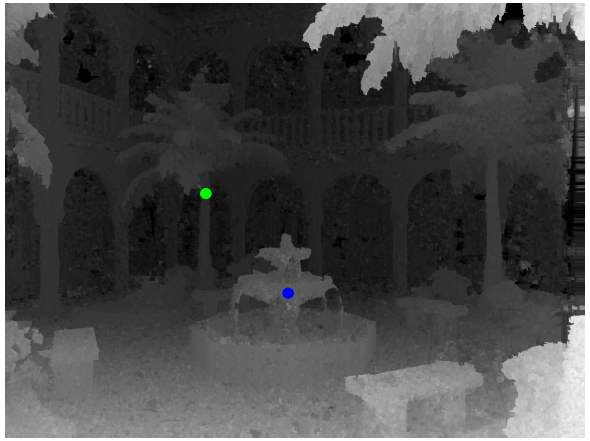

Manual adjustement hints

- Answers to the questions:
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  - Sometimes, some questions cannot be answered
  - *details in the paper*

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CONCLUSION

Conclusion and Future Work

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- 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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This work was done within the 3DLive project supported by the French Ministry of Industry
http://3dlive-project.com/