Novel View Synthesis for Stereoscopic Cinema: Detecting and Removing Artifacts

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Introduction

- Why novel view synthesis from a stereoscopic movie?
  - Adaptating the movie to given screen size and distance
  - Original shot may have the wrong stereoscopic parameters
  - Modifying the 3-D scene geometry
- Usually done using baseline modification [Koppal2010, Zitnick2004, Rogmans2009]
- Hybrid disparity remapping is a more general solution, which preserves image content and restores perceived depth [Devernay2010]
- May be symmetric (generate left and right views) or asymmetric (e.g. keep left view, generate right view)
- Requires correct (perfect?) disparity estimation

Artifacts in new view synthesis

- 2-D artifacts will basically happen where stereo fails:
  - depth discontinuities or highly sloped surfaces
  - non-textured areas
  - specular reflections
  - repetitive patterns
  - optical blur and motion blur
- Usually localized and high-frequency, they may also cause:
  - 3-D artifacts (phantom objects)
  - Flickering (lack of temporal consistency)
- Stelmach et al. [2000] and Seuntiens et al. [2009] showed:
  - the perceived quality of a mixed blurred/non-blurred stereo pair is that of the highest quality image, regardless of eye dominance

Artifacts detection and removal

Our approach:

• Use **asymmetric** synthesis, so that one view keeps the highest possible image quality

• **Detect** artifacts in the synthesized view

• **blur out** the artifacts by anisotropic filtering

Why it should work:

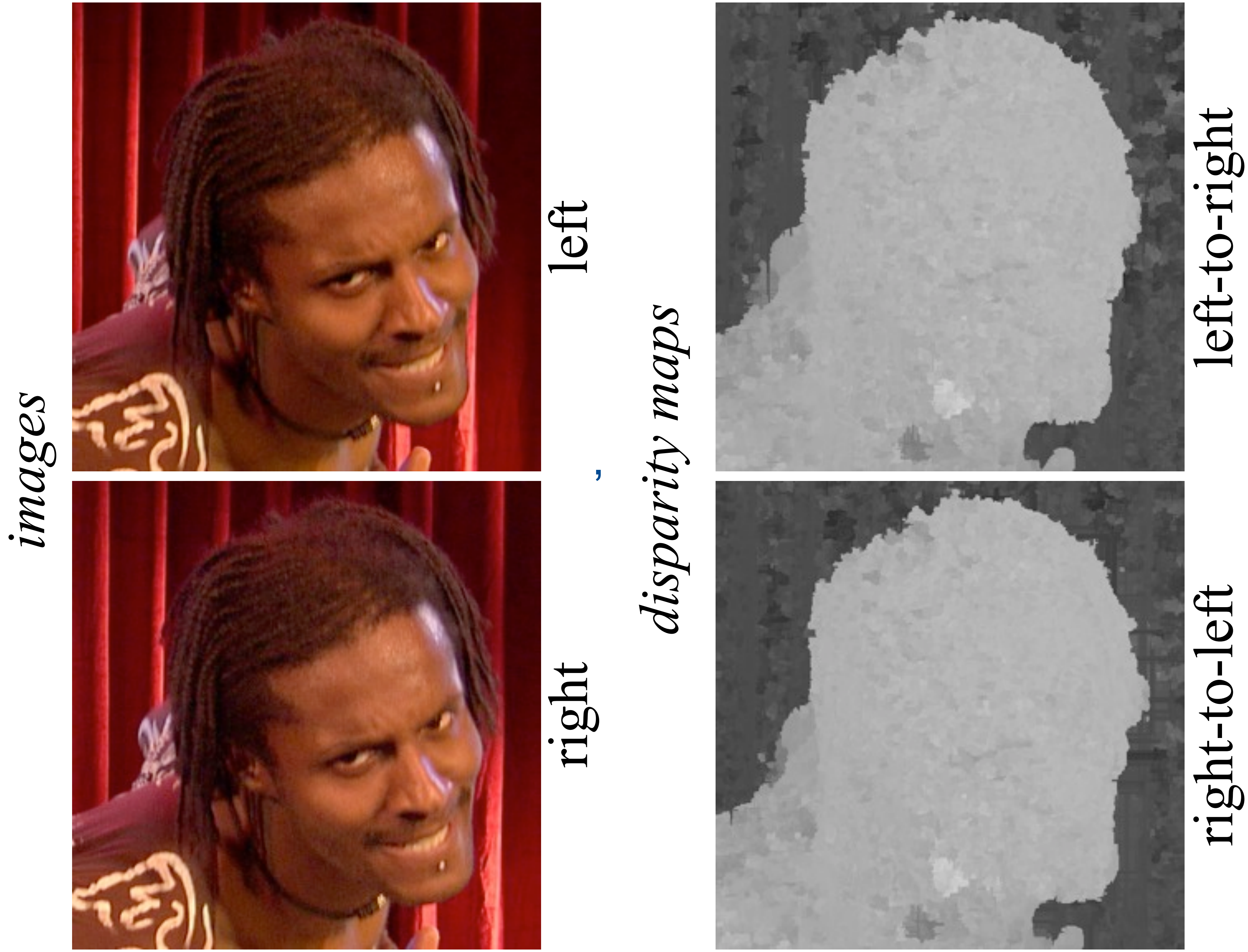
• This locally reduces the image frequency content on artifacts

• The visual system will use other 3-D cues from the other (original)view to perceive 3-D in these areas

• Temporal consistency should not be critical because of low spatial frequency (to be validated)

New View Synthesis from Stereo

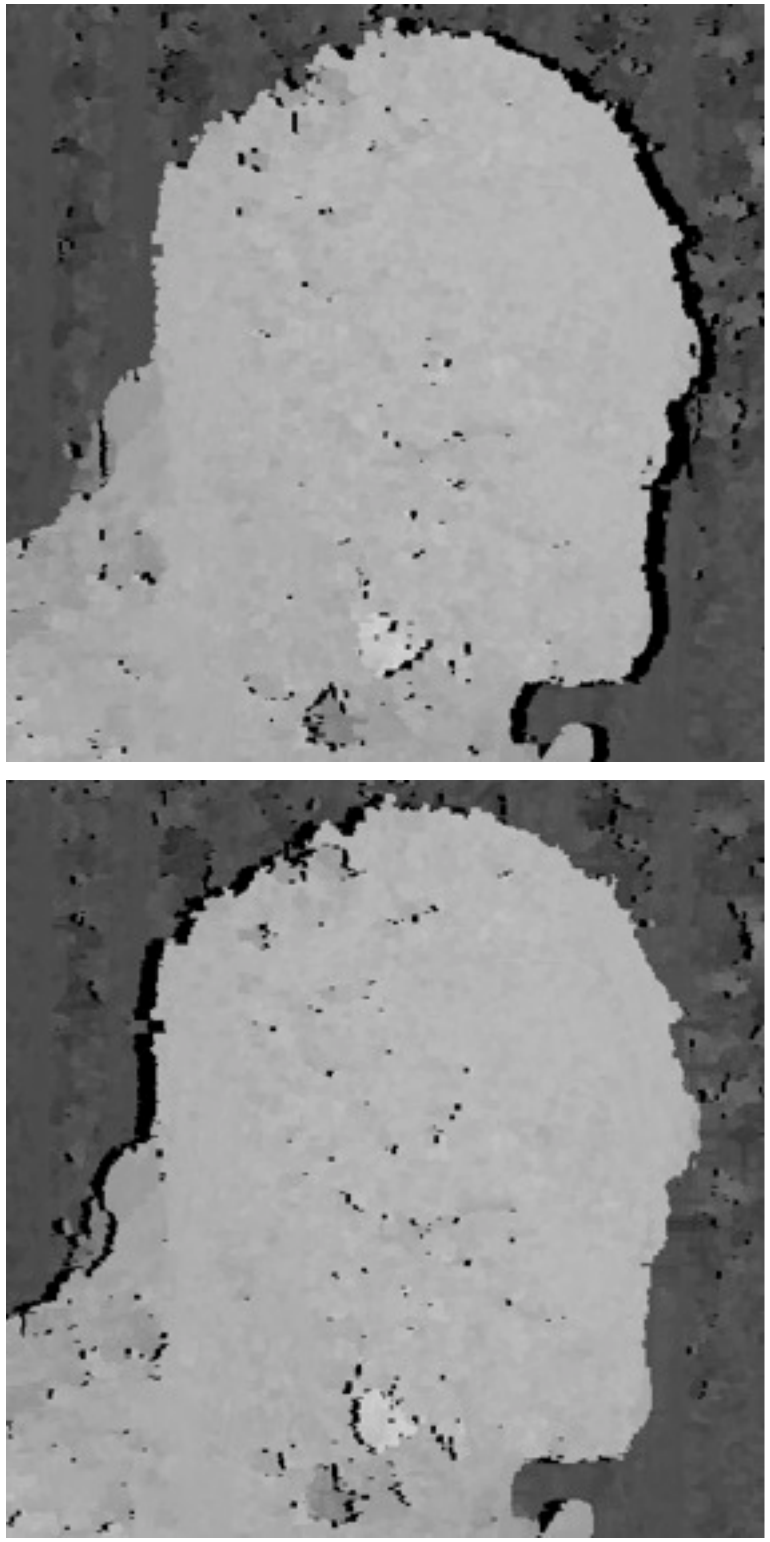
input=(



)

New View Synthesis from Stereo (2)

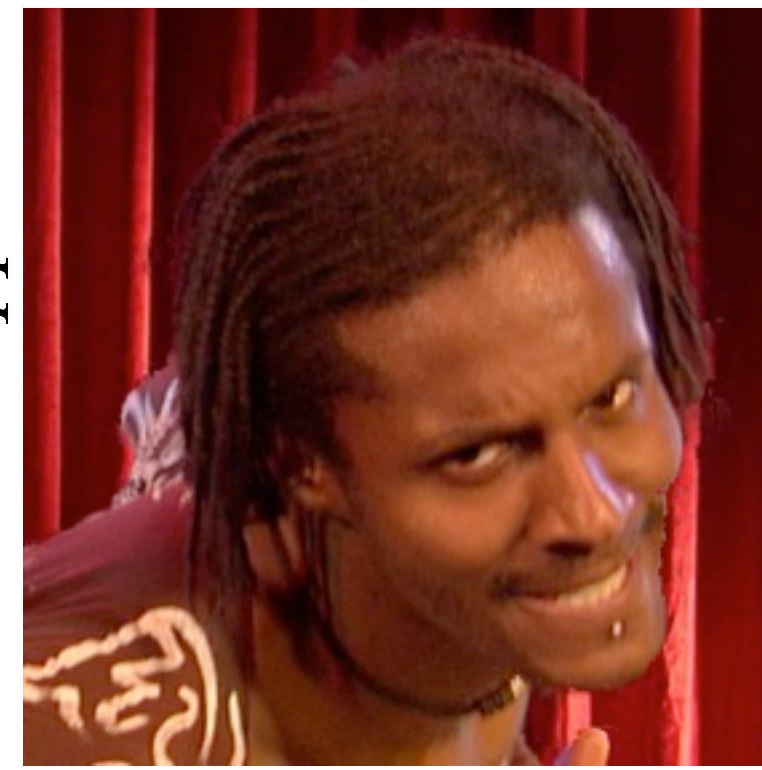
→ output=(*backward disparity maps (with holes!)*



view-to-left

view-to-right

, *blended remapped view*



view)


Artifacts!

Detecting artifacts

Color difference between interpolated and original images

- Artifacts
- Specular reflections (false positives)

Laplacian difference

- High frequency artifact contours, even hair-like structures, even in blurry areas
- Does not detect inside artifacts (false negatives)

Differences are computed using the backward disparity maps (with holes)

- Laplacian should be composed with map Jacobian... NOT!

Combine both to compute a confidence map:

- Dilate Laplacian difference to fill artifacts
- Multiply by color difference to mask with the artifacts areas
- Threshold so that at most 5% of the image is detected as artifacts, and 0.1% have the maximum value
- Scale between 0.0-1.0 (1.0 = low confidence)

Removing artifacts

Anisotropic filtering: The Perona-Malik diffusion equation [PAMI1990].

$$\frac{\partial I}{\partial t} = \nabla \cdot (c(x,y,t)\nabla I) = c(x,y,t)\Delta I + \nabla c \cdot \nabla I$$

conduction $c \in [0,1]$

Laplacian

gradients

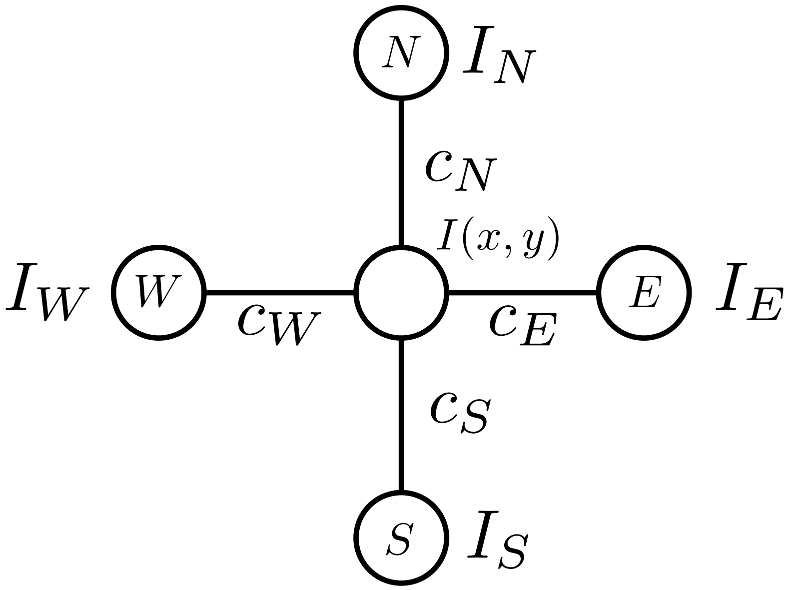
Will diffuse I depending on the conduction *c*. (*c* = const. ⇔ heat equation)

Use the **confidence** as conduction (could be recomputed at each time t).

Removing artifacts: Implementation

Discrete computational scheme to solve Perona-Malik:

$$
\begin{aligned}
I^{t+1}(x,y) =& I^t(x,y) + \\
& \Delta t \left(c_N \cdot \nabla_N I + c_S \cdot \nabla_S I + c_E \cdot \nabla_E I + c_W \cdot \nabla_W I \right) \\
c_N =& (c(x,y) + c(x,y-1))/2, \ldots \\
\nabla_N I =& I^t(x,y-1) - I^t(x,y), \ldots \\
\Delta t \in& [0, 1/4] \text{ for stability}
\end{aligned}
$$



The confidence map should be dilated so that the «right» colors bleed onto the artifact area.

10 iterations, Δt = 0.25 in our implementation. Parallelizable.

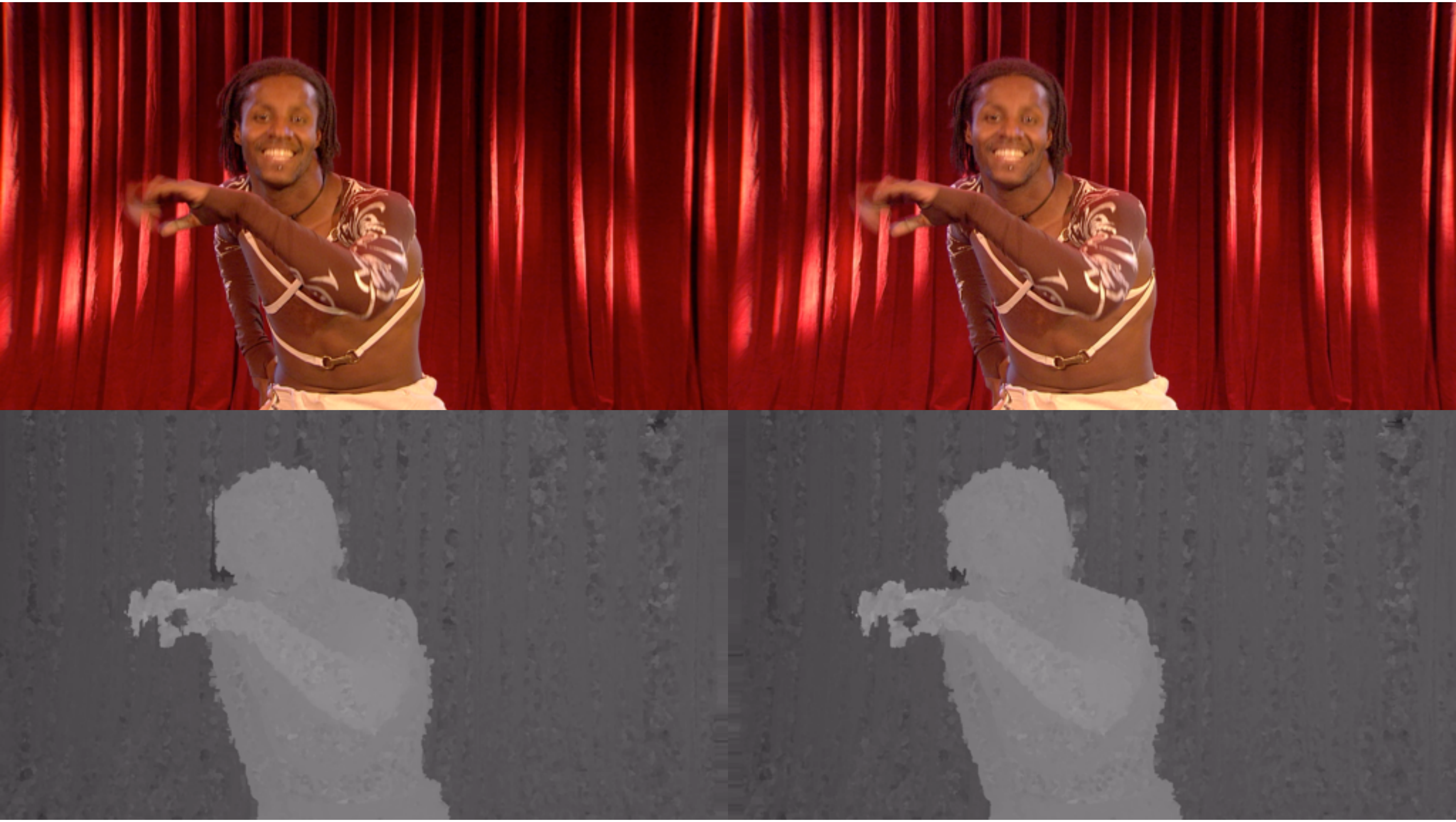
Interpolated frame

Artifacts removed

Interpolated frame

Interpolated frame, artifacts removed

Original movie + disparity maps



Interpolated view

Interpolated view, artifacts removed

Confidence map

Conclusions

A generic method to detect and remove artifacts.

Based on classical Perona-Malik anisotropic diffusion: *good properties!*

Works well even where stereo fails (motion blur, specularities...)

Results look good, but there’s still room for improvements.

Viewer survey required for complete validation.

May be adapted to more than two views (?)

Thank you!

Post-docs available at INRIA Grenoble:

Visual fatigue assesment *on stereoscopic movies based on image processing: will this 3-D movie give you a headache?*

Beyond the stereo rig: *what can we do with three cameras?*

please contact me (frederic.devernay@inria.fr)

Work done within the 3DLive project: http://3dlive-project.com

With motion blur...

Interpolated

Interpolated, artifacts removed

Confidence map