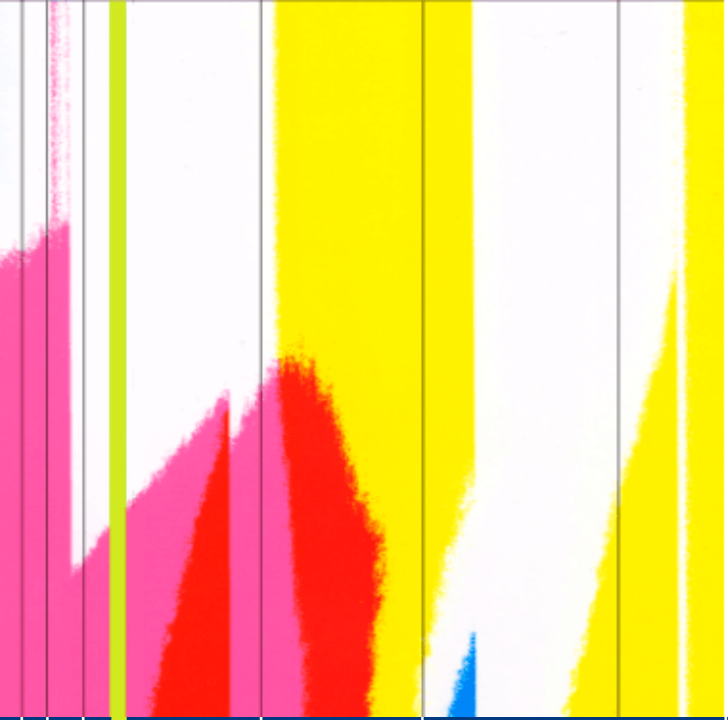

New View Synthesis for Stereo Cinema by Hybrid Disparity Remapping

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INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

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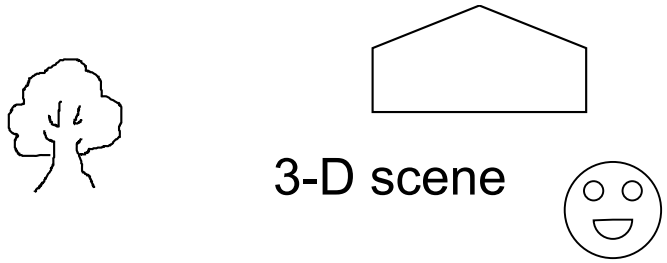
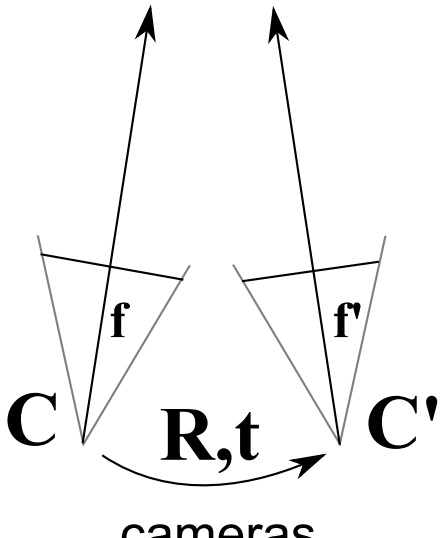
Introduction

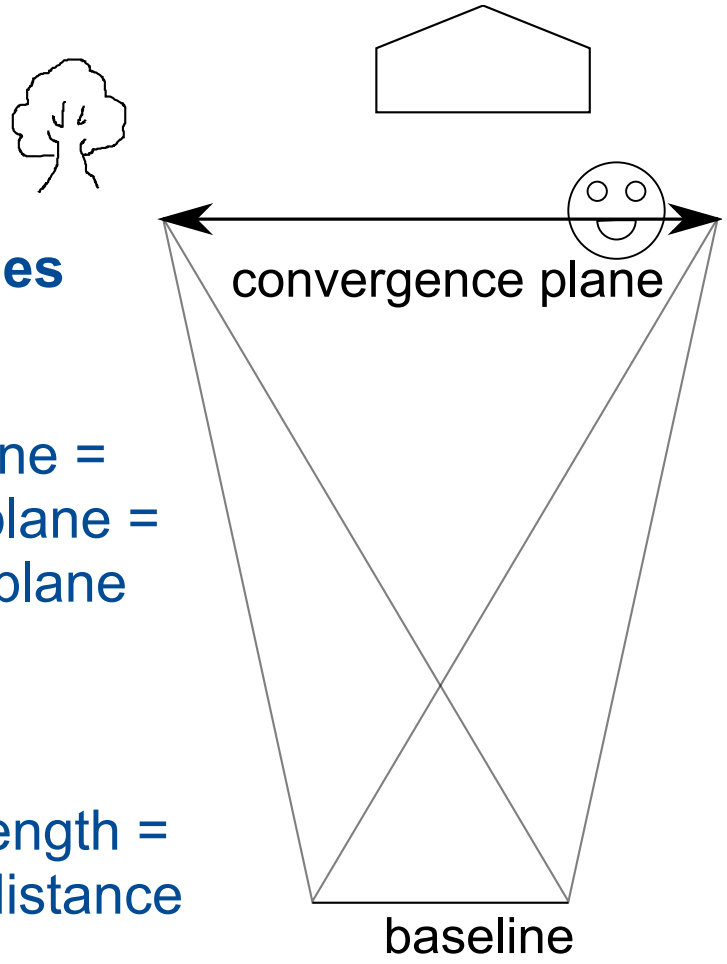
- Projecting a stereoscopic movie on **different screen sizes** produces **different perceptions of depth** [Spottiswoode1952]
- Theoretically, a stereoscopic movie **has to be shot for given viewing conditions**, e.g. movie theater or 3DTV
- **Depth distortion**, or even eye divergence, may happen for different viewing geometries: screen size and distance have a strong impact
- **New view synthesis** [Zitnick2004,Rogmans2009] is a possible solution, but what kind of geometric transform should be applied to the images to minimize depth distortions and divergence?
- **Classical synthesis methods** (baseline modification and viewpoint modification) have **strong drawbacks**
- We propose a depth-preserving synthesis method: **hybrid disparity remapping**

The shooting geometry: classical representation (top view)





The shooting geometry: simplified representation

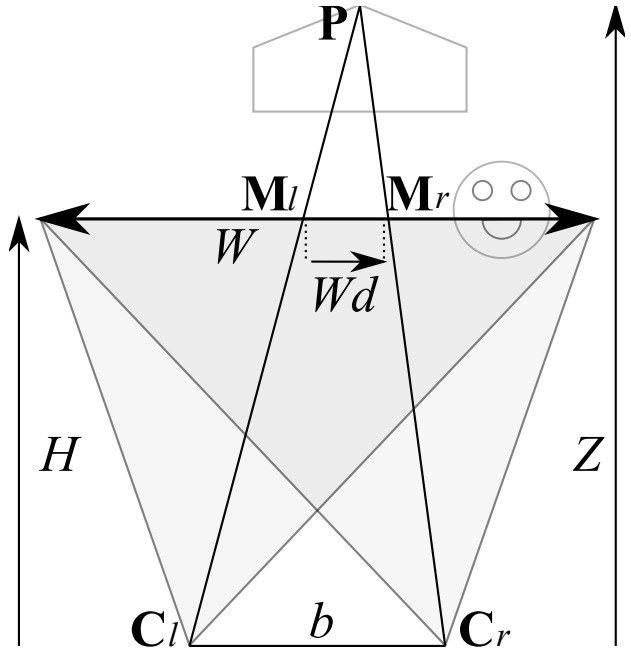


rectified images

rectification plane =
convergence plane =
zero-disparity plane
(// to baseline)

rectified focal length =
convergence distance

Shooting and viewing geometry share the same parameters



Symbol	Camera	Display
$\mathbf{C}_l$, $\mathbf{C}_r$	camera optical center	eye optical center
$\mathbf{P}$	physical scene point	perceived 3-D point
$\mathbf{M}_l$, $\mathbf{M}_r$	image points of $\mathbf{P}$	screen points
b	camera interocular	eye interocular
H	convergence distance	screen distance
W	width of convergence plane	screen size
Z	real depth	perceived depth
d	left-to-right disparity (as a fraction of W)	

d is the same in both geometries.

Z can be expressed as a function of *d*:

$$Z = \frac{H}{1 - dW/b} \qquad d = \frac{b}{W}\frac{Z - H}{Z}$$

*... same **with primes** in the **viewing geometry***

Viewing the unmodified 3-D movie: depth distortions

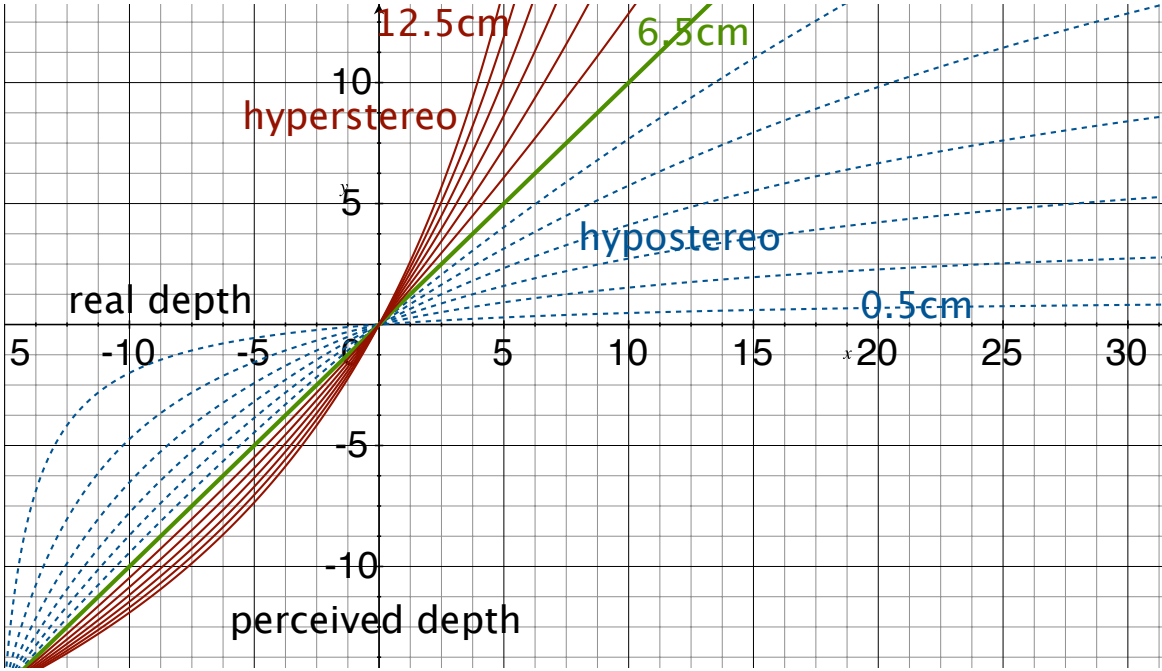
substituting *d* gives
perceived depth *Z'* as a function of *Z*:

$$Z' = \frac{H'}{1 - \frac{W'}{b'}\left(\frac{b}{W}\frac{Z-H}{Z}\right)}$$

Highly **nonlinear**!

Eye divergence:

$Z' < 0$ i.e. $d > b'/W'$



Z' = f(*Z*) for different values of *b* (baseline)

Viewing the unmodified 3-D movie: X-Y size distortions and roundness factor

image scale ratio σ': how much an object at depth Z seems to be enlarged in X-Y directions wrt an object at depth H (σ'=1 on screen),

$$\sigma' = \frac{H'}{Z'}\frac{Z}{H} = \frac{1 - dW'/b'}{1 - dW/b}$$

roundness factor: does a sphere at depth Z appear as flattened (ρ<1) or ellongated (ρ>1),

$$\rho = \sigma' \frac{W}{W'}\frac{\partial Z'}{\partial Z}$$

on screen: $\rho_{\text{screen}} = \frac{b}{H}\frac{H'}{b'}$

*The **only** shooting geometries that preserve the roundness factor **everywhere** are **scaled versions of the viewing geometry**!*

Impossible to hold this constraint in practice (sports, wildlife...).

Fixing the roundness factor issue using new view synthesis

Virtually changing the shooting parameters to fix the roundness factor:

- **Baseline modification** (or view interpolation) only changes *b*, but distorts off-screen depth and image size, and may cause *eye divergence*
- **Viewpoint modification** is geometrically 100% correct, but difficult in practice because of large disoccluded areas
- We propose **hybrid disparity remapping**, which fixes the on-screen roundness factor, does not distort depth, and does not cause divergence

We only deal with the geometry of the synthesized view, not the rendering method.

See paper for the maths: mapping and blending functions

New view synthesis: symmetric or assymetric

Experimental evaluation [Seuntiens2009] showed that:
perceived_quality(stereoscopic_pair) ≈ quality(best_image_in_pair)

Not affected by eye dominance.

⇒ If possible, **synthesize only one view**, and keep the original other view :

- baseline modification and hybrid disparity remapping **OK**
- viewpoint modification **NO**

High-frequency **artifacts** *must not appear* in the synthesized view, *or must be removed* (cf. ACM MM Workshop 3DVP'10 in october).

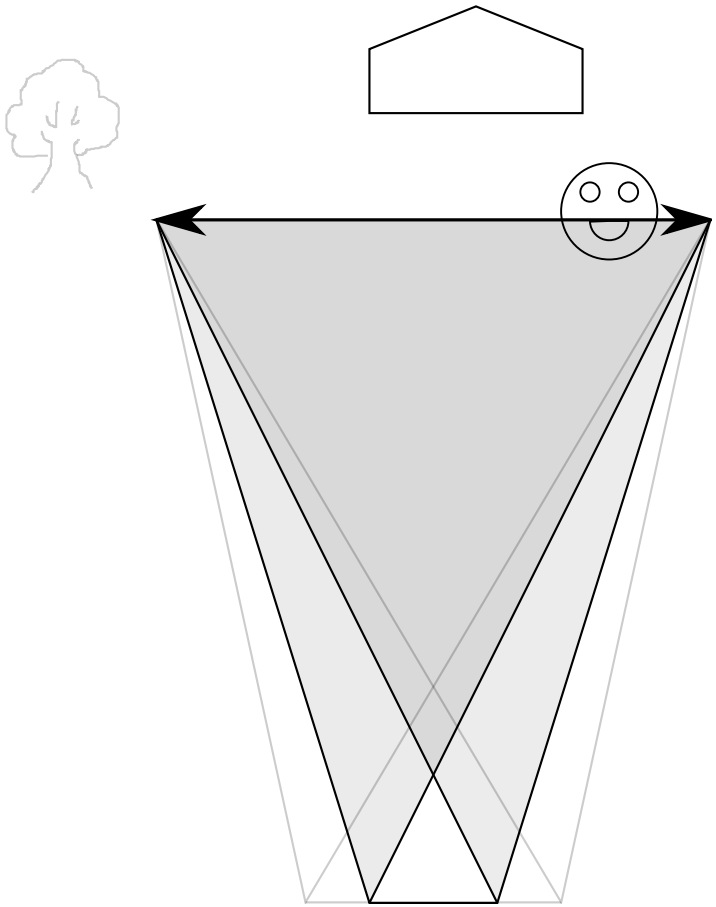
Baseline modification

new baseline *b”* computed by setting $\rho_{screen}=1$

view interpolation (*b”* < *b*) or extrapolation (*b”* > *b*)

symmetric or asymmetric (one view is left untouched)

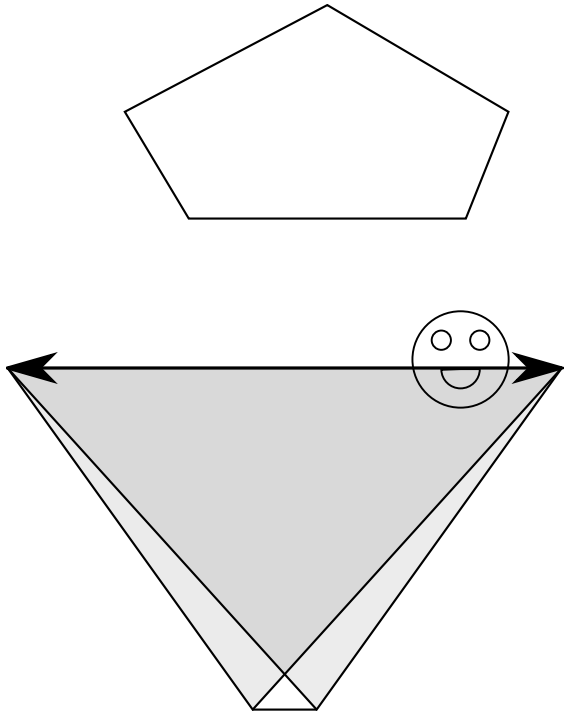
Baseline modification



shooting geometry

3-D geometry is distorted

eye divergence may happen



viewing geometry

Viewpoint modification

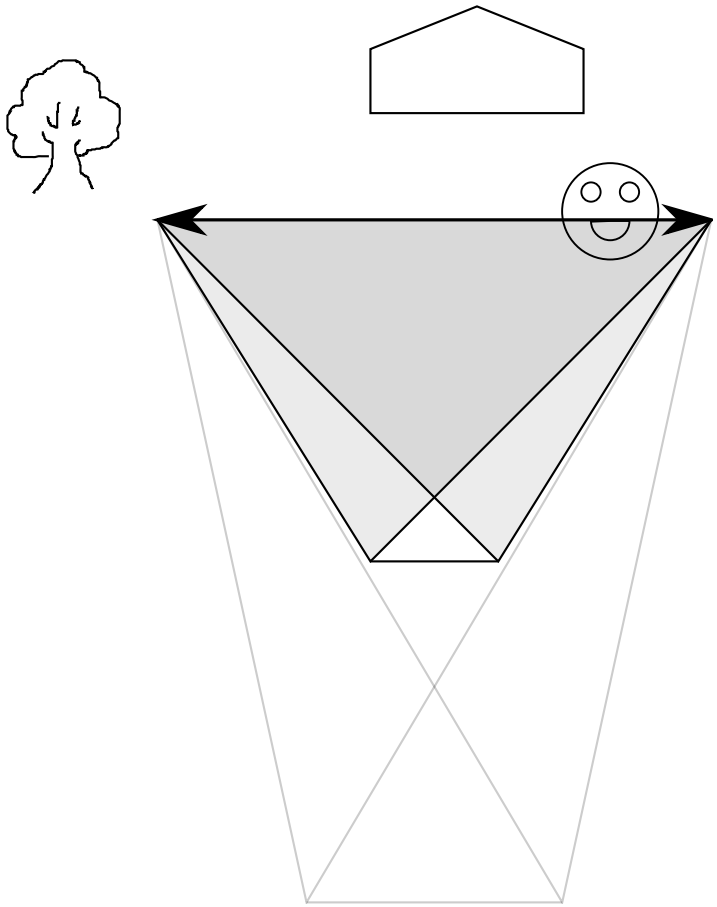
Synthesize a scaled version of the viewing geometry:
on zoomed-up shots, the virtual viewer is placed **on the playing field**

Both views must be synthesized (**symmetric**)

Large scene parts that are not visible in the original views may become **disoccluded**, because focal length change causes depth-dependent image scaling.

⇒ Produces many holes and image artifacts...

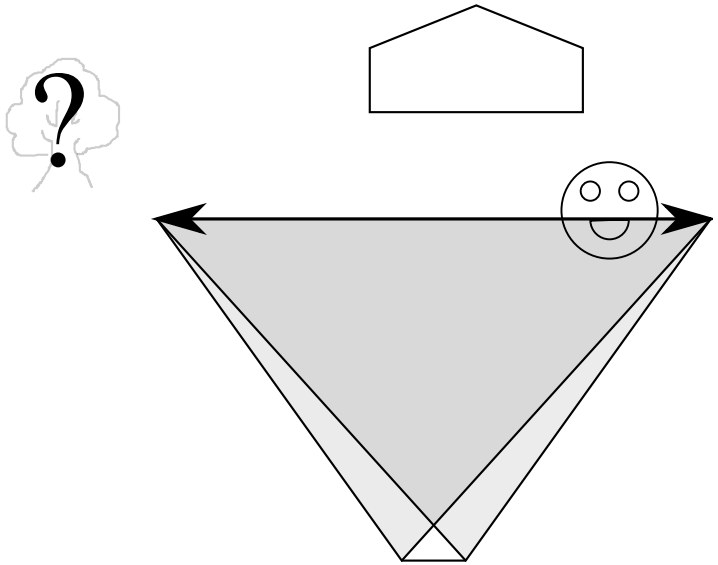
Viewpoint modification



shooting geometry

3-D geometry is preserved

unseen objects become disoccluded



viewing geometry

Hybrid disparity remapping

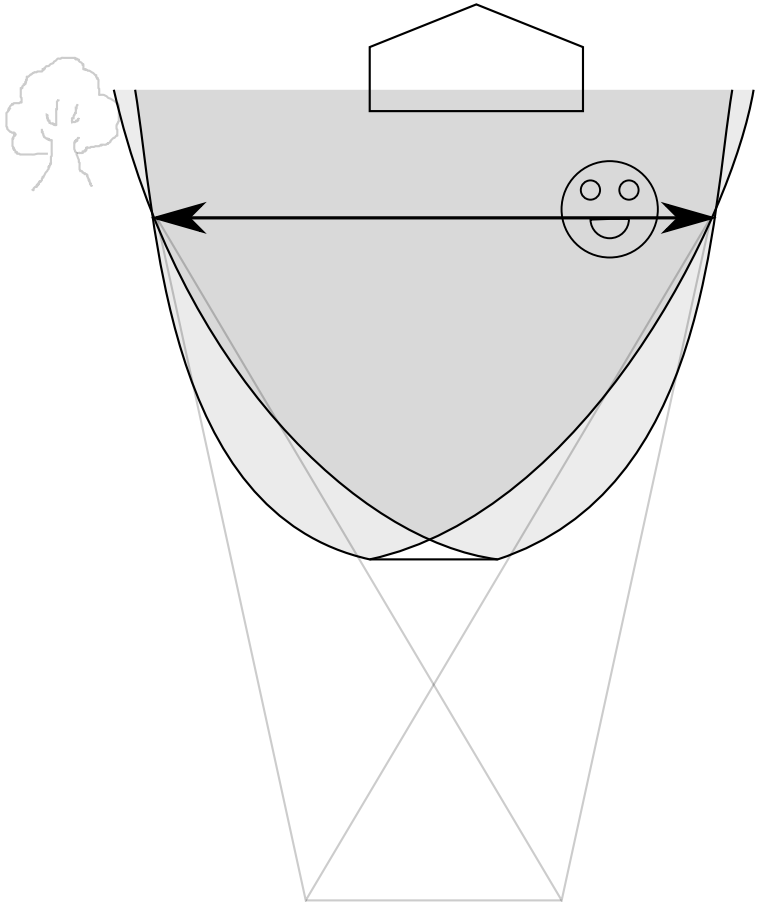
Compute a disparity remapping function $d''(d)$ so that $\rho_{screen}=1$

and $Z'=\alpha Z$: *same disparity as viewpoint modification.*

But don't apply image scaling.

Depth is preserved, but image scale is not respected for off-screen objects - *Just like when zooming with a 2-D camera.*

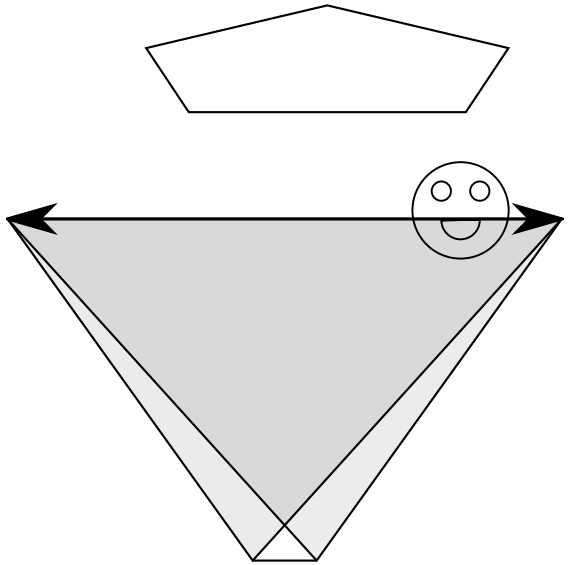
Hybrid disparity remapping



shooting geometry

depth is preserved

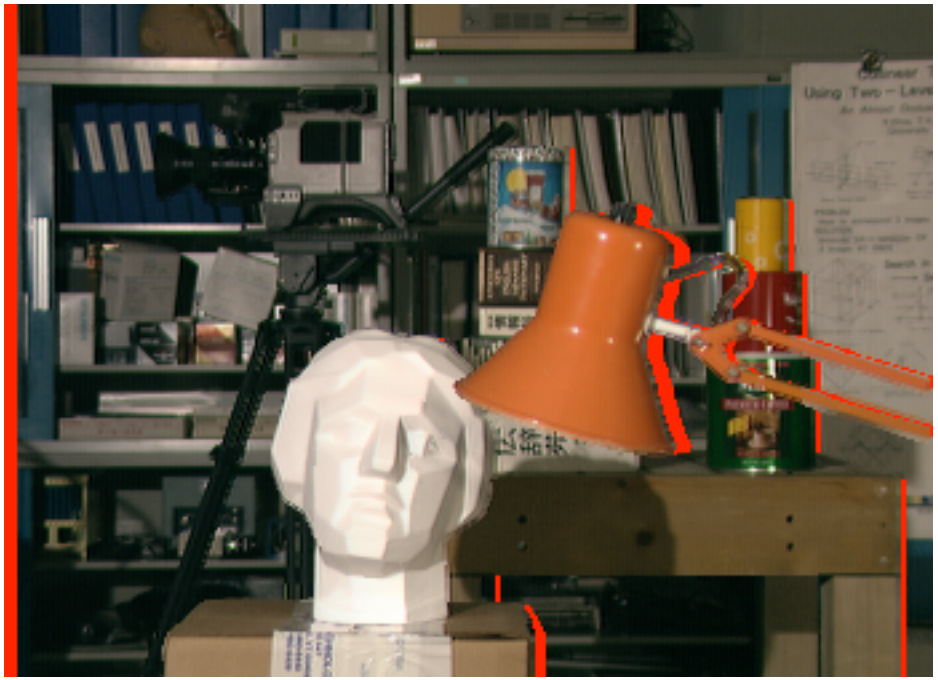
X-Y scale is distorted



viewing geometry

Results

Results



Results

Results

Conclusions

Hybrid disparity remapping of stereoscopic content solves most issues caused by classical new view synthesis methods.

Asymmetric synthesis helps preserving perceived quality.

Real-time processing is possible using GPU-based stereo and view-synthesis algorithms (work in progress).

There are still **parameters** to play with: roundness factor (must be > 0.2, but does not have to be 1), virtually changing the convergence plane...

The **perceived effects** on depth and image scale of hybrid disparity remapping still have **to be validated** on viewers.

Thank you!

One-year **post-doc position** available at INRIA Grenoble:

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

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

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