30 JULY – 3 AUGUST Los Angeles
SIGGRAPH2017

Christian Richardt

Stereoscopic 3D Videos and Panoramas

CAMERA
Centre for the Analysis of Motion, Entertainment Research and Applications

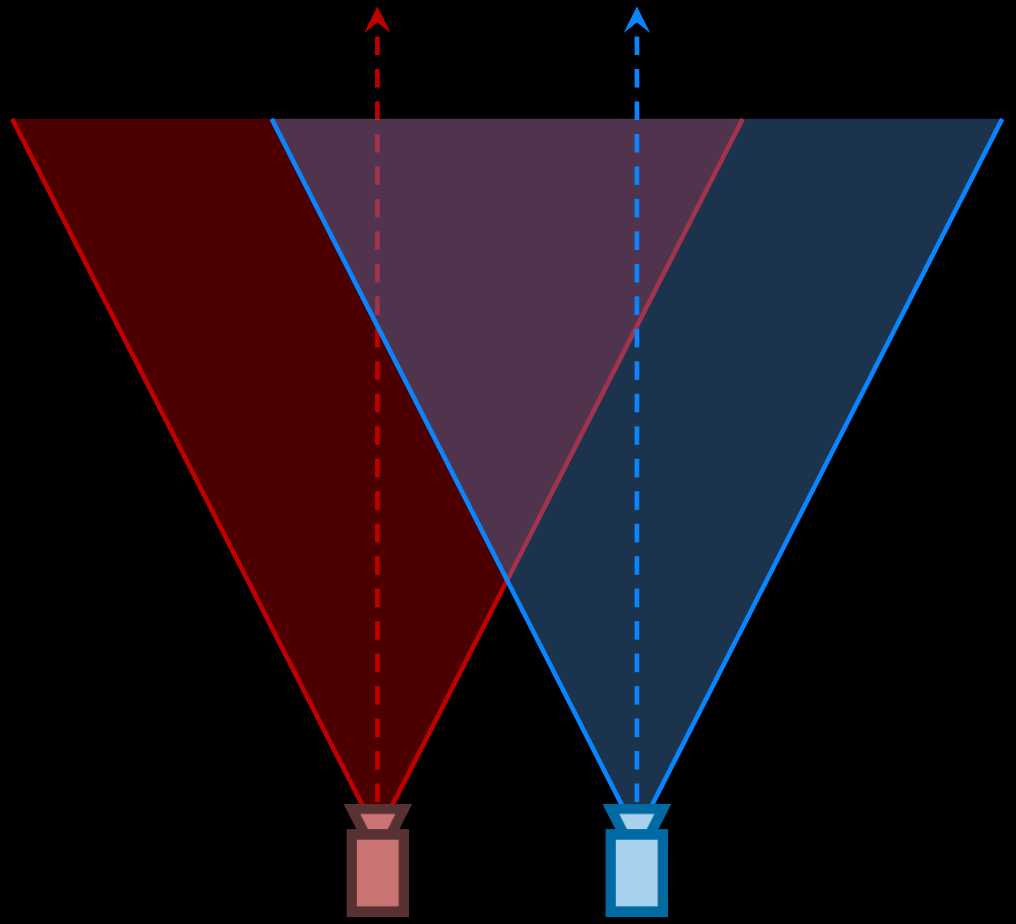
UNIVERSITY OF BATH

Stereoscopic 3D videos and panoramas

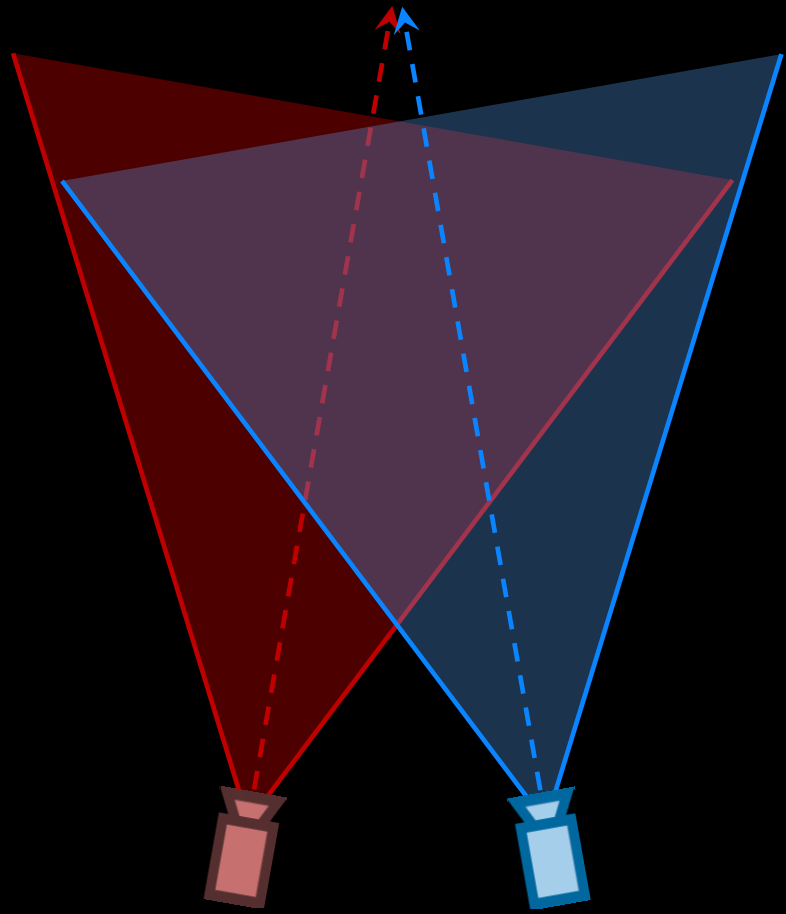
1. Capturing and displaying stereo 3D videos
2. Viewing comfort considerations
3. Editing stereo 3D videos (research papers)
4. Creating stereo 3D panoramas

Stereo camera rigs

Parallel

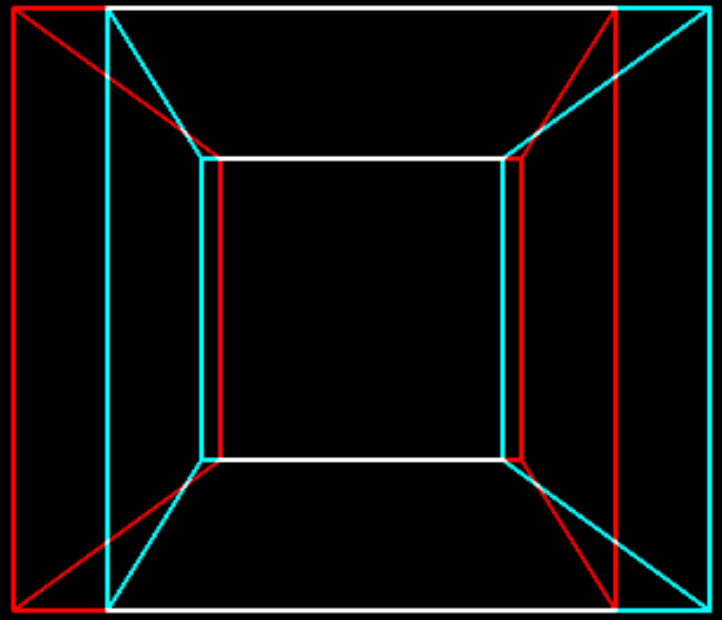


Converged (‘toed-in’)



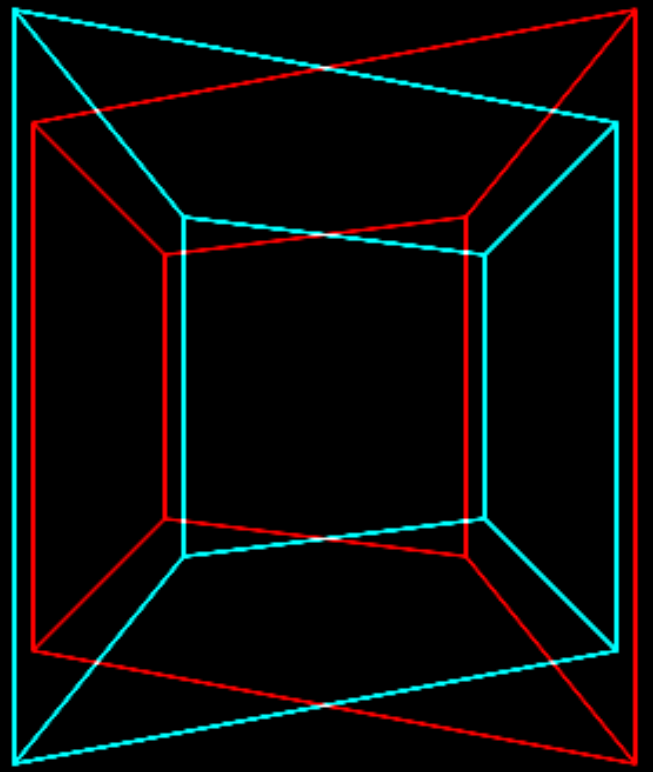
Stereo camera rigs

Parallel



©2012 Oliver Kreylos

Converged (‘toed-in’)



©2012 Oliver Kreylos

Computational stereo 3D camera system

Computational stereo camera system with programmable control loop
S. Heinzle, P. Greisen, D. Gallup, C. Chen, D. Saner, A. Smolic, A. Burg, W. Matusik & M. Gross
ACM Transactions on Graphics (SIGGRAPH), 2011, 30(4), 94:1–10

Commercial stereo 3D projection

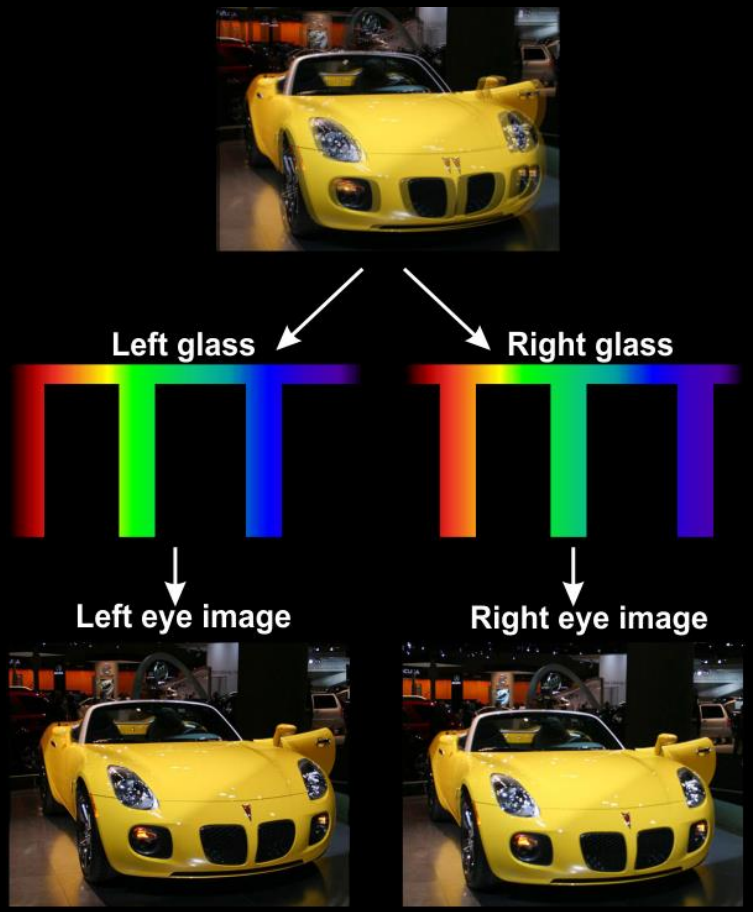
Polarised projection

e.g. RealD 3D, MasterImage 3D

©2011 Scott Wilkinson/Sound and Vision

Wavelength multiplexing

e.g. Dolby 3D



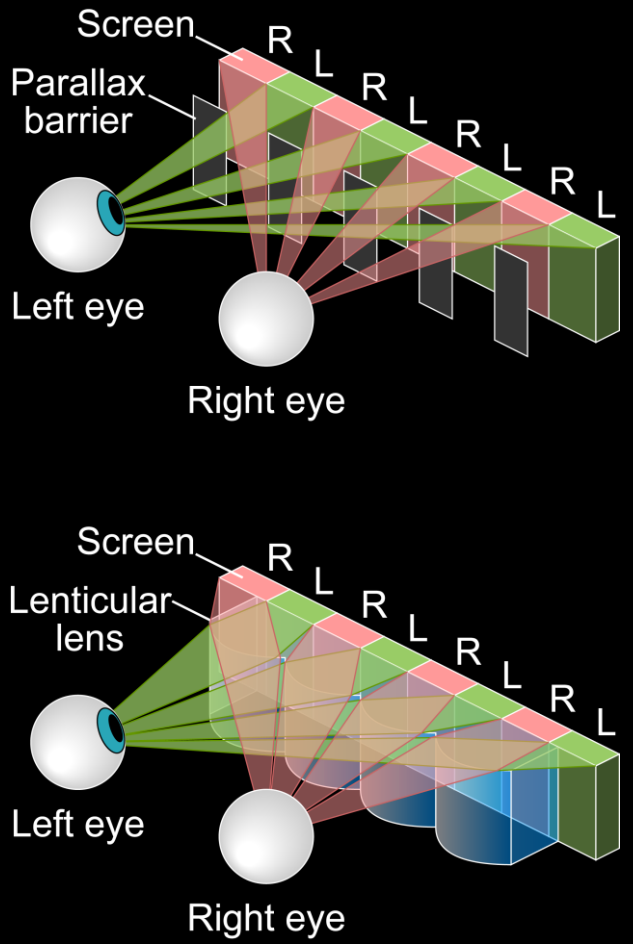
©Raoul NK, 3dnatureguy/Wikimedia Commons/CC-BY-SA-3.0

Medium-scale stereo 3D displays

Active shutter glasses

e.g. NVIDIA 3D Vision, 3D TVs

Autostereoscopy



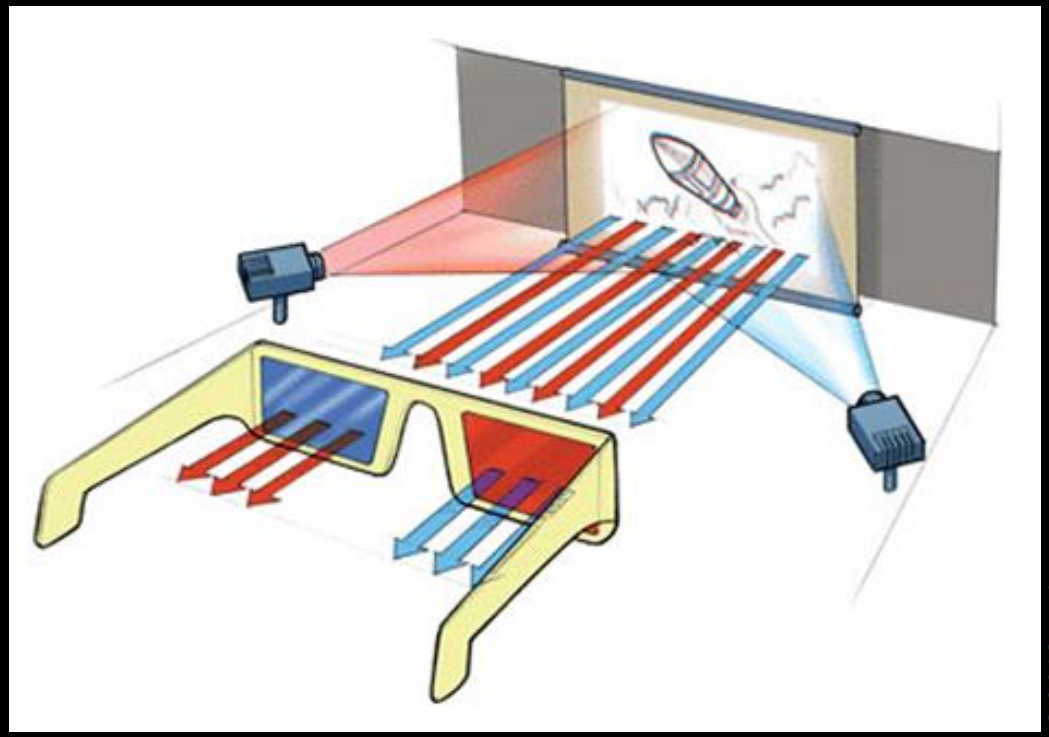
Other stereo 3D displays

Head-mounted displays (HMDs)

e.g. HTC Vive, Oculus Rift, Google Cardboard

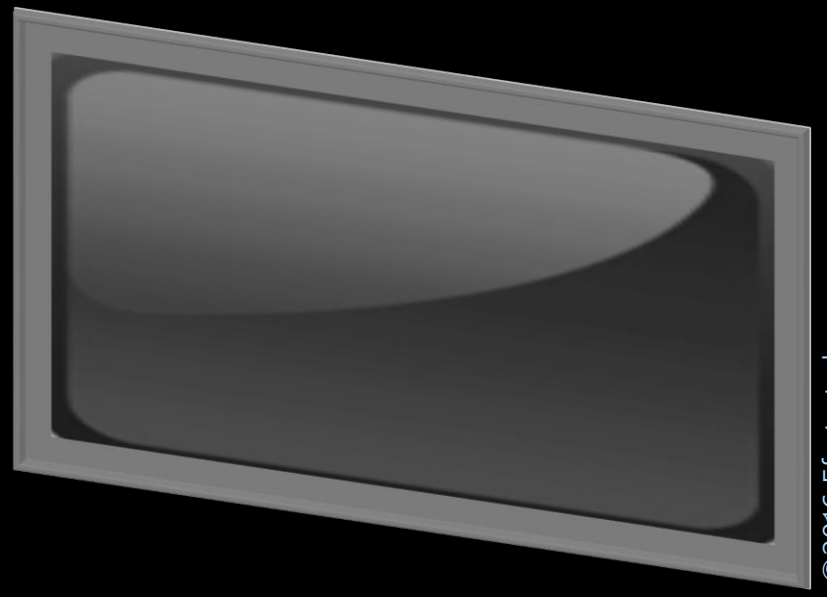
Anaglyph stereo

e.g. red cyan glasses, ColorCode 3-D, Inficolor 3D



Cinema 3D

Narrow angular range that spans a single seat



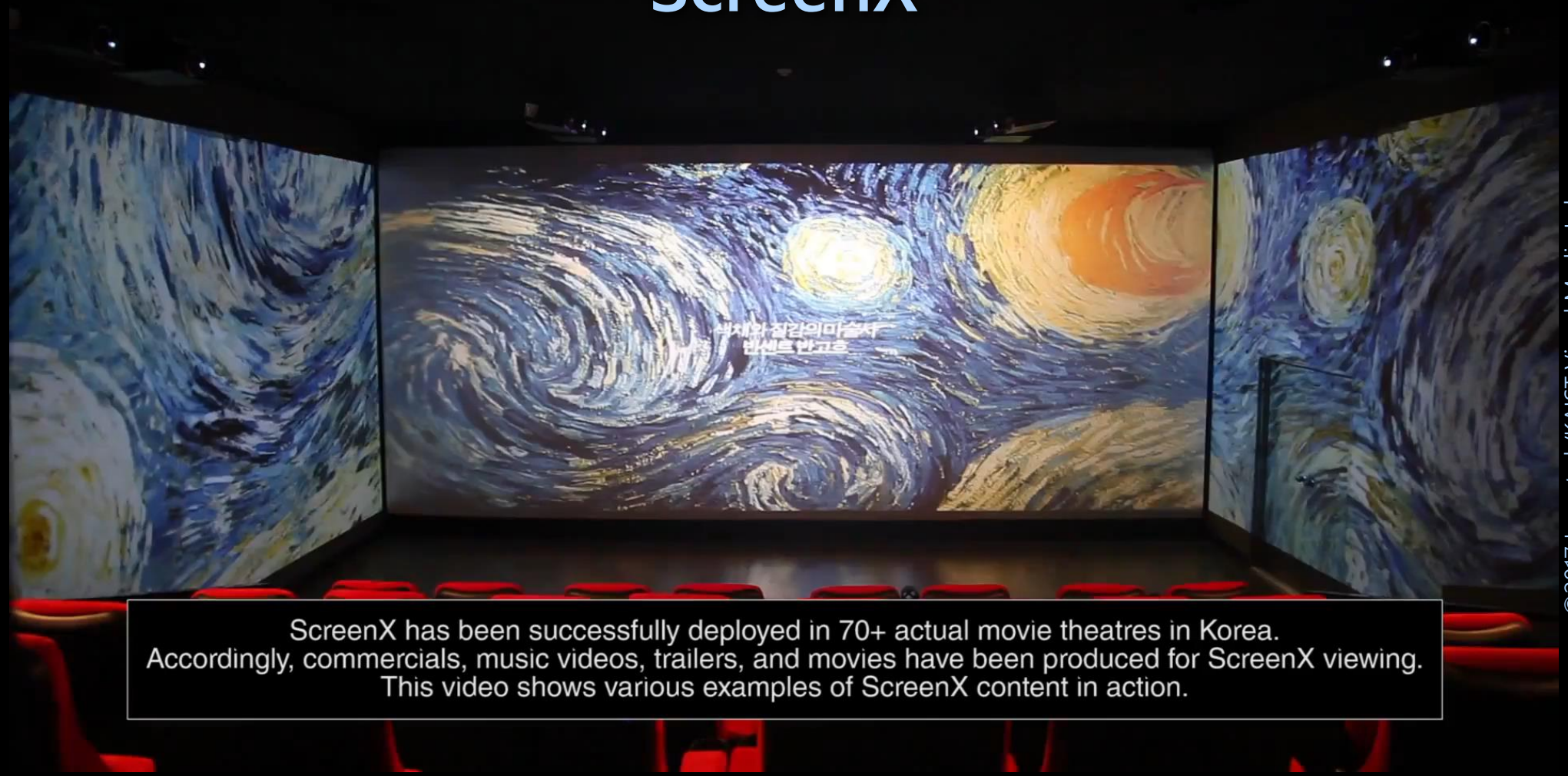
Cinema 3D: large scale automultiscopic display
N. Efrat, P. Didyk, M. Foshey, W. Matusik & A. Levin
ACM Transactions on Graphics (SIGGRAPH), 2016, 35, 59:1–12

Cinema 3D

Narrow angular range that spans a single seat

Cinema 3D: large scale automultiscopic display
N. Efrat, P. Didyk, M. Foshey, W. Matusik & A. Levin
ACM Transactions on Graphics (SIGGRAPH), 2016, 35, 59:1–12

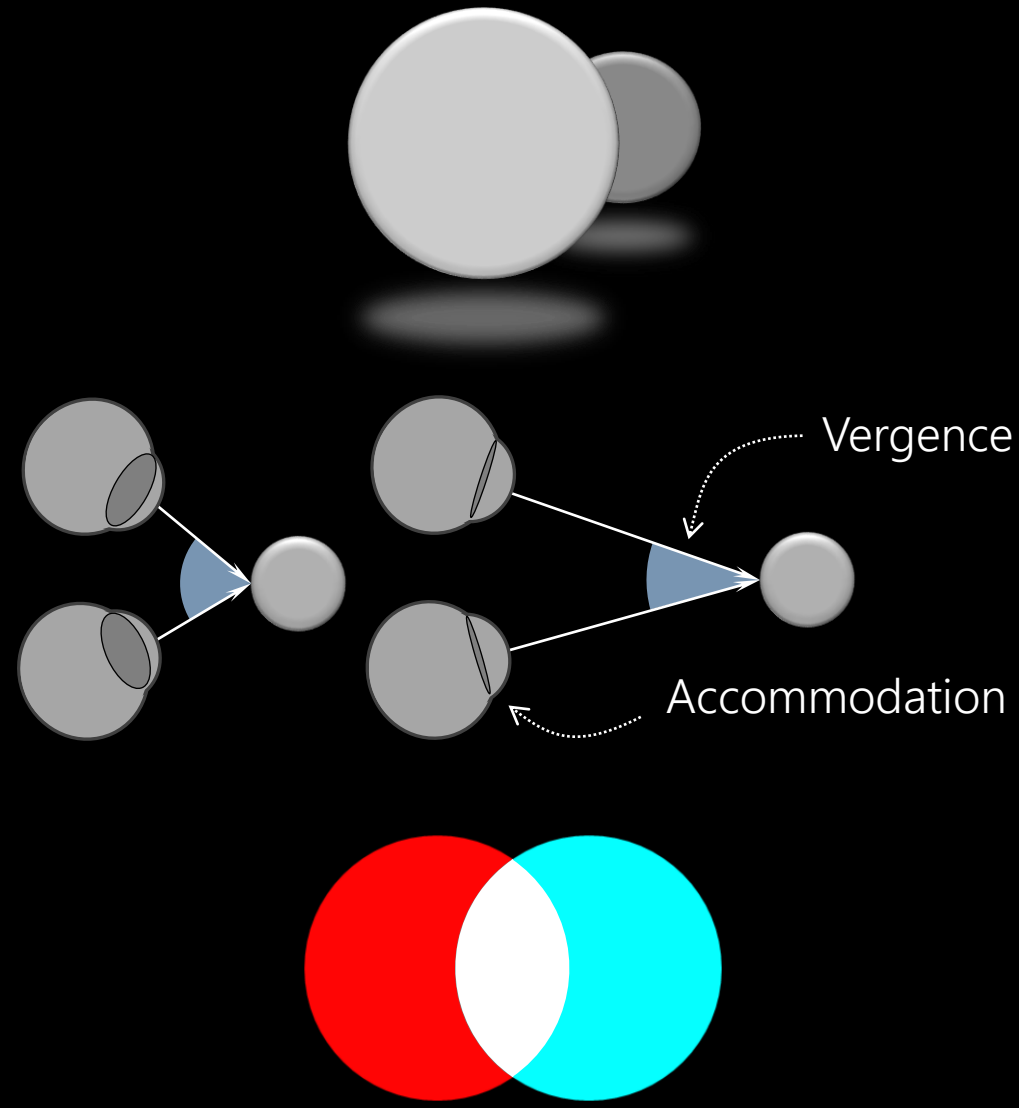
ScreenX



ScreenX: public immersive theatres with uniform movie viewing experiences
J. Lee, S. Lee, Y. Kim & J. Noh
IEEE Transactions on Visualization and Computer Graphics, 2017, 23(2), 1124–1138

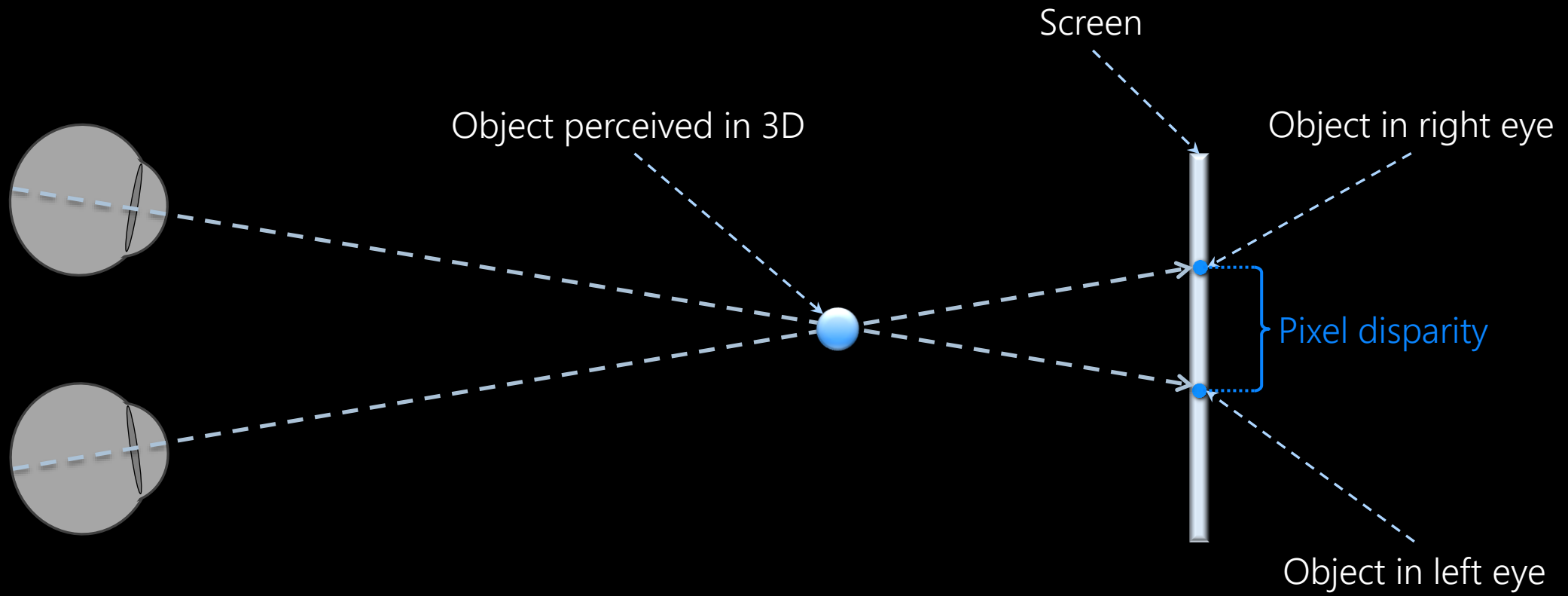
Depth cues

- Pictorial depth cues:
  - size, occlusion, perspective, aerial perspective, texture gradient, motion parallax, depth of field, …
- Ocular depth cues:
  - Accommodation
  - Vergence
- Binocular disparity



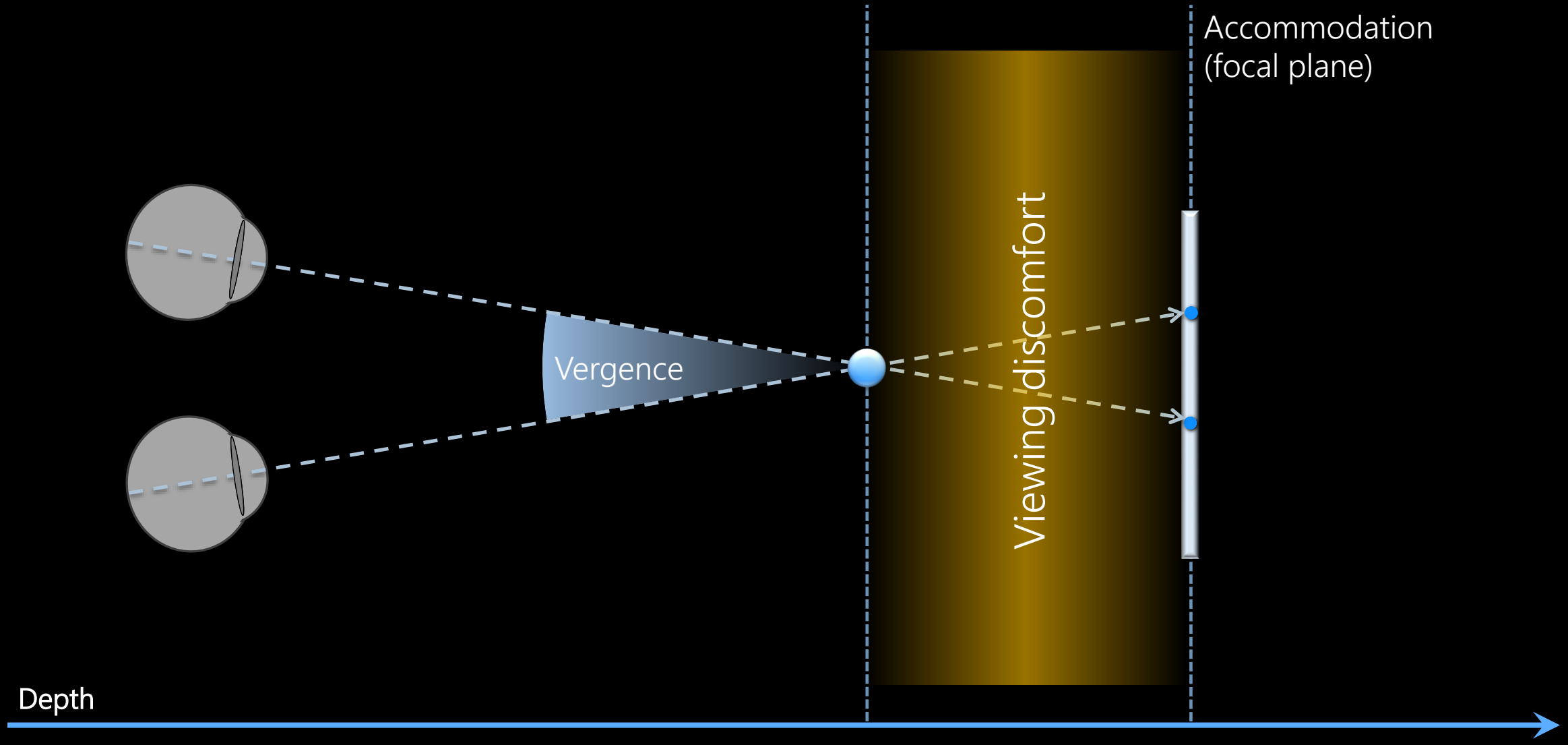
Slide courtesy of Petr Kellnhofer

How does disparity work?



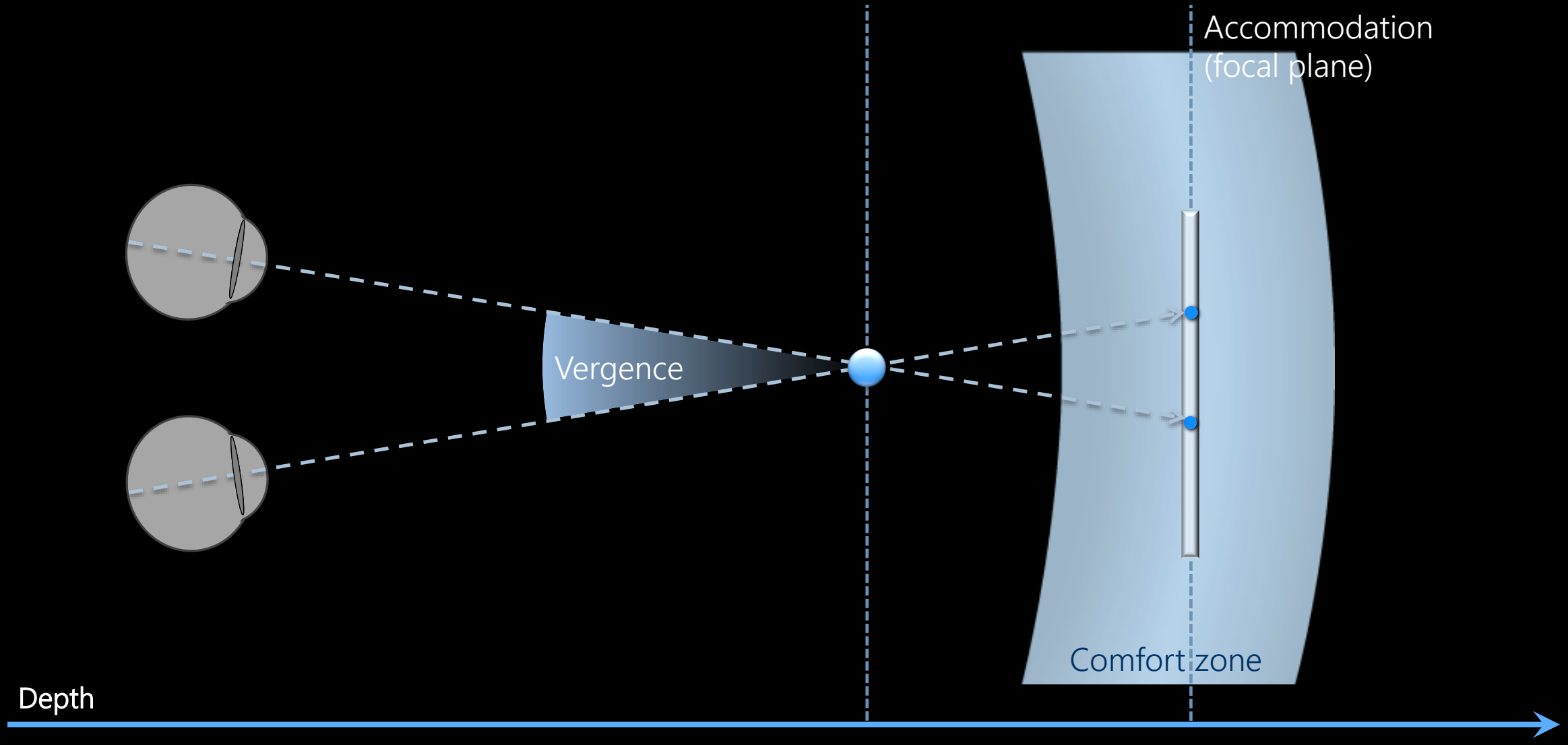
Slide courtesy of Petr Kellnhofer

How does disparity work?



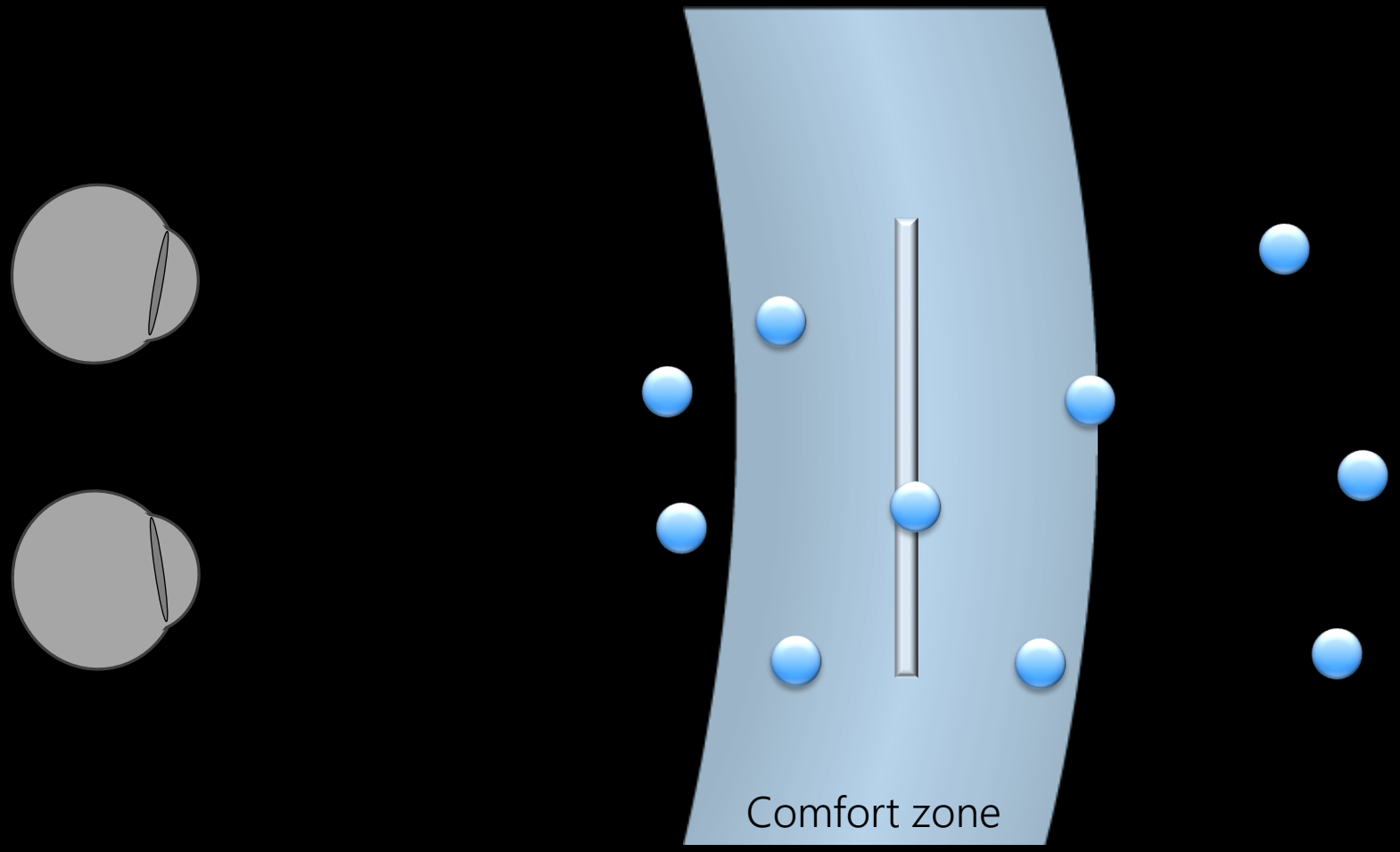
Slide courtesy of Petr Kellnhofer

How does disparity work?



Slide courtesy of Petr Kellnhofer

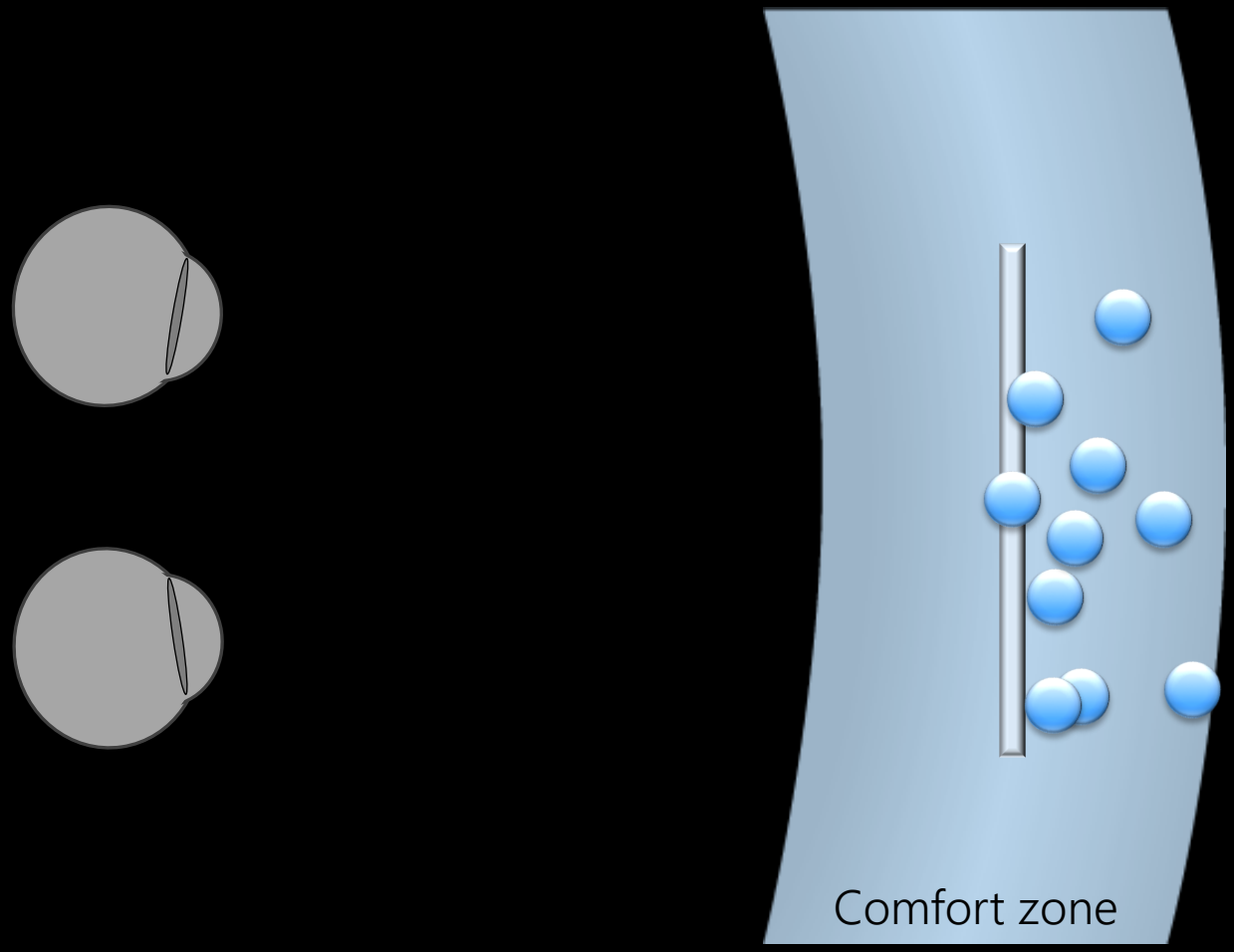
Preventing viewing discomfort



Viewing discomfort

Slide courtesy of Petr Kellnhofer

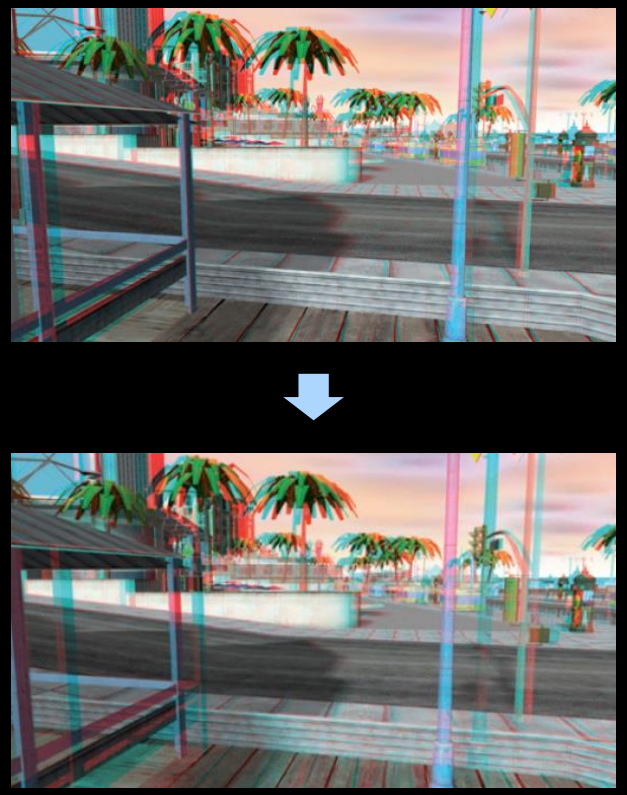
Preventing viewing discomfort



Viewing discomfort → Scene manipulation → Viewing comfort

Slide courtesy of Petr Kellnhofer

Disparity manipulation

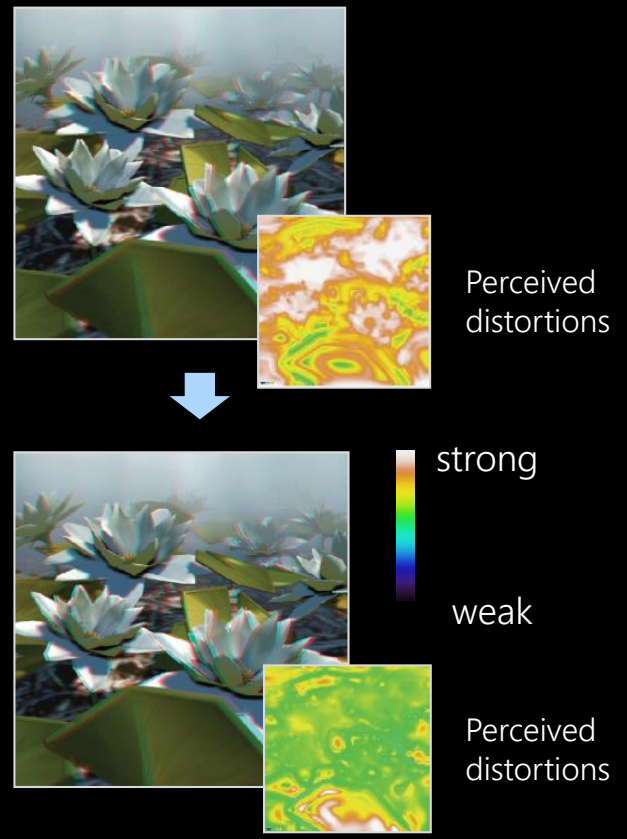


OSCAM – Optimized stereoscopic camera control for interactive 3D

Oskam et al., *SIGGRAPH Asia 2011*

Nonlinear disparity mapping for stereoscopic 3D

Lang et al., *SIGGRAPH 2010*



A perceptual model for disparity

Didyk et al., *SIGGRAPH 2011*

Slide courtesy of Petr Kellnhofer

Additional reading on viewing comfort

- **Production rules for stereo acquisition**
  Zilly et al., *Proc. IEEE 2011*
- **Predicting stereoscopic viewing comfort using a coherence-based computational model**
  Richardt et al., *CAe 2011*
- **A luminance-contrast-aware disparity model and applications**
  Didyk et al., *SIGGRAPH Asia 2012*
- **A metric of visual comfort for stereoscopic motion**
  Du et al., *SIGGRAPH Asia 2013*
- **Modeling and optimizing eye vergence response to stereoscopic cuts**
  Templin et al., *SIGGRAPH 2014*
- **What makes 2D-to-3D stereo conversion perceptually plausible?**
  Kellnhofer et al., *SAP 2015*
- **GazeStereo3D: seamless disparity manipulations**
  Kellnhofer et al., *SIGGRAPH 2016*
- **Causes of discomfort in stereoscopic content: a review**
  Terzic & Hansard, *arXiv:1703.04574*

2D-to-3D conversion

©2011 Wang et al./ACM

StereoBrush: interactive 2D to 3D conversion using discontinuous warps
Wang et al., *SBIM 2011*

©2016 Leimkühler et al.

Perceptual real-time 2D-to-3D conversion using cue fusion
Leimkühler et al., *IEEE TVCG 2017*

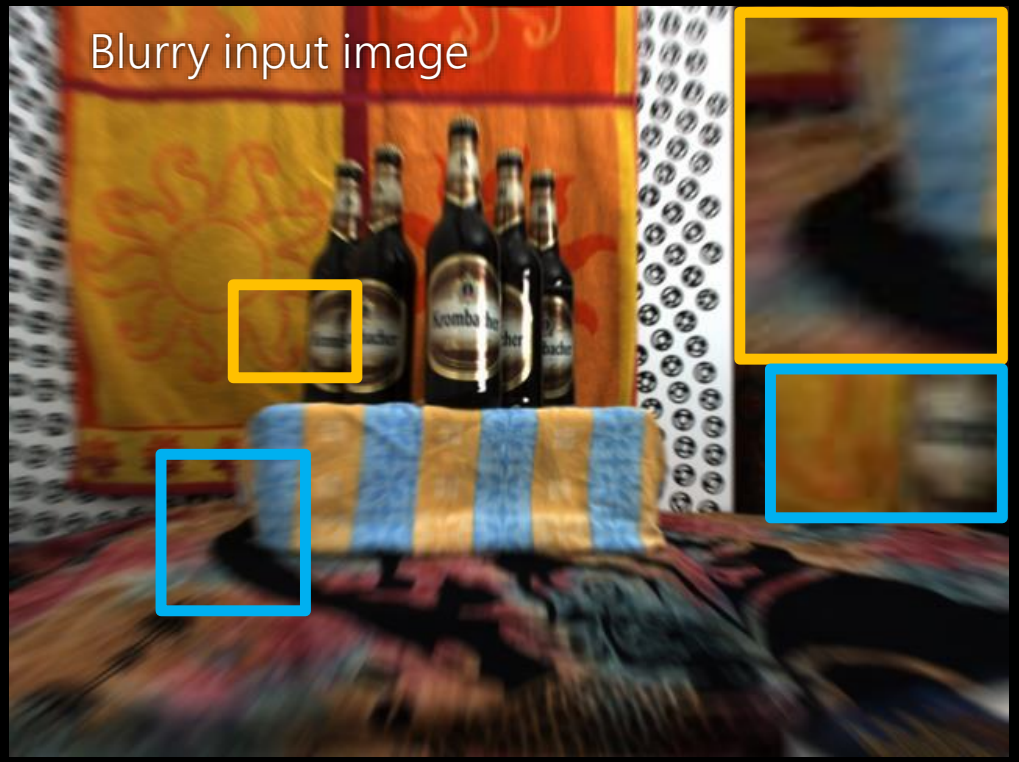
Additional reading on 2D-to-3D conversion

- **Deep3D: fully automatic 2D-to-3D video conversion with deep convolutional neural networks**
  Xie et al., *ECCV 2016*
- **Hallucinating stereoscopy from a single image**
  Zeng et al., *CGF (Eurographics) 2015*
- **Video stereolization: combining motion analysis with user interaction**
  Liao et al., *IEEE TVCG 2012*
- **Depth Director: a system for adding depth to movies**
  Ward et al., *IEEE CG&A 2011*
- **Stereoscopic video synthesis from a monocular video**
  Zhang et al., *IEEE TVCG 2007*

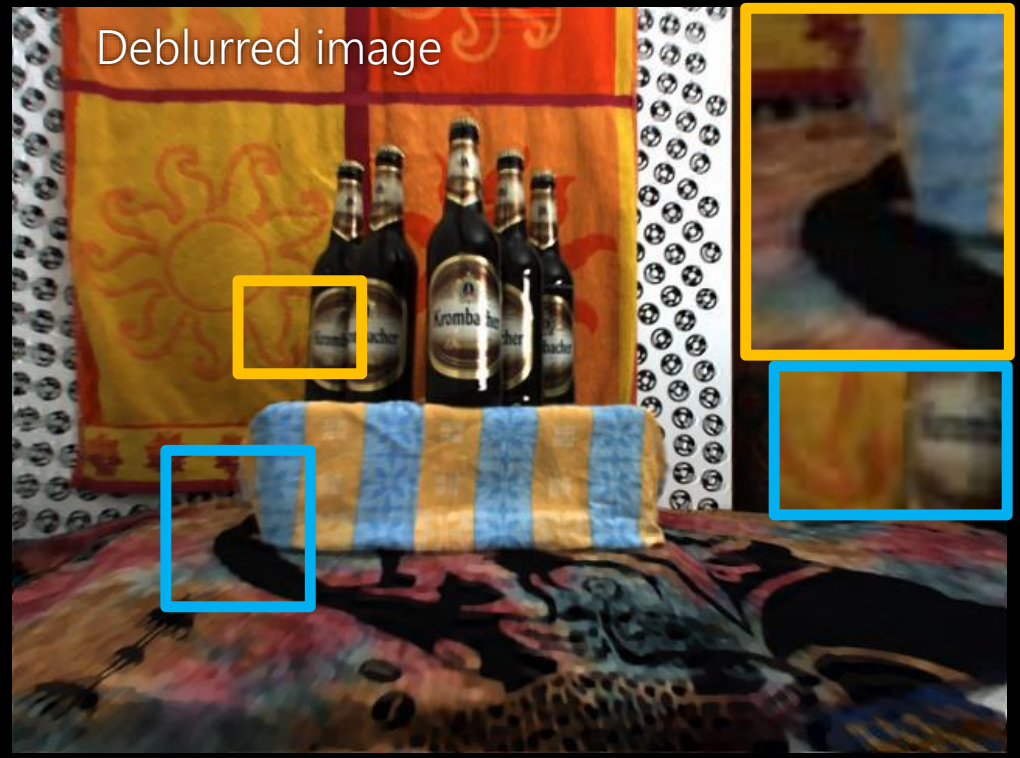
Video de-anaglyph

Temporally Coherent Video De-Anaglyph
Roo & Richardt, *SIGGRAPH Talks 2014*

Stereo 3D video deblurring



©2016 Sellent et al.



©2017 Pan et al.

Simultaneous stereo video deblurring and scene flow estimation ↑
Pan et al., *CVPR 2017*

Stereo Video Deblurring
Sellent et al., *ECCV 2016*

Stereo 3D video stabilisation

Input video frames (anaglyph)

Stabilised video frames (anaglyph)

Joint Subspace Stabilization for Stereoscopic Video
Liu et al., *ICCV 2013*

Correspondence finding

©2013 Hung et al.

← **Consistent binocular depth and scene flow with chained temporal profiles**
Hung et al., *IJCV 2013*

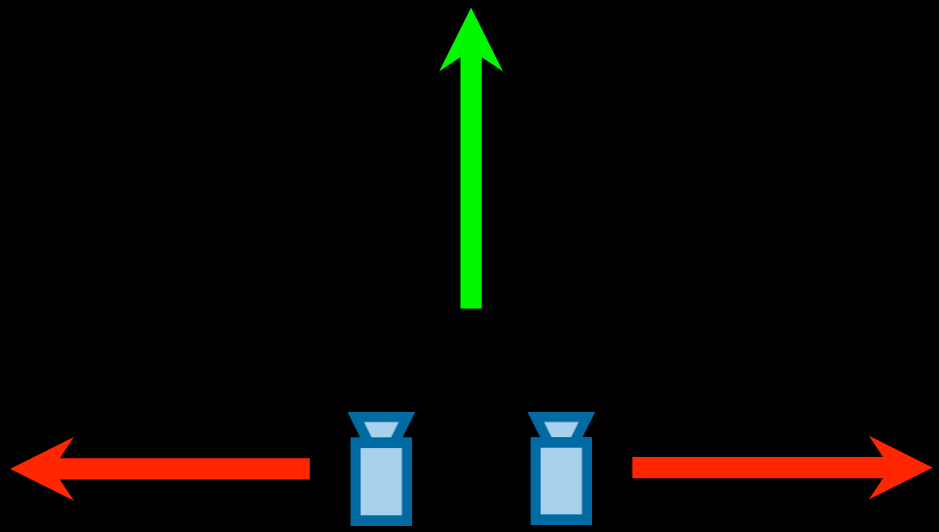
Real-time spatiotemporal stereo matching using the dual-cross-bilateral grid
Richardt et al., *ECCV 2010*

Image-only techniques

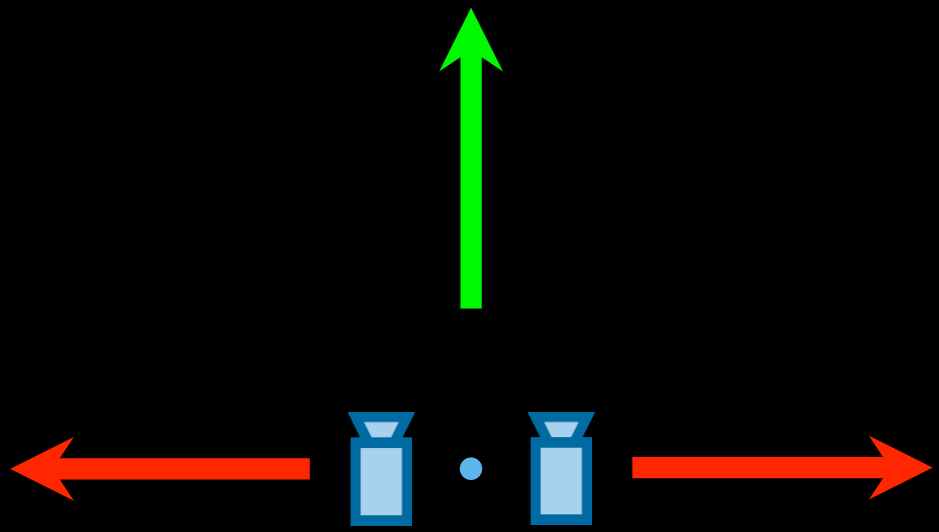
- Retargeting:
  - **Object-coherence warping for stereoscopic image retargeting**
    Lin et al., *IEEE TCSVT 2014*
  - **Stereo seam carving a geometrically consistent approach**
    Basha et al., *IEEE TPAMI 2013*
- Compositing:
  - **StereoPasting: interactive composition in stereoscopic images**
    Tong et al., *IEEE TVCG 2013*
  - **Stereoscopic 3D copy & paste**
    Lo et al., *SIGGRAPH Asia 2010*
- Warping:
  - **Perspective-aware warping for seamless stereoscopic image cloning**
    Luo et al., *SIGGRAPH Asia 2012*
  - **Enabling warping on stereoscopic images**
    Niu et al., *SIGGRAPH Asia 2012*

Capturing 3D panoramas

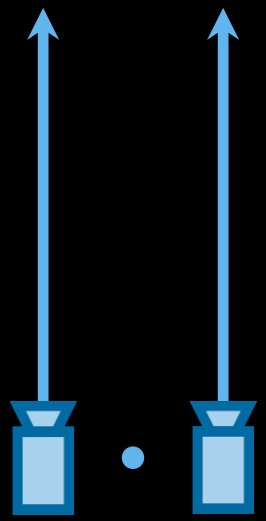
Capturing 3D panoramas



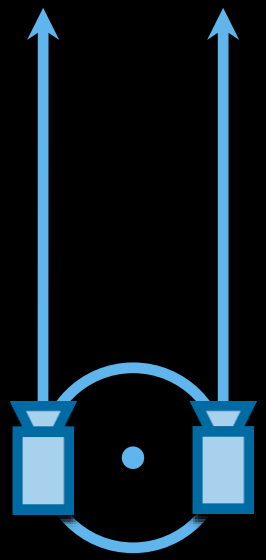
Capturing 3D panoramas



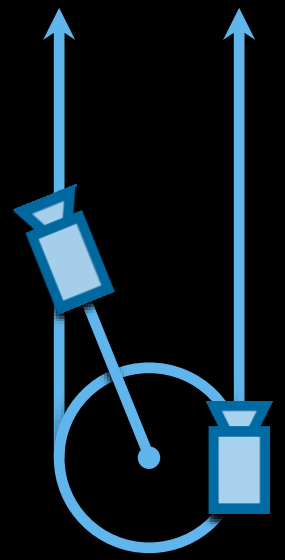
Capturing 3D panoramas



Capturing 3D panoramas

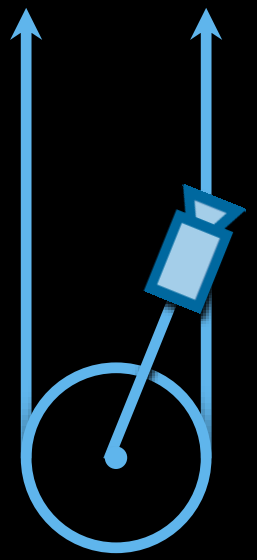


Capturing 3D panoramas



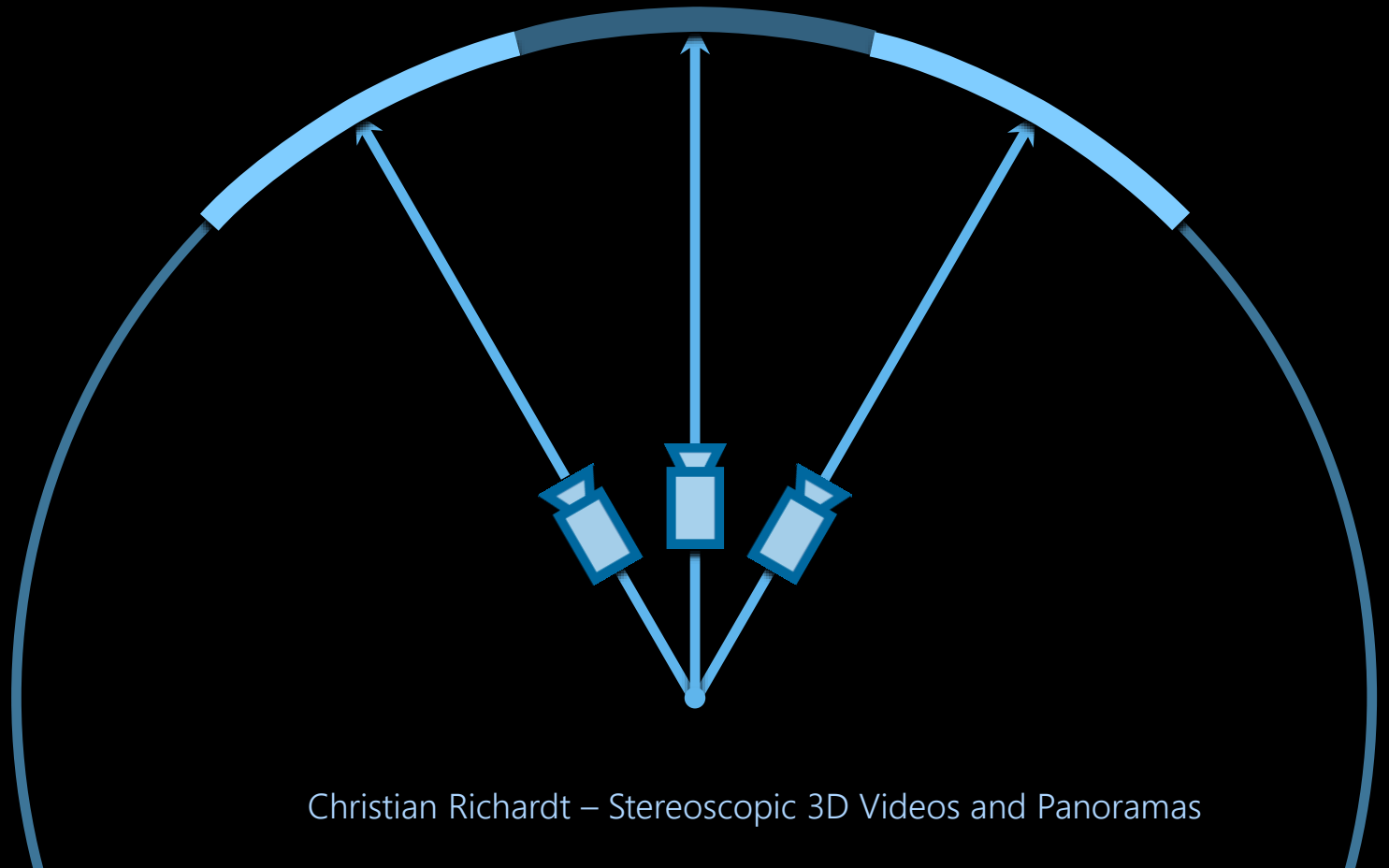
Omnistereo: Panoramic Stereo Imaging
Peleg et al., *IEEE TPAMI 2001*

Capturing 3D panoramas

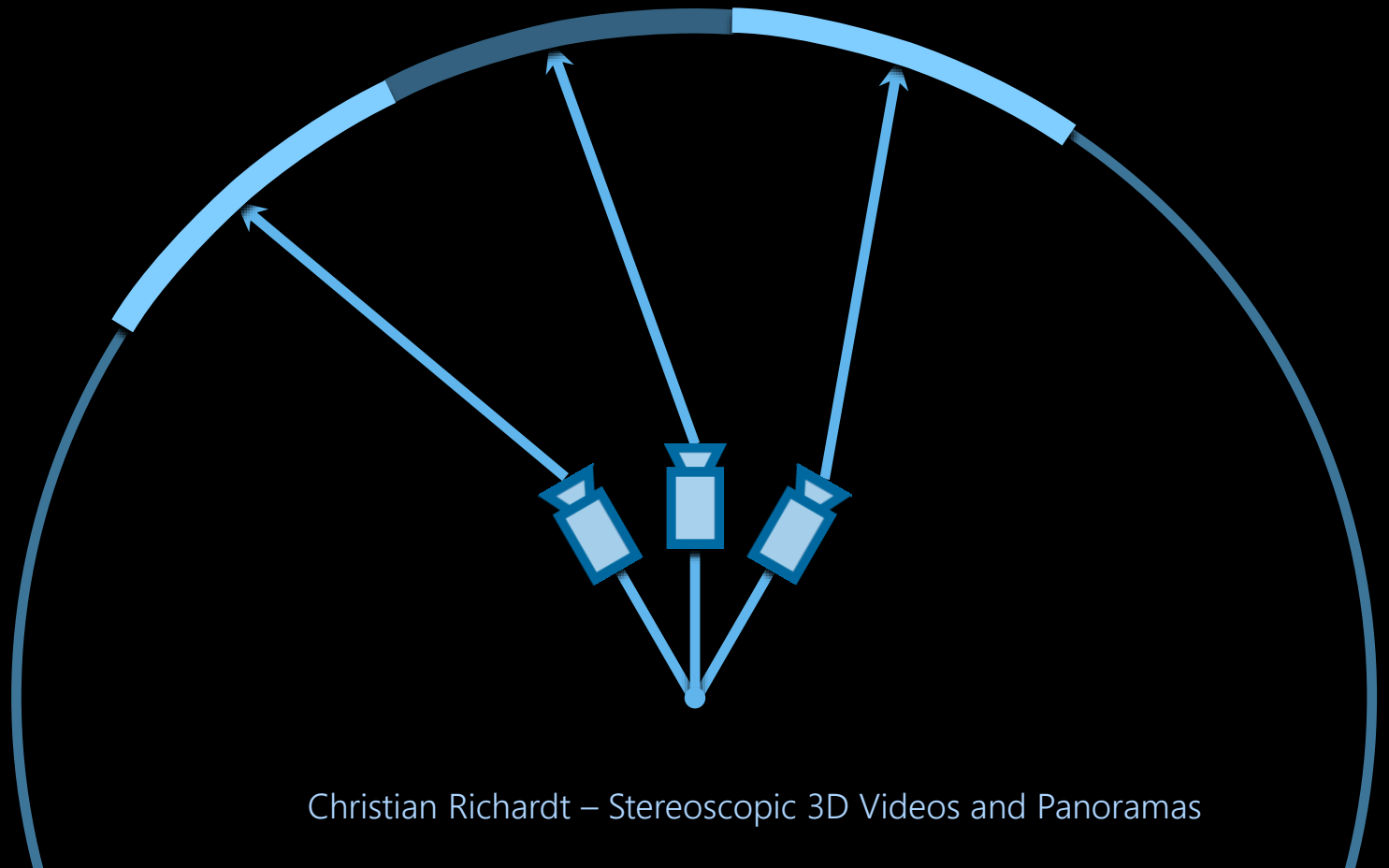


Omnistereo: Panoramic Stereo Imaging
Peleg et al., *IEEE TPAMI 2001*

Capturing 3D panoramas



Capturing 3D panoramas



Capturing 3D panoramas

Input video:

Capturing 3D panoramas

Megastereo: Constructing High-Resolution Stereo Panoramas
Richardt et al., *CVPR 2013*

Image alignment

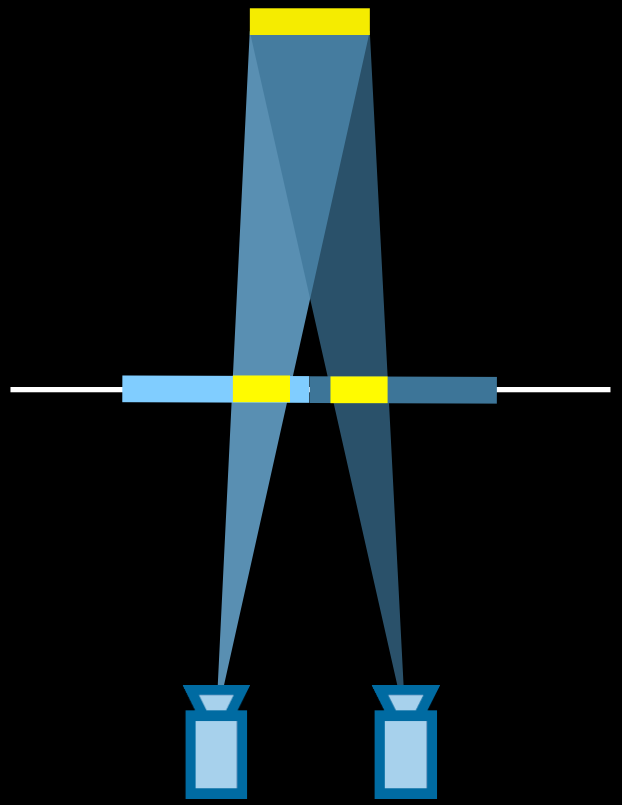
image-based alignment

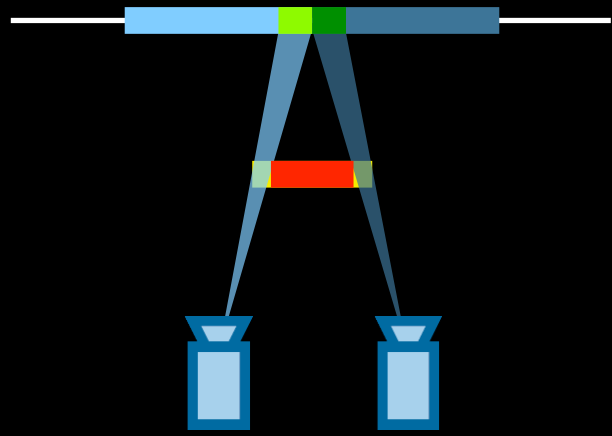
SfM-based alignment

Strip blending artefacts

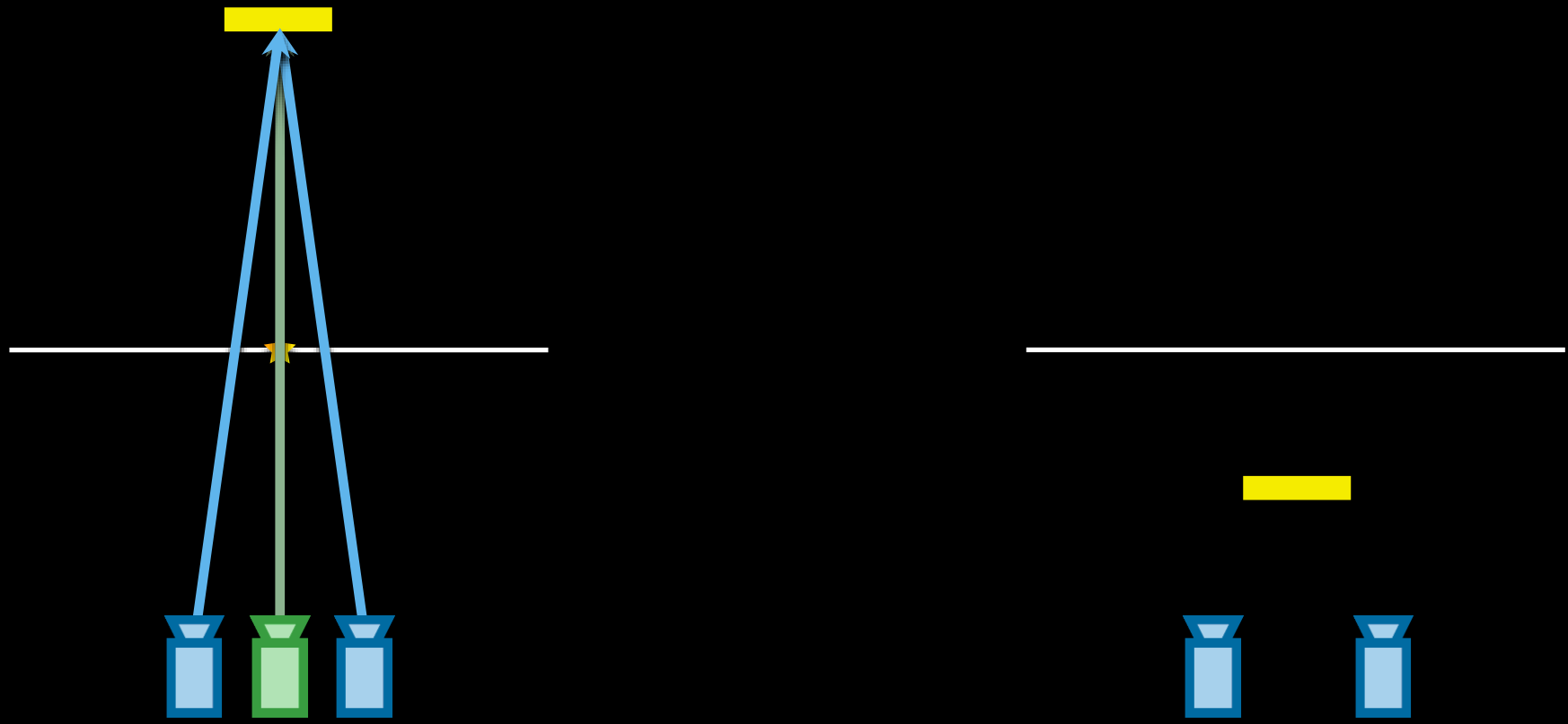
© dataset 'refaim' by Rav-Acha et al., IJCV 2008

Duplication + truncation

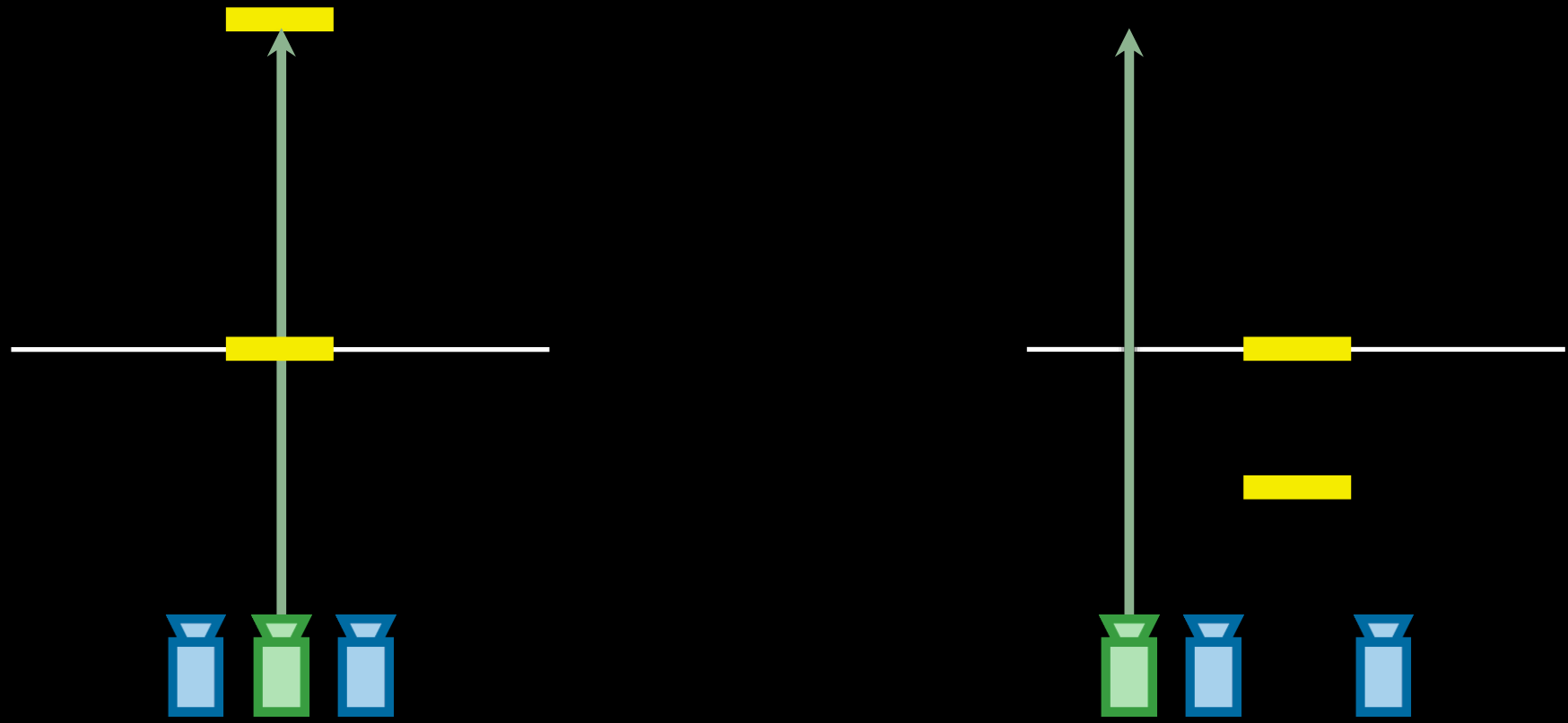




Flow-based ray interpolation



Flow-based ray interpolation



Strip blending artefacts

© dataset 'refaim' by Rav-Acha et al., IJCV 2008

Flow-based blending

Blending comparison

No blending

Flow-based blending

Stereo 3D panorama

Megastereo: Constructing High-Resolution Stereo Panoramas
Richardt et al., *CVPR 2013*

Stereo 3D panorama

Megastereo: Constructing High-Resolution Stereo Panoramas
Richardt et al., *CVPR 2013*


360°


zoom
©2013 Richardt et al.


360°
140 MP stereo panorama
©2013 Richardt et al.


100% zoom

Quick recap

- stereo video = videos for left + right eyes
  - good: binocular disparity provides depth perception
  - bad: does not react to head motion
- accommodation–vergence conflict:
  - excessive disparity causes viewing discomfort
- editing stereo video needs to preserve consistency of views
  - many tasks still difficult to achieve, even with research software
- high-quality stereo panoramas created with Megastereo
  - SfM-based alignment + flow-based blending

30 JULY – 3 AUGUST Los Angeles
SIGGRAPH2017

Christian Richardt

Stereoscopic 3D Videos and Panoramas