Computational Photography

Prof. Feng Liu

Spring 2022

http://www.cs.pdx.edu/~fliu/courses/cs510/

05/19/2022

Last Time

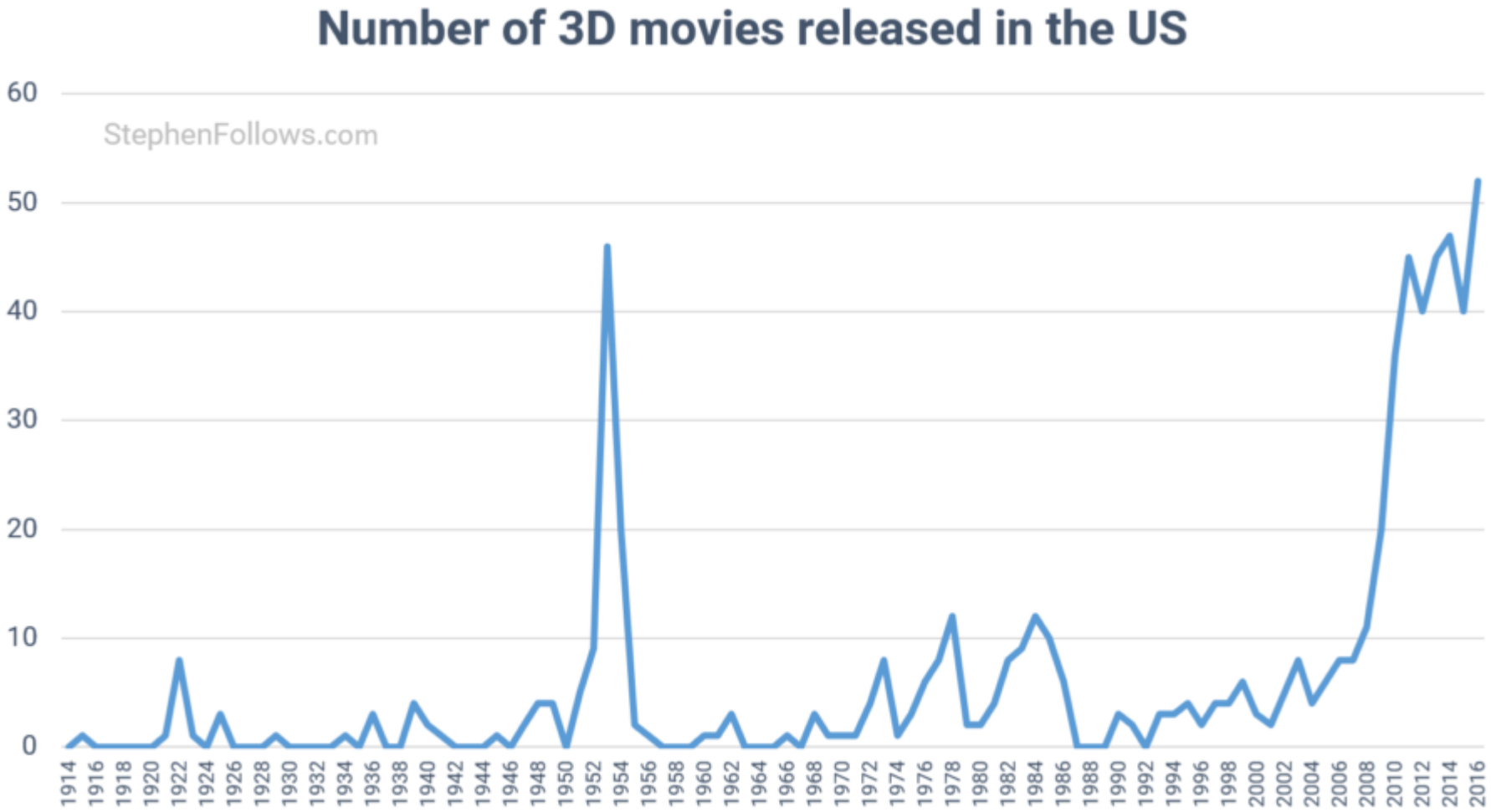
- Video Stabilization

Today

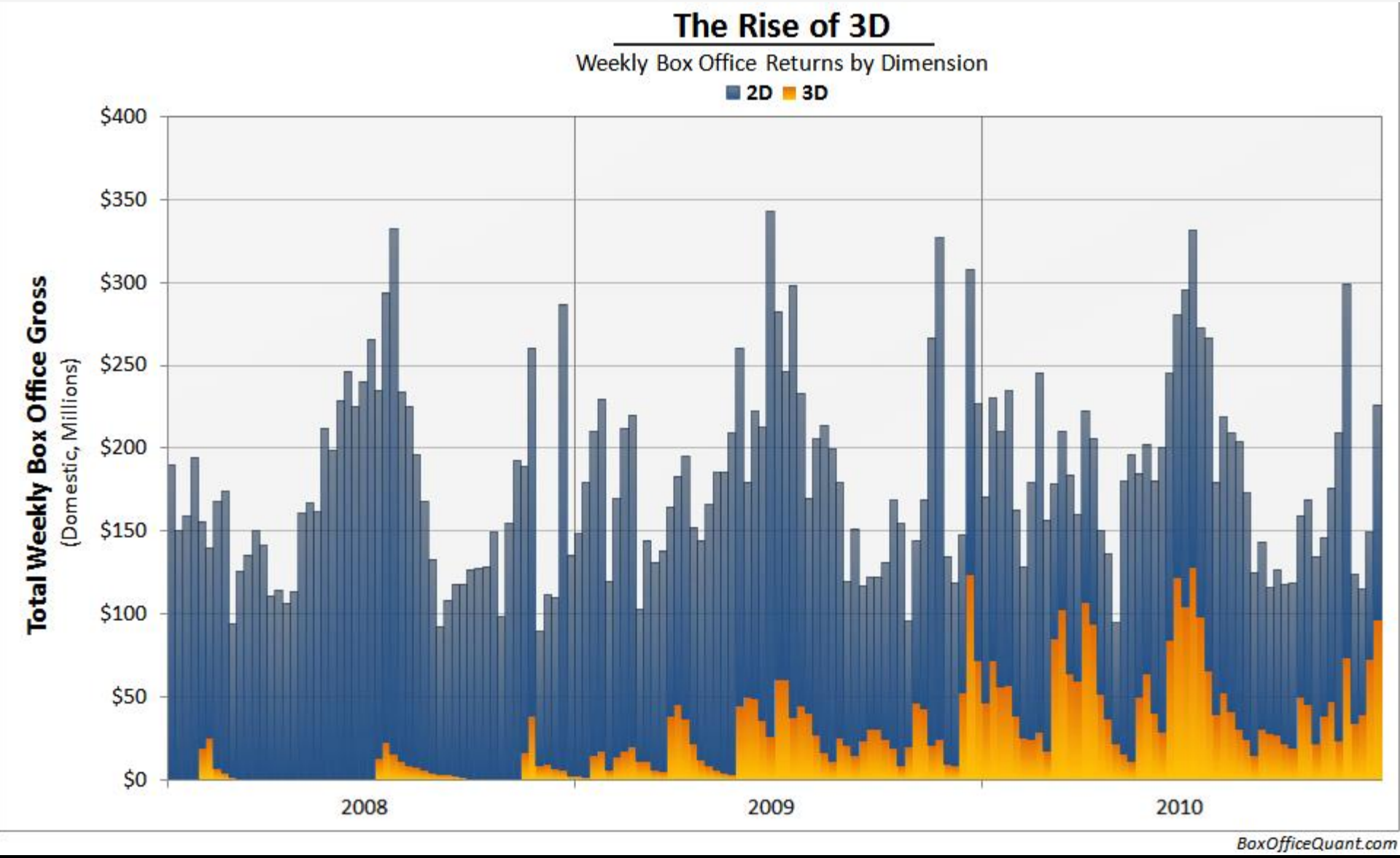
- Stereoscopic 3D
  - 3D Cinematography
  - Stereoscopic media post-processing

Stereoscopic 3D

History



https://stephenfollows.com/audiences-tiring-of-3d-movies/


The Rise of 3D
Weekly Box Office Returns by Dimension
2D
3D
Total Weekly Box Office Gross
(Domestic, Millions)
$400
$350
$300
$250
$200
$150
$100
$50
$0
2008
2009
2010
BoxOfficeQuant.com

Ubiquitous Stereoscopic 3D

Stereoscopic 3D Camera

Stereo Photo

Left

Right

Red-cyan anaglyph

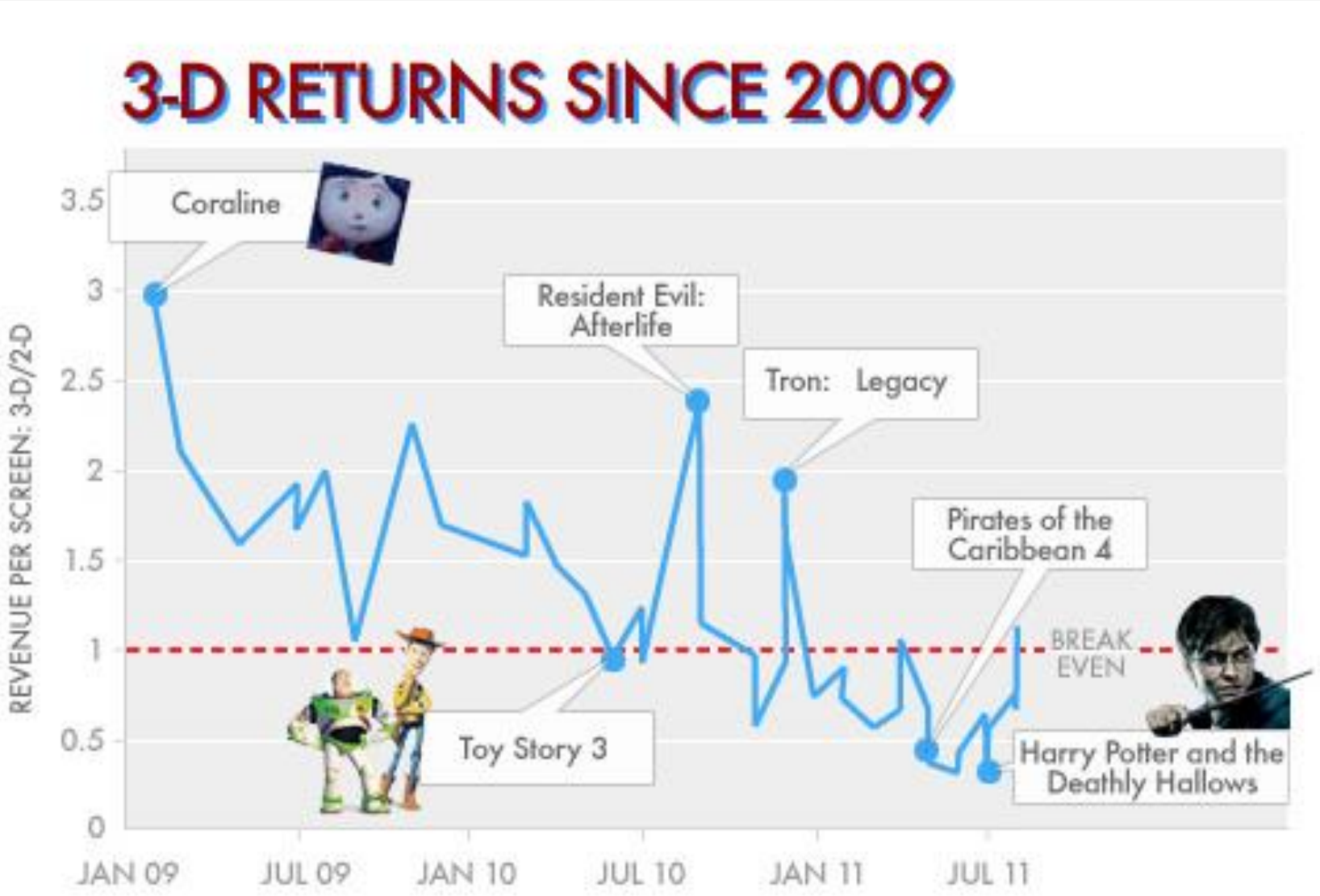


Image source: http://www.slate.com/id/2303814/

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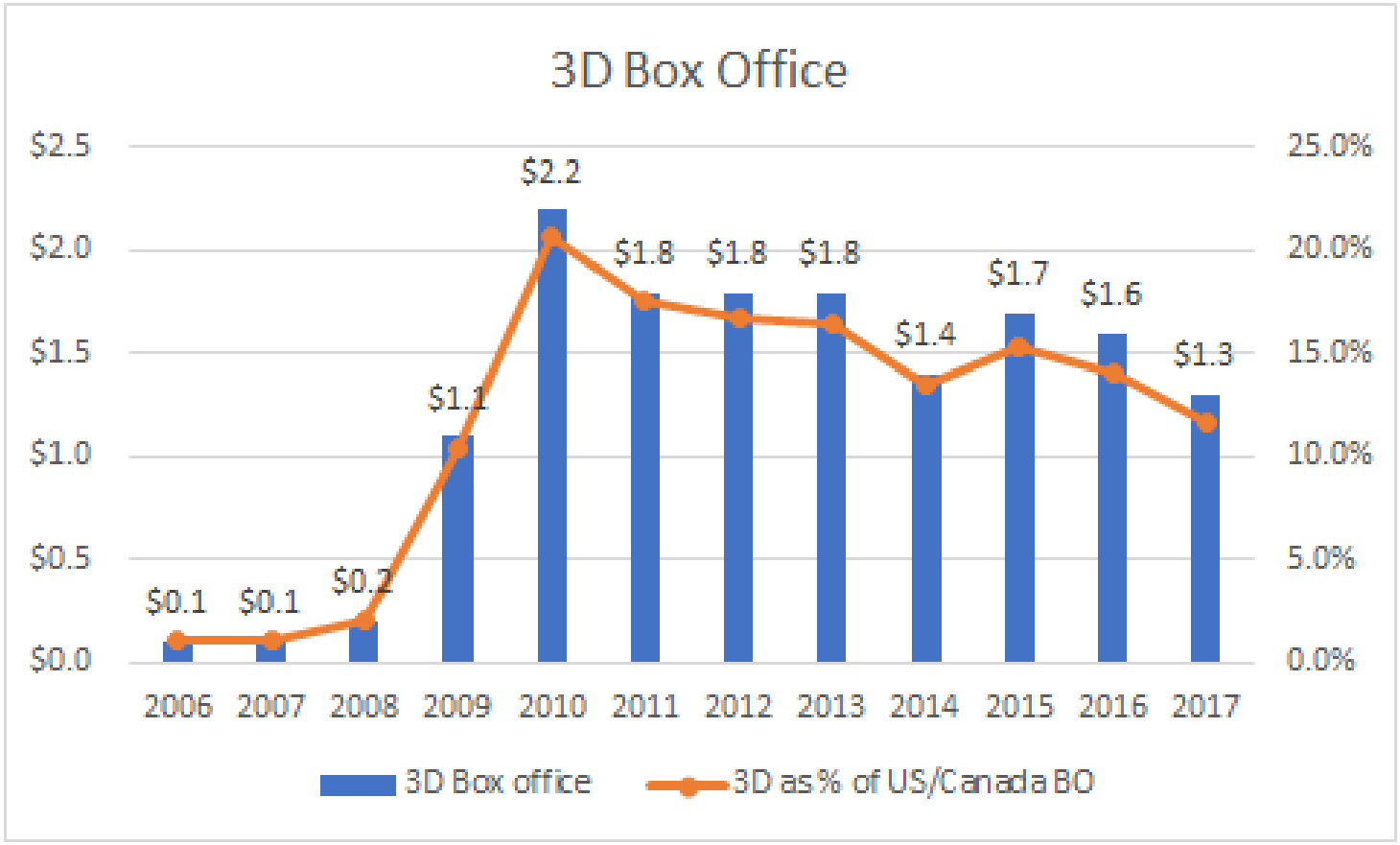


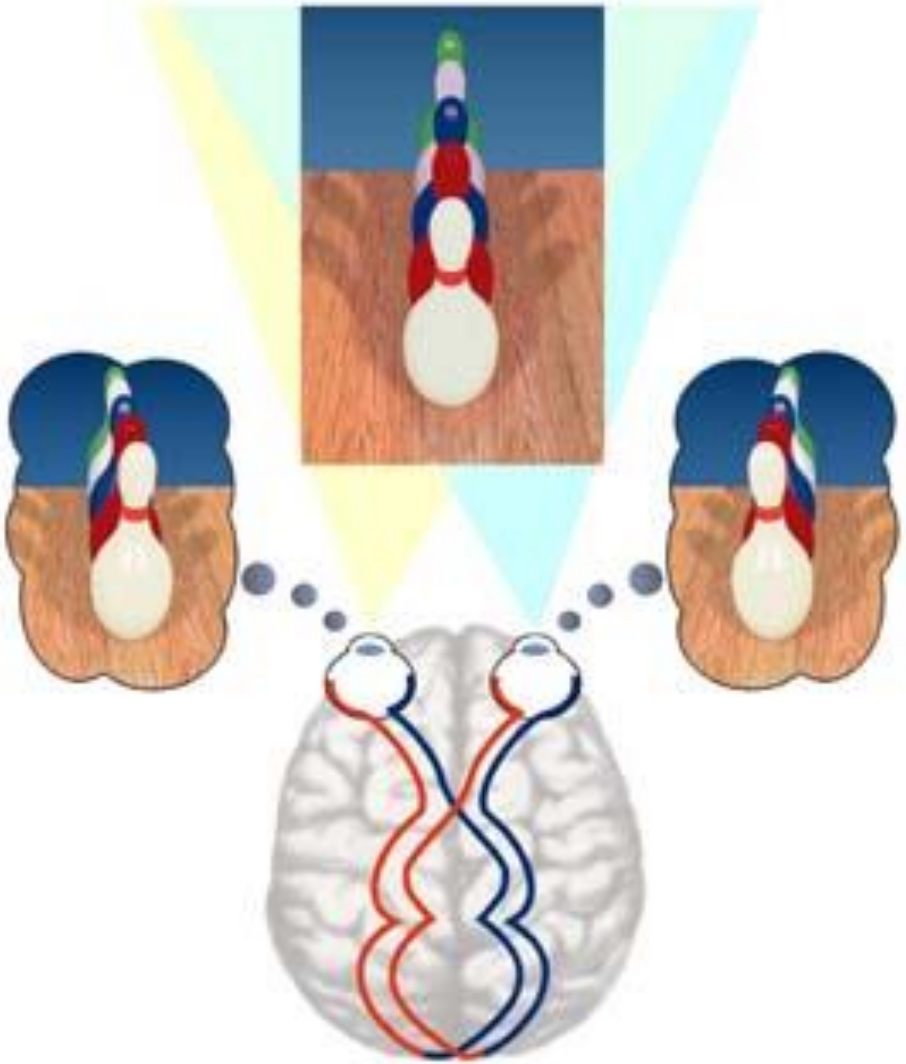
Image source: https://variety.com/2018/film/news/3d-box-office-1202743603/

3D Fatigue

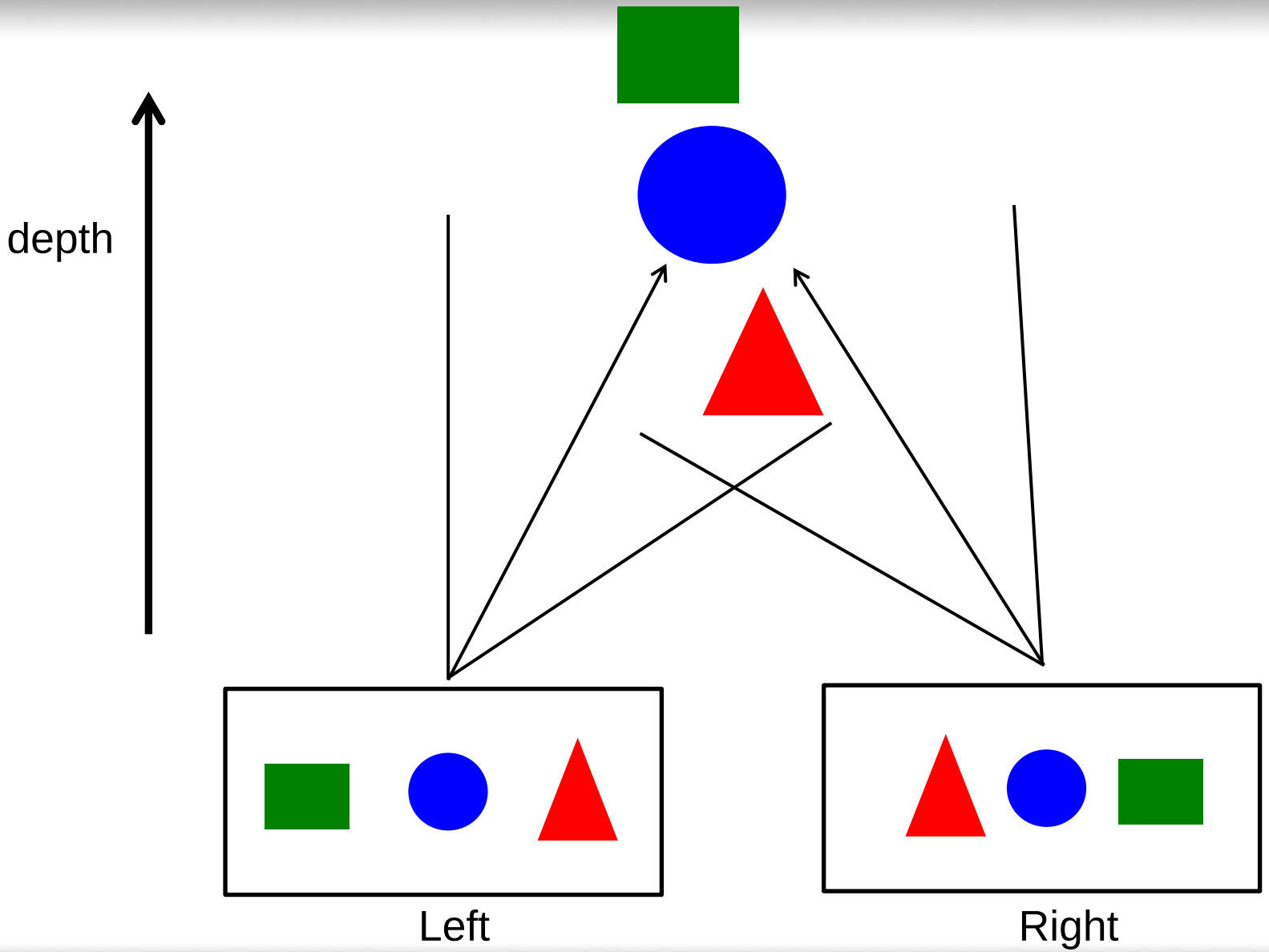
- Blurring vision
- Eyestrain
- Headache

Image source:
http://www.digitalproductionme.com/article-4580-3d--bad-for-you/#.UI-QfGdTDK0

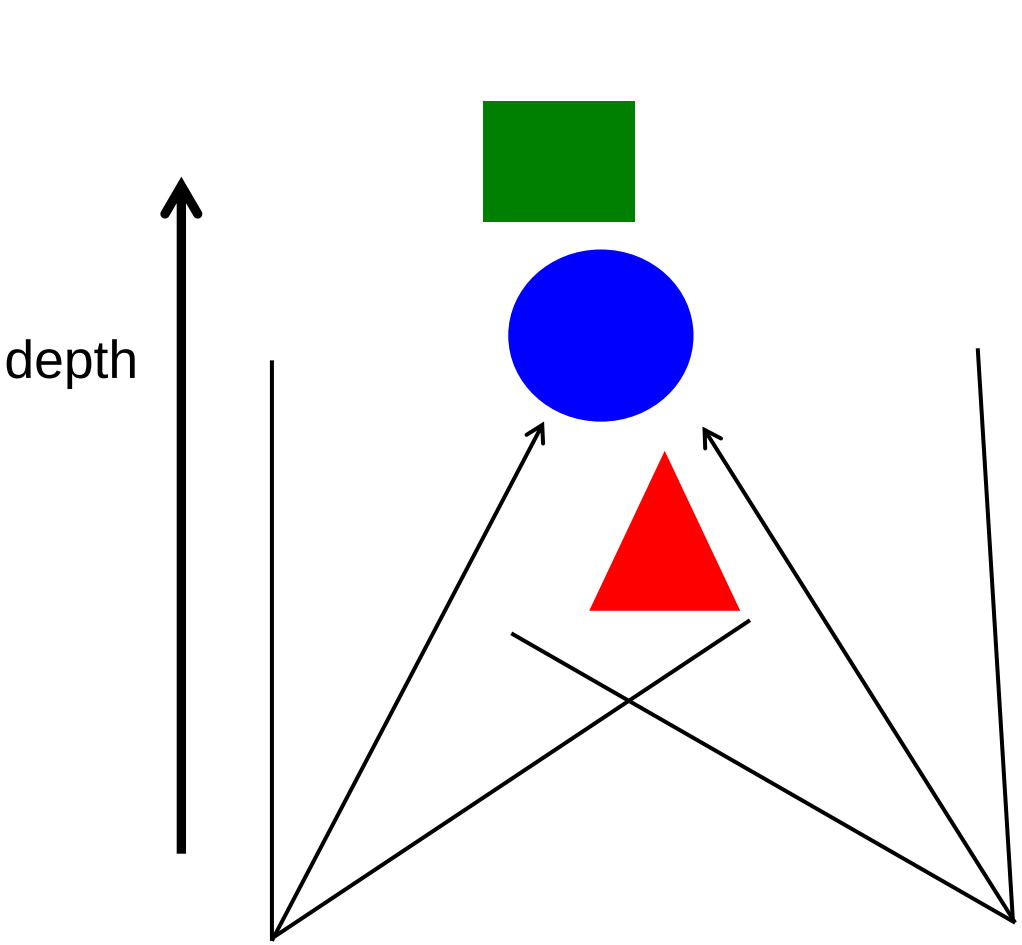
Stereopsis

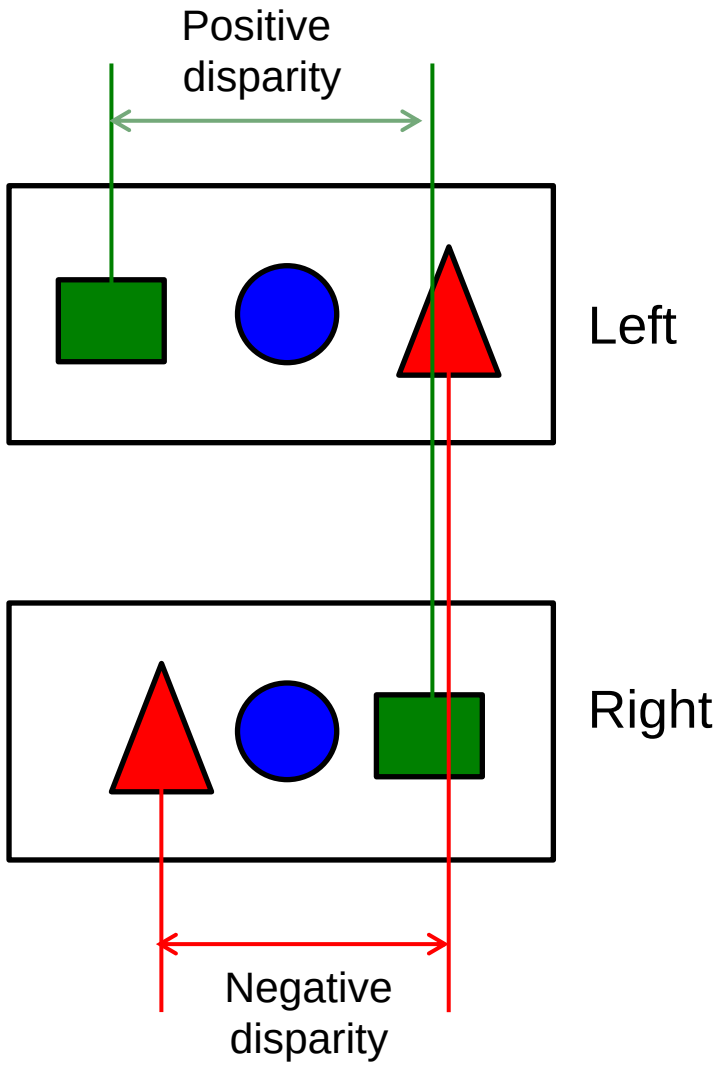


Disparity and Perceived Depth



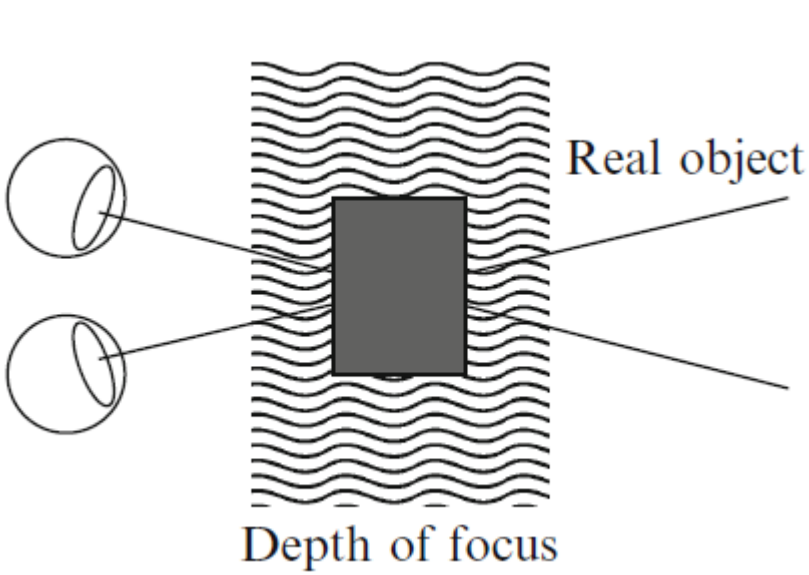
Disparity and Perceived Depth

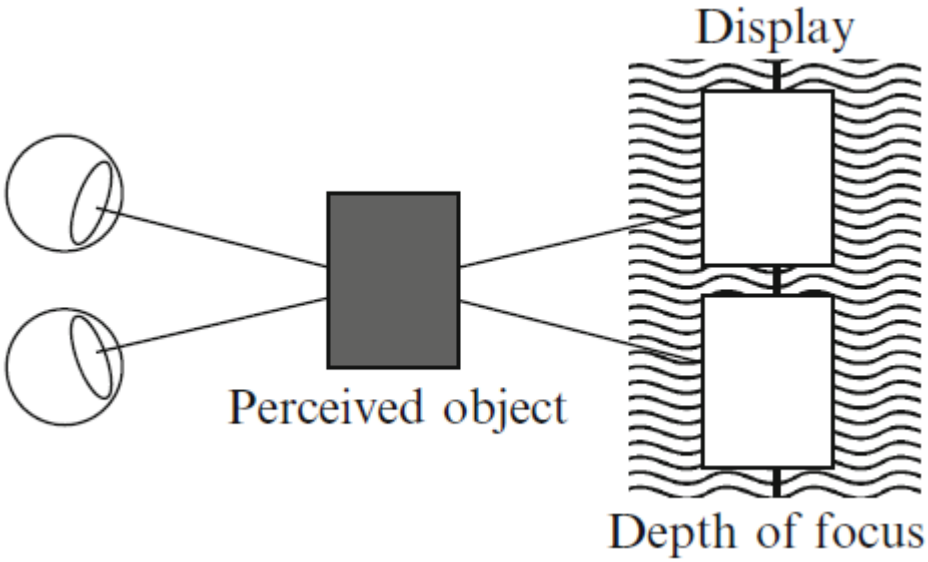




Vergence-accommodation

- There is an area around it where vergence and accommodation agree, which is called zone of comfort.

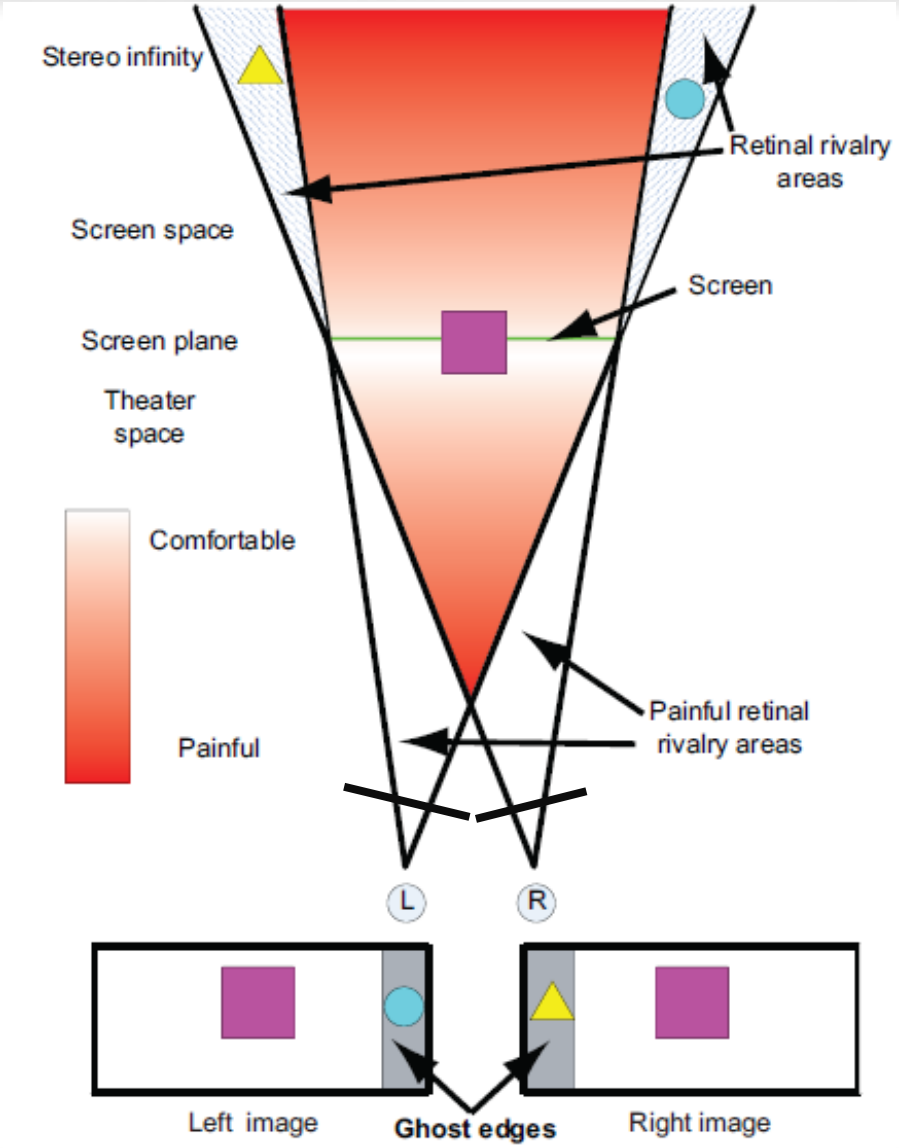




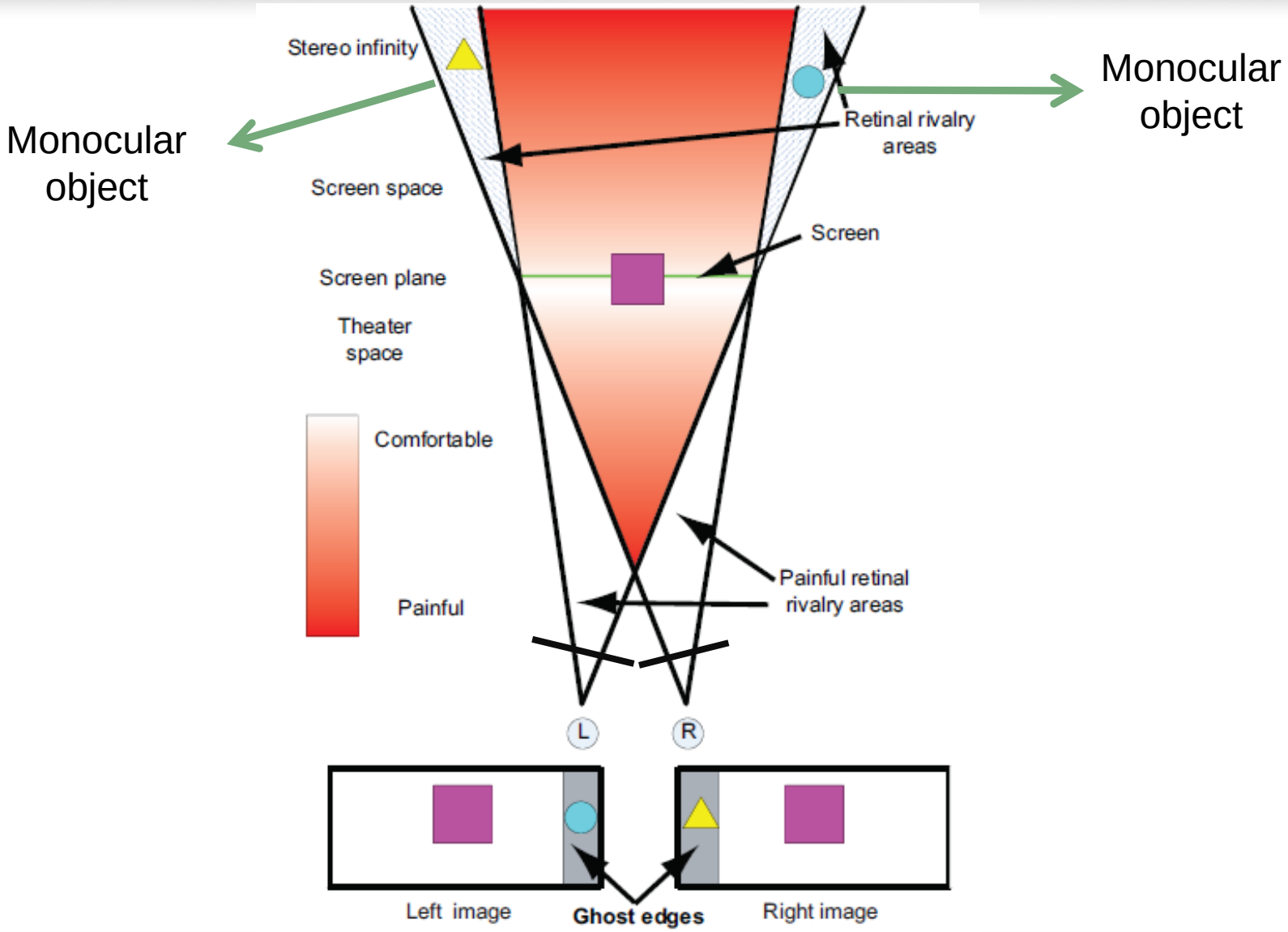
real world

stereoscopic displays

Stereoscopic Comfort Zone



Monocular Object



Stereo Window Violation

(a) Ideal 3D perception

(b) Actual 3D perception

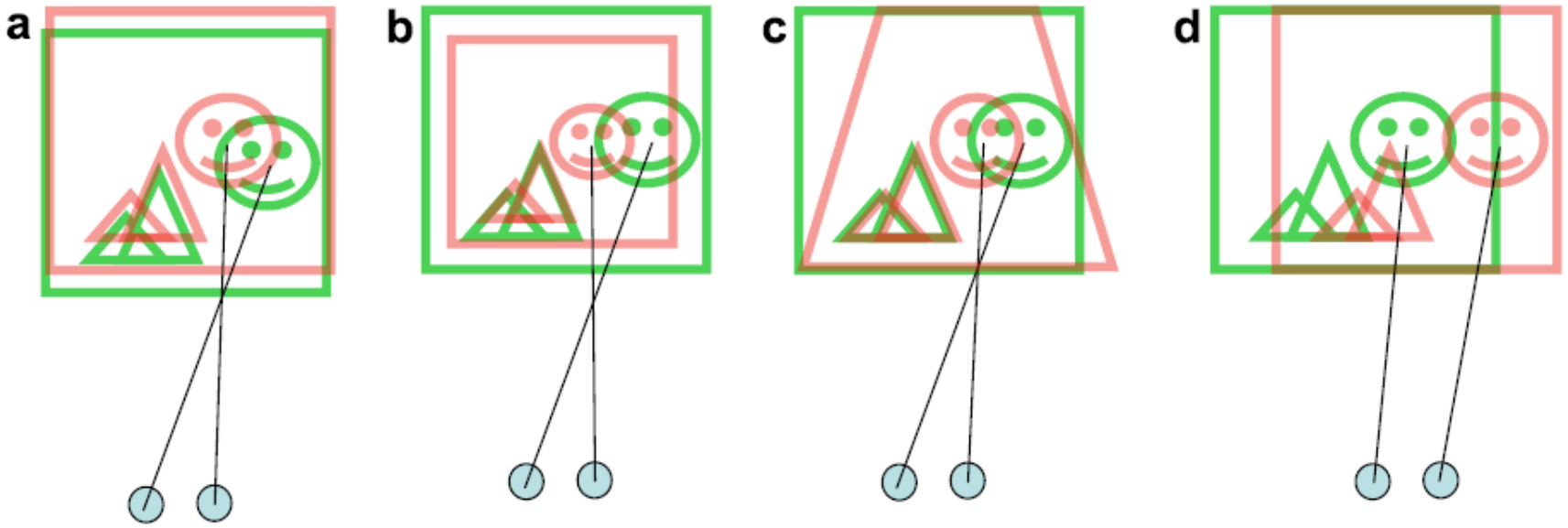
When an object with negative disparities is cut by the screen edge, it suffers from the stereo window violation. That is, the object is perceived in front of the screen, but is occluded by the screen edge.

Stereo Window Violation

Left

Right

More Visual Fatigue Sources

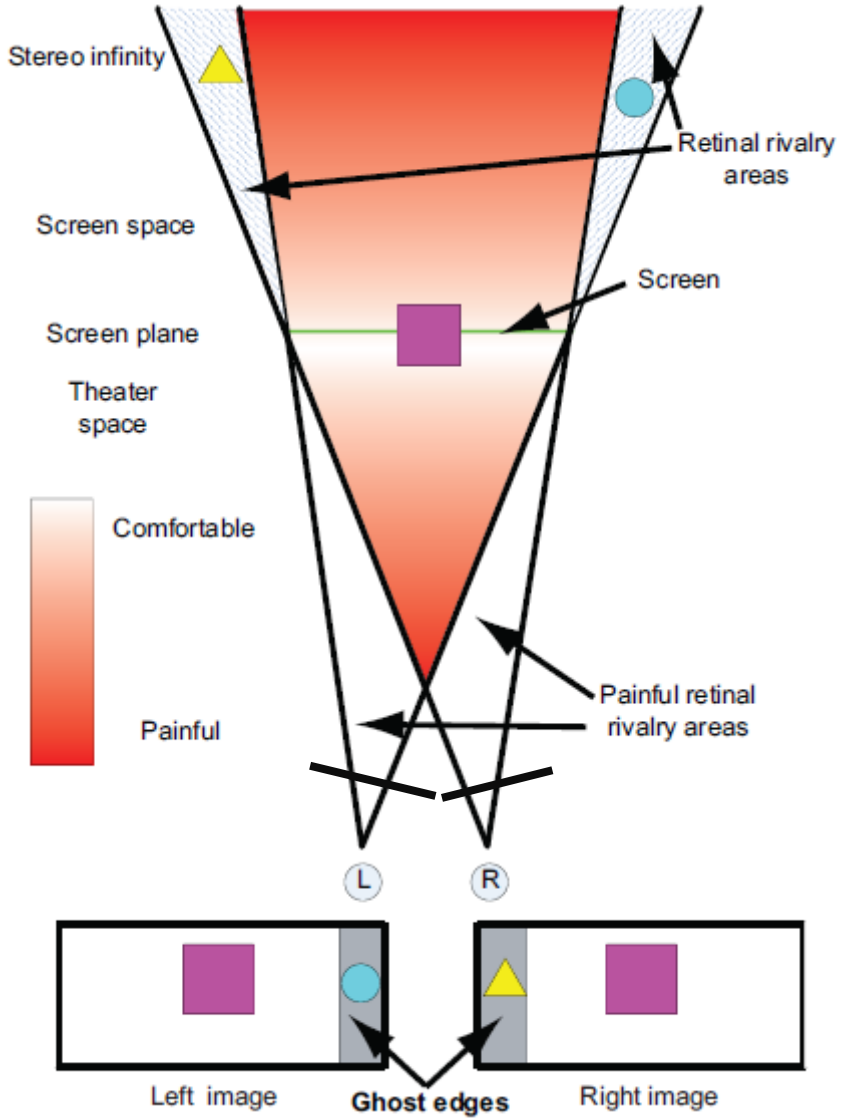


Slide credit: Y.Y Chuang

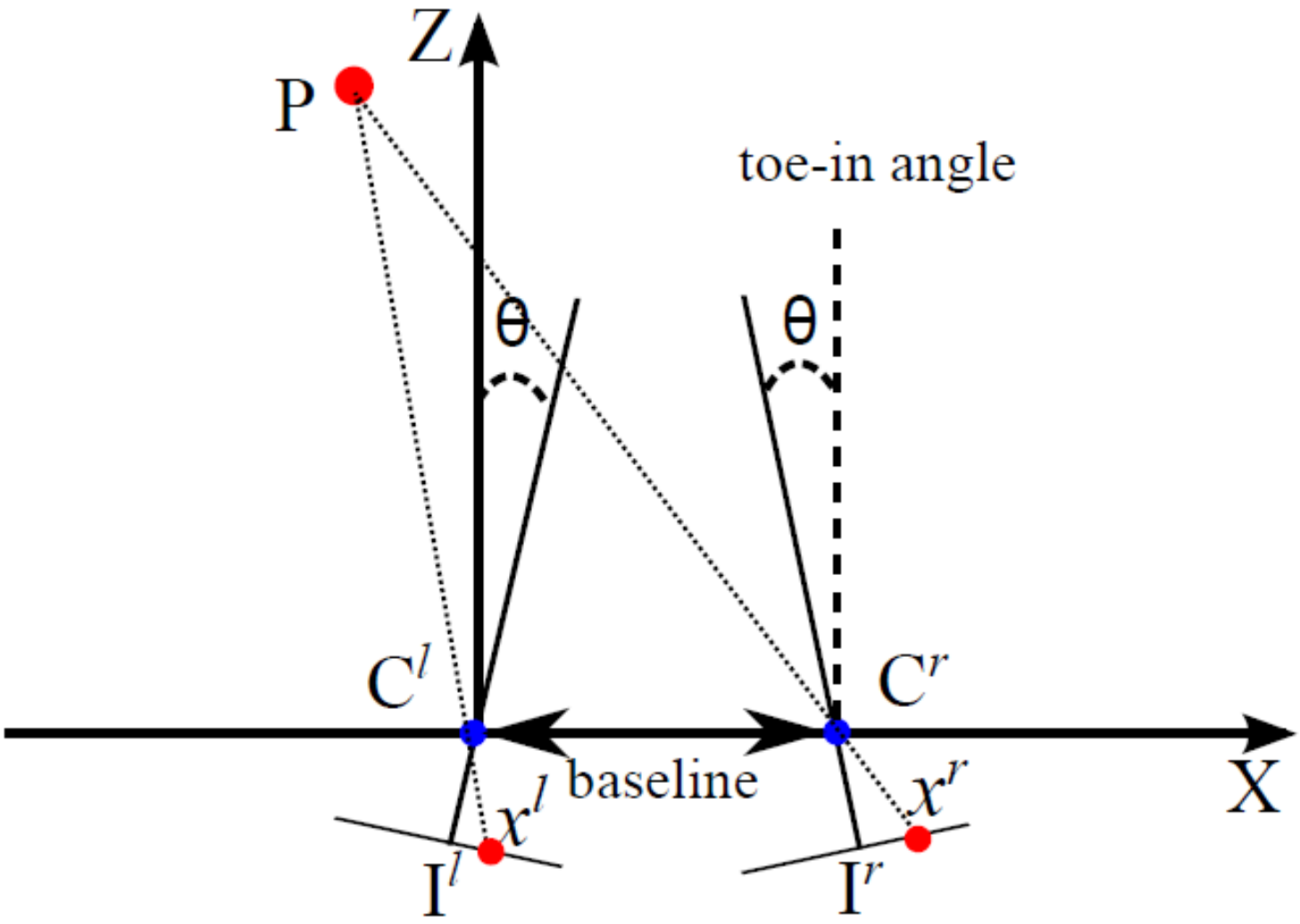
Keystone Correction for Stereoscopic Cinematography

Feng Liu, Yuzhen Niu, and Hailin Jin. Keystone Correction for Stereoscopic Cinematography. IEEE 3-D Cinematography 2012, Providence, RI, June 2012

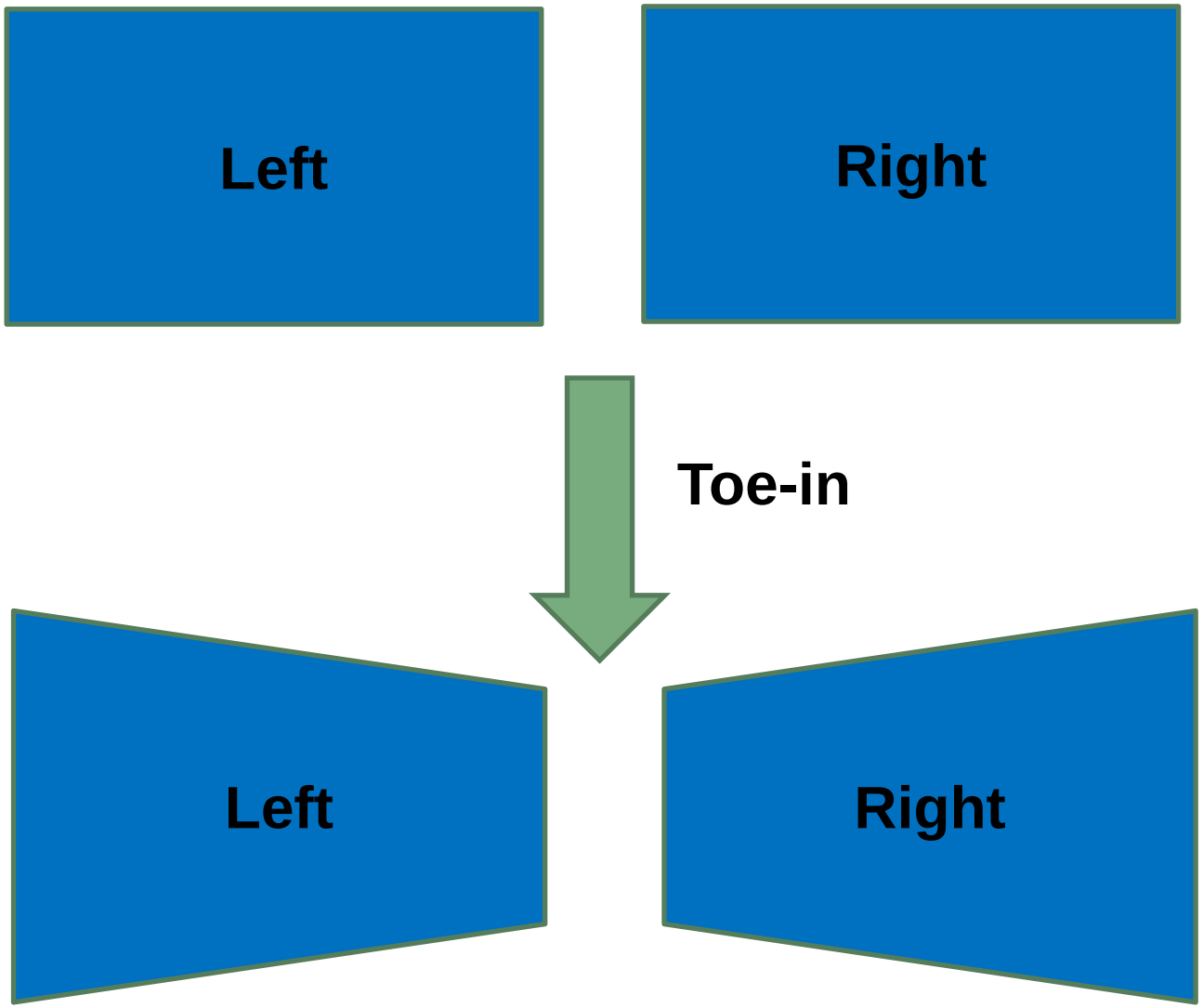
Stereoscopic Comfort Zone



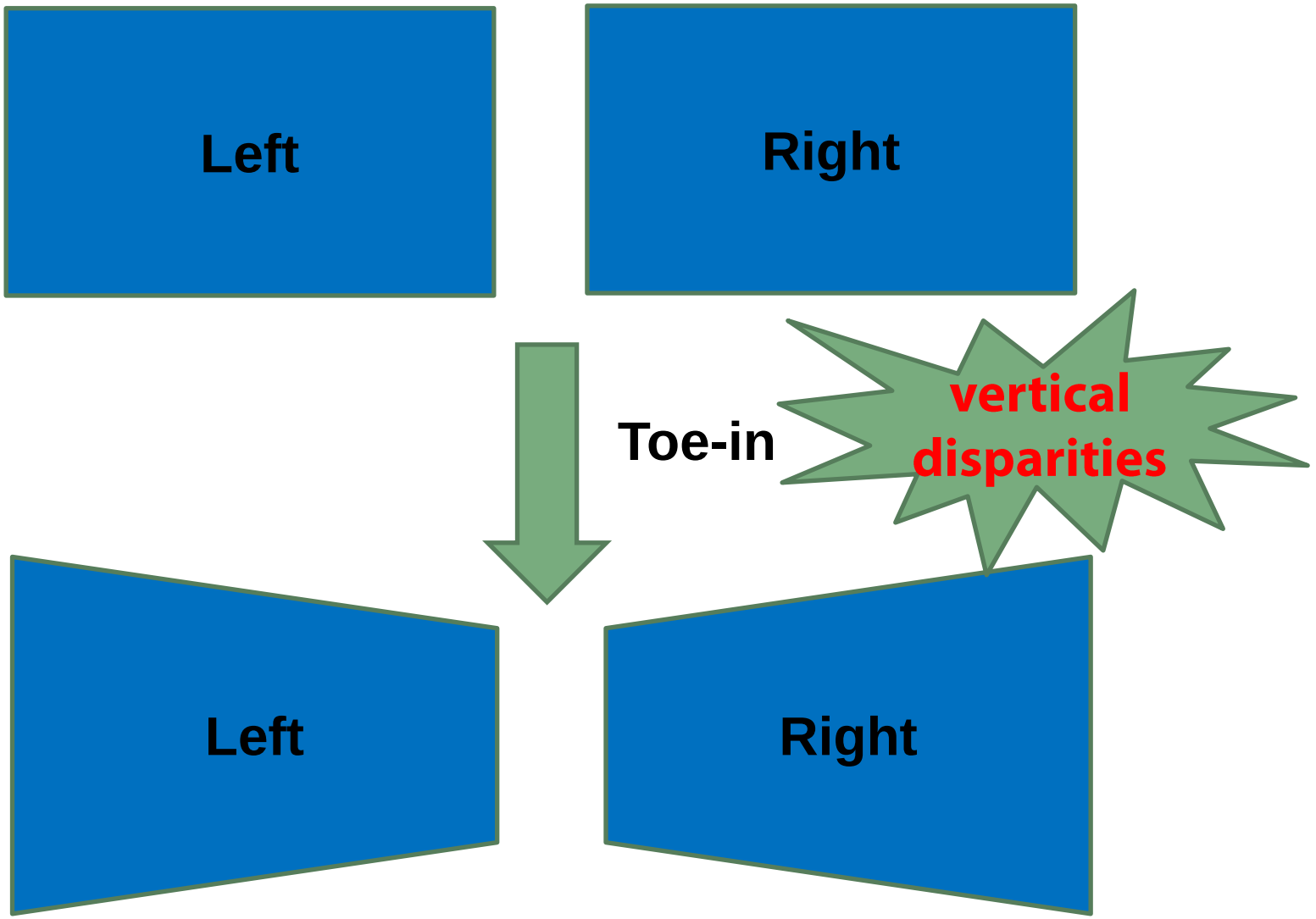
Stereoscopic Camera Model



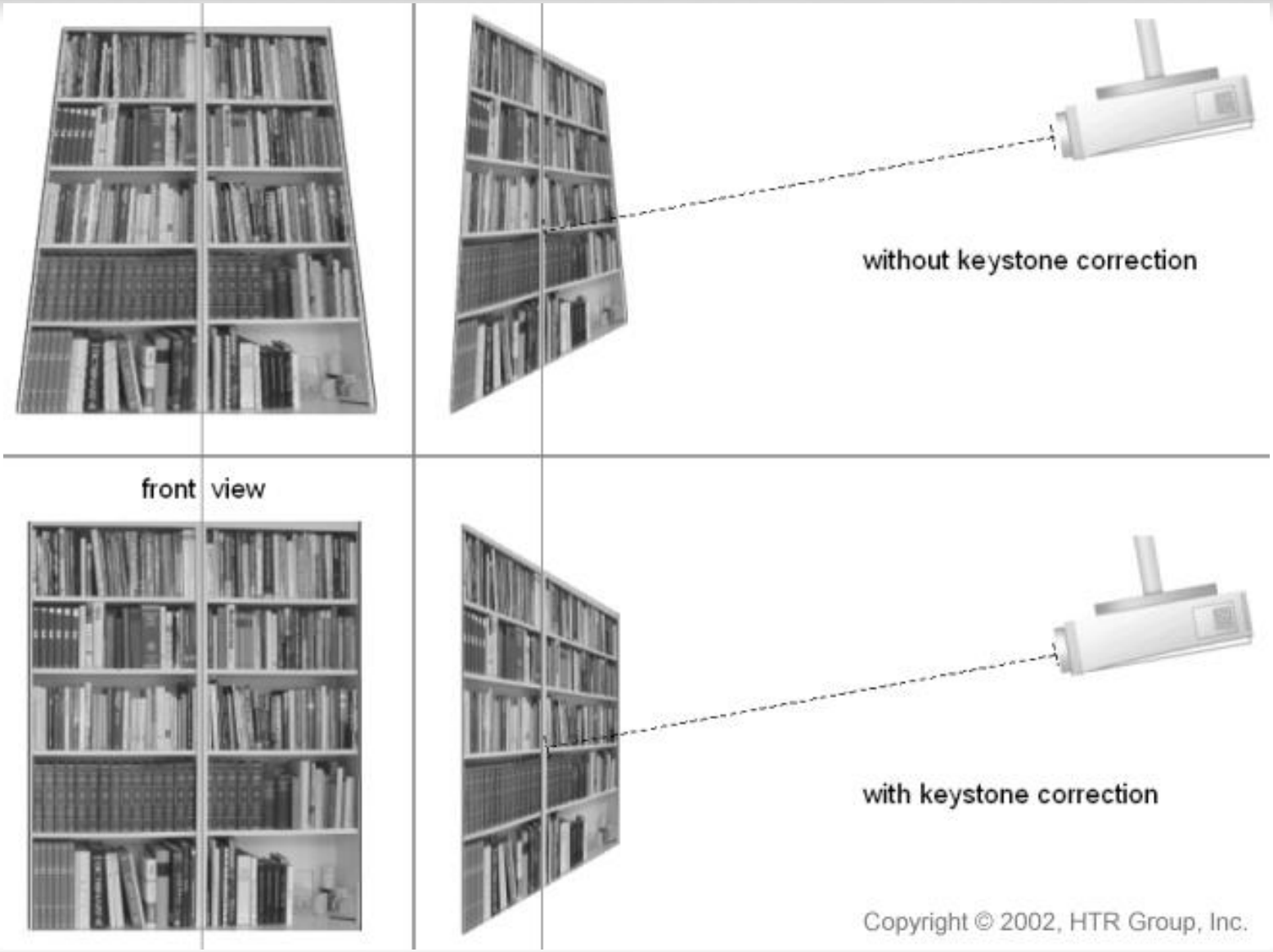
Keystone distortion



Keystone distortion



Keystone in projectors



Images from http://htrgroup.com/

Keystone correction for projectors

- Basics: 3D rotation can be modeled by a homography
- Keystone correction [Raskar and Beardsley 01, Li et al. 04, etc]
  - Estimate 3D rotation or homography
  - Optical keystone correction by modifying the lens system
  - Or digital keystone correction by image warping

Stereo keystone correction

- Projector keystone correction cannot work
  - Revert the toe-in operation
  - Change the desirable (horizontal) disparity distribution
- Stereo keystone correction requires
  - Eliminate vertical disparities
  - Preserve horizontal disparities

Content-preserving warping

- Non-uniformly move image content to target positions
- Avoid noticeable distortion
- Applications:
  - Video stabilization [Liu et al. '09]
  - Disparity editing [Lang et al. '10]

Correction by content-preserving warping

- Use a spatially-varying warping method
  - Non-uniformly move image content to remove vertical disparities and preserve horizontal disparities
  - Avoid noticeable image distortion

Stereo keystone correction

- Feature correspondence estimation
- Target feature position estimation
- Image transformation via content-preserving warping

Feature correspondence estimation

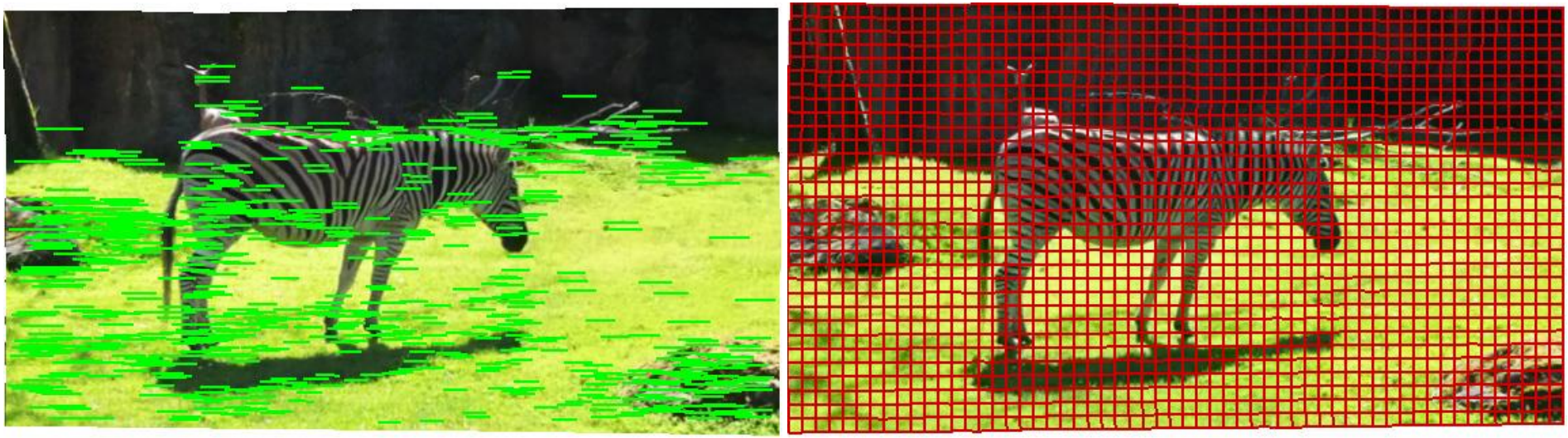
Input: left image with disparity and right image

- Detect SIFT features from the left and right image
- Establish feature correspondence [Lowe ‘04]
- Remove outliers using the epipolar geometry constraint [Hartley and Zisserman ‘00]

Target feature position estimation

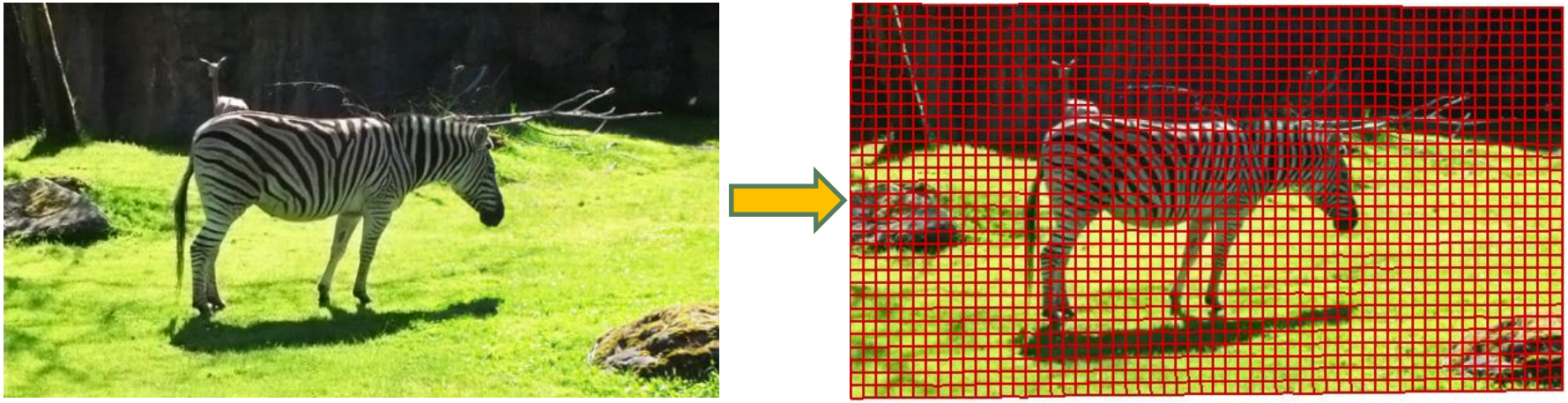
- Keep the input horizontal coordinates to
  - preserve horizontal disparities
- Average the left and right vertical coordinates for each feature pair to
  - remove vertical disparities

Content-preserving warping



Keystone correction result: left with disparity and right with mesh

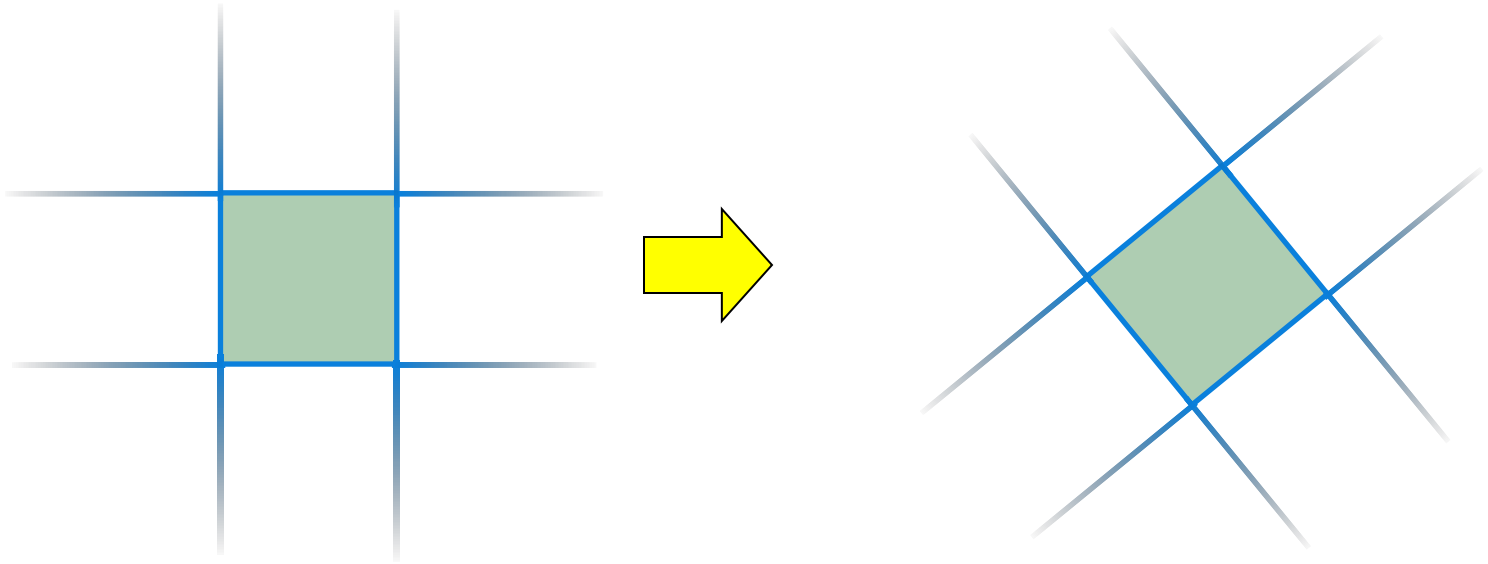
Warping algorithm



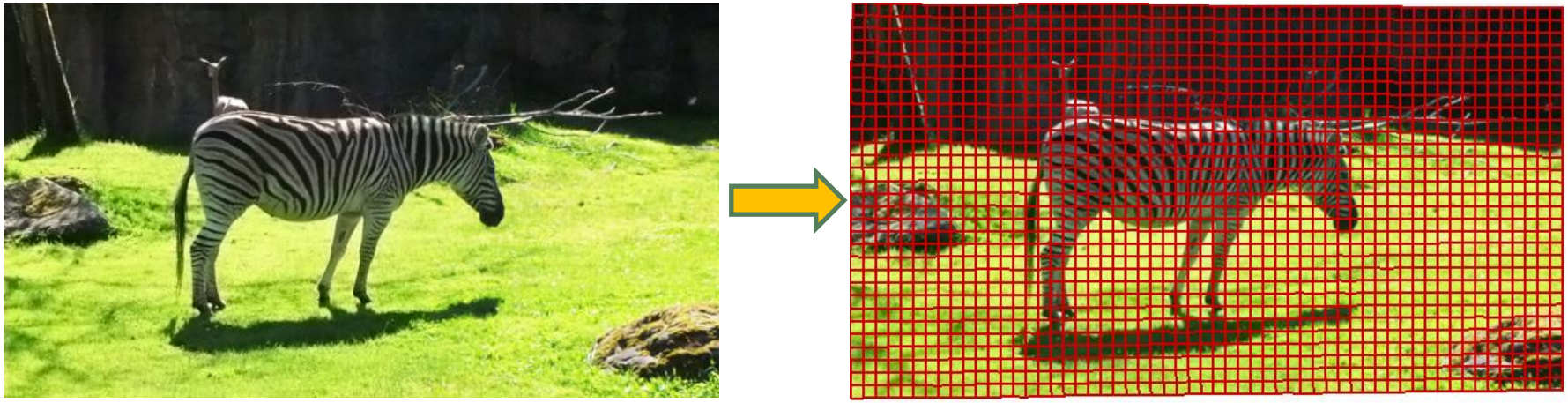
- Build a grid mesh from input image
- Warp input image by least-squares minimization
  - Data term: move features to target positions
  - Smoothness term: avoid visual distortion

Smoothness term: minimize visual distortion

Local similarity transformation constraint



Warping algorithm



- Build a grid mesh from input image
- Warp input image by least-squares minimization
  - Data term: move features to target positions
  - Smoothness term: avoid visual distortion
  - Solved by a linear solver

Camera-centric disparity editing

- Estimate the relative camera pose between the left and right camera and a sparse set of 3D points
  - 6-point algorithm [Stewenius et al. '05]
- Adjust the baseline and toe-in angle
  - Compute output feature positions
- Content-preserving warping

Disparity adjustment

Input

Disparity adjustment

Input

Disparity adjustment

Input

Vertical disparity from 3D rotation

Disparity adjustment

Input

Our result

Disparity adjustment

Examples

Input anaglyph and disparity

Examples: Move the train near the screen

Toe-in result

Examples: Move the train near the screen

Output anaglyph and disparity

Examples: Move the walker near the screen

Examples

Input

Output 1 and 2

Video example


Input sequence


Output sequence

Input

Result

Student Paper Presentations

- Presenter: Zwovic, Kitt
  - A global sampling method for alpha matting
    K. He, C. Rhemann, C. Rother, X. Tang, and J. Sun
    CVPR 2011
- Presenter: Filgas, Ryan
  - A Closed Form Solution to Natural Image Matting
    A. Levin, D. Lischinski, and Y. Weiss
    CVPR 2006

Next Time

- Student paper presentations
  - 05/24: Hall, Timothy
    - First-person Hyper-lapse videos
      J. Kopf, M. F. Cohen, R. Szeliski
      SIGGRAPH 2014
  - 05/24 : Kim, David
    - 360° Video Stabilization
      J. Kopf
      SIGGRAPH Asia 2016
  - 05/24 : Panthala, Krishna Sai
    - Steadiface: Real-Time Face-Centric Stabilization on Mobile Phones
      F. Shi, S. Tsai, Y. Wang, C. Liang
      ICIP 2019