Computational illumination (Lecture #7)

➡ + Computational displays (Lecture #6)

- Temporal resolution
- Angular resolution (stereo and light field displays)

- Temporal resolution
- Angular resolution (stereo and light field displays)

- 100,000:1 real world

- 100,000:1 real world

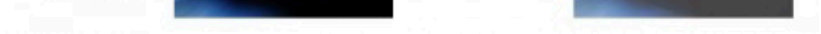
- => Complicated to create blacks
- => Reduced contrast

Source: Flexenable

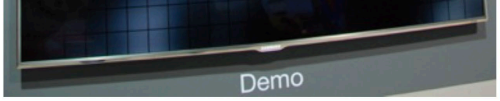
[Seetzen et al. 2004, Dolby 2008]

image details and colors (LCD)

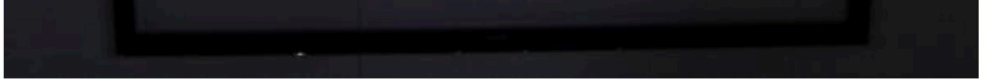
Source: Wetzstein et al. Comp. Displays Course.



Local dimming, Sony



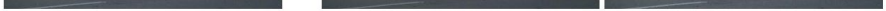
Micro-dimming, Samsung



consumption.

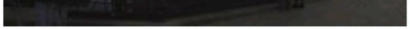
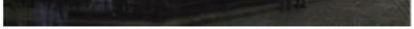
Source: Wetzstein et al. Comp. Displays Course.

[Trentacoste et al. 2012] Unsharp masking, countershading and halos: enhancements or artifacts? Comp. Graph. Forum.



(a) Monocular LDR (b) Binocular LDR pair

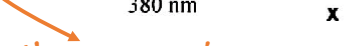
[Yang et al. 2012] Binocular tone mapping. ACM Trans. on Graph. & [Zhang et al. 2018] Binocular Tone Mapping with Improved Overall Contrast and Local Details. Comp. Graph. Forum.

[Yang et al. 2012] Binocular tone mapping. ACM Trans. on Graph. & [Zhang et al. 2018] Binocular Tone Mapping with Improved Overall Contrast and Local Details. Comp. Graph. Forum.

Luminance:

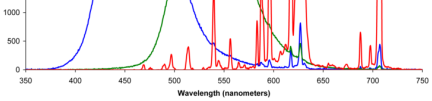
Luminous intensity per unit area (cd/m^2).



Human gamut:

All chromaticities visible to the average HVS.

Source: Makers Portal



primary colors of a CRT display.

Source: Wikipedia.

380 nm

x

[Chellappan et al. 2010] Laser-based displays: A review. Applied Optics.

[den Engelsen et al.]
[Masia et al.]

(More saturation = Narrower spectral width of the emitted light)

(Use of 4, 5 and 6 primaries has been proposed. In this example, yellow (J) and cyan (C))

subpixel-shifted low-res images perceptually-integratec high-res image

subpixel-shifted low-res images perceptually-integratec high-res image

- Wobulation, vibrating displays, apparent resolution increase…

unwobulated

wobulated [Allen and Ulichney 2005]

flickering frequency of the HVS.

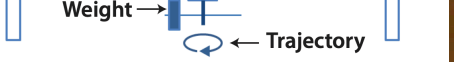
subpixel-shifted low-res images

perceptually-integrated high-res image

[Allen and U

Can be more than 2 sub-frames (but requires higher speed switching)

[Allen and U



[Berthouzou and Fattal 2012]

[Berthouzou

perceptual (cannot be observed in the content!).

Low persistence displays interleave black frames with original content to reduce hold-type blur.

Input Image A

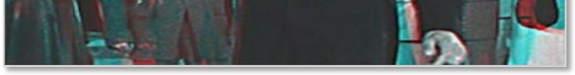
Interpolated Frames

Input Image B

[Ma

2009 - now: increasing popularity

year



year


0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

- But still: missing cues & conflict problems

They are flat!

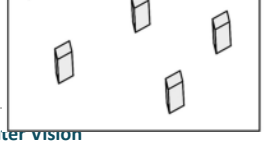
Source: Banterle et al. Multidimensional Image Retargeting Course.

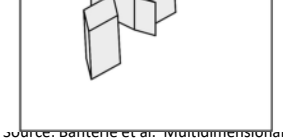
Source: Banterle et al. Multidimensional Image Retargeting Course.

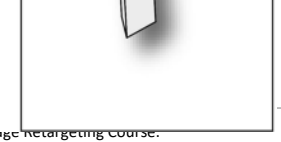
Source: Banterle et al. Multidimensional Image Retargeting Course.

Source: Banterle et al. Multidimensional Image Retargeting Course.

Occlusion, size, shadows…







Source: Bantelé et al. "Multidimensional Image Retargeting Course."

Source: Banterle et al. Multidimensional Image Retargeting Course.

Occlusion, size, shadows…

Source: Banterle et al. Multidimensional Image Retargeting Course.

Taxonomy adapted from Hong Hua

Source: Wetzstein et al. Comp. Displays Course.

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Source: Wetzstein et al. Comp. Displays Course.

Stereoscopic

Multiplexed
(stereo pair with same display surface)

Source: Wetzstein et al. Comp. Displays Course.

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Multiplexed
(stereo pair with same display surface)

Source: Wetzstein et al. Comp. Displays Course.

Stereoscopic

Multiplexed
(stereo pair with same display surface)

Spatially-multiplexed (field-concurrent)
(color filters, polarizers, etc.)

Temporally-multiplexed (field-sequential)
(LCD shutter glasses)

Source: Wetzstein et al. Comp. Displays Course.

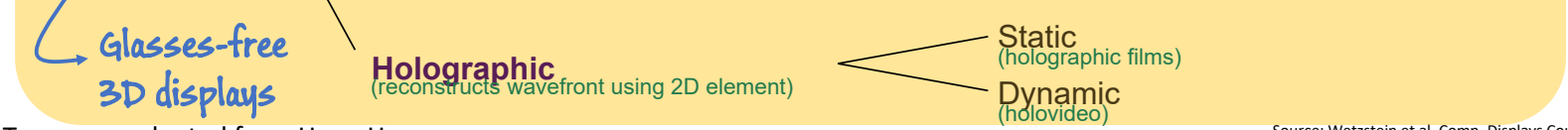
Stereoscopic

Multiplexed
(stereo pair with same display surface)

Spatially-multiplexed (field-concurrent)
(color filters, polarizers, autostereograms, etc.)

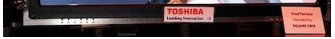
Temporally-multiplexed (field-sequential)
(LCD shutter glasses)

Source: Wetzstein et al. Comp. Displays Course.

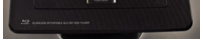


Taxonomy adapted from Hong Hua

Source: Wetzstein et al. Comp. Displays Course.



Toshiba 3DTV Prototype
CES 2011



Sony 3DTV Prototype
CES 2011

LG 3DTV Prototype
CES 2011

- Requires light-attenuating layers (i.e., masks)
- Allows multi-view display, but results in dim images due to attenuation

Source: Wetzstein et al. Comp. Displays Course.

- Requires two light-attenuating layers (i.e., masks)
- Allows multi-view display, but results in dim images due to attenuation

Source: Wetzstein et al. Comp. Displays Course.

- Requires a refractive lenslet array to be affixed to a conventional display
- Allows multi-view display, but imposes fixed trade-off between spatial and angular resolution

Source: Wetzstein et al. Comp. Displays Course.

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- Requires a refractive lenslet array to be affixed to a conventional display
- Allows multi-view display, but imposes fixed trade-off between spatial and angular resolution

Source: Wetzstein et al. Comp. Displays Course.

- One could generalize and consider a **multi-layer design** *(Layered 3D)*

Source: Wetzstein et al. Comp. Displays Course.

light box

Layered 3D

Source: Wetzstein et al. Comp. Displays Course.

light box

Layered 3D

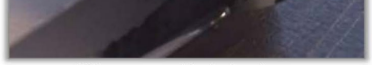
Source: Wetzstein et al. Comp. Displays Course.

light box

Layered 3D

Source: Wetzstein et al. Comp. Displays Course.

Raytrix™



125µ square-sided microlenses

Source: Gkioulekas. CMU Comp. Imaging Course.

Source: Gkioulekas. CMU Comp. Imaging Course.

[Kim et al.

2D Light Field

Scene...

...and assume this is the light field we want to show on the display.

2D Light Field

[Wetzstein et al. 2011] Layered 3D. SIGGRAPH.

2D Light Field

[Wetzstein et al. 2011] Layered 3D. SIGGRAPH.

2D Light Field

[Wetzstein et al. 2011] Layered 3D. SIGGRAPH.

2D Light Field

[Wetzstein et al. 2011] Layered 3D. SIGGRAPH.

2D Light Field

[Wetzstein et al. 2011] Layered 3D. SIGGRAPH.

Projection matrix
(see paper for deriv.)

Attenuation coeff.

2D Light Field

[Wetzstein et al. 2011] Layered 3D. SIGGRAPH.

Projection matrix
(see paper for deriv.)

Attenuation coeff.

2D Light Field

[Wetzstein et al. 2011] Layered 3D. SIGGRAPH.

Multi-Layer Decomposition

[Wetzstein et al. 2011] Layered 3D. SIGGRAPH.

Transparency stack with acrylic spacers

Prototype in front of LCD (backlight source)

[Wetzstein et al. 2011] Layered 3D. SIGGRAPH.

Source: P. Didyk. Stereo Retargeting. Multidimensional Image Retargeting Course. SIGGRAPH Asia 2011.

Source: P. Didyk. Stereo Retargeting. Multidimensional Image Retargeting Course. SIGGRAPH Asia 2011.

0.3 1 3 10 30

Distance to content (m)

"The zone of comfort: Predicting visual discomfort with stereo displays" by Shibata et al. 2011

Source: P. Didyk. Stereo Retargeting. Multidimensional Image Retargeting Course. SIGGRAPH Asia 2011.

Scene manipulation

~~Viewing discomfort~~ > Viewing comfort

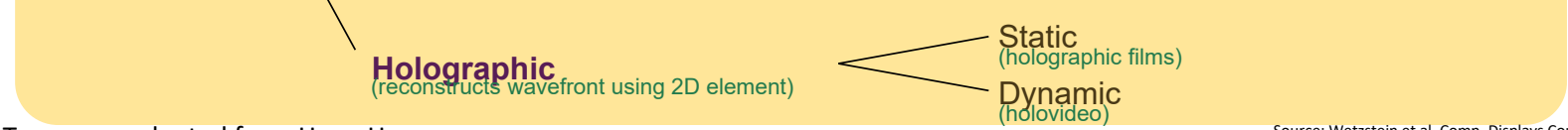
Source: P. Didyk. Stereo Retargeting. Multidimensional Image Retargeting Course. SIGGRAPH Asia 2011.

[Masia et al. 2013] Display adaptive 3D content remapping. Computers and Graphics.

Fig. 4. Perspective sketch of the illusory depth surface. Left part looks apparently nearer than the right part.

[Anstis et al. 1978] A Craik-Obrien-Cornsweet illusion for visual depth. Vision Res.

[Masia et al. 2013] Display adaptive 3D content remapping. Computers and Graphics.



Taxonomy adapted from Hong Hua

Source: Wetzstein et al. Comp. Displays Course.

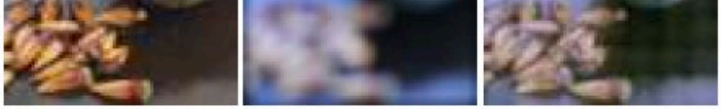
Holograms

- all depth cues
- computationally expensive

[Jones et al. 20

Joint co-design of hardware, and software, taking also into account perception.

[Pamplona et al. 2012]



(a) Input Image (b) Regular Display (c) Tailored Display

[Pamplona

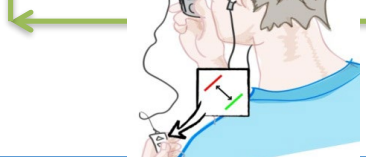
Local Slope
of the Wavefront

[Pamplona et al. 2010]

Source: Wetzstein et al. Comp. Displays Course.

Displace 25 points but **<u>3 parameters</u>**

[Pamplona et al. 2010]



Source: Wetzstein et al. Comp. Displays Course.

[Pamplona et al. 2011]

Source: Wetzstein et al. Comp. Displays Course.

Cell Phone Display

[Pamplona et al. 2011]

Source: Wetzstein et al. Comp. Displays Course.