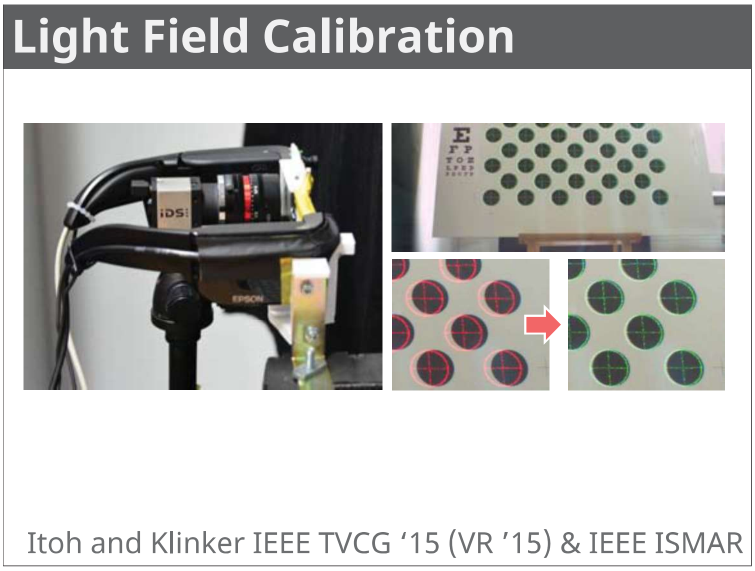
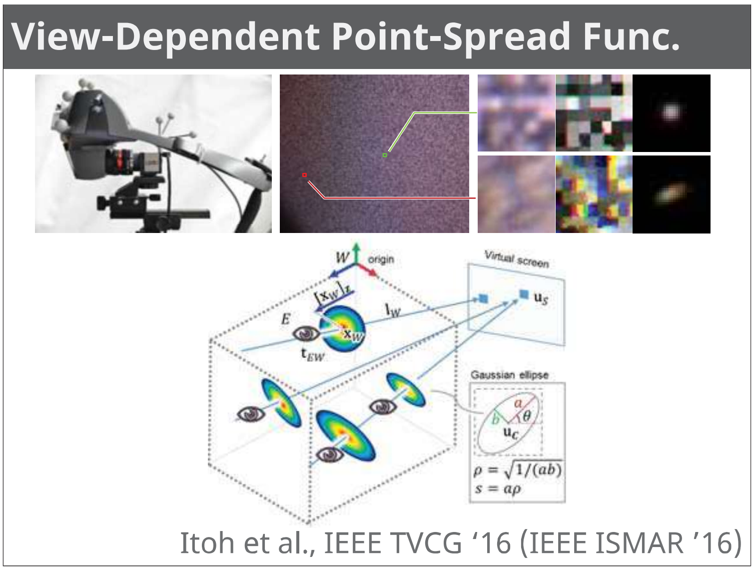
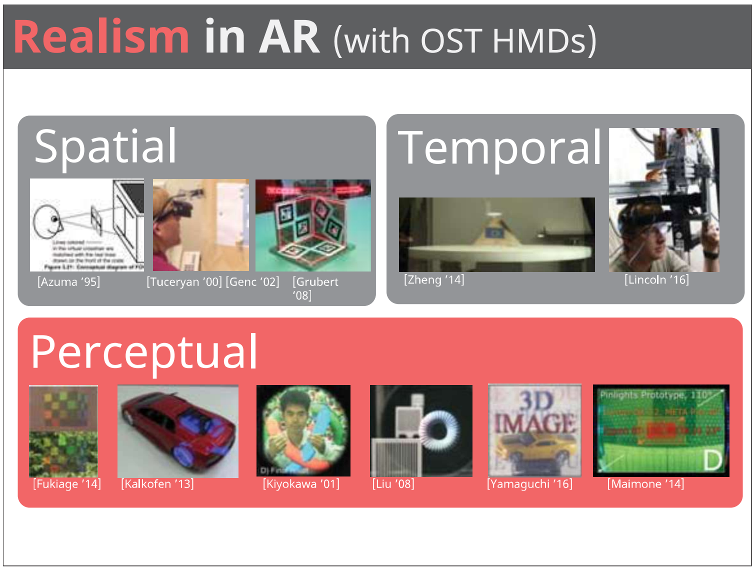
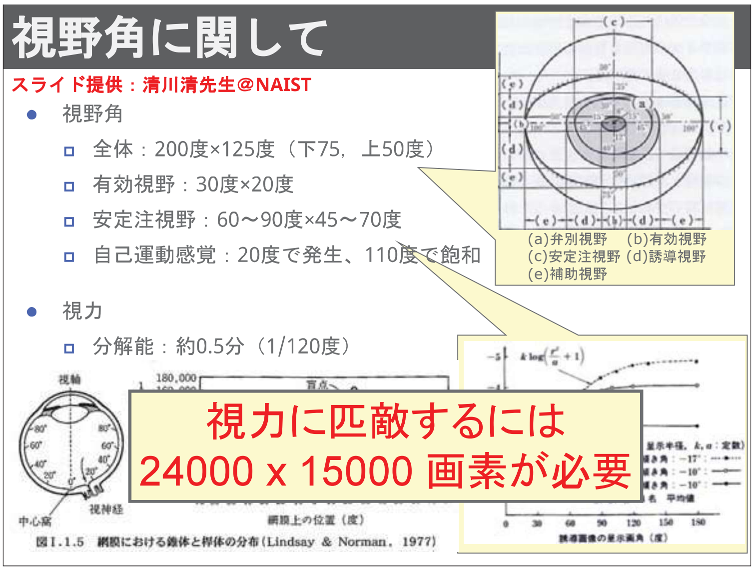
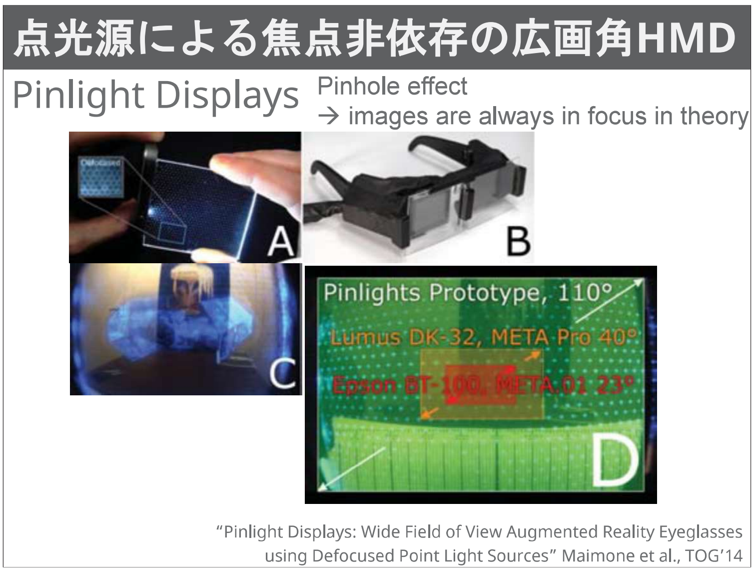

Light Field Calibration
Itoh and Klinker IEEE TVCG ‘15 (VR ’15) & IEEE ISMAR


View-Dependent Point-Spread Func.
origin
Virtual screen
Gaussian ellipse
$\rho = \sqrt{1/(ab)}$
$s = a\rho$
Itoh et al., IEEE TVCG ‘16 (IEEE ISMAR ’16)


Realism in AR (with OST HMDs)
Spatial
[Azuma ’95]
[Tuceryan ’00] [Genc ’02]
[Grubert ’08]
Temporal
[Zheng ’14]
[Lincoln ’16]
Perceptual
[Fukiage ’14]
[Kalkofen ’13]
[Kiyokawa ’01]
[Liu ’08]
[Yamaguchi ’16]
[Maimone ’14]

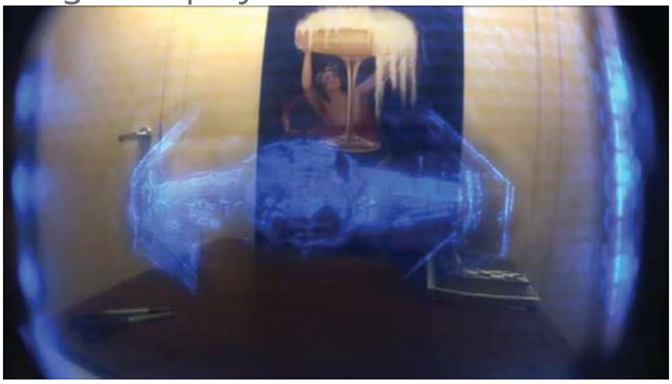

視野角に関して
スライド提供：清川清先生@NAIST
視野角
全体：200度×125度（下75，上50度）
有効視野：30度×20度
安定注視野：60～90度×45～70度
自己運動感覚：20度で発生、110度で飽和
(a)弁別視野　(b)有効視野
(c)安定注視野 (d)誘導視野
(e)補助視野
視力
分解能：約0.5分（1/120度）
視力に匹敵するには
24000 x 15000 画素が必要
中心窩
視神経
網膜上の位置（度）
図 I.1.5　網膜における錐体と桿体の分布 (Lindsay & Norman，1977)


Field of View
https://twitter.com/ksasao/status/715569511684911105


点光源による焦点非依存の広画角HMD
Pinlight Displays
Pinhole effect
→ images are always in focus in theory
A
B
C
Pinlights Prototype, 110°
Lumus DK-32, META Pro 40°
Epson BT-100, META.01 23°
D
“Pinlight Displays: Wide Field of View Augmented Reality Eyeglasses using Defocused Point Light Sources” Maimone et al., TOG’14

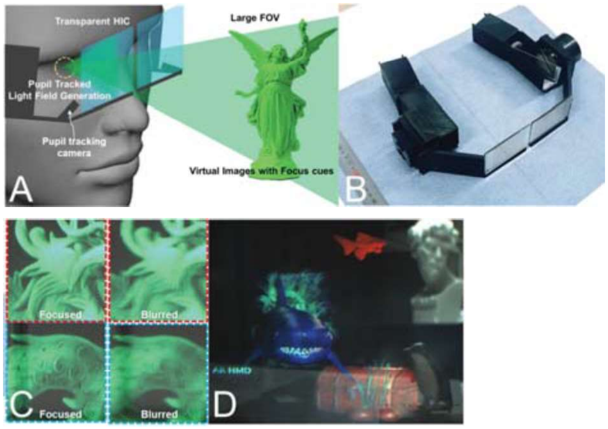
点光源による焦点非依存の広画角HMD

Pinlight Displays



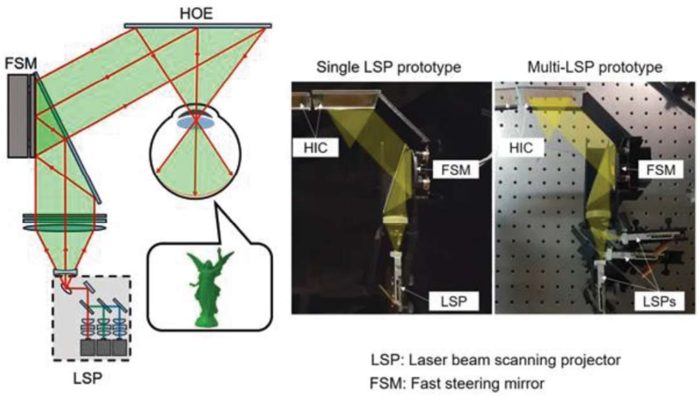
"Pinlight Displays: Wide Field of View Augmented Reality Eyeglasses using Defocused Point Light Sources" Maimone et al., TOG'14

視線追跡＋網膜投影



"Retinal 3D: Augmented Reality Near-Eye Display Via Pupil-Tracked Light Field Projection on Retina," Changwon Jang et al., SIGGRAPH Asia 2017

視線追跡＋網膜投影



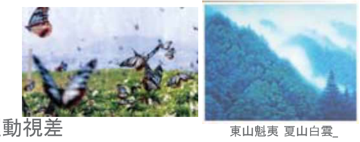
LSP: Laser beam scanning projector
FSM: Fast steering mirror

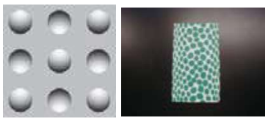
"Retinal 3D: Augmented Reality Near-Eye Display Via Pupil-Tracked Light Field Projection on Retina," Changwon Jang et al., SIGGRAPH Asia 2017

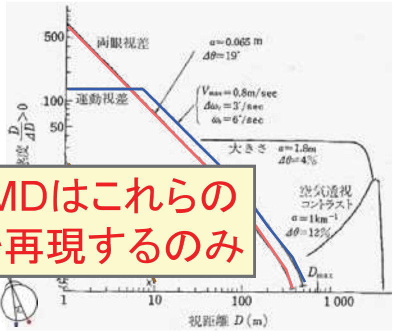
奥行き知覚

スライド提供：清川清先生@NAIST

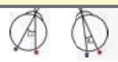
- 単眼性
  - 生得的：調節、単眼性輻輳
  - 経験的：線遠近，空気遠近，テクスチャ勾配，遮蔽，陰影，運動視差





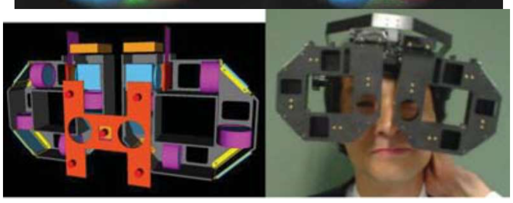


- 両眼性
  - 生得的：
  - 経験的：
  9m以内では最も強力



現在のHMDはこれらのごく一部を再現するのみ

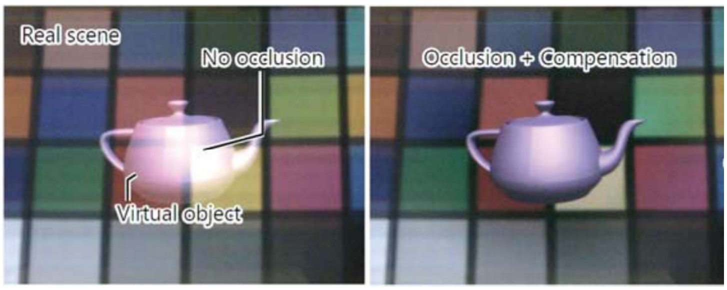
Occlusion (光学遮蔽 "Z-buffer")



Kiyokawa, K., Billinghurst, M., Campbell, B., & Woods, E. (2003, October). An occlusion-capable optical see-through head mount display for supporting co-located collaboration. In *Proceedings of the 2nd IEEE/ACM ISMAR* (p. 133). IEEE Computer Society.

遮蔽領域のボケを補間するHMD

LCD mask & Image compensation



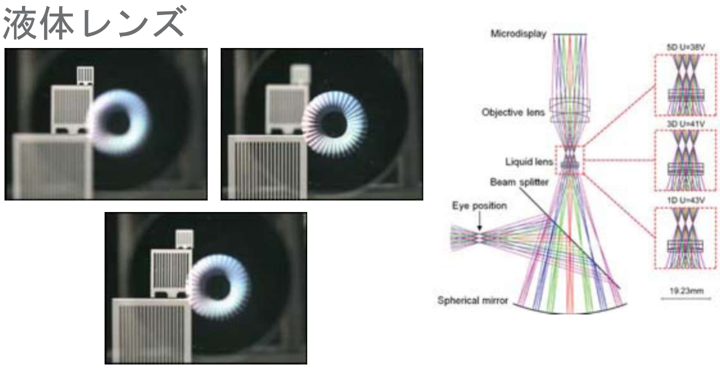
IEEE TVCG (to be presented at ISMAR 2017) "Occlusion Leak Compensation for Optical See-Through Displays using a Single-layer Transmissive Spatial Light Modulator," Yuta Itoh, Takumi Hamasaki, Maki Sugimoto.

遮蔽領域のボケを補間するHMD

IEEE TVCG (to be presented at ISMAR 2017) "Occlusion Leak Compensation for Optical See-Through Displays using a Single-layer Transmissive Spatial Light Modulator," Yuta Itoh, Takumi Hamasaki, Maki Sugimoto.

Depth (eye accommodation)

液体レンズ



S. Liu, H. Hua, and D. Cheng, "A novel prototype for an optical see-through head mounted display with addressable focus cues," IEEE Trans. Vis. Comput. Graphics, vol. 16, no. 3, pp. 381–393, May 2010.

Depth (eye accommodation)

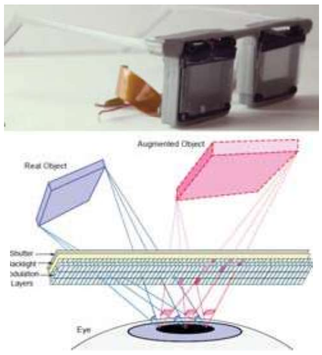
液体レンズ

VR HMD

Computational focus-tunable near-eye displays R Konrad, N Padmanaban, E Cooper, G Wetzstein, ACM SIGGRAPH 2016 Emerging Technologies, 3

Depth (eye accommodation)

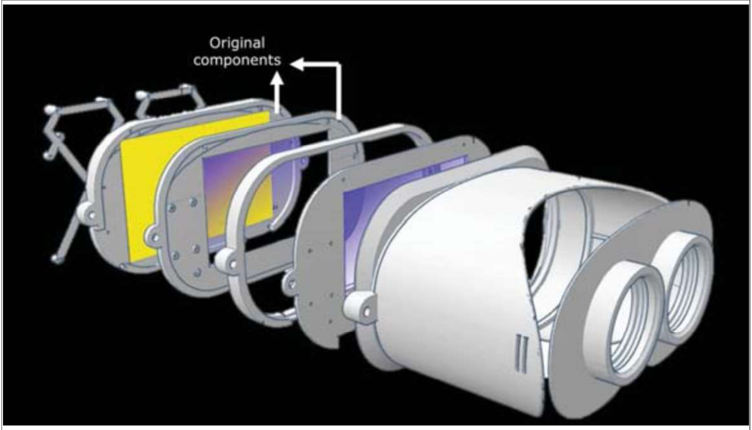
Light Field Display (Multi-layer LCD)



Accommodatio
n & Occlusion

Maimone, A., Lanman, D., Rathinavel, K., Keller, K., Luebke, D., & Fuchs, H. (2014, July). Pinlight displays: wide field of view augmented reality eyeglasses using defocused point light sources. In *ACM SIGGRAPH 2014 Emerging Technologies* (p. 20). ACM.

Depth (eye accommodation)

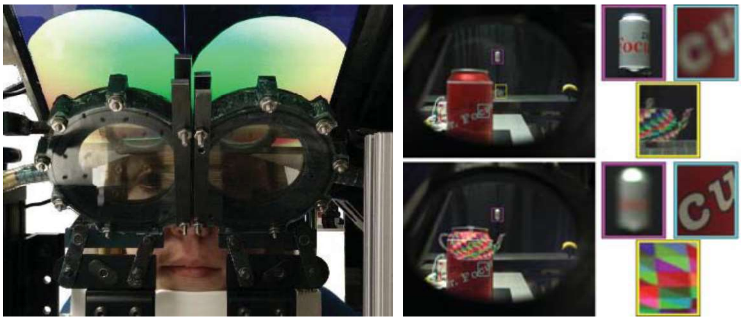


The Light Field Stereoscope,
F. Huan, K. Chen, G. Wetzstein, SIGGRPAH 2015

Depth (eye accommodation)

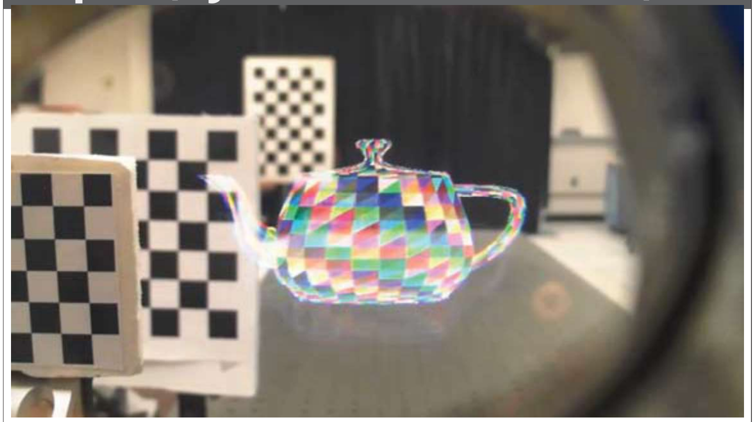
Deformable
Membrane Mirrors

Accommodation
& Wide FoVを**両立！**



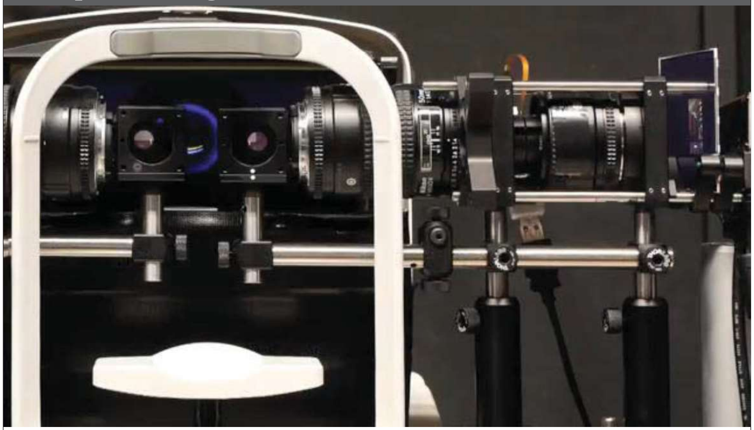
"Wide Field of View Varifocal Near-Eye Display using See-Through Deformable Membrane Mirrors," D. Dunn, C. Tippets, K. Torell, P. Kellnhofer, K. Aksit, P. Didyk, K. Myszkowski, D. Luebke, and H. Fuchs, TVCG (IEEE VR 2017)

Depth (eye accommodation)



"Wide Field of View Varifocal Near-Eye Display using See-Through Deformable Membrane Mirrors," D. Dunn, C. Tippets, K. Torell, P. Kellnhofer, K. Aksit, P. Didyk, K. Myszkowski, D. Luebke, and H. Fuchs, TVCG (IEEE VR 2017)

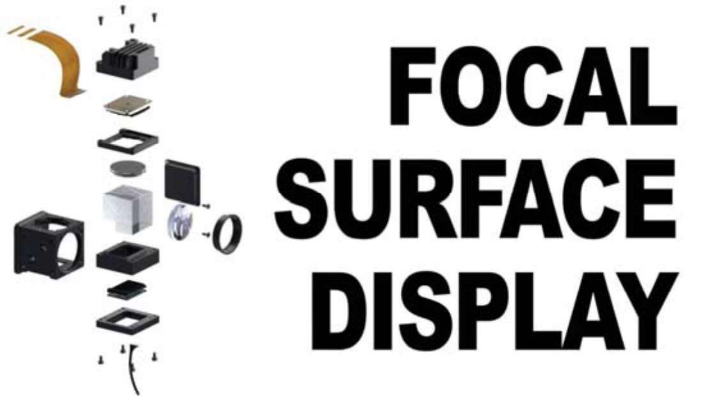
Depth (eye accommodation)



Konrad, R., Padmanaban, N., Molner, K., Cooper, E. A., & Wetzstein, G. (2017). Accommodation-invariant computational near-eye displays. *ACM Transactions on Graphics (TOG)*, *36*(4), 88.

Depth (eye accommodation)

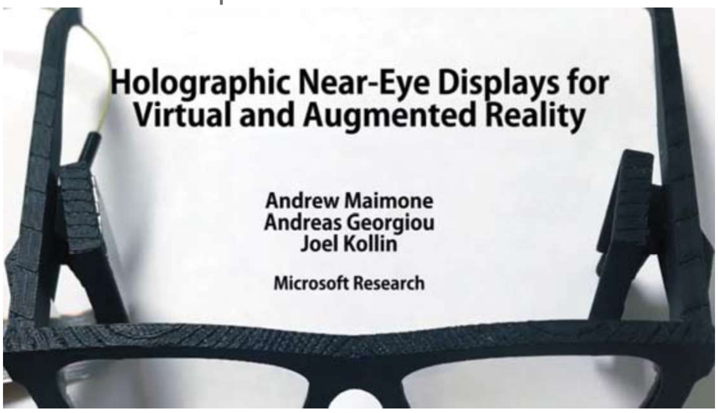
LCoS→"Computational Lens"



Oculus Research , "Focal Surface Display Discovery"
Nathan Matsuda, Alexander Fix, Douglas Lanman, SIGGRAPH 2017

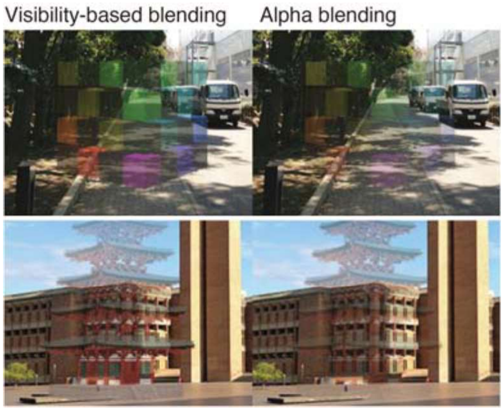
Depth (eye accommodation)

LCoS→"Computational Lens"



"Holographic Near-Eye Displays for Virtual and Augmented Reality," Microsoft Research, Andrew Maimone, Andreas Georgiou, Joel Kollin, Established: May 19, 2017

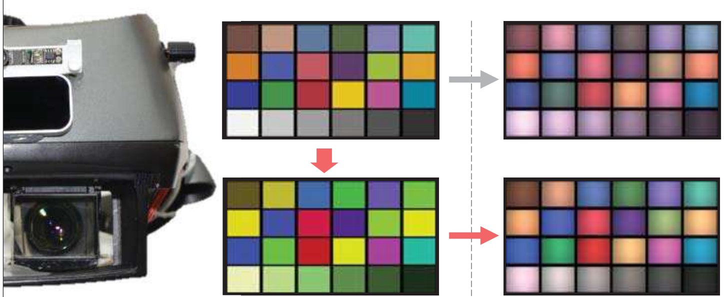
Color Consistency



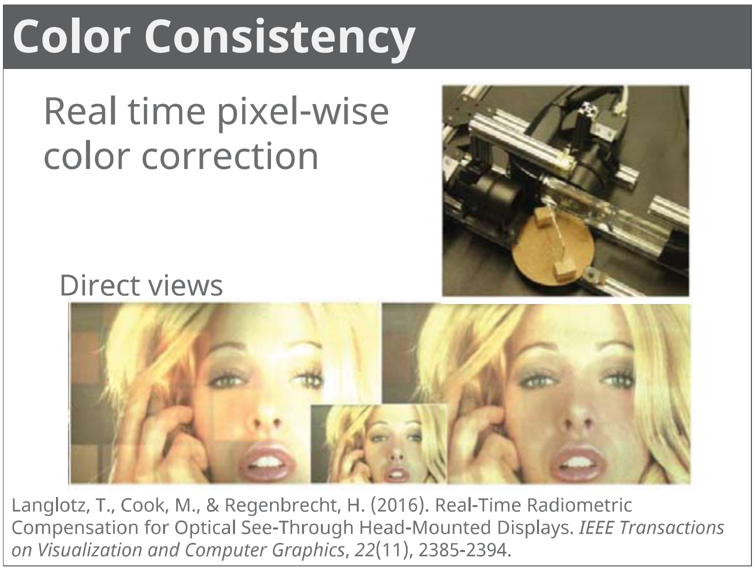
Fukiage, T., Oishi, T., & Ikeuchi, K. (2014, September). Visibility-based blending for real-time applications. In *Mixed and Augmented Reality (ISMAR), 2014 IEEE International Symposium on* (pp. 63-72). IEEE.

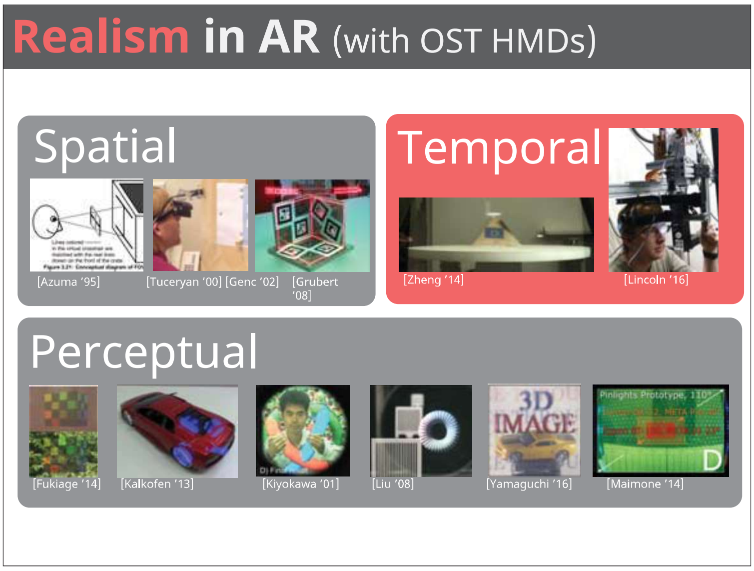
Color Consistency

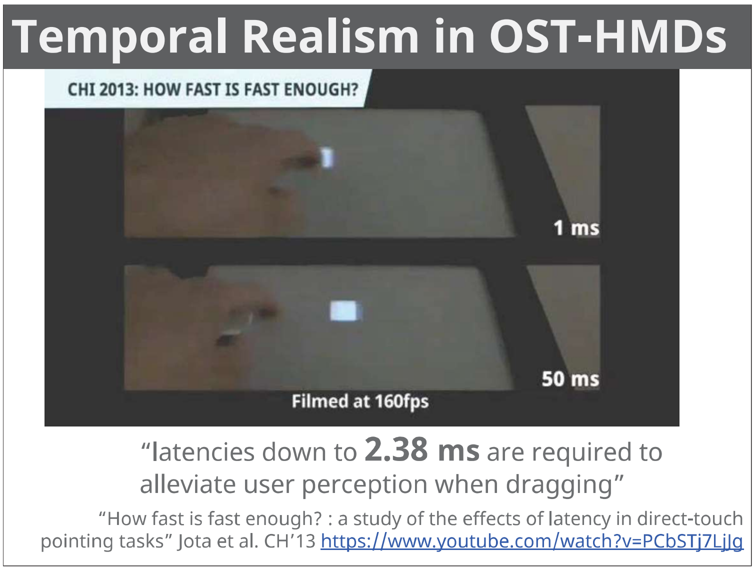
ガウス補正+線形モデル

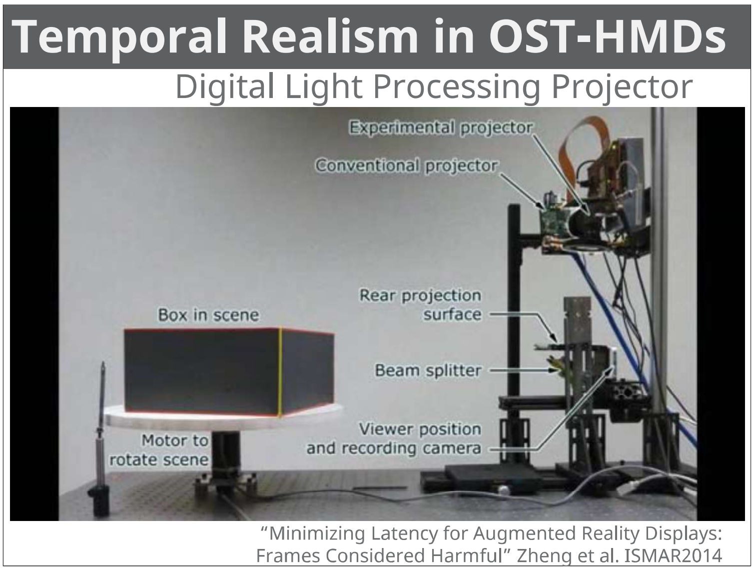


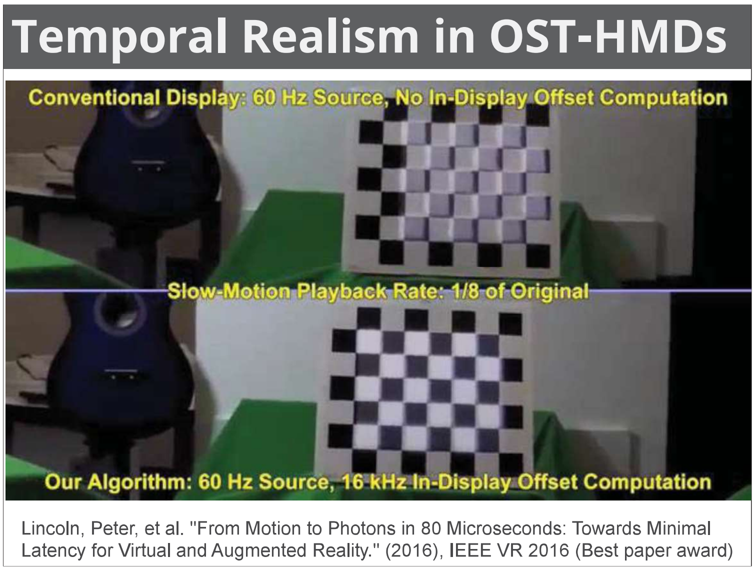
Itoh, Yuta, et al. "Semi-parametric color reproduction method for optical see-through head-mounted displays." *IEEE transactions on visualization and computer graphics* 21.11 (2015): 1269-1278.


Color Consistency
Real time pixel-wise color correction
Direct views
Langlotz, T., Cook, M., & Regenbrecht, H. (2016). Real-Time Radiometric Compensation for Optical See-Through Head-Mounted Displays. *IEEE Transactions on Visualization and Computer Graphics*, *22*(11), 2385-2394.

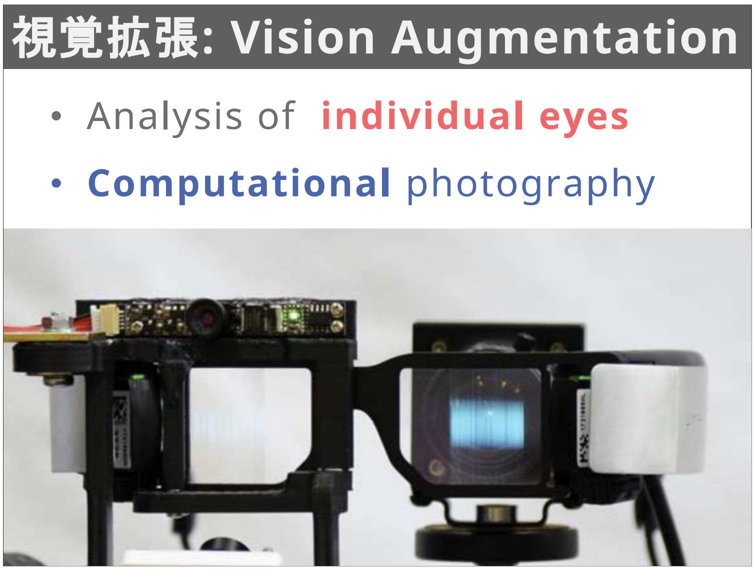

Realism in AR (with OST HMDs)
Spatial
[Azuma '95]
[Tuceryan '00] [Genc '02]
[Grubert '08]
Temporal
[Zheng '14]
[Lincoln '16]
Perceptual
[Fukiage '14]
[Kalkofen '13]
[Kiyokawa '01]
[Liu '08]
[Yamaguchi '16]
[Maimone '14]

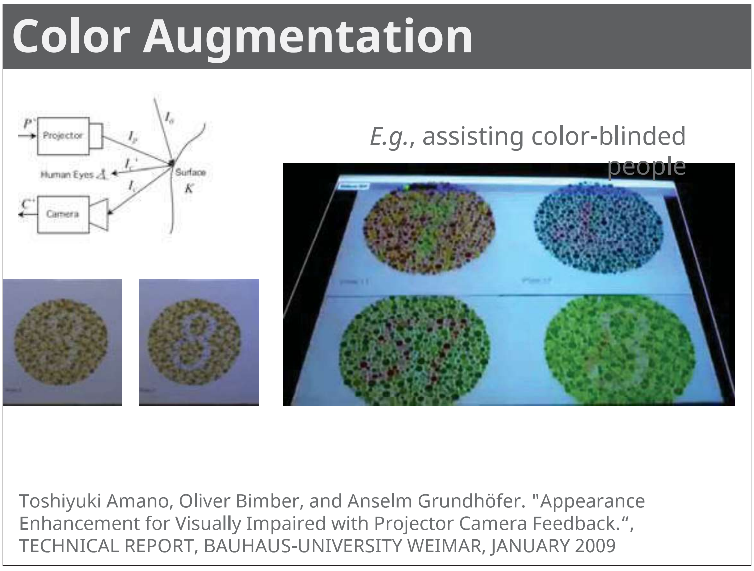

Temporal Realism in OST-HMDs
CHI 2013: HOW FAST IS FAST ENOUGH?
1 ms
50 ms
Filmed at 160fps
"latencies down to 2.38 ms are required to alleviate user perception when dragging"
"How fast is fast enough? : a study of the effects of latency in direct-touch pointing tasks" Jota et al. CH'13 https://www.youtube.com/watch?v=PCbSTj7LjJg

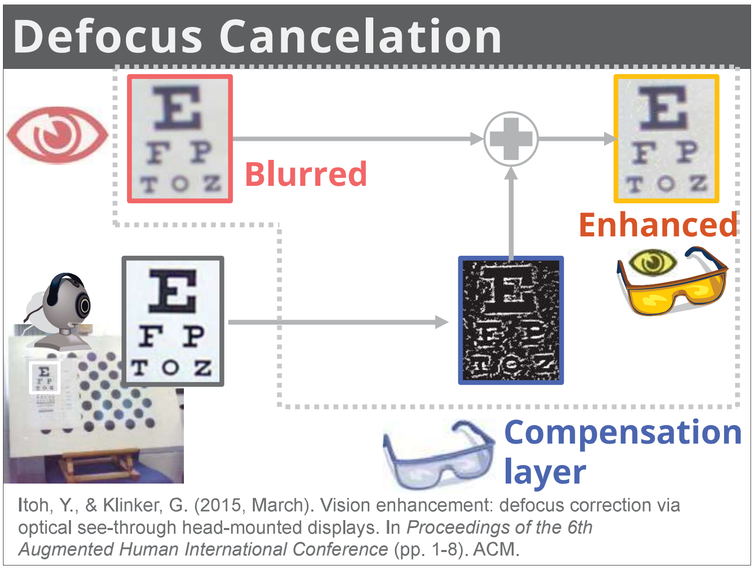

Temporal Realism in OST-HMDs
Digital Light Processing Projector
Experimental projector
Conventional projector
Rear projection surface
Box in scene
Beam splitter
Viewer position and recording camera
Motor to rotate scene
"Minimizing Latency for Augmented Reality Displays: Frames Considered Harmful" Zheng et al. ISMAR2014

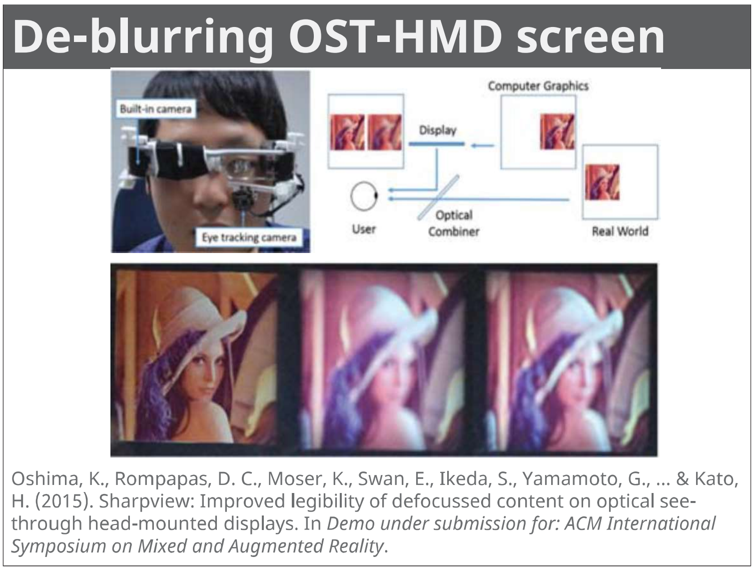

Temporal Realism in OST-HMDs
Conventional Display: 60 Hz Source, No In-Display Offset Computation
Slow-Motion Playback Rate: 1/8 of Original
Our Algorithm: 60 Hz Source, 16 kHz In-Display Offset Computation
Lincoln, Peter, et al. "From Motion to Photons in 80 Microseconds: Towards Minimal Latency for Virtual and Augmented Reality." (2016), IEEE VR 2016 (Best paper award)


If we have a perfect HMD
in the future....
Vision
Augmentation

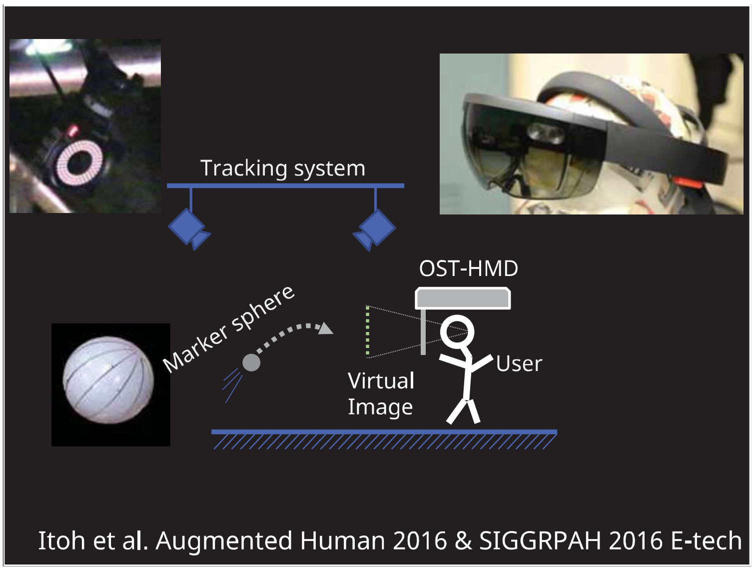

視覚拡張: Vision Augmentation
• Analysis of individual eyes
• Computational photography


Color Augmentation
Projector
Human Eyes
Camera
Surface
E.g., assisting color-blinded people
Toshiyuki Amano, Oliver Bimber, and Anselm Grundhöfer. "Appearance Enhancement for Visually Impaired with Projector Camera Feedback.", TECHNICAL REPORT, BAUHAUS-UNIVERSITY WEIMAR, JANUARY 2009

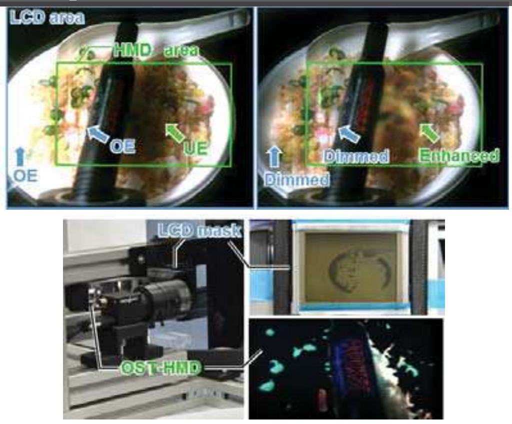

Defocus Cancelation
E F P T O Z
Blurred
Enhanced
Compensation layer
Itoh, Y., & Klinker, G. (2015, March). Vision enhancement: defocus correction via optical see-through head-mounted displays. In Proceedings of the 6th Augmented Human International Conference (pp. 1-8). ACM.


De-blurring OST-HMD screen
Built-in camera
Eye tracking camera
Computer Graphics
Display
User
Optical Combiner
Real World
Oshima, K., Rompapas, D. C., Moser, K., Swan, E., Ikeda, S., Yamamoto, G., ... & Kato, H. (2015). Sharpview: Improved legibility of defocussed content on optical see-through head-mounted displays. In Demo under submission for: ACM International Symposium on Mixed and Augmented Reality.


Predictive vision
OST-HMD + World sensing
SIGGRAPH2016
Itoh et al. Augmented Human 2016 & SIGGRPAH 2016 E-tech

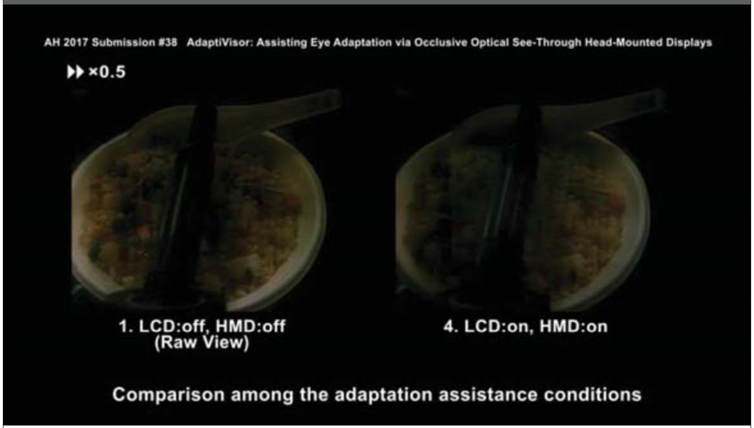

Tracking system
OST-HMD
Marker sphere
User
Virtual Image
Itoh et al. Augmented Human 2016 & SIGGRPAH 2016 E-tech

Eye adaptation assistance



Hiroi, Y., Itoh, Y., Hamasaki, T., & Sugimoto, M. (2017, March). AdaptiVisor: assisting eye adaptation via occlusive optical see-through head-mounted displays. In *Proceedings of the 8th Augmented Human International Conference* (p. 9). ACM.

Eye adaptation assistance



Hiroi, Y., Itoh, Y., Hamasaki, T., & Sugimoto, M. (2017, March). AdaptiVisor: assisting eye adaptation via occlusive optical see-through head-mounted displays. In *Proceedings of the 8th Augmented Human International Conference* (p. 9). ACM.

まとめ

OST-HMD **x 立体映像・高臨場感**

- 現実世界との**整合性**を担保する
  - 時間的・空間的・視覚的
- AR・VRの普及期

- 視覚拡張（HMDによる視覚の再定義？）
  - **Computational Photography**
    x Optical See-Through HMDs

お勧めの論文誌・国際会議

- 論文誌（ARやVR, Display）
  - IEEE TVCG (Tran. Visualization and C. G.)
  - ACM ToG (Transaction on Graphics)
- 国際会議
  - IEEE ISMAR, IEEE VR
    - Full paperは**直接TVCG Special Issue**へ
  - Augmented Human
    - 人間拡張技術全般
  - SIGGRAPH
    - 最近HMD系が多い