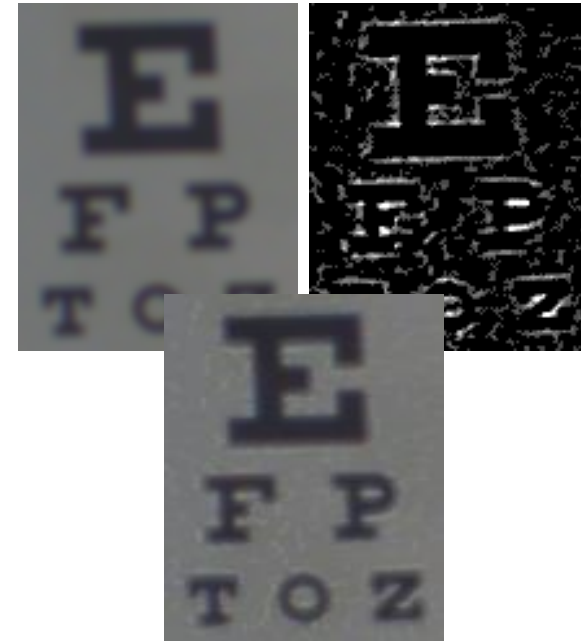
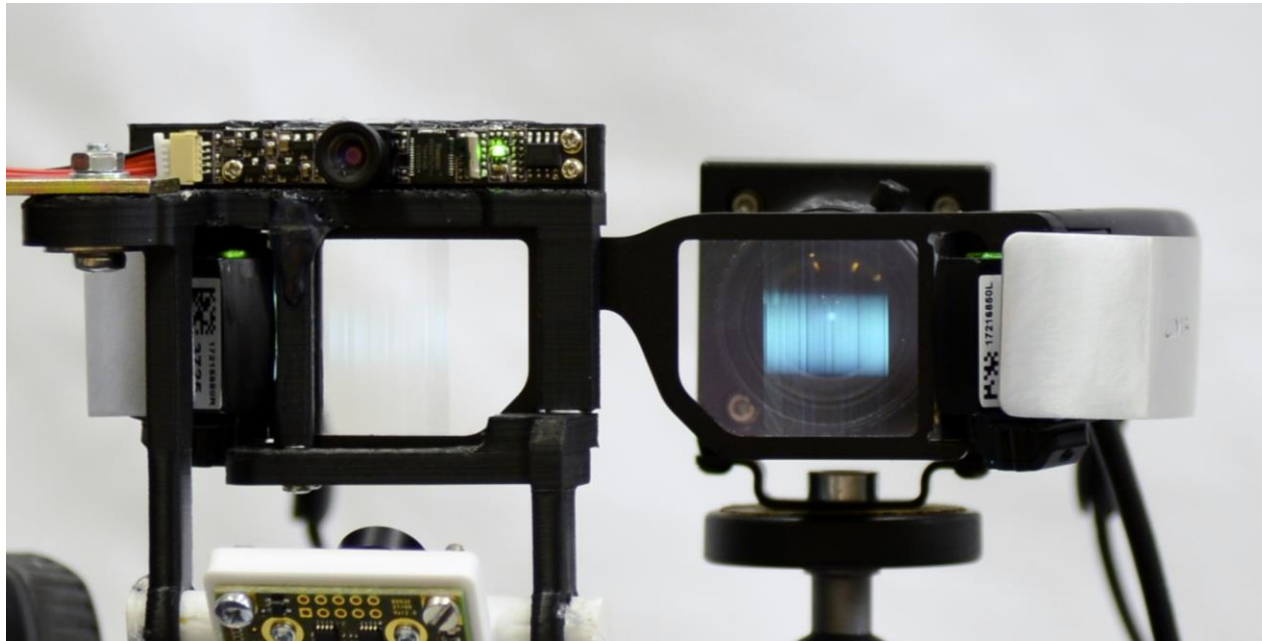


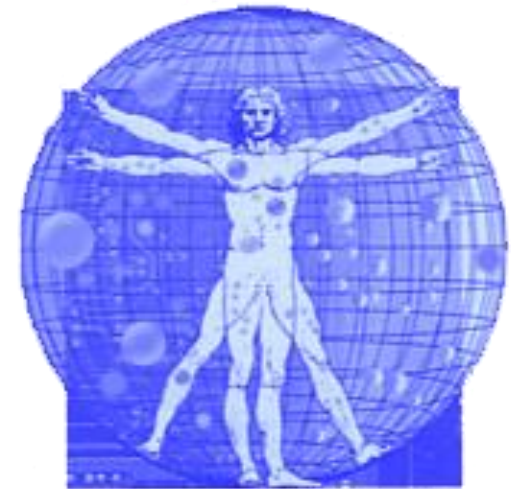
# Vision Enhancement: Defocus Correction via Optical See-Through Head-Mounted Displays

Yuta Itoh and Gudrun Klinker  
TU Munich, WARM2015, 5<sup>th</sup> Feb 2015



# This work

To appear in proc. of the 6 th  
**Augmented Human** Int. conf.  
**(AH'15, March, Singapore)**



**AUGMENTED HUMAN**



# Head-Mounted Displays

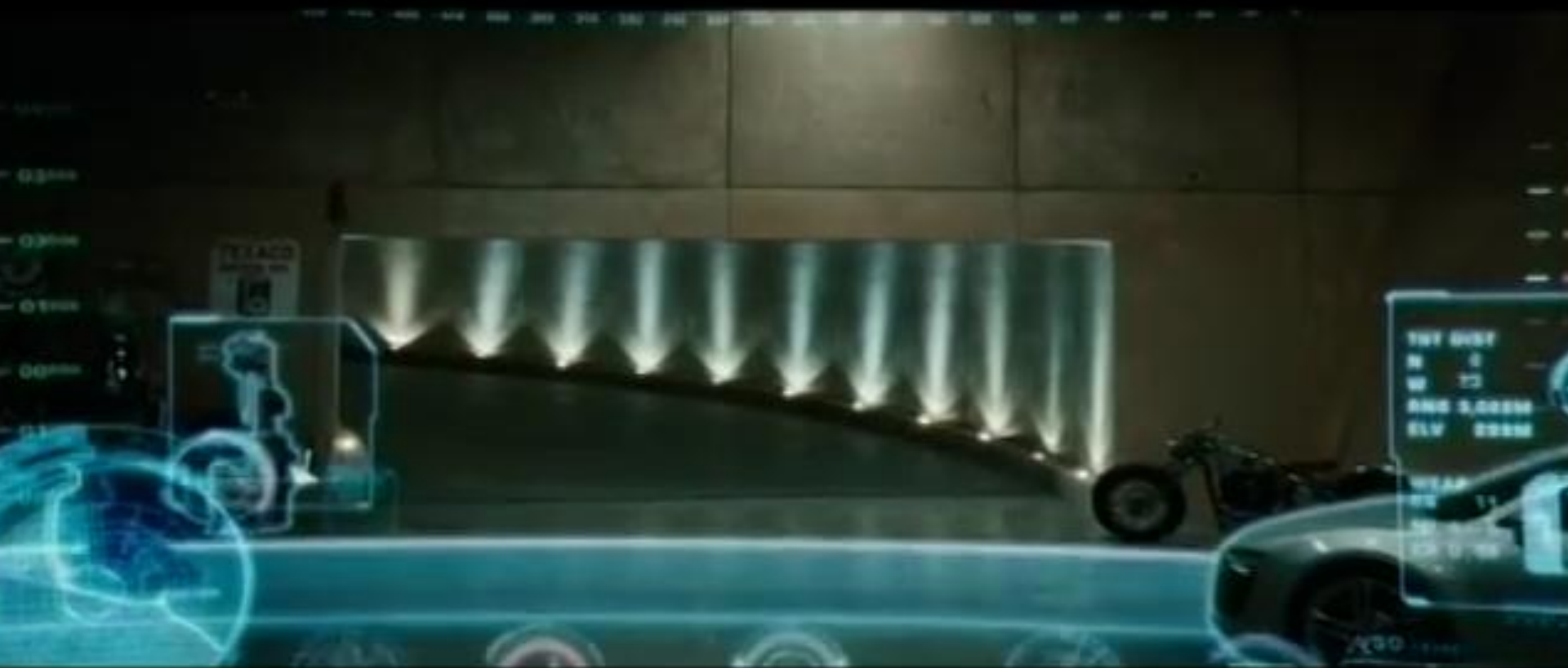
## Non Optical See-Through



## Optical See-Through (OST-HMD)



# Vision Enhancement in Science Fictions...



From Ironman, 2008 ©Marvel Entertainment

# Vision Enhancement in Science Fictions...



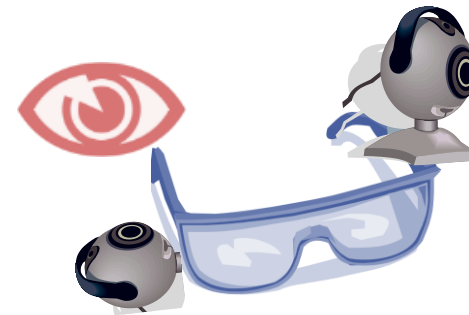
- World **sensing**
- **Eye** tracking

# Vision Enhancement in Science Fictions...



From Mission: Impossible - Ghost Protocol , 2011 ©Paramount Pictures

# Vision Enhancement in Science Fictions...

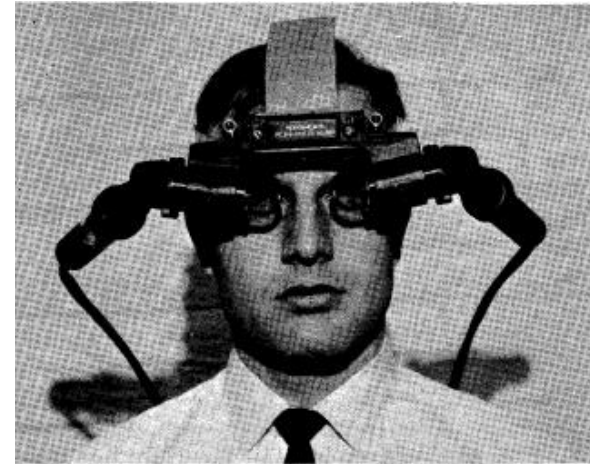


- World sensing
- Eye tracking
- Color replication
- Fine resolution

# Vision Enhancement

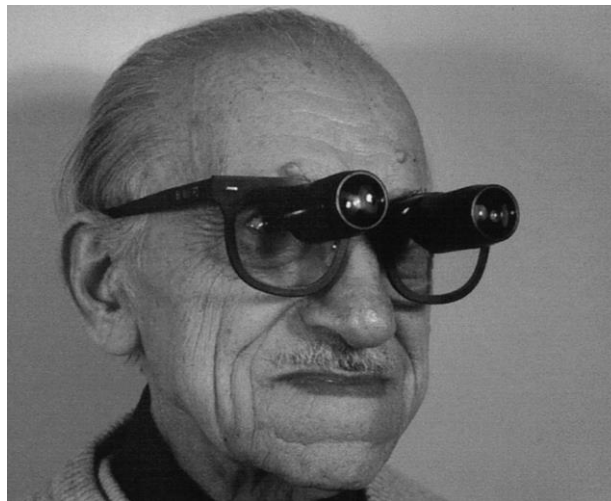
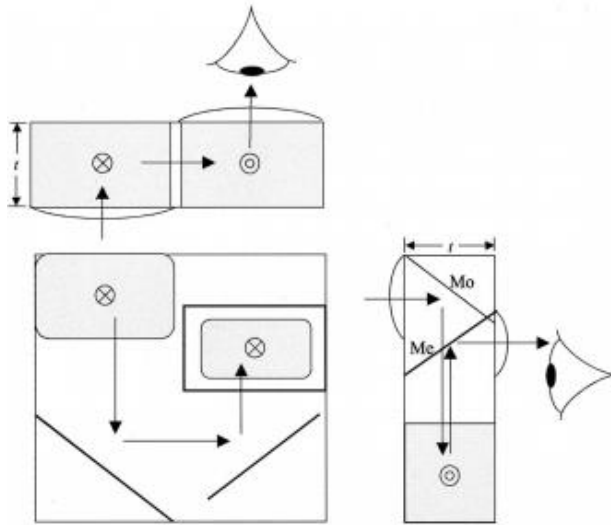
Given an ultimate OST-HMD....

- ▣ What's unique in theoretical **formulation**?
- ▣ Current **limitations** and **open issues**?





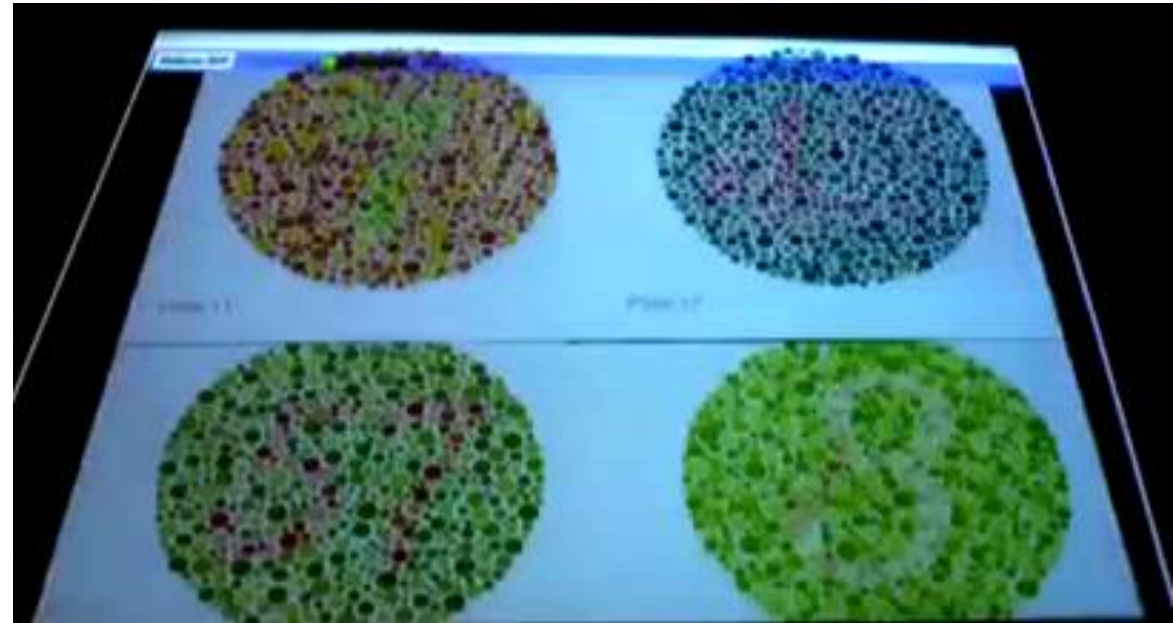
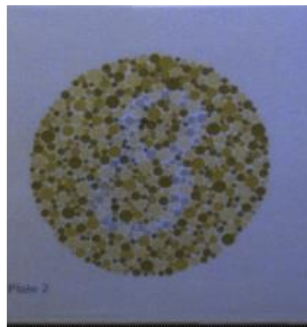
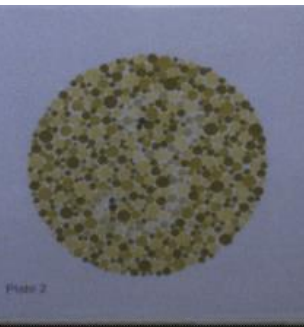
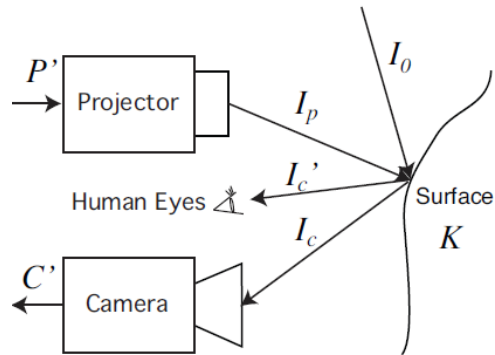
# Related Work | low-vision devices



Peli, Eli. "Vision multiplexing: an engineering approach to vision rehabilitation device development." *Optometry & Vision Science* 78.5 (2001): 304-315.

Peli, Eli. "Treating with spectacle lenses: a novel idea!?" *Optometry & Vision Science* 79.9 (2002): 569-580.

# Related Work | color enhancement



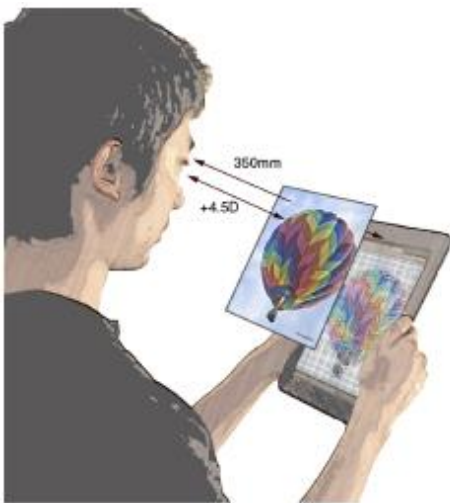
[AmanoBG09] Toshiyuki Amano, Oliver Bimber, and Anselm Grundhöfer. "Appearance Enhancement for Visually Impaired with Projector Camera Feedback." TECHNICAL REPORT, BAUHAUS-UNIVERSITY WEIMAR, JANUARY 2009

# Related Work | contrast enhancement



Broecker, Markus, Ross T. Smith, and Bruce H. Thomas. "Adaptive substrate for enhanced spatial augmented reality contrast and resolution." *transport* 3.6 (2011): 22.

# Related Work | de-blurring displays



Huang, Fu-Chung, et al. "Computational light field display for correcting visual aberrations." *ACM SIGGRAPH 2013 Posters*. ACM, 2013.

# Related Work | Super-resolution displays

Cascaded LCD Prototype



Conventional Display



Cascaded Display



Factorizations

Layer 1

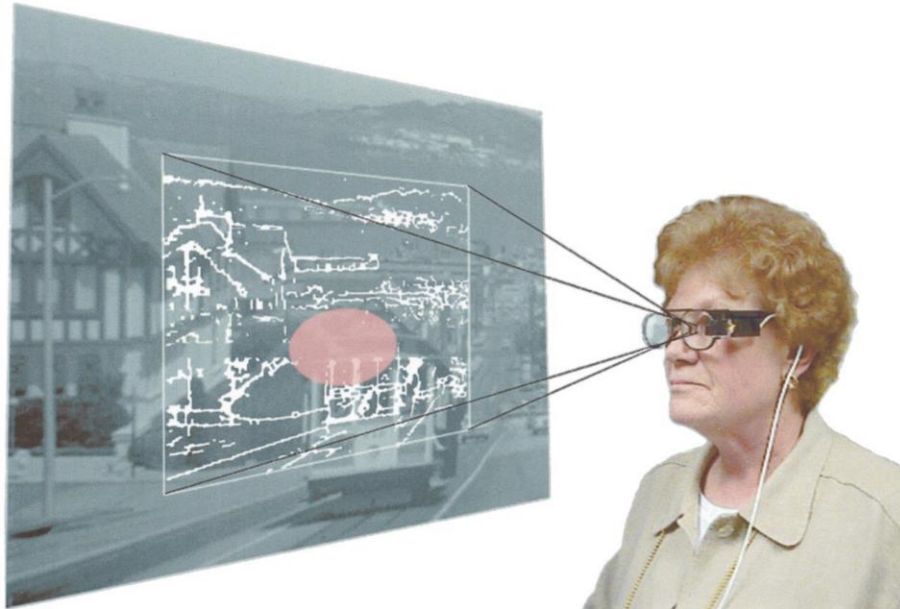


Layer 2



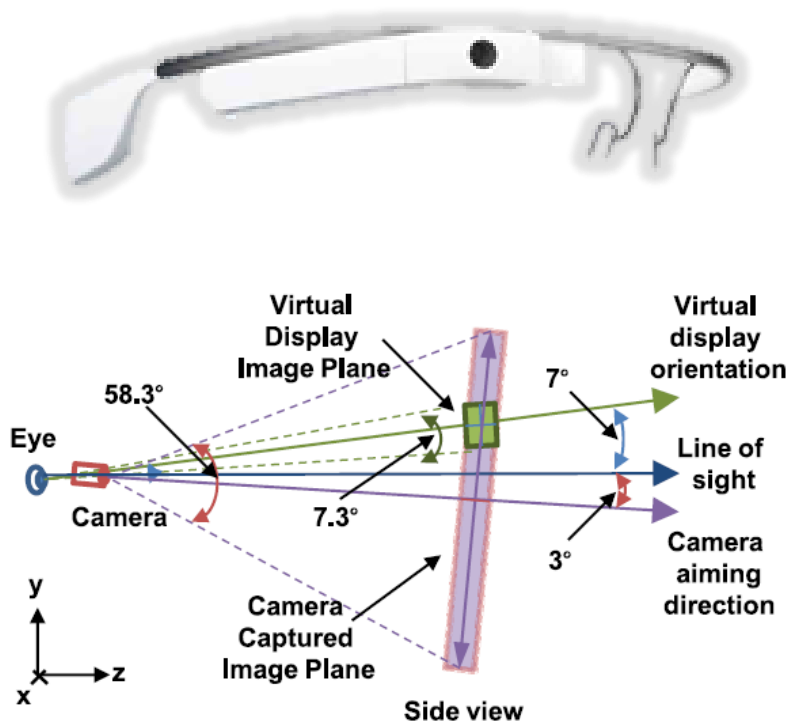
Lanman, Douglas, et al. "Cascaded displays: spatiotemporal superresolution using offset pixel layers." *ACM SIGGRAPH 2014 Emerging Technologies*. ACM, 2014.

# Related Work | Edge Enhancement



Luo, Gang, and Eli Peli. "Use of an augmented-vision device for visual search by patients with tunnel vision." *Investigative ophthalmology & visual science* 47.9 (2006): 4152-4159.

# Related Work | Edge Enhancement



Hwang, Alex D., and Eli Peli. "An augmented-reality edge enhancement application for Google Glass." *Optometry & Vision Science* 91.8 (2014): 1021-1030.

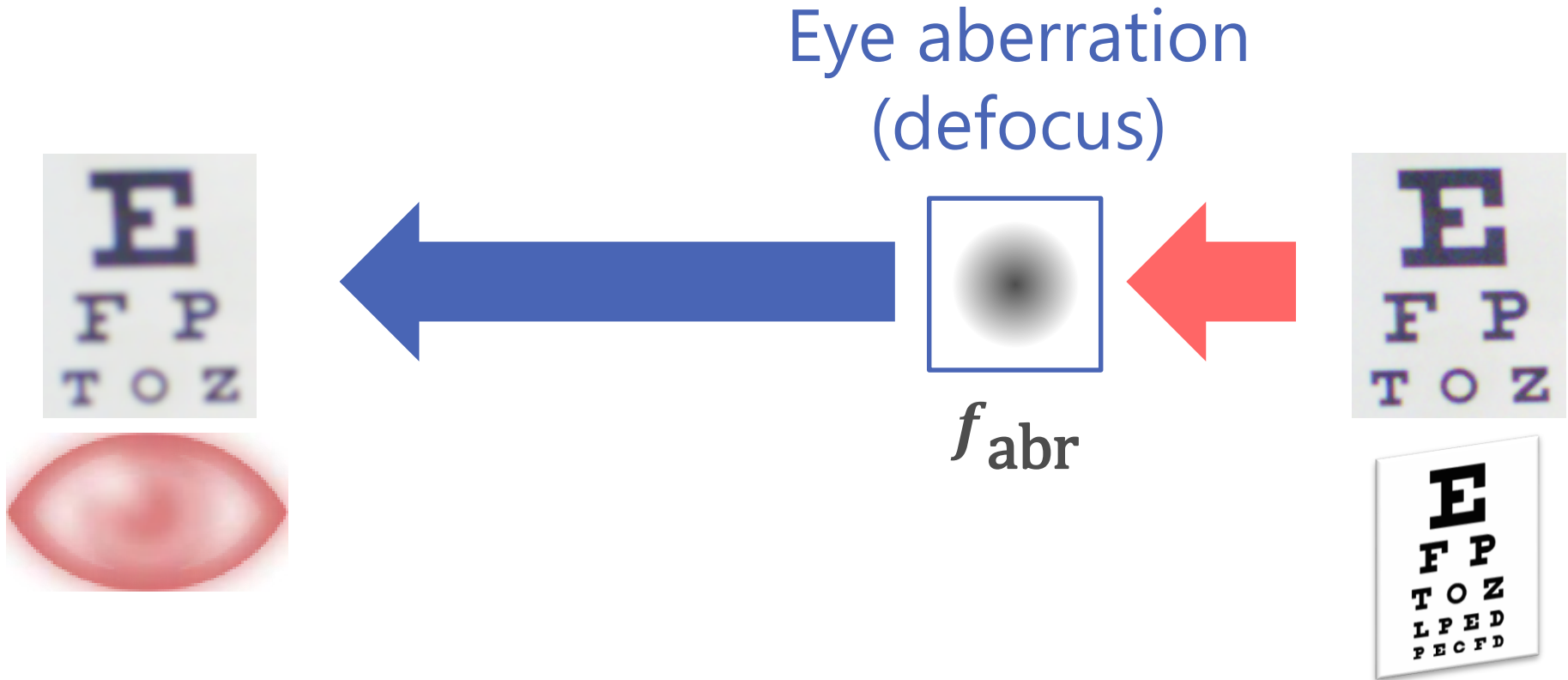
# Related Work | AR X-ray vision



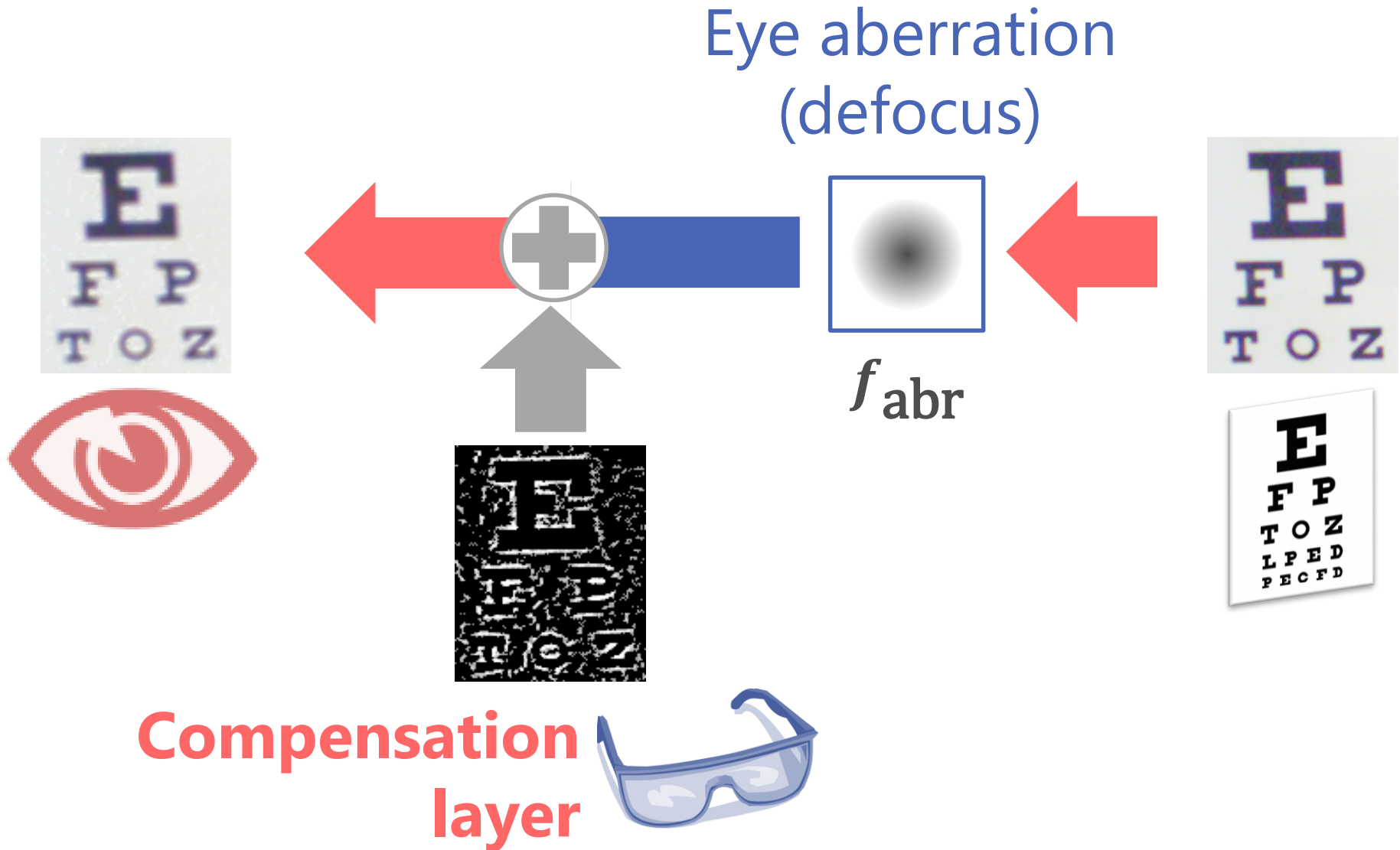
Avery, Ben, Christian Sandor, and Bruce H. Thomas. "Improving spatial perception for augmented reality x-ray vision." *Virtual Reality Conference, 2009. VR 2009. IEEE. IEEE, 2009.*



# Our focus: Eye aberration



# Defocus Correction via OST-HMDs



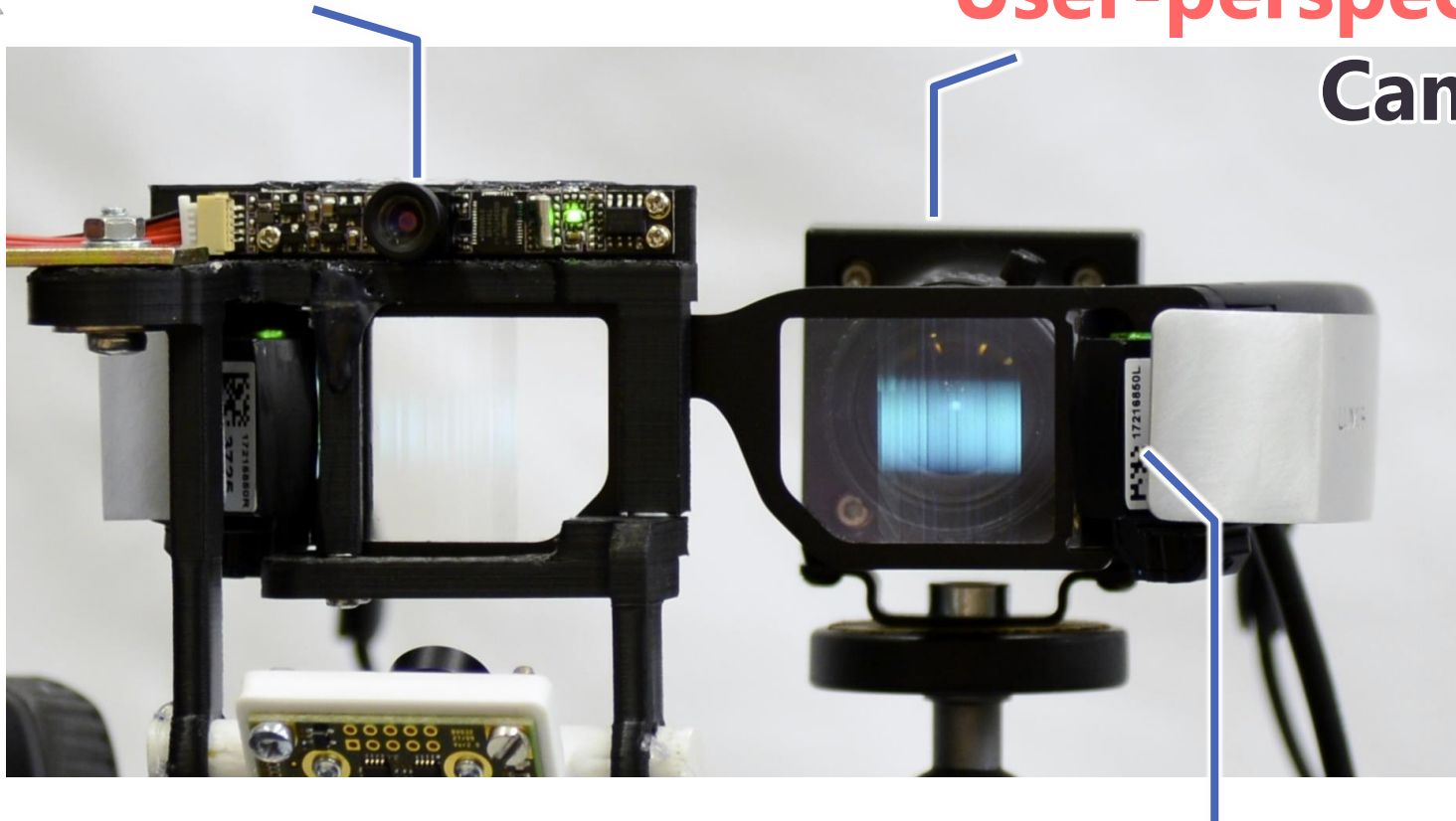
# Hardware setup



**World Camera**

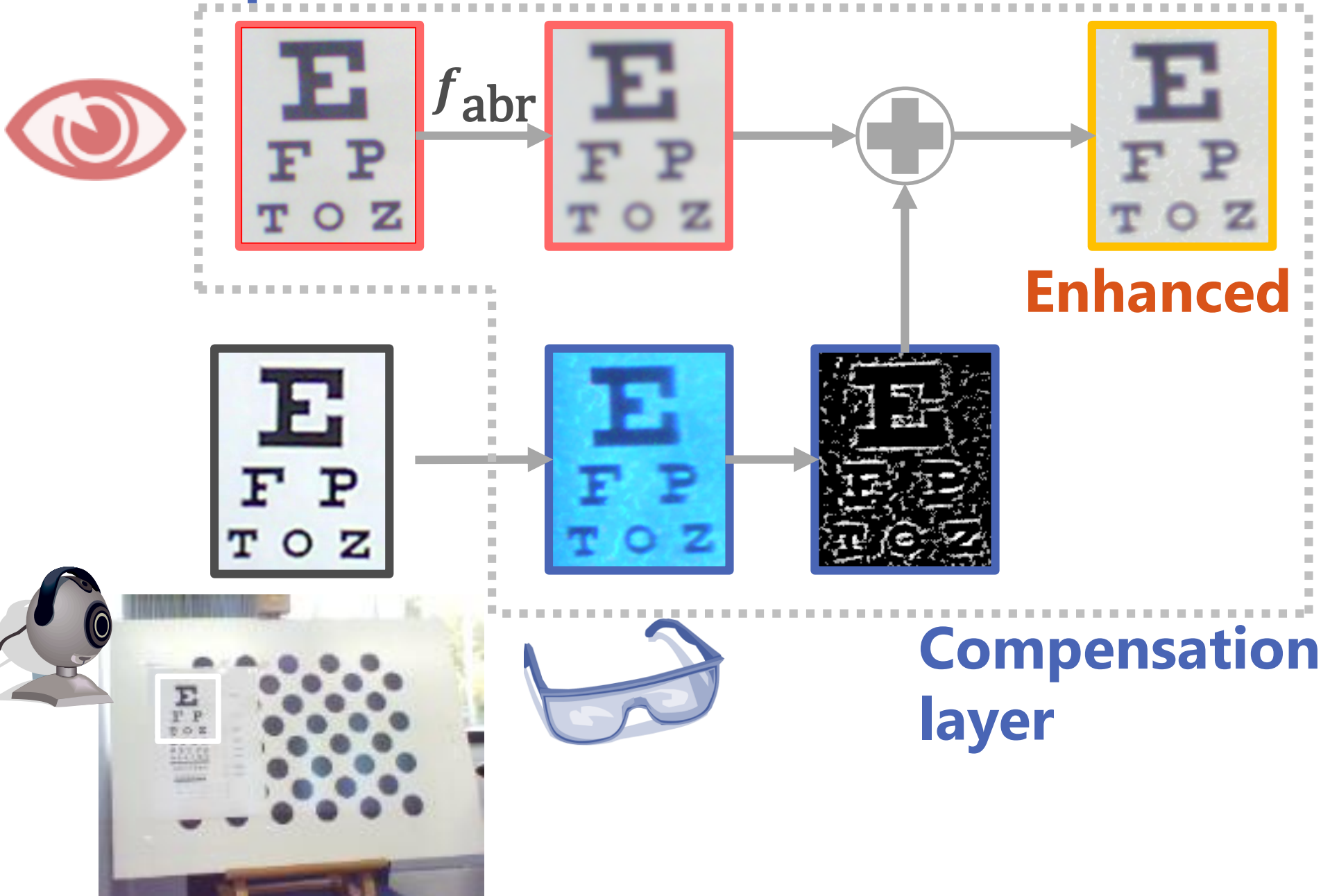


**User-perspective  
Camera**



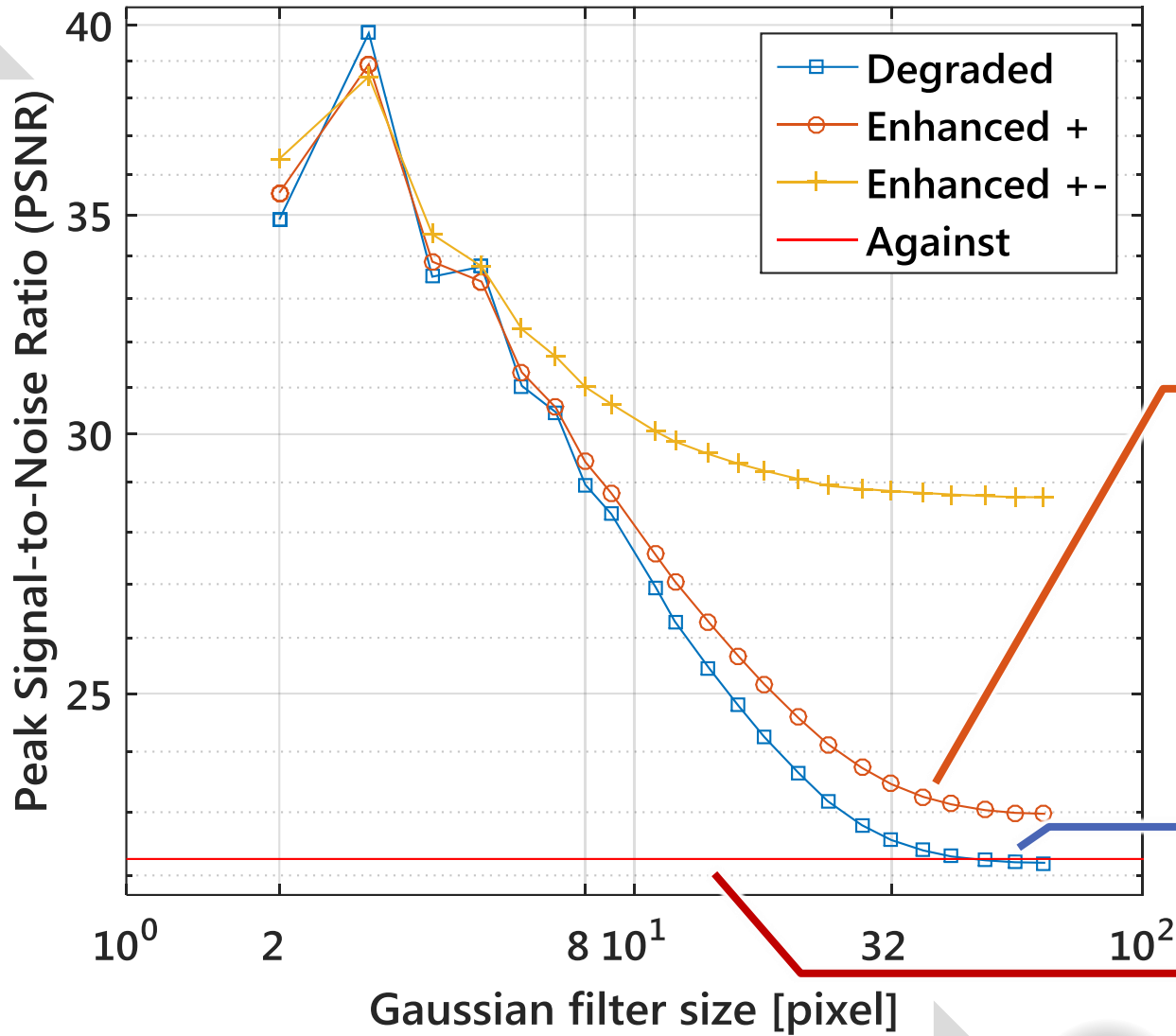
**Optical See-Through HMD**  
(Lumus DK32)

# Conceptual Evaluation



# Results

Better



Enhanced

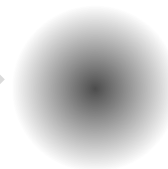


Original






World Cam.



Defocus



# Open problems

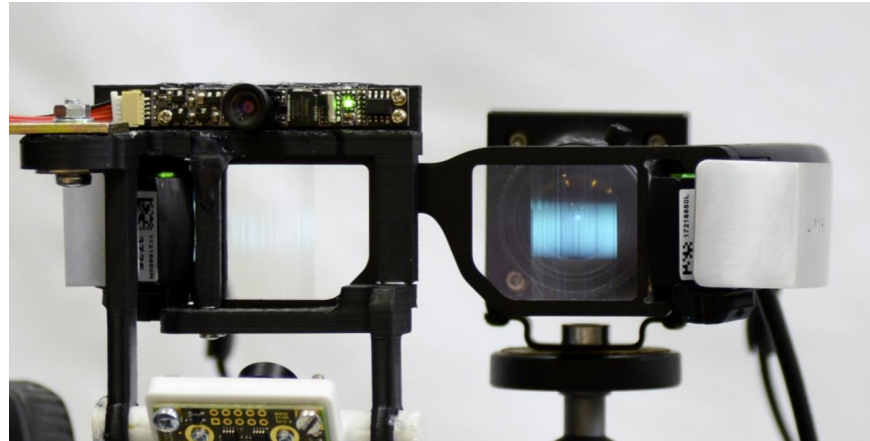
-  • User-perspective rendering
-  • Eye aberration estimation
-  • Display resolutions
-  • Negative color display
-  • Color replication
- ...

# Summary

Can **ultimate** OST-HMDs **enhance vision**?

- Investigated **defocus correction** in a conceptual OST-HMD setup
- Provided **open problems** toward a **practical** vision enhancement with OST-HMDs

# Any questions?



This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under PITN-GA-2012-316919-EDUSAFE.



# Appendix

# Vision Enhancement Applications

- Dynamic range (sunglasses, night vision goggles)
- Focal length (corrective glasses)
- Field of view (telescopes, microscopes, low-vision glasses [23, 24])
- Spectrum range (thermal goggles)
- Exposure (stroboscopic/shutter glasses [15])

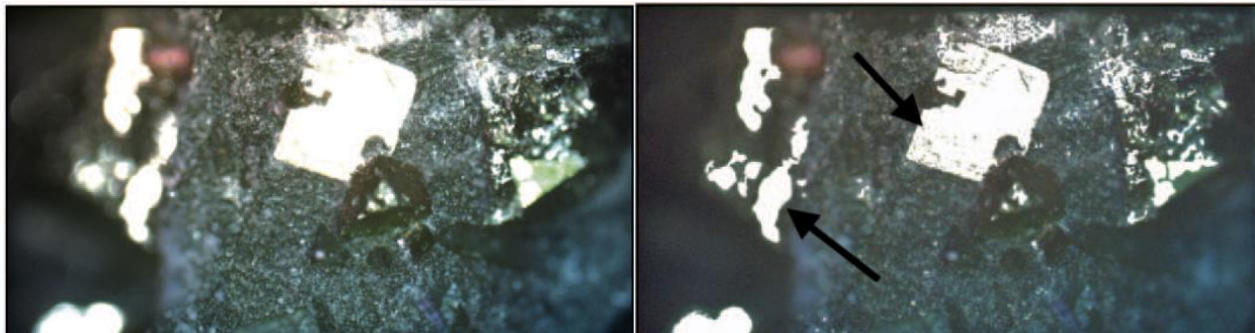
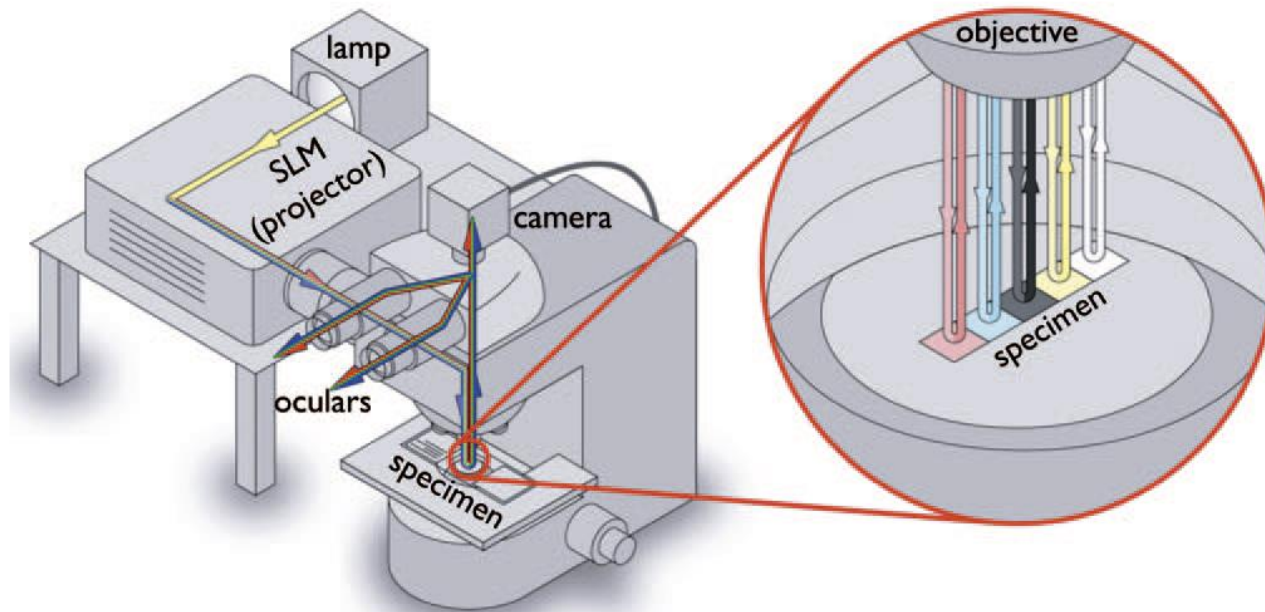
# A military OST-HMD system



BAE Systems, Q-warrior

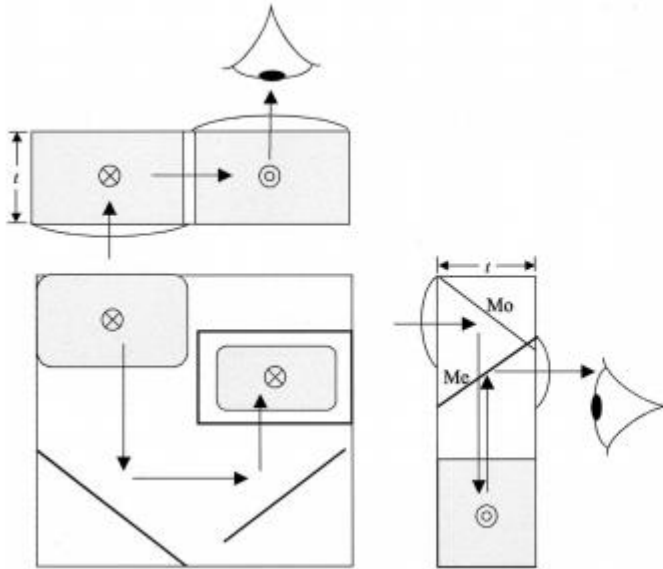
<http://www.telegraph.co.uk/finance/newsbysector/industry/defence/10640078/BAE-Systems-launches-high-tech-Iron-Man-helmet.html>

# Related Work | HDR microscopy



Bimber, Oliver, et al. "Closed-loop feedback illumination for optical inverse tone-mapping in light microscopy." *Visualization and Computer Graphics, IEEE Transactions on* 17.6 (2011): 857-870.

# Related Work | Field of view enhan.



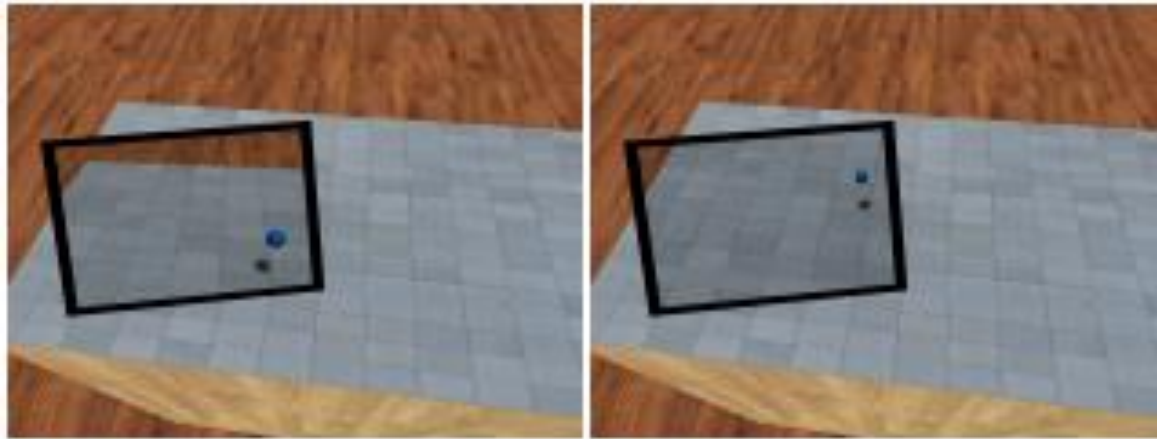
**FIGURE 14.**

An illustration of the view of the SimulVision effect that is possible with



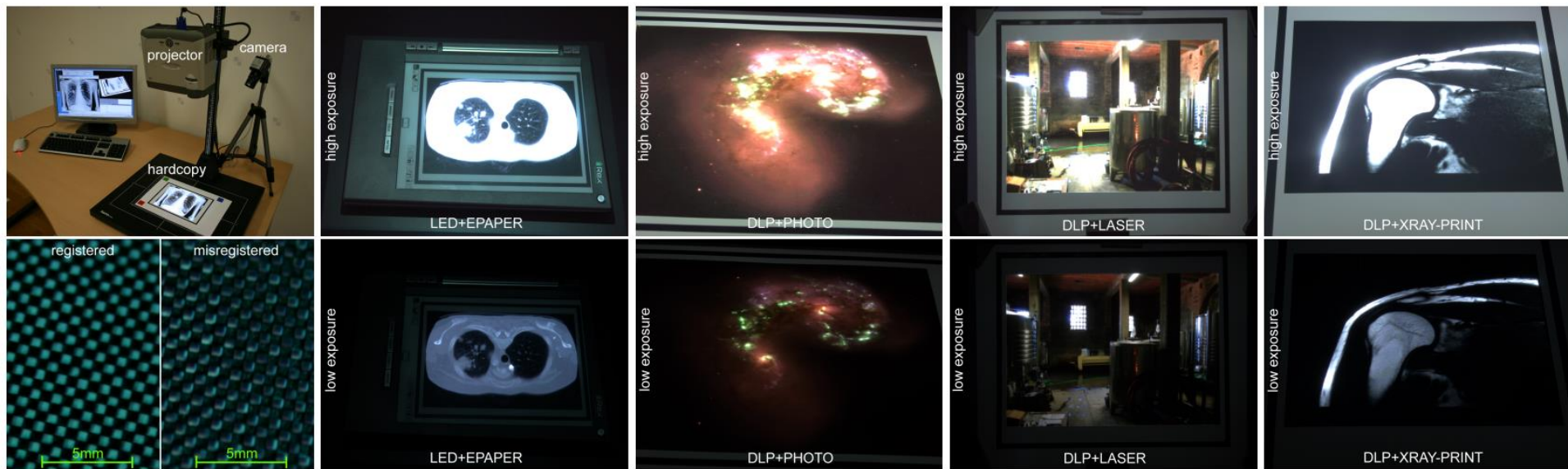
Treating with Spectacle Lenses: a Novel Idea!?  
PELI, ELI MSc, OD, FAAO

# Related Work | User-perspective image rendering



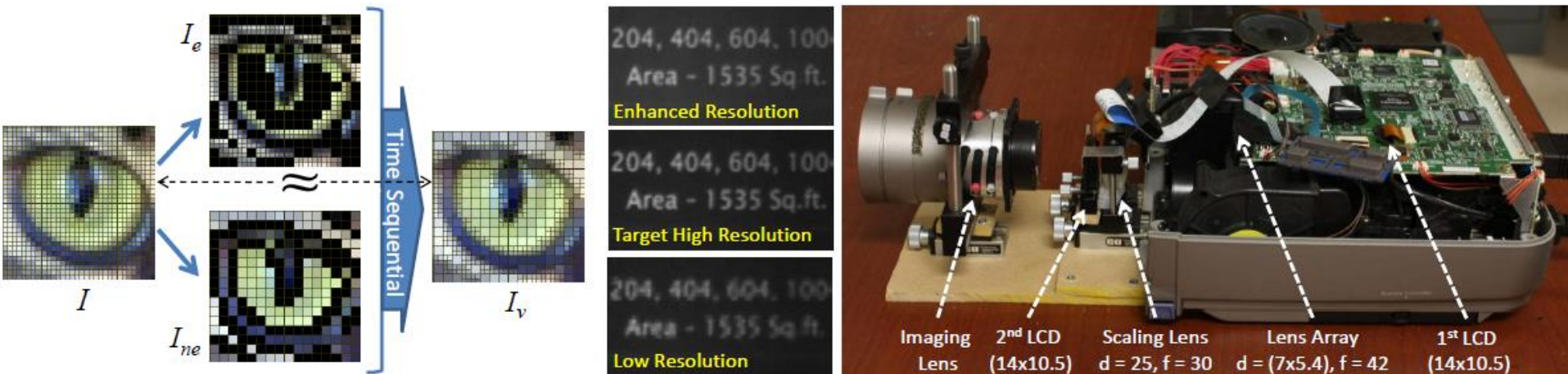
Baricevic, Domagoj, et al. "A hand-held AR magic lens with user-perspective rendering." *Mixed and Augmented Reality (ISMAR), 2012 IEEE International Symposium on*. IEEE, 2012.

# Related Work | HDR by projector



Bimber, Oliver, and Daisuke Iwai. "Superimposing dynamic range." *ACM Transactions on Graphics (TOG)*. Vol. 27. No. 5. ACM, 2008.

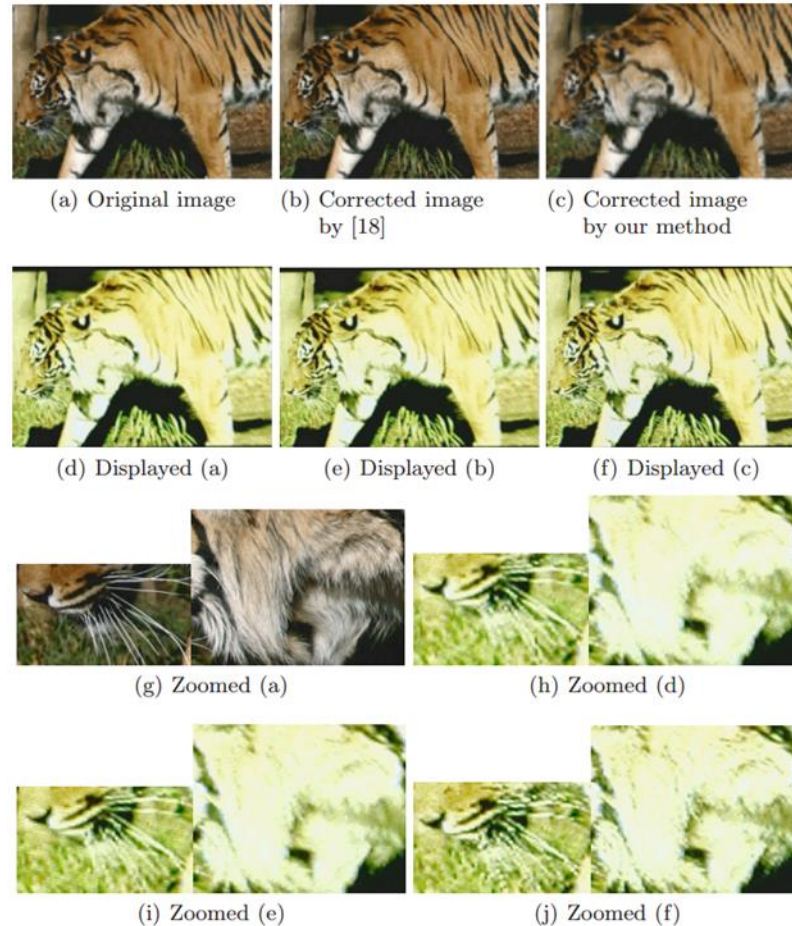
# Related Work | temporal super resolution



Sajadi, Behzad, M. Gopi, and Aditi Majumder. "Edge-guided resolution enhancement in projectors via optical pixel sharing." ACM Transactions on Graphics (TOG) 31.4 (2012): 79.



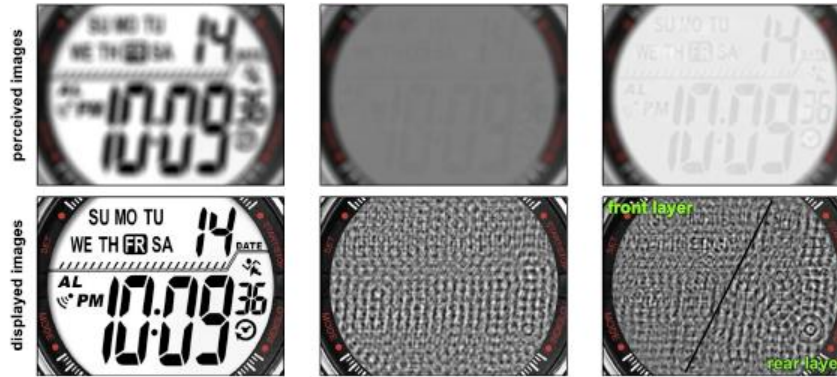
# Related Work | de-blurring



Oyamada, Yuji, and Hideo Saito. "Defocus blur correcting projector-camera system." *Advanced Concepts for Intelligent Vision Systems*. Springer Berlin Heidelberg, 2008.

# Related Work | de-blurring displays

## Correct visual aberrations



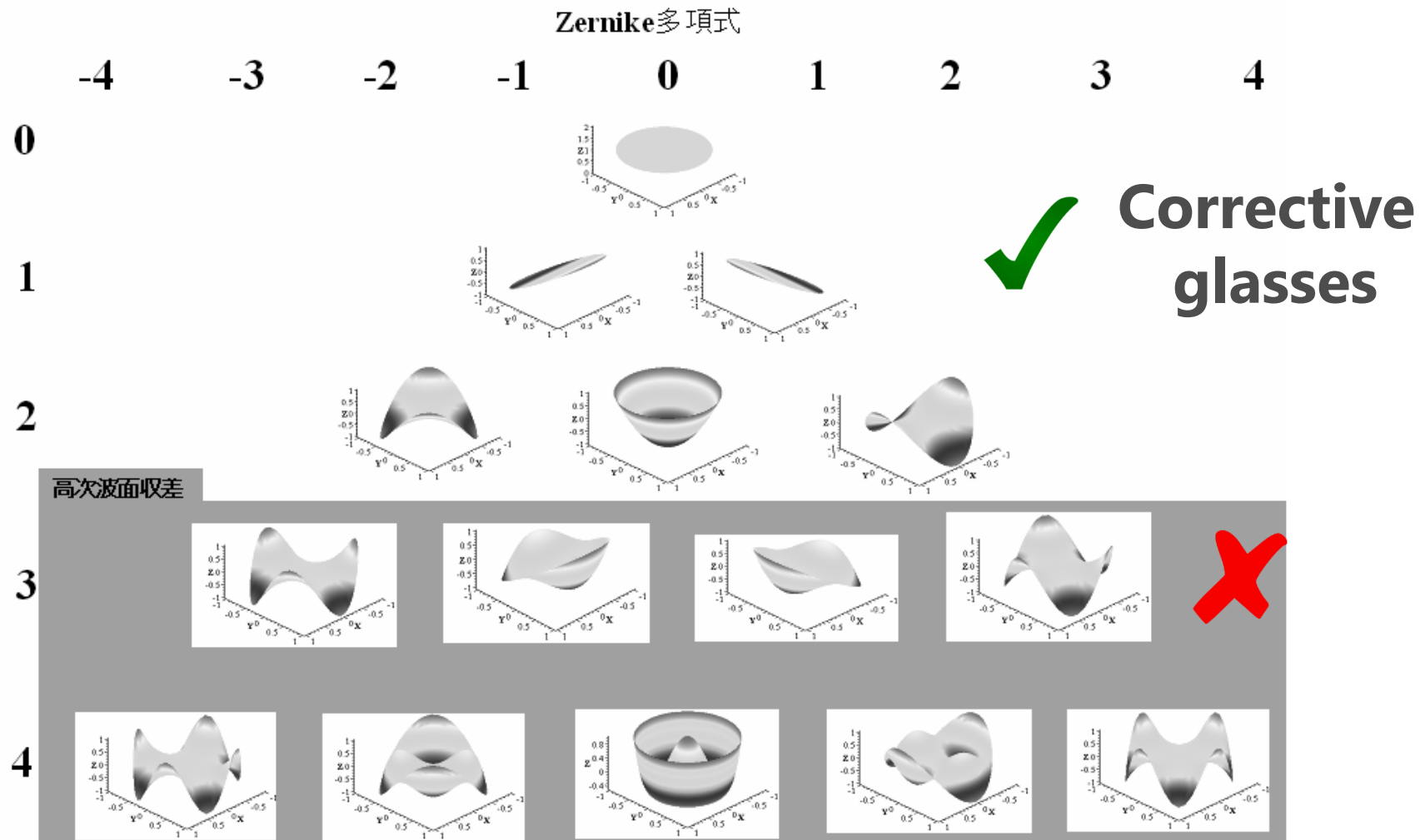
Strong Presbyopia  
(farsightedness)



Huang, Fu-Chung, et al. "Correcting for optical aberrations using multilayer displays." *ACM Transactions on Graphics (TOG)* 31.6 (2012): 185.

Pamplona, Vitor F., et al. "Tailored displays to compensate for visual aberrations." *ACM Trans. Graph.* 31.4 (2012): 81.

# Zernike Polynomial

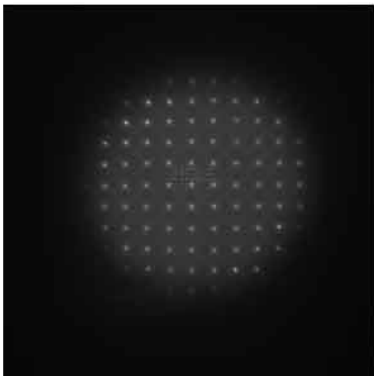


二宮さゆり. "波面センサーによる眼球の波面収差測定と網膜像推定." *Medical imaging technology* 23.1 (2005): 47-51.

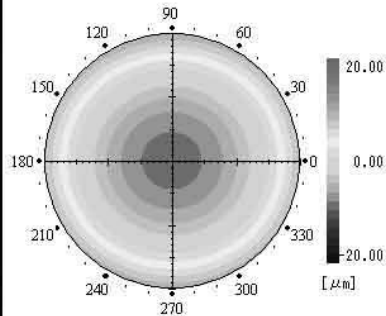
# Related Work | Wave-front sensor

瞳孔直径 = 5.99 mm / WF解析中心 = 瞳孔中心 / WF中心移動量 = 0.282 mm

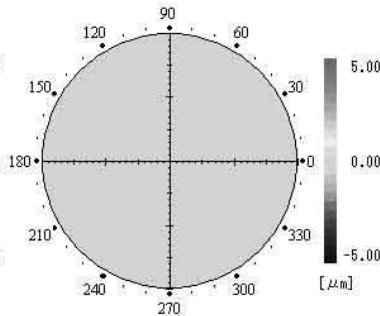
Hartmann Image



Total Aberrations

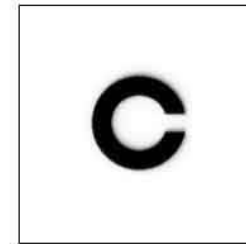


Higher Order Aberrations



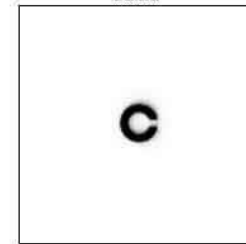
## Emmetropia

Landolt



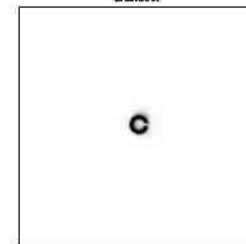
VA 20/100

Landolt



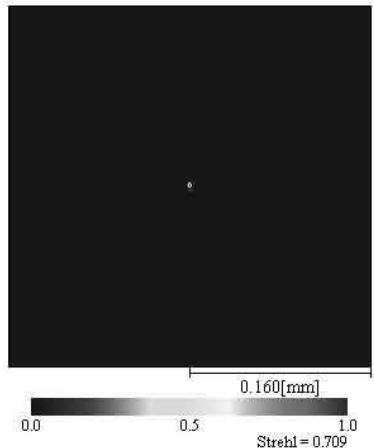
VA 20/40

Landolt

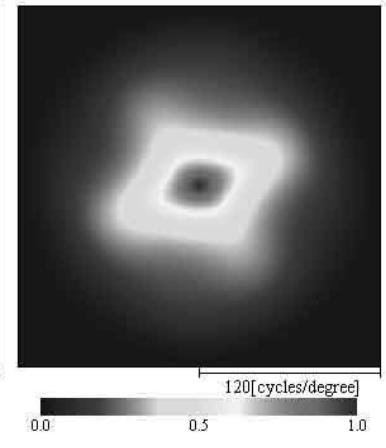


VA 20/20

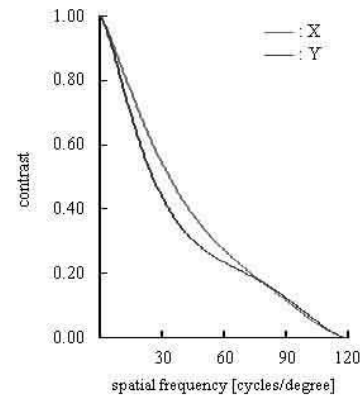
wave-front/PSF



MTF



MTF Graph



<< Simulated by ocular wavefront zernike coefficient (4mm) >>

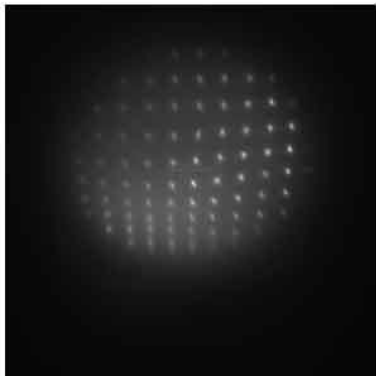
二宮さゆり. "波面センサーによる眼球の波面収差測定と網膜像推定." *Medical imaging technology* 23.1 (2005): 47-51.

# Related Work | Wave-front sensor

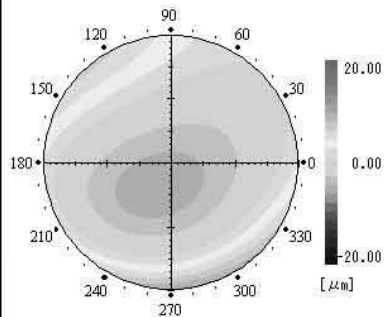
瞳孔直径 = 6.13 mm / WF解析中心 = 瞳孔中心 / WF中心移動量 = 0.326 mm

## Keratoconus/円錐角膜

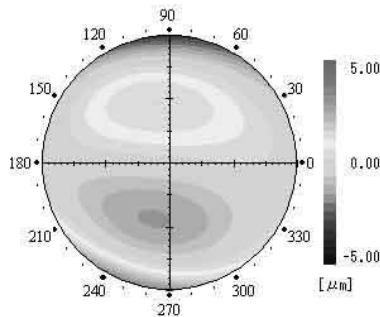
Hartmann Image



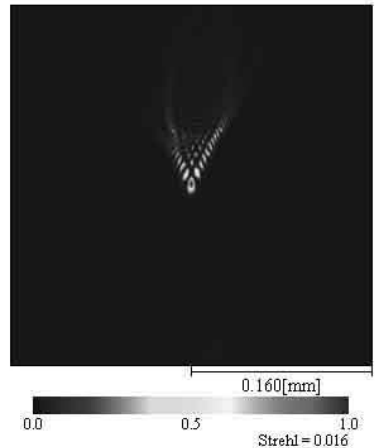
Total Aberrations



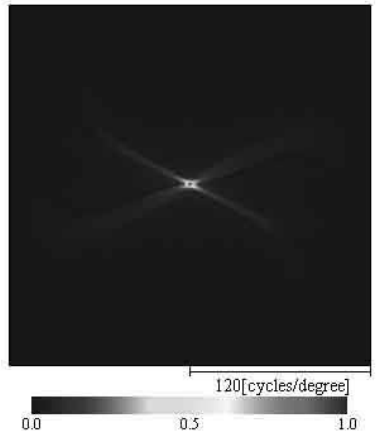
Higher Order Aberrations



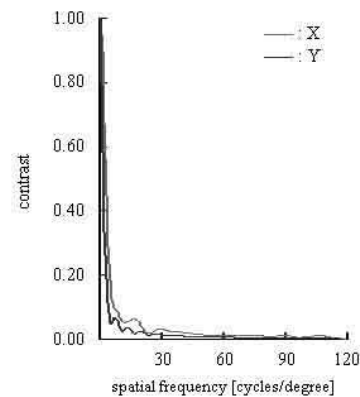
wave-front/PSF



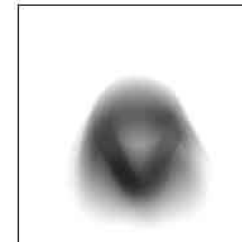
MTF



MTF Graph

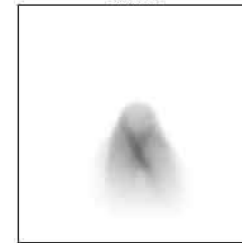


Landolt



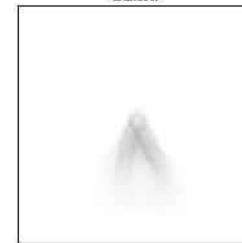
VA 20/100

Landolt



VA 20/40

Landolt

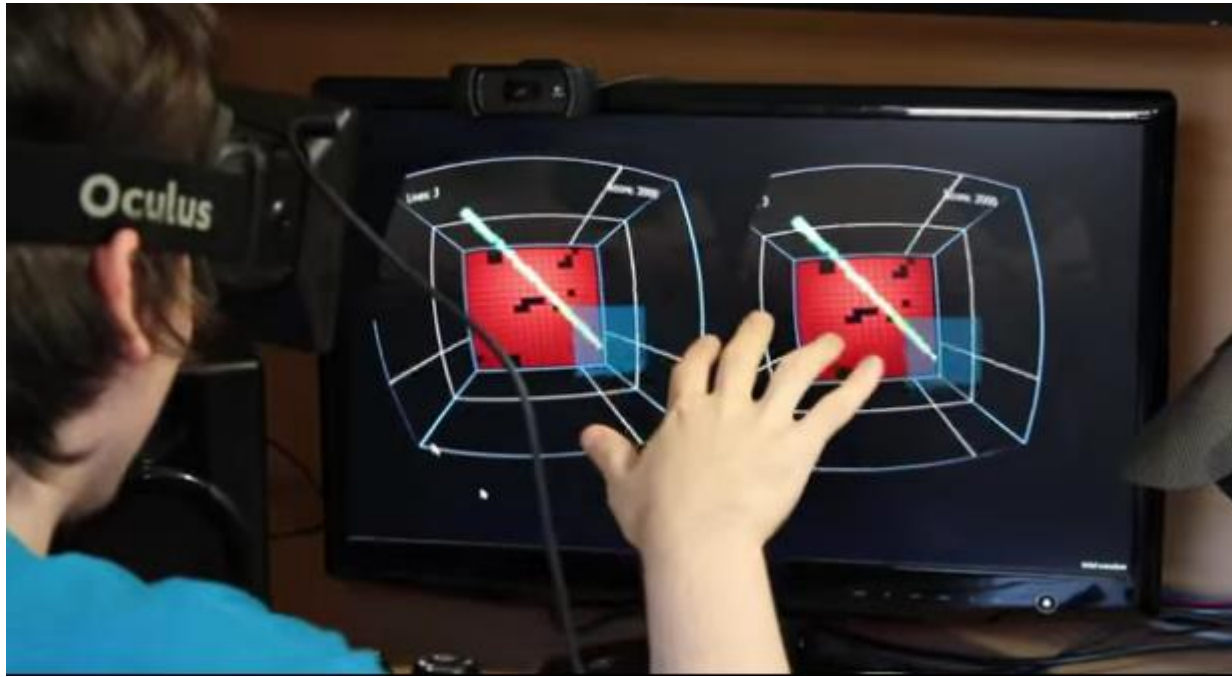


VA 20/20

<< Simulated by ocular wavefront zernike coefficient (4mm) >>

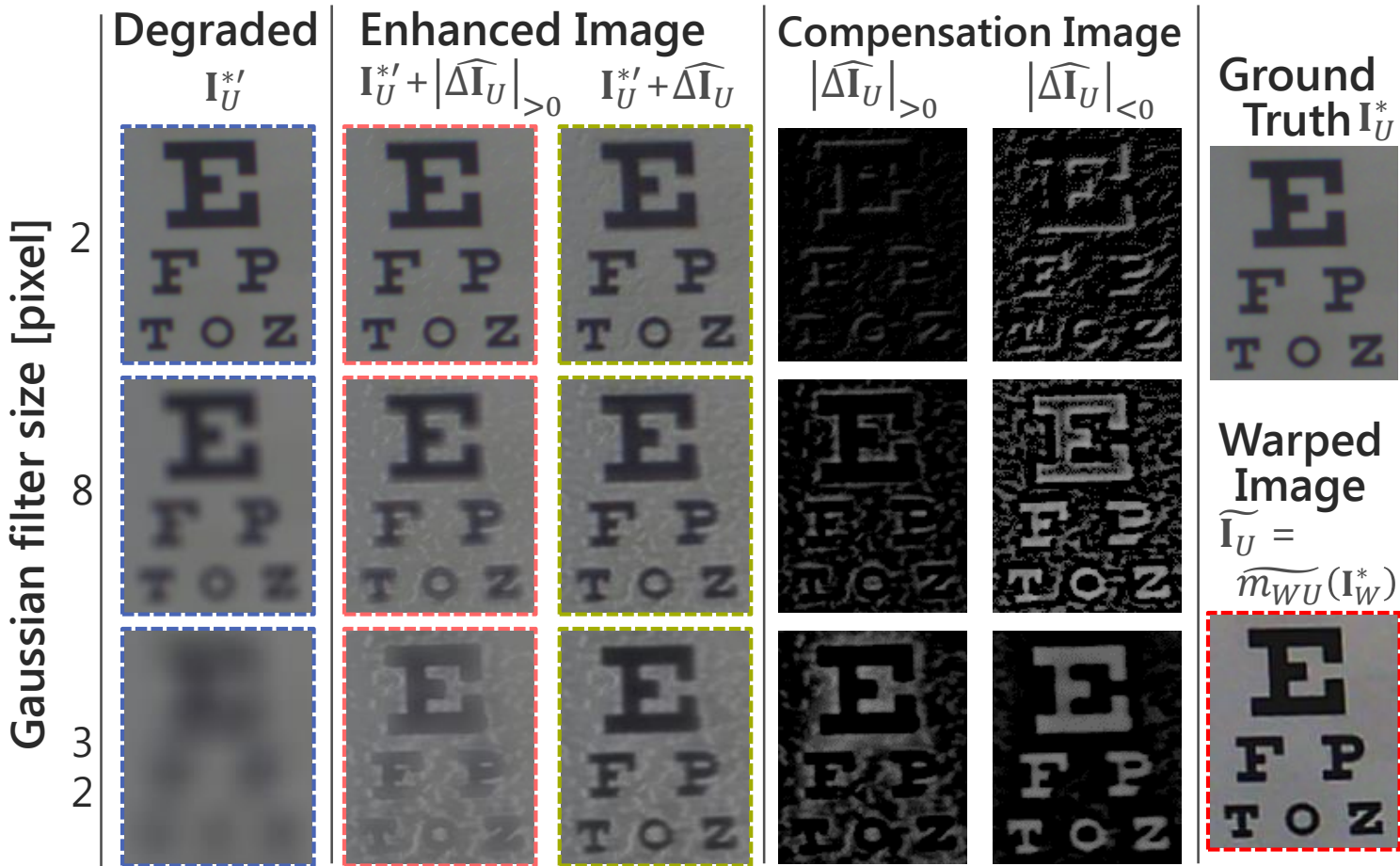
二宮さゆり. "波面センサーによる眼球の波面収差測定と網膜像推定." *Medical imaging technology* 23.1 (2005): 47-51.

# Diplopia - A VR Game to For Strabismus and Amblyopia

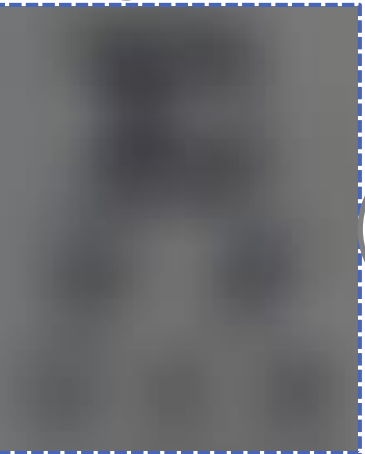


*"Strabismus, better known as crossed eye, is present in about 4% of children."*

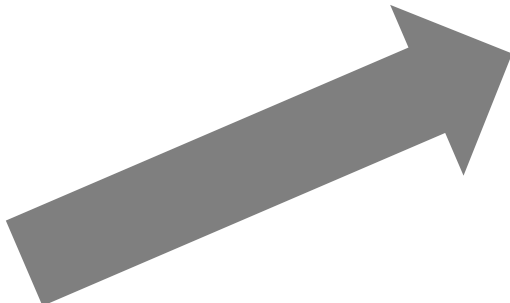
<https://www.indiegogo.com/projects/diplopia-a-vr-game-to-for-strabismus-and-amblyopia>



Degraded

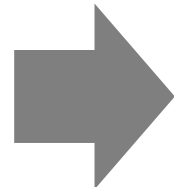


Compensation  
Images

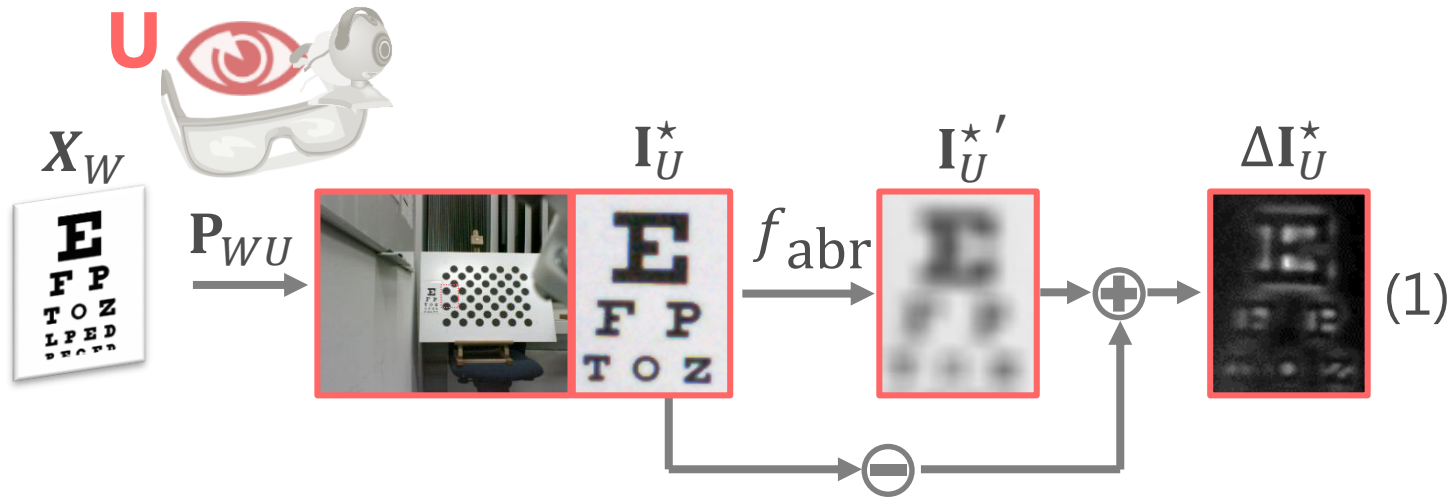


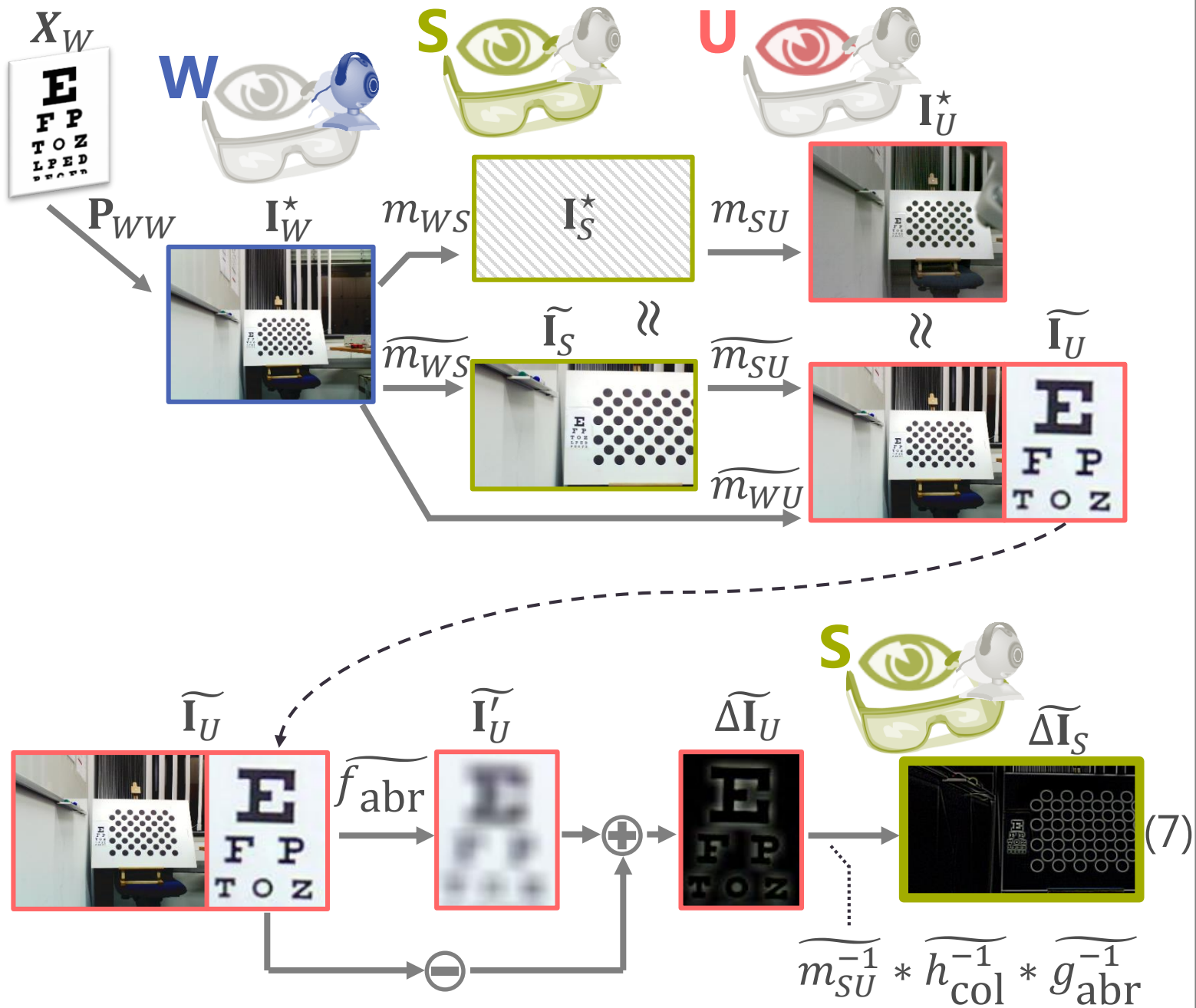
Enhanced +

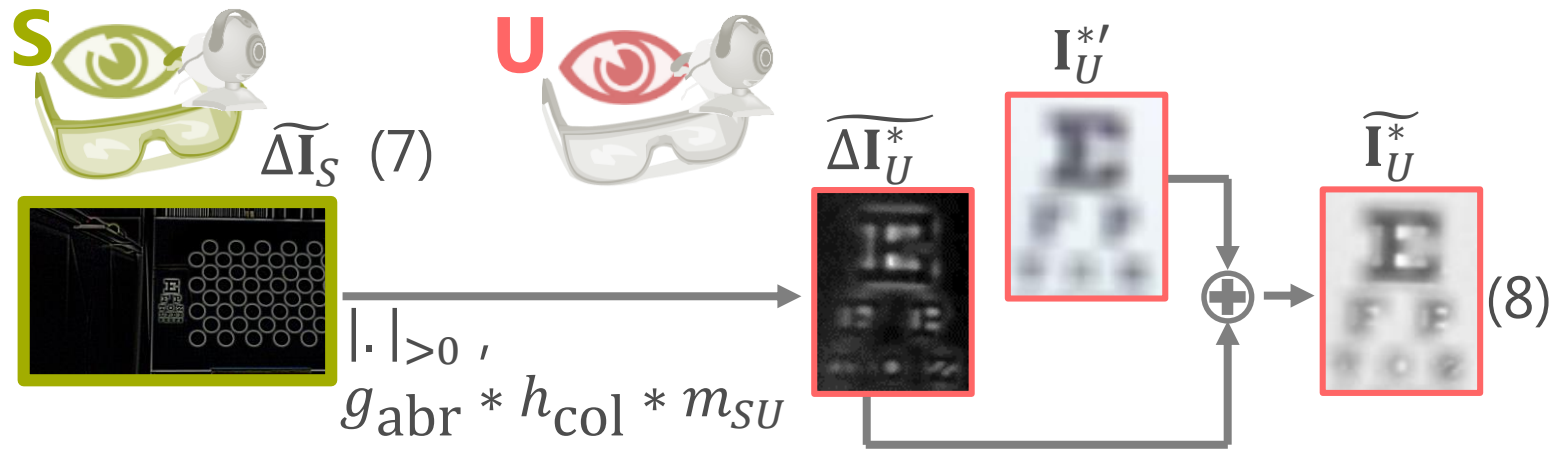
Enhanced +-







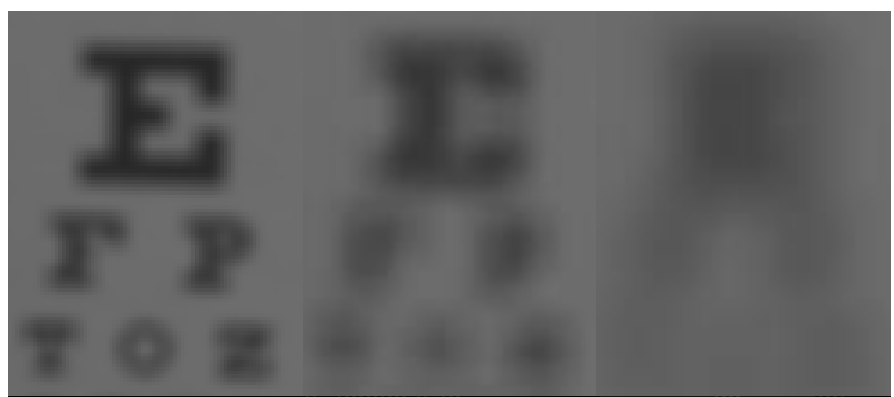
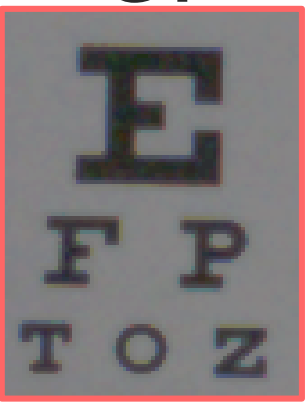




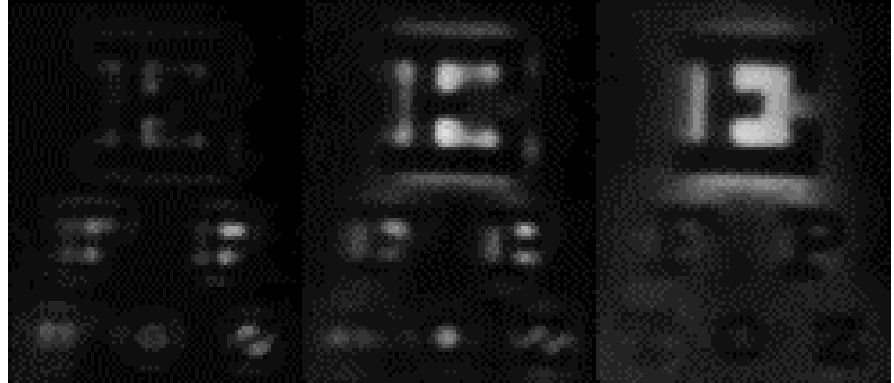
Blur size  
[pixel]

7      15      31

GT

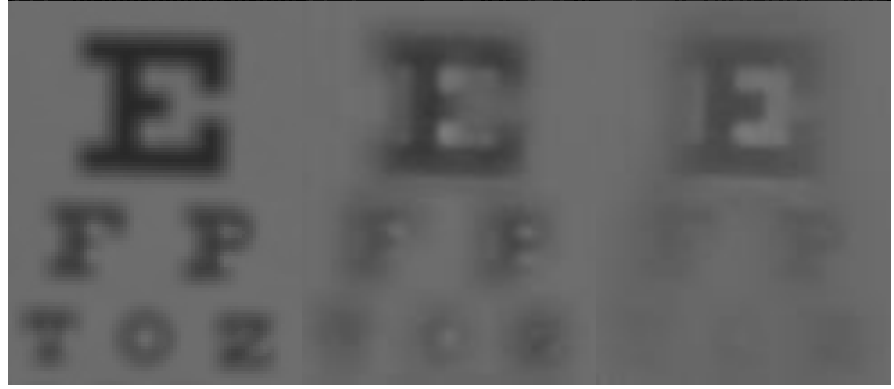
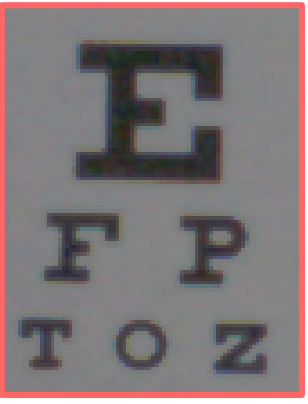


Degraded



Compensation  
Images

GT



Enhanced +

