AR in VR
Simulating augmented reality glass for image fusion

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HASLERSTIFTUNG

Growth in Augmented Reality

- New wearable headsets

- Used in
  - Industry
  - Gaming
  - Military
  - Architecture
  - Music

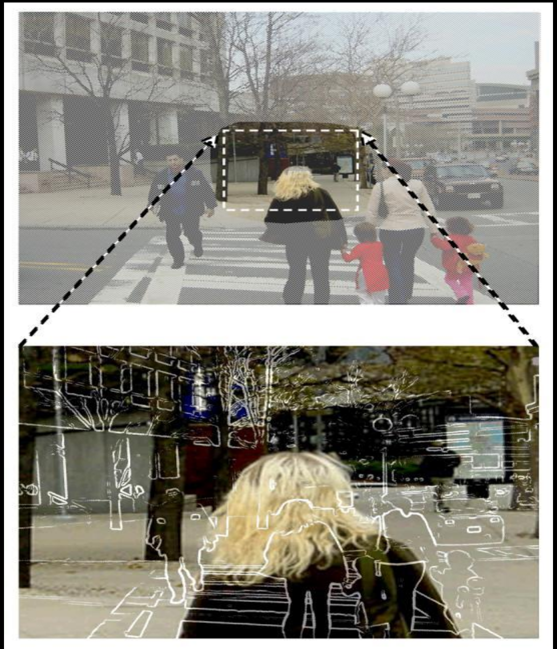
https://www.microsoft.com/en-us/hololens

https://epson.com/moverio-augmented-reality

Augmented Vision in OST HMD

Optical See-Through Head-Mounted Displays

Projects a virtual image onto a transparent screen, allowing users to see through it.



Eli Peli, Gang Luo, Alex Bowers, and Noa Rensing, “Applications of augmented-vision head-mounted systems in vision rehabilitation,” Journal of the Society for Information Display, 2007.

Chunjia Hu, Guangtao Zhai, and Duo Li, “An augmented-reality night vision enhancement application for see-through glasses,” IEEE International Conference on Multimedia & Expo Workshops (ICMEW), 2015.

Augmented vision for firefighters

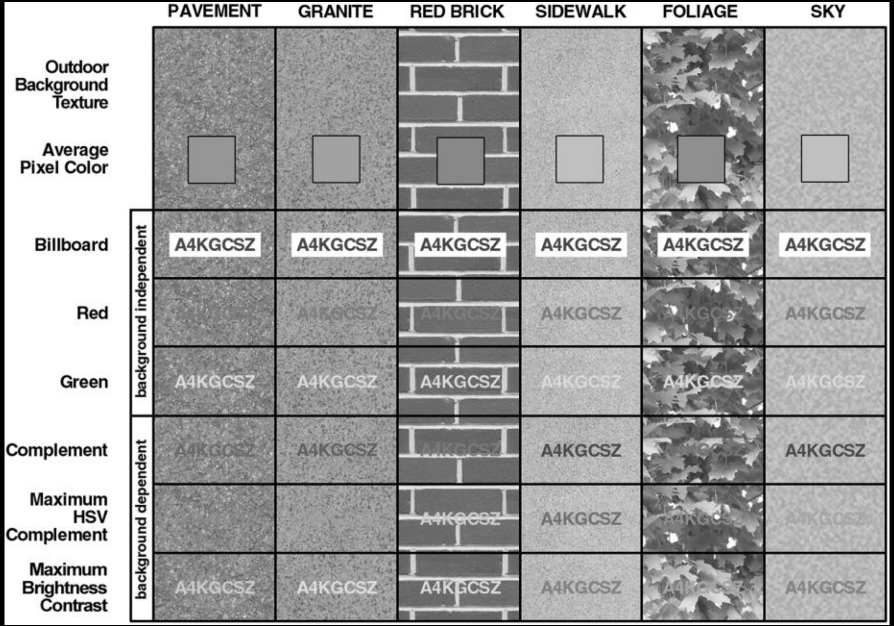
- Low visibility
- Vision through **Thermal** Camera
  - At the price of limiting hand movements
- Optical See-Through HMD
  - Free hand movements

http://darix.ch/

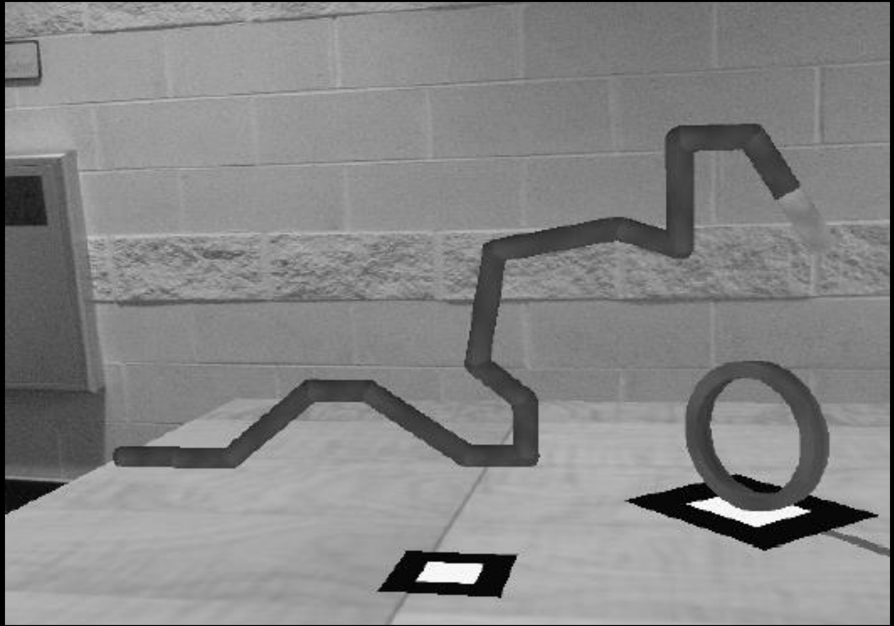
AR device for firefighters

- Harsh conditions
  - Limited, null visibility
  - Extreme heat
  - Risk of collapses
  - Heavy gear
- Testing
  - Acceptance issues
  - Controlled studies
  - Multiple factors in play
  - Chaotic real world

Simulating AR in VR

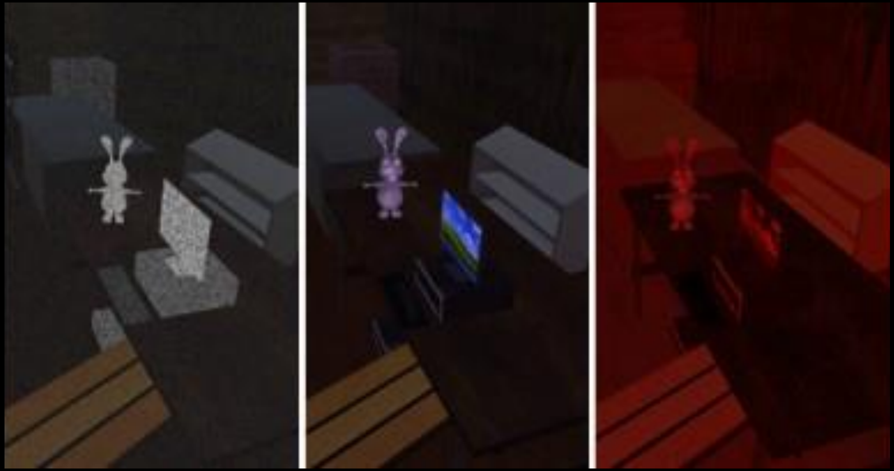


J. L. Gabbard, I. J Edward Swan, and D. Hix, “The effects of text drawing styles, background textures, and natural lighting on text legibility in outdoor augmented reality, ” Presence: Teleoperators and Virtual Environments, 2006.



E. Ragan, C. Wilkes, D. A. Bowman, and T. Hollerer, “Simulation of augmented reality systems in purely virtual environments,” Proceedings of IEEE Virtual Reality, 2009.

Simulating AR in VR



J. Orlosky, P. Kim, K. Kioykawa, T. Mashita, P. Ratsamee, Y. Uranishi, and H. Takemura, "VisMerge: Light Adaptive Vision Augmentation via Spectral and Temporal Fusion of Non-visible Light, IEEE International Symposium on Mixed and Augmented Reality (ISMAR), 2017.

P. Renner and T. Pfeiffer, "Attention guiding techniques using peripheral vision and eye tracking for feedback in augmented-reality-based assistance systems," IEEE Symposium on 3D User Interfaces (3DUI), 2017.

AR in VR for firefighters

- Developed tools
- AR Display Model

Developed Tools

Thermal Camera

- Assign temperatures to objects ranging from 0 to 1

- Thermal Shader looks at this information
    - Replaces camera's shader to obtain the thermal image

F.Lahoud and S. Süsstrunk, "AR in VR: Simulating Infrared Augmented Vision," *25th IEEE International Conference on Image Processing (ICIP), 2018*.

Image Fusion

- Combining Thermal and Color images to reveal more information in a single image
- 6 Methods
- R, G and B correspond to the color channels and I to the infrared or thermal channel

Spectral Compression

$$R_i' = \frac{3I_i + R_i}{4} \quad G_i' = \frac{G_i + R_i}{2} \quad B_i' = \frac{3B_i + G_i}{4}$$

Binary Blending

$$RGB_i' = \begin{cases} (1-\alpha)RGB_i + \alpha I_i, & \text{if } intensity(RGB_i) >= \beta \\ \alpha I_i, & \text{otherwise} \end{cases}$$

Inverse

$$RGB_i' = avg_i RGB_i + (1 - avg_i) I_i$$

Noise Modulation

$$RGB_i' = RGB_i + 0.5 I_i * rand(0,1)$$

Adaptive Blending

$$RGB_i' = \begin{cases} \frac{RGB_i}{RGB_i + I_i} RGB_i + \frac{I_i}{RGB_i + I_i} I_i, & \text{if } intensity(RGB_i) >= \beta \\ \frac{I_i}{RGB_i + I_i} I_i, & \text{otherwise} \end{cases}$$

Inverse Square

$$RGB_i' = avg_i^2 RGB_i + (1 - avg_i)^2 I_i$$

J. Orlosky, P. Kim, K. Kioykawa, T. Mashita, P. Ratsamee, Y. Uranishi, and H. Takemura, “VisMerge: Light Adaptive Vision Augmentation via Spectral and Temporal Fusion of Non-visible Light, IEEE International Symposium on Mixed and Augmented Reality (ISMAR), 2017.

Visibility Conditions

No light

Low light

Cold smoke

Normal light

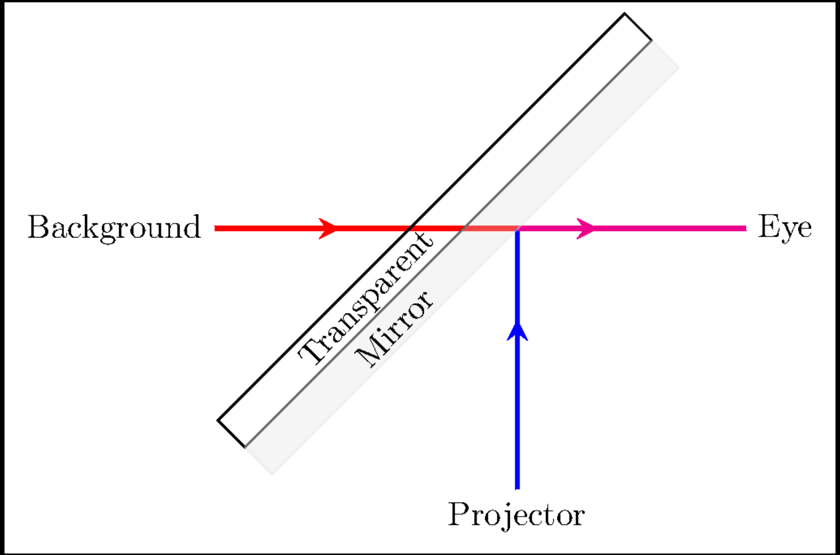
Bright light

Hot smoke

AR Display Model

Why we need an accurate model

- Critical application
- Immersion
- Oversimplified combiner model
- Projector vs. Background light
- Potential for training



Background Light

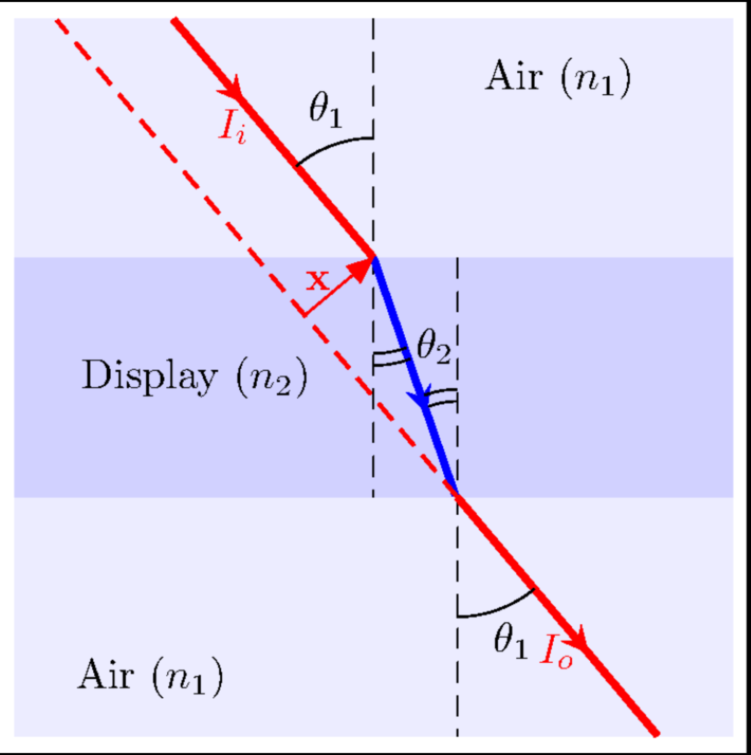
- Refraction

- Snell's Law

$$\frac{n_1}{n_2} = \frac{\sin(\theta_2)}{\sin(\theta_1)}$$

- Offset

$$|\vec{x}| = \frac{t}{\cos(\theta_2)} \sin(\theta_1 - \theta_2)$$



Refraction

AR Screen alone

AR Screen with AR Projection

Transmission

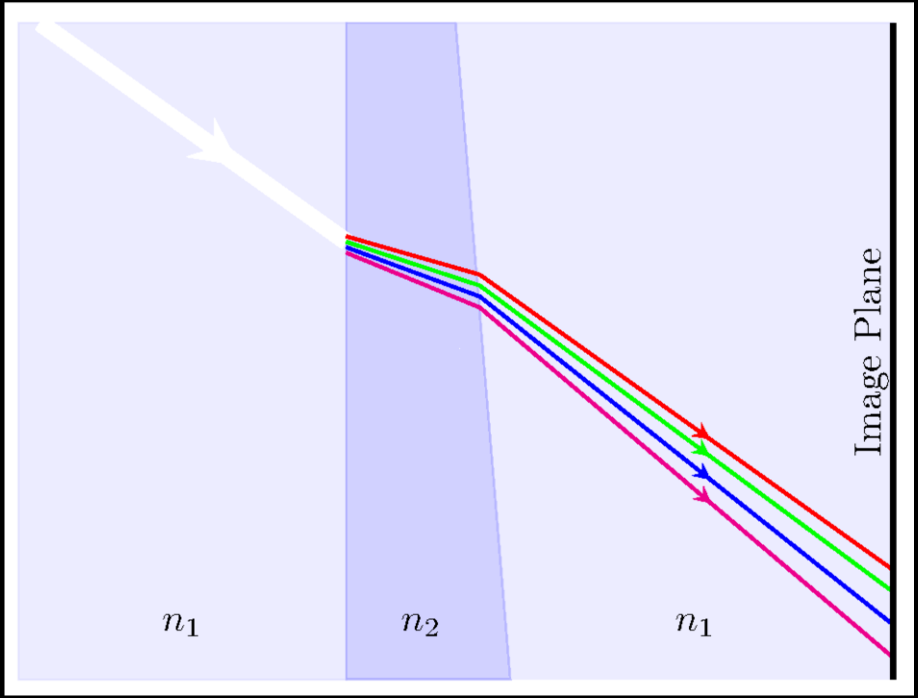
$t_D = 1$

$t_D = 0.48$

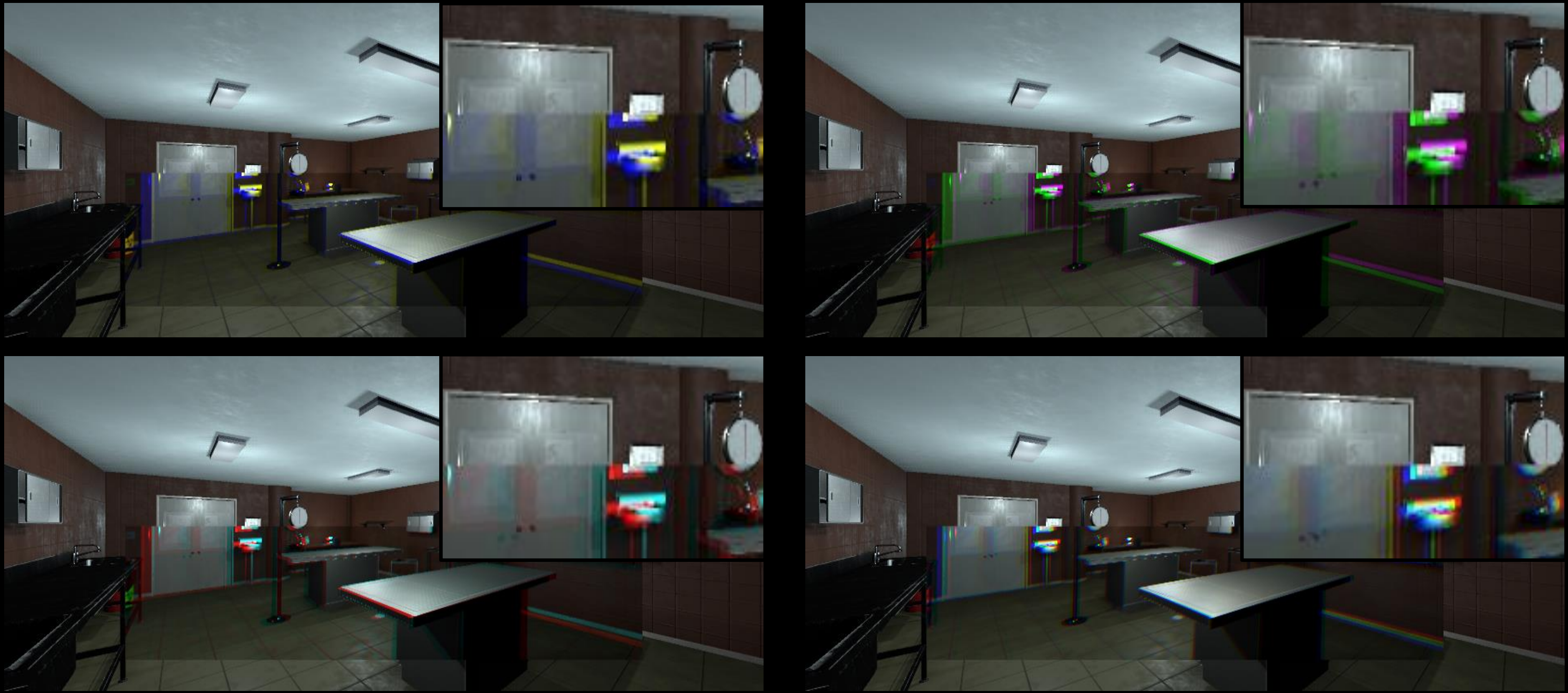
J. R. Racine, Evaluation of user experiences with wearable augmented reality in firefighting operations." Ecole Polytechnique Fédérale de Lausanne, I&C school, 2016.

Chromatic Aberration

- Refractive Index ~ Wavelength
- Light Dispersion
- Color fringing



Dispersion

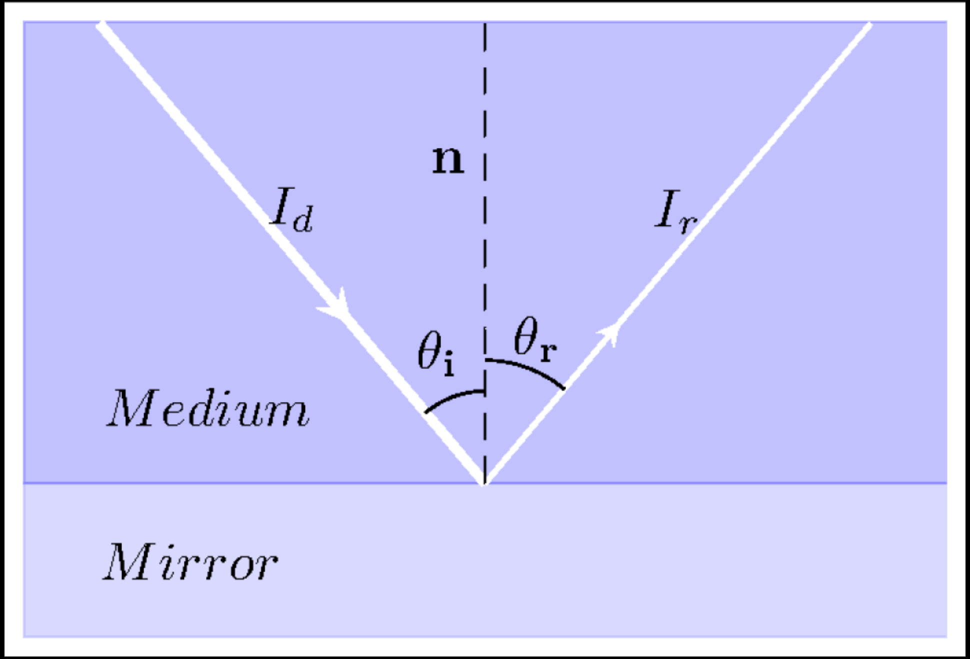


Display Light

- Intensity

- Reflectivity

$$I_r = r_D I_d$$



Intensity

Low intensity projector

High intensity projector

Reflectivity

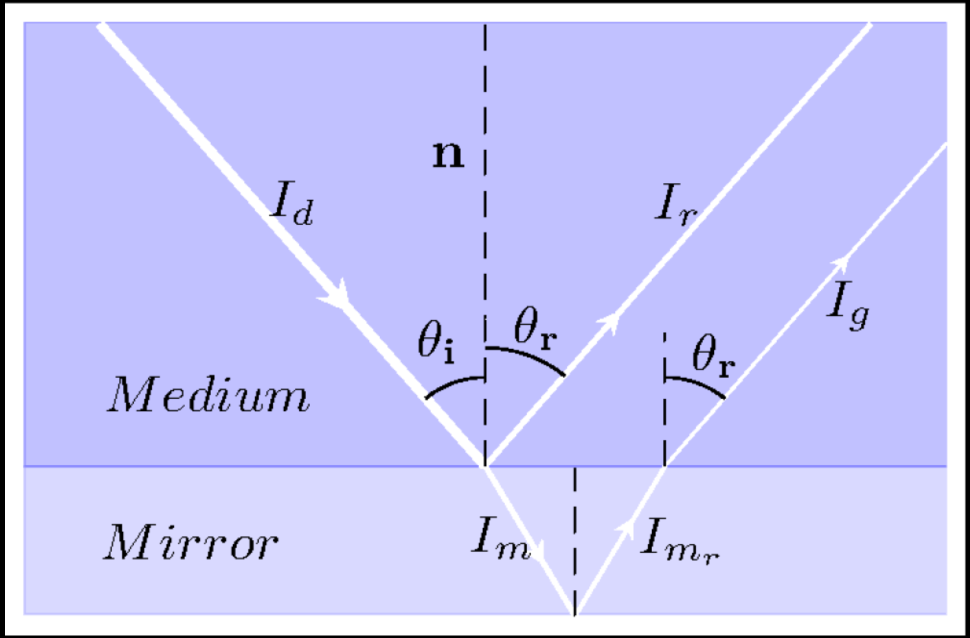
Low reflectivity glass

High reflectivity glass

Ghost Images

- Ghost Images

$I_g = r_G(1 - r_D)I_d$



Ghost Images

No ghost effect

With ghost effect

Blending in XYZ Space

- Background Light > Projector Light
- RGB → XYZ Space using different illuminant Y values
- Bright background eclipses display light as it should

Blending in XYZ Space

Blending in RGB

Blending in XYZ

Conclusion

- Realistic and configurable AR display model
- Incorporates light interactions with the combiner

$$I_o = I_b + I_d \qquad\qquad I_o = t_D I_b + r_D I_d + r_G (1 - r_D) I_d$$

- Next
  - Experiments with the new model
  - Field of View, border artifacts
  - Realistic thermal camera

Thank you