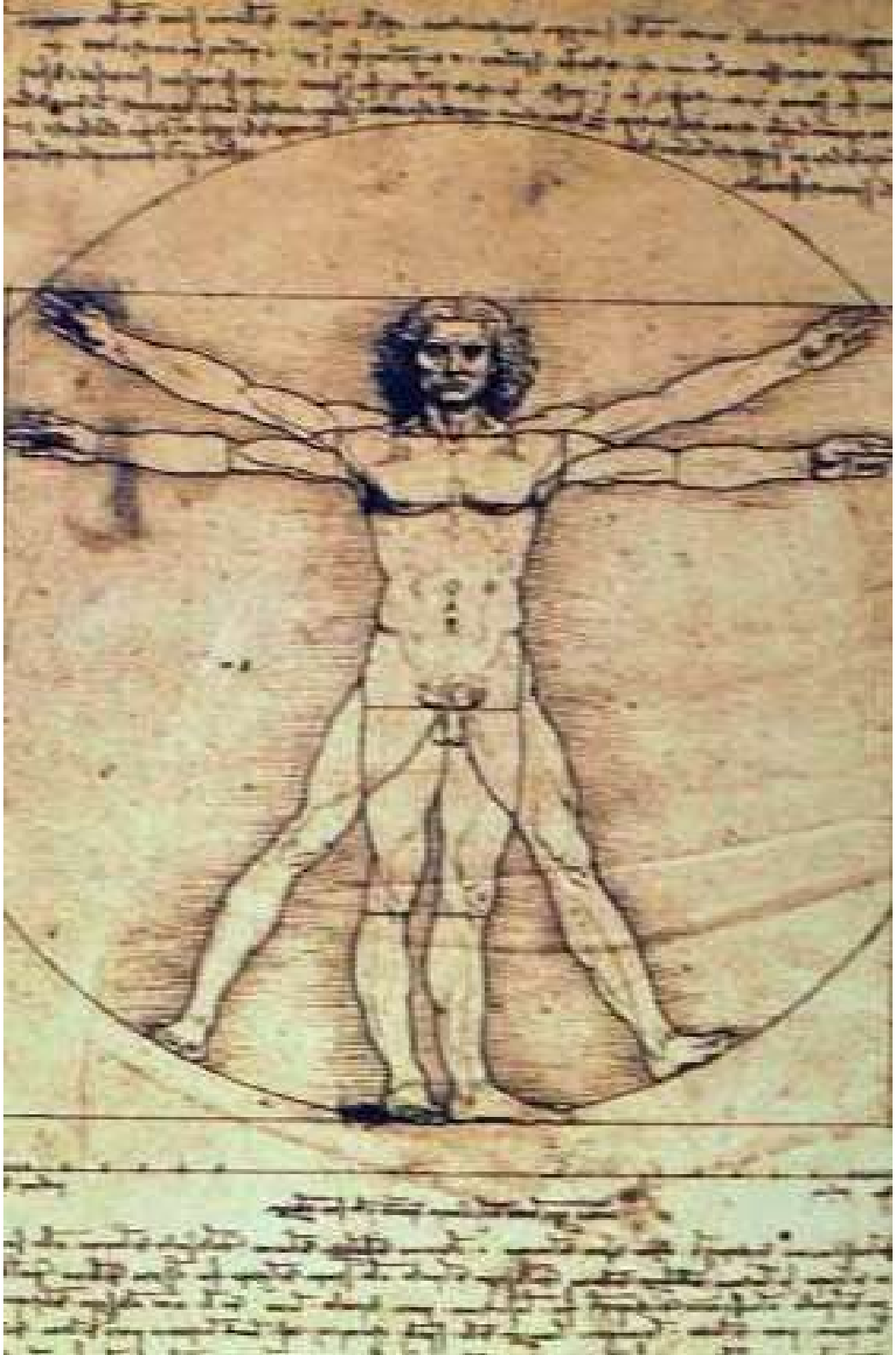
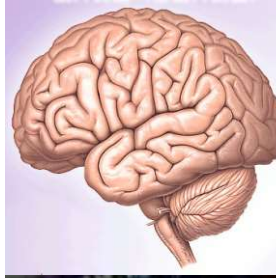


Interactive System
インタラクティブシステム特論 (4)

Hiroyuki Kajimoto
kajimoto@uec.ac.jp
Twitter kajimoto

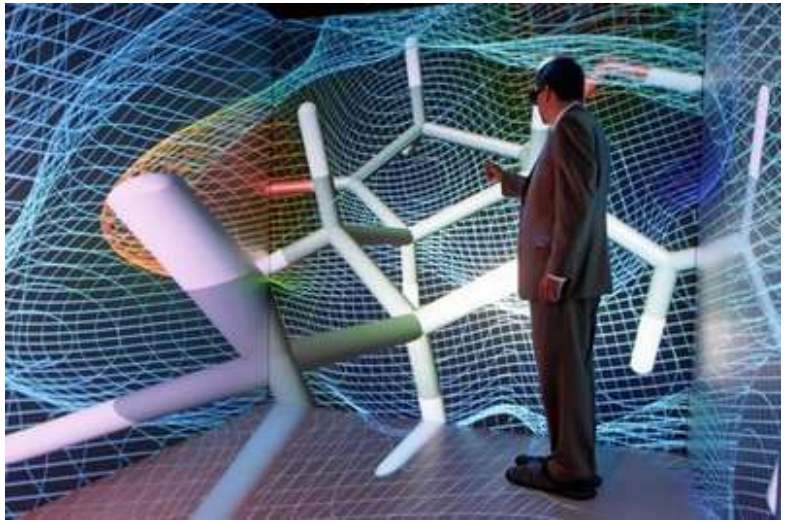
Outline of the lecture

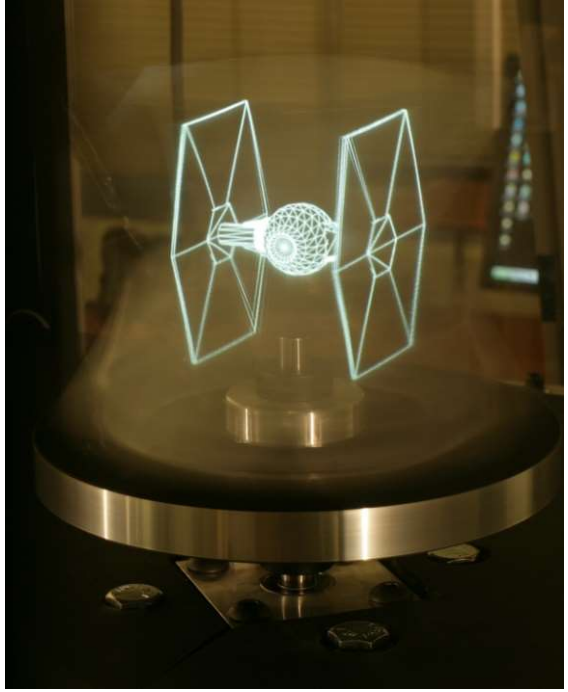
1. 人間計測手法／Measuring Human
2. 視覚／Human Vision System
3. 視覚センシング／Visual Sensing
4. 視覚ディスプレイ／Visual Display
5. 聴覚、聴覚インタフェース／Auditory Interface
6. 触覚、触覚インタフェース／Tactile Interface
7. 力覚、力覚インタフェース／Haptic Interface
8. 移動感覚インタフェース／Locomotion Interface






From 2D to 3D





- 3D：奥行きの提示
  Stereoscope display can present Depth
- ＝自己と対象の距離の提示
  Distance between image and myself is perceivable.

- つまり3Dディスプレイは対象を映すばかりでなく、自己を含んだ系を完成させる
  The image is not only a thing to view and appreciate, but it becomes a world in which “I” am included.

TODAY's TOPIC

- 3Dディスプレイ／3D Display
  - HMD
    - HMDとカメラ／HMD & Camera
    - HMDとAR ／HMD & AR
  - 環境型／Environmental Display
    - メガネあり／With Eyeglasses
    - 環境型とカメラ／Environmental Display & Camera
    - メガネなし／Without Eyeglasses
      - 左右の目に違う映像を入れる／Input Different Images to Two Eyes
      - ボリューメトリックな再構成／Volumetric Reconstruction
      - 光線群の制御による多視点映像／Ray Reconstruction
      - 錯覚を利用する／Using Illusion
- その他の話題
  - 光線群制御からCSCWへ／From Ray Control to CSCW
  - 光線群視点制御から視線制御へ／From Ray Control to Eye Control

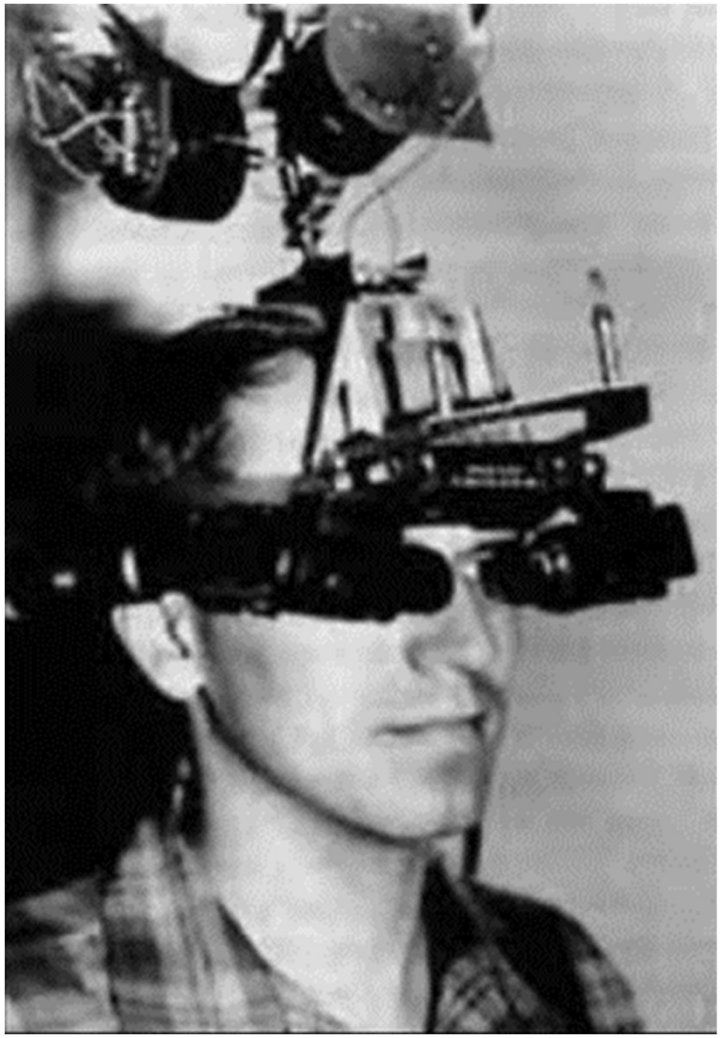
Two types of 3D displays

Head Mounted Display (wikipedia)
https://en.wikipedia.org/wiki/Head-mounted_display

CAVE automatic virtual environment (Wikipedia)
https://en.wikipedia.org/wiki/Cave_automatic_virtual_environment

- HMD／Head Mounted Display
- 設置型／Ground-Fixed Display

Head Mounted Display (HMD)



https://www.youtube.com/watch?v=NtwZXGprxag

Ivan Sutherland, Sword of Damocles (1966) - First augmented reality head-mounted display

The Ultimate Display (Sutherland1965)

- We live in a physical world whose properties we have come to know well through long familiarity. We sense an involvement with this physical world which gives us the ability to predict its properties well. For example, we can predict where objects will fall, how well known shapes look from other angles, and how much force is required to push objects against friction. We lack corresponding familiarity with the forces on charged particles, forces in non-uniform fields, the effects of nonprojective geometric transformations, and high-inertia, low friction motion. A display connected to a digital computer give s us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland.

- The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.

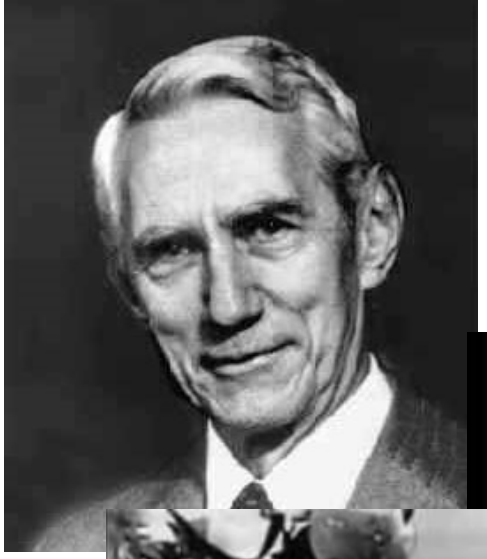
http://worrydream.com/refs/Sutherland%20-%20The%20Ultimate%20Display.pdf

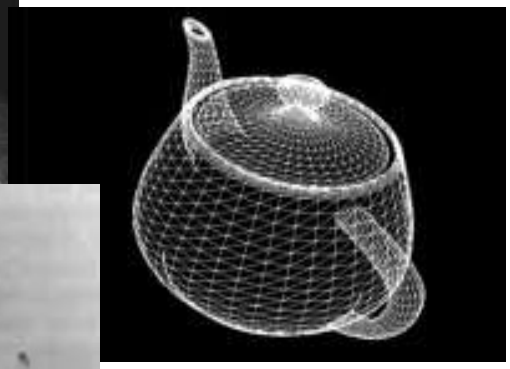
師匠と弟子
Master and Apprentice

- C. E. Shannon
  Father of Information Theory

- Apprentice
  - Ivan Sutherland
    Father of Computer Graphics, and
    Father of Virtual Reality
    Invented most part of fundamental CG technique, and the first HMD

- Grand-Apprentice
  - Jim Clark: Founder of SGI and Netscape
  - Alan Kay: Proposed the notion of personal computer “Dynabook”





TODAY's TOPIC

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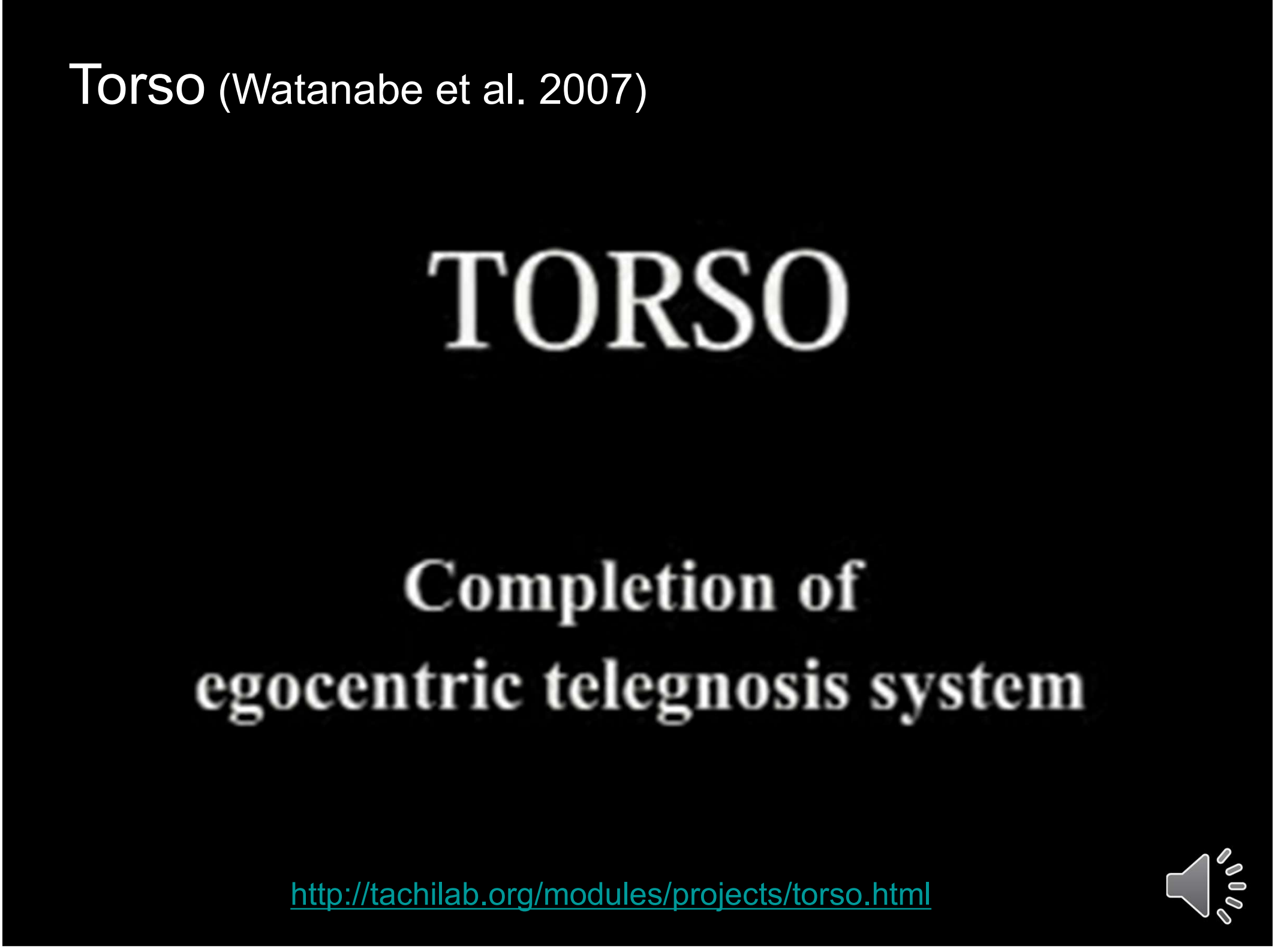
HMD用の実世界カメラとは？／Camera for HMD?

TELESAR（Tachi et al., 1989）https://www.youtube.com/watch?v=3gImo2OftPg

Two cameras, which are at the same position as the HMD are used.

Torso (Watanabe et al. 2007)

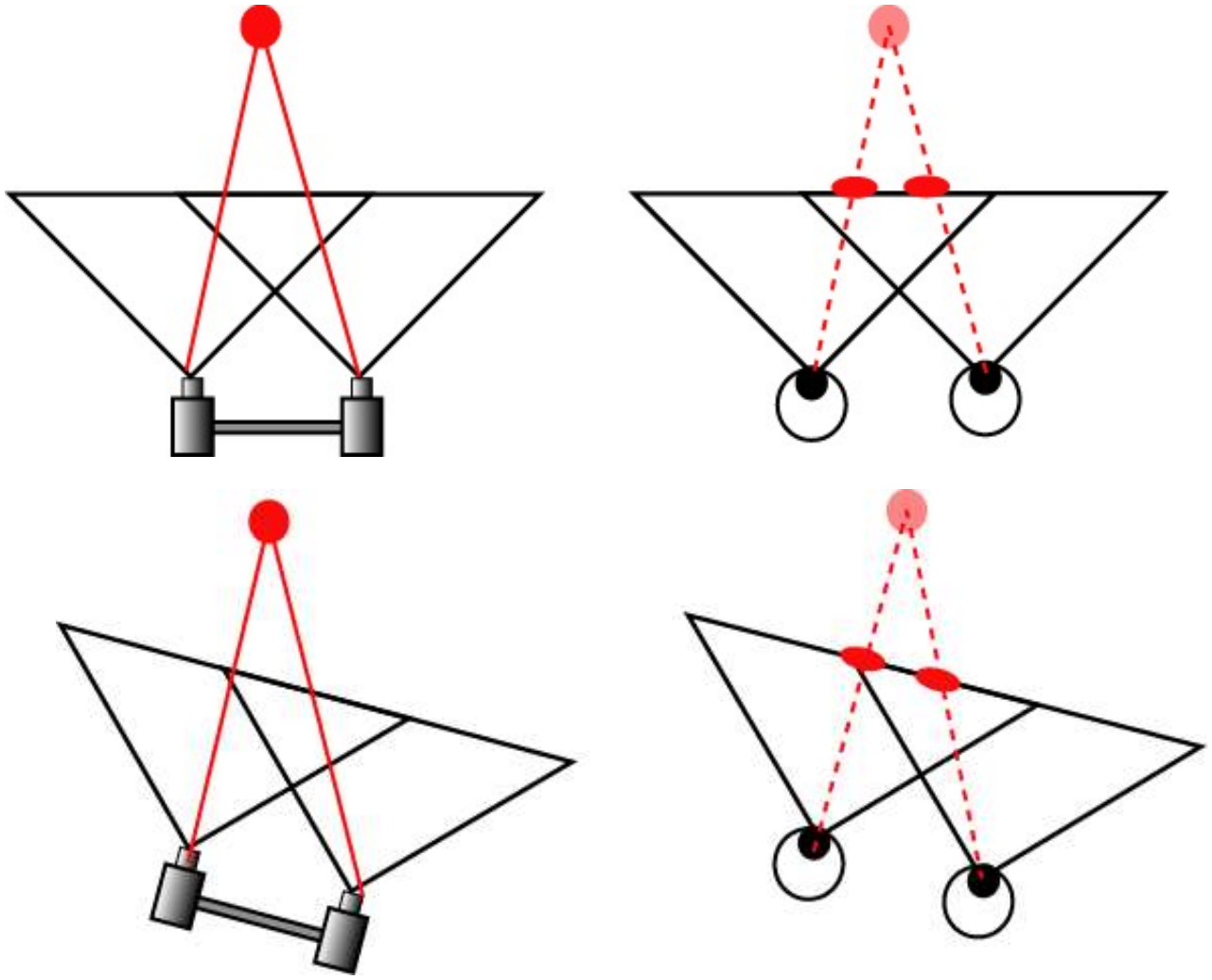


http://tachilab.org/modules/projects/torso.html

頭部回転？問題なし
Head Rotation? No problem!!

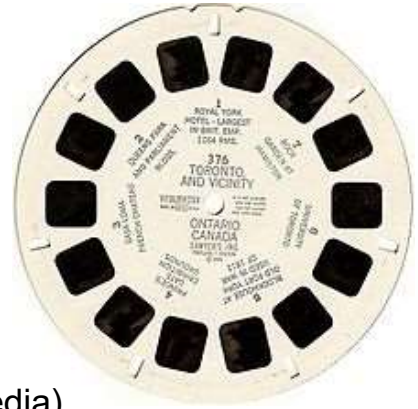
Robot Camera

HMD

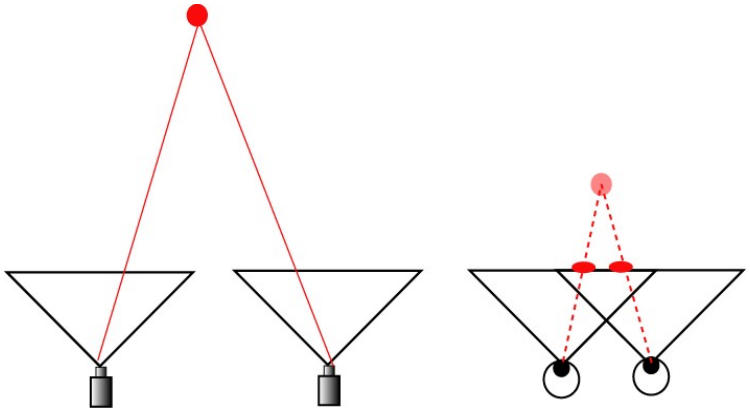


その他の注意点（1）眼間距離と視野角の問題
Other concerns(1) Eye distance & view angle

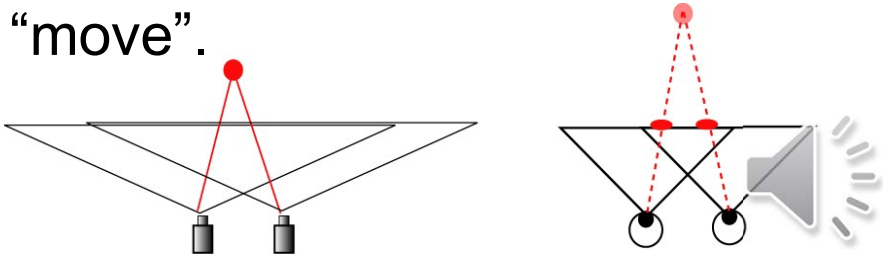
- 眼間距離（カメラ間距離）の不一致: 両眼立体視を行うと自分が巨人or小人になったかのような感覚. (立体視おもちゃの「箱庭感」)
  Difference of eye distances generate odd size feeling (miniature garden)



View-Master (Wikipedia)
https://en.wikipedia.org/wiki/View-Master



- 視野角の不一致／Difference of viewing angle
  - 奥行きがおかしくなる. Distance is changed
  - 頭部回転運動の際，正面の物体が観察者の頭にくっついて動くか，逆方向に流れる. When head rotates, objects “move”.
  - 眼鏡を初めてかけたときの違和感

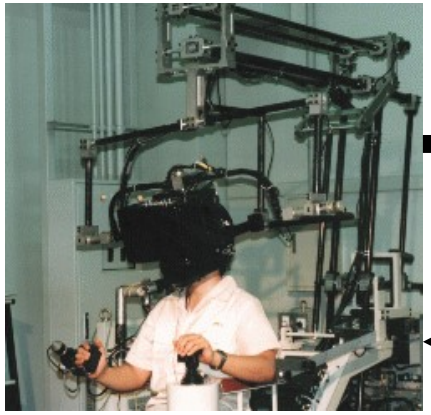


(CHI2019) Egocentric Smaller-person Experience through a Change in Visual Perspective Jun Nishida, Soichiro Matsuda, Mika Oki, Hikaru Takatori, Kosuke Sato, Kenji Suzuki

https://www.youtube.com/watch?v=ZkZjfqo6h3I

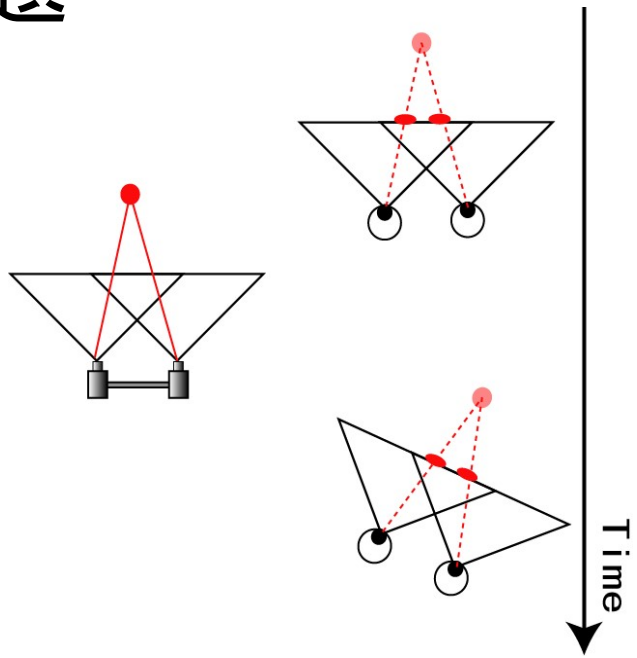
- 元IVRC作品．子供の視点を体験

その他の注意点(2)時間遅れの問題
Other concerns(2) Time Latency

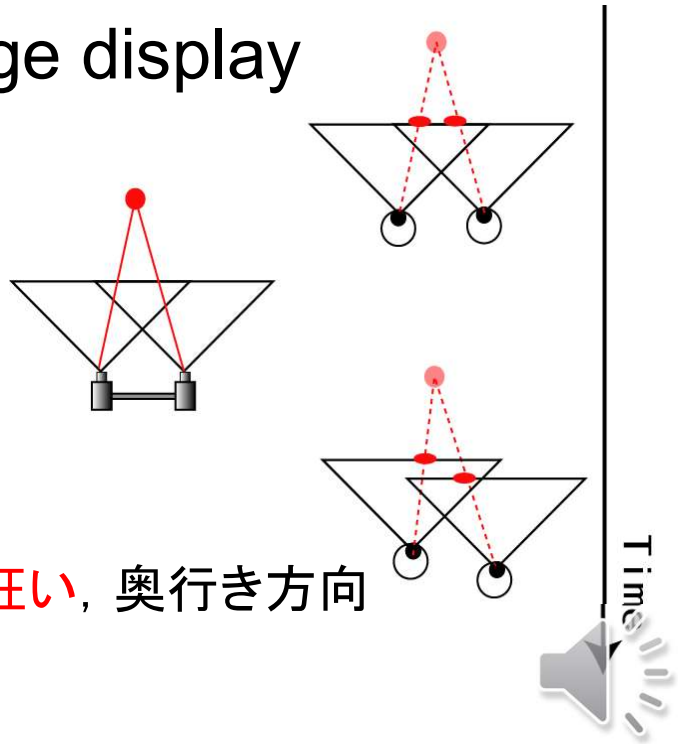


頭の動きの伝送
Head Motion

画像の伝送
Imge transfer

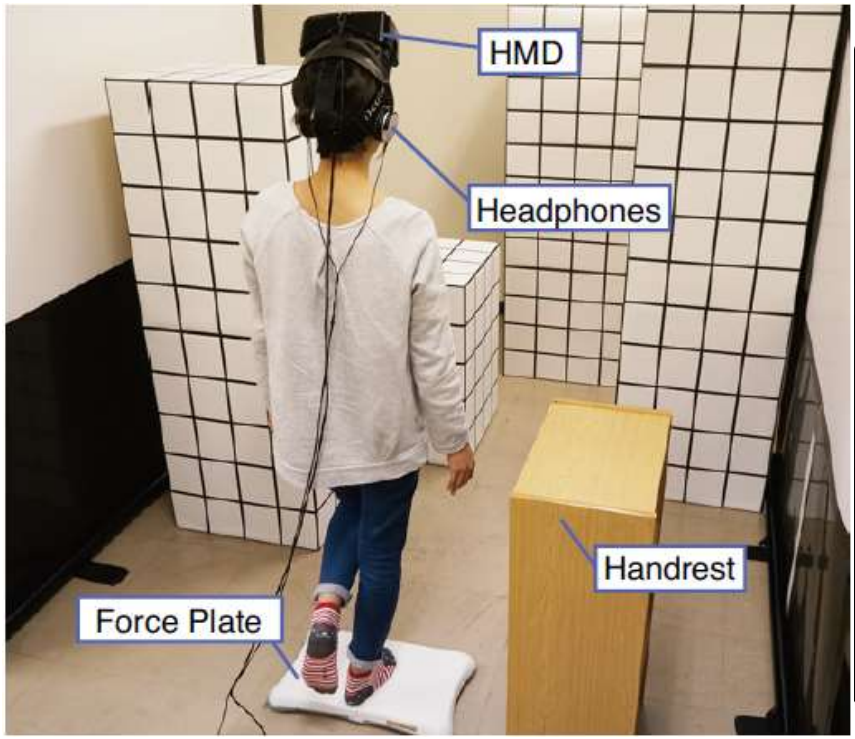


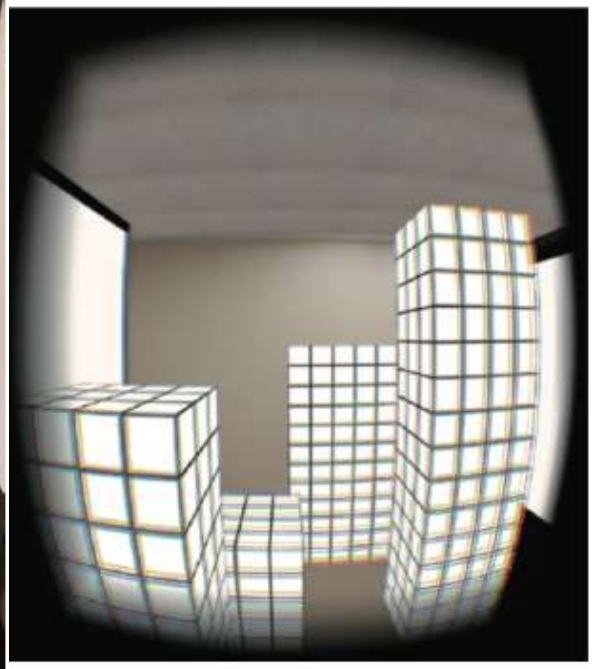
- 頭の動きから描画までに時間遅れ.
  Latency between head motion and image display



- 首を振ったとき When the head rotates:
  - HMD:
    - 画像が首の回転に付いてくる
      The image moves
  - 設置型 Ground fixed disply:
    - 画像は付いてこない. しかし立体視に関しては狂い, 奥行き方向にひずみを生じる.
      The image does not move, but distort.

(IEEEVR2016) Effect of HMD Latency on Human Stability during Quiescent Standing on one Foot, Soma Kawamura, Ryugo Kijima





HMDの時間遅延が，「片足で立ち続けるタスク」に与える影響を調べた．重心の動き量で計測．時間遅延が大きいほど大きな動揺が見られ，途中で実験を中止（片足立ちを継続できない）人の数が増加．

Investigated the effect of the time delay of HMD on the task of standing on one leg. Measured by the amount of movement of the center of gravity. The greater the time delay, the number of people who stopped the experiment (unable to continue standing on one leg) increased.

HMDの利点と欠点／Pros & Cons of HMD

Head Mounted Display (wikipedia)
https://en.wikipedia.org/wiki/Head-mounted_display

- 行動範囲が広い／Users can walk freely
- 自分の体を隠せるため自己投射性が高くなる。時間遅れ、座標ずれに対してロバストに／Users can hide their bodies, meaning they can “deceive” themselves. Becomes robust to latency and coordinate distortion
- 遠隔ロボット（カメラ）との相性が良い／Easy to design distance robot camera.
- 装着するので重い、閉塞感／Heavy and feeling of being caged
- 顔が隠されるため双方向コミュニケーションには不向／Face is hidden, meaning two way communication is difficult.
- 視野角を大きくとる設計が難しい／Design of large field of view is quite difficult.

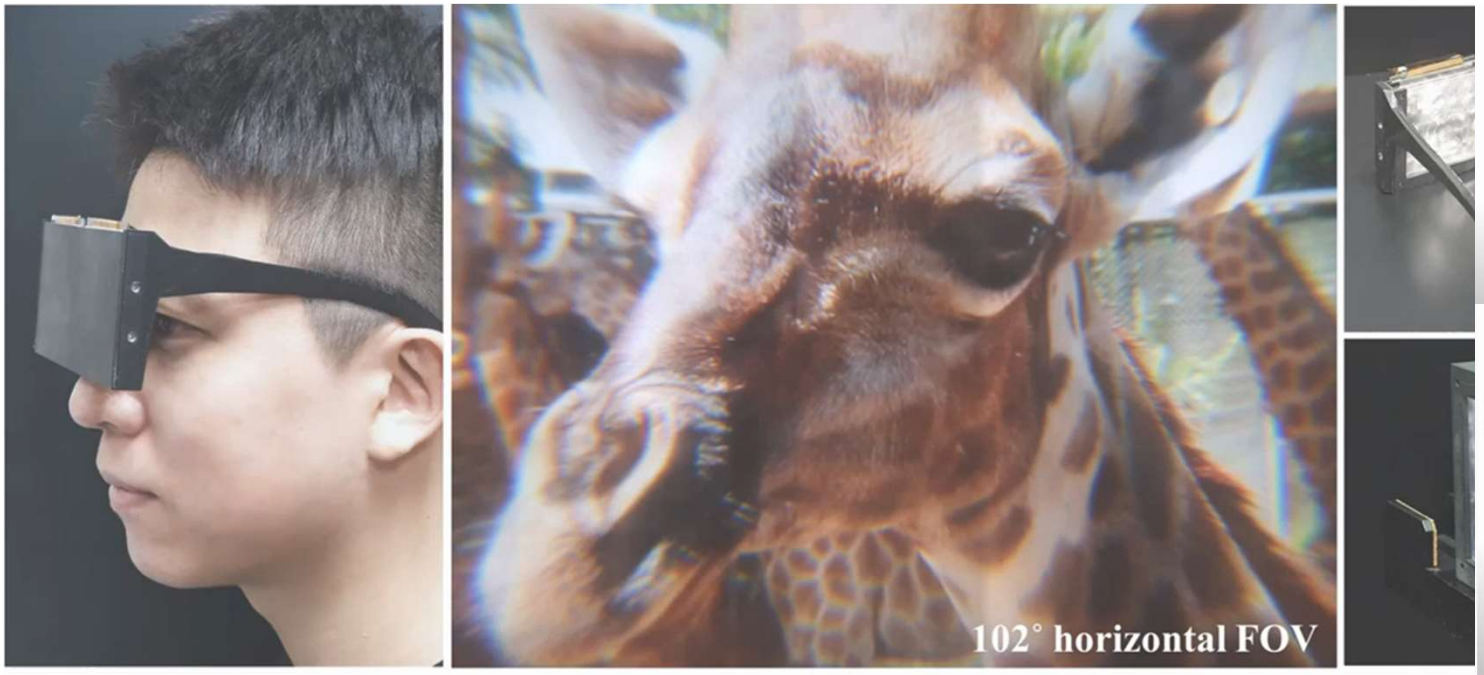
HMDの普及 Oculus Rift(2013～)

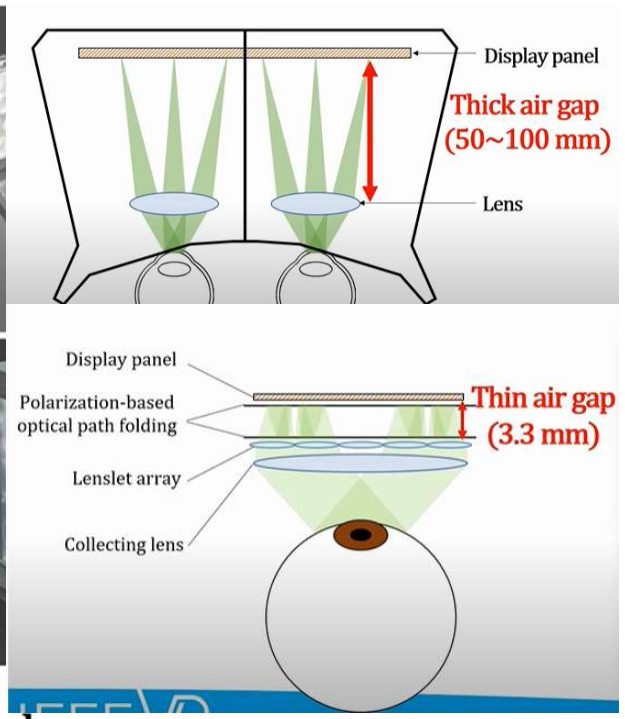
Oculus Rift (Wikipedia) https://en.wikipedia.org/wiki/Oculus_Rift

- 安くする工夫 (to make it cheaper)
  - 従来の両眼に対応した二台のディスプレイではなく，一つのディスプレイに両眼映像を描画
  - 高価なレンズで歪みを補正するのではなく，ディスプレイに描画する時点で逆の歪みを表示
    Single display is used for two-eyes images. Anti-distortion image is calculated in realtime.
- 安定化の工夫 (to make it stable)
  - 首振り運動に対する補償を行い，「頭を動かすと画像がついてくる」問題を解消
    Head rotation is cancelled in realtime.
- そのうえで視野角も大きく、臨場感高い提示が可能に

(参考) 木島他，Reflex HMD：前庭反射機能を備えたHMDの開発 A Development of - Reflex HMD - Head Mounted Display with Vestibular Reflex
日本バーチャルリアリティ学会論文誌 6(2), 107-114, 2001

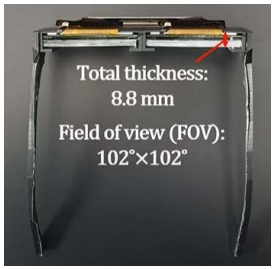
（IEEEVR2021) Kiseung Bang, Youngjin Jo, Minseok Chae, Byoungho Lee:
Lenslet VR: Thin, Flat and Wide-FOV Virtual Reality Display Using Fresnel Lens and Lenslet Array





Lenslet VR **:Thin, Flat and Wide-FOV Virtual Reality Display Using Fresnel Lens and Lenslet Array**

IEEE VR 2021 VIRTUAL
Seoul National University
Kiseung Bang, Youngjin Jo, Minseok Chae, and Byoungho Lee
IEEE COMPUTER SOCIETY
IEEE



https://www.youtube.com/watch?v=8tw8mSYuqX8

- レンズ群による焦点距離の短縮と偏光を利用した複数回反射の利用で薄いHMDを作る

顔が見えない問題を解決する / Show your face!

https://www.youtube.com/watch?v=UDjNBZ14mUI

(IEEEVR2017) Recognition and Mapping of Facial Expressions to Avatar by Embedded Photo Reflective Sensors in Head Mounted Display, Katsuhiro Suzuki, Fumihiko Nakamura, Jiu Otsuka, Katsutoshi Masai, Yuta Itoh, Yuta Sugiura, and Maki Sugimoto
https://lclab.org/projects/affectivehmd

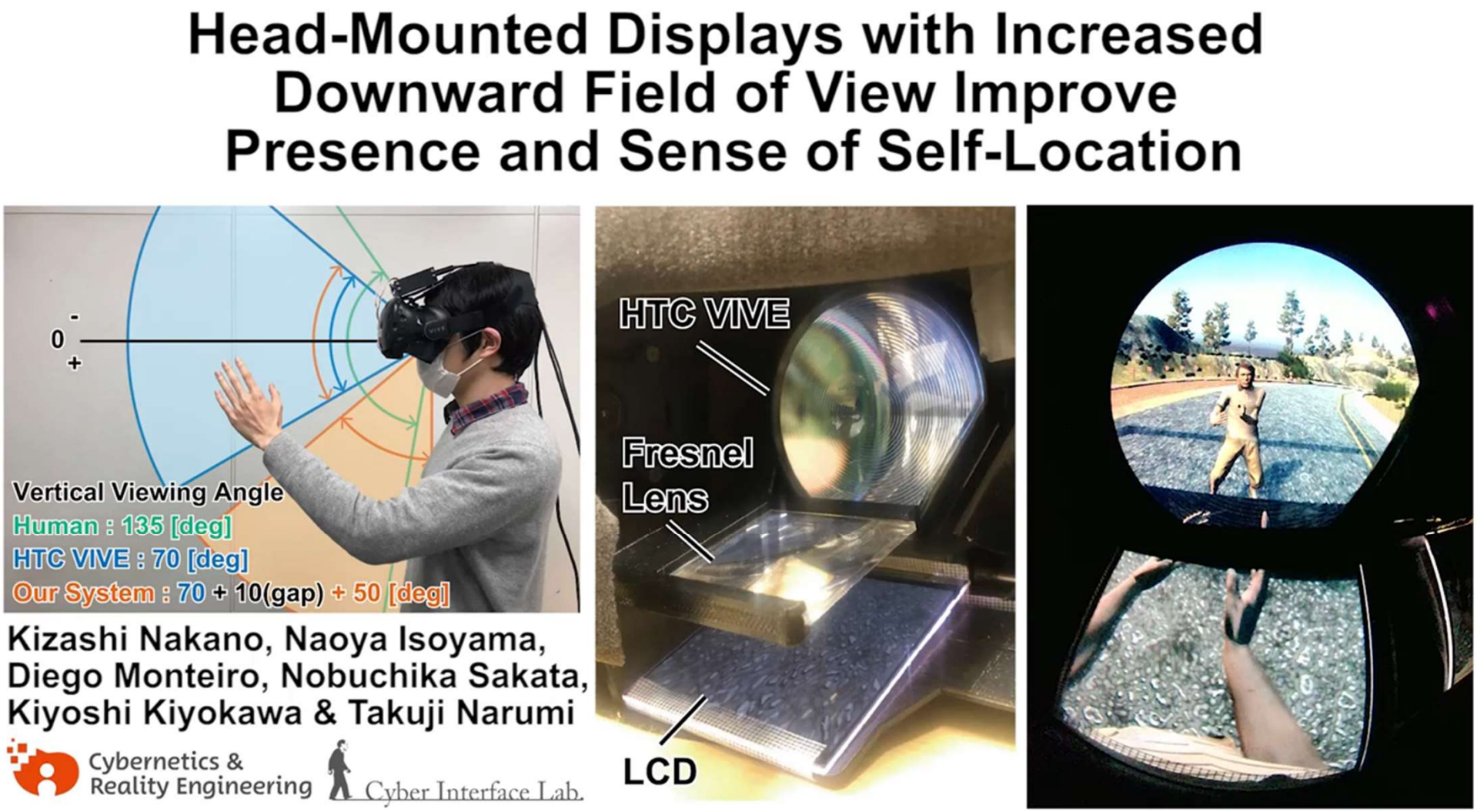
HMD周辺のフォトリフレクタベース距離センサで顔の表情認識．NNでトレーニング

https://www.youtube.com/watch?v=jIlujM5avU8

(SIGGRAPH2018) FaceVR: Real-Time Gaze-Aware Facial Reenactment in Virtual Reality, Justus ThiesMichael ZollhöferMarc StammingerChristian TheobaltMatthias Nießner

外部に設置したRGB-Dカメラと HMD中の片目用IRカメラの情報を組み合わせてフォトリアリスティックな顔の再現.

地面が見えない問題を解決する / Ground is important



Head-Mounted Display with Increased Downward Field of View Improves Presence and Sense of Self-Location
Kizashi Nakano, Naoya Isoyama, Diego Monteiro, Nobuchika Sakata, Kiyoshi Kiyokawa, and Takuji Narumi
https://www.youtube.com/watch?v=T1hjYtyncRQ
地面視野は大切→地面視野を提示する部分をHMDに内蔵

TODAY's TOPIC

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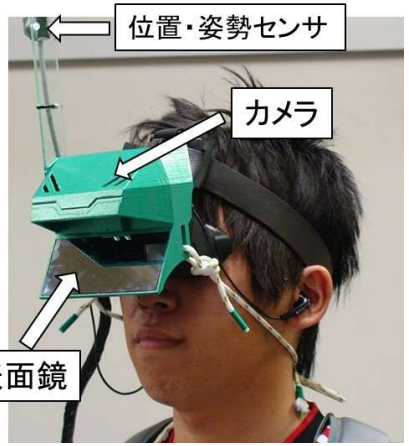
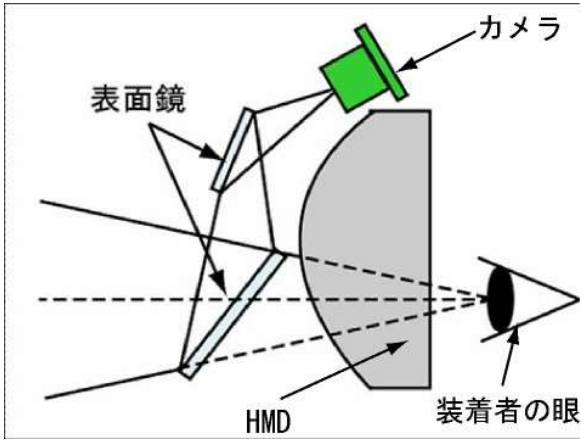
Augmented Reality (AR) and See-Through HMD

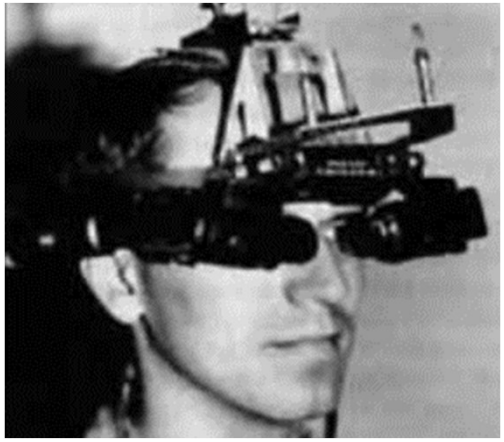
https://cinoptics.com/product/visette45sxga-seethrough-hmd/





http://www-hiel.ist.osaka-u.ac.jp/cms/index.php/services

https://en.wikipedia.org/wiki/Microsoft_HoloLens



Ivan Sutherland, Sword of Damocles (1966)

Overlap VR world and the real world

– Video See-Through (VST-HMD) : Capture the real world by camera.

– Optical See-Through (OST-HMD) : Use half-mirror-like element & optically overlap.

Video see-through HMD (Canon, MREAL)

https://www.youtube.com/watch?v=a4hwCU-LUSM

https://www.canon-its.co.jp/solution/mr/

（IEEEVR2021) Leonardo Pavanatto, Chris North, Doug Bowman, Richard Stoakley, Carmen Badea: Do we still need physical monitors? An evaluation of the usability of AR virtual monitors for productivity work

Figure 2: (a) Physical condition had three monitors side-by-side; (b) Virtual condition had three monitors rendered through HoloLens; (c) Hybrid condition combined a central physical monitor with two peripheral virtual monitors.

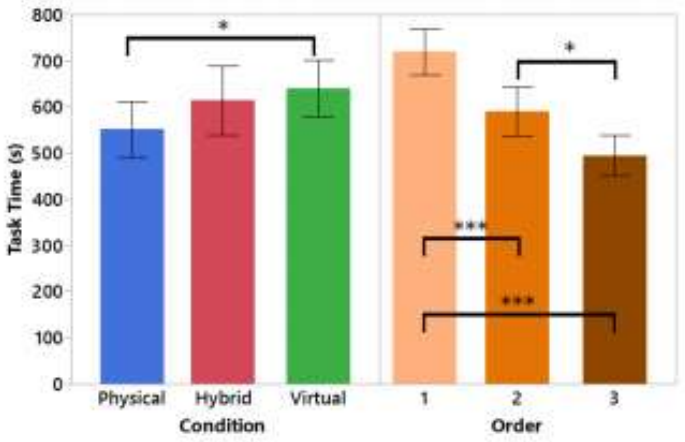


Figure 3: Total time in seconds to complete the experimental task on each condition (left) and order (right). Error bar represents the confidence interval (95%).

https://youtu.be/Ag3LRcqxpo4?t=2824

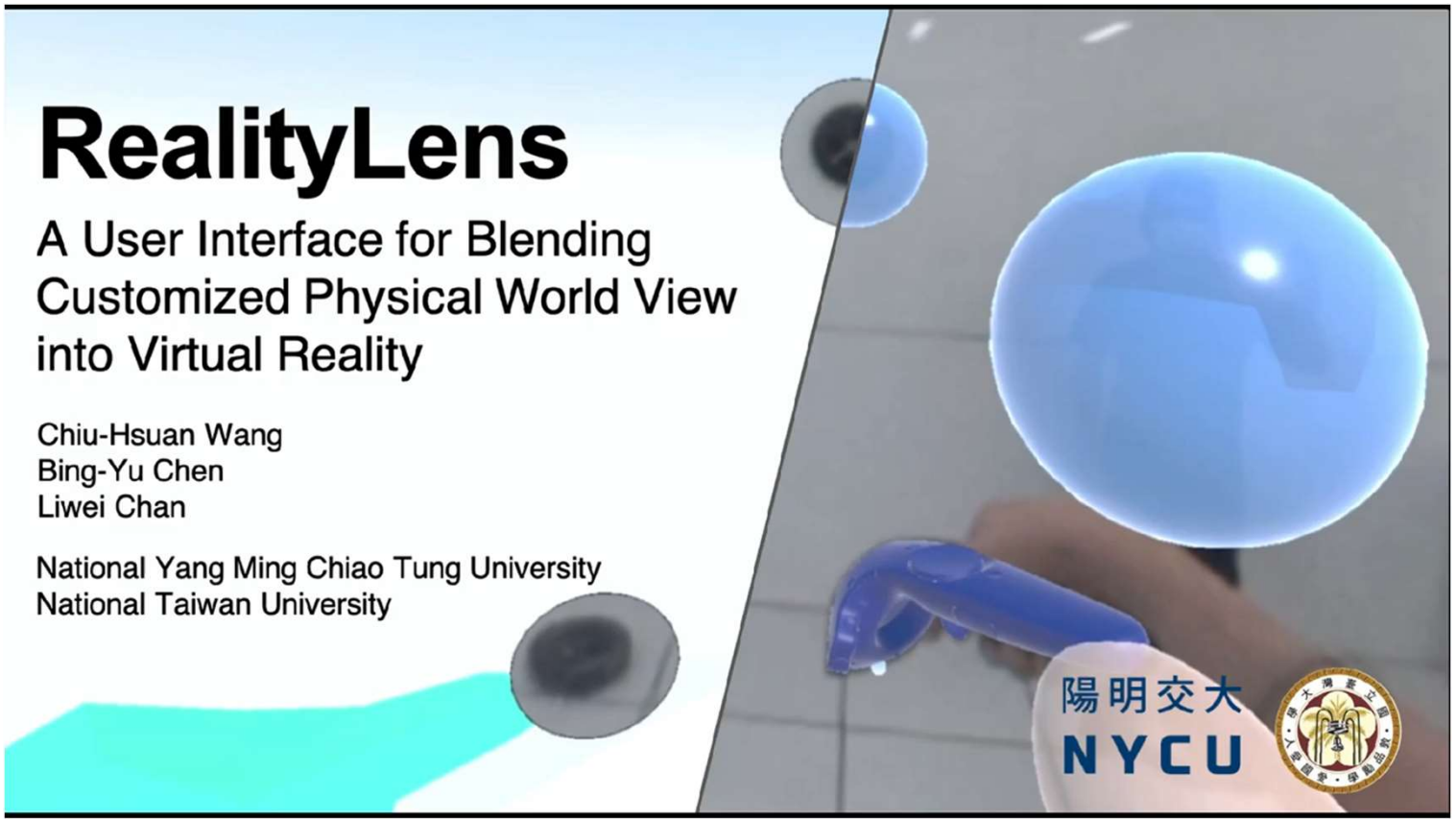
https://leonardopavanatto.com/wp-content/uploads/2021/01/VR21__Do_we_still_need_physical_monitors__An_evaluation_of_the_usability_of_AR_virtual_monitors_for_productivity_work.pdf

- See-through HMDでモニタを表示するモードで仕事できるか？⇒結構できる。
- Hololens使用。

ARの派生

(UIST2023) RealityLens: A User Interface for Blending Customized Physical World View into Virtual Reality

Chiu-Hsuan Wang, Bing-Yu Chen, Liwei Chan

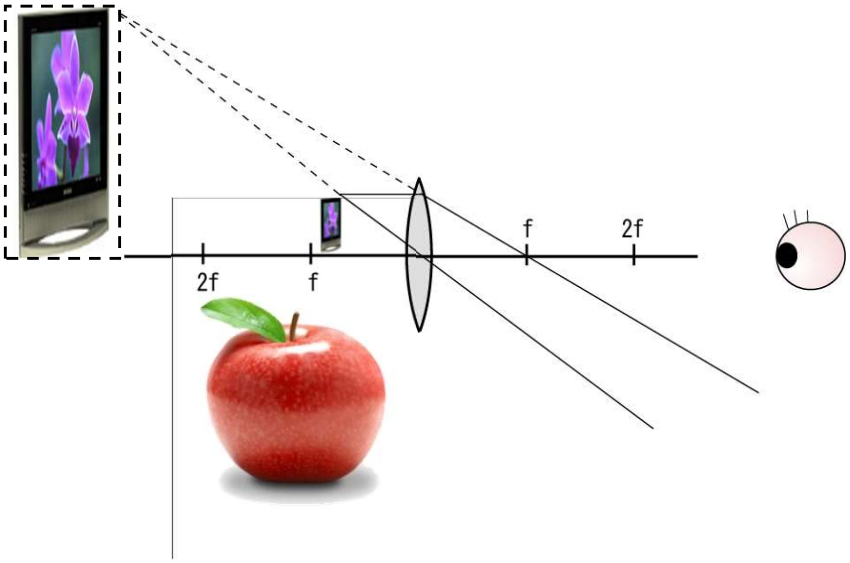


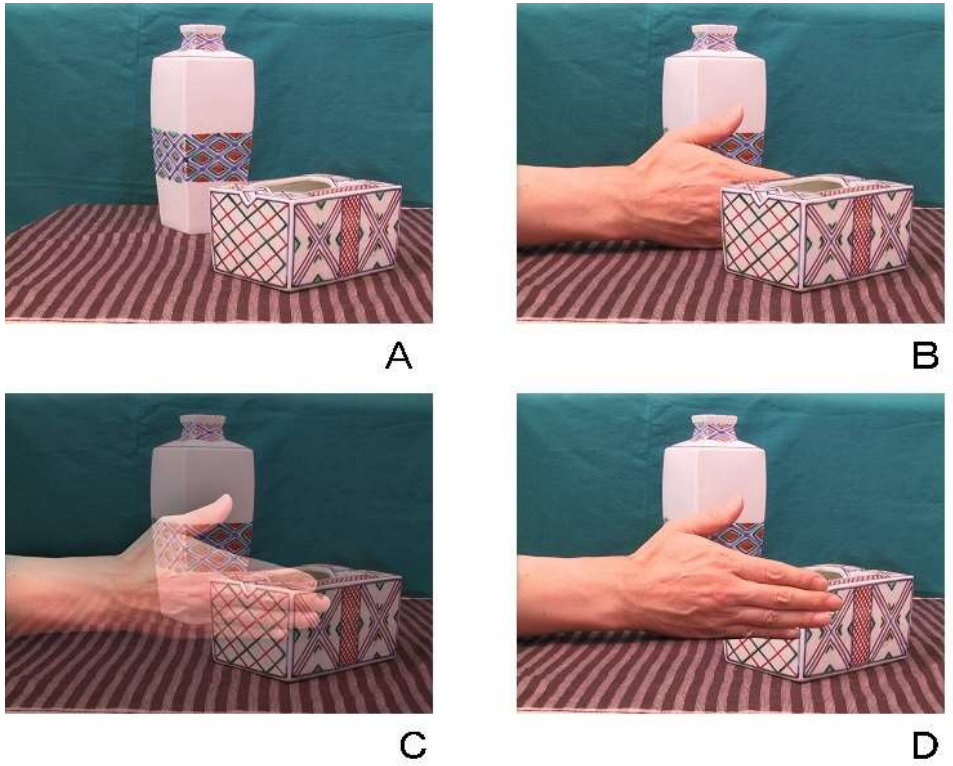
https://www.youtube.com/watch?v=RGGkWFHLUxM&list=PLqhXYFYmZ-VdaPIMTFVH5K5brMDJClfAn&index=20

VR空間の中で、現実空間の映像をレンズのように埋め込む。ちょっとこれまでと違うAR

Images of real space are embedded like lenses in a VR space.

ARの問題 / Issues of AR



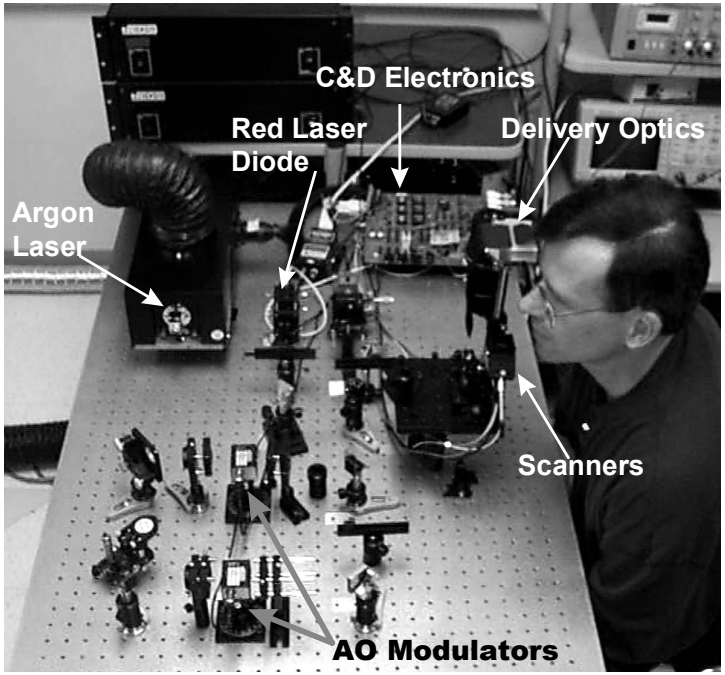


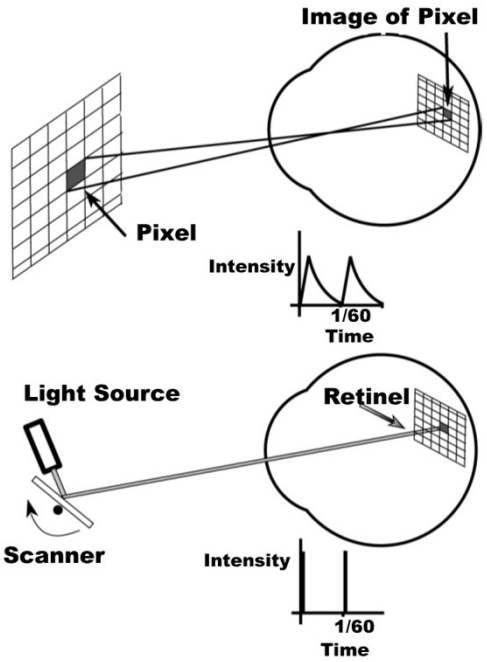
●焦点調節
- HMD像：結像位置固定 /　HMD image: always at the same distance.
- 実世界の物体：距離はまちまち /　Distance of real world object is arbitrary.

●視野角
- HMD像：一般に狭い / HMD field of view is narrow.
- 実世界の物体：非常に広い / Real world has wide field of view.

●遮蔽 (Occlusion)
- （A) 通常のHMD. Ordinary HMD （B)理想的な遮蔽状態. Ideal occlusion （C)See-Through HMD. (D)設置型／Ground fixed display.

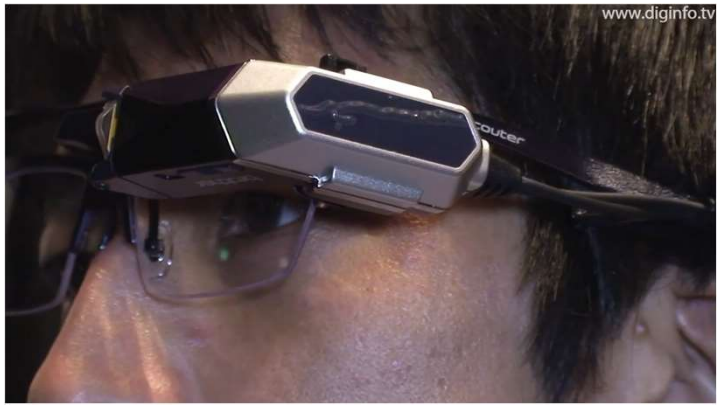
焦点調節への対応：網膜書き込み型HMD / Retina scan display



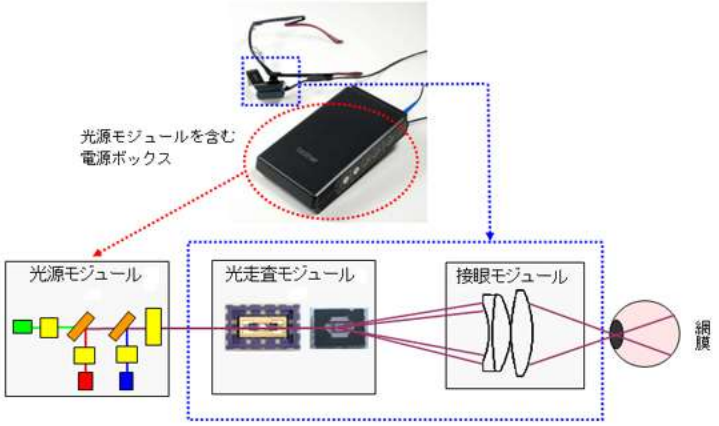


http://www.hitl.washington.edu/projects/vrd/

- Washington university, HIT Lab('99)
- レーザ光線による網膜直接書き込み
  Direct writing to retina by laser beam
  - 眼球のレンズによる結像が不要
    Image focus by the eye lens is unnecessary
- ブラザー工業の網膜走査ディスプレイ(2008-)
  Retina Scan display by Brother Inc.
  - MEMS+レンズにより像を網膜に投影



Head-mounted display projects directly onto the retina : DigInfo
https://www.youtube.com/watch?v=9l0hF0cbw8E



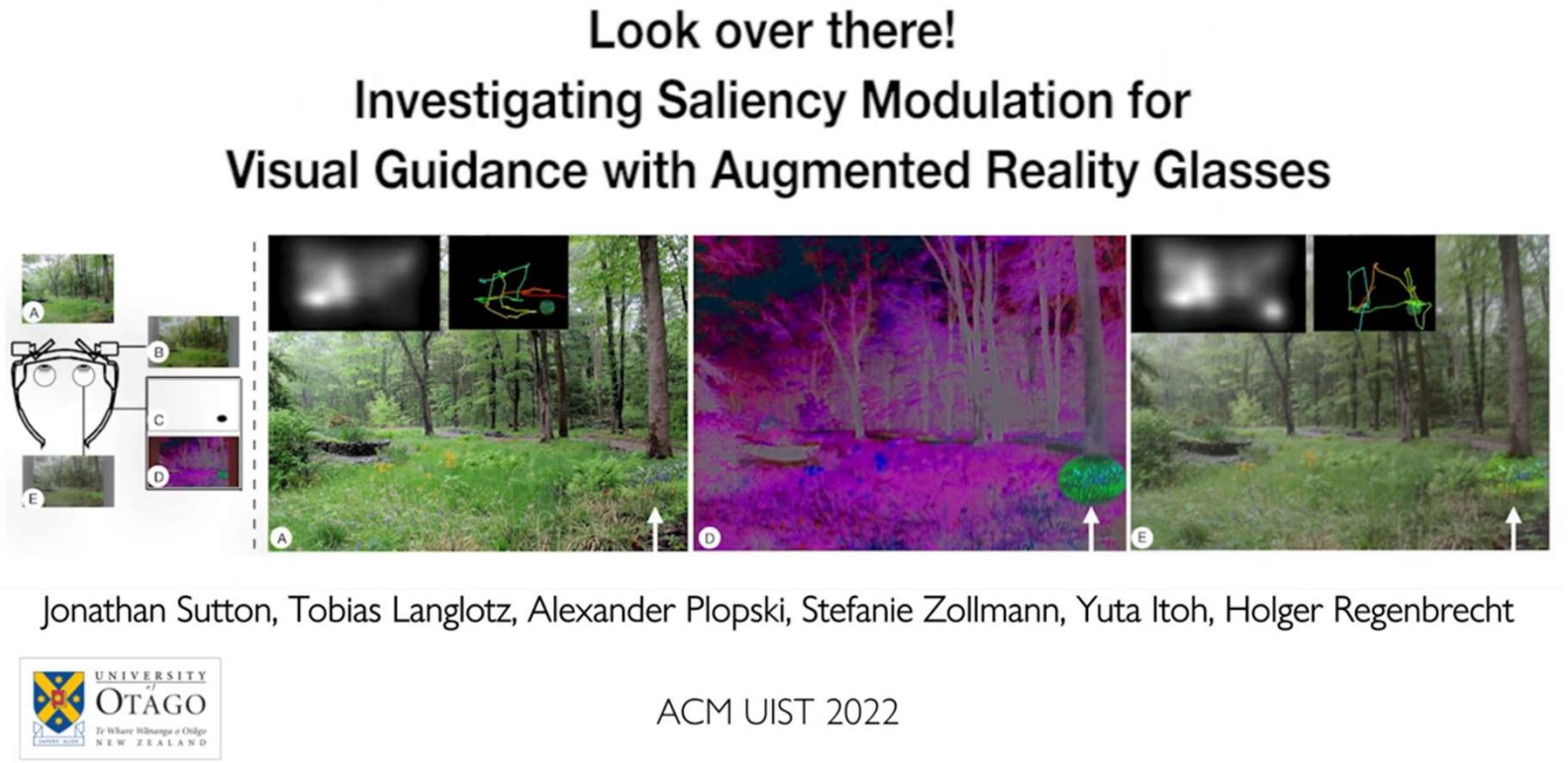
ITMedia news
https://www.itmedia.co.jp/news/articles/0910/21/news021.html#l_sk_brother_02.jpg&_ga=2.208577813.608477848.1589877978-811114375.1574162731

(SIGGRAPH2018) Autofocals: Gaze-Contingent Eyeglasses for Presbyopes
Nitish Padmanaban, Robert Konrad, Gordon Wetzstein

https://www.youtube.com/watch?v=JYw6zlmeS38

- 老眼用眼鏡．眼球の輻輳運動と外向きの奥行きカメラによって，今見ようとしている対象の奥行きを計測，その距離に適したピント調整を動的に行う．

(UIST2022) Look over there! Investigating Saliency Modulation for Visual Guidance with Augmented Reality Glasses
Jonathan Sutton, Tobias Langlotz, Alexander Plopski, Stefanie Zollmann, Yuta Itoh, Holger Regenbrecht

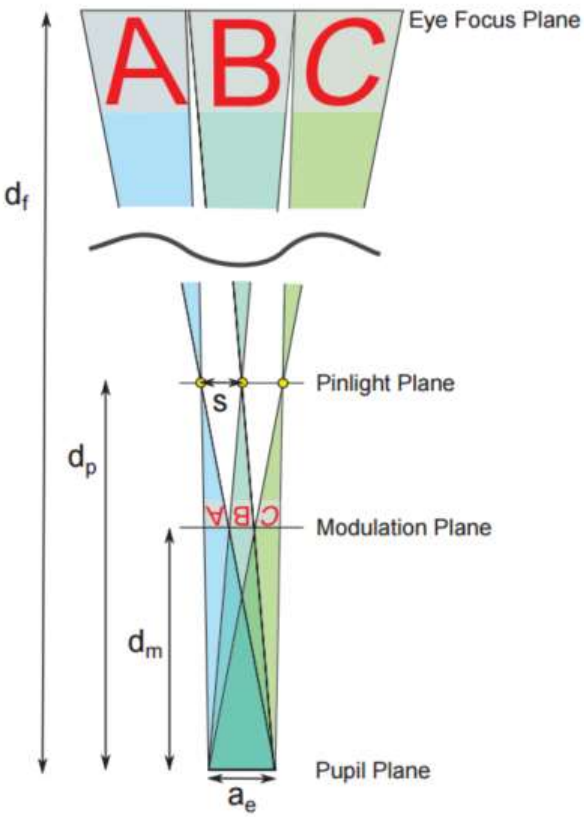


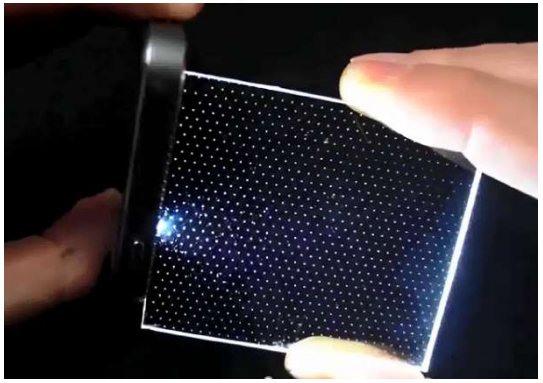
https://www.youtube.com/watch?v=92j6ncPG_D8&list=PLqhXYFYmZ-VdaPIMTFVH5K5brMDJCIfAn&index=37

光学透過型ヘッドマウントディスプレイを使用して実環境の物体の顕著性を変調し、視覚的な混雑を軽減しながらユーザーの視線を誘導

Modulates the prominence of real-world objects using an optically transparent head-mounted display to guide the user's gaze while reducing visual crowding

(SIGGRAPH 2014) Pinlight Displays: Wide Field of View Augmented Reality Eyeglasses



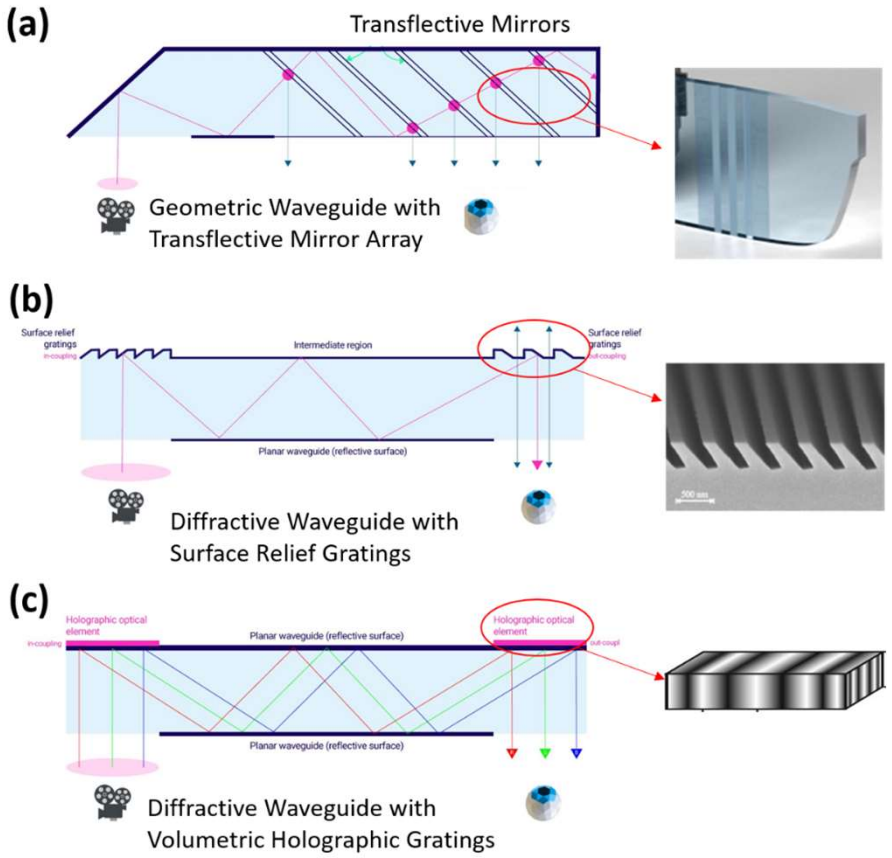


https://www.youtube.com/watch?v=P407DFm0PFQ

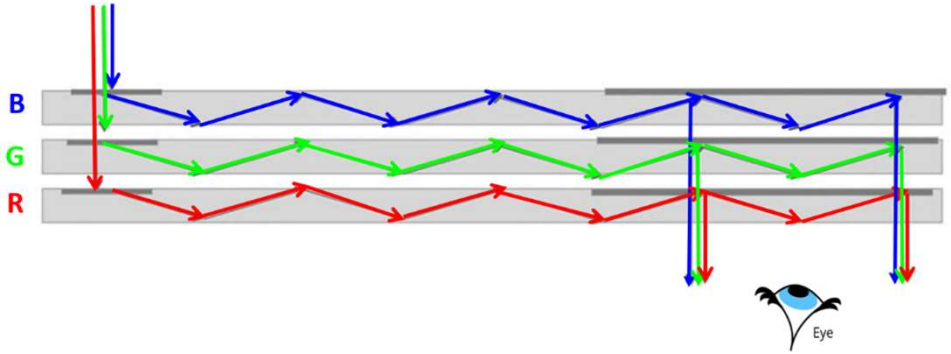
ピンライト光源＋液晶パネルを眼の前に配置、レンズを使用しない光学系。→広い画角を実現
ピンライトの形成にはFTIR的な手法が取られている。

Hololens (Microsoft)

https://en.wikipedia.org/wiki/Microsoft_HoloLens



ホログラフィック回折格子による屈折で光路を稼ぎ、薄いARグラスと広い視野角を実現。
光学シースルーHMDの小型化を実現。

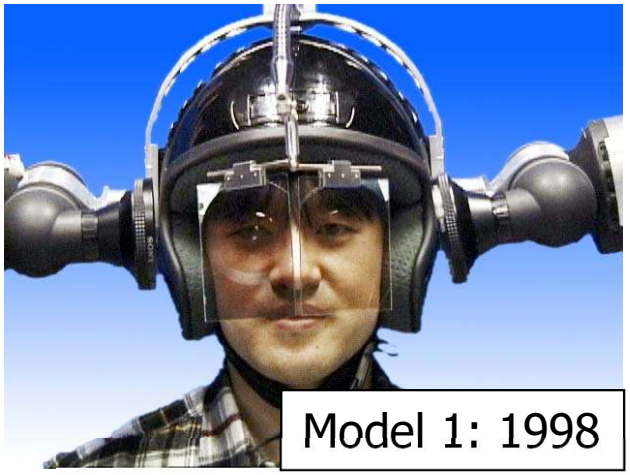


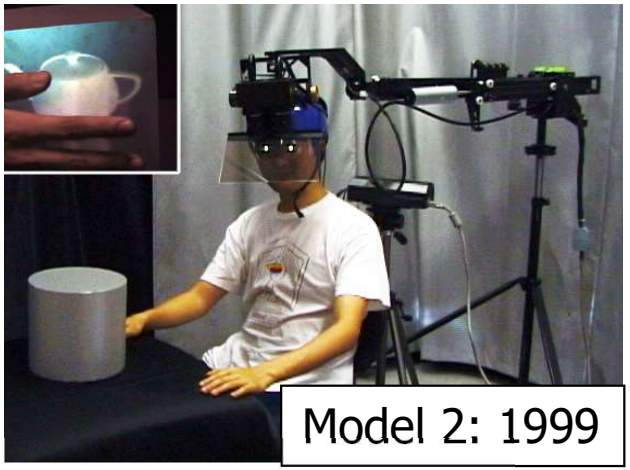
↓ずっとよい解説（あるしおうねさん）
https://www.slideshare.net/AmadeusSVX/hololens-85758620

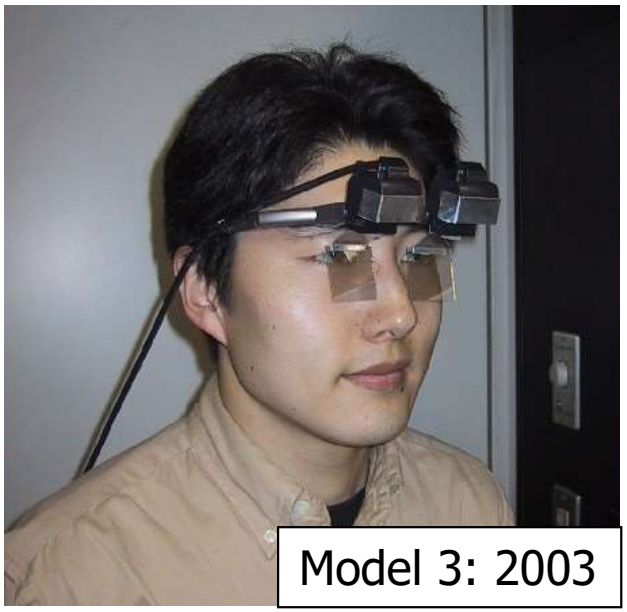
Understanding Waveguide: the Key Technology for Augmented Reality Near-eye Display (Part II)
https://arvrjourney.com/understanding-waveguide-the-key-technology-for-augmented-reality-near-eye-display-part-ii-fe4bf3490fa

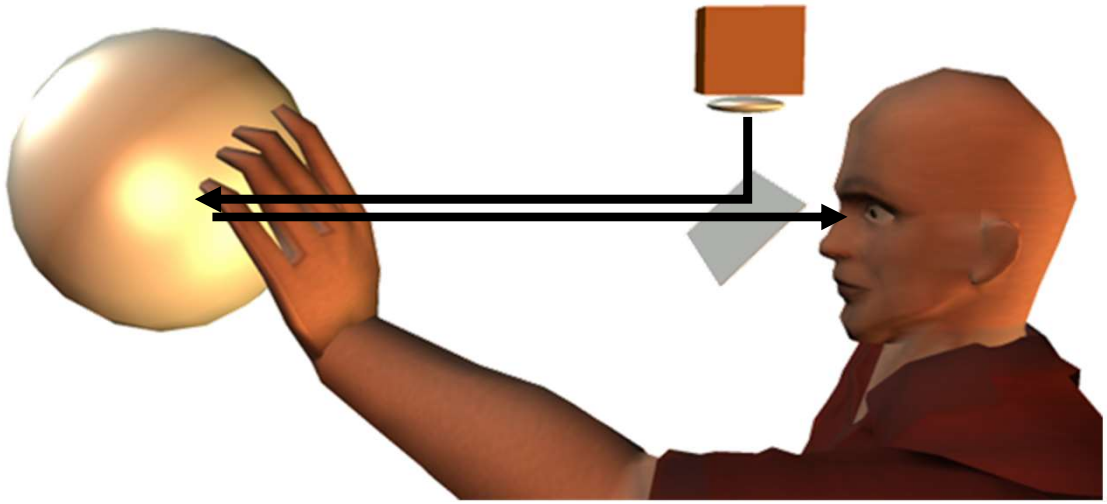
プロジェクションとHMD（1）
再帰性反射材を用いた頭部搭載プロジェクタ
Head Mounted Projector by Retroreflector

http://projects.tachilab.org/rpt/

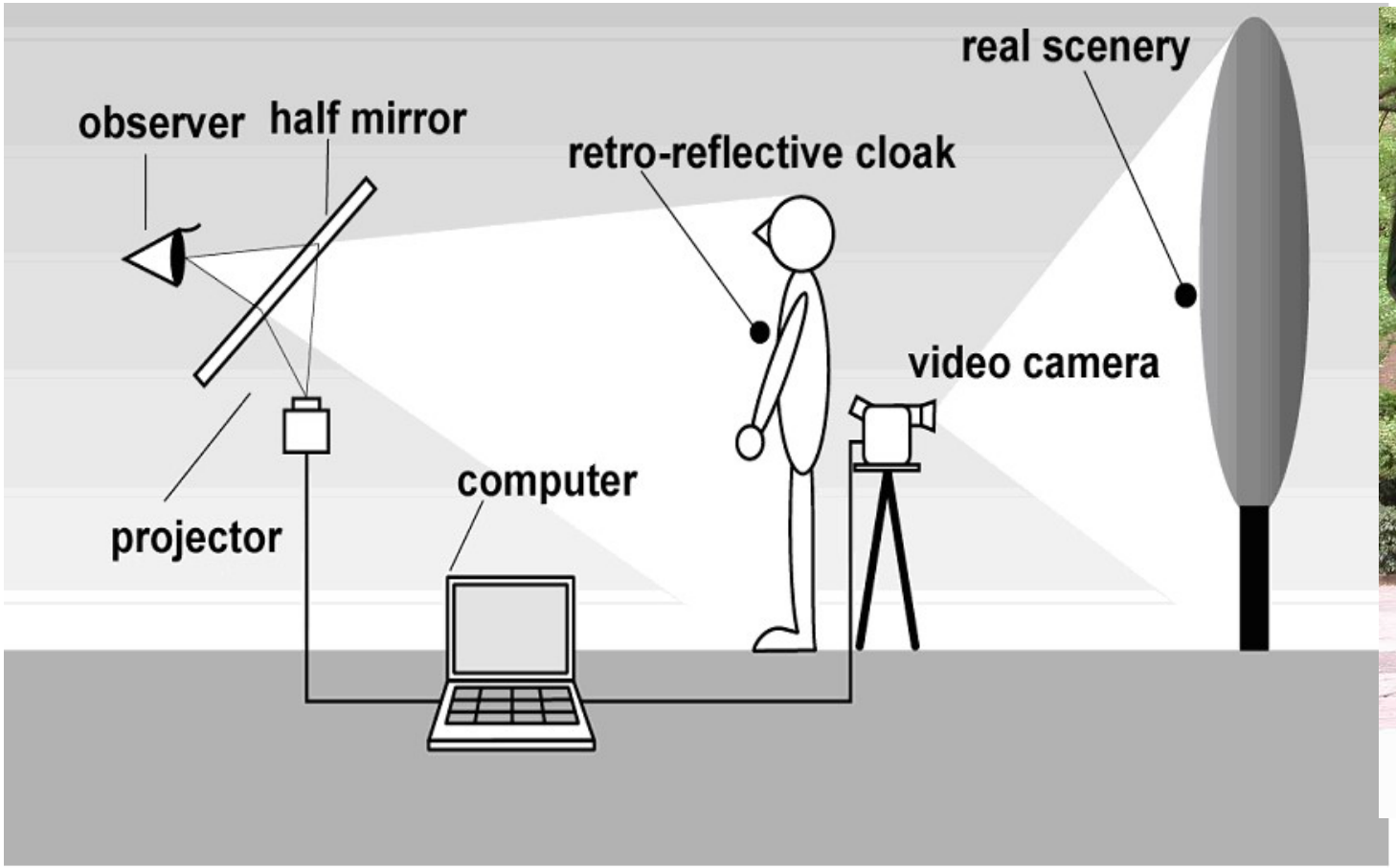

Model 1: 1998


Model 2: 1999


Model 3: 2003



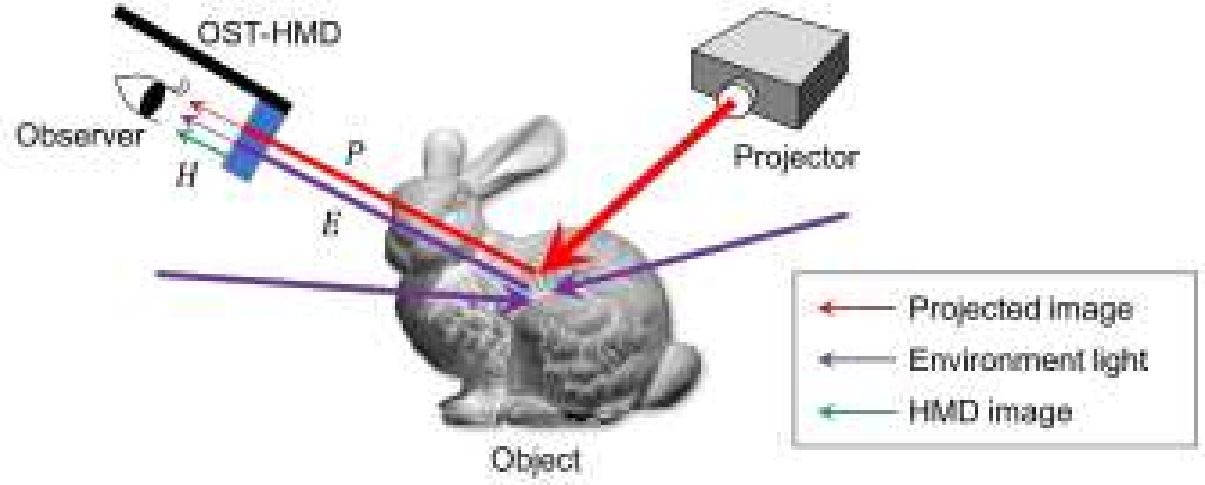
Optical Camouflage by RPT (Inami et al.)



http://www.star.t.u-tokyo.ac.jp/projects/MEDIA/xv/oc-j.html

プロジェクションとHMD（2）

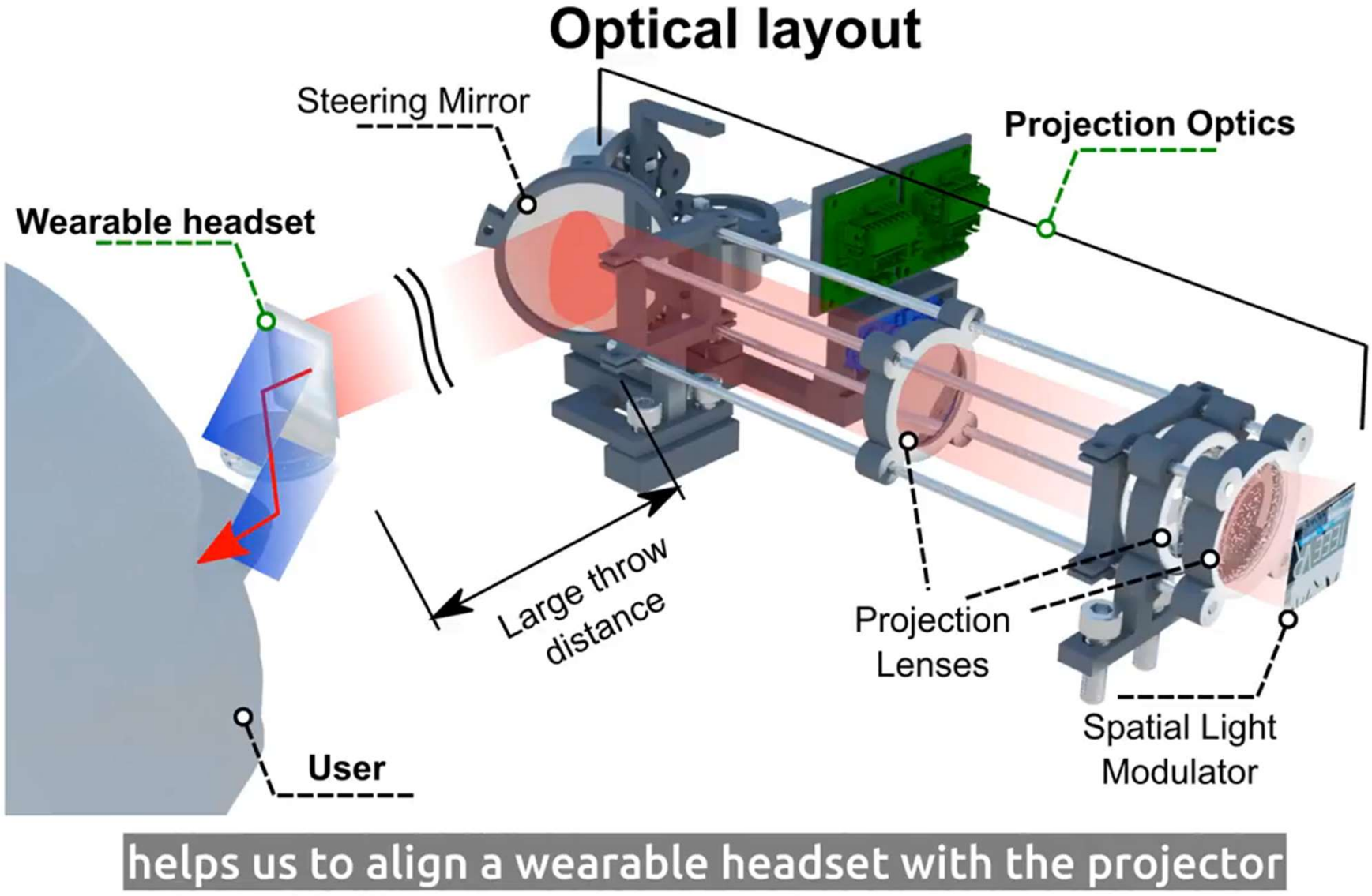
(IEEEVR2018) HySAR: Hybrid Material Rendering by an Optical See-Through Head-Mounted Display with Spatial Augmented Reality Projection Takumi Hamasaki, Yuta Itoh, Yuichi Hiroi, Daisuke Iwai, Maki Sugimoto



プロジェクションとOptical See-Through HMDを組み合わせる．プロジェクションは「視点位置に対して不変の映像（対象物の色）」を提示，OST-HMDは「視点位置に依存した映像（鏡面反射成分など）」を提示．

プロジェクションとHMD（3）

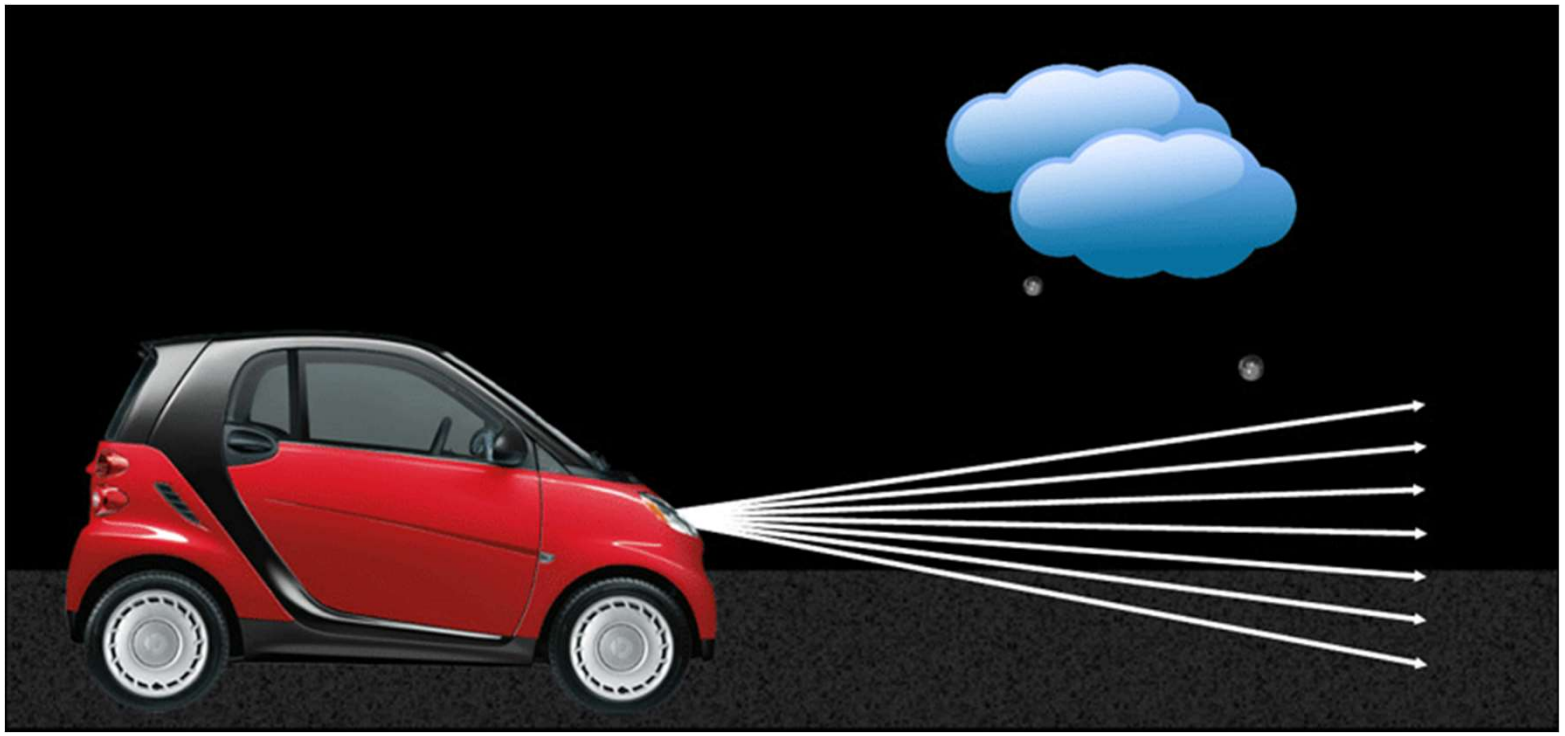
（IEEEVR2021) Yuta Itoh, Takumi Kaminokado, Kaan Akşit: Beaming Displays



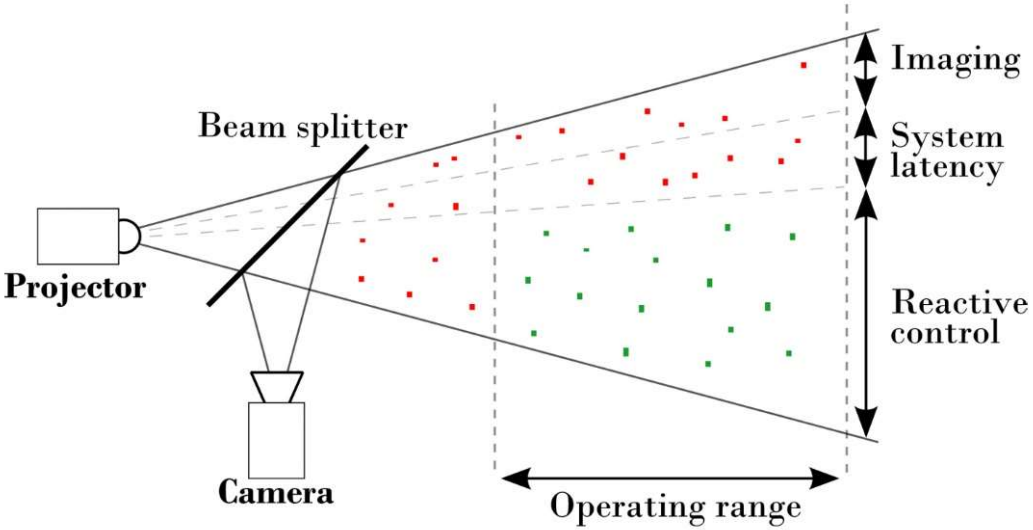
https://www.youtube.com/watch?v=TKI1I3b-LDs&t=13s

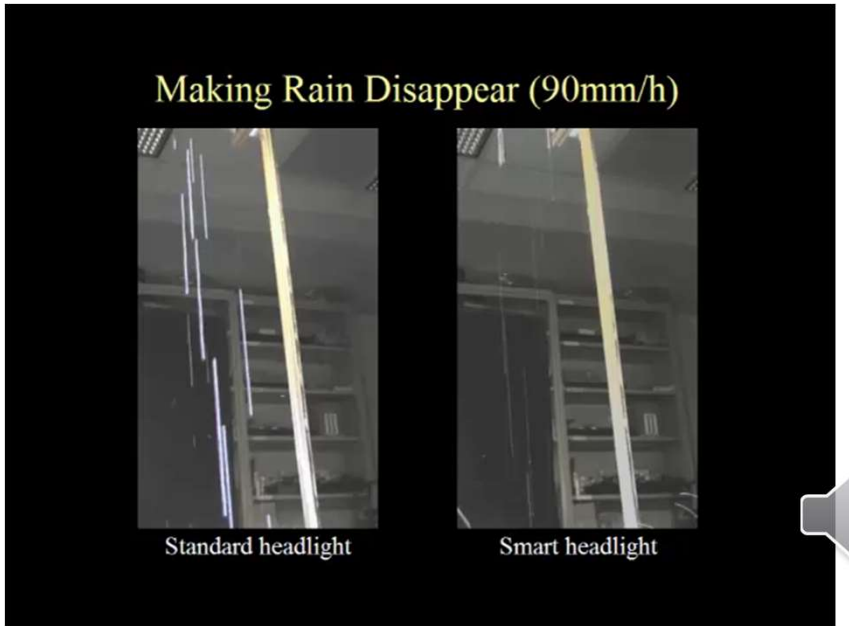
- 頭にはスクリーンとレンズのみ搭載し、そこに向けて外部に設置されたプロジェクタから映像を投影する。超軽量の（AR)HMDが作れる

（参考）雨を避けるヘッドライト /Smart Headlight



http://www.cs.cmu.edu/~ILIM/projects/IL/smartHeadlight/index2.html





TODAY's TOPIC

- 3Dディスプレイ／3D Display
  - HMD
    - HMDとカメラ／HMD & Camera
    - HMDとAR ／HMD & AR
  - 環境型／Environmental Display
    - メガネあり／With Eyeglasses
    - 環境型とカメラ／Environmental Display & Camera
    - メガネなし／Without Eyeglasses
      - 左右の目に違う映像を入れる／Input Different Images to Two Eyes
      - ボリューメトリックな再構成／Volumetric Reconstruction
      - 光線群の制御による多視点映像／Ray Reconstruction
      - 錯覚を利用する／Using Illusion
- その他の話題
  - 光線群制御からCSCWへ／From Ray Control to CSCW
  - 光線群視点制御から視線制御へ／From Ray Control to Eye Control

(Re) Two types of 3D displays

Head Mounted Display (wikipedia)
https://en.wikipedia.org/wiki/Head-mounted_display

CAVE automatic virtual environment (Wikipedia)
https://en.wikipedia.org/wiki/Cave_automatic_virtual_environment

- HMD／Head Mounted Display
- 設置型／Ground-Fixed Display

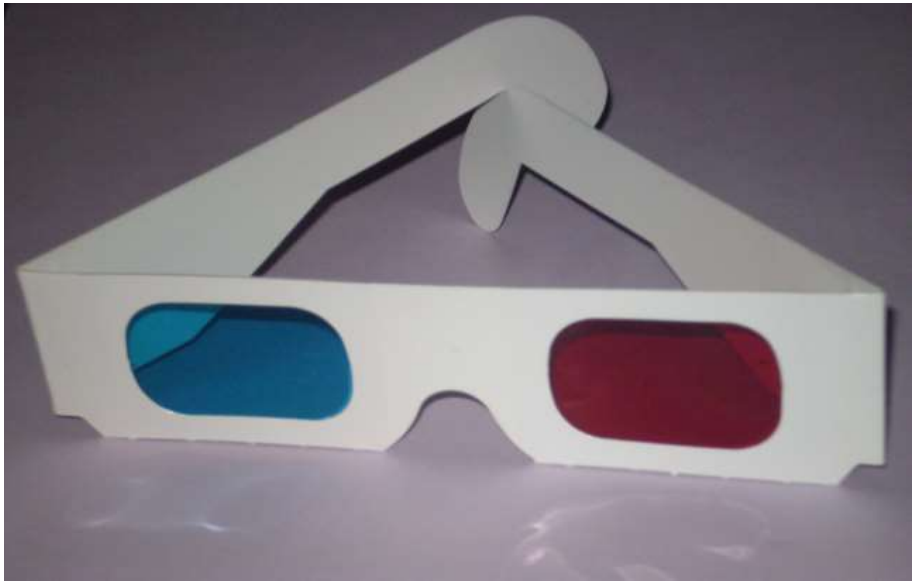
Ground Fixed Display

CAVE automatic virtual environment (Wikipedia)
https://en.wikipedia.org/wiki/Cave_automatic_virtual_environment

LCD shutter type IPT system: CABIN @ U-Tokyo

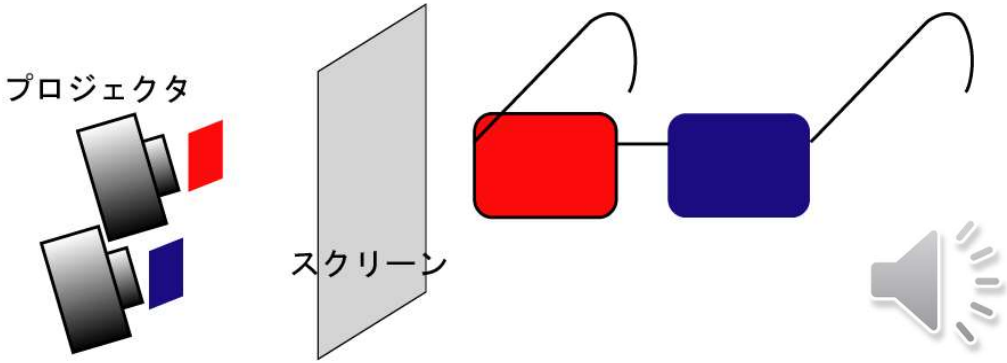
- “Filter” is necessary to display separate image to each eyes.
- By using projectors, surrounding display is possible
  (IPT: Immersive Projection Technology)

Filter (1) Color Filter



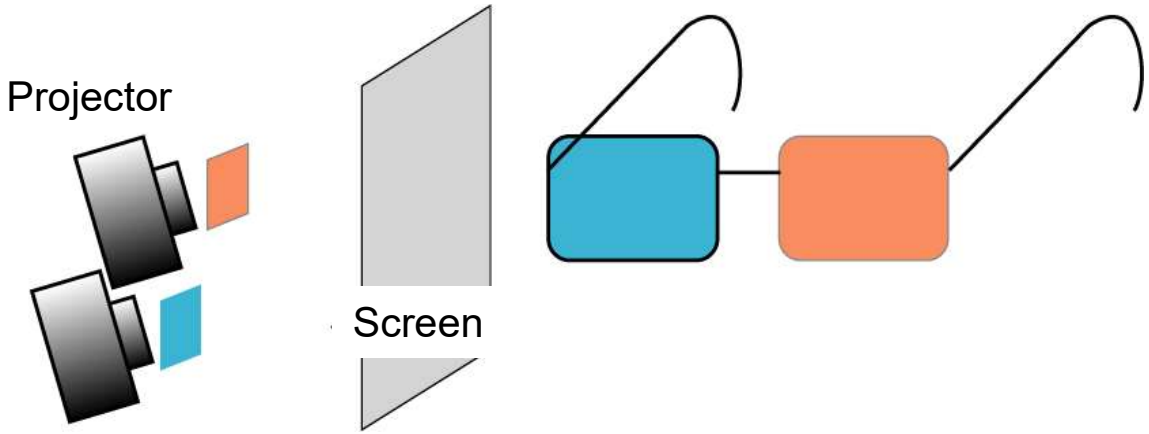
Anaglyph 3D (Wikipedia)
https://en.wikipedia.org/wiki/Anaglyph_3D

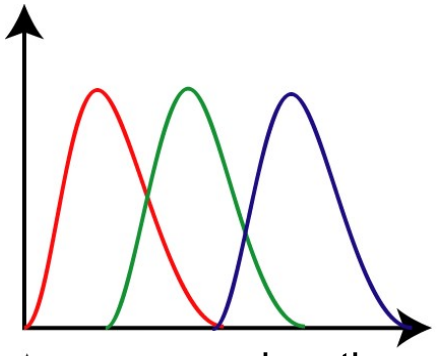
- Red cellophane and Blue cellophane. That's it.
  - $$Cheap!$$
  - Color is strange.

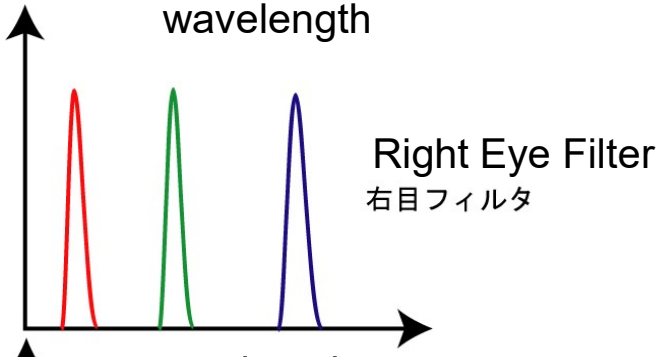


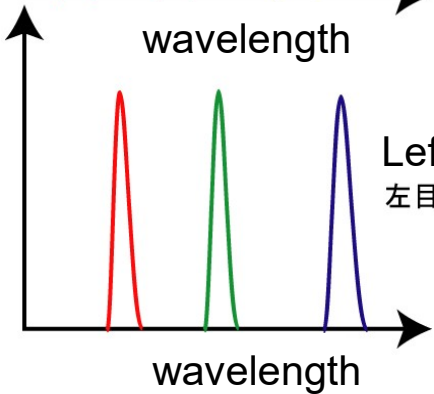
Filter (1.5) Full-color “color filter”

https://en.wikipedia.org/wiki/Dolby_3D



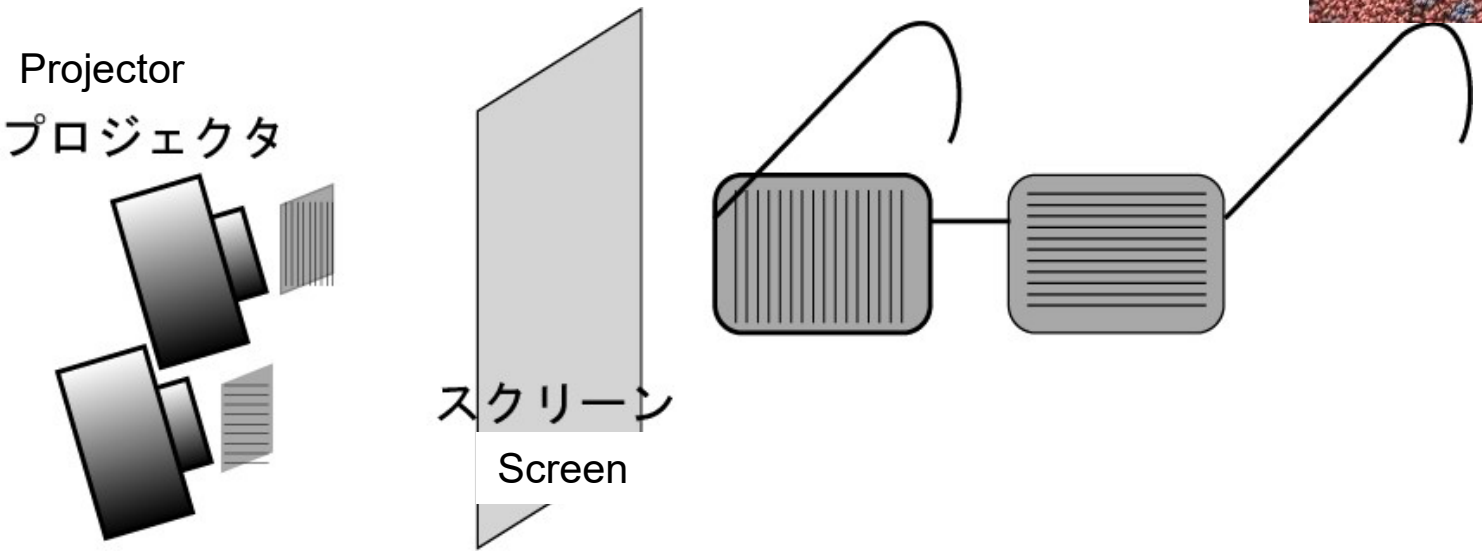






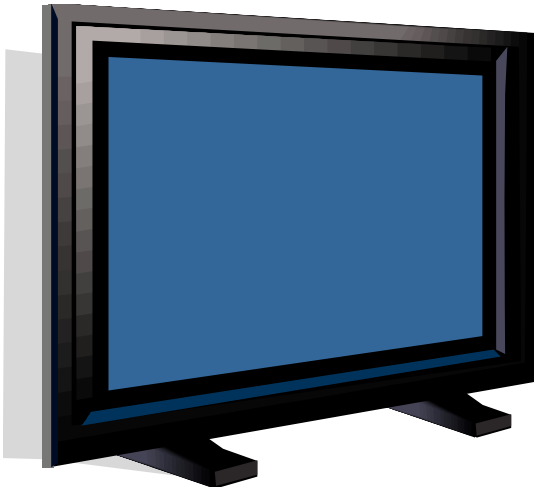
- Very narrow band-pass filters
- The same “red” for right-eye and left-eye red have slightly different wavelength.
- Dolby 3D employs this method

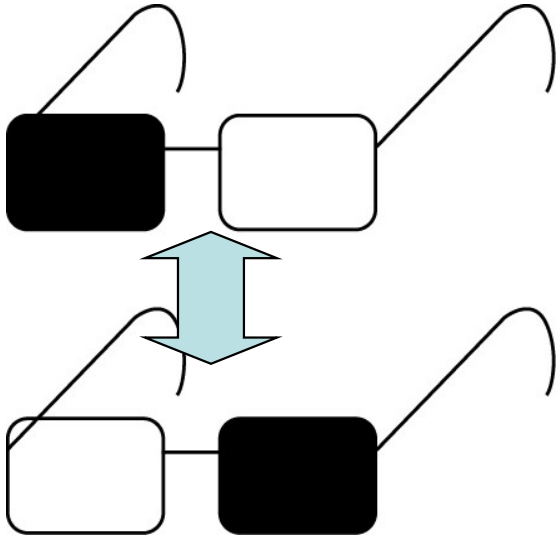
Filter (2) Polarization Filter



- Horizontally polarized light can not pass through vertical polarizer, and vice-versa.
- Cheap and color is OK.
- Circular polarization is used for tilt robustness.

Filter (3) Time-multiplexing





- High speed “LCD shutters” are put on each eyes.
- At one flame, only one eye can see.
- The refresh rate becomes half.
  Quite high fps display is necessary (×LCD ○CRT)
- Many people can observe different image
  (image becomes darker and fps becomes lower, though)

AVATAR(2009)

XpanD

RealD

Dolby3D

IMAX3D

- いくつかの方式で同時上映された
  - **XpanD: Time multiplexing**
  - **RealD: Polarization filter (circular)**
  - **Dolby3D：Full color “color filter”**
  - **IMAX3D: Polarization filter (linear)**
- 3Dの字幕問題を認識させた：ARの問題に等しい
  Showed problem of “caption”: Equal to AR problem

Avatar (Wikipedia)
https://en.wikipedia.org/wiki/Avatar_(2009_film)

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- 3Dディスプレイ／3D Display
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    - HMDとカメラ／HMD & Camera
    - HMDとAR ／HMD & AR
  - 環境型／Environmental Display
    - メガネあり／With Eyeglasses
    - 環境型とカメラ／Environmental Display & Camera
    - メガネなし／Without Eyeglasses
      - 左右の目に違う映像を入れる／Input Different Images to Two Eyes
      - ボリューメトリックな再構成／Volumetric Reconstruction
      - 光線群の制御による多視点映像／Ray Reconstruction
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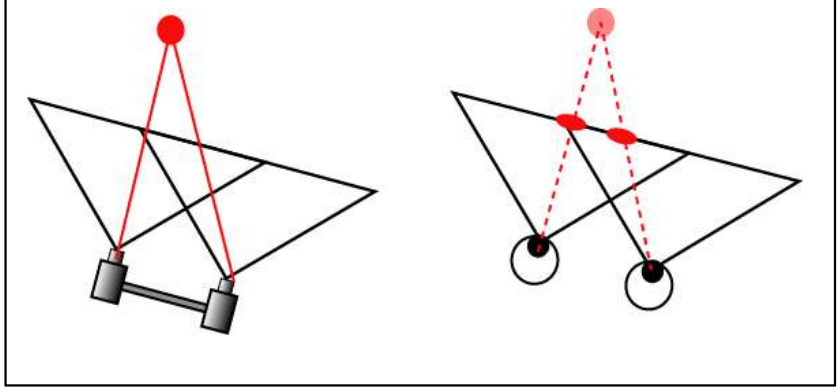
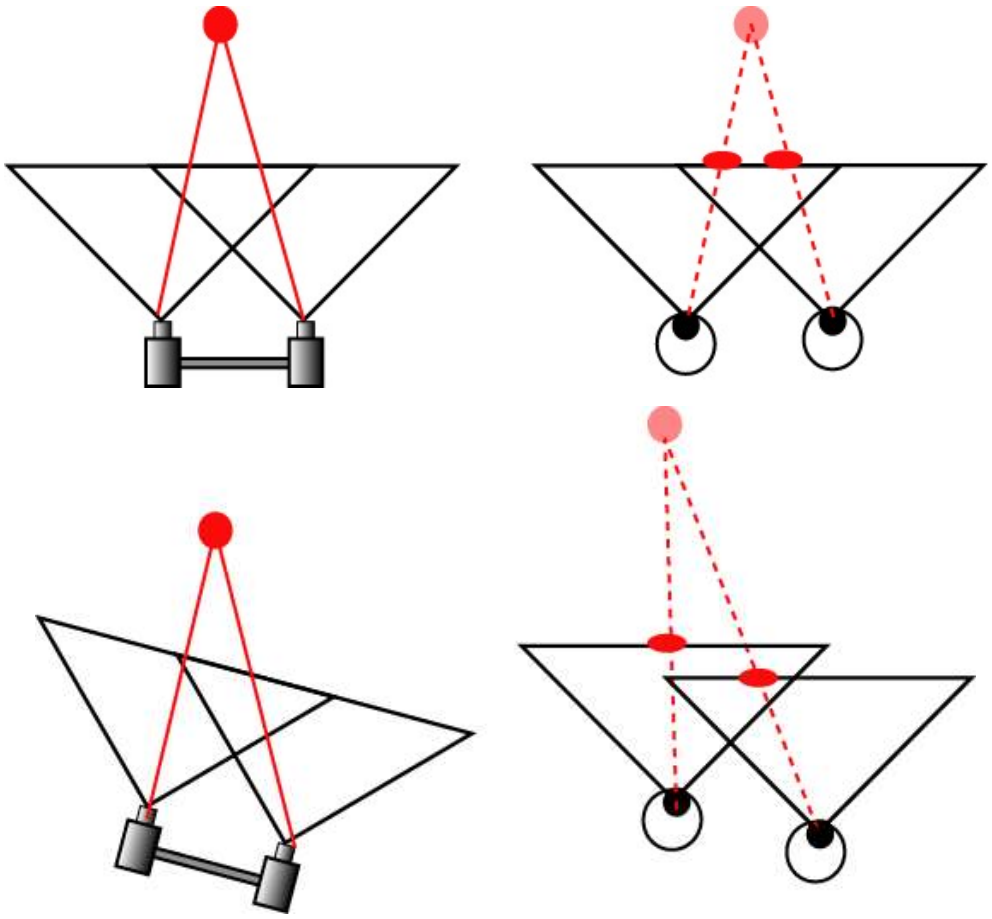
HMD用のカメラを設置型ディスプレイに使うと
If we use HMD camera for Ground fixed Display

HMD sytem



HMDcam

Ground fixed Display

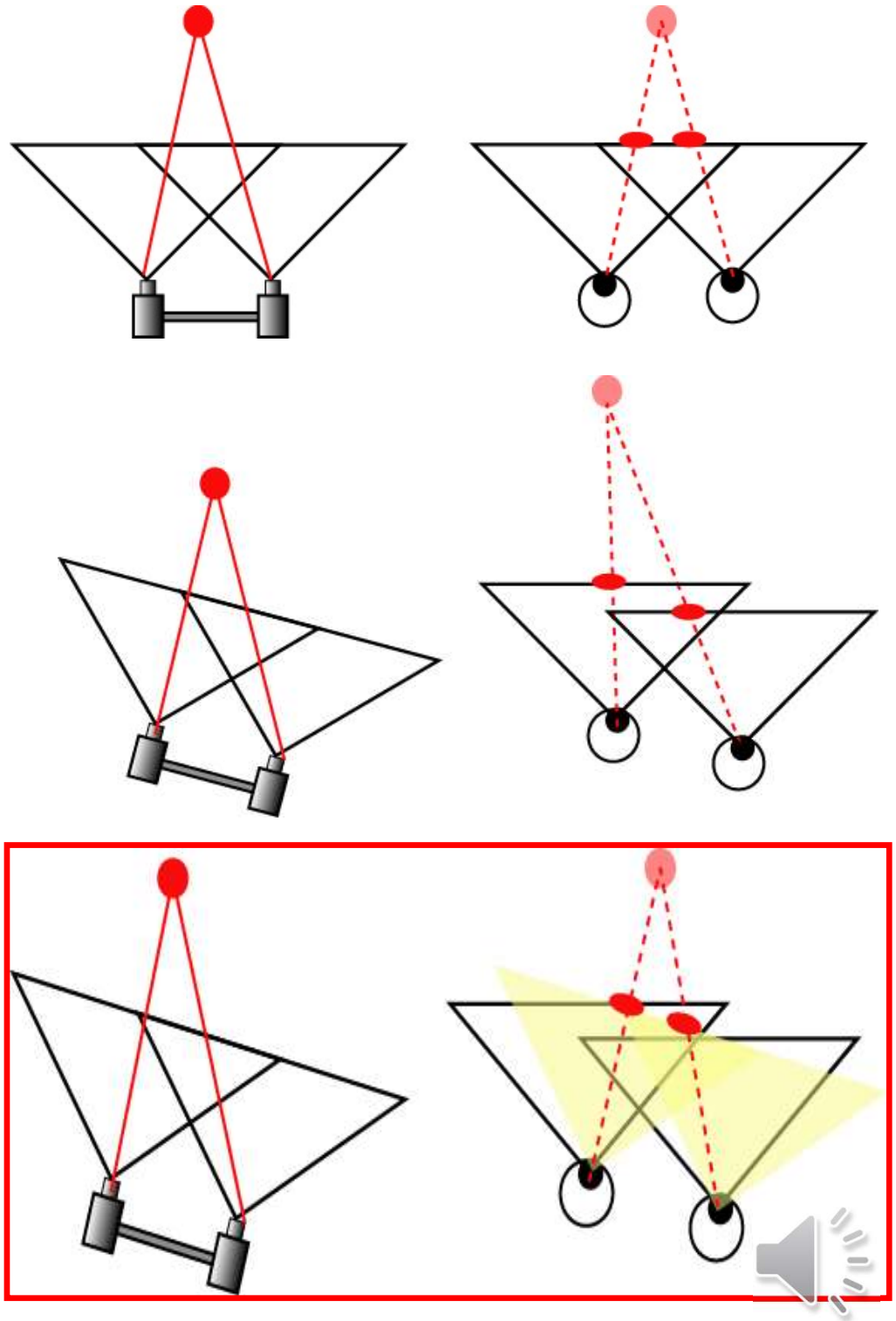


Head rotation change position and distance

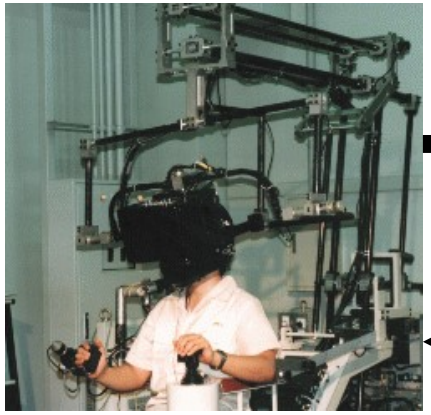
= The world is twisted

Virtual Screen

- Treat the Video stream in CG world.
- Put “virtual screen” on any place of the CG world.
- “Texture map” the video stream.
- Conversion of HMDcam to IPT is possible.

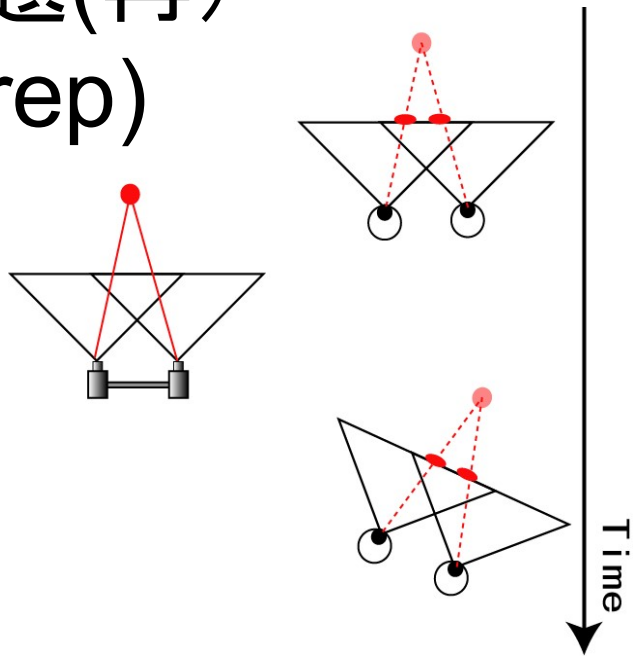


その他の注意点（2）時間遅れの問題(再）
Other concerns(2) Time Latency(rep)

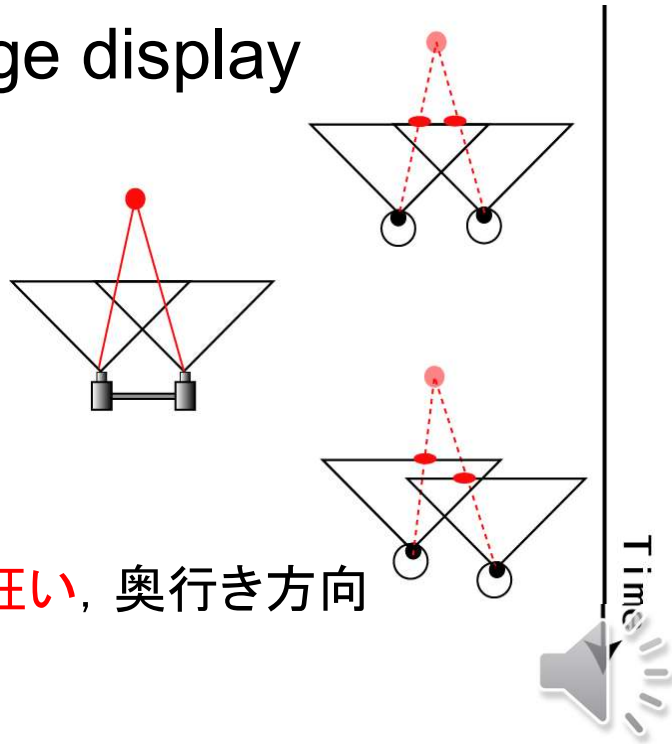


頭の動きの伝送
Head Motion

画像の伝送
Imge transfer



- 頭の動きから描画までに時間遅れ.
  Latency between head motion and image display



- 首を振ったとき When the head rotates:
  - HMD:
    - 画像が首の回転に付いてくる
      The image moves
  - 設置型 Ground fixed disply:
    - 画像は付いてこない. しかし立体視に関しては狂い, 奥行き方向にひずみを生じる.
      The image does not move, but distort.

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    - 環境型とカメラ／Environmental Display & Camera
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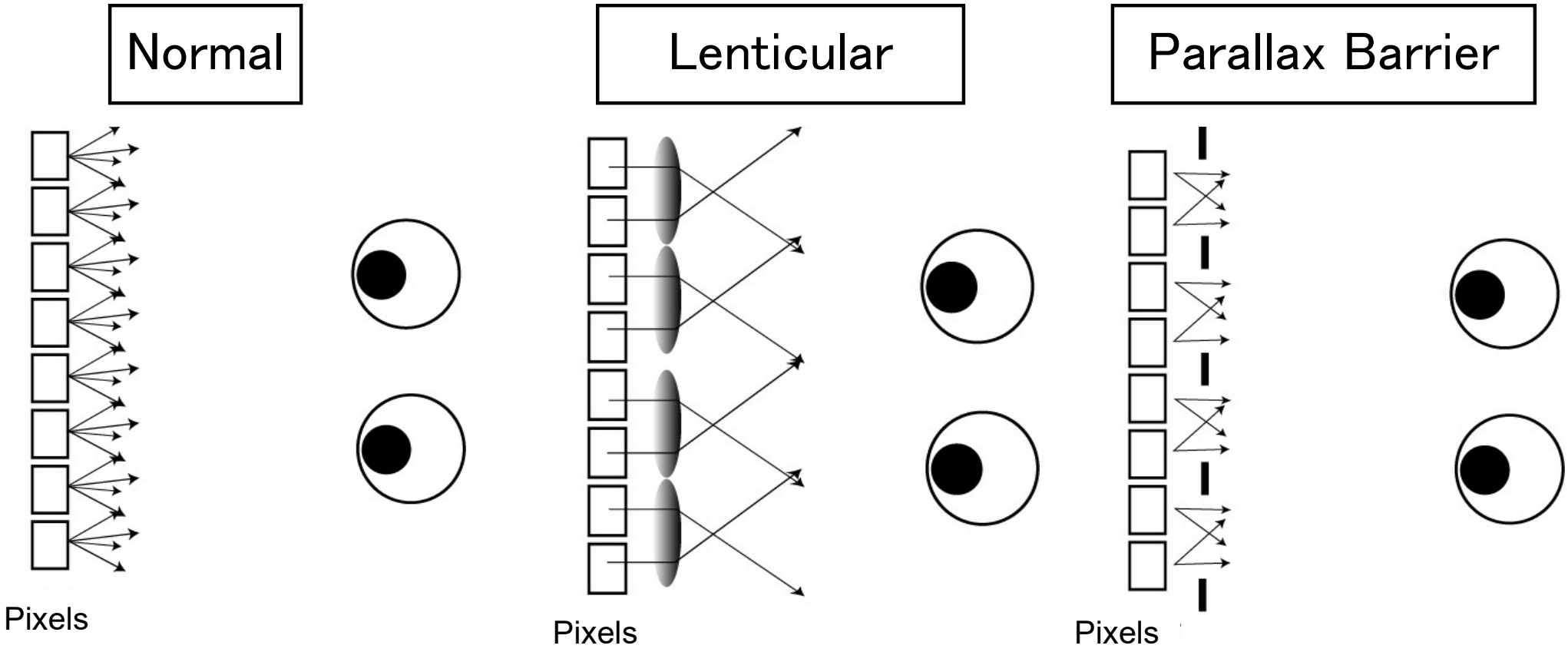
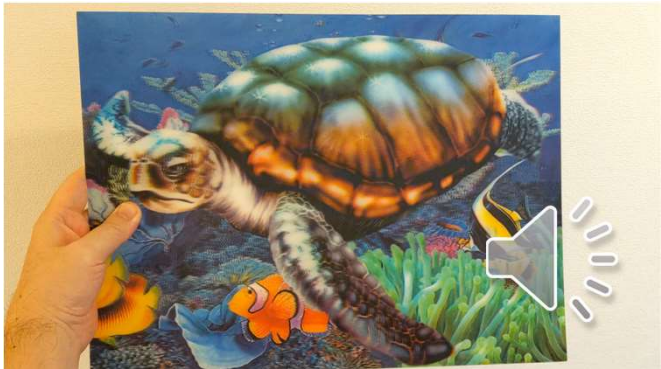
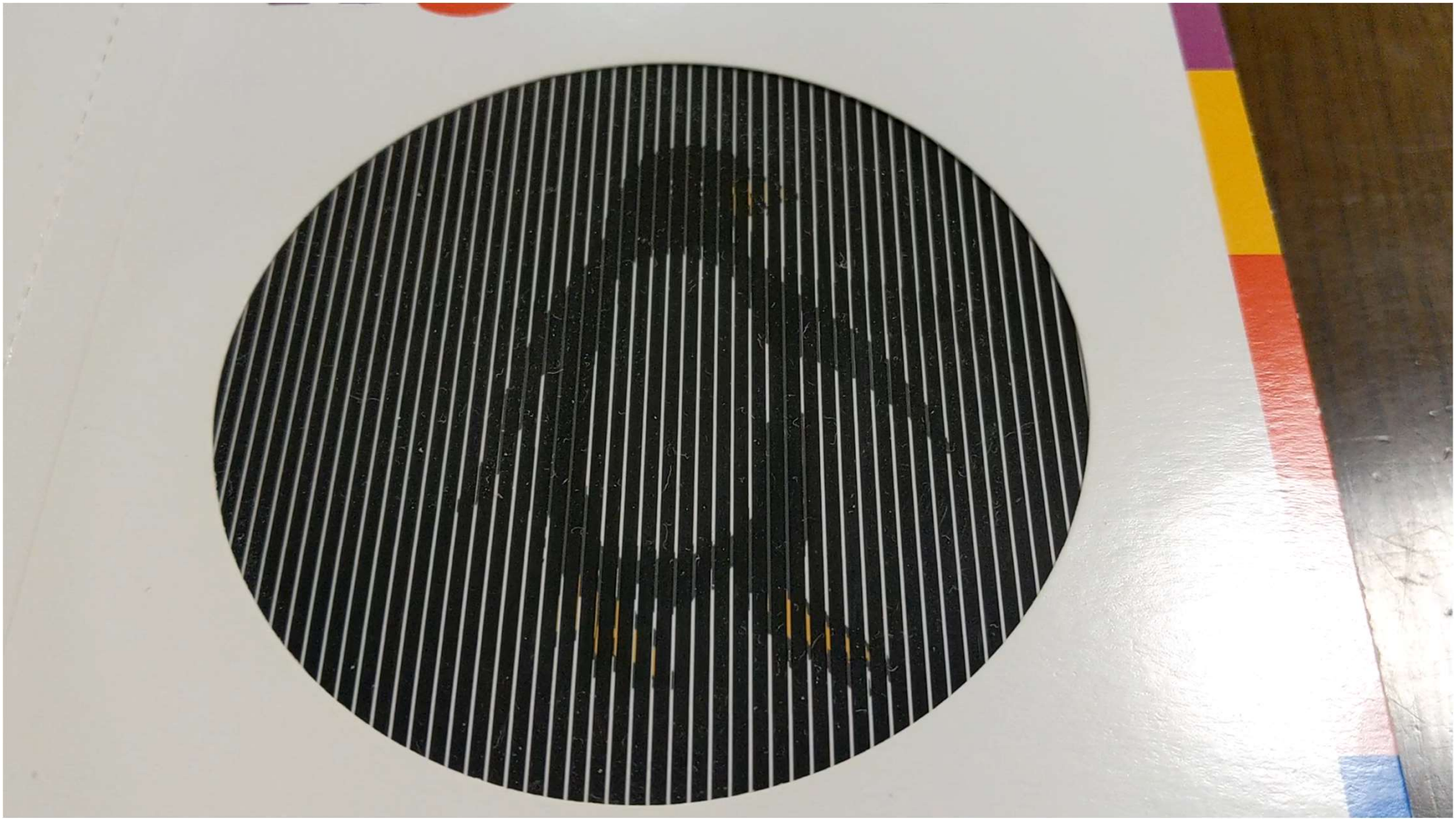
Control Rays

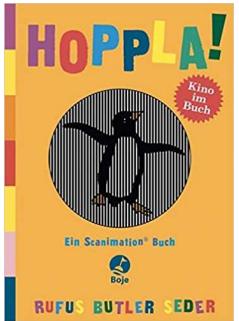


- Put different rays to different direction
- No Eyeglasses!
- No Head tracking!
- Resolution is lowered



Parallax Barrier





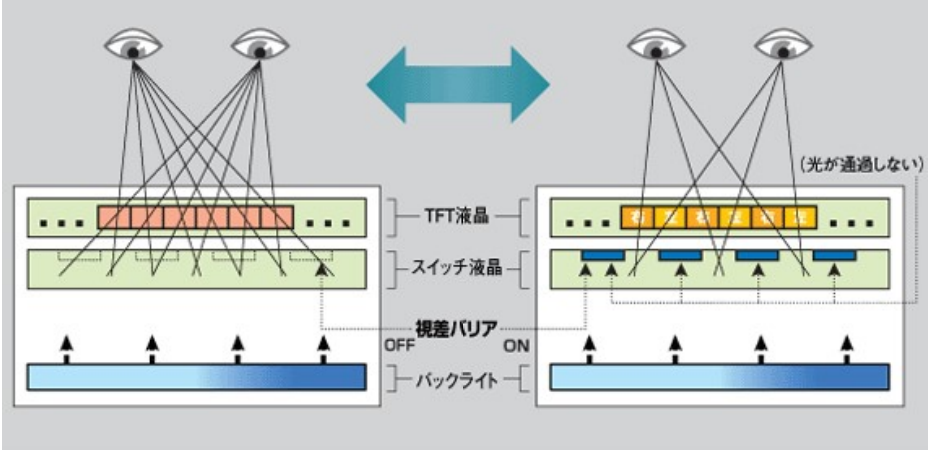
Seder, R: Hoppla
https://www.amazon.co.jp/dp/3414822555

Nintendo 3DS: LCD Parallax Barrier

バリア用の液晶層：2D／3D切り替え。強度も可変。

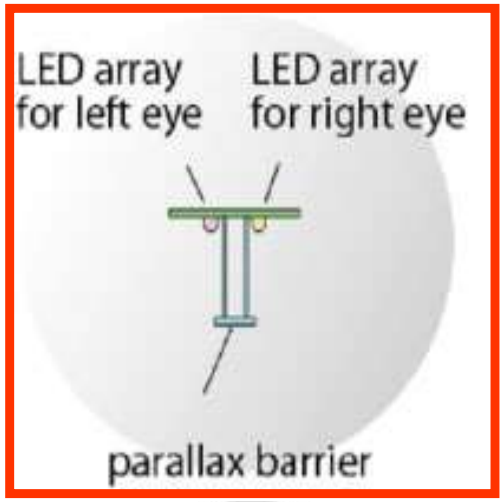
2眼カメラ付きでビデオシースルー型のARも可能。

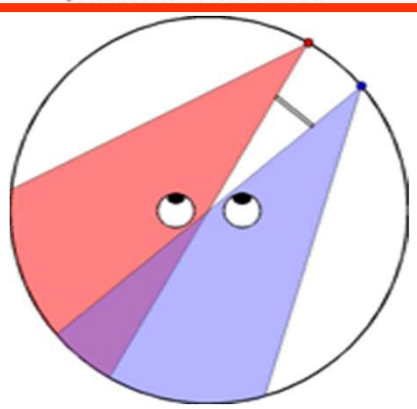
LCD layer for parallax barrier：2D/3D mode change



http://www.sharp.co.jp/products/device/about/lcd/3d/index.html

TWISTER: Use Moving Parallax Barrier





http://www.youtube.com/user/tachilab#p/a/u/0/SX_IKm1rT4I

- Left and Right eye receive different LED light by the barrier.
- Rotates very fast, and the barrier “vanishes”

http://projects.tachilab.org/TWISTER/

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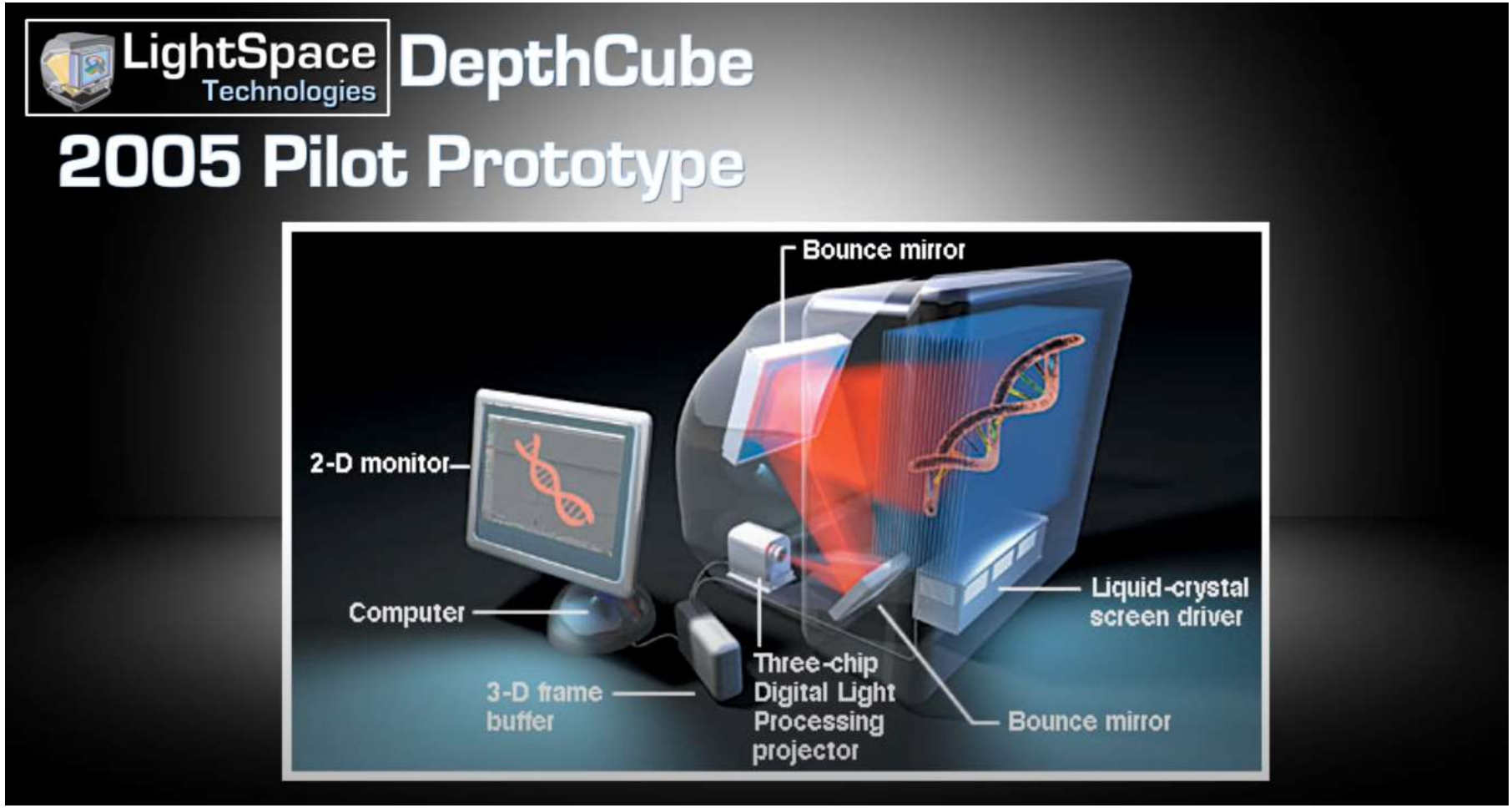
Volumetric Representation

Volumetric Display (Wikipedia)
https://en.wikipedia.org/wiki/Volumetric_display

Voxon VX1 3D Volumetric Display - Demonstration
https://www.youtube.com/watch?v=FVYoWsxqK8g

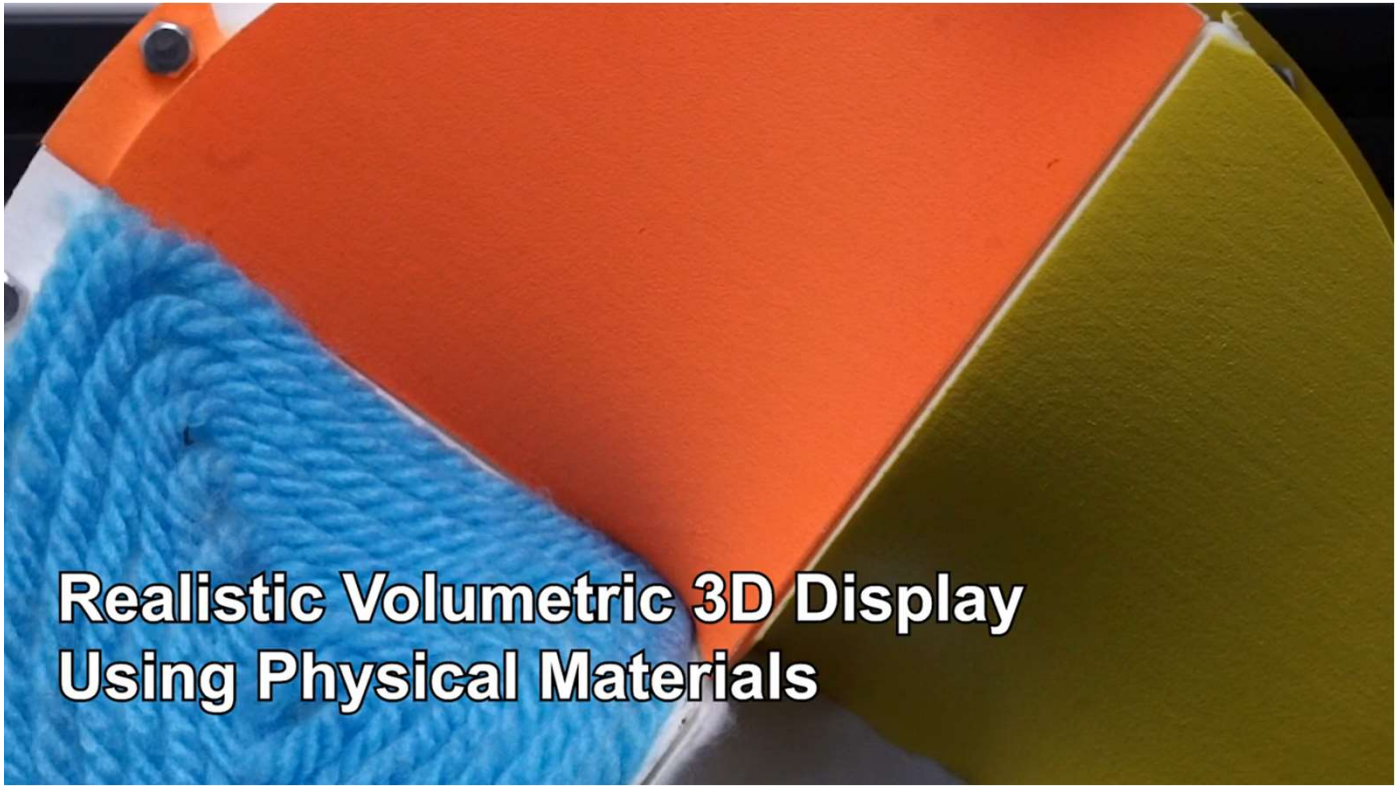
- Rotate or vibrate the screen or mirror
- “Cross-section” image is projected according to the motion.

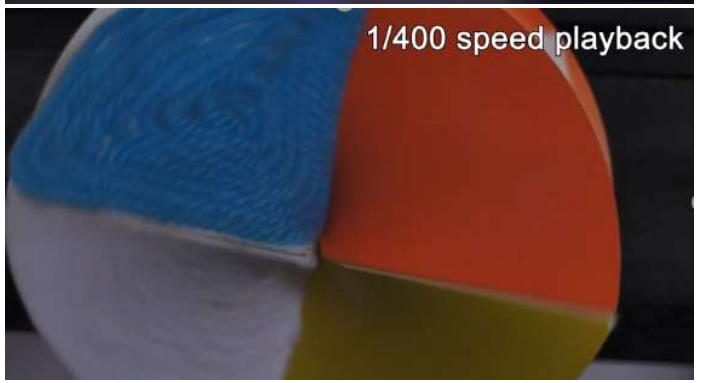
Volumetric representation by layered LCDs



- https://www.youtube.com/watch?v=RAasdH10Irg
- LightScape Technologies, DepthCube Z1024
- スクリーンの役割をする液晶スキャッタリング・シャッター20枚。DLPプロジェクターで背面投影。20 LCD shutters are stacked as layered screen.
- 20枚の内、常に1枚だけシャッターが閉じる。高速にスクリーンが動くのと等価。One shutter works at a time, equivalent to moving screen.

（IEEEVR2021) Ray Asahina, Takashi Nomoto, Takatoshi Yoshida, Yoshihiro Watanabe
Realistic 3D Swept-Volume Display with Hidden-Surface Removal Using Physical Materials

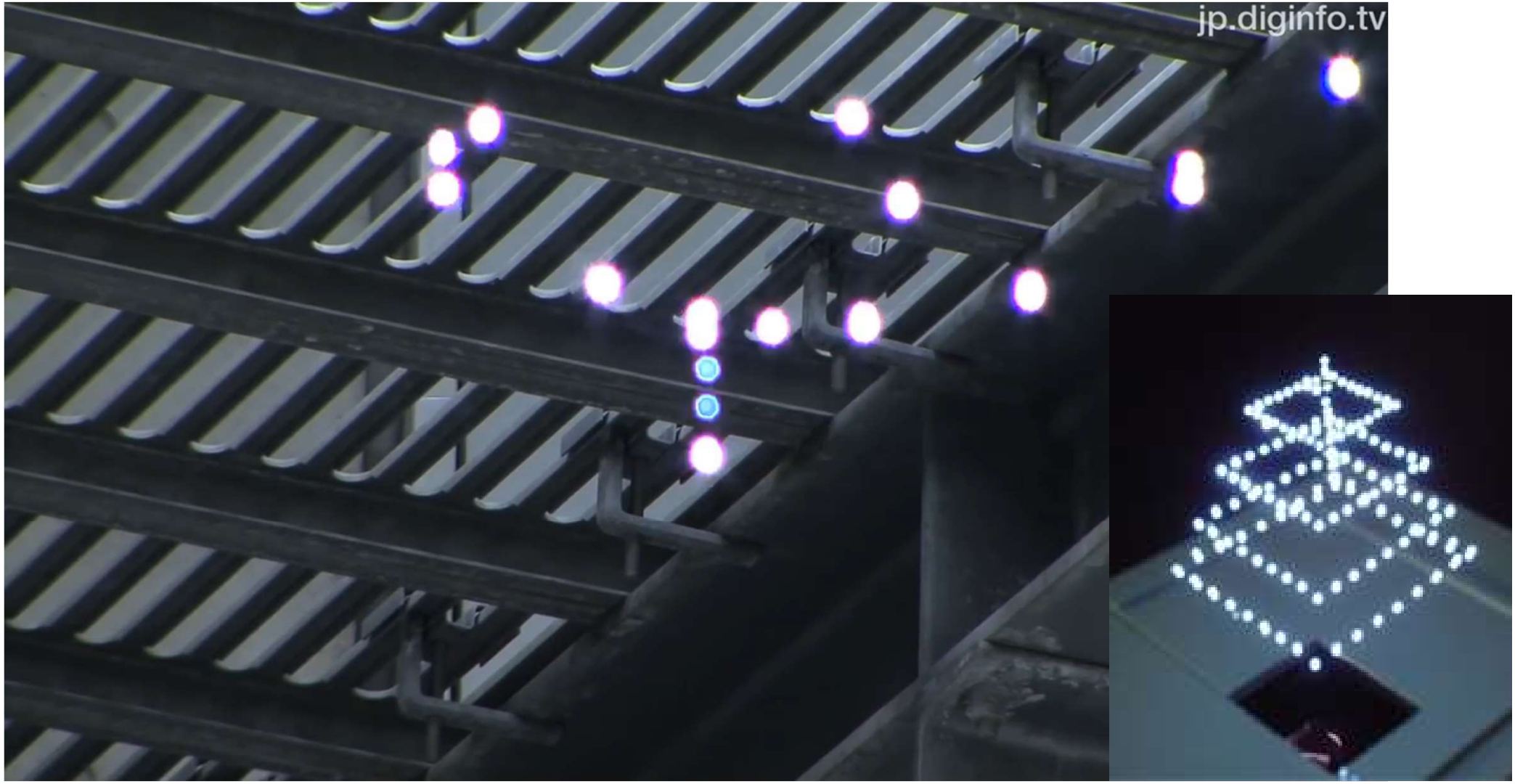




https://www.youtube.com/watch?v=Cm_PKSPoctk&t=2s

- 複数のマテリアルを高速回転＋高速プロジェクションにより材質感を表現。
- 回転体の立体形状の工夫で3次元形状を表現。
- 通常発生する「透けておくが見えてしまう」問題を、視点位置にあわせたレンダリングにより解決。

プラズマディスプレイ (2006-)／Plasma display

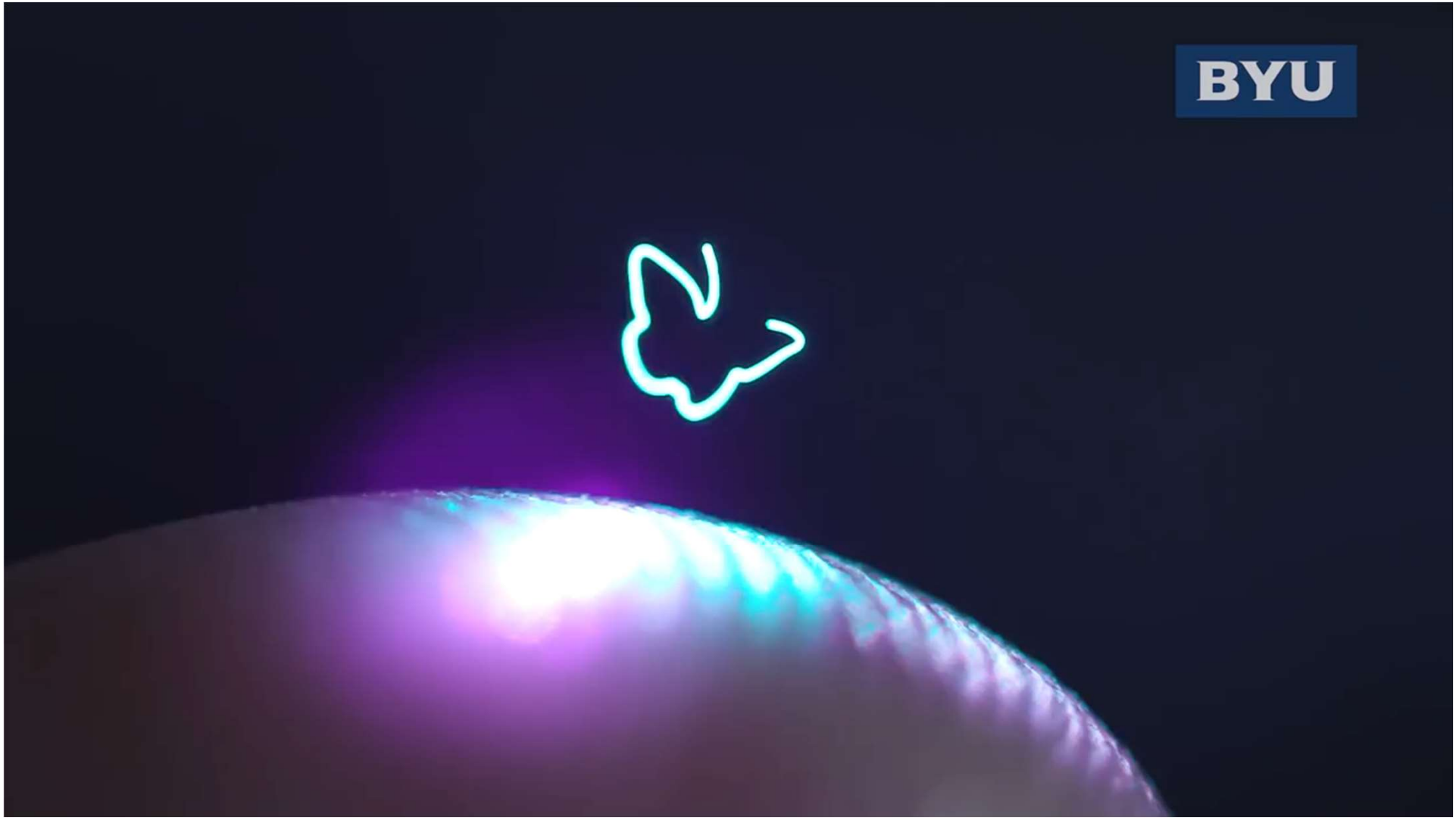


http://www.aist.go.jp/aist_j/press_release/pr2006/pr20060207/pr20060207.html
http://www.burton-jp.com/en/
https://www.youtube.com/watch?v=OnoEymLoSsE

赤外レーザーを空間中にフォーカス、空気をプラズマ化して発光させる

Focused IR Laser beam generates plasma light spot

A photophoretic-trap volumetric display (2018)

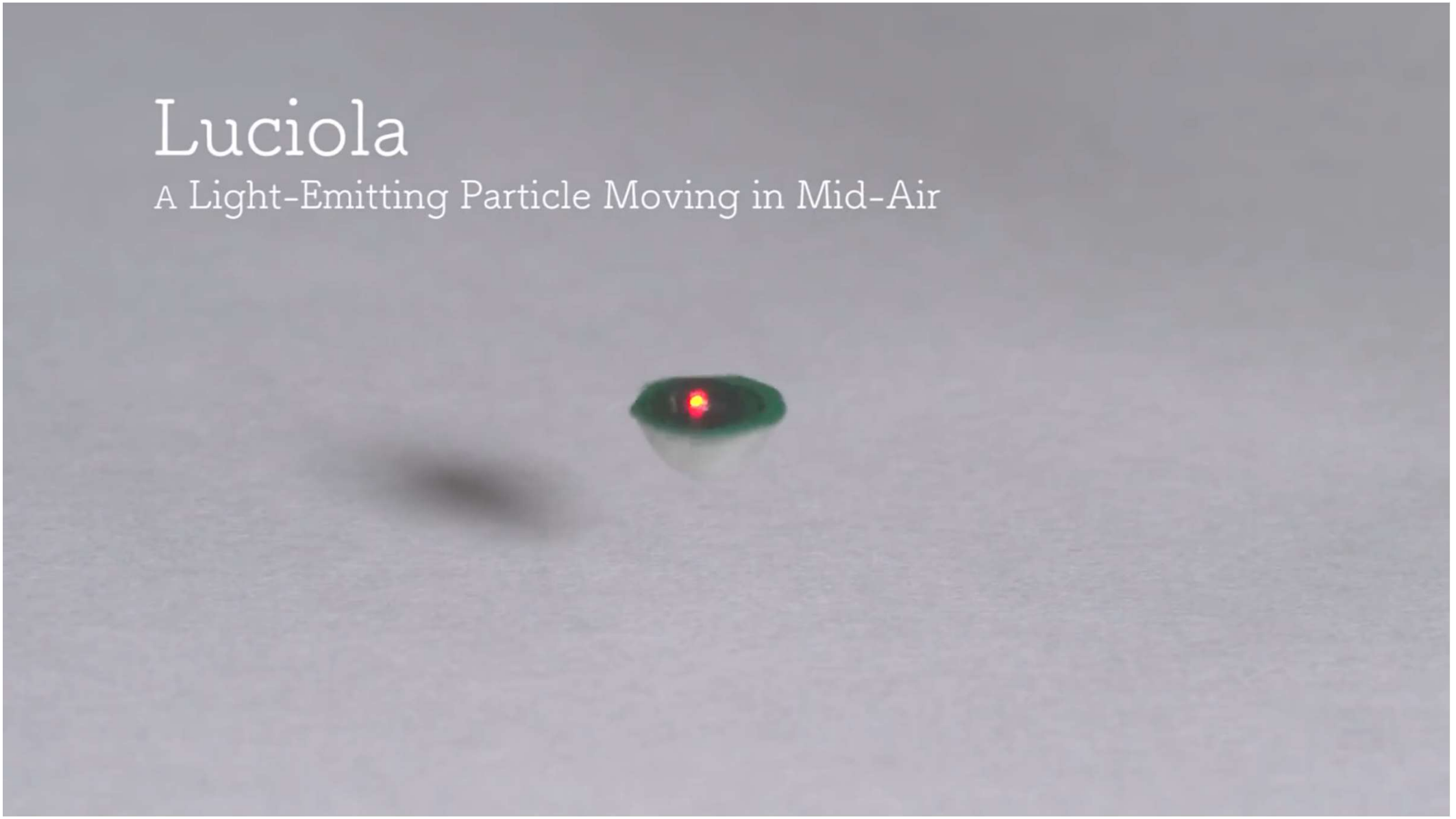


https://www.youtube.com/watch?v=1aAx2uWcENc

D. E. Smalley, E. Nygaard, K. Squire, J. Van Wagoner, J. Rasmussen, S. Gneiting, K. Qaderi, J. Goodsell, W. Rogers, M. Lindsey, K. Costner, A. Monk, M. Pearson, B. Haymore & J. Peatross (2018)
A photophoretic-trap volumetric display

- 空間上のパーティクルをレーザで捉えて動かす

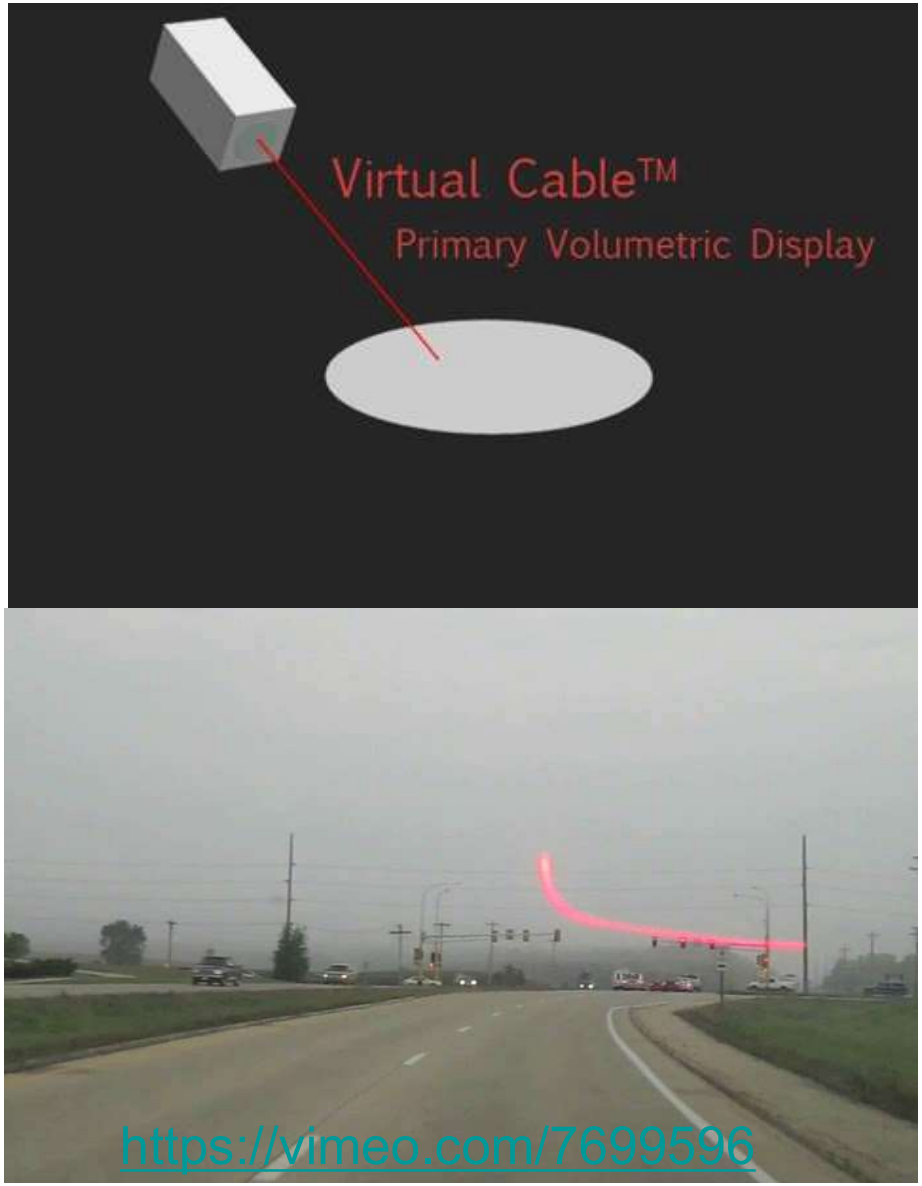
Luciola (2018) 超音波浮遊＊空中給電



https://www.youtube.com/watch?time_continue=2&v=w3GnzpdsWUs

Luciola: A Millimeter-Scale Light-Emitting Particle Moving in Mid-Air Based On Acoustic Levitation and Wireless Powering
Yuki Uno, Hao Qiu, Toru Sai, Shunta Iguchi, Yota Mizutani, Takayuki Hoshi, Yoshihiro Kawahara, Yasuaki Kakehi, Makoto Takamiya

Virtual Cable (2007, Making Virtual Solid (MVS-California)



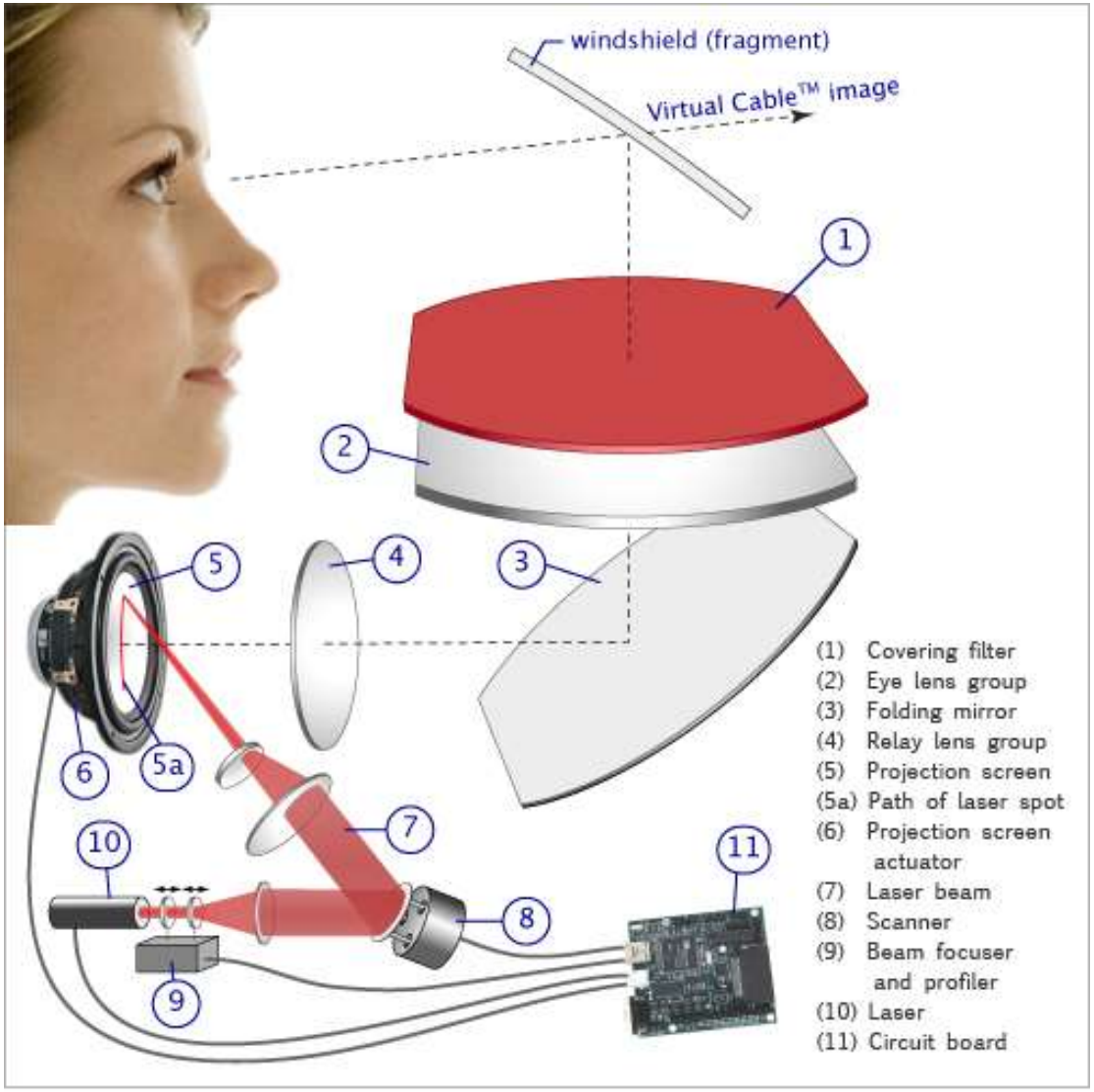


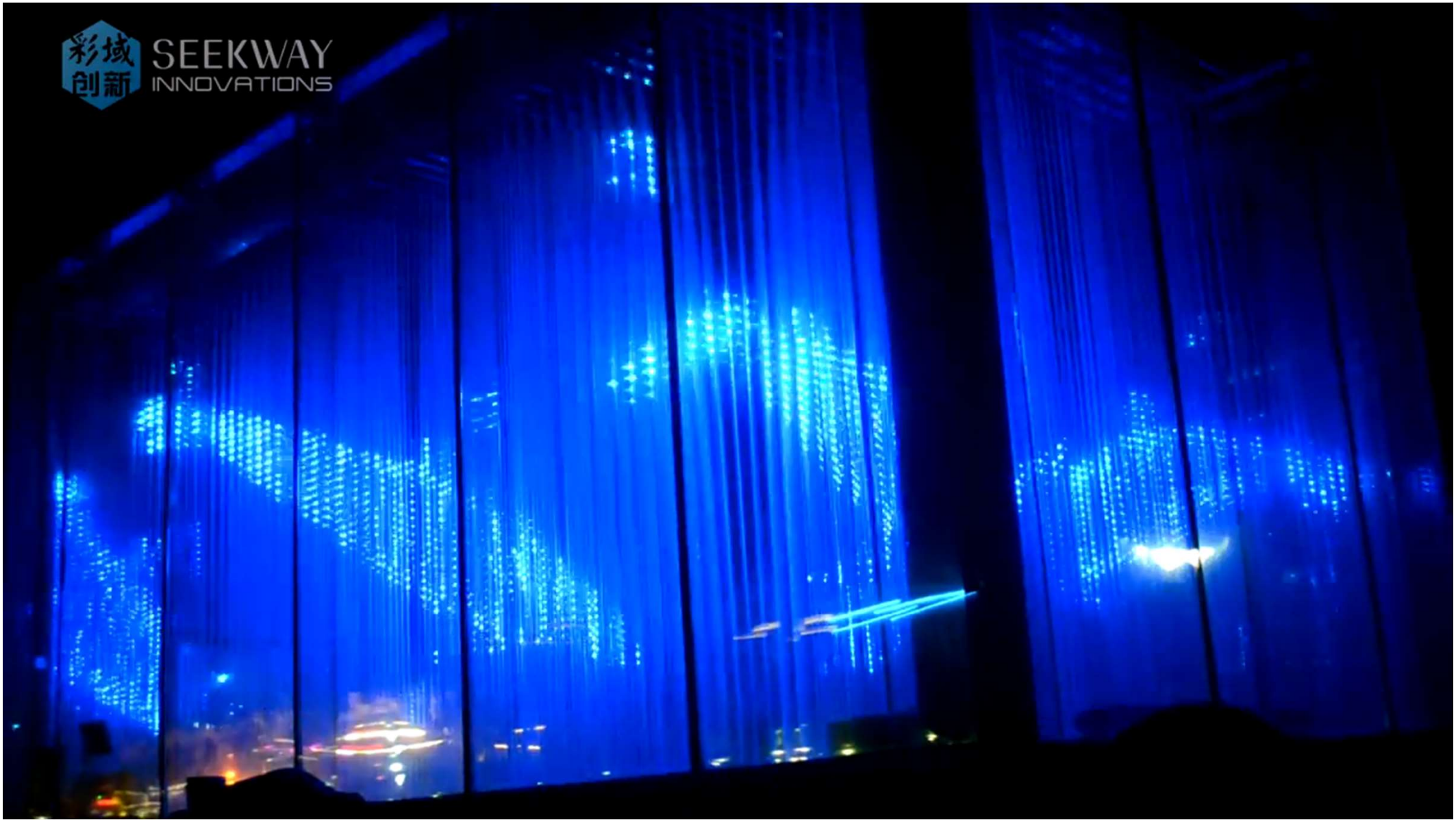
Fig. 3 Hardware components the Virtual Cable™ display (illustration)
https://phys.org/news/2011-10-head-up-prize-munich.html

- ミラー＋振動子による3次元像をフロントガラスで自動車の外に飛ばす。一種のvolumetric表現。一種のAR

Pioneer AR HUD (2011-)

http://www.youtube.com/watch?v=koEyBO_RxZE
実際の風景にナビ情報を重ねて表示する「AR HUD」 #DigInfo

3D LED matrix display



https://www.youtube.com/watch?v=TRGdjrnj5Y8

3次元的に配置されたLEDで立体表現

Drone Display

https://www.youtube.com/watch?v=ead2EfbIvxk

大量のドローンを3D点光源として利用。2021年4月時点で3000台以上。

Kinetic Screen (PJ-Link, 2020)

https://www.youtube.com/watch?v=5FwejErDWcE

多数のLEDパネルが前後に動く http://www.pj-link.com/en/news/show2-68.html

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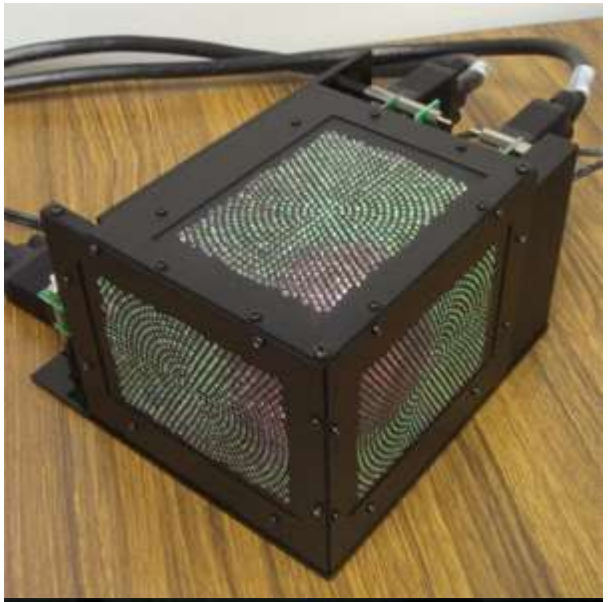
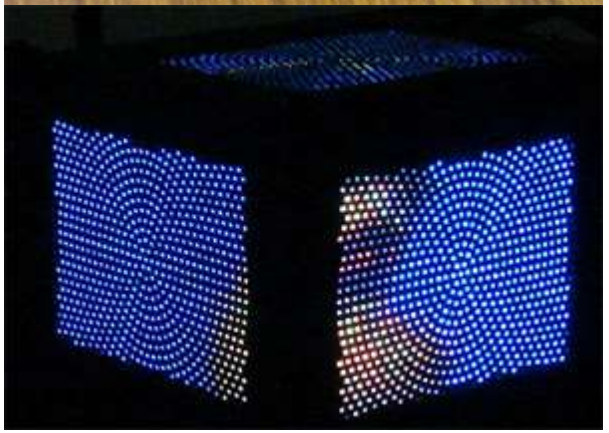
レンズアレイ方式／Using lens array





http://www.youtube.com/watch?v=H4ShPbCve2M

http://www2.nict.go.jp/pub/whatsnew/press/h20/080609/080609.html

レンチキュラーレンズを2次元に拡張

gCubik (Yoshida et al.(NICT), SIGGRAPH2008)

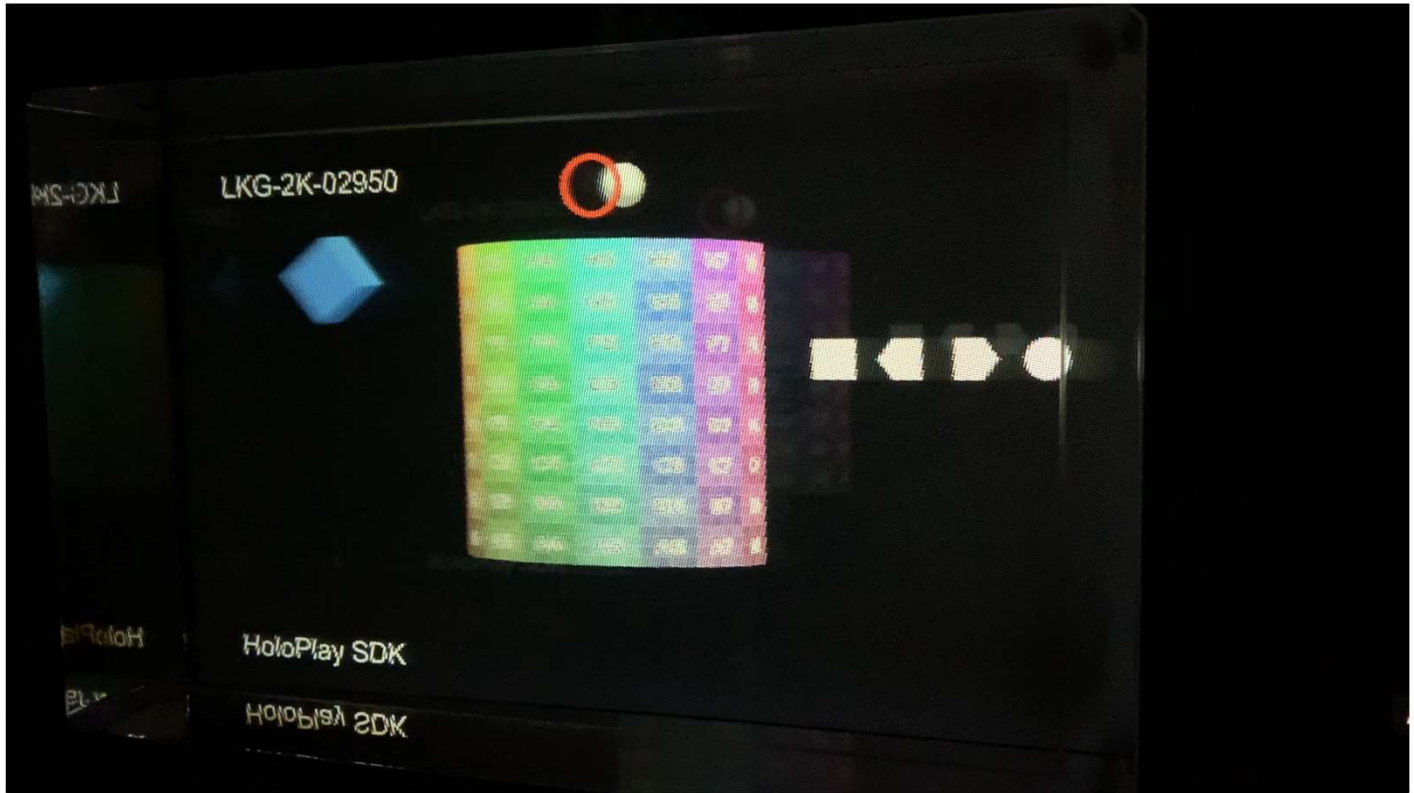
Looking Glass (2018) https://lookingglassfactory.com/

8K Immersive Display*

*8x the size and resolution of the 8.9" Development Kit.

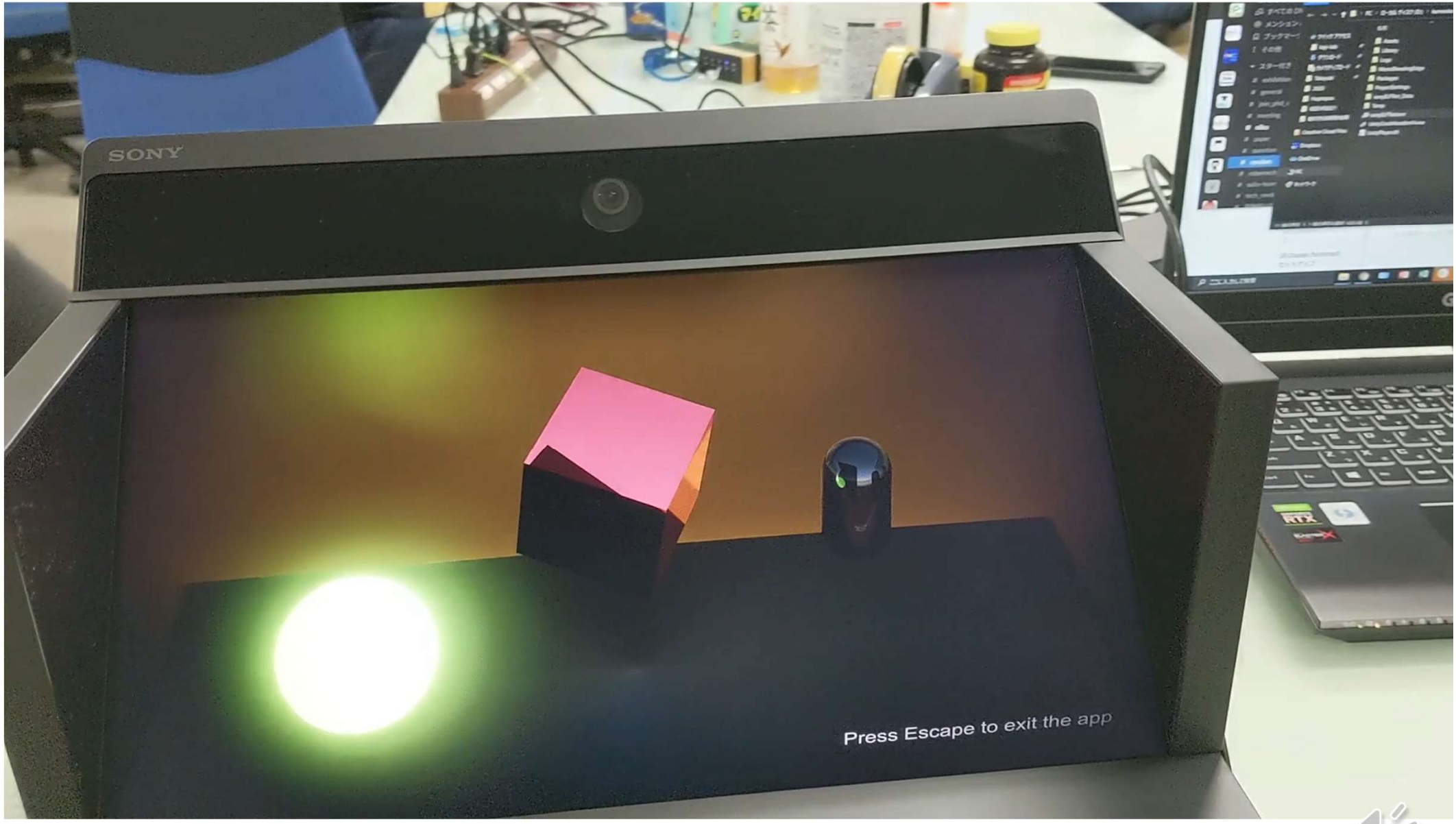
15.6" Development Kit
(credit: Simulia)

8.9" Development Kit
(credit: Algae by Marpi)



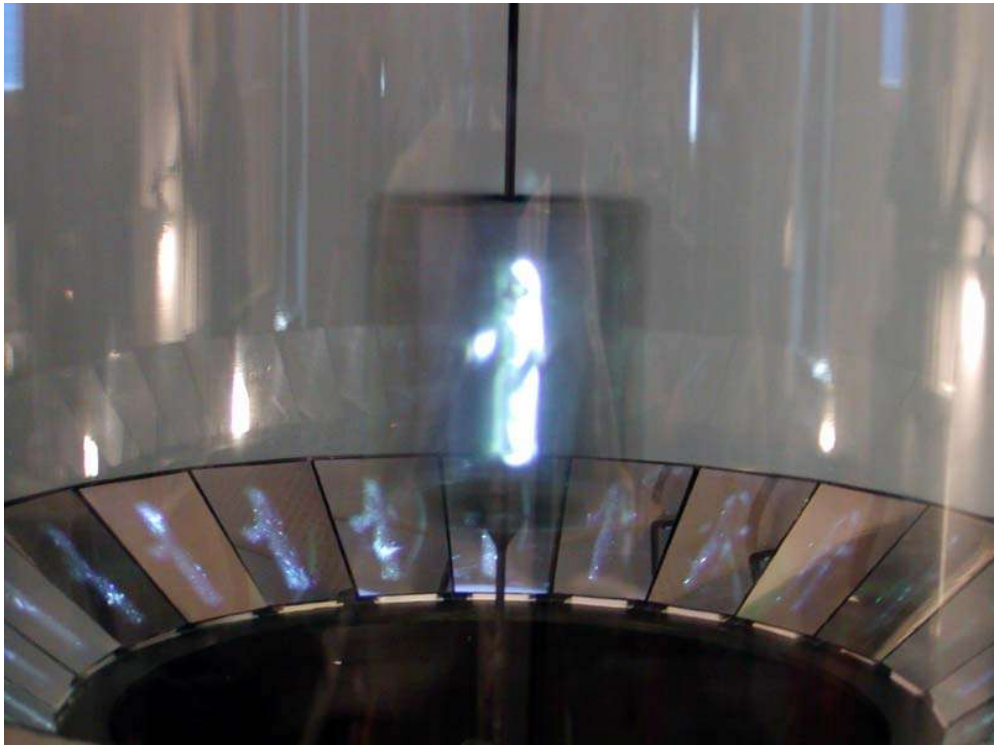
レンチキュラー方式45視点

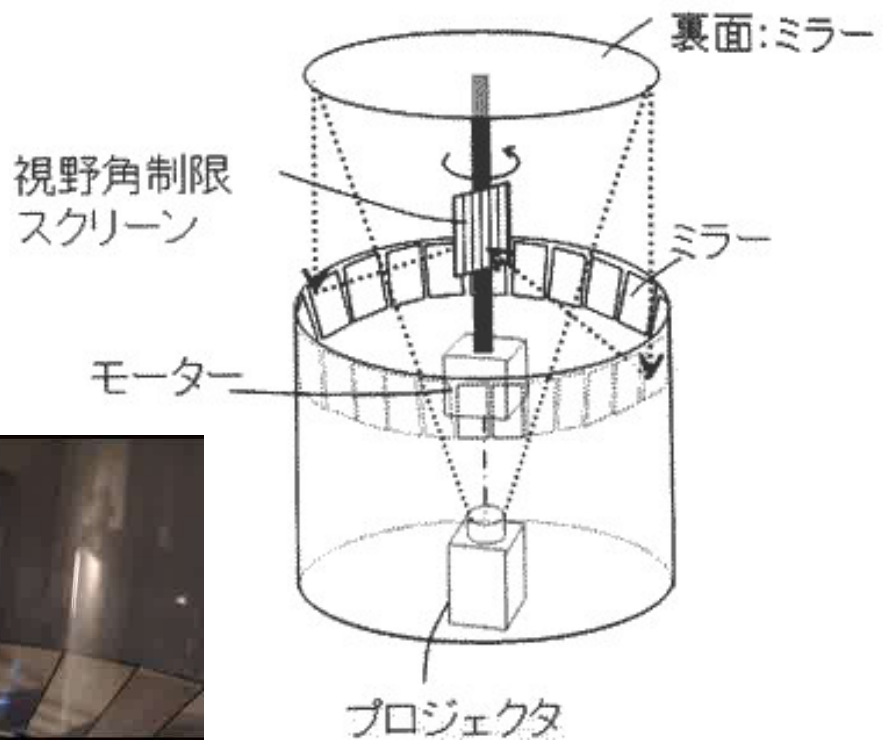
elf-sr1(Sony, 2020) https://www.sony.jp/spatial-reality-display/products/ELF-SR1/



レンチキュラー方式＋顔認識による眼球運動計測により、一人用だが高精細な裸眼立体像

多視点映像を再帰性反射材で実現





https://pc.watch.impress.co.jp/docs/2004/0224/hitachi.htm

再帰性反射材を用いた全周囲回転型3Dディスプレイ (日立、2004)

●回転スクリーンに、各角度から見た映像を投影

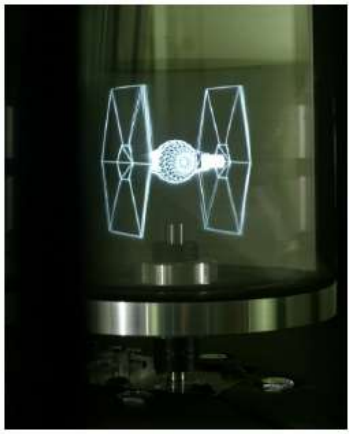
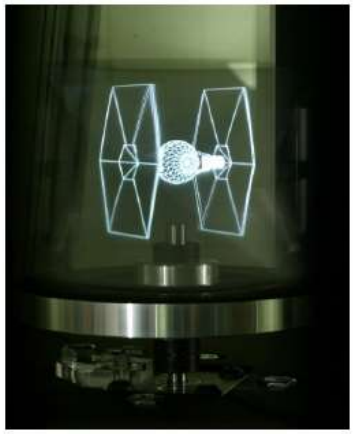
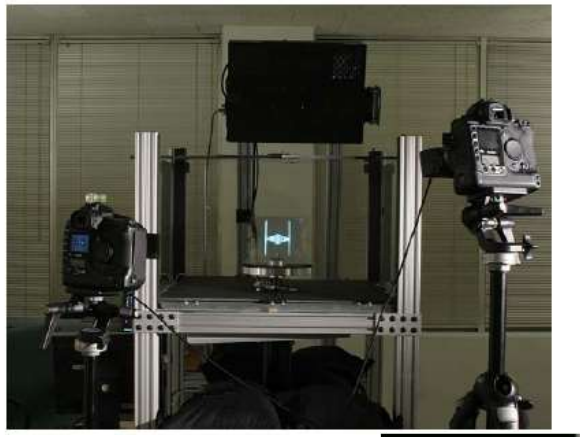
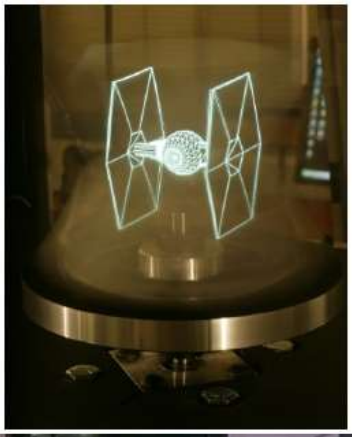
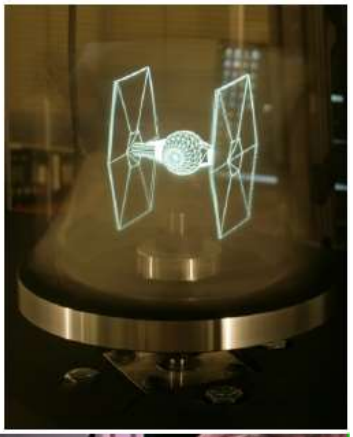
Images from different direction is projected on rotational screen.

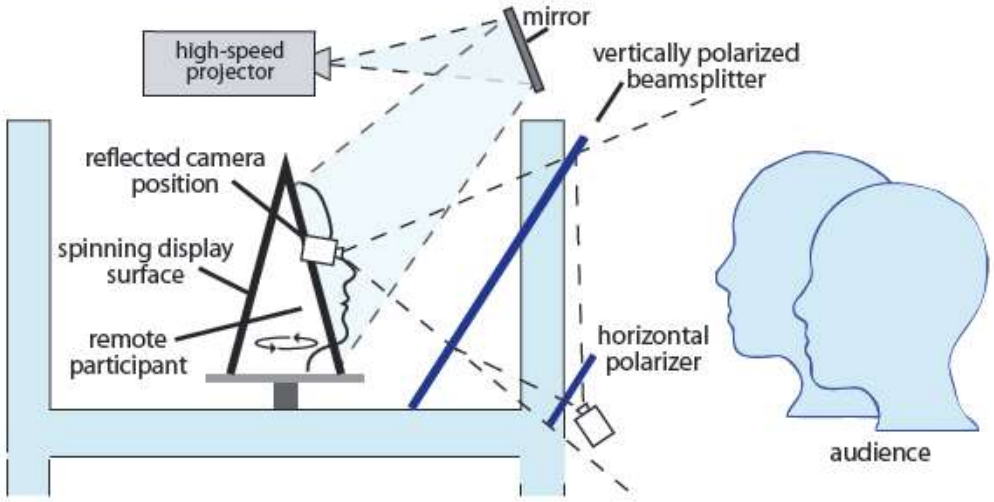
●スクリーンは水平方向のみ再帰性反射特性を持つ

Screen is retroreflective only for horizontal direction

Rendering for an Interactive 360° Light Field Display

-HeadSPIN (A. Jones, 2007, 2009)

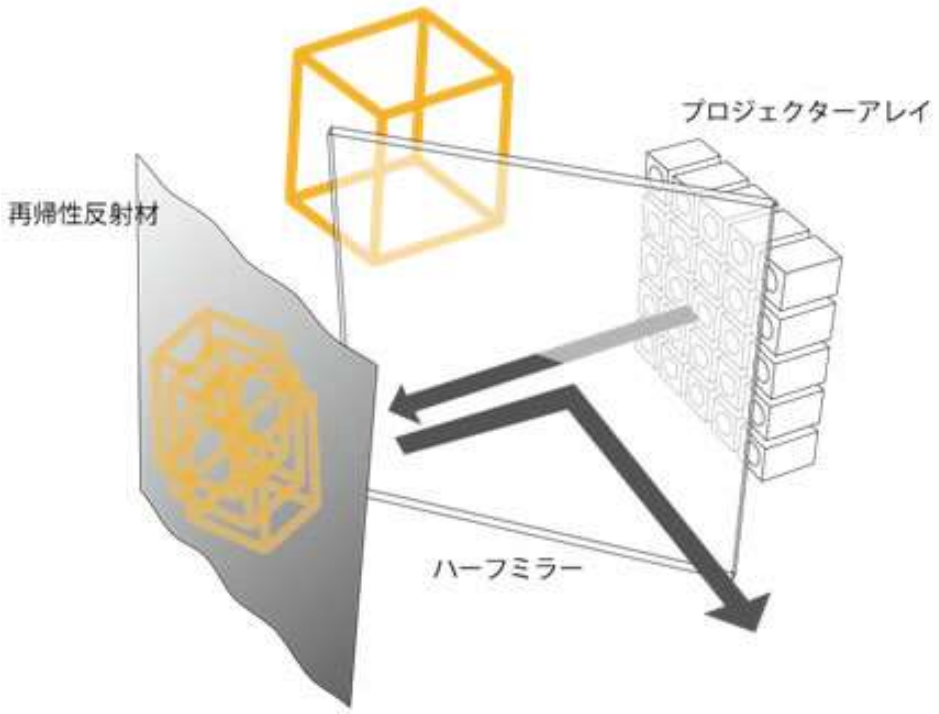


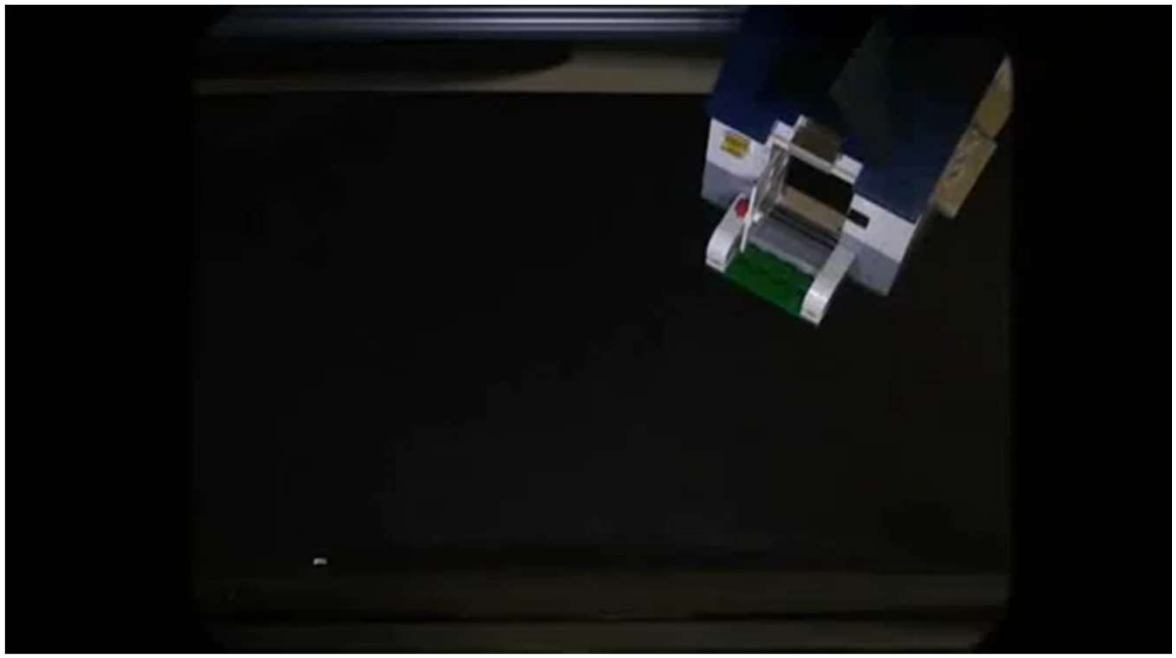
http://vimeo.com/5812643

回転ミラー表面にホログラフィックフィルム。垂直方向に拡散、水平方向は鏡面反射
→ミラーの正面からしか映像が見えない

Rotational mirror has holographic film, enabling vertical diffusion and horizontal reflection

RePro3D (TYoshida et al. 2010)





http://www.youtube.com/watch?v=8TbSBYiwZIs

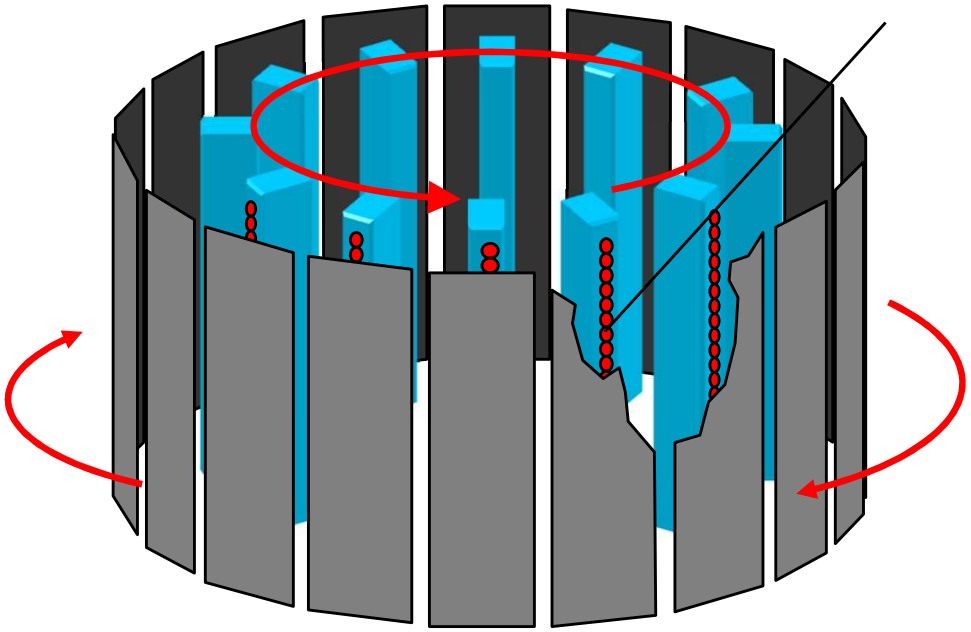
http://www.jst.go.jp/pr/announce/20101012/index.html

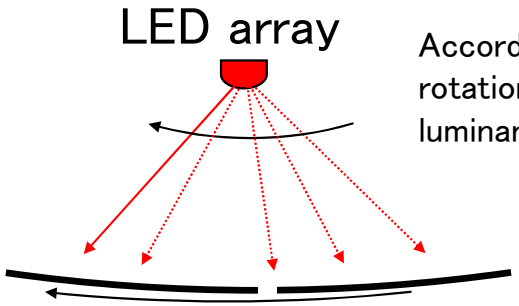
T. Yoshida, S. Kamuro, K. Minamizawa, H. Nii, S. Tachi: RePro3D: Full-parallax 3D Display using Retro-reflective Projection Technology, ACM SIGGRAPH 2010, Emerging Technologies, Los Angeles, CA, USA (2010. 7)

●プロジェクタアレイを高輝度液晶モニタ＋レンズアレイで擬似的に構成
●再帰性反射材による多視点の実現
Projector array and retroreflector generate eye position dependent images.

SeeLinder (Yendo et al., 2005)

LED arrays move relatively slow

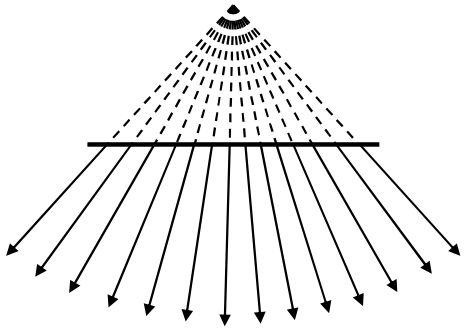




According to the barrier rotation, LED changes its luminance.

Barrier moves VERY fast

https://www.youtube.com/watch?v=ys1yJMouGGQ



Using the fast-rotating parallax barrier, omni-directional rays are reconstructed.

(Siggraph 2018) Spherical Full-Parallax Light-Field Display Using Ball of Fly-Eye Mirror, H. Yano, T. Yendo

https://shiropen.com/seamless/spherical-full-parallax-light-field-display-using-ball-of-fly-eye-mirror

小形反射球群を高速回転、高速プロジェクタと組み合わせ多視点立体を提示

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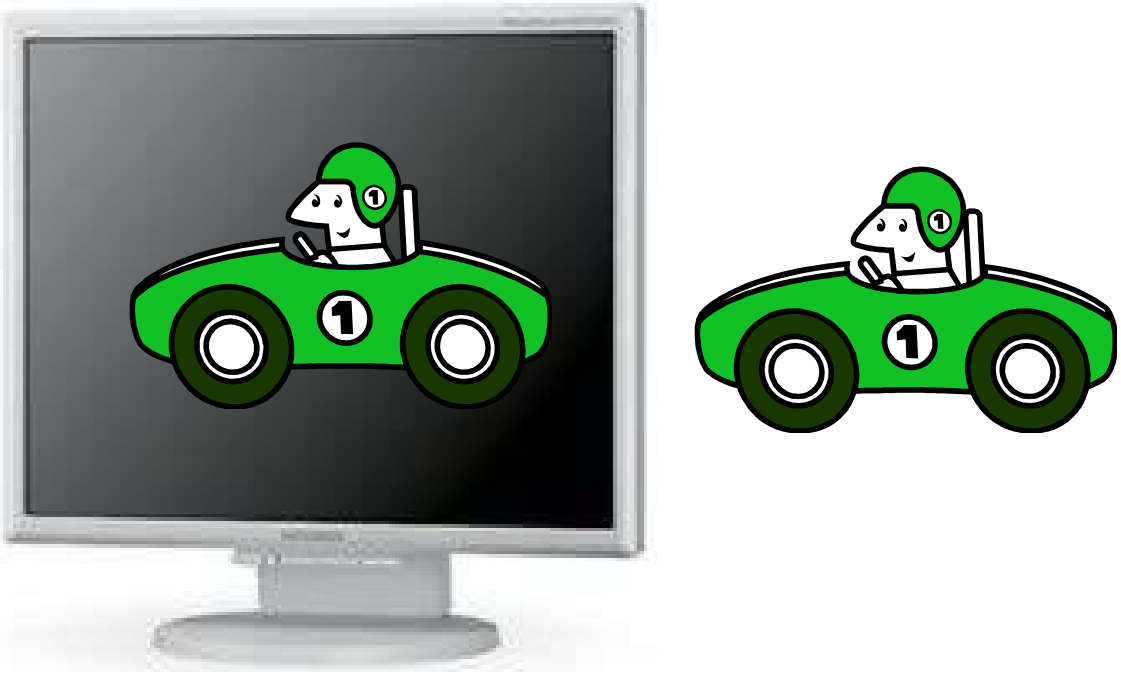
3Dディスプレイは必要か
Is 3D display really necessary?

- Maybe, but not for all works
  - To *observe* something, resolution is more important than 3D. (You can observe with single eye!)

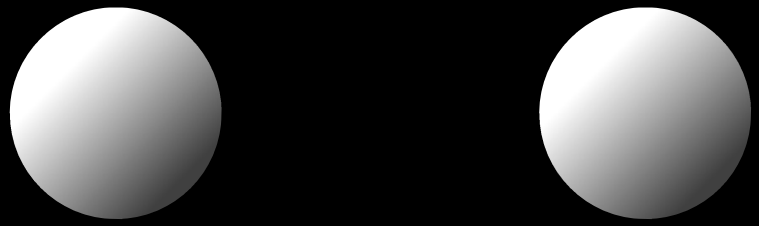
- However,
  - To *handwork* in a virtual space, *distance* perception is critically important.

空中像による錯覚／Illusion by floating image



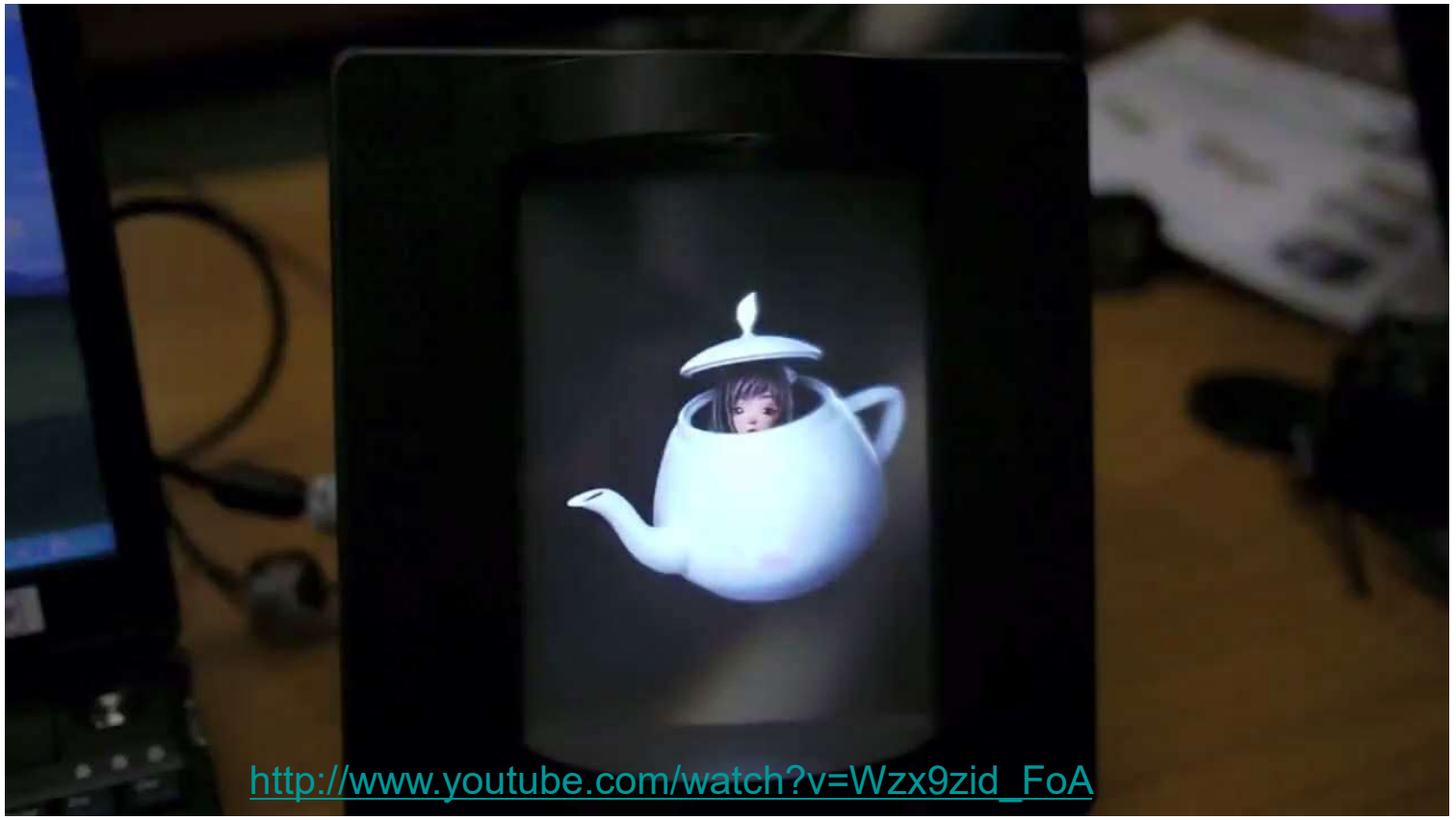
http://www.fogscreen.com/

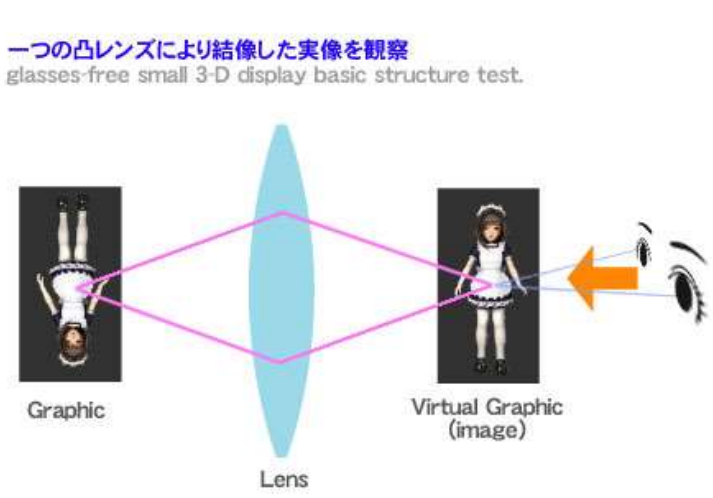
- 空中に（他の支えが無く）映像が浮いている場合，
  人は勝手に「立体的」と判断する
  When the image is floating in the air without anchorage, we feel it as 3D

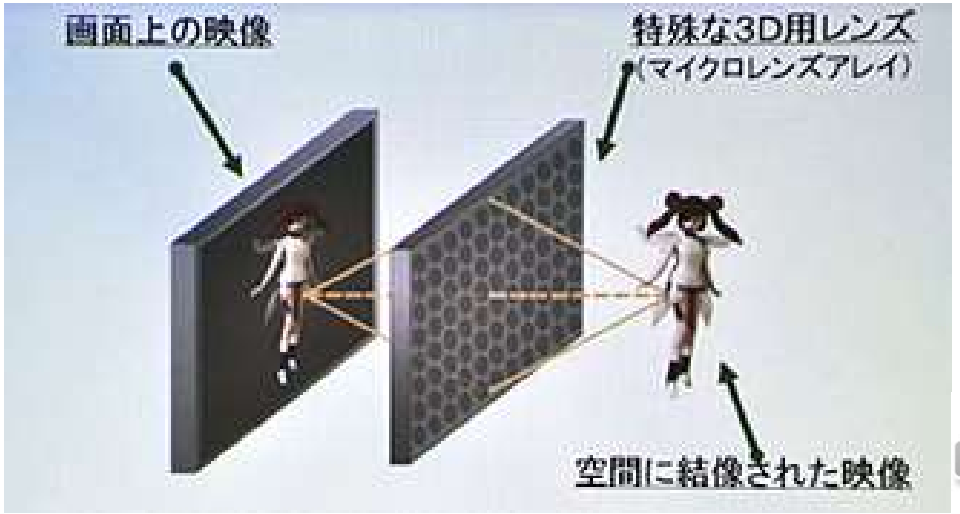


なるべく周りを暗くして観察。片目だとなお良い。

フローティングビジョン /Floating Vision（パイオニア, 2008)

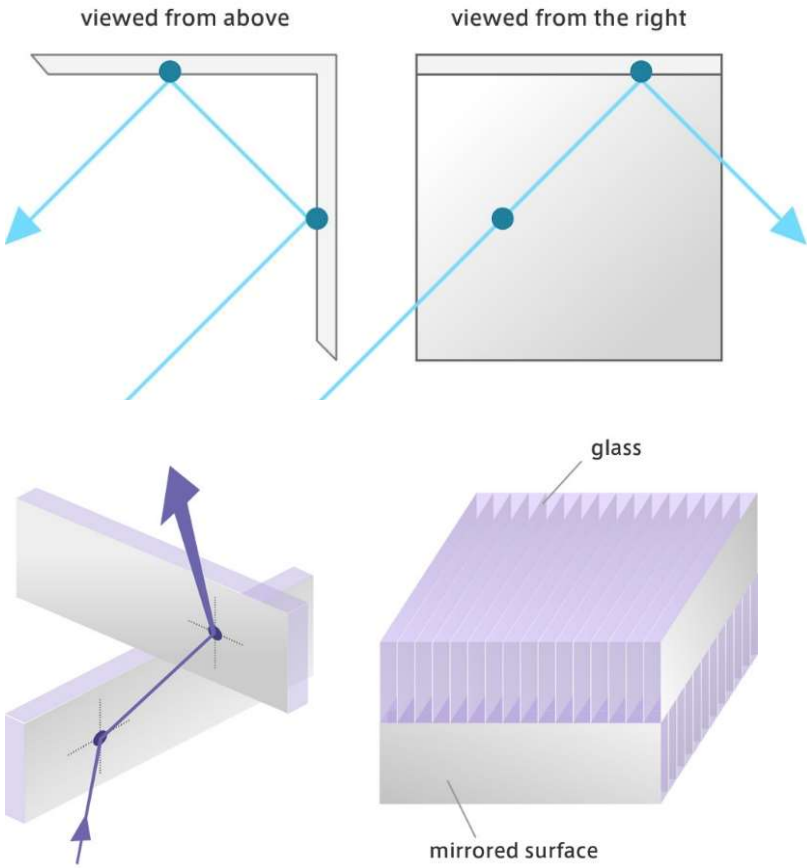


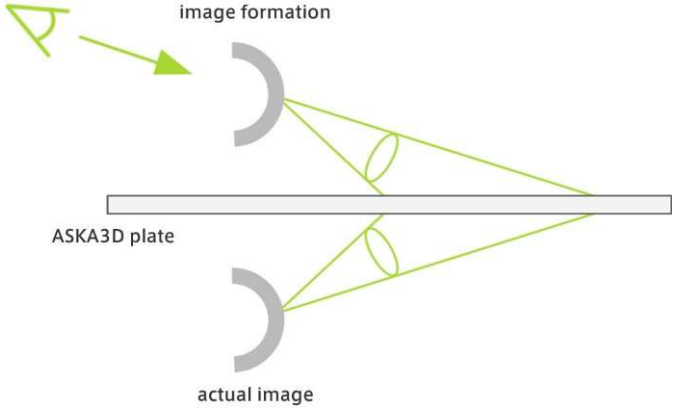


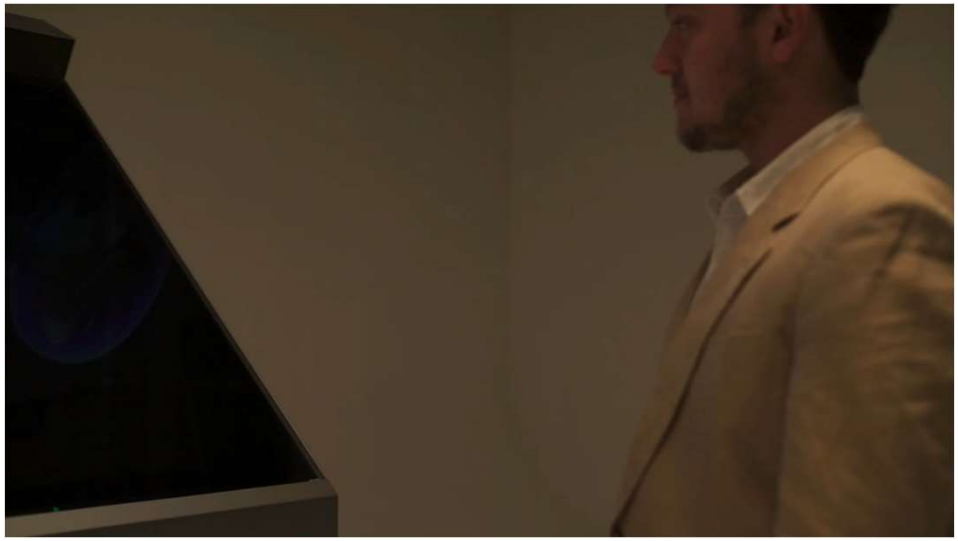


http://www.schaft.net/n00bs/2010/02/24230148.html

（再）再帰透過光学素子 / Micro Mirror Array Plates (MMAPs)





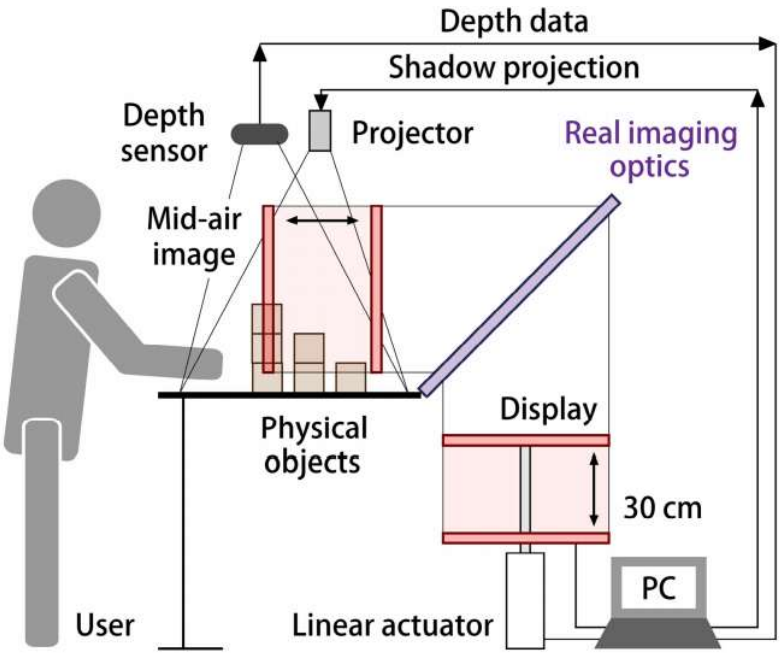


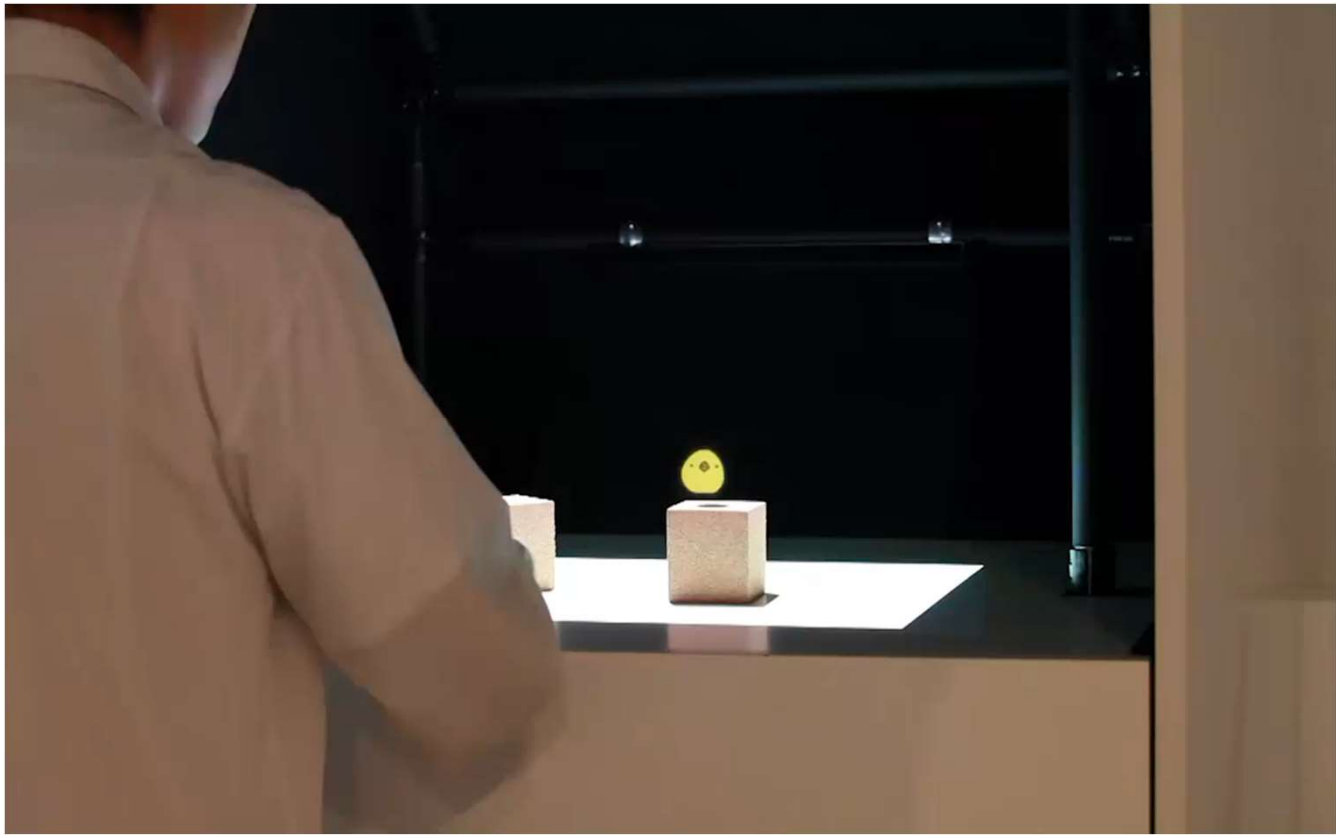
https://aska3d.com/en/technology.php

https://www.youtube.com/watch?v=KgAvRtpPY-4
DS976 - ASKA3D

- 直交する短冊状ミラーの集合体を貼り合わせたもの。
- コーナーキューブと同様に再帰反射する軸と透過する軸。
- 歪みのない空中像（実像）を簡便なセットアップで実現可能。
- 2D corner cubes made by orthogonal plates, to achieve retroreflection and transparency.

MARIO (2014)



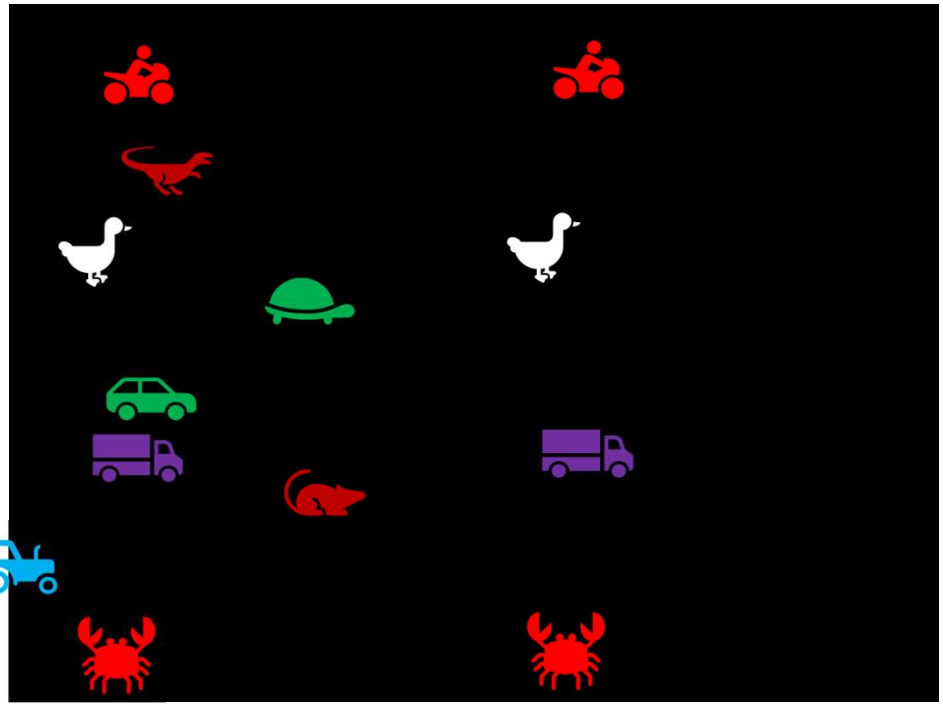


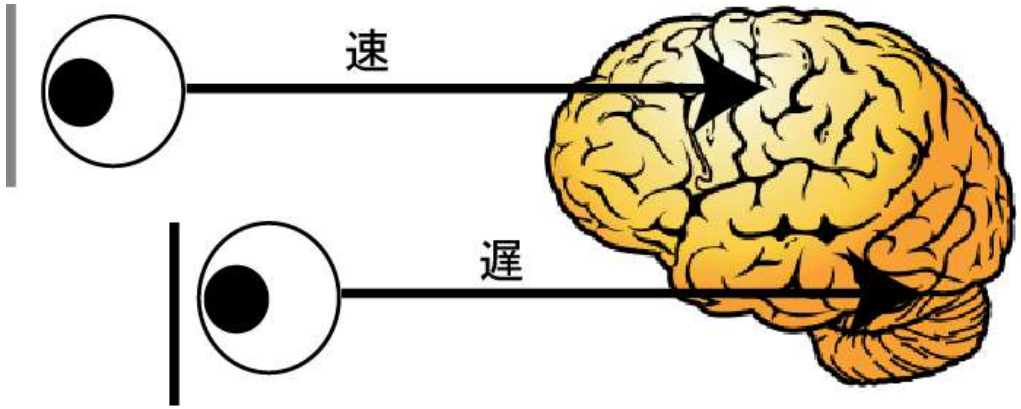
https://www.youtube.com/watch?v=chK85xBu8AQ

Hanyuool Kim, Issei Takahashi, Hiroki Yamamoto, Satoshi Maekawa, and Takeshi Naemura: “MARIO: Mid-air Augmented Reality Interaction with Objects,” Elsevier Entertainment Computing, vol. 5, issue 4, pp. 233 – 241 (2014.12).

- MMAPsによりディスプレイ映像を空中像に。ディスプレイの移動で像を移動。
  Combination of monitor mounted on linear actuator and MMAPs.
- 他に多数MMAPsに関する研究 (EnchanTable(2015), SkyAnchor(2017)等)
  チェック→https://www.youtube.com/user/NaemuraLab

プルフリッヒ効果／Pulfrich Effect





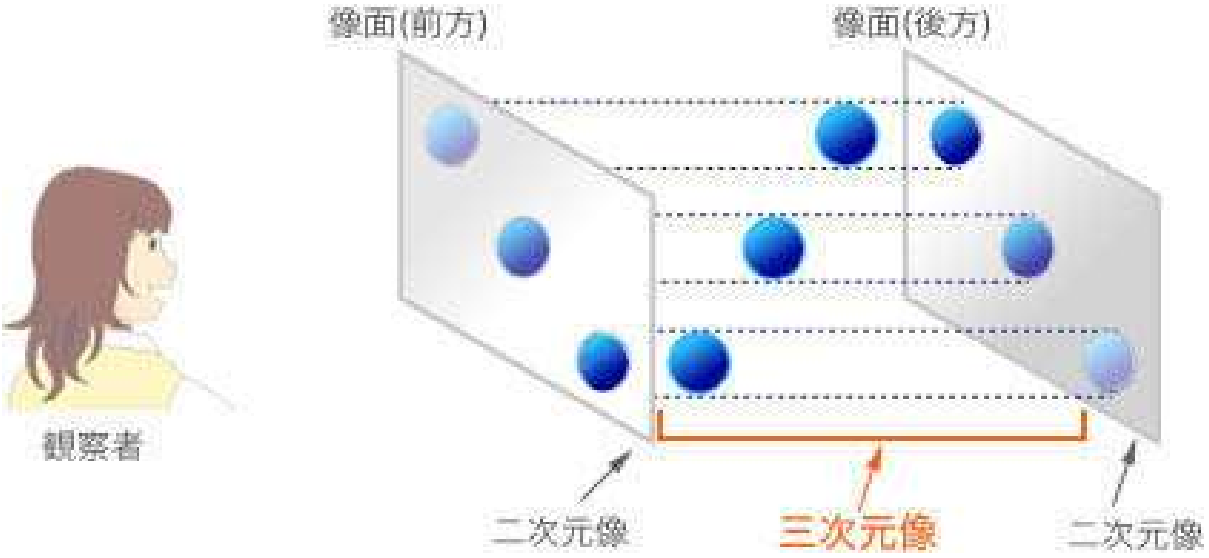
- 両目の濃度が違うサングラスをかけて見る
  Put eyeglasses with two different darkness for each eye
- 明るさの違いによって脳への視覚情報伝達に時間差を生じる.
  Different brightness genertates temporal difference
- 動画の横の動きによって視差が生じ、奥行きが体感される
  Horizontal motion of the movie causes disparity, generates 3D feeling

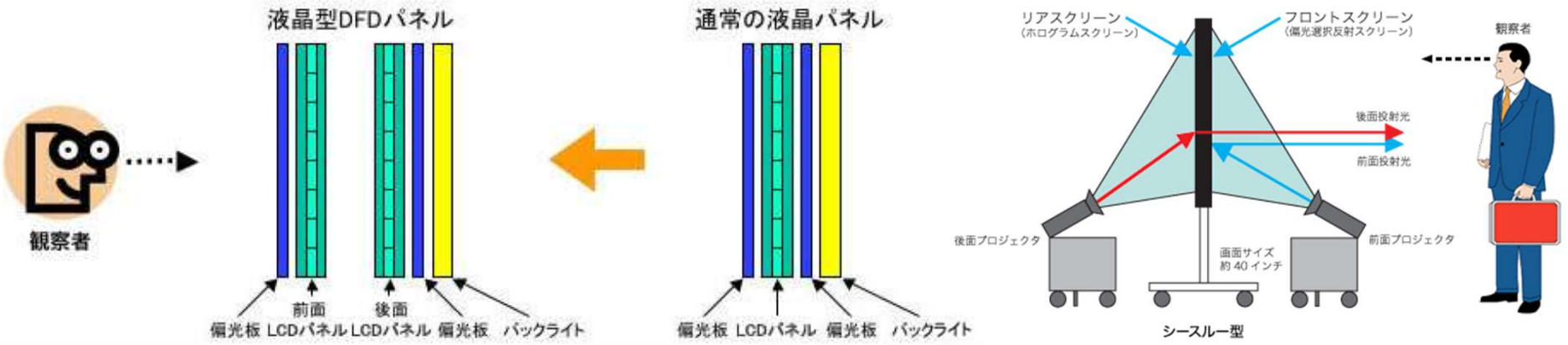
プルフリッヒ効果／Pulfrich Effect

https://www.youtube.com/watch?v=IZdWlXjhMo4

The Pulfrich Effect- 3D and 2D Simultaneously (optical illusion)

立体錯視現象／Pseudo 3D by 2 stacked images



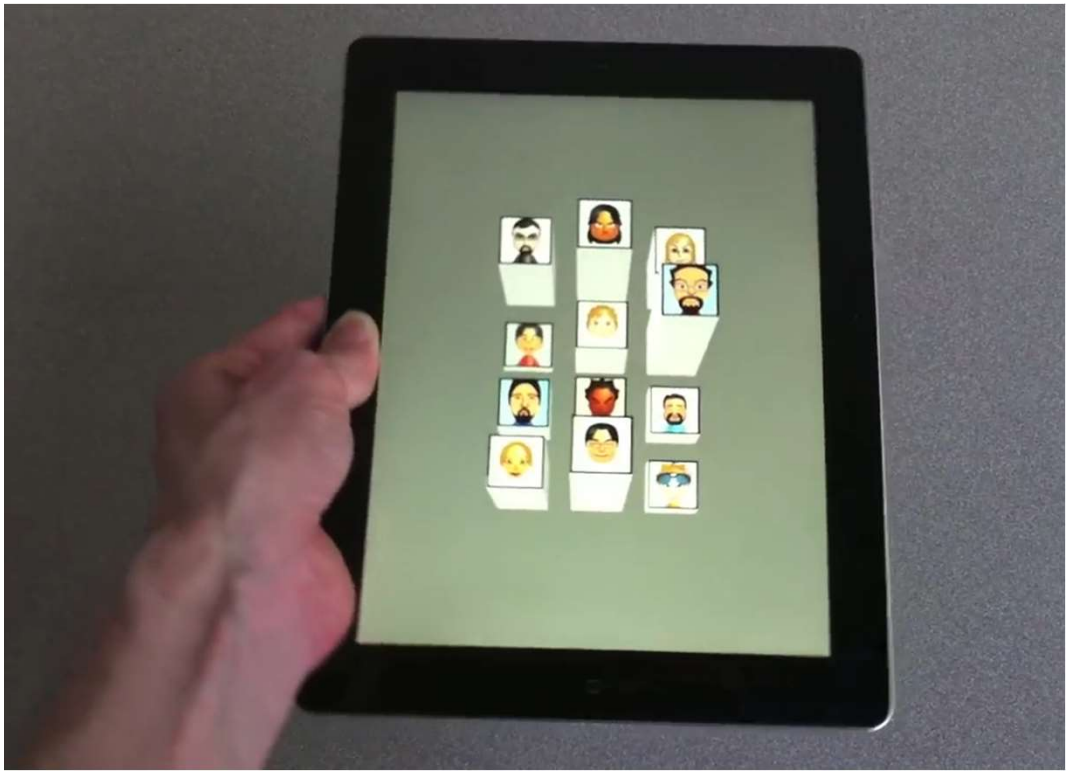


https://www.bcm.co.jp/site/2007/05/tamatebako/ntt-it/0705-ntt-it.html

NTT:SpaceIllusion

DFD方式：明るさの異なる同一の二枚の画像を重ねて表示すると、奥行き感を感じられる

運動視差を用いる／Using Motion Parallax



http://www.youtube.com/watch?v=bBQQEcfkHoE
i3D — Head Tracking for iPad: Glasses-Free 3D Display

https://www.youtube.com/watch?time_continue=666&v=J8YvKIxFmTs
IVRC2003 DIMENSION / 武蔵野美術大学，東京大学

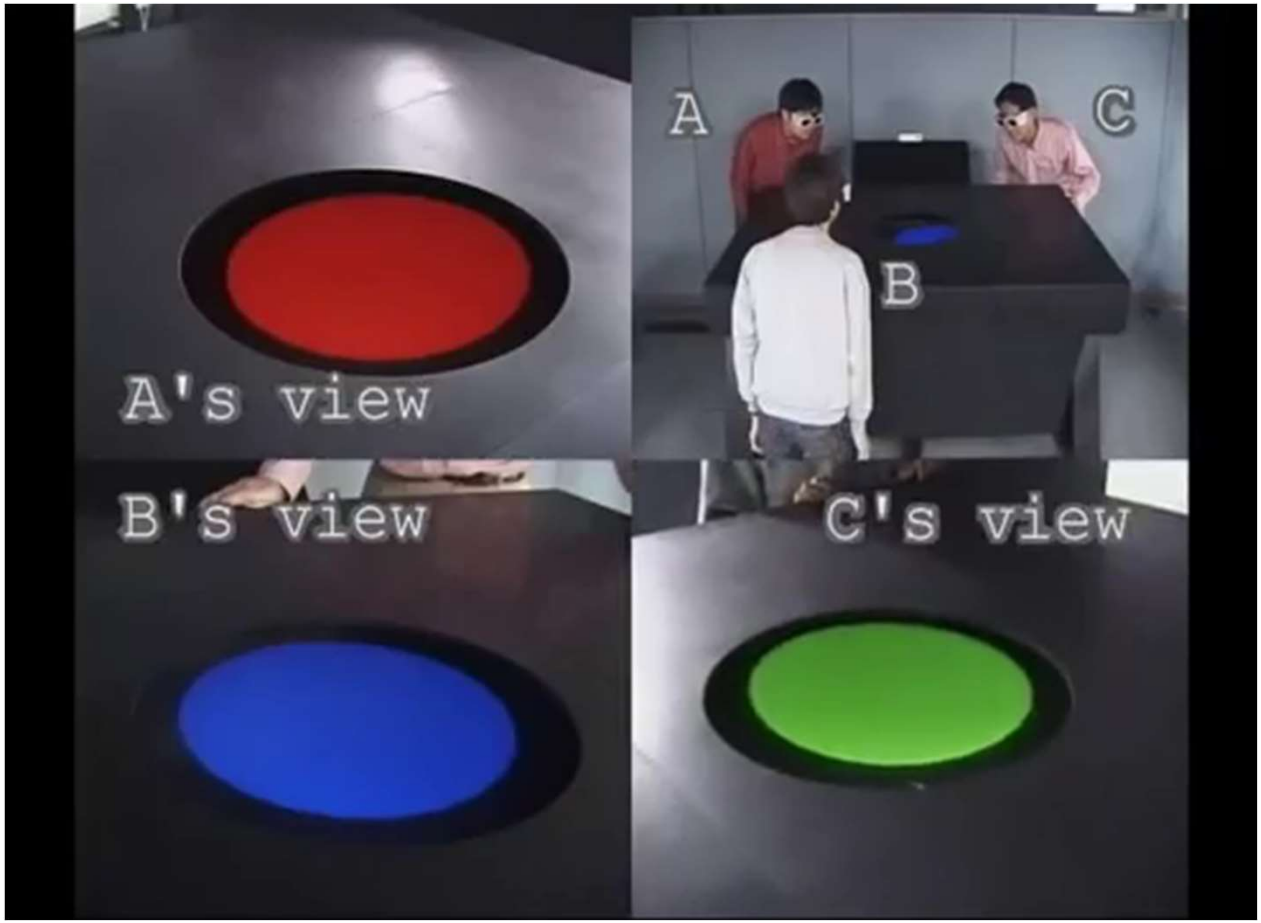
- 視点位置に合わせて画像を変化させると奥行き感を明瞭に感じる
- IVRC2003 DIMENSION BOOKは運動視差＋ポータブルディスプレイの組み合わせとしては初期のもの。外部からのライティングや風にも反応する仕組みを持っていた。

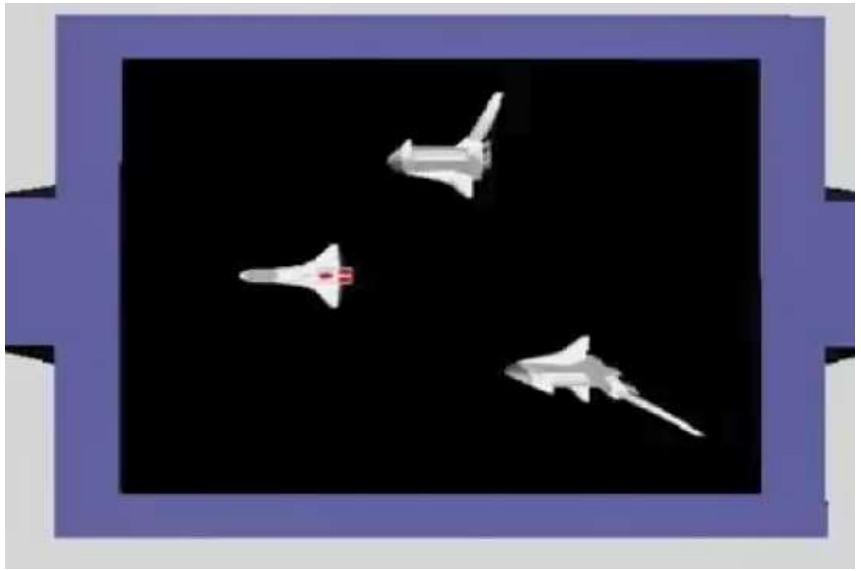
TODAY's TOPIC

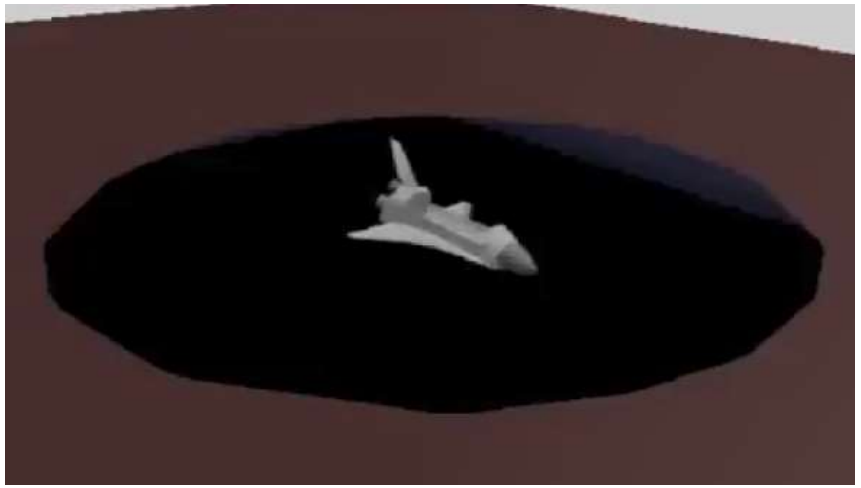
- 3Dディスプレイ／3D Display
  - HMD
    - HMDとカメラ／HMD & Camera
    - HMDとAR ／HMD & AR
  - 環境型／Environmental Display
    - メガネあり／With Eyeglasses
    - 環境型とカメラ／Environmental Display & Camera
    - メガネなし／Without Eyeglasses
      - 左右の目に違う映像を入れる／Input Different Images to Two Eyes
      - ボリューメトリックな再構成／Volumetric Reconstruction
      - 光線群の制御による多視点映像／Ray Reconstruction
      - 錯覚を利用する／Using Illusion
- その他の話題
  - 光線群制御からCSCWへ／From Ray Control to CSCW
  - 光線群視点制御から視線制御へ／From Ray Control to Eye Control

(SIGGRAPH2001, Etech) IllusionHole

Y. Kitamura. T. Nakashima, K. Tanaka, T. Johkoh





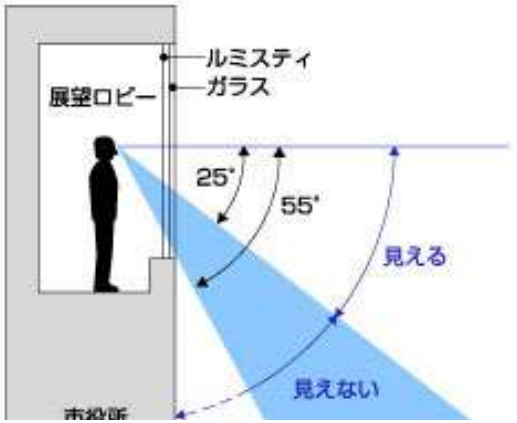


https://www.youtube.com/watch?v=HnIh3u6hNs0

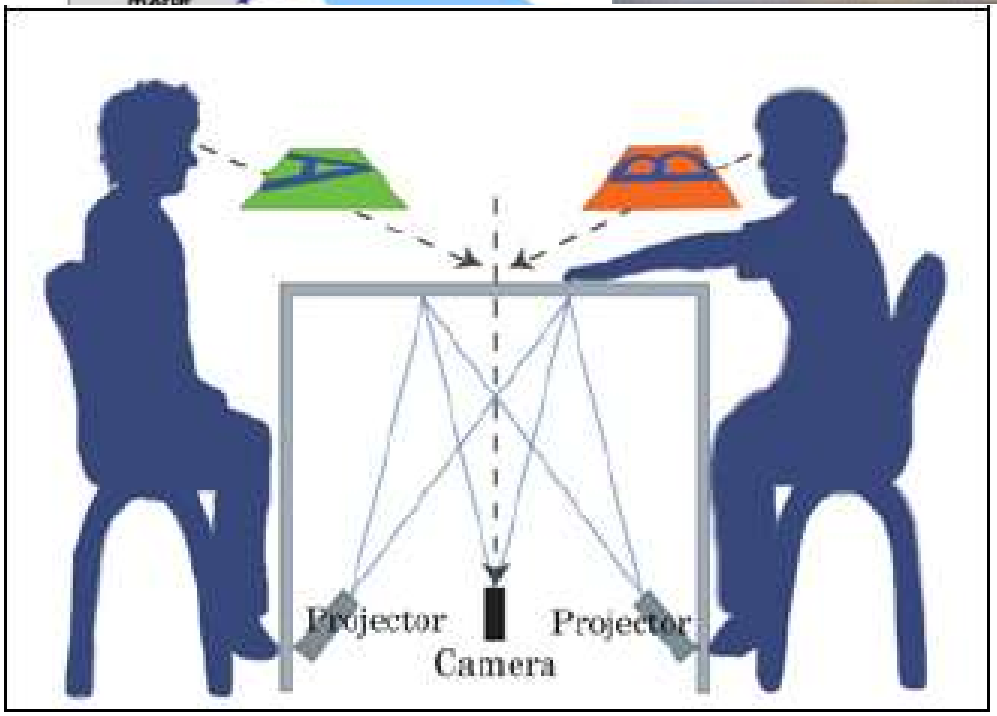
https://www.icd.riec.tohoku.ac.jp/project/displays-and-interface/IllusionHole/index1.html

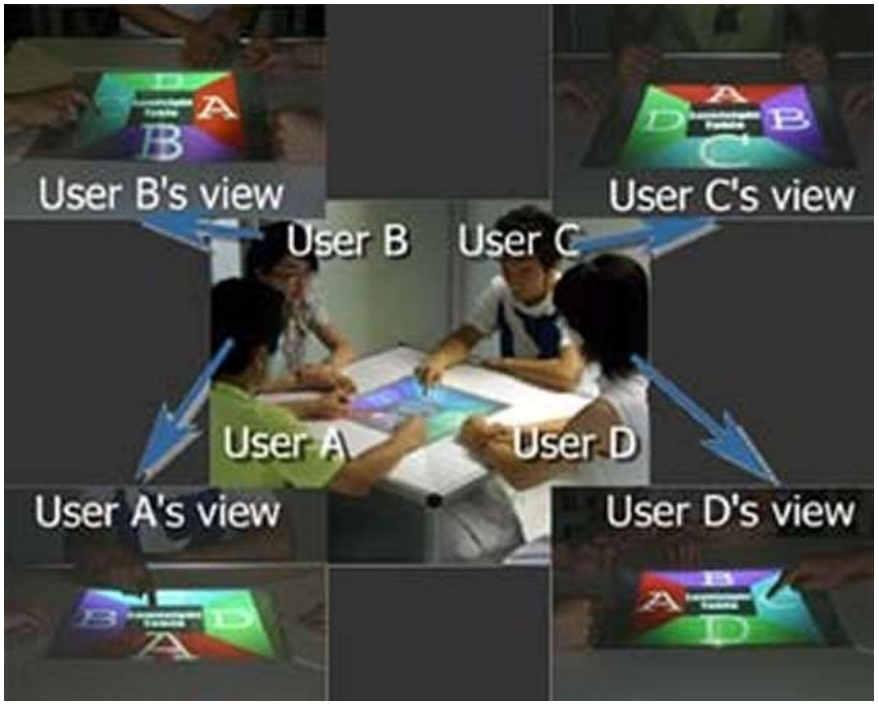
Lumisight Table (Kakehi et al., 2003-)

Y. Kakehi, M. Iida, T. Naemura, Y. Shirai, M. Matsushita, T. Ohguro: Lumisight Table: Interactive View-Dependent Display-Table Surrounded by Mutiple Users, SIGGRAPH 2004 E-Tech



https://www.yamahira.com/products/lumisty/





- 特殊素材フィルム：視線の角度に応じて視界がぼやけて見える光学フィルム。
  Light control film works as diffuser from specific angle.
- 4人が別々の映像を観察　Different images for different user
- 透明性を利用して手の動きを測定　Simultaneous motion analysis is possible

TODAY's TOPIC

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  - HMD
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    - HMDとAR ／HMD & AR
  - 環境型／Environmental Display
    - メガネあり／With Eyeglasses
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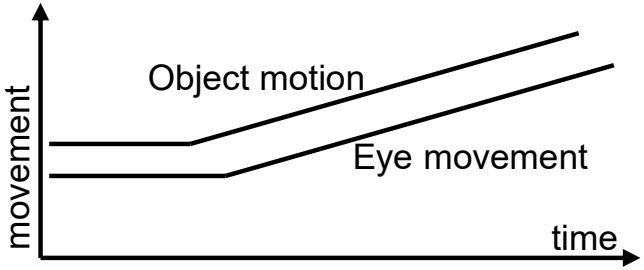
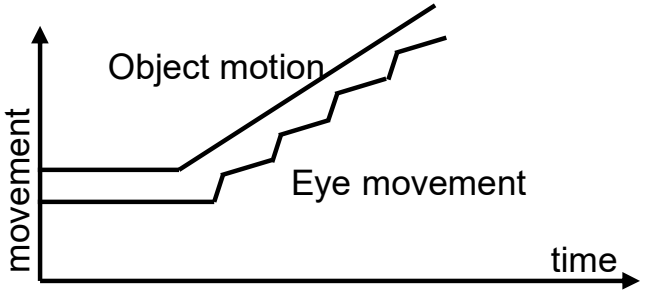
      - 錯覚を利用する／Using Illusion
- その他の話題
  - 光線群制御からCSCWへ／From Ray Control to CSCW
  - 光線群視点制御から視線制御へ／From Ray Control to Eye Control

眼球運動の利用／Using eye movement

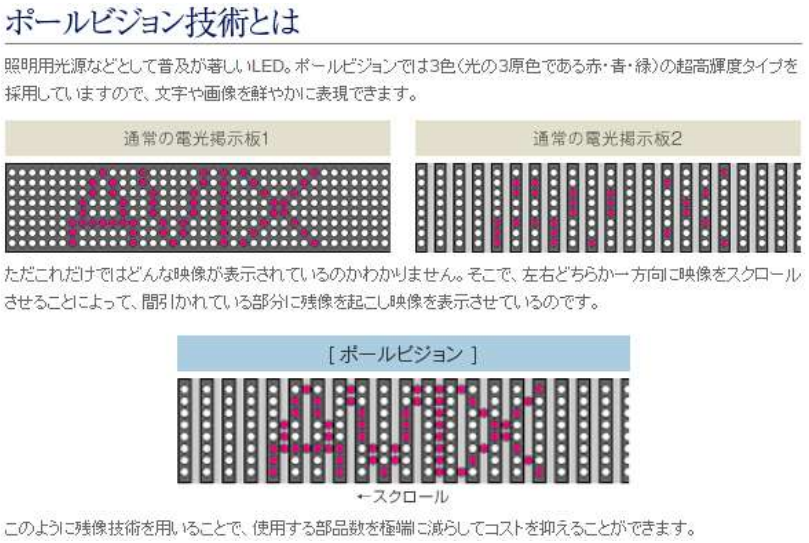




- （再）主に2種類の眼球運動
  - Smooth Persuit（滑動性眼球運動）
    ゆっくりと動く小さな点を追跡する随意性の眼球運動.
  - Saccade(跳躍性（衝動性）眼球運動)
    ステップ状の眼球運動. 不随意／随意.

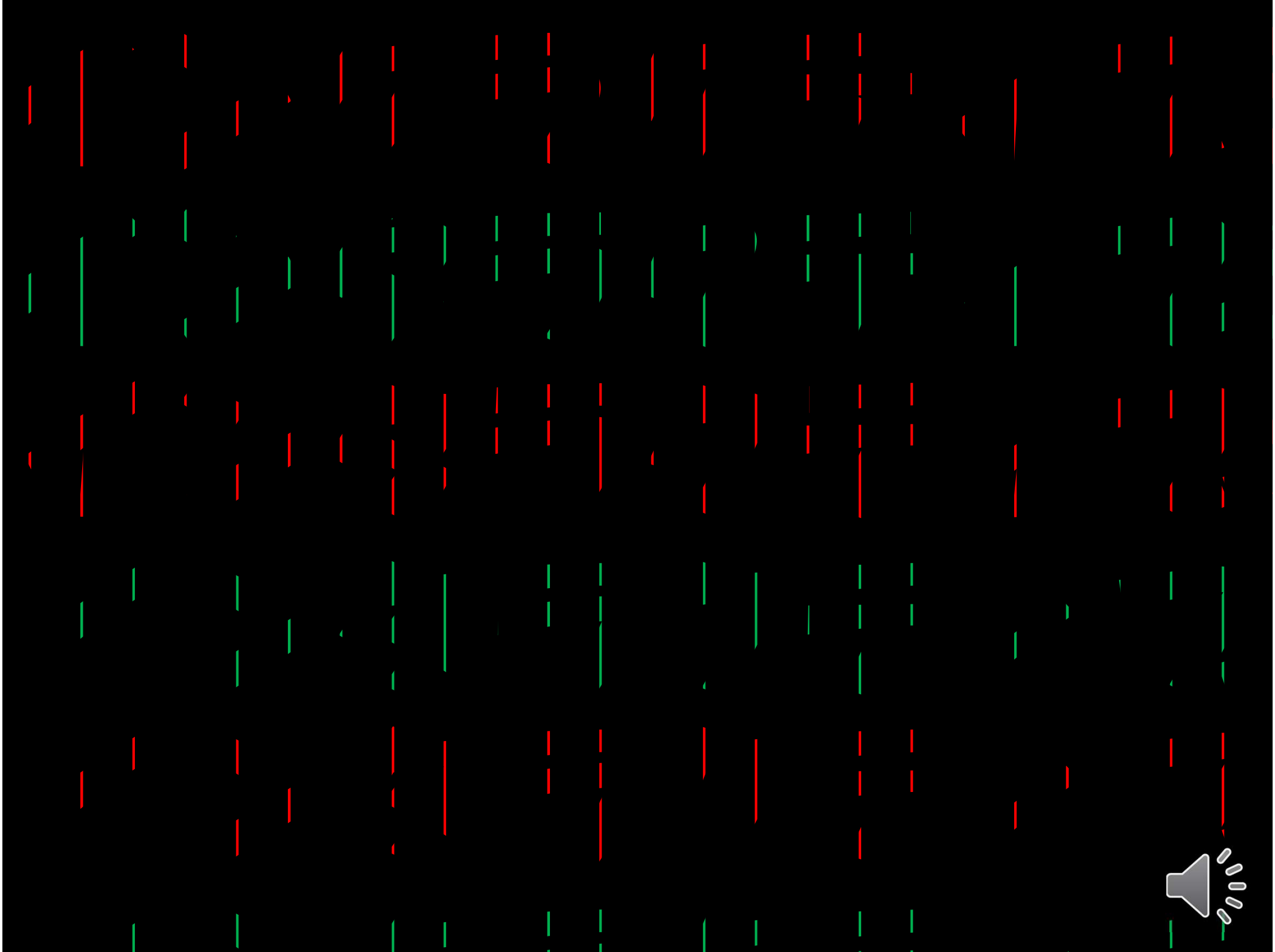
スムーズパースートの利用／Using Smooth persuit

http://www.youtube.com/watch?v=KhpMzNYetis

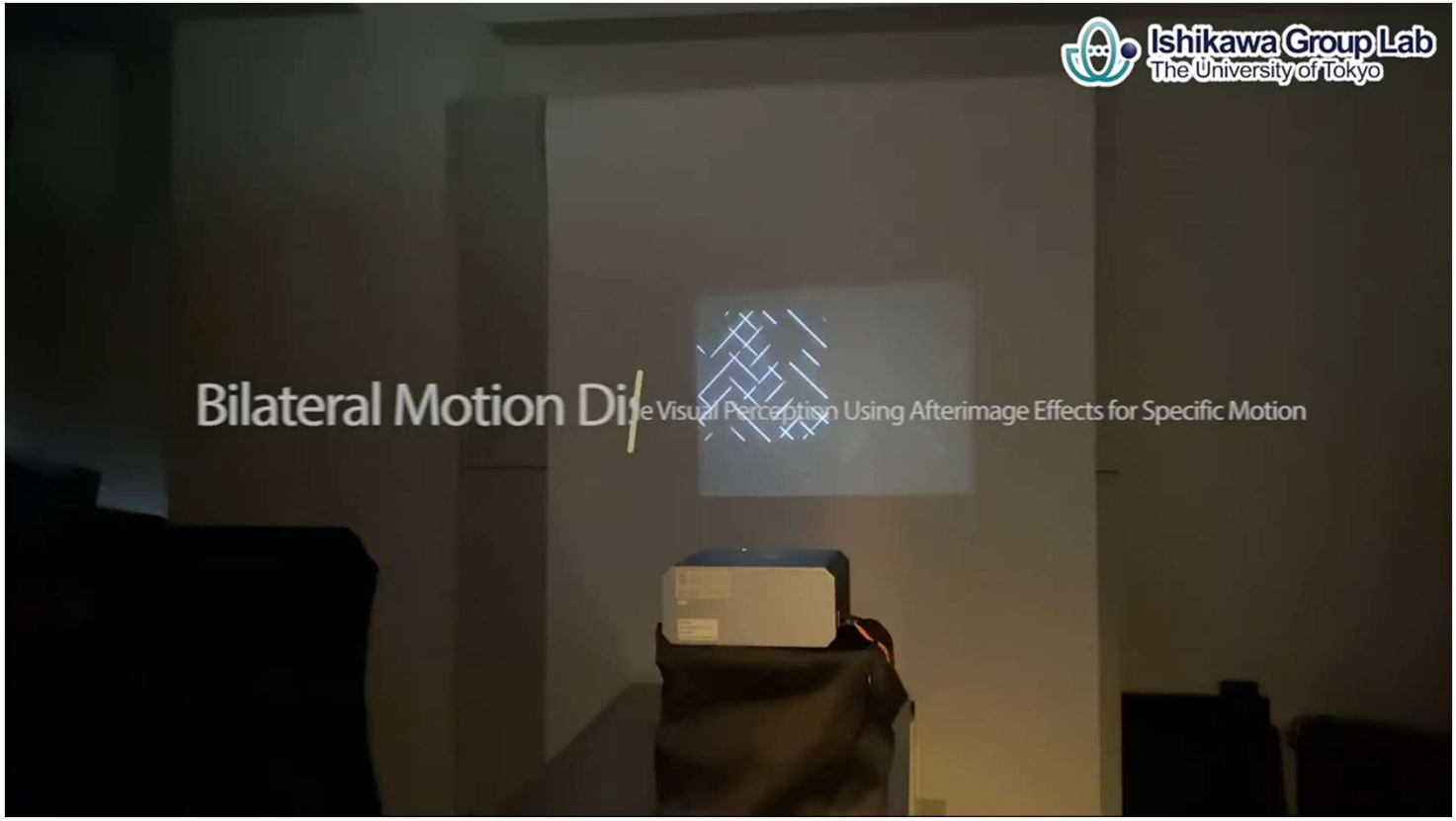


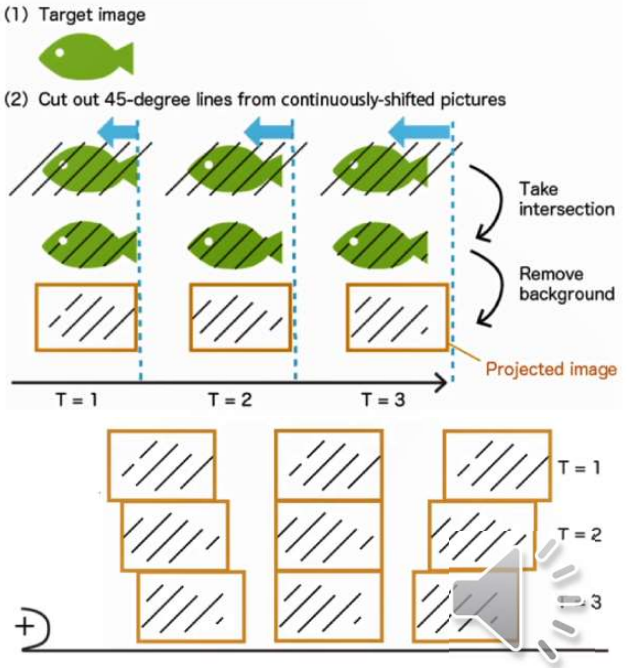
http://www.avix.co.jp/service/billboard/pole_vision/index02.html

- アビックス社ポールビジョン等。
- 極端に間引いた電光掲示板。注視していると表示内容がわからない。
  Very sparce LED message board. Cannot see the contents if you gaze at.
- 眼球をゆっくりと移動させると網膜書き込みによって完成する。
  You can see the image when you slowly move your eyes.



(VRST2019) H. Ikeda, T. Hayakawa, M. Ishikawa Bilateral Motion Display : Multiple Visual Perception Using Afterimage Effects for Specific Motion

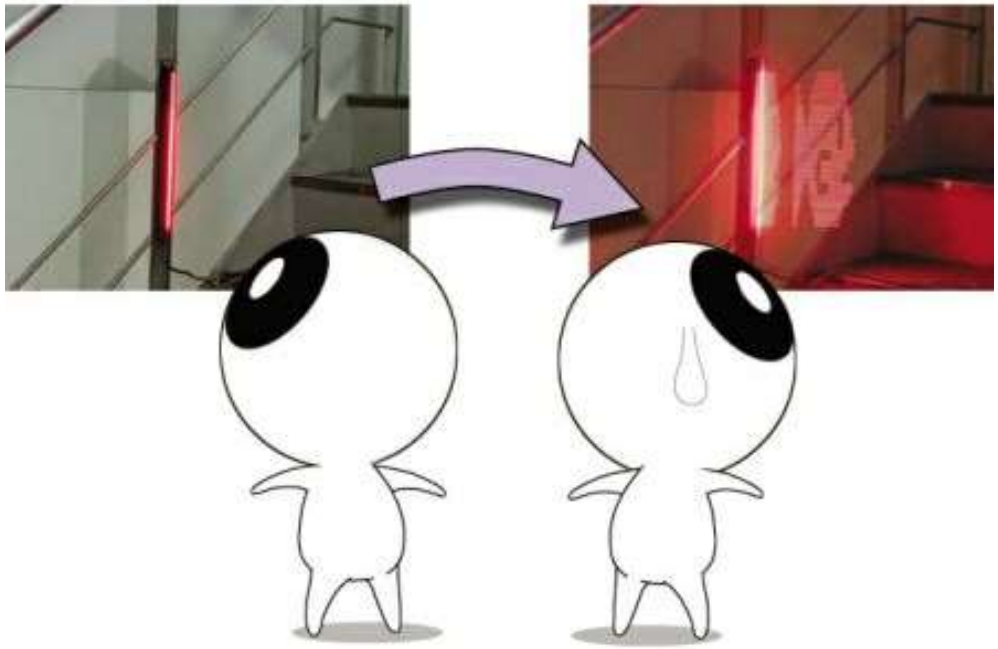




https://www.youtube.com/watch?v=BhRZDjrLBKE
https://dl.acm.org/doi/10.1145/3359996.3364241

- 一見して意味のない線分の動きに見えるが視点位置が適切な速度で動くと網膜上で積算されて意味のある画像に。
- 移動方向によって複数の画像を埋め込むことが可能。

Saccade Based Display (Watanabe et al.)



http://www.junji.org/saccade/index.html

http://www.youtube.com/watch?v=d_pjvSt3w18

H. Ando, J. Watanabe, T. Amemiya, T. Maeda: Full- Scale Saccade-Based Display: Public/Private Image Presentation Based on Gaze-Contingent Visual Illusion, SIGGRAPH 2007 ETech

- 瞬間的に大きく跳躍するサッケードの瞬間に網膜に書き込むことで，一本のLED列で画像を提示できる / Present image at the instance of saccadic eye movement, using linear LED array
- サッケードを誘発する視覚刺激を用いる／眼球運動計測と組み合わせる
  Use visual stimuli that induce saccade, or combine eye movement measurement.

小テスト：一週間以内に提出
Mini Test: Submit in one week

以下の全てに100字以内程度で解答せよ／Answer all questions within 50 words

1. ARを実現するHMDの代表的な二つの方式をなんと呼ぶか
   What are two types of HMD for AR?
2. ARにおける焦点調節の問題について説明せよ
   Explain problem related to focal distance in AR system
3. ARにおける遮蔽問題について説明せよ
   Explain problem related to occlusion in AR system.
4. 波長フィルタを用いた両眼立体視でフルカラーを実現する方法について説明せよ
   Explain how to realize full-color stereoscopic display by wavelength filter.
5. 3D映画における字幕の問題について説明せよ
   Explain problem related to caption in 3D theatre.
6. 遠隔ロボットの両眼カメラを設置型ディスプレイで表示した場合の問題点について説明せよ。
   Explain problem when using robotics two cameras for ground-fixed screen.
7. レンチキュラーにより視差を生成する方法について説明せよ
   Explain how to achieve parallax by lenticular lens
8. パララクスバリアにより視差を生成する方法について説明せよ
   Explain how to achieve parallax by barrier.
9. プルフリッヒ効果について説明せよ
   Explain Pulfrich effect