ETH
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Multi-user Systems

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The Office of the Future

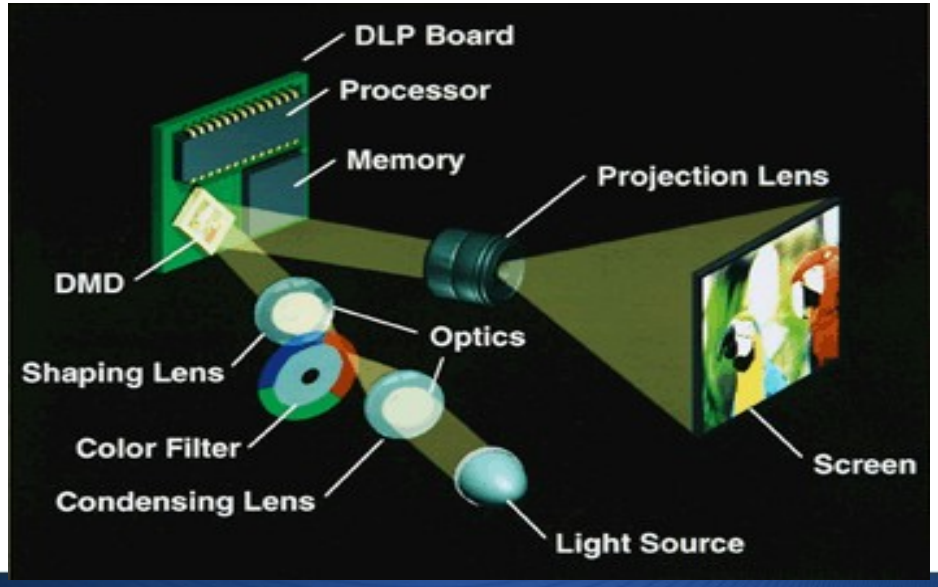
[http://web.media.mit.edu/~raskar/UNC/Office]

Projectors

- Project a video signal onto a reflective projection screen or a translucent rear-projection screen.
- Important characteristics: Resolution, light output, contrast, …
- Important projection technologies:
  - Cathode Ray Tubes (CRT)
  - Liquid crystal (LCD)
  - Micro-Mirrors (DLP)
  - etc.

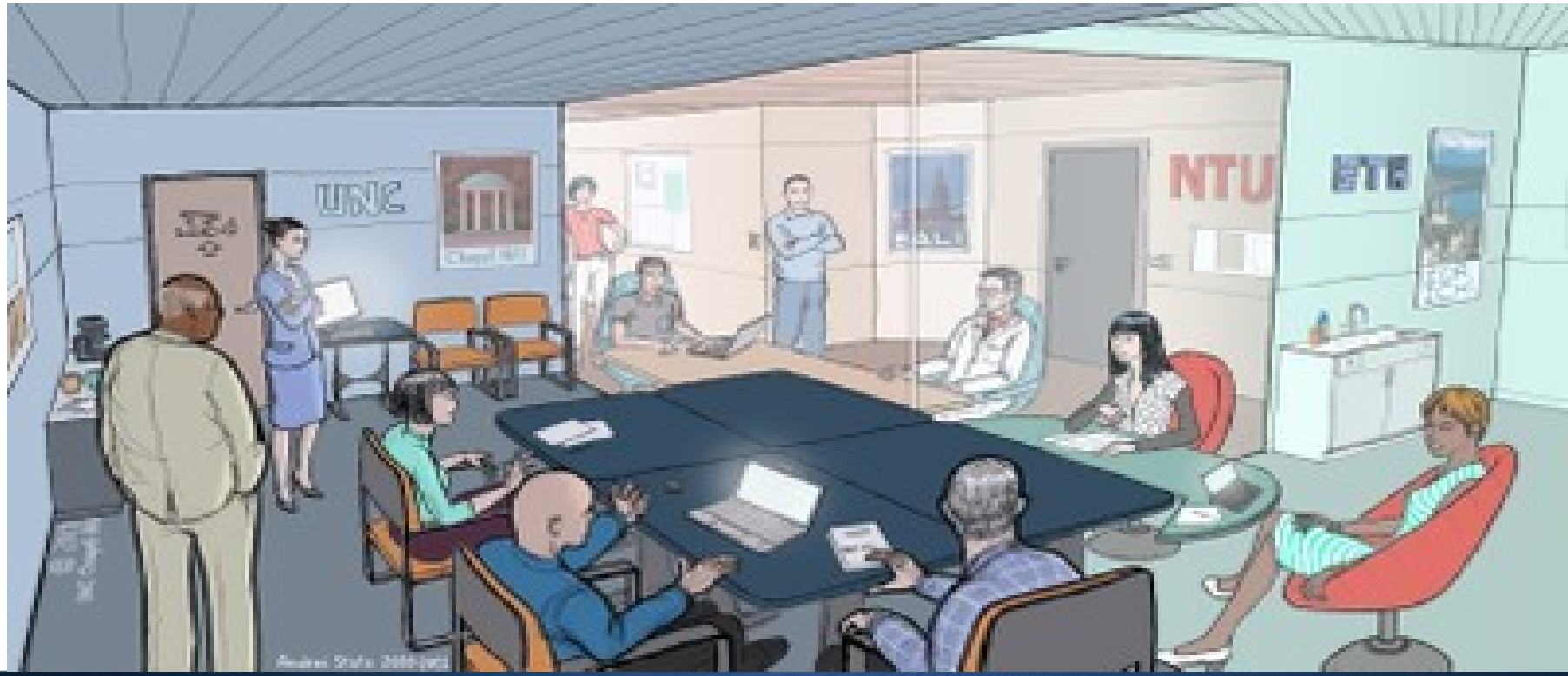
Digital Light Processing Projector (DLP)

- Microscopic mirrors arranged in an rectangular array on a semiconductor chip called the *Digital Micromirror Device* (DMD)
  - Mirrors can be individually rotated to an off or on state.
- Colors are produced by placing a color wheel between a white lamp and the DLP chip.



Telepresence

- Create the illusion of physical presence of a person that is miles away.
- Goal: Telepresence should be indistinguishable from physical presence.



[http://www.vtctalk.com/blog/telepresence/the-future-of-telepresence-uncs-augmented-reality-research.php]

Why Telepresence is important

- Face-to-Face meetings (or the illusion thereof) are important for business.
- Air travel is expensive (and annoying). Apart from air fares, cost appear for
  - Lost productivity of being inaccessible to colleagues and away from information and corporate resources
  - Lost time while being in an airliner or jet lagged („opportunity cost”)

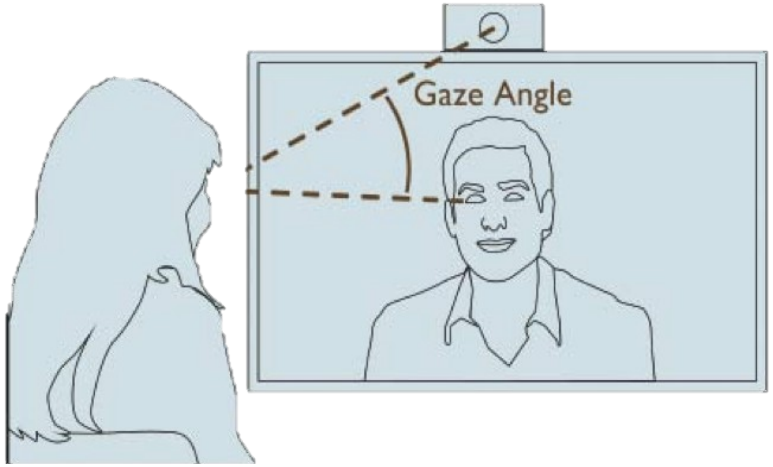
[http://www.desertjet.com/gulfstream-v]

Traditional Videoconferencing fails

- Tiny remote participants, jerky motion, poor audio, etc.
- It fails the human brain's „smell test”: Experience not realistic.
- Most people prefer real face-to-face meetings.

Eye Contact impossible

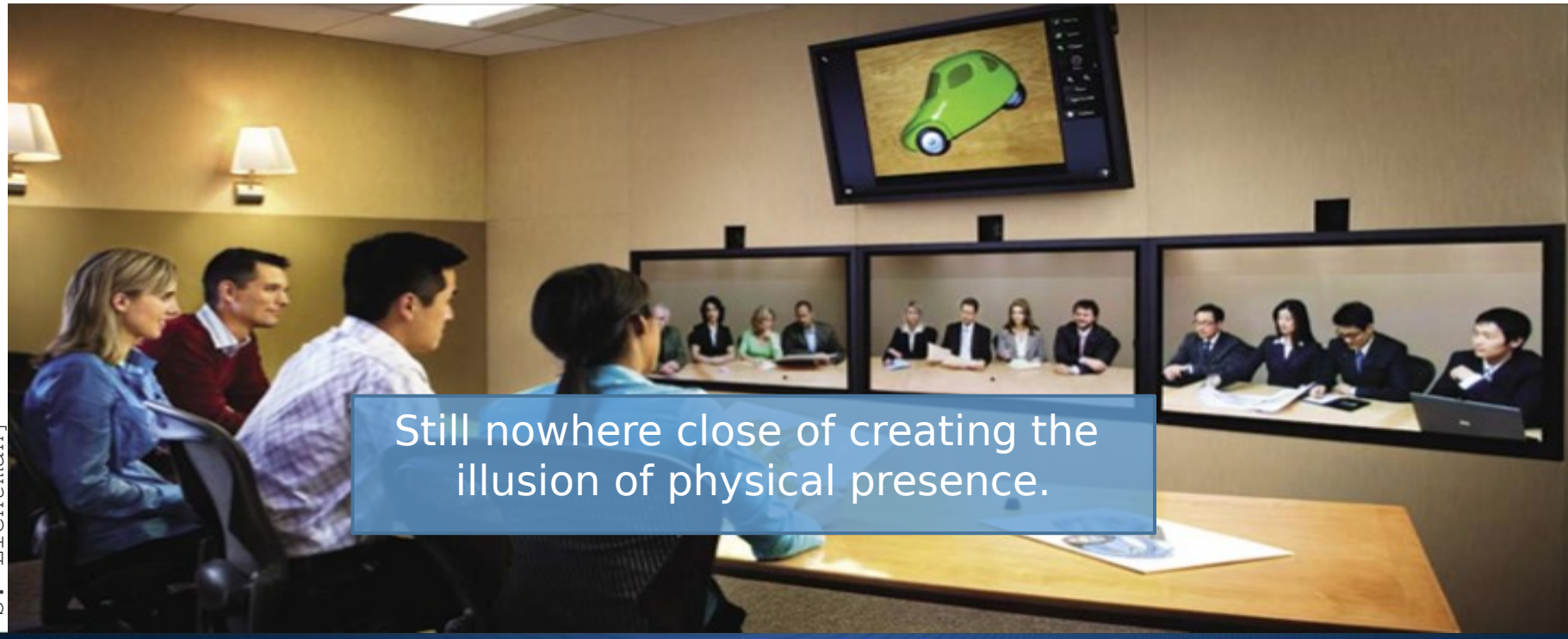
- Important aspect of face-to-face communication.
- Provides many communication fundamentals, such as
  - Feedback
  - Conversational regulation (turn taking)
  - Expressions that punctuate emotion.
- Impossible with traditional videoconferencing systems.



[Telepresence, Effective Visual Collaboration and the Future of Global Business at the Speed of Light by Howard S. Lichtman]

Contemporary Telepresence Systems

- Improve the experience by offering features such as
  - Life-size participants
  - Accurate flesh tones
  - Studio quality video, lightning and acoustics



[Telepresence, Effective Visual Collaboration and the Future of Global Business at the Speed of Light by Howard S. Lichtman]

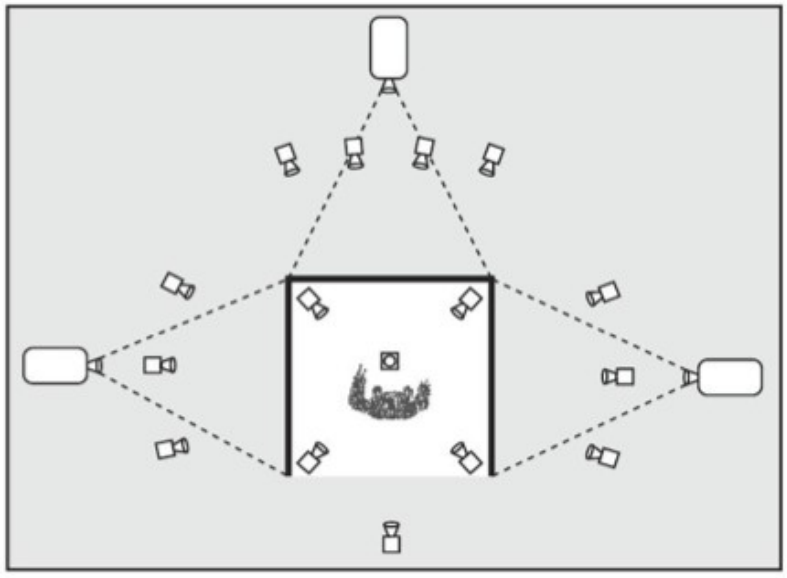
blue-c: Taking Telepresence to the next Level

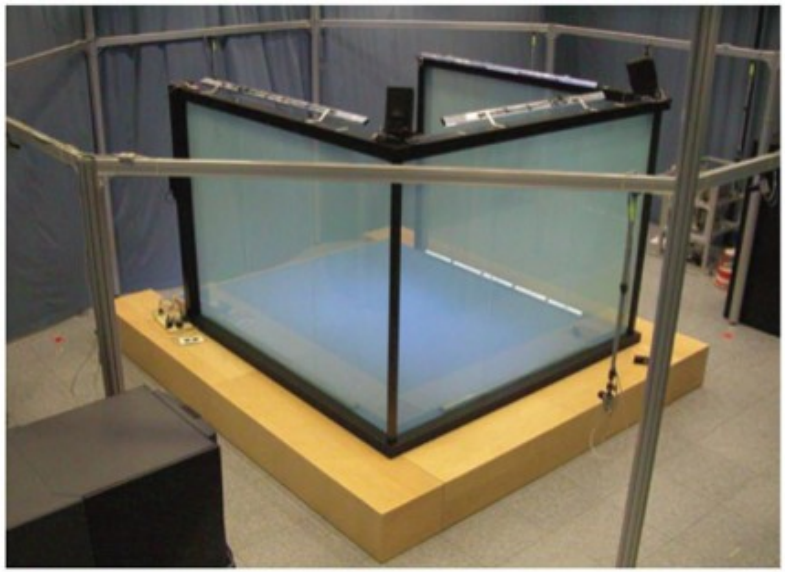
- Goal: Seamless and realistic integration of a remotely located user into a synthesized virtual space.
- User is located in a three-sided cube-like structure.
- From multiple video streams, a 3D video representation of the user is computed in real-time.

[Gross2003]

blue-c: Setup

- Time multiplexing between image acquisition and image projection.
- Walls are build from glass panels containing liquid crystal layers.
  - Can be switched from an opaque state to a transparent state.
- Active stereo using two LCD projectors per screen.

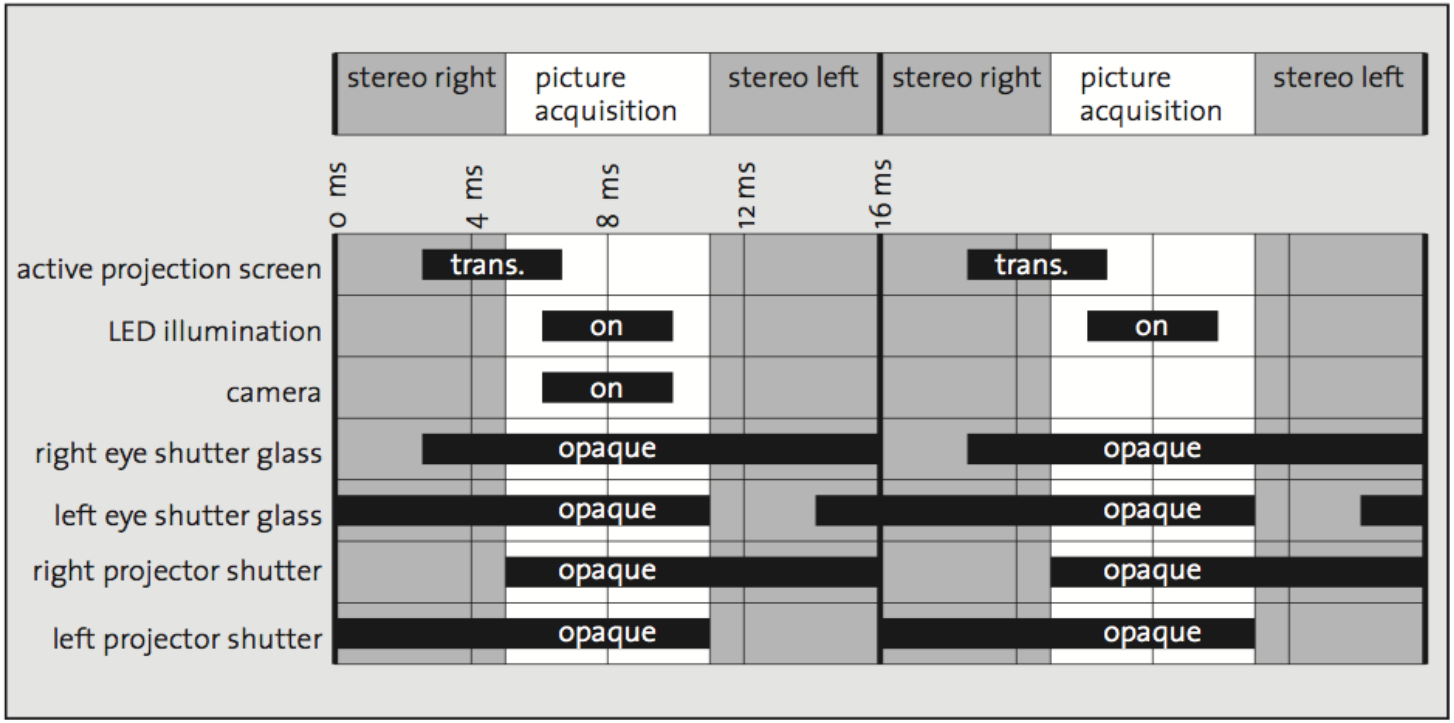




[Gross2003]

blue-c: Image Acquisition

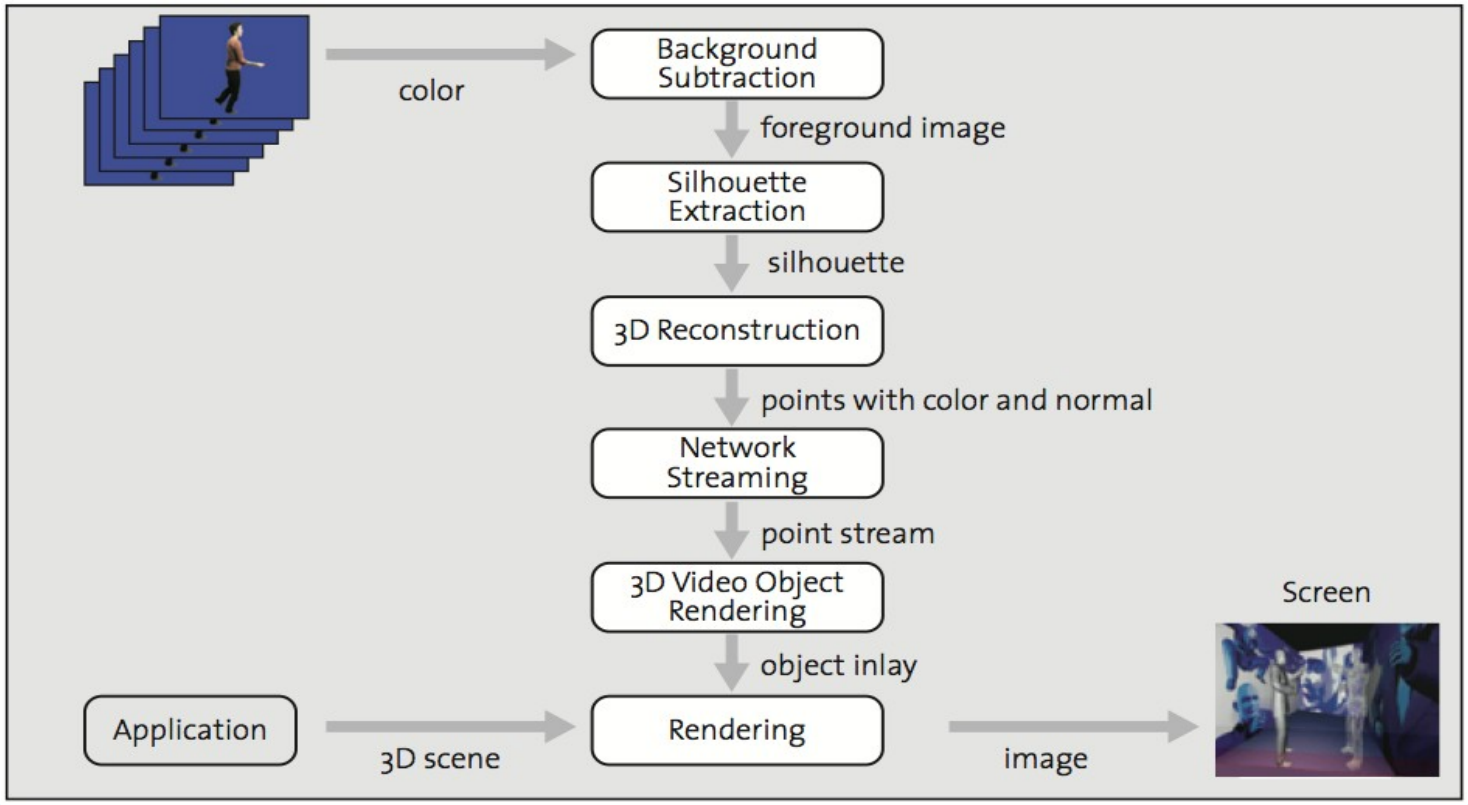
- Happens between the projection frames for the left and right eye.
- User is actively illuminated during image acquisition.
- Custom-build hardware to generate the neccessary timing and trigger pattern.



[Gross2003]

blue-c: 3D Processing

- 3D Processing happens in real-time on a Linux PC cluster.
- A point-based representation of the user is computed.
  - Allows efficient streaming, rendering and 3D compositing.



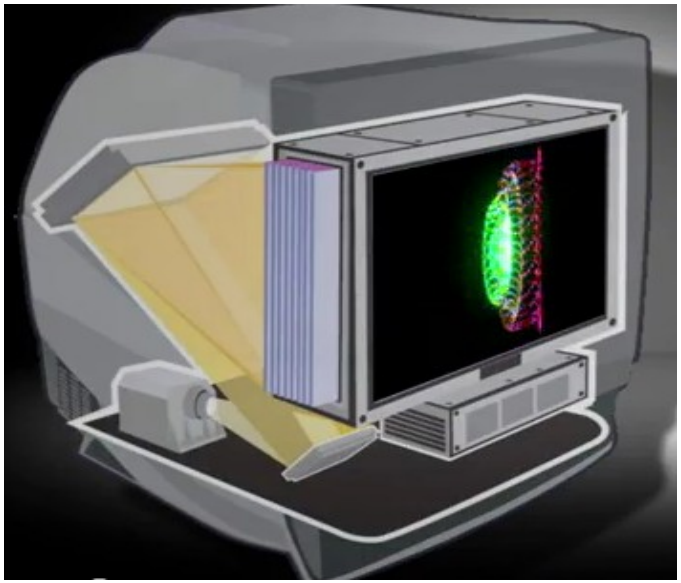
[Gross2003]

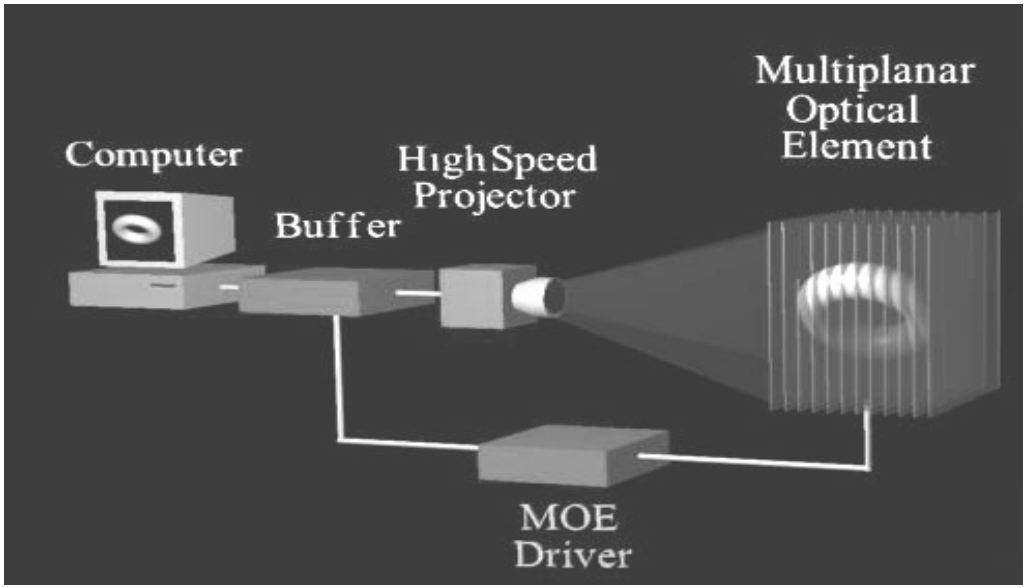
blue-c: Demo

[Gross2003]

DepthCube

- Multi-planar volumetric display system.
- A high speed projector projects slices of the 3D scene onto a stack of LC shutters.
- Multi-planar anti-aliasing algorithms are used to create continuous appearing 3D images.





[A Solid-state Multi-planar Volumetric Display by Alan Sullivan]

DepthCube: Applications

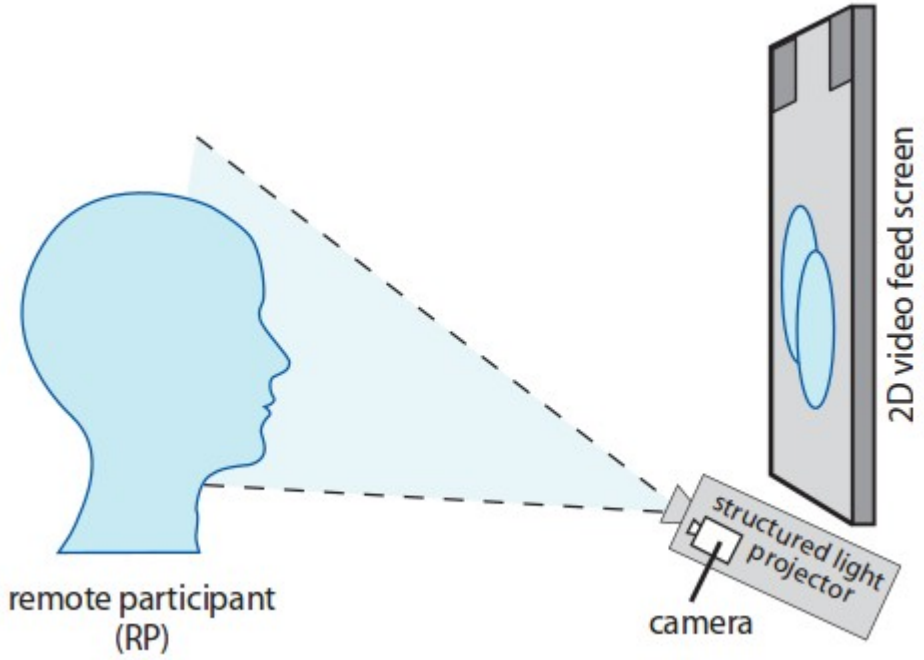
[A Solid-state Multi-planar Volumetric Display by Alan Sullivan]

Eye Contact in One-To-Many Videoconferencing

- Major limitation of blue-c: One user per portal
- One-To-Many Videoconferencing: Single remote participant attends a larger meeting.

[Jones2009]

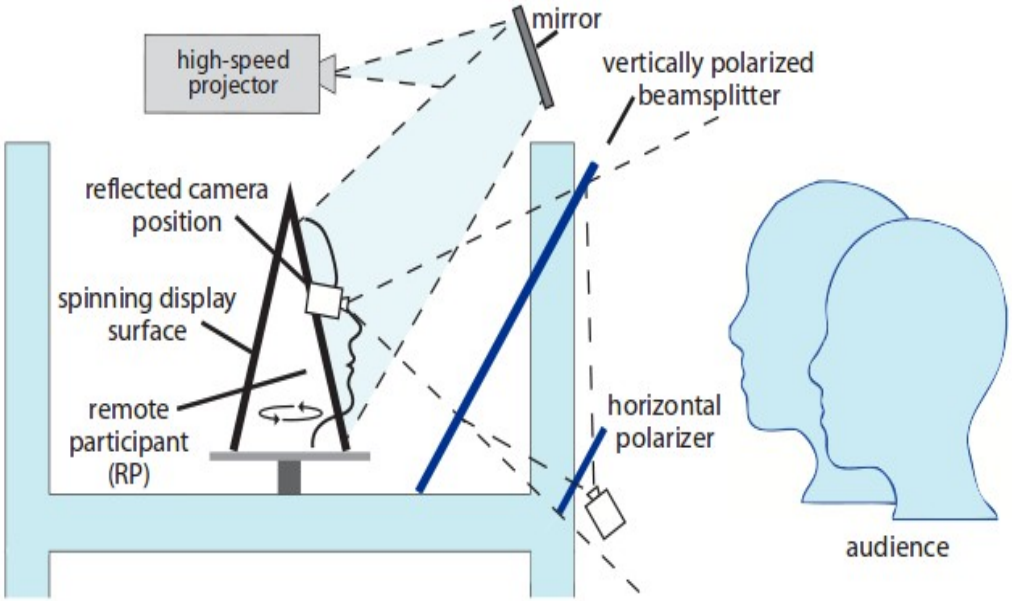
3D Image Acquisition



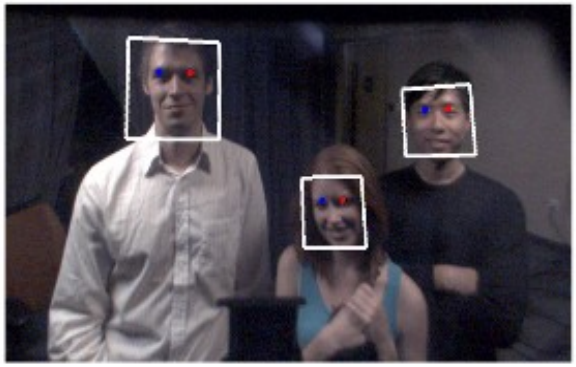
- 4 repeated patterns are projected onto face.
- Creates a depth map image for the face.
- 2D video feed allows the remote participant to view their adience.

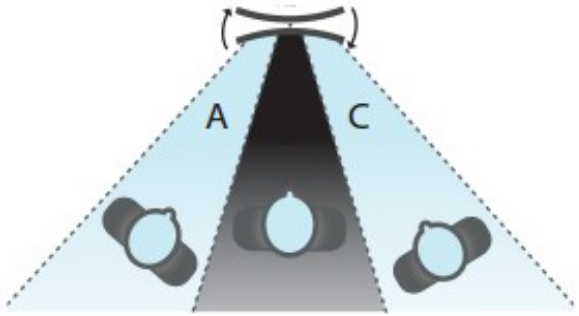
[Jones2009]

Autostereoscopic 3D Display



- 2 brushed aluminium display surfaces spinning at 900 rpm.
- Viewer's position is tracked in the 2D video feed.
- Each projector frame can addresses just one adience member.





[Jones2009]

Eye Contact in One-To-Many Videoconferencing

[Jones2009]

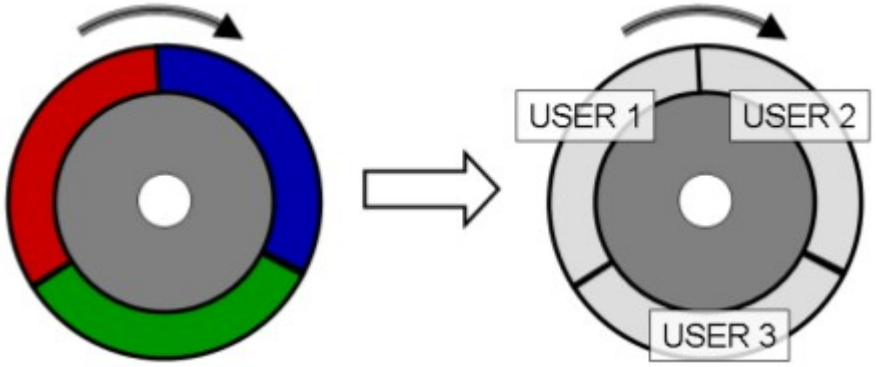
C1x6: Multi-User 3D Display

- In 3D cinemas, there is only a single location from where a person observes a perspectively correct view.
- C1x6: Each user is provided an individual stereoscopic image pair (up to 6 users).

[Kulik2011]

C1x6: Multi-User 3D Display

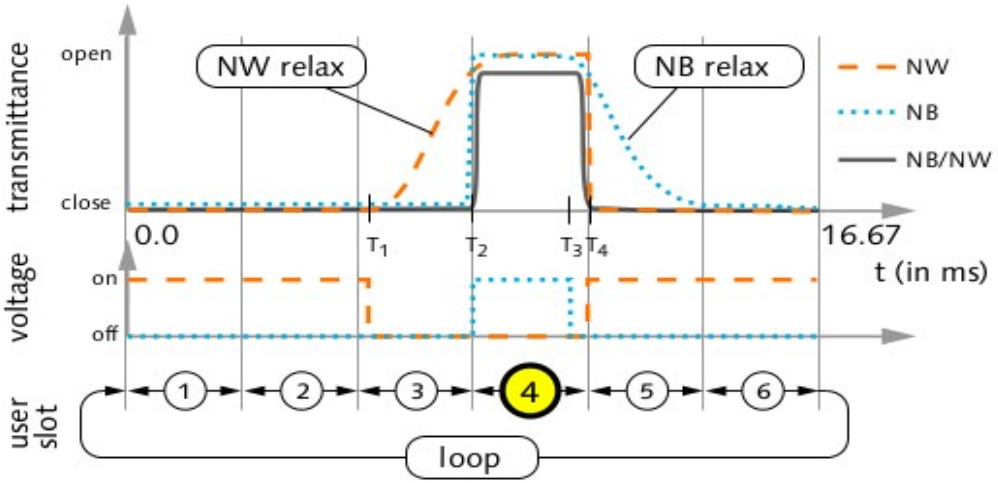
- 6 customized DLP projectors, each of which projects images in one of the primary colors.
- Modern DLP projectors rotate the color wheel at least twice per video frame while 60 Hz input is provided (→ running at 120 Hz).
  - This allows 6 different images at 360 Hz.
- Different polarizing of the light output of the first three projectors than those of the second three.
  - 12 different full-color images.



[Kulik2011]

C1x6: Multi-User 3D Display

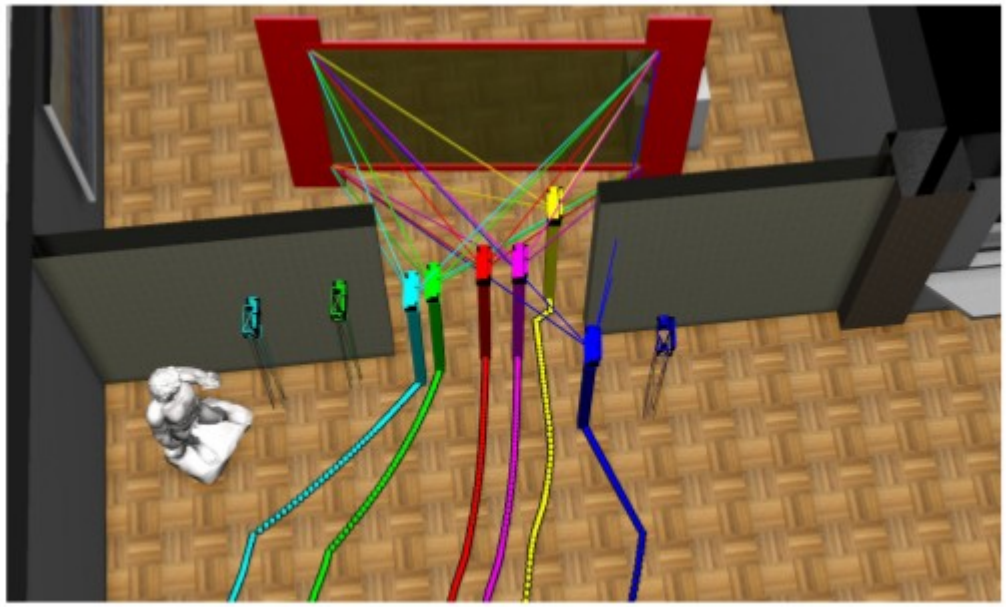
- Usual LC Shutters: Close quickly (< 0.2 ms) and open slowly (> 2 ms).
- Double cell shutter:
  - Regular shutter that is transparent if no voltage is applied (NW).
  - Second shutter is opaque if no voltage is applied (NB).



[Kulik2011]

C1x6: Group navigation

- Perception of a consistant virtual world of all users.
  - Users are placed in the same spatial configuration as in the real world (apart from scaling factor).
  - When virtually navigating, not all users might fit through a constriction such as a door.



[Kulik2011]

C1x6: Group navigation

1

Stop and crowd

- Stop the navigation if one users collides.

2

Disort

- Move head position of colliding user towards head position of navigator.
- Distortion of the perspective.

3

Detour

- Move user along a collision-free path while maintaining a perspectivly correct rendering.

4

Fade

- If user is on a path towards an obstacle, fade obstacle out.

[Kulik2011]

Multi-User Interaction in the Office

- Multi-touch tabletop
- Handheld projectors
- Multi-projector tiled display walls

Multi-Projector Tiled Displays

Traditionally

- Flipchart with many sheets of paper. Sheets can be teared off and hanged somewhere.
- Classrooms with multiple blackboards, often wrapping around the room.

Today

- Single projector
- … but projectors are cheap.

Combine multiple projectors to form a single large display surface.

Multi-Projector Tiled Displays: Setup

- Scalable
- Reconfigurable
- Easily installable

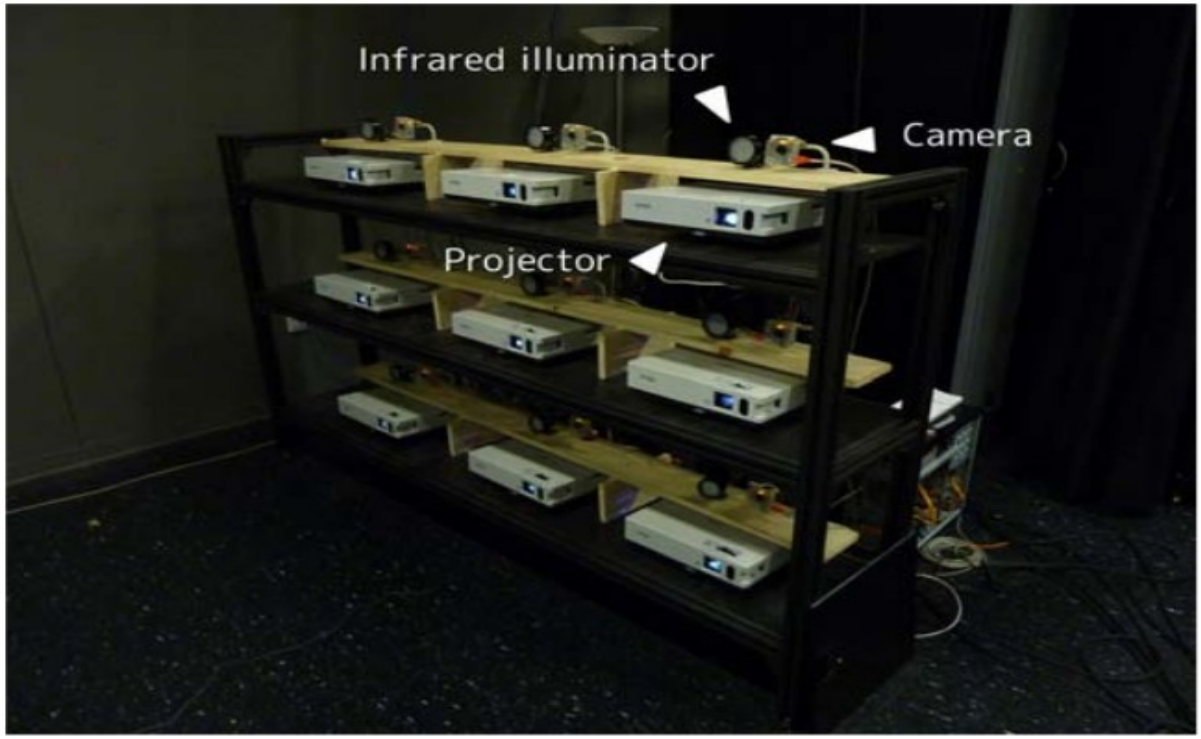
Computation Unit

Plug-and-play projector (PPP)

[Roman2010]

Multi-Projector Tiled Displays: Setup

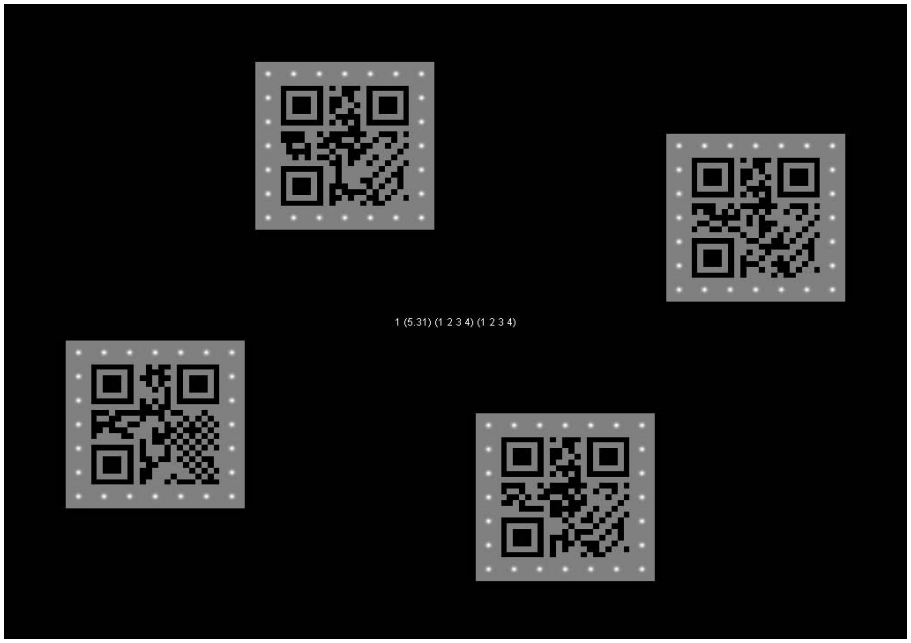
- N PPPs casually arranged in a rectangular array.
  - Overlapping between neighbours.
- PPPs use constant IP multicast group for communication.



[Roman2010]

Multi-Projector Tiled Displays: Registration

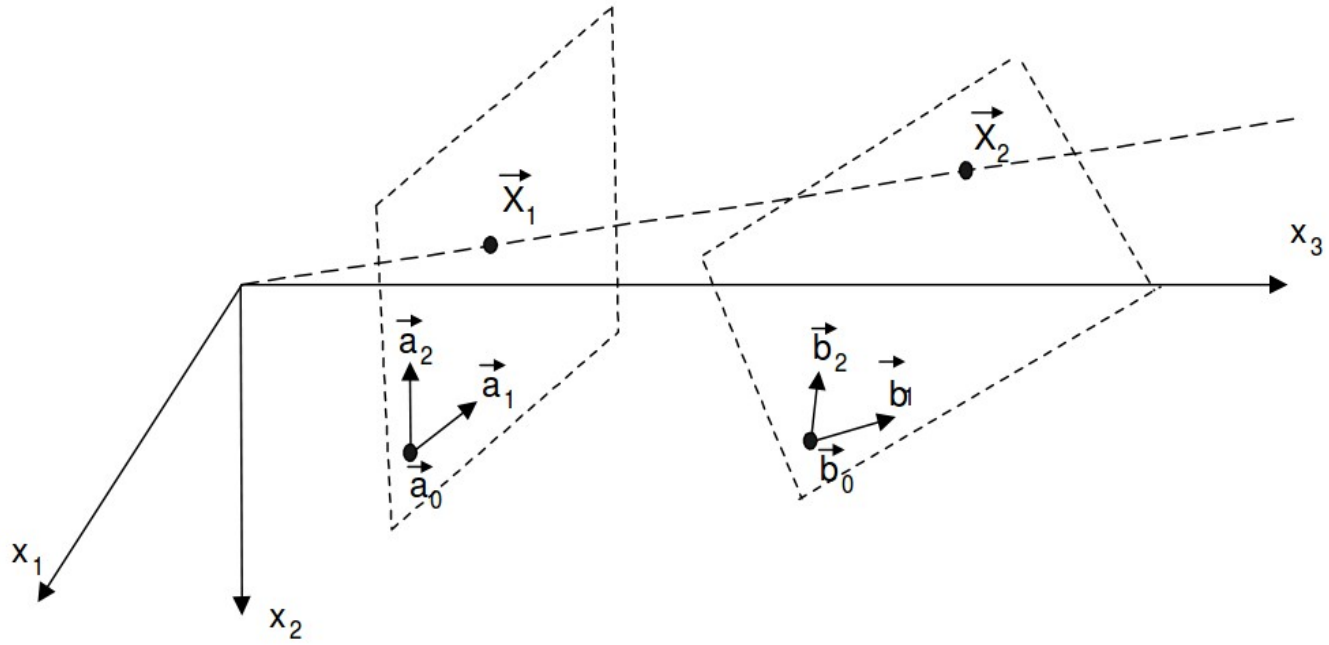
- Each PPP projects 4 QR codes (one per corner) containing its IP address / port.
- Each PPP broadcasts the location of each neighbour along with the associated IP-address.
- Each PPP builds the connectivity graph for the entire display.



[Roman2010]

Multi-Projector Tiled Displays: Geometric Registration

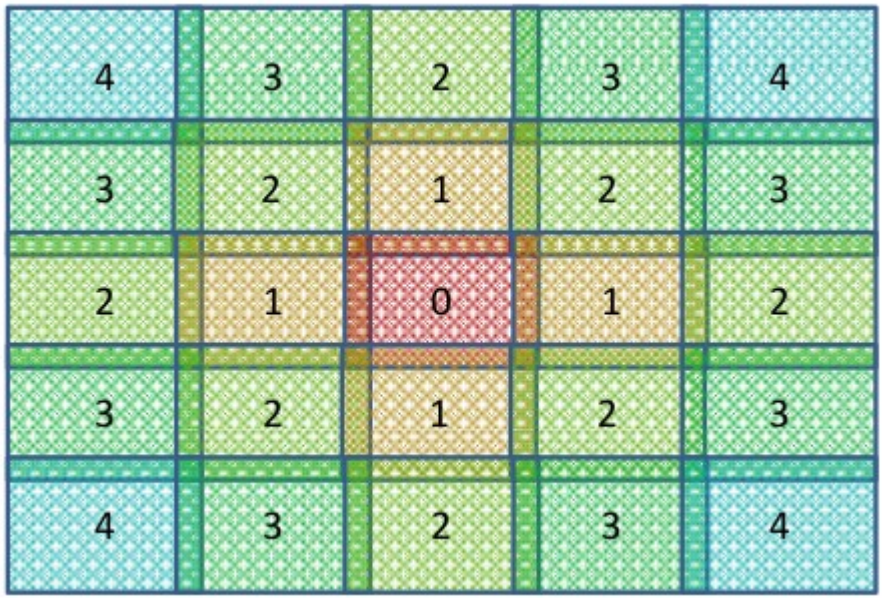
- PPPs might not be perfectly aligned at their boundaries.
  - Visible breaks in the image content.
- Relation between the coordinates of two projectors can be described ba a 3 x 3 matrix H called **planar homography**.



[Roman2010]

Multi-Projector Tiled Displays: Geometric Registration

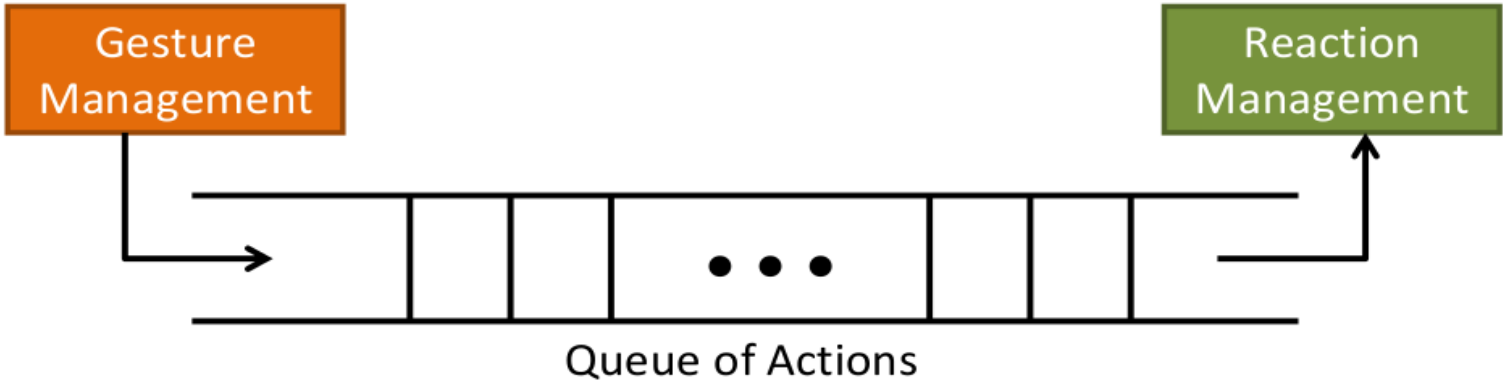
- QR codes are augmented with blobs embedded in the quiet zone.
- Step 1: Each PPP detect self-homography between its projector and camera.
- Step 2: Detect homographies with its adjacent projector.
- Step 3: Concatenate self-homography with homography of adjacent projectors.



[Roman2010]

Multi-Projector Tiled Displays: Interaction

- We assume hand guestures for interaction.
- No centralized server, each PPP manages observed actions of the user.



[Roman2010]

Multi-Projector Tiled Displays: Gestures

- A gesture is a sequence of action.
- If action occurs in an area that multiple PPPs overlap, the PPP with the lowest ID is responsible for tracking it.
- If a gesture moves into the neighborhood of an adjacent PPP, send an anticipatory message.

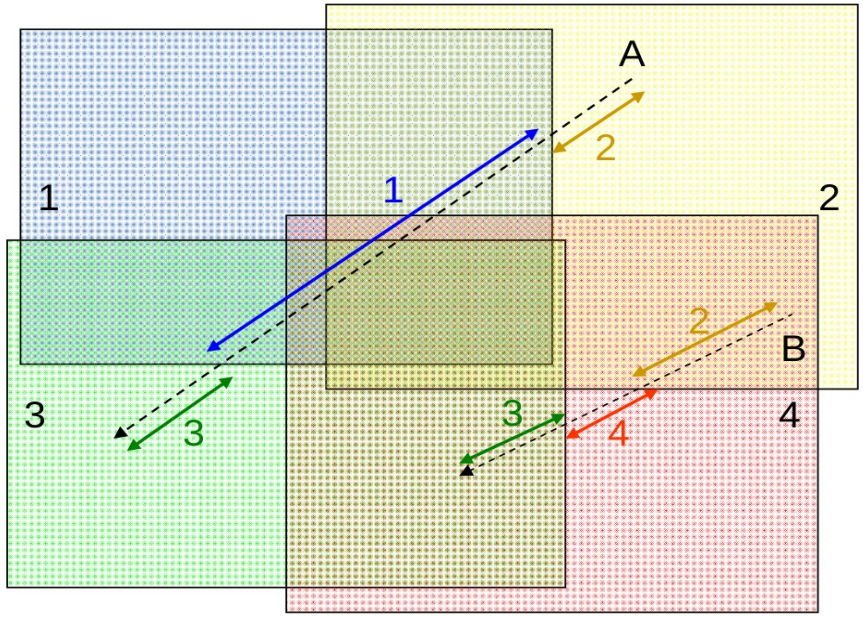
ACTION

- Size
- Position
- Orientation
- Timestamp
- PPP ID

Action-specific Attributes

- Gesture ID
- Gesture Type
- Speed
- Acceleration

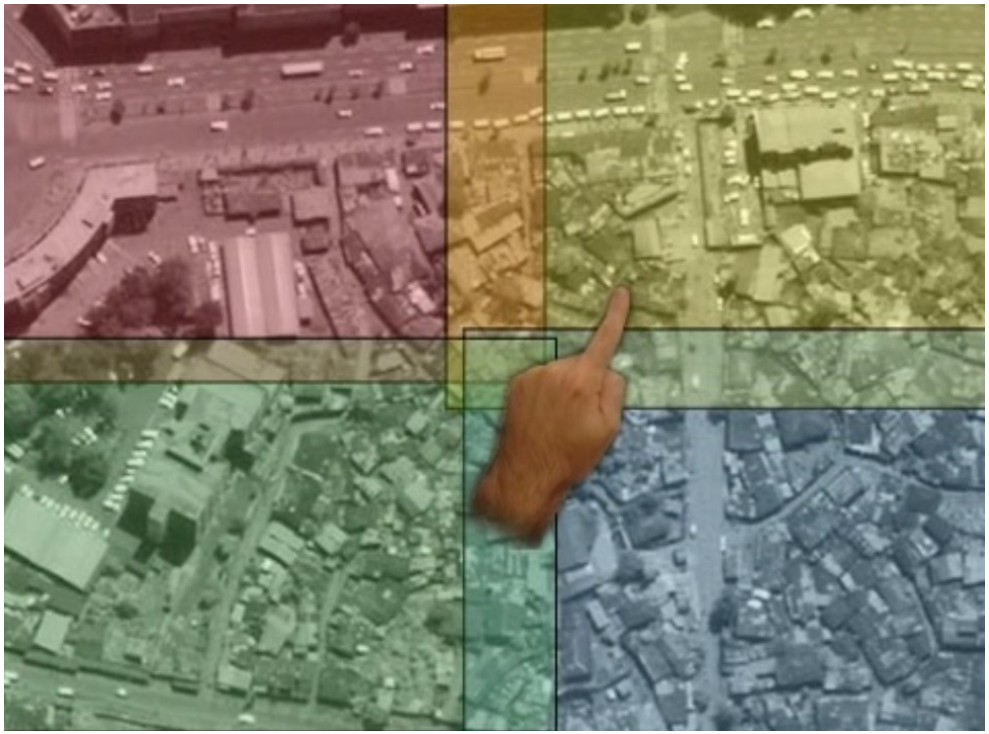
Gesture-specific Attributes



[Roman2010]

Multi-Projector Tiled Displays: Reactions

- React to Action, not to Gestures
- Reaction monstly application specific
- All PPPs might need to react to a user action.

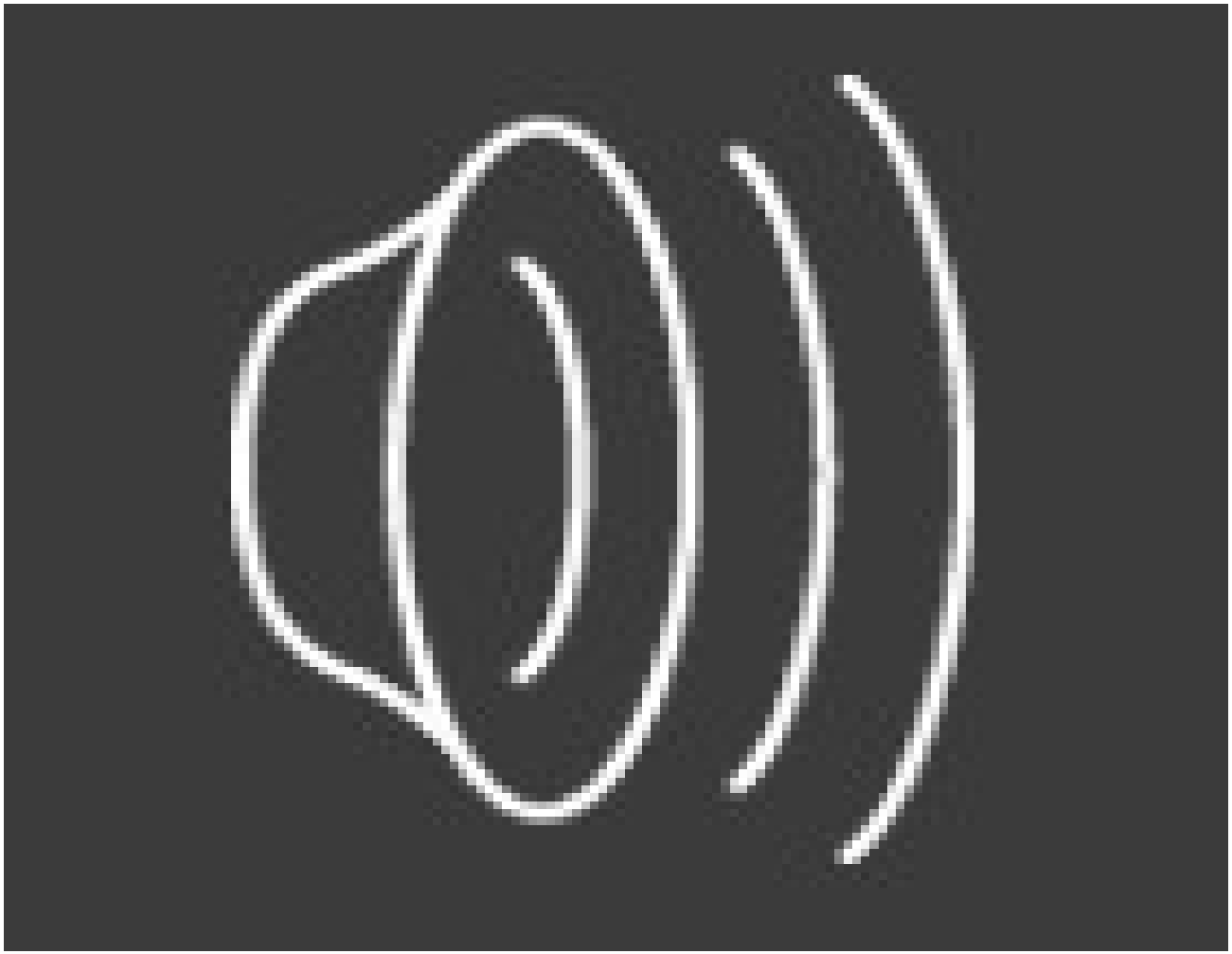


[Roman2010]

Multi-Projector Tiled Displays: Virtual Graffiti

[Roman2010]

Multi-Projector Tiled Displays: Map Visualization



[Roman2010]

Multi-Projector Tiled Displays: Emergency Room

[Roman2010]

Summary

1

Telepresence

- Contemporary telepresence is not enough
- Blue-c: Time multiplexing between image aquisition and projection
- Eye contact in One-To-Many Videoconferencing

2

Volumetric Displays

- DepthCube

3

Multi-User 3D Display

- C1x6: Up two 12 different images using 6 DLP projectors.

4

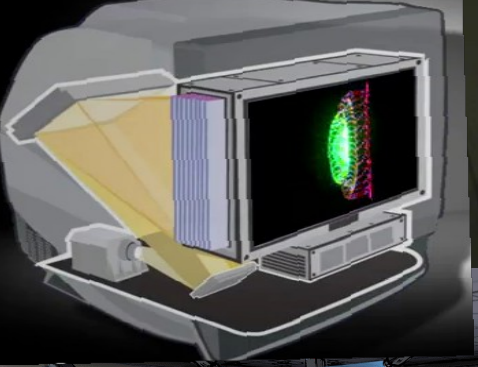
Group Navigation

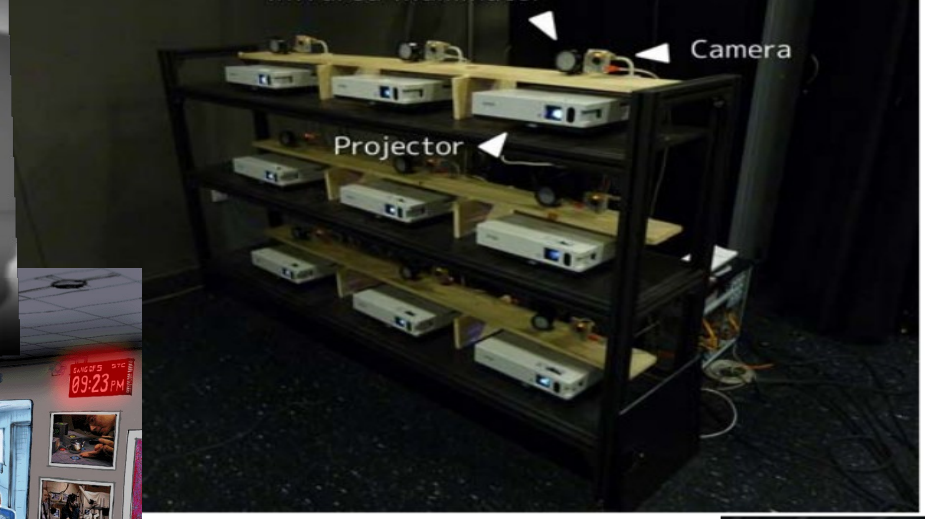
- Fade or detour.

5

Tiled Displays

- Plug-and-Play Projectors (PPP)
- Completly distributed registration, guesture- and reaction management.





Thank you!

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