

Computational Camera & Photography:

A blue-tinted photograph of a water splash. The water is captured in mid-air, creating a crown-like shape. In the background, a camera lens is visible, with some text like '8.5mm' and '1:2.8' partially legible. The overall scene is set against a dark background.

Ramesh Raskar

MIT Media Lab

<http://cameraculture.media.mit.edu/>

Schedule

- Assignment #3, Oct 16th to Oct 30
- Assignment #4, Oct 30 to Nov 13th
- Mid-term exam: Nov 13th (fast review Nov 6th), open book, open laptop
- Final Project
 - Credit 30%
 - Novelty, coolness (+execution), impact (+evaluation)
 - (roughly 1/3 each)
 - Pre-proposals: Oct 30th
 - NOW: Try to meet I, Ankit or other mentors with at least 3 ideas
 - If you are listener, pitch your ideas today, recruit students
 - Pre-proposal: (send by email for your main one or two ideas)
 - Motivation, Goal, Novelty and Prior Art, Approach, References
 - 3 minute presentation on Nov 6th
 - Final Proposals: Nov 20th
 - Initial experiments
 - Presentation: Dec 4th (End of Semester)
 - Conference quality technical paper report

Cameras for HCI

- Camera looking at people
 - Face detection/recognition
 - People tracking, segmentation
- Camera looking at fingers
 - FTIR
 - Optical mouse
 - Anoto Pen
- Multi-flash
- Complexity of Optical Transmission
- Motion capture
 - 2D, 1D, 0D
 - Motion detector
 - Wii

Boring Camera HCI Projects

- Locate/Track/Segment
 - But fails under lighting, skin-color, clothing, background change
- Track LED from one/two webcams
 - Triangulate
- Segment finger or face
 - Background segmentation
 - Put on a glove/hat for better segmentation
- Artistic interactive display
 - Human figure segmentation
 - Proximity/blob size
 - Motion (hand waving etc)
- You can impress
 - some of the people all of the time, and all of the people some of the time, but not all of the people all of the time
- Solution:
 - Use smarter sensors, processing to create magic

Classic rear-projector interaction

Images removed due to copyright restrictions.
See "HoloWall: An Architecture for Wall-based Interaction."
<http://ftp.csl.sony.co.jp/person/rekimoto/holowall/>

Video Mouse

Three photos removed due to copyright restrictions.

See Fig. 1 and 4 (left) in Hinkley, K., et al.

“The VideoMouse: A Camera-Based Multi-Degree-of-Freedom Input Device.”

Proceedings of UIST 1999.

<http://research.microsoft.com/pubs/68670/Hinckley-UIST99.pdf>

Camera to sense six degree of freedom
motion in a mouse-like form factor.

Curved base to afford tilting the device

Frustrated TIR

- Refraction
- Beyond *critical angle*, total internal reflection:
 - Fiber optics, light pipes, and other optical waveguides for light transport with low loss
- FTIR: New material at the interface can frustrate this total internal reflection, causing light to escape the waveguide there instead.
 - Finger-print detection

Cameras for HCI

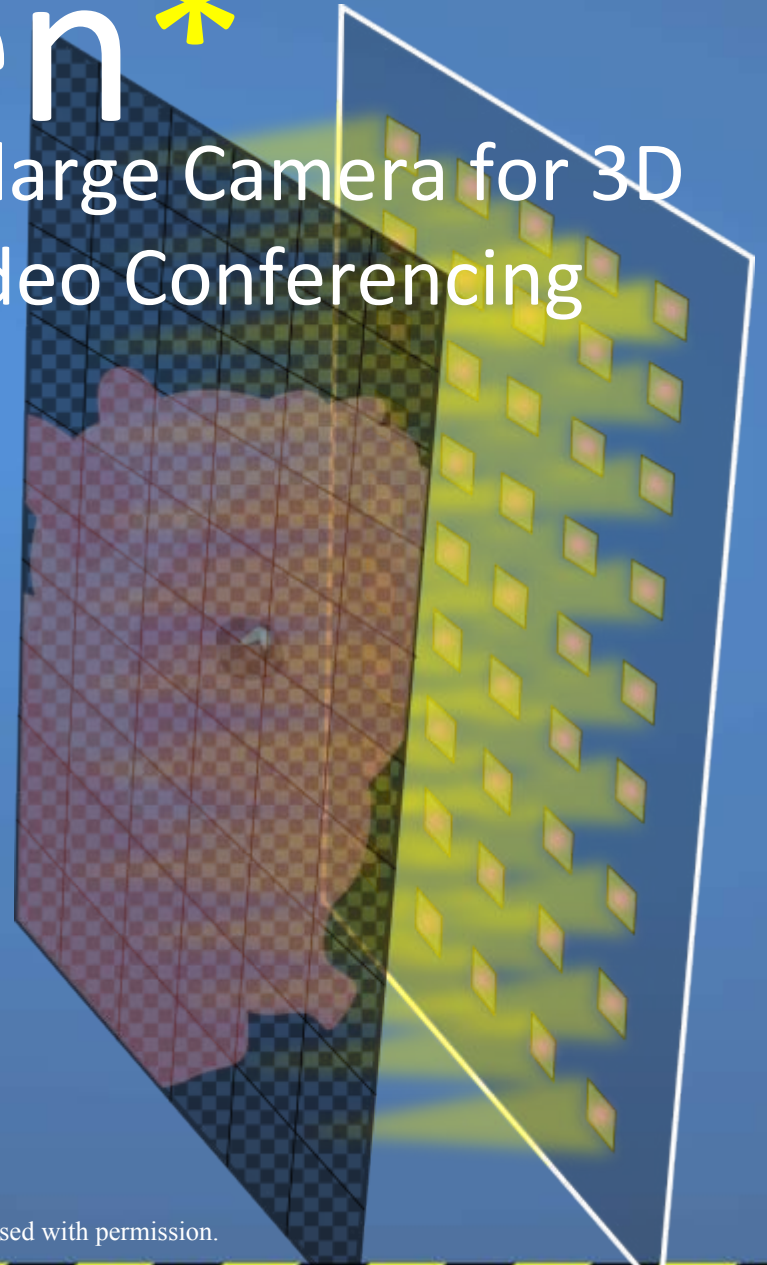
- Frustrated total internal reflection

Two images removed due to copyright restrictions.

Han, J. Y. 2005. Low-Cost Multi-Touch Sensing through Frustrated Total Internal Reflection. In *Proceedings of the 18th Annual ACM Symposium on User Interface Software and Technology*

BiDi Screen*

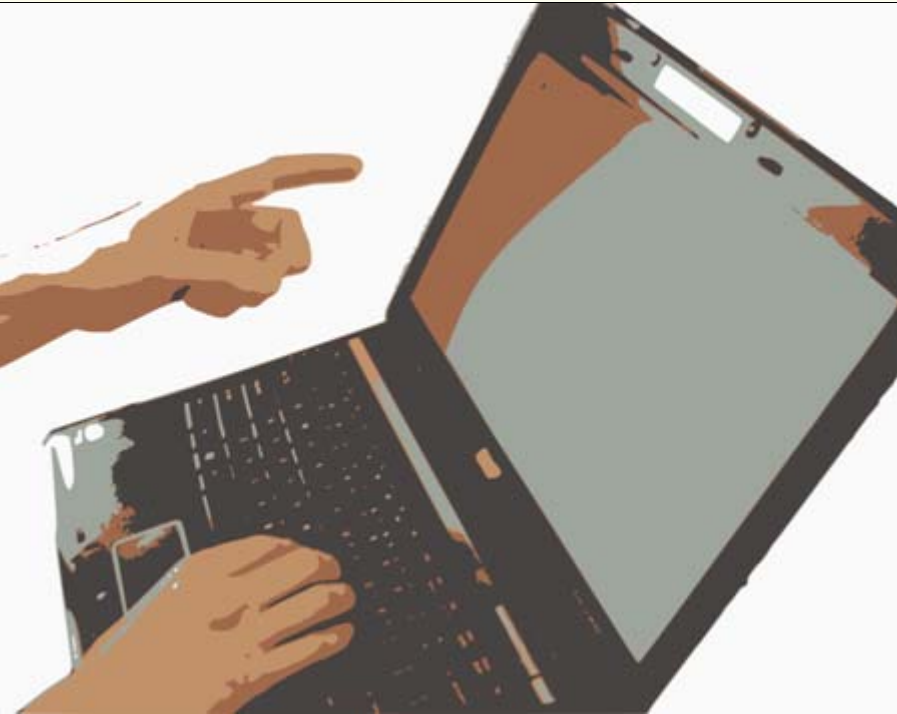
Converting LCD Screen = large Camera for 3D
Interactive HCI and Video Conferencing



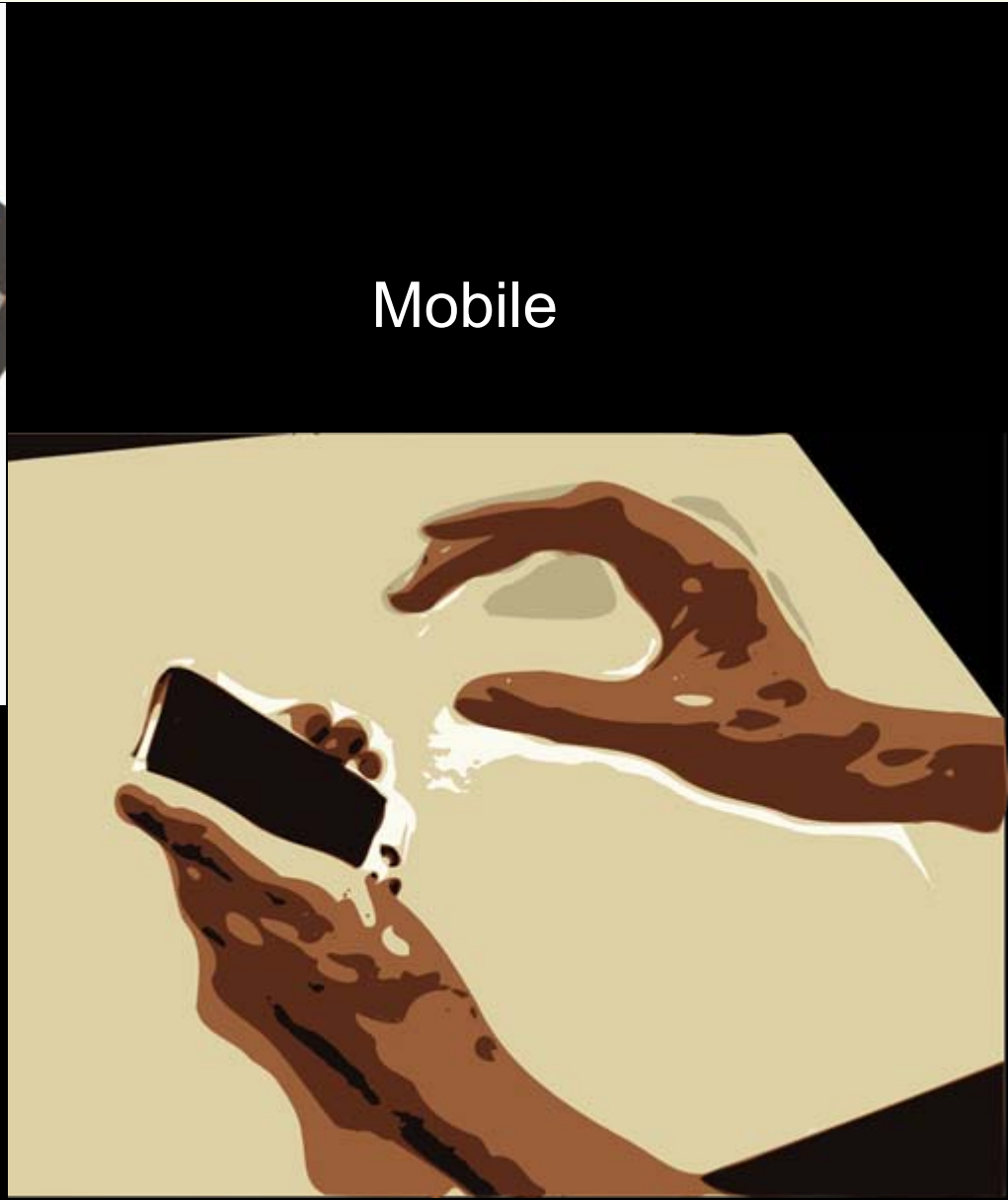
Matthew Hirsch, Henry Holtzman
Doug Lanman, Ramesh Raskar
Siggraph Asia 2009
Class Project in CompCam 2008
SRC Winner

Courtesy of Matt Hirsch. Used with permission.

Beyond Multi-touch: Mobile

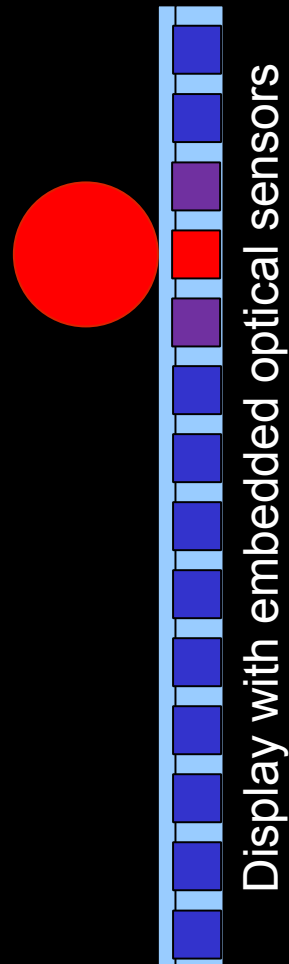


Laptops

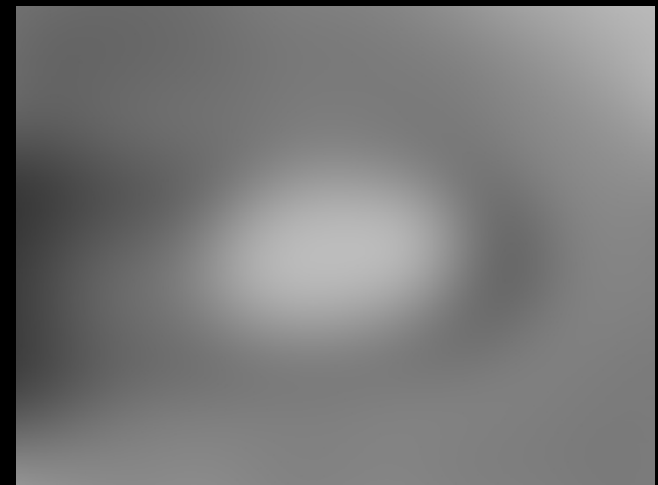
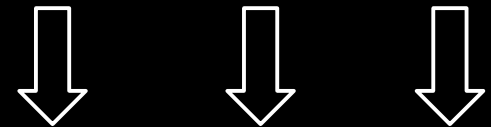
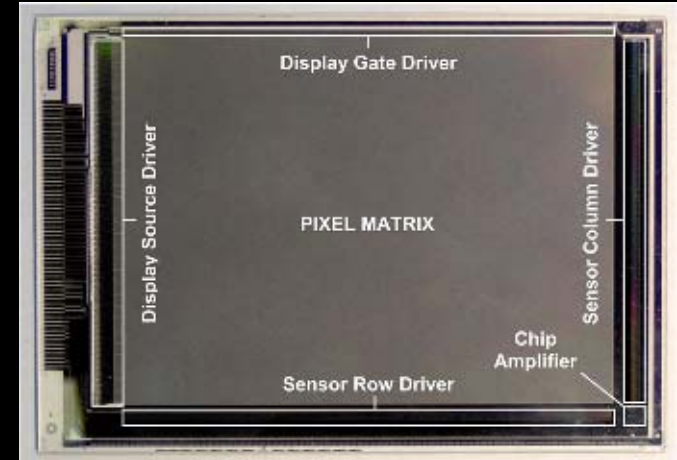


Mobile

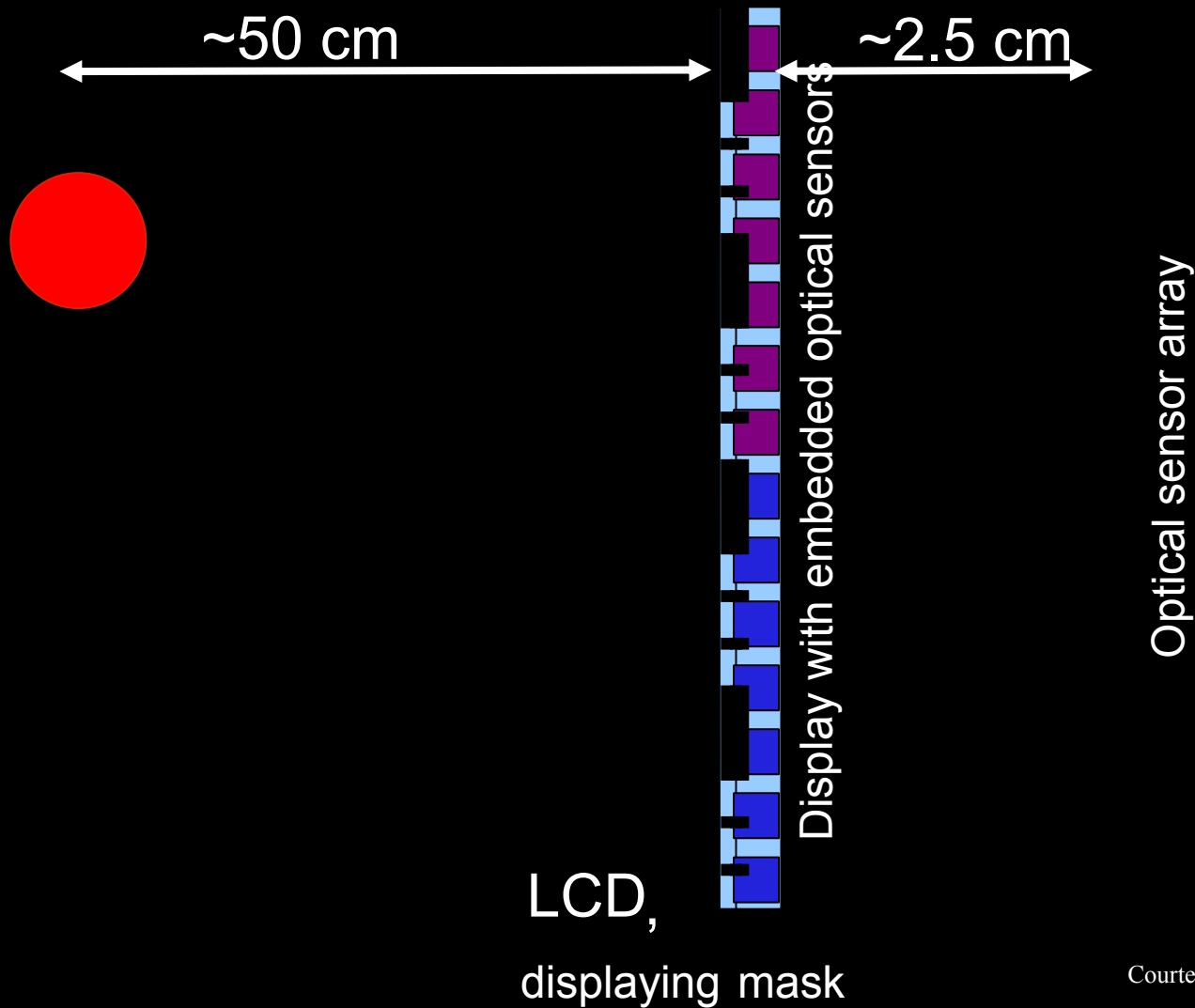
Light Sensing Pixels in LCD



Sharp Microelectronics Optical Multi-touch Prototype

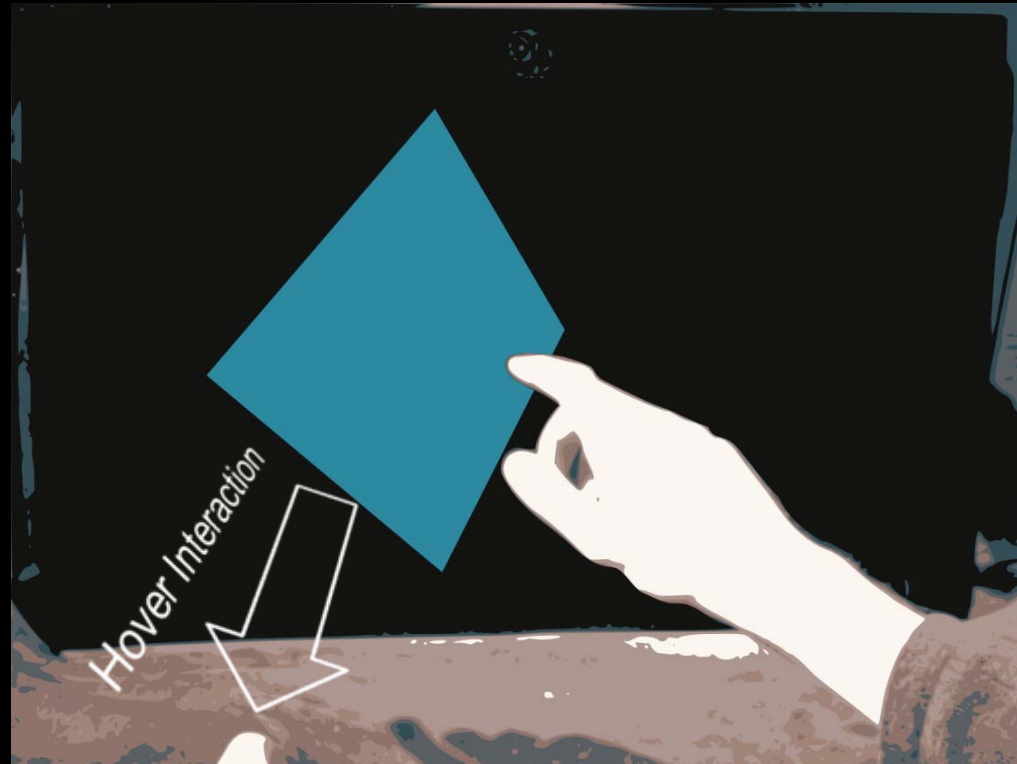
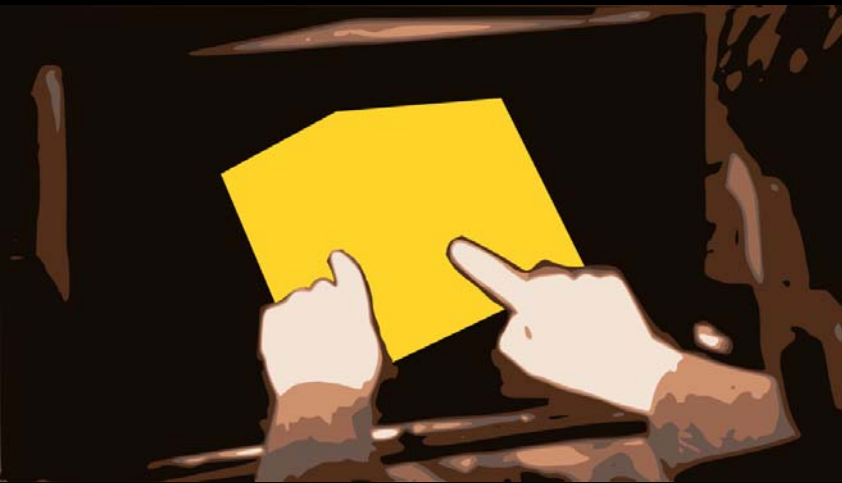


Design Overview

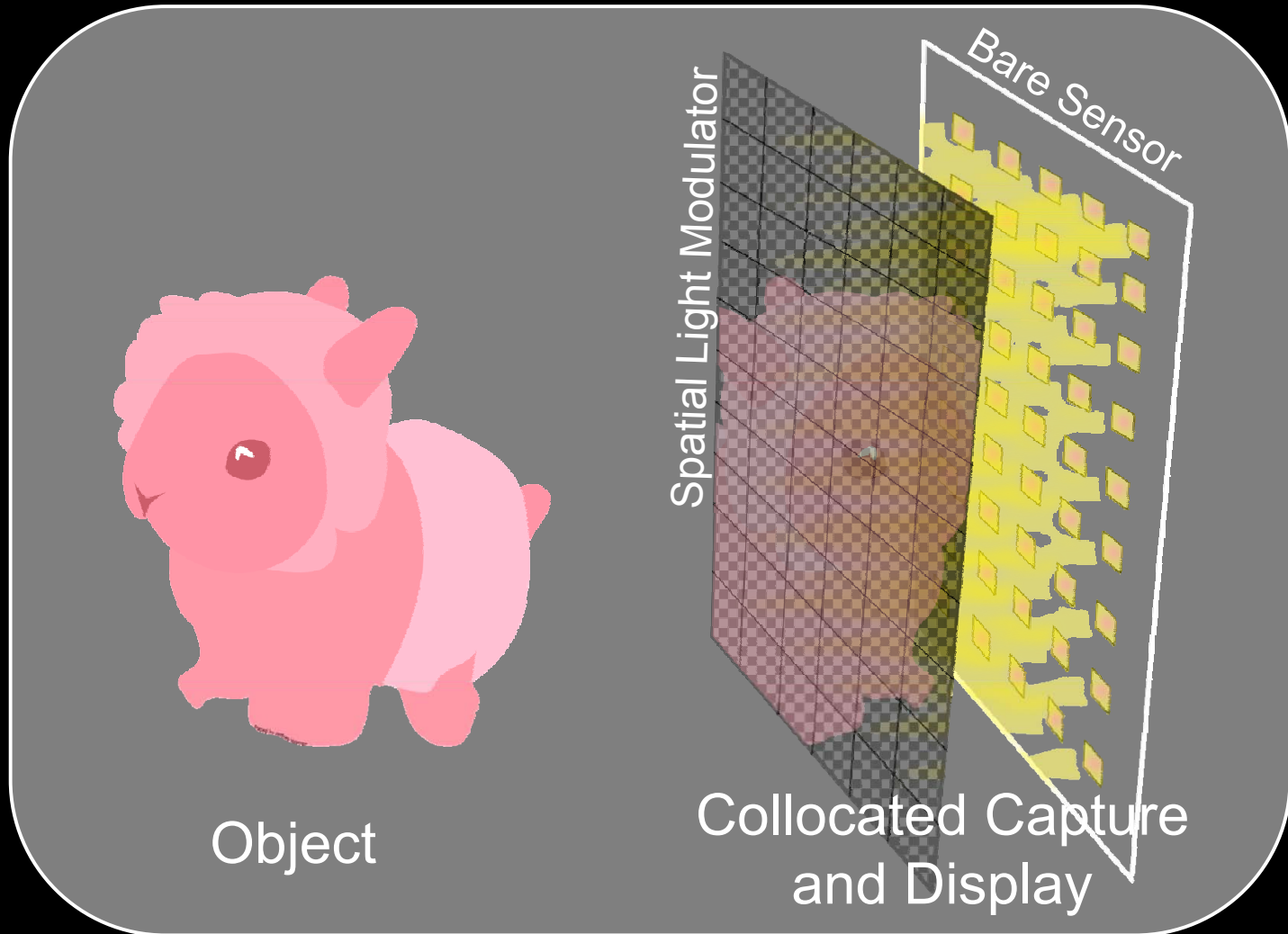


Beyond Multi-touch: Hover Interaction

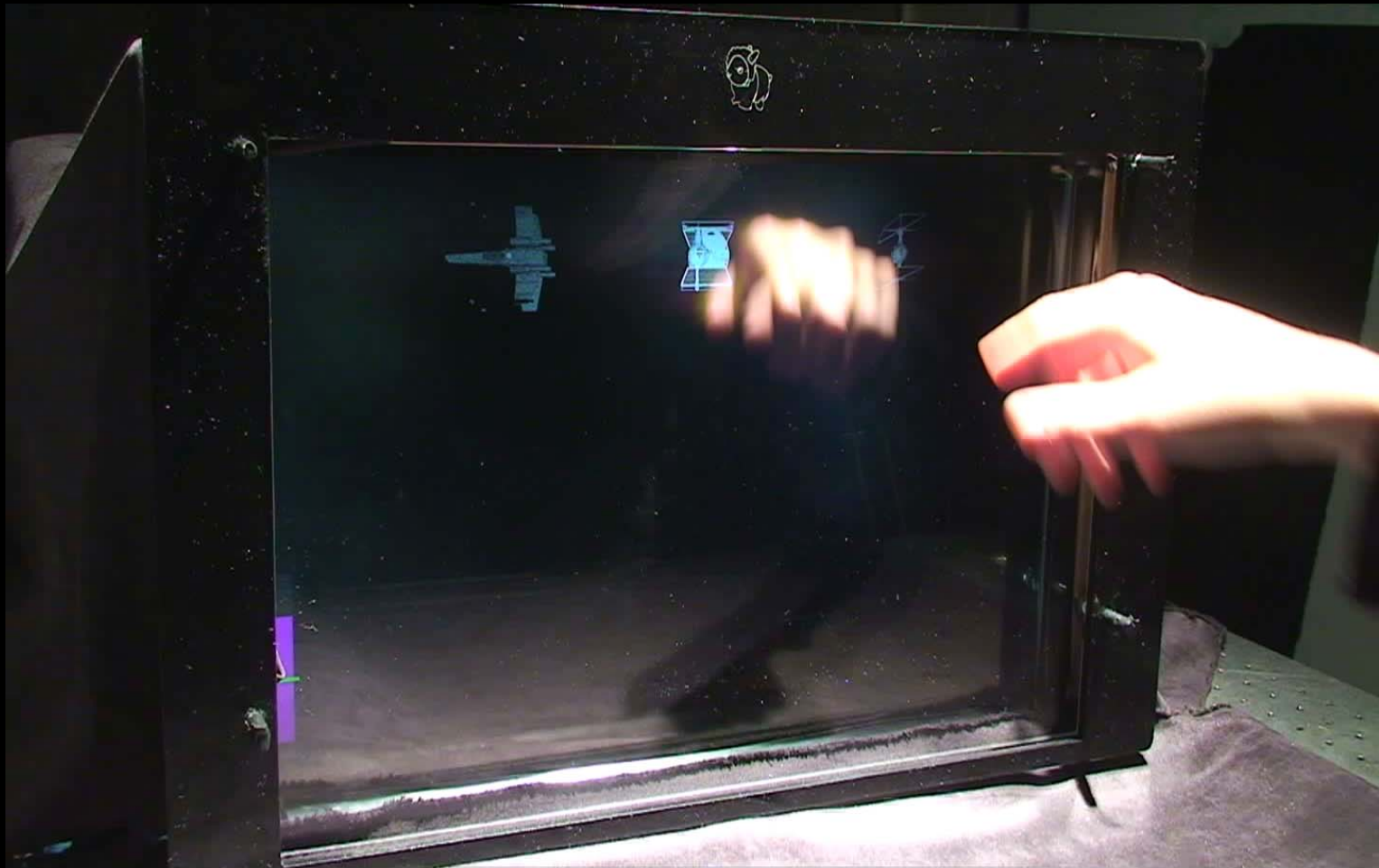
- Seamless transition of multitouch to gesture
- Thin package, LCD



Design Vision

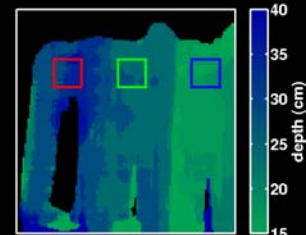
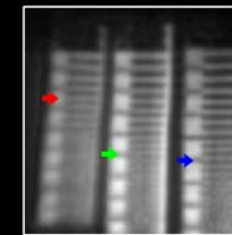
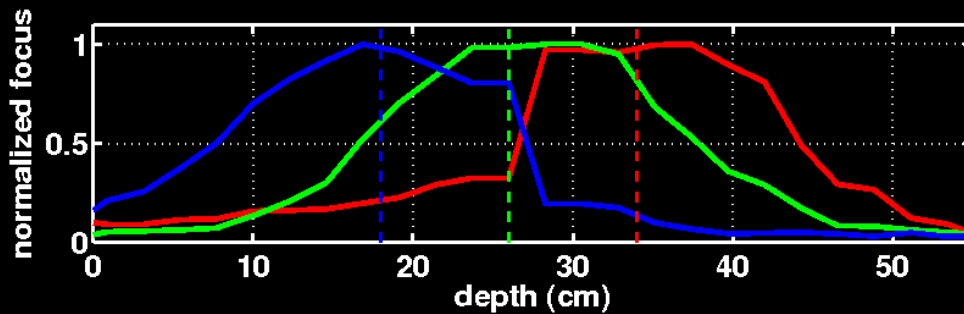
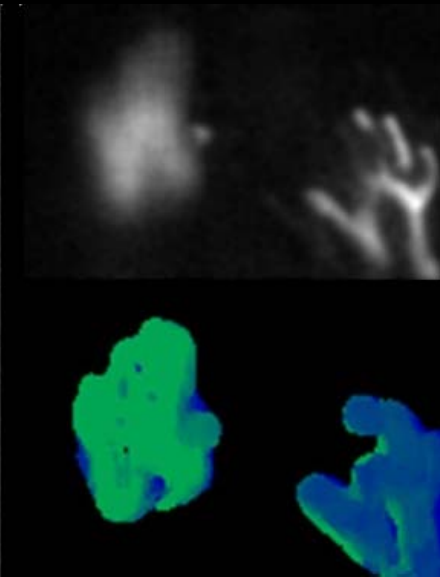
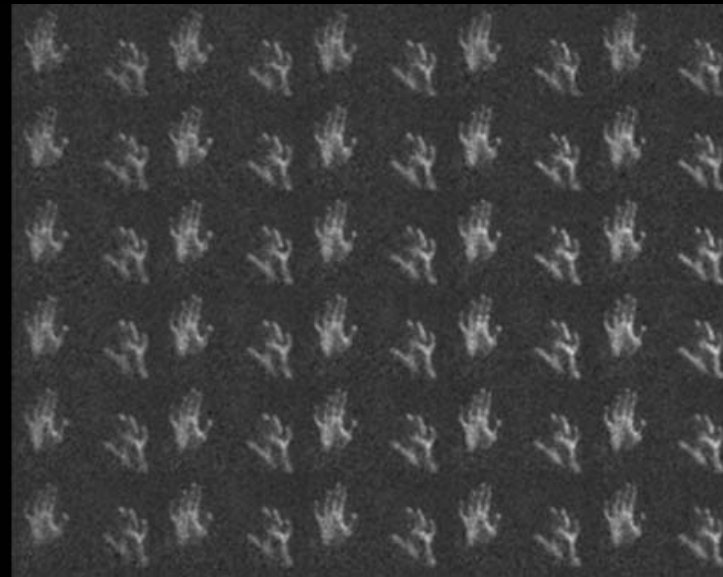
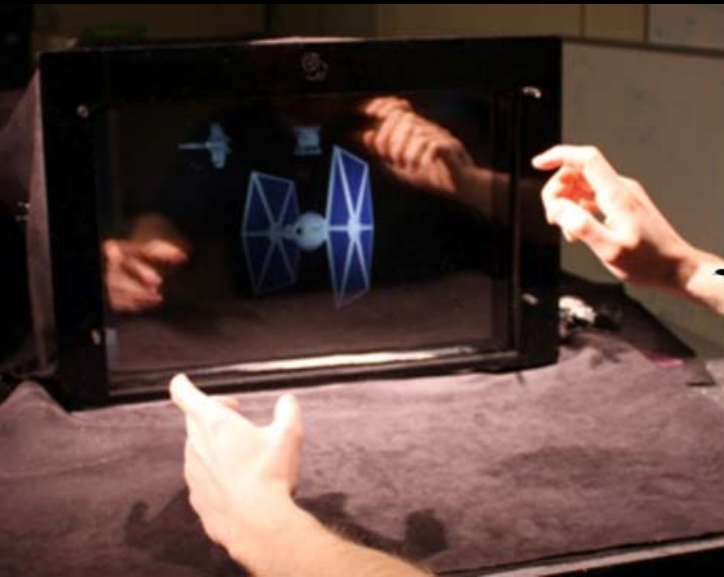


Touch + Hover using Depth Sensing LCD Sensor



Courtesy of Matt Hirsch. Used with permission.

Overview: Sensing Depth from Array of Virtual Cameras in LCD



FTIR Mouse

Several photos removed due to copyright restrictions.

See Microsoft Applied Sciences Group, "[Mouse 2.0: Multi-touch Meets the Mouse.](#)"

Video demonstrations at <http://www.youtube.com/watch?v=z6krcU6mZW0>

Side Mouse

Several photos removed due to copyright restrictions.

See Microsoft Applied Sciences Group, "[Mouse 2.0: Multi-touch Meets the Mouse.](#)"

Video demonstrations at <http://www.youtube.com/watch?v=z6krcU6mZW0>

Wii Mote



Figure 2. The PixArt IR camera chip. Integrated multiblob tracking minimizes wireless data transmission.

Resolution of $1,024 \times 768$ pixels, more than 4 bits of dot size or light intensity, a 100 Hz refresh rate, and a 45 degree horizontal field of view.

Lee, Johnny Chung. "Hacking the Nintendo Wii Remote." *IEEE Pervasive Computing* 7, no. 3 (July 2008): 39-45.

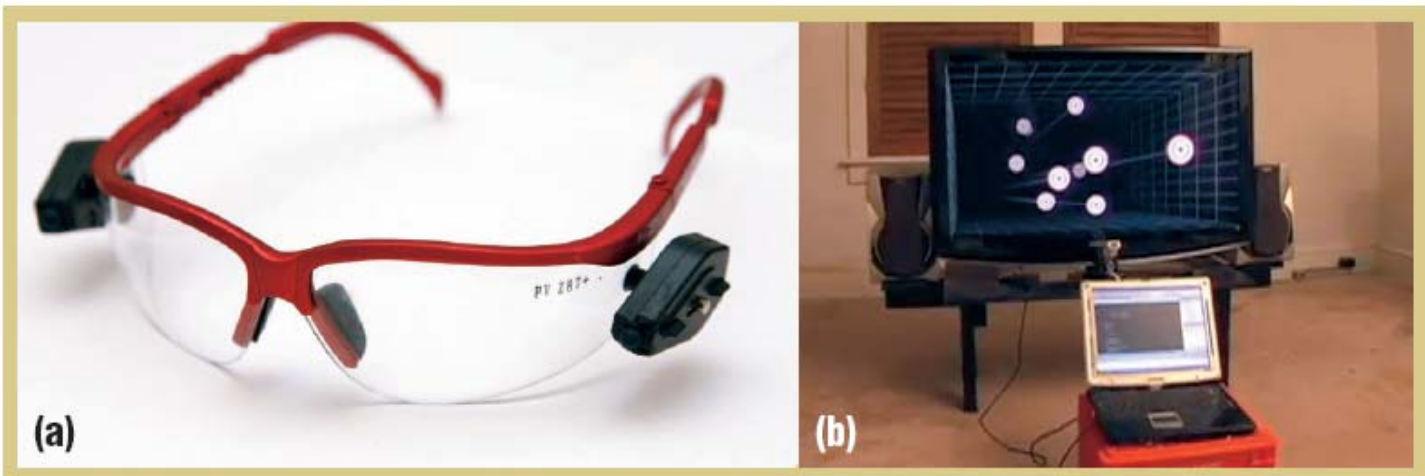
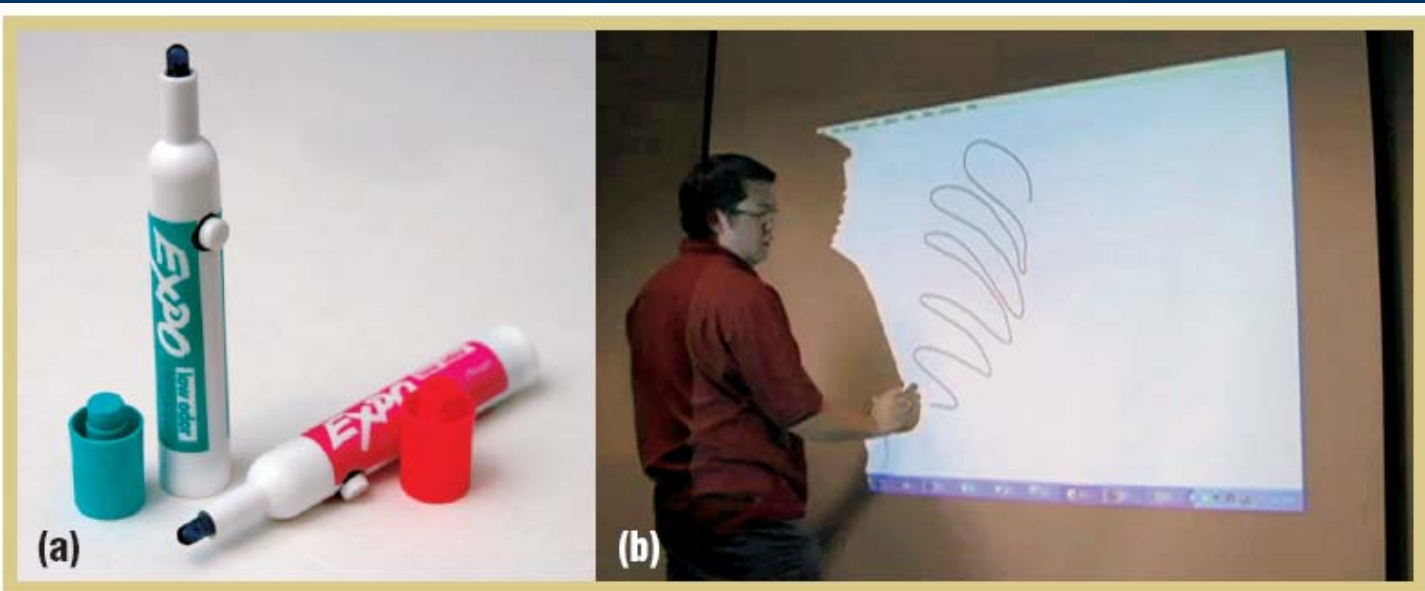
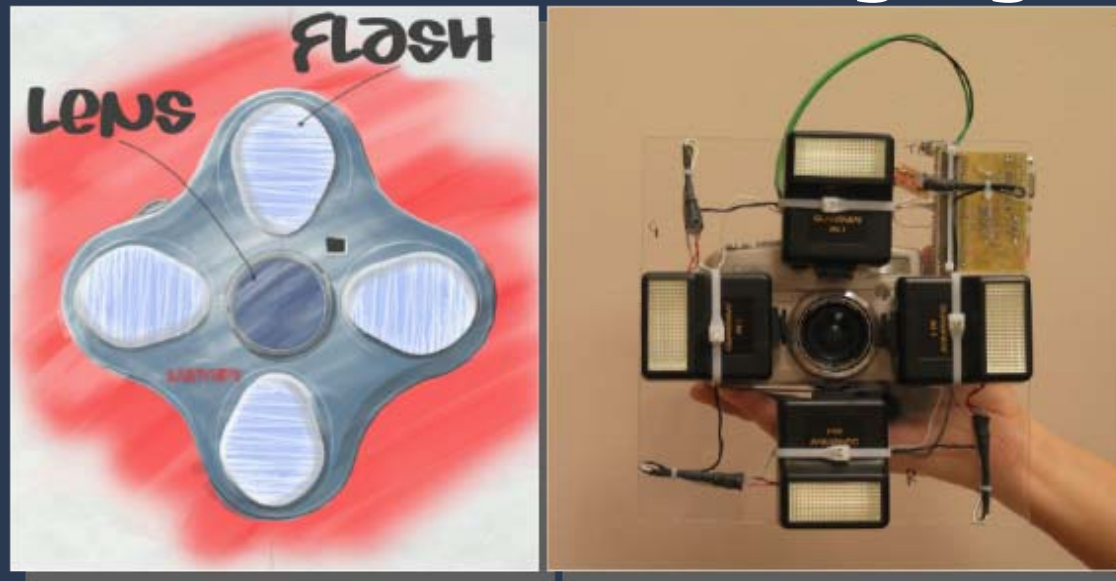


Figure 5. Desktop VR. (a) Rigid IR emitters on glasses together with (b) the Wii remote can render view-angle-dependent displays that simulate motion parallax and a changing field of view.

Non-photorealistic Camera: Depth Edge Detection and Stylized Rendering using Multi-Flash Imaging



Ramesh Raskar, Karhan Tan, Rogerio Feris,
Jingyi Yu, Matthew Turk

Mitsubishi Electric Research Labs (MERL), Cambridge, MA

U of California at Santa Barbara

U of North Carolina at Chapel Hill



Gestures

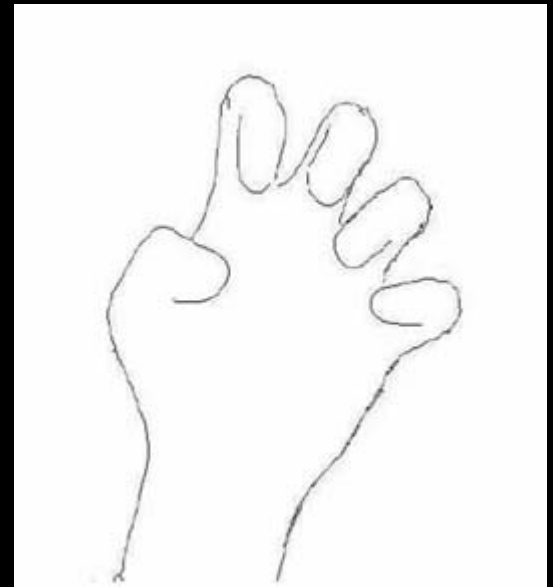
Input Photo



Canny Edges

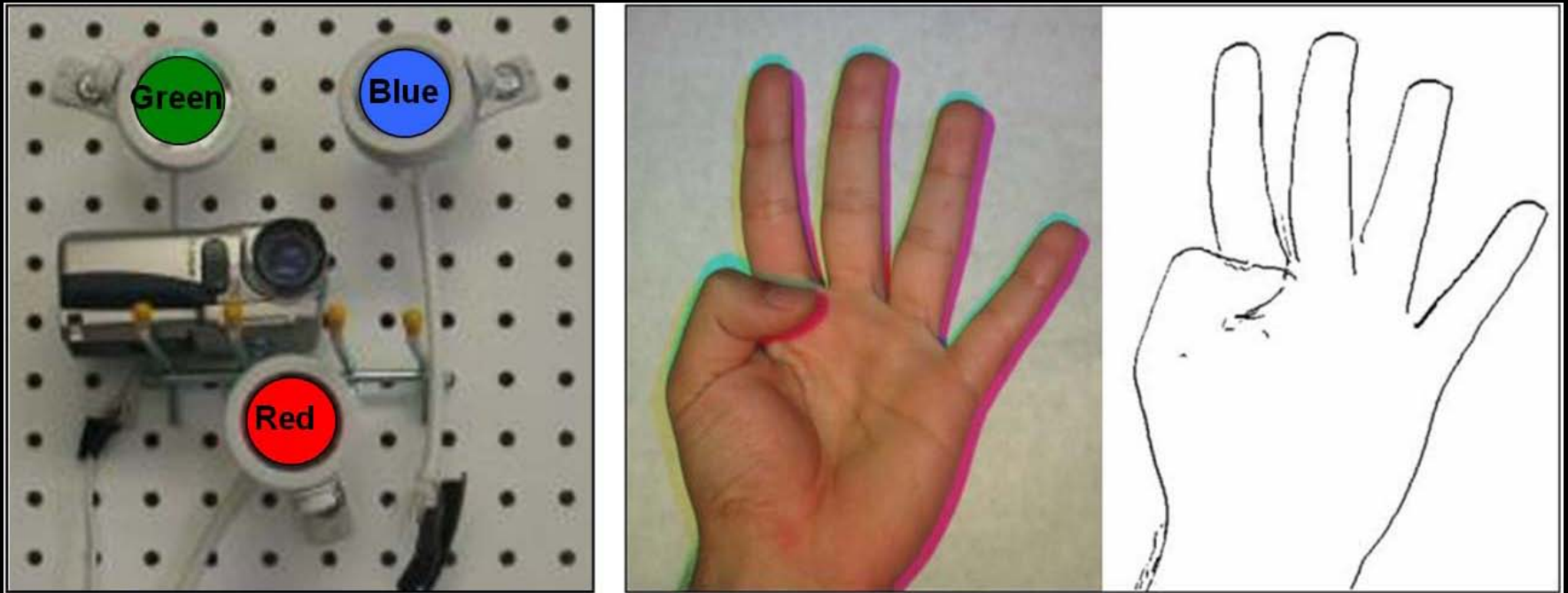


Depth Edges



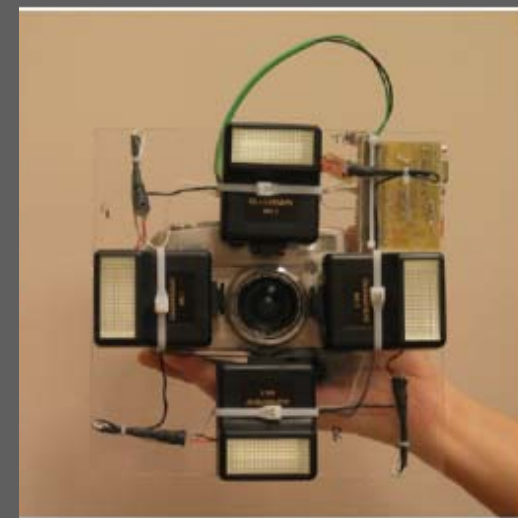
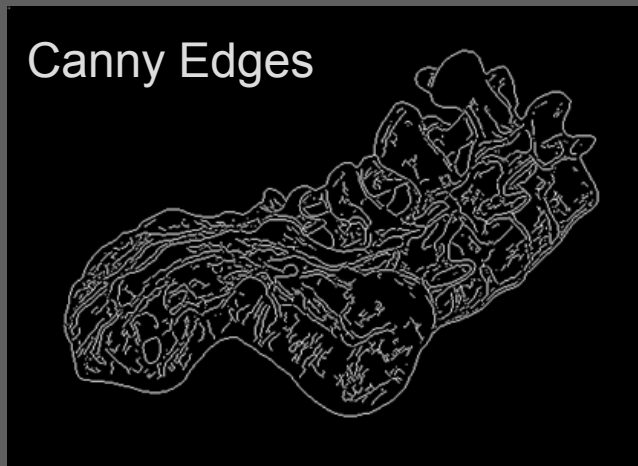
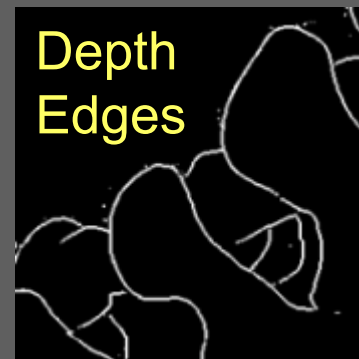
Courtesy of MERL. Used with permission.

Colored Lights (Single snapshot)



<http://ilab.cs.ucsb.edu/publications/FerisSIB06.pdf>

Courtesy of MERL. Used with permission.



Courtesy of MERL. Used with permission.

Anoto Pen

- 36 bit code at 0.3mm resolution
- 100 fps camera at 8800 nm

Image removed due to copyright restrictions. Schematic of ANOTO pen, from <http://www.acreo.se/upload/Publications/Proceedings/OE00/00-KAURANEN.pdf>

Optical Mouse

Mouse schematic diagram and photo removed due to copyright restrictions.

STMicroelectronics VT5363: Technical Specifications table removed due to copyright restrictions.
See <http://www.stmicroelectronics.com/stonline/products/literature/bd/11895.pdf>

Gaze Tracking

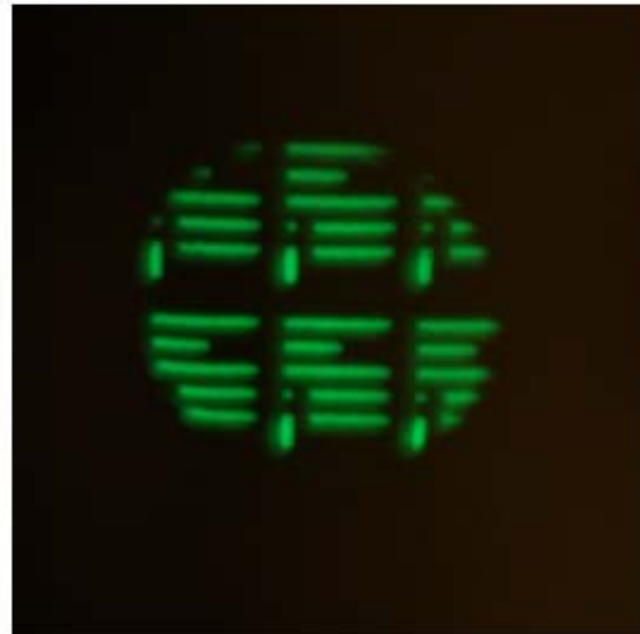
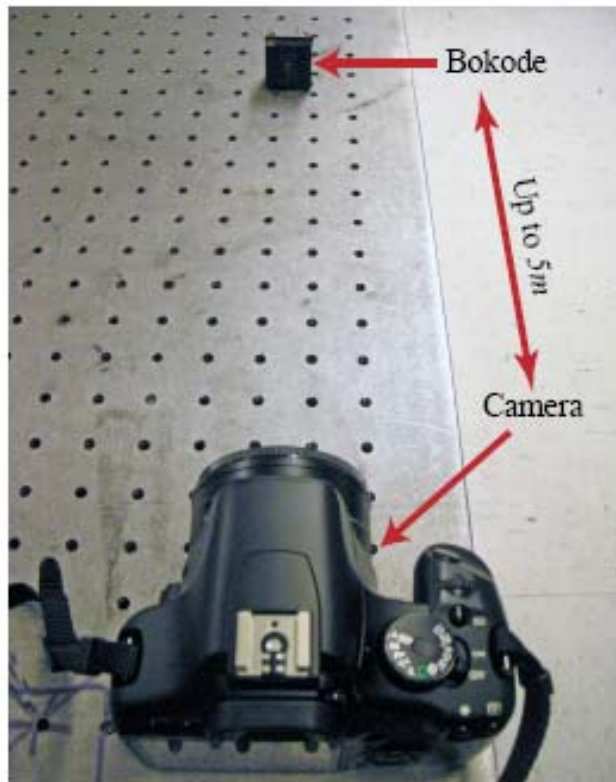
Photo illustrating the paths traced by gaze tracking removed due to copyright restrictions.

Thermal IR motion detector

Diagram about how Thermal IR motion detection works removed due to copyright restrictions.

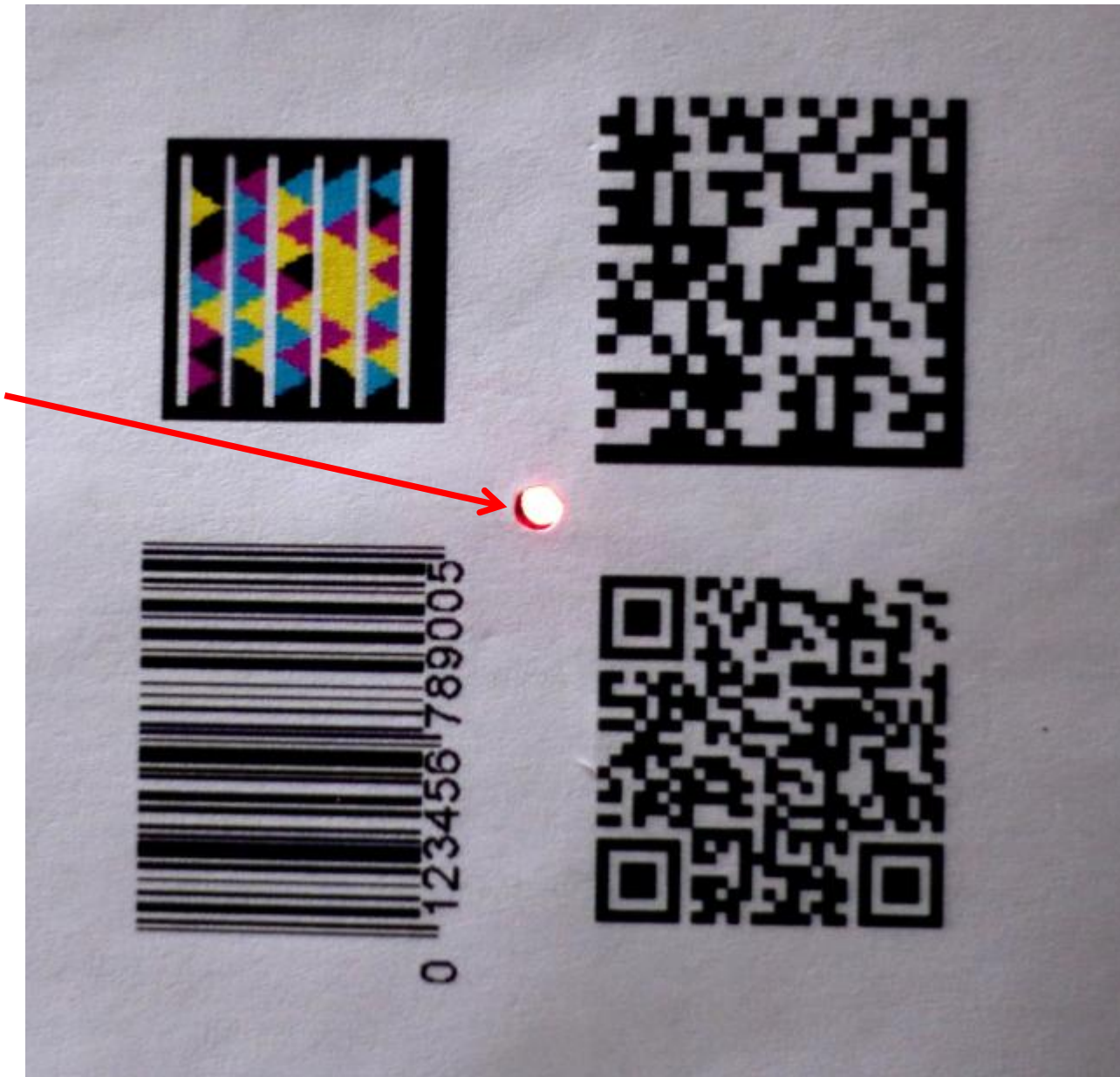
Long Distance Barcodes

- Smart Barcode size : 3mm x 3mm
- Ordinary Camera: Distance 3 meter

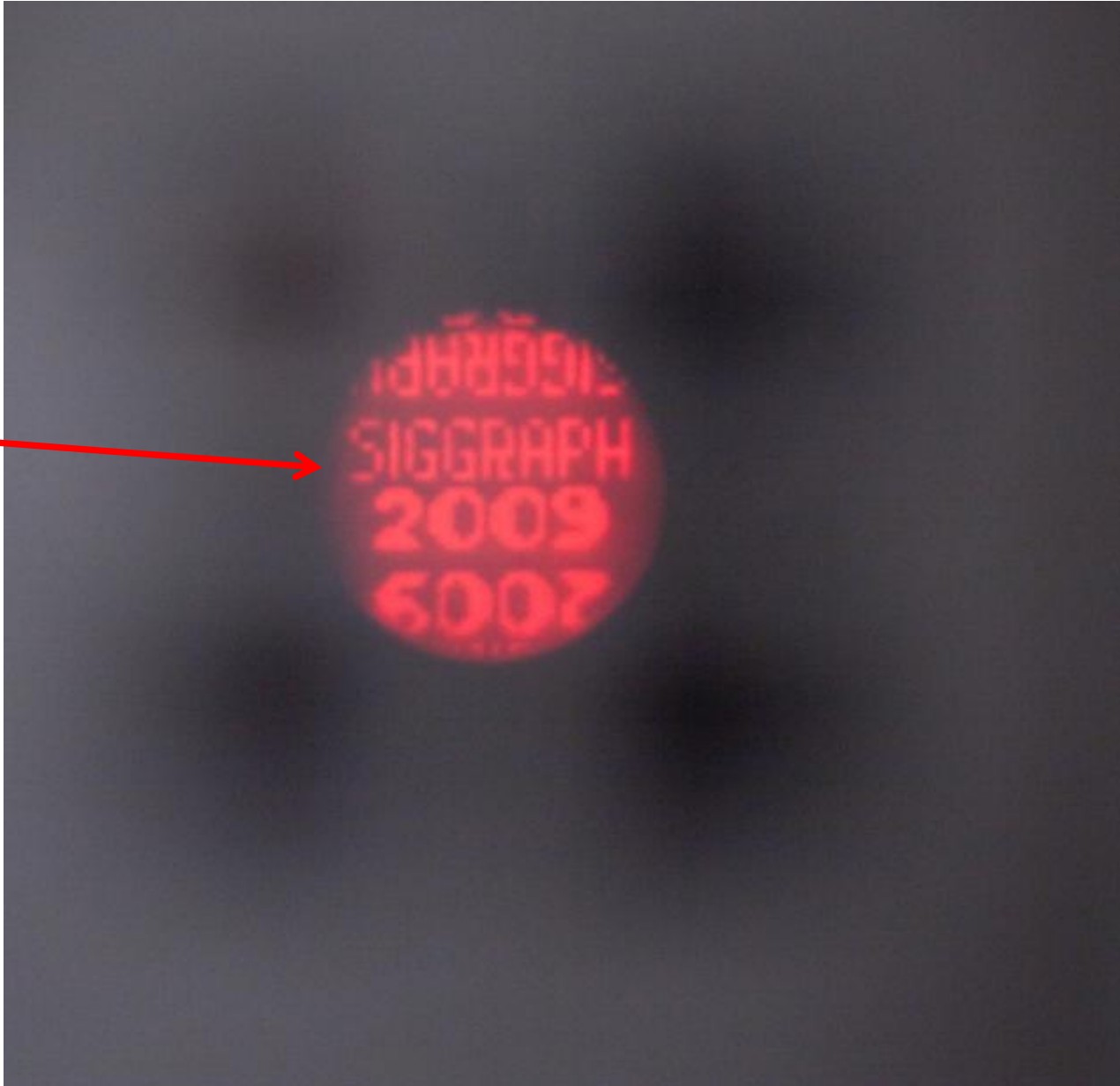




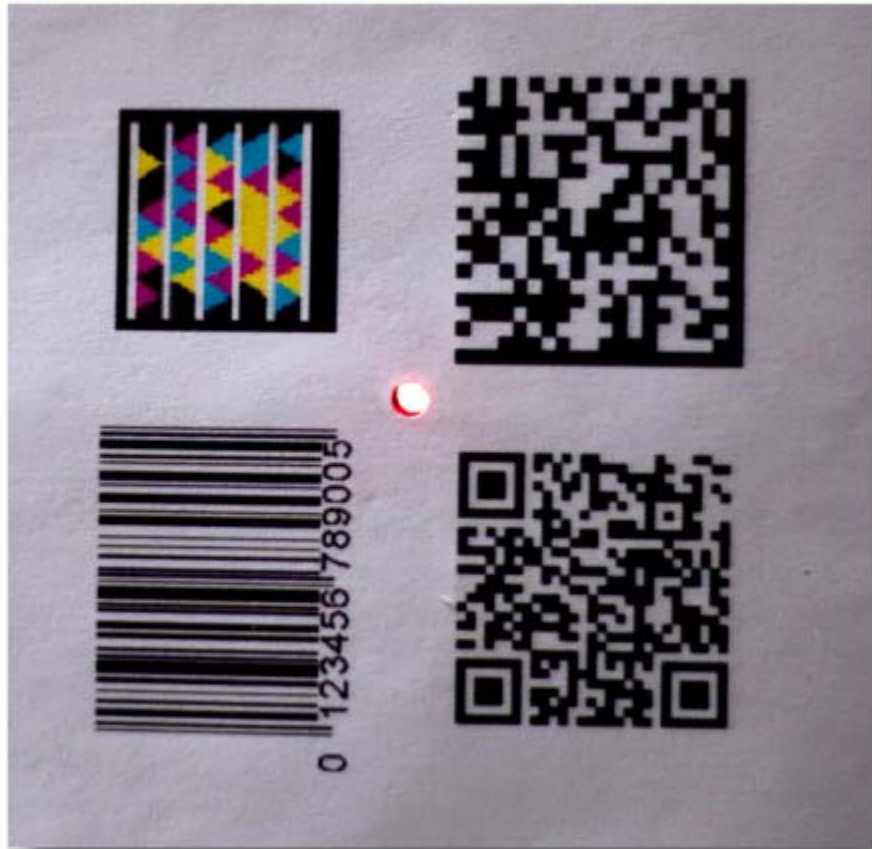
Bokode



Defocus
blur of
Bokode



Coding in Angle

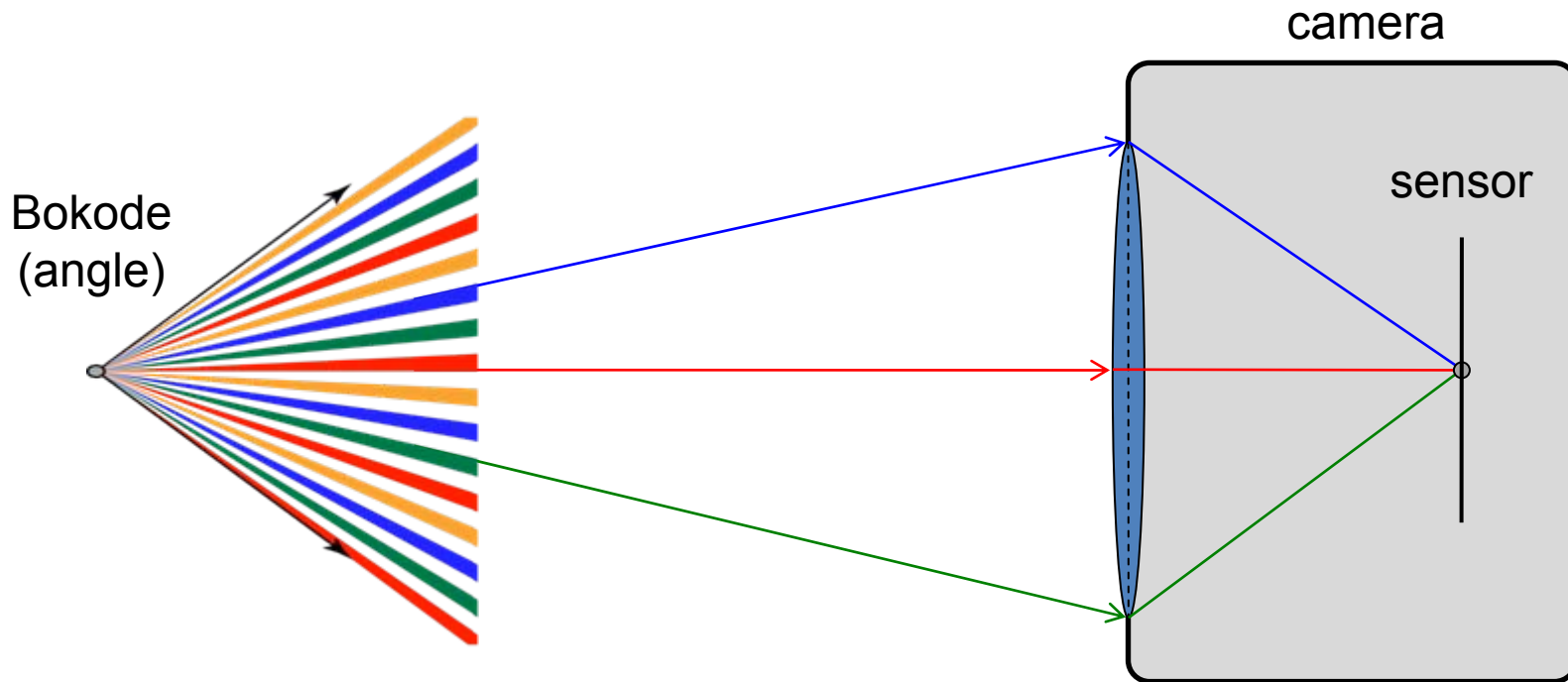


In Focus Photograph

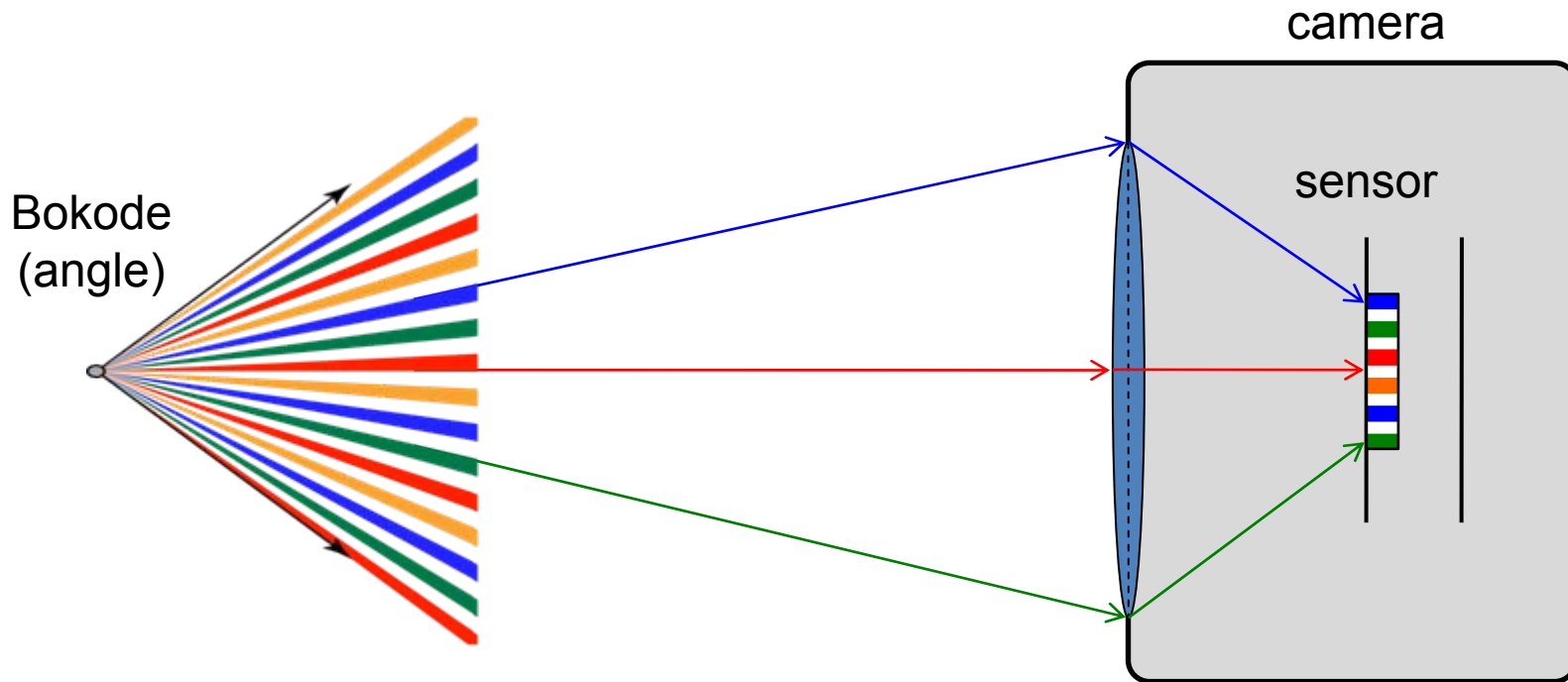


Out of Focus Photograph

Encoding in Angle, not space, time or wavelength

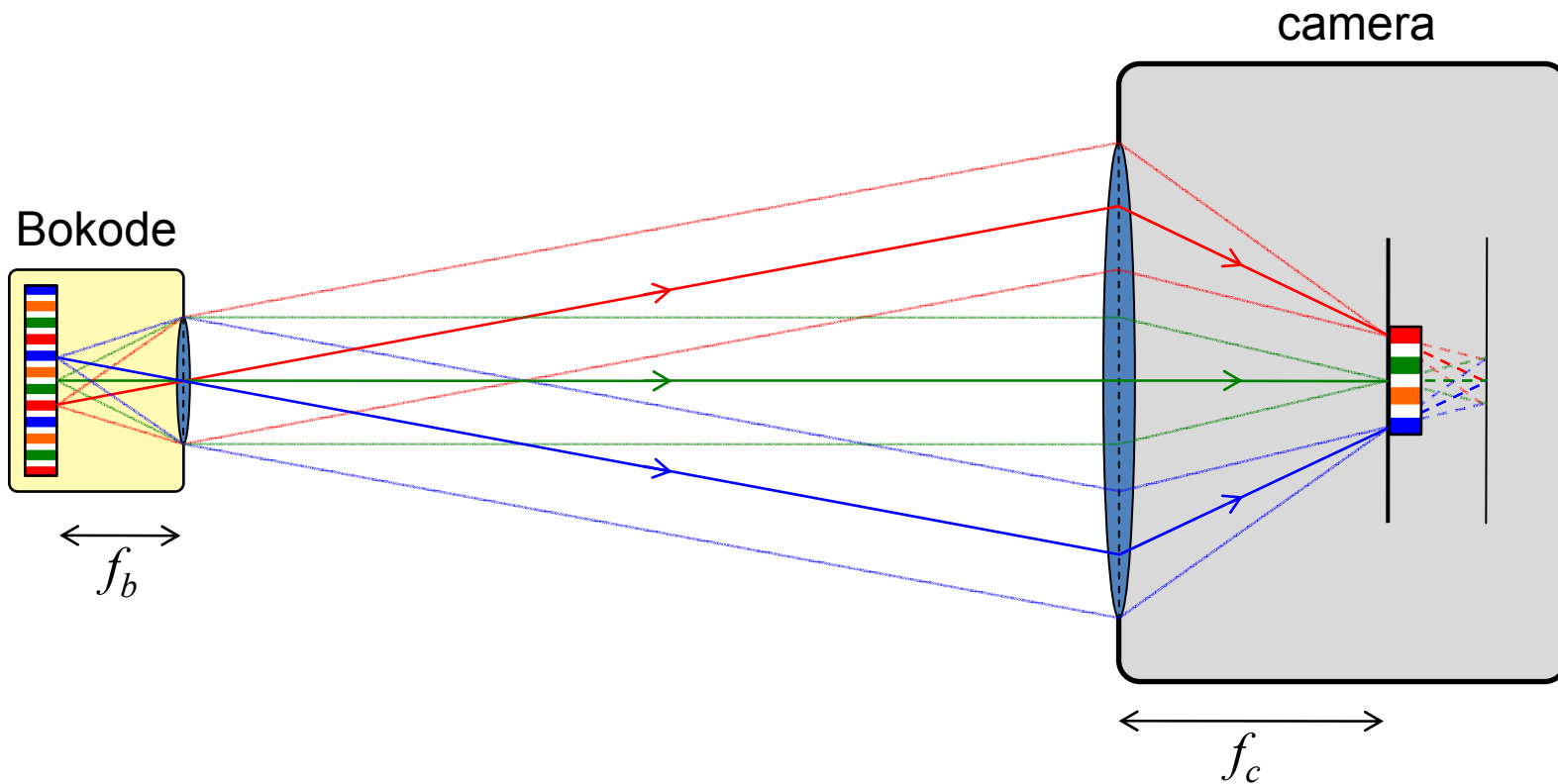


Encoding in Angle, not space, time or wavelength



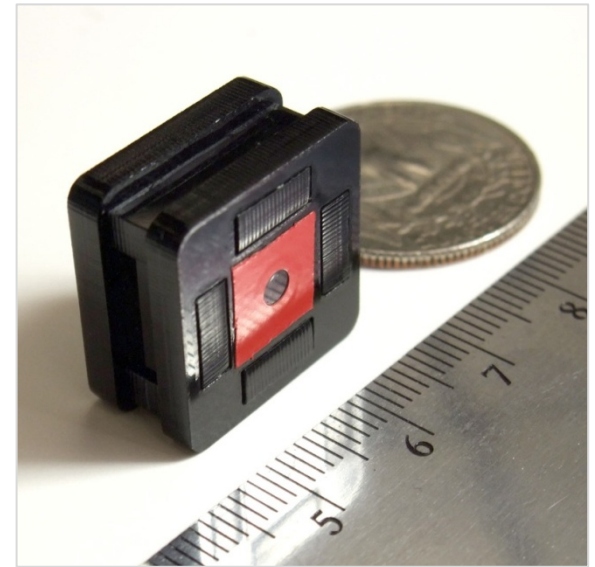
circle of confusion \rightarrow circle of information

'long-distance microscope'

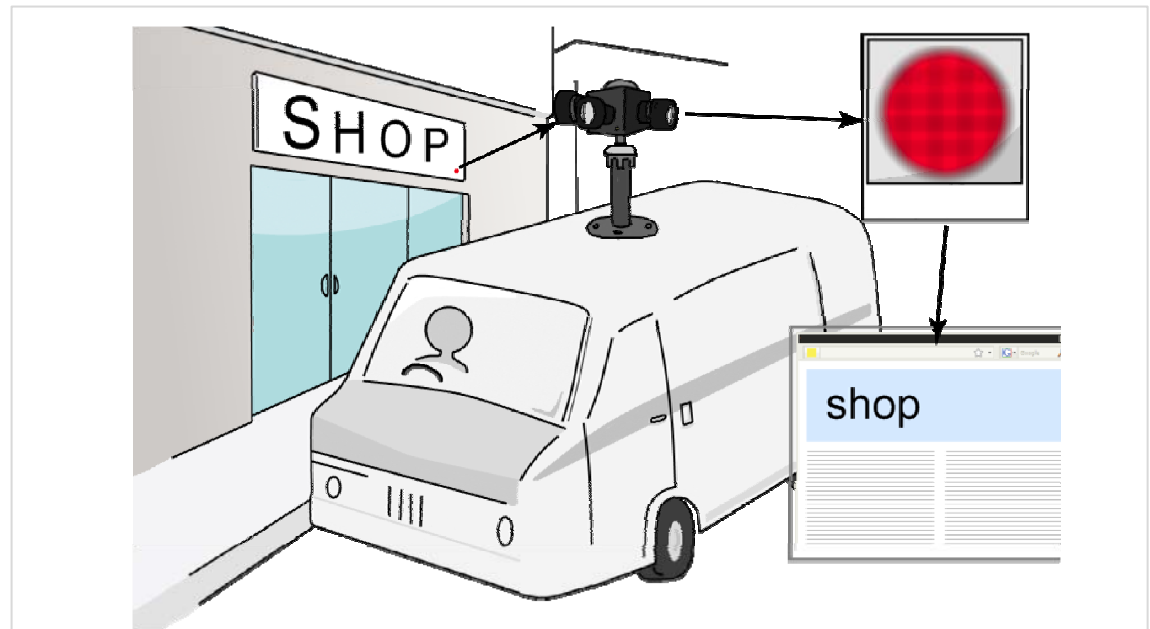


magnification = f_c/f_b (microscope);

focus always at infinity



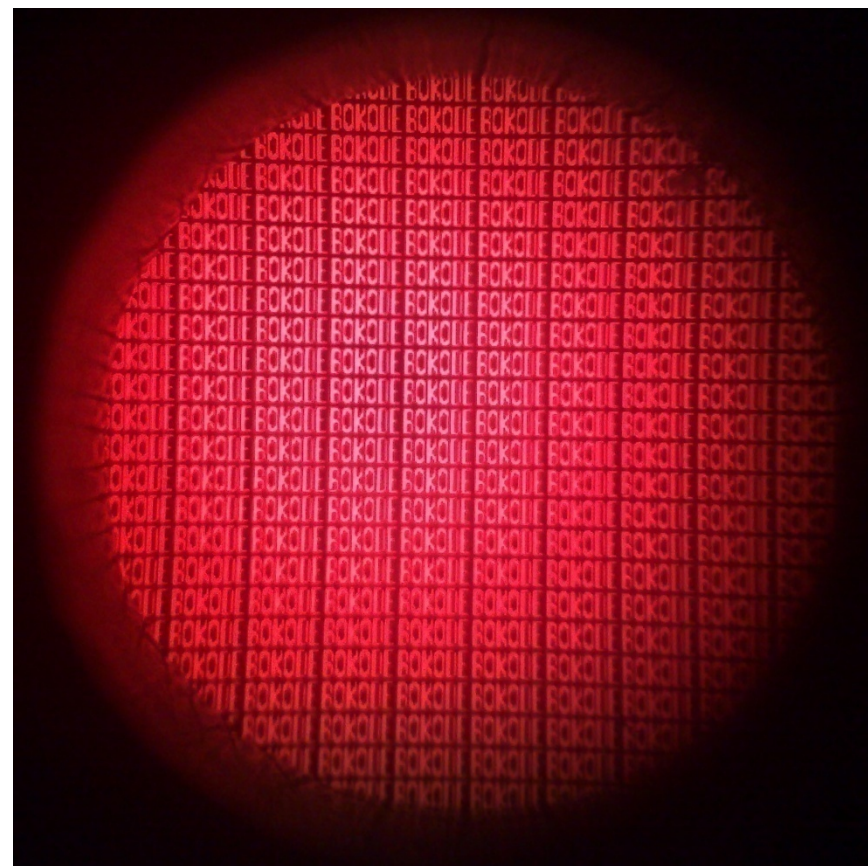
Product labels

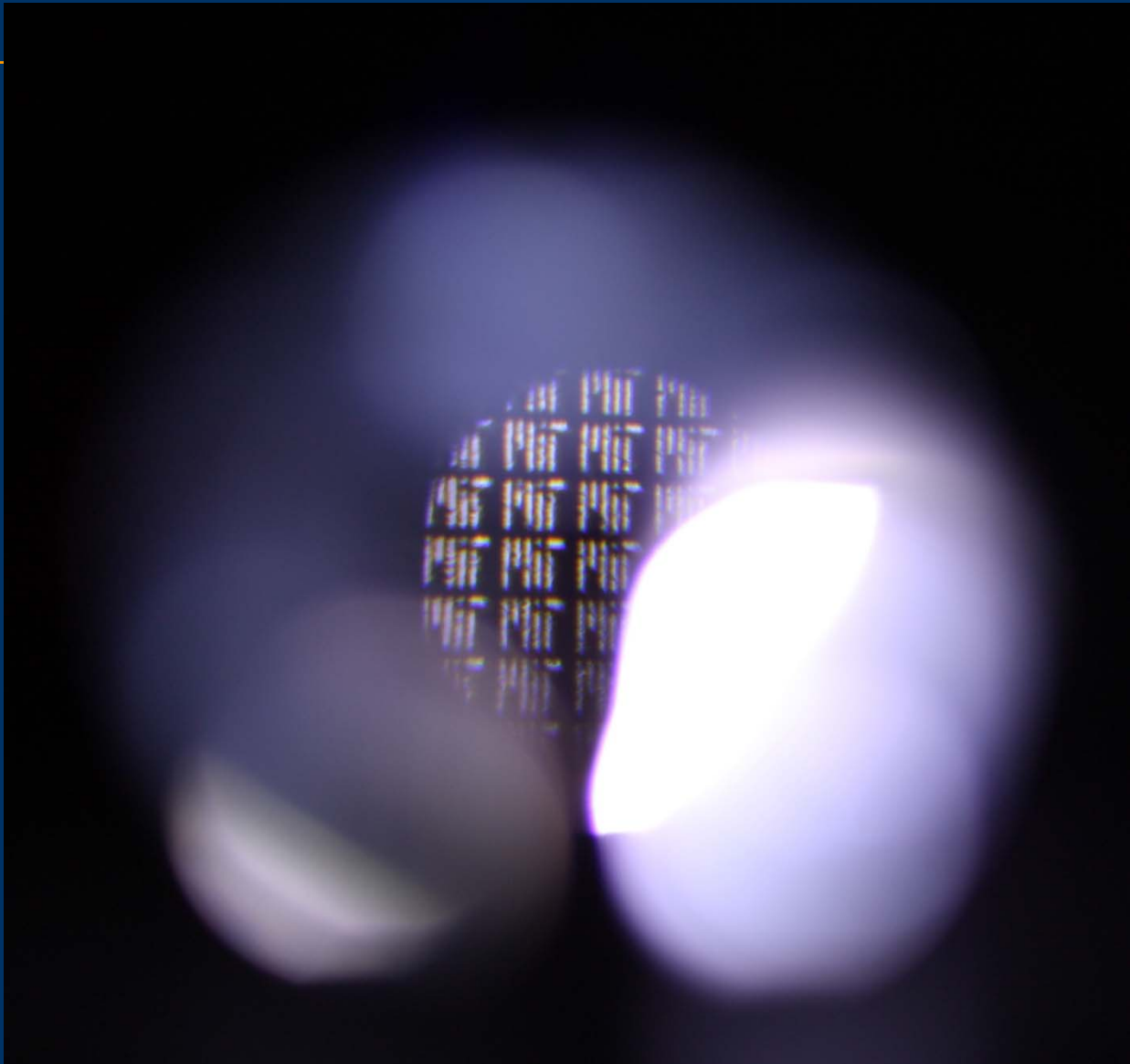


Street-view Tagging

capturing Bokodes

cell-phone camera
close to the Bokode
(10,000+ bytes of data)





Vicon Motion Capture

Medical Rehabilitation

Athlete Analysis

Body-worn markers

Images of Vicon motion capture camera equipment and applications removed due to copyright restrictions. See <http://www.vicon.com>

High-speed IR Camera

Performance Capture

Biomechanical Analysis

Demodulating Cameras

- Simultaneously decode signals from blinking LEDs and get an image
 - Sony ID Cam
 - Phoci

- Motion Capture Cameras
 - Visualeyex™ VZ4000 Tracking System
 - PhaseSpace motion digitizer

Line Scan Camera: PhotoFinish 2000 Hz

Images removed due to copyright restrictions.

Demodulating Cameras

- Decode signals from blinking LEDs + image
 - Sony ID Cam
 - Phoci

Block diagram and photo examples removed due to copyright restrictions.

- Motion Capture Cameras

Tagged Books in a Library

✓ **Id** : List of books in RF range



✗ **No Precise Location Data**
Are books in sorted order ?

AR Issues

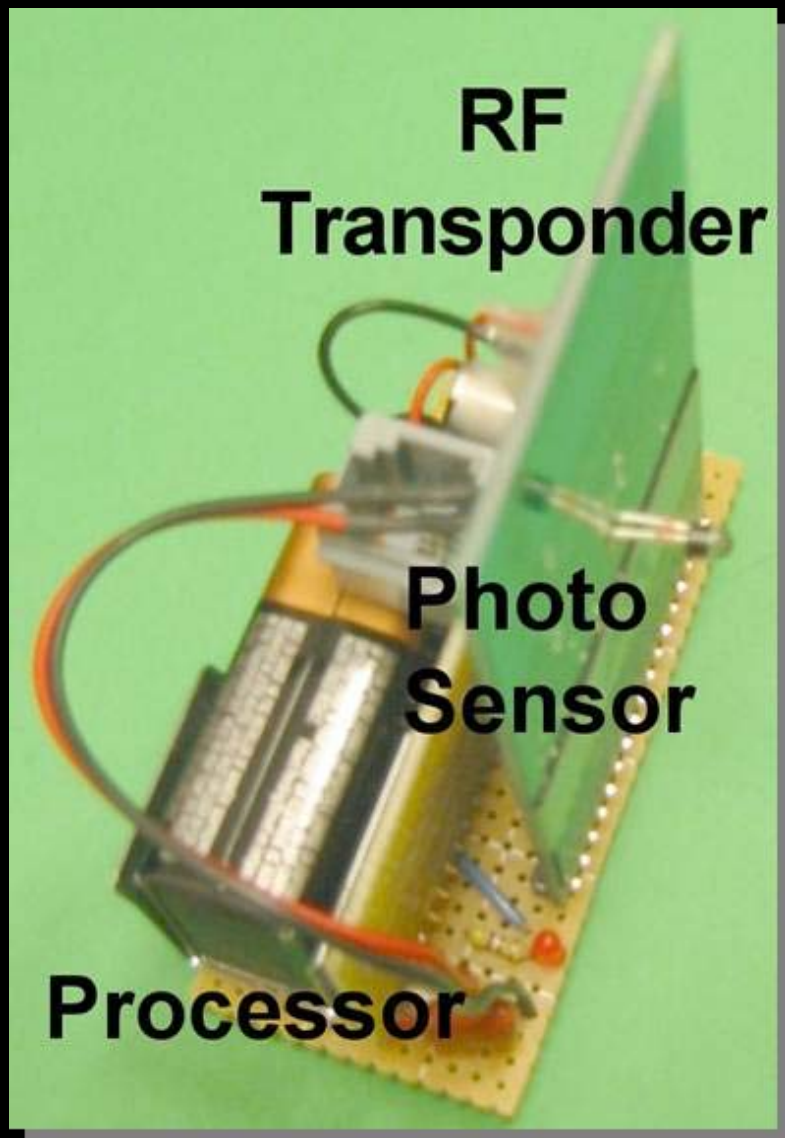
- Preprocessing:
 - Authoring
- Runtime:
 - **Identification**: Recognition of objects
 - Using markers and visual tags
 - **Registration**: Finding relationships
 - Dynamic estimate of translation and rotation
 - Render/Warp images
 - **Interaction**:
 - Widgets, Gesture

RFID

Photosensing RFID

Projector for visual feedback

RF Tag + Photosensor



Conventional RF tag

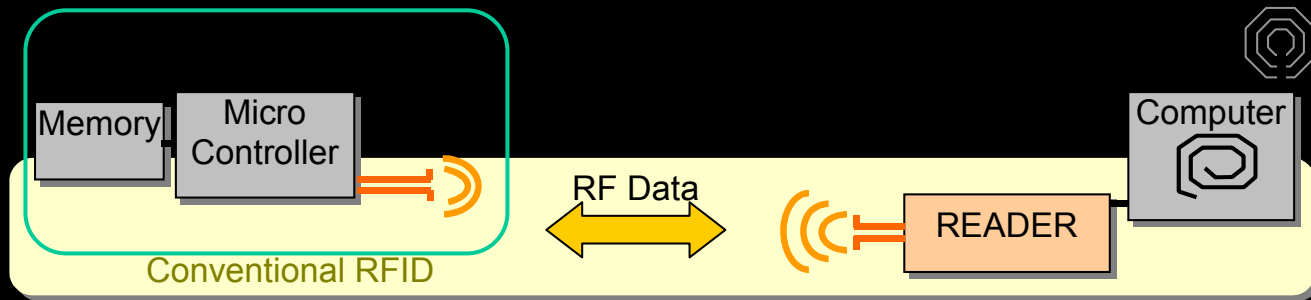
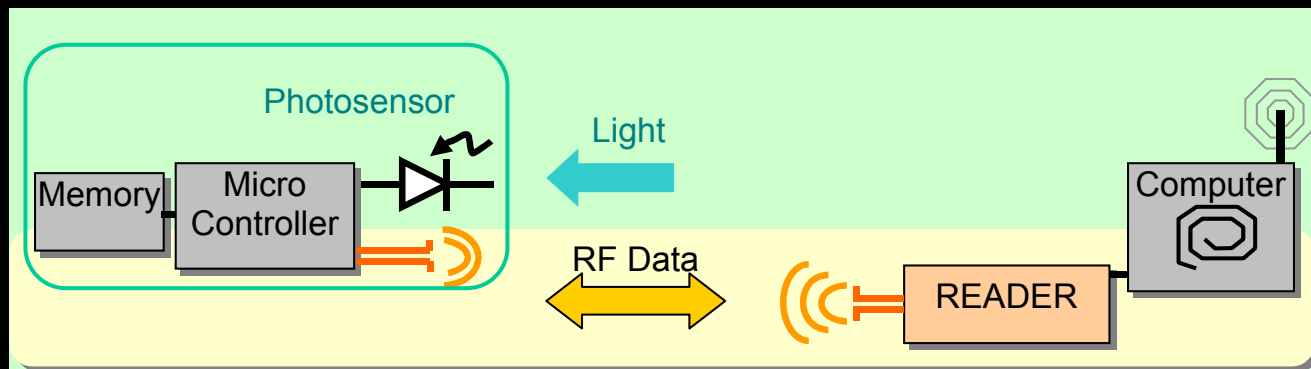
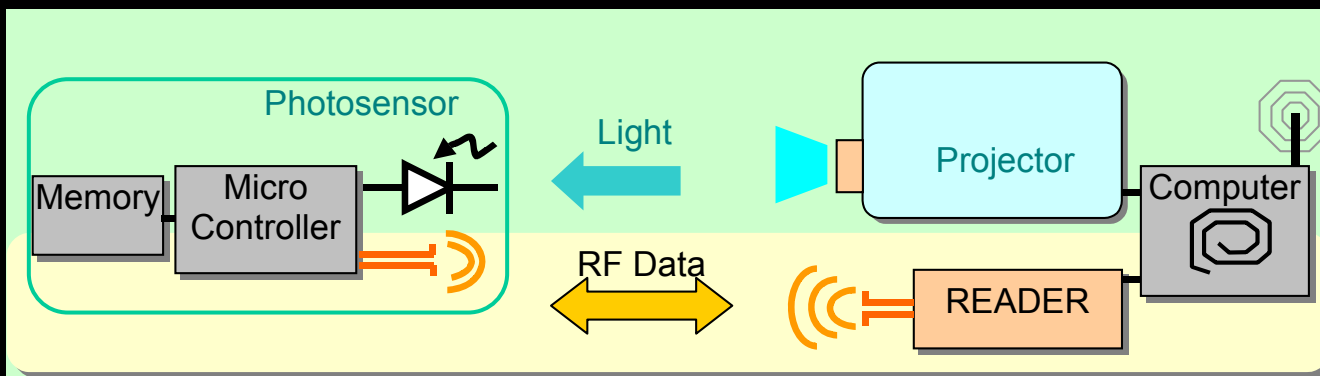


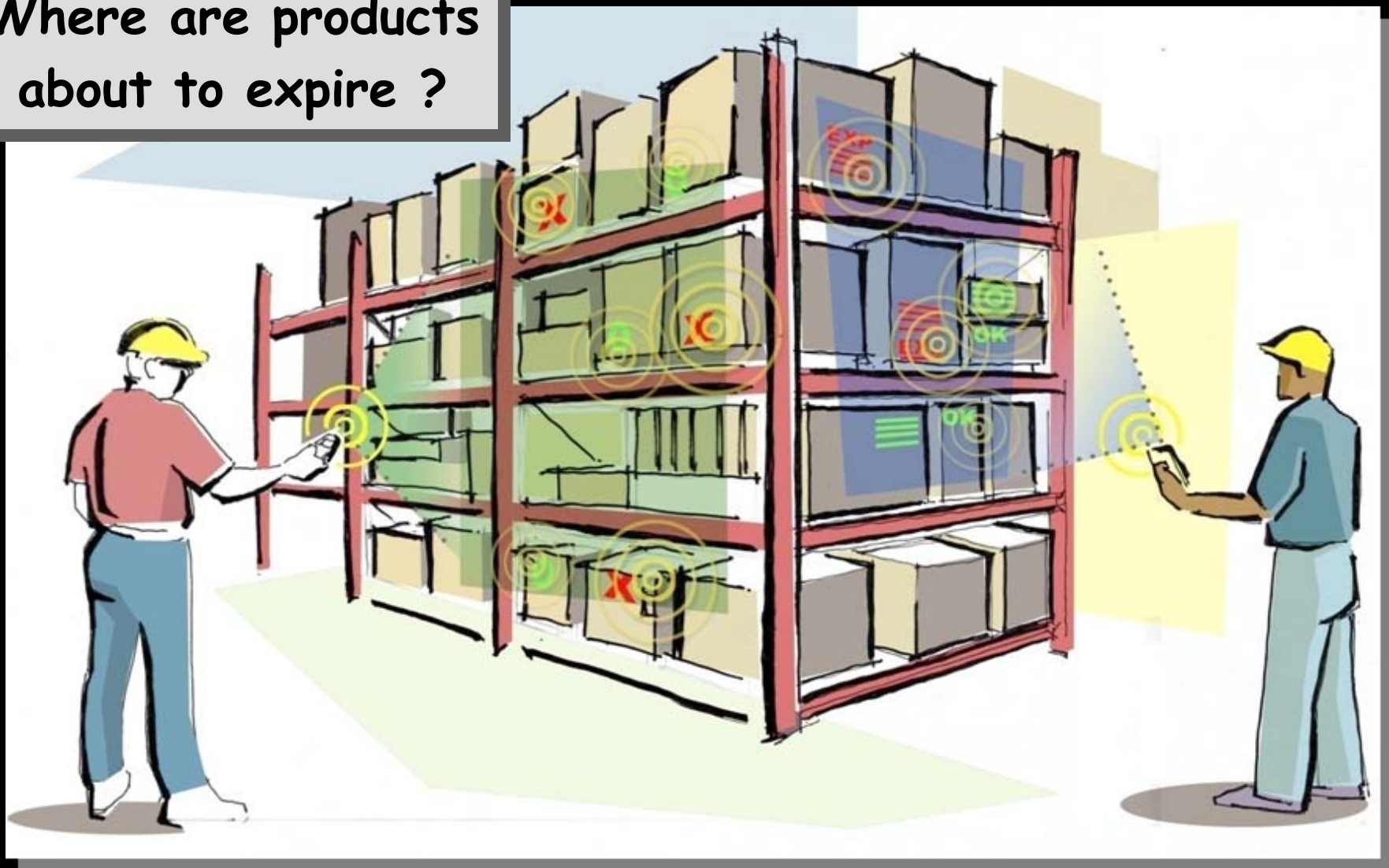
Photo-sensing RF tag



Projector + Photo-sensing RF tag



Where are products
about to expire ?



AR with Photosensing RFID and Handheld Projector

Inverse Optical Mo-Cap

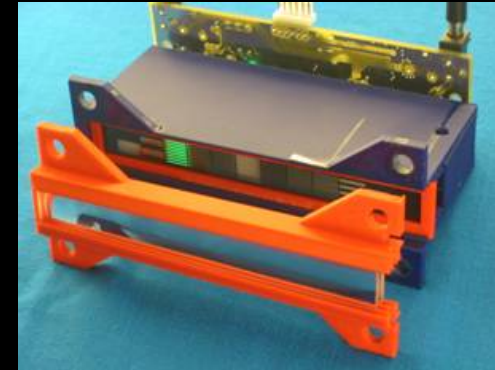
High Speed Camera

Detect blobs in each frame



High Speed Projector

Label the 3D space



Reflective/Emitting Marker

Disambiguate in camera

Only Location



Photosensing Marker

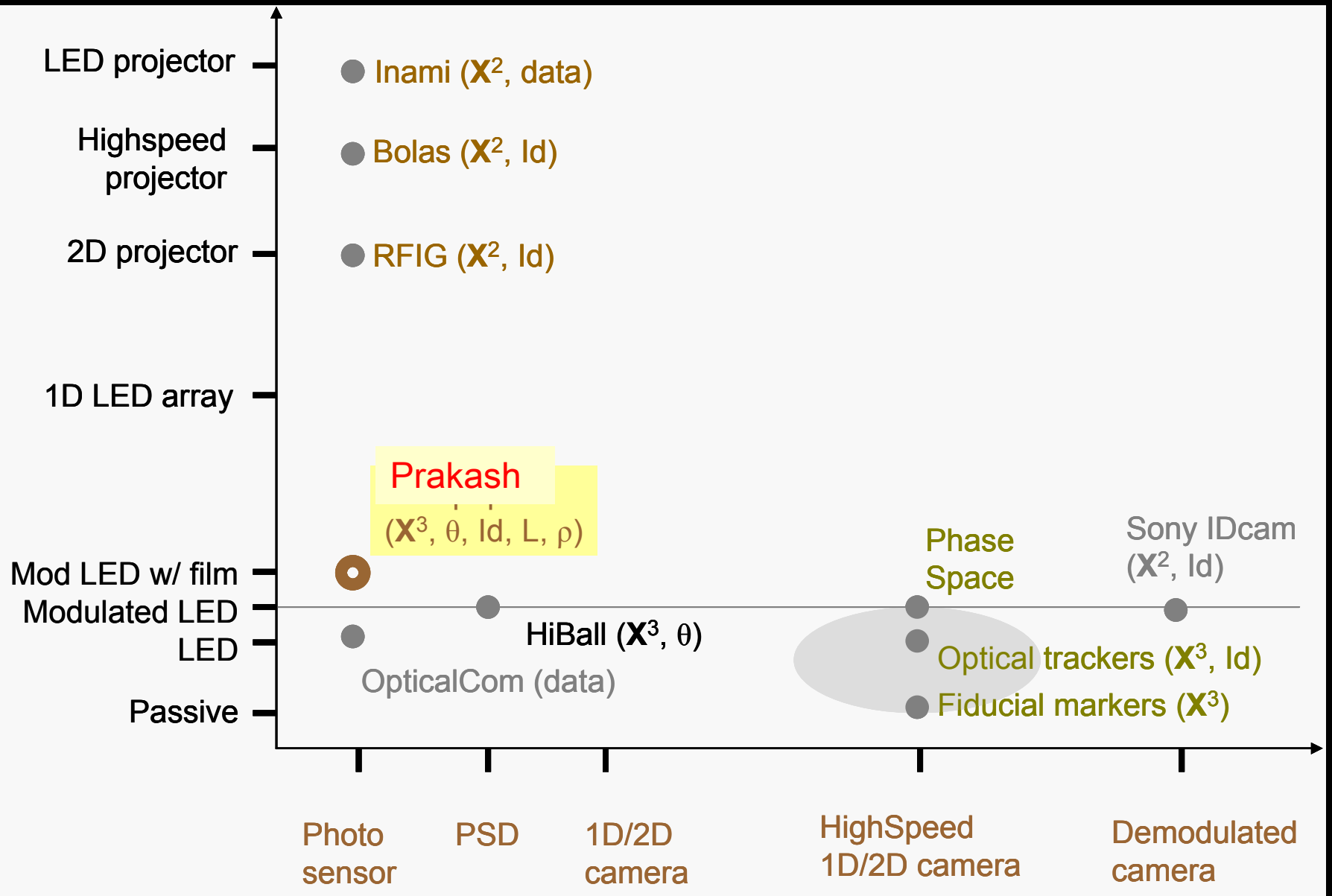
Find ego-position

Location, Orientation, Illum

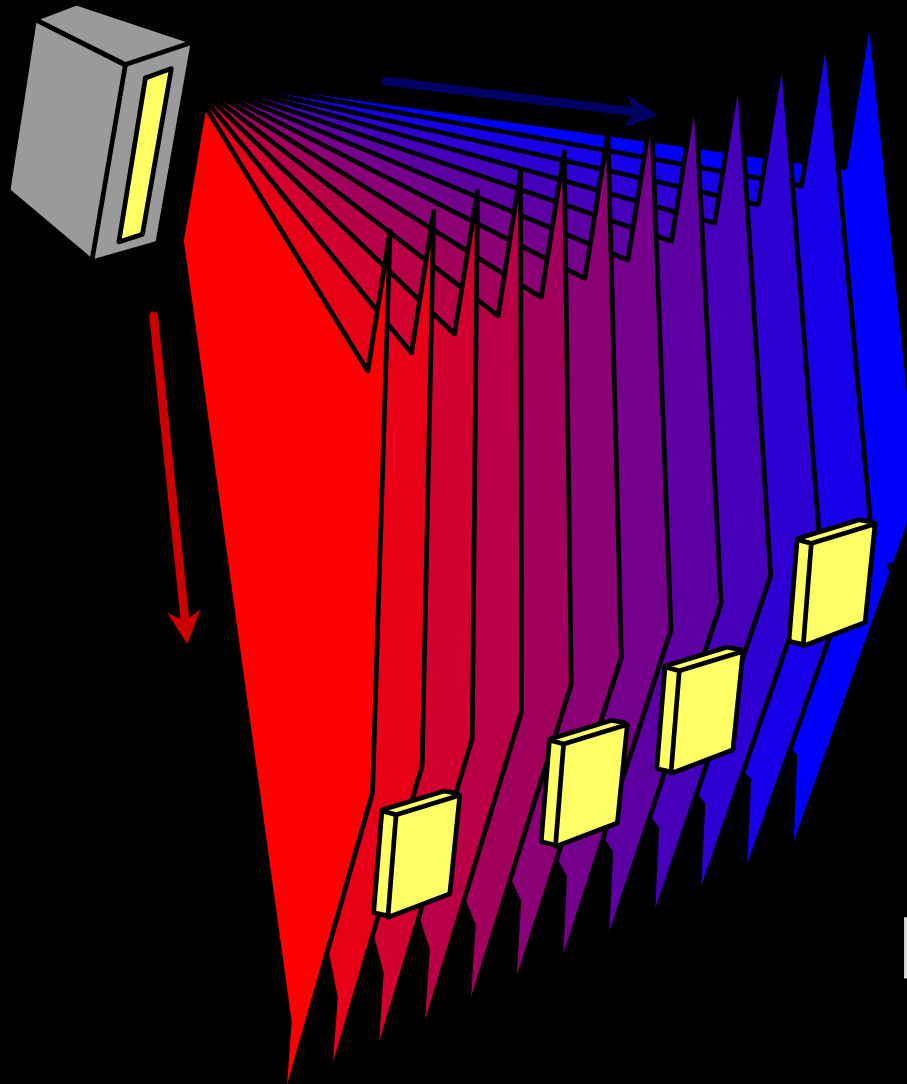


Images of Vicon motion capture camera equipment and applications removed due to copyright restrictions. See <http://www.vicon.com>

Optical Communication Options



Labeling Space

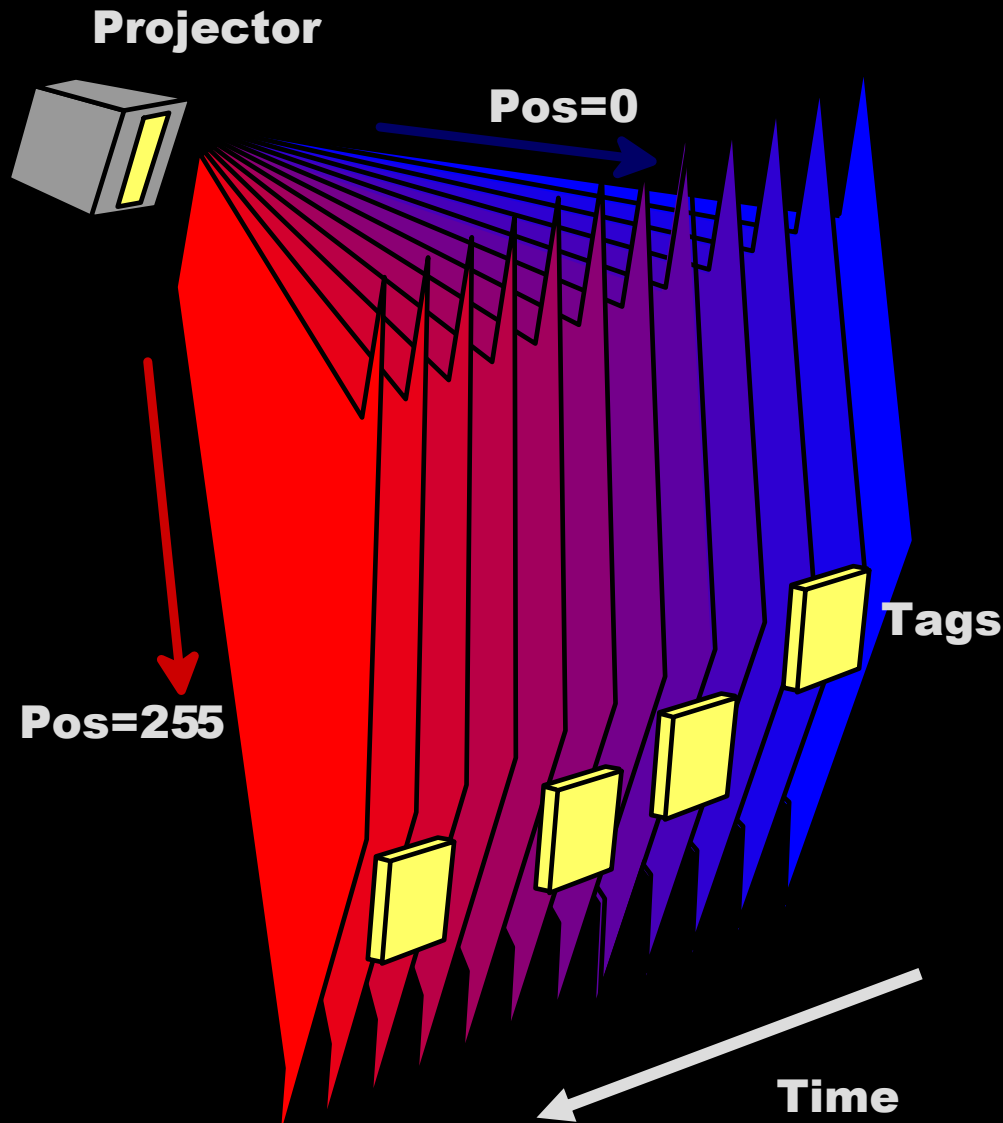


Each location receives a unique signal based upon its physical location.

High Speed Tracking



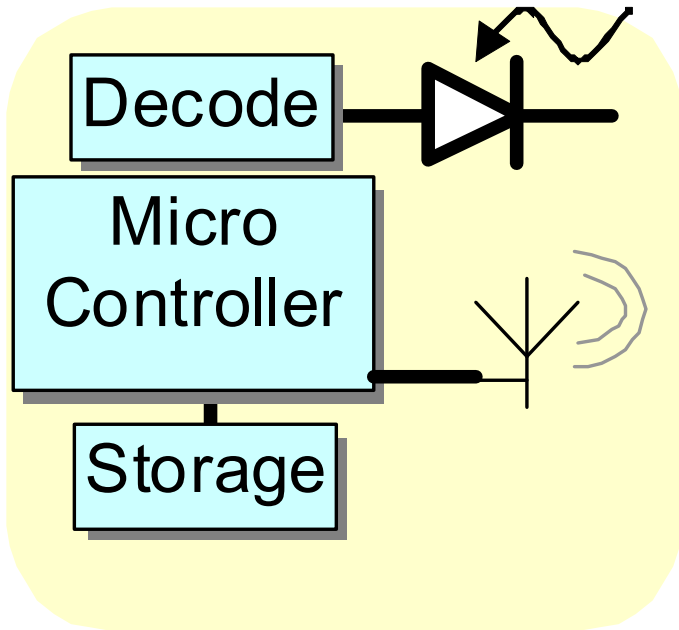
Labeling Space (Indoor GPS)



Each location
receives a unique
temporal code

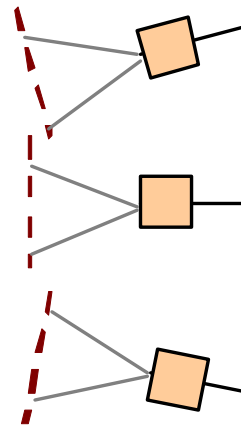
But 60Hz
video projector
is too slow

Photosensor



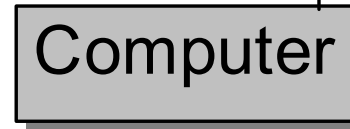
Coded Light

Masks

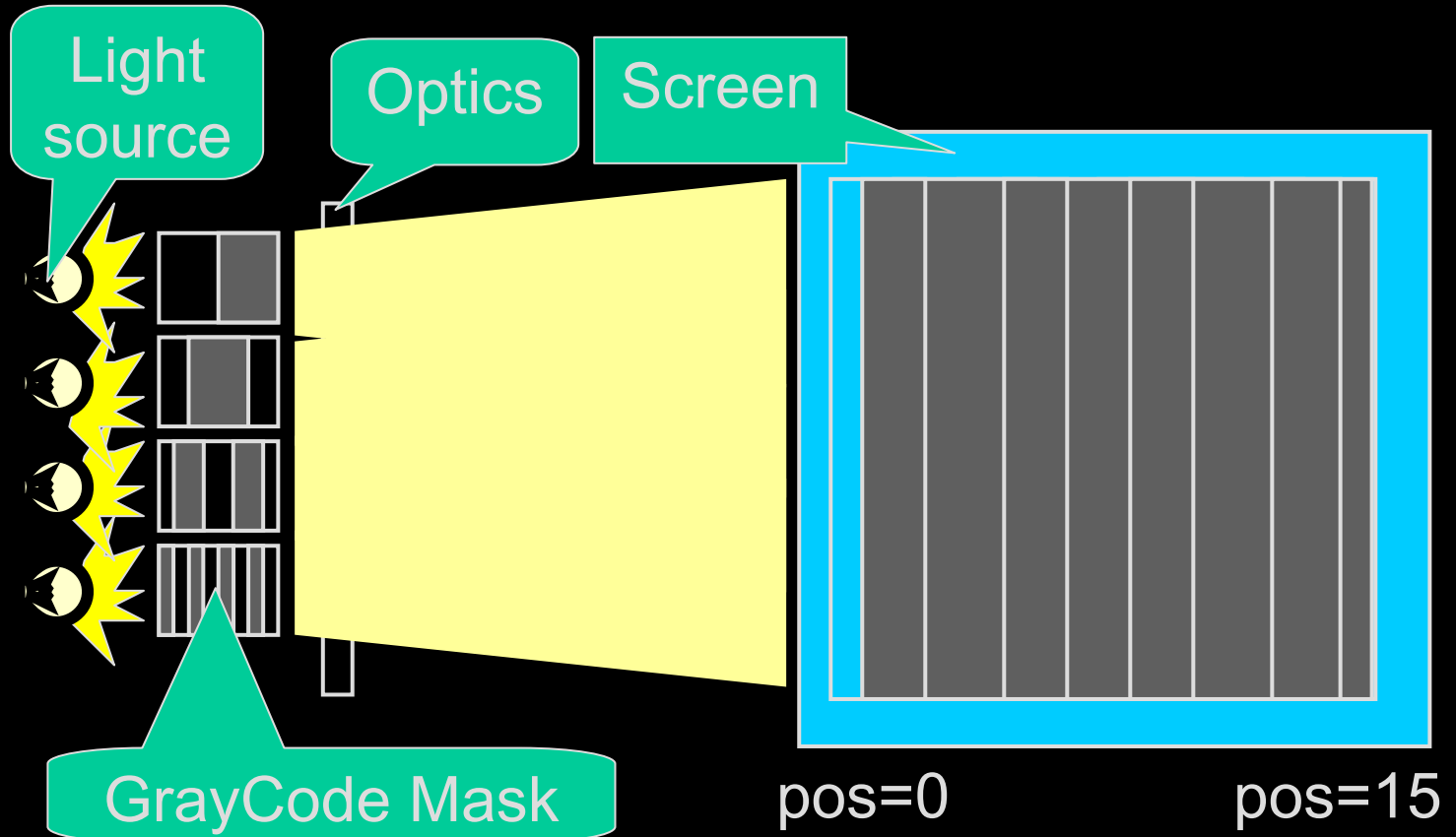


Modulated LEDs

Camera



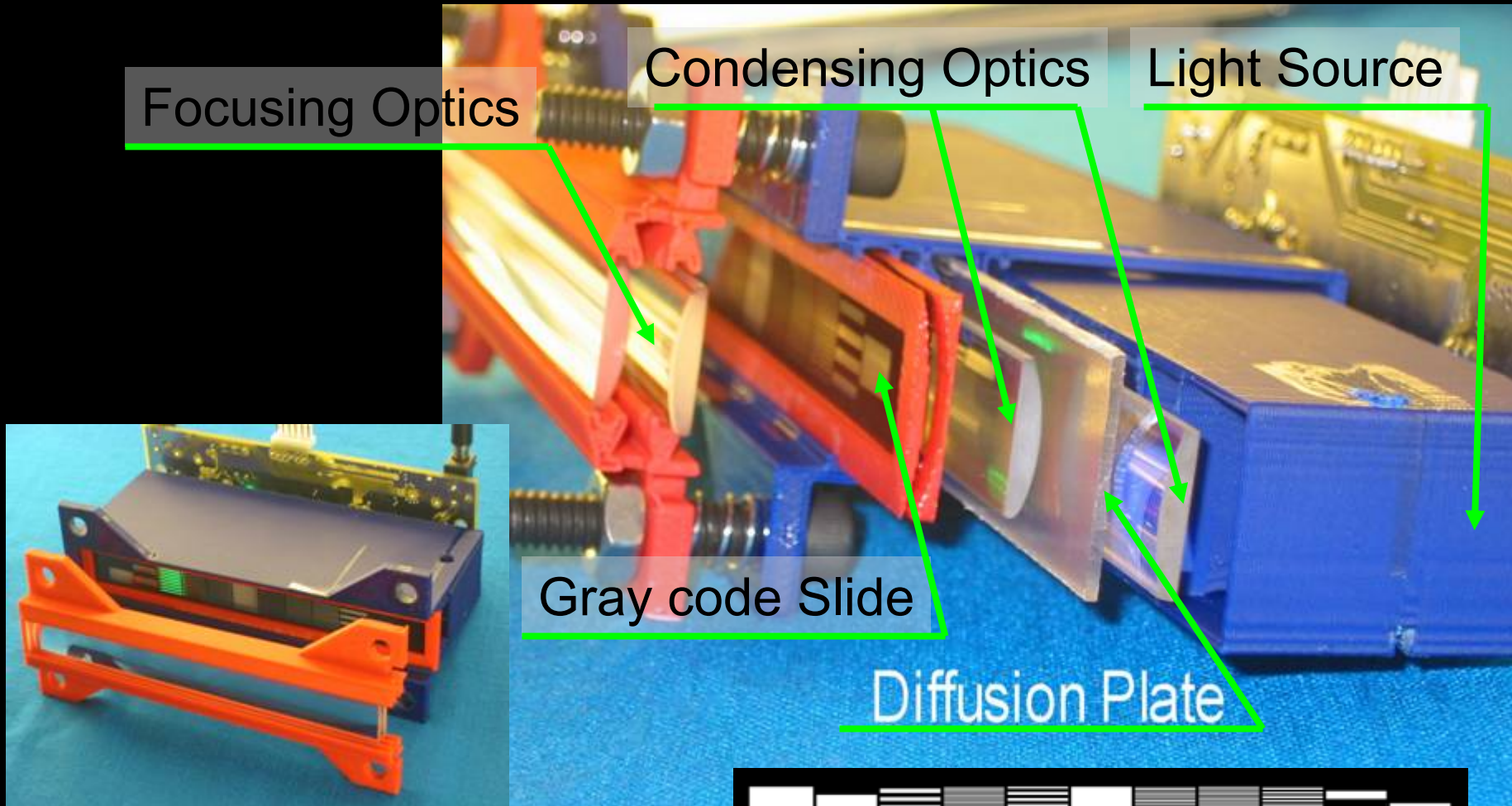
How Labeling Works



Light source blink one by one and each position on the screen has different light pattern.

4 light make 4 bit position resolution

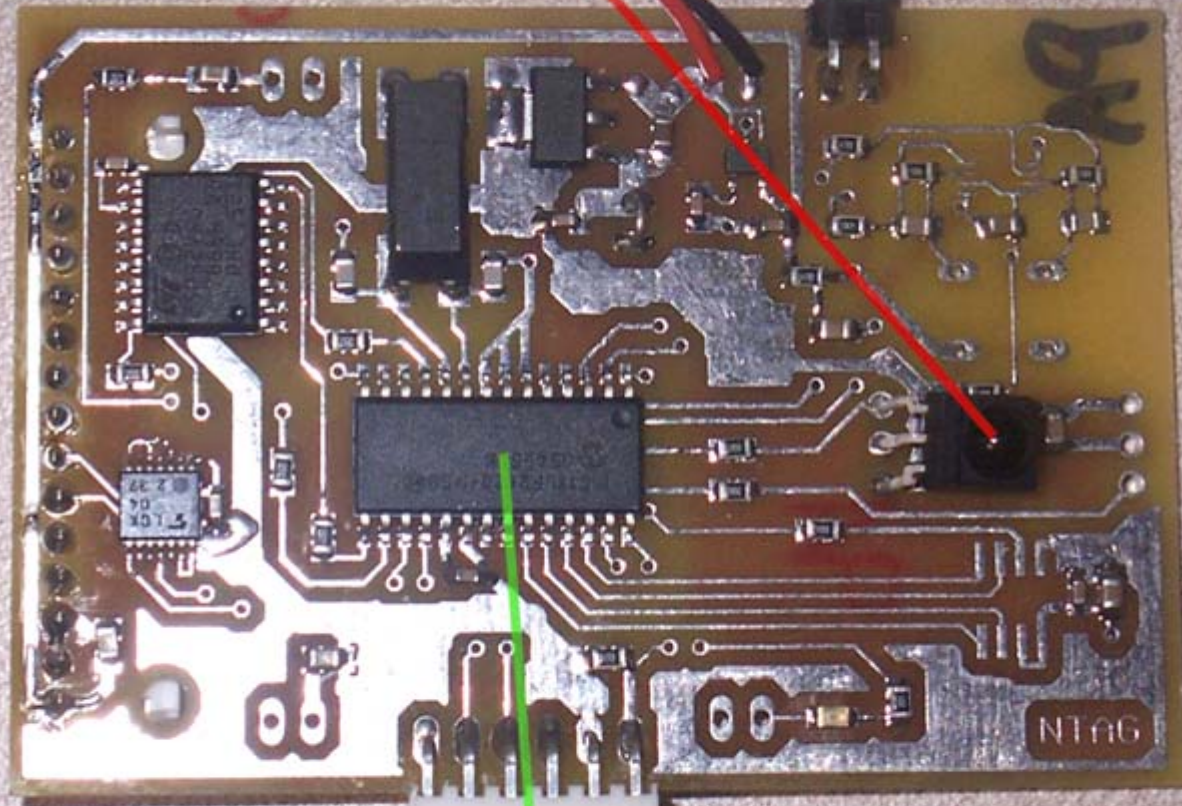
Inside Modulated LED Projector



The Gray code pattern

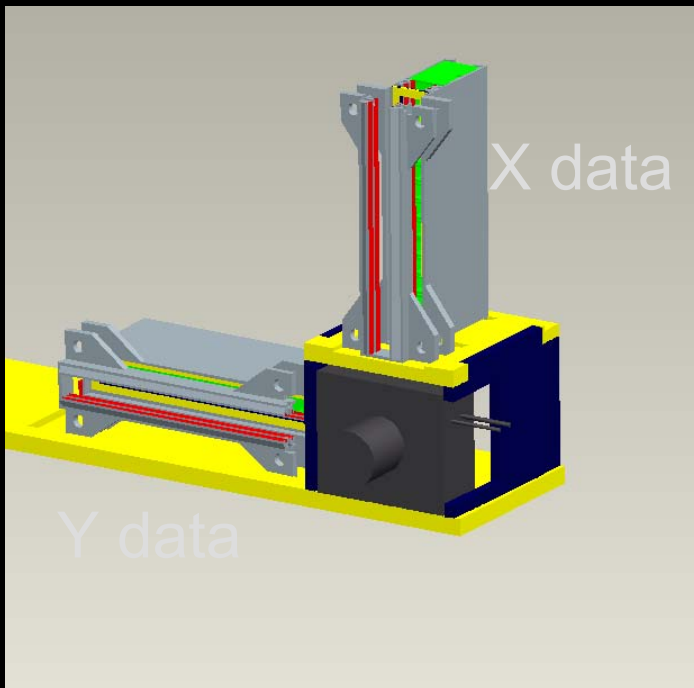
Tag

Location Sensor

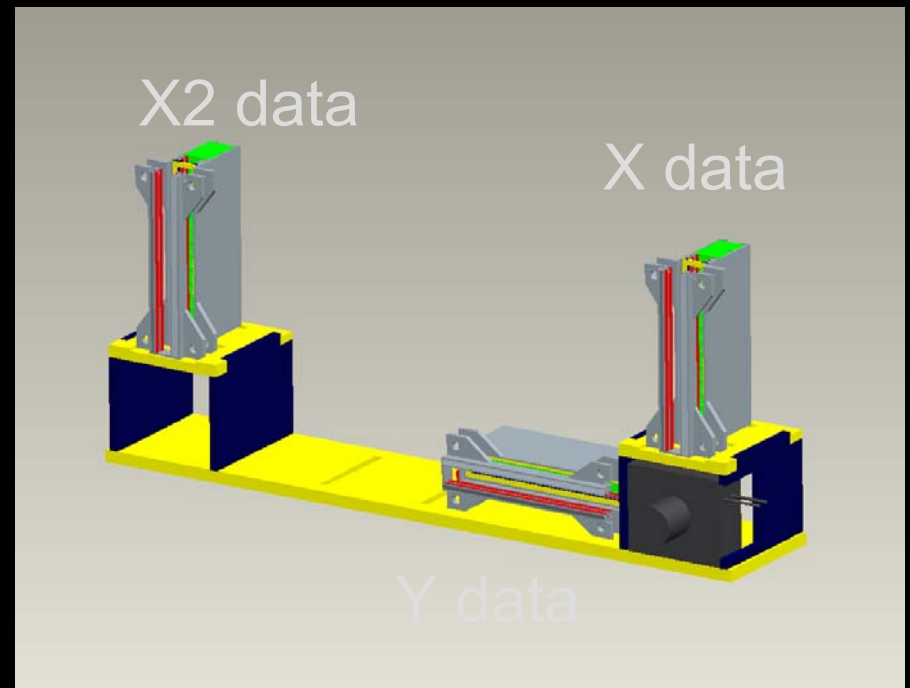


Embedded CPU

2D Location



3D Location

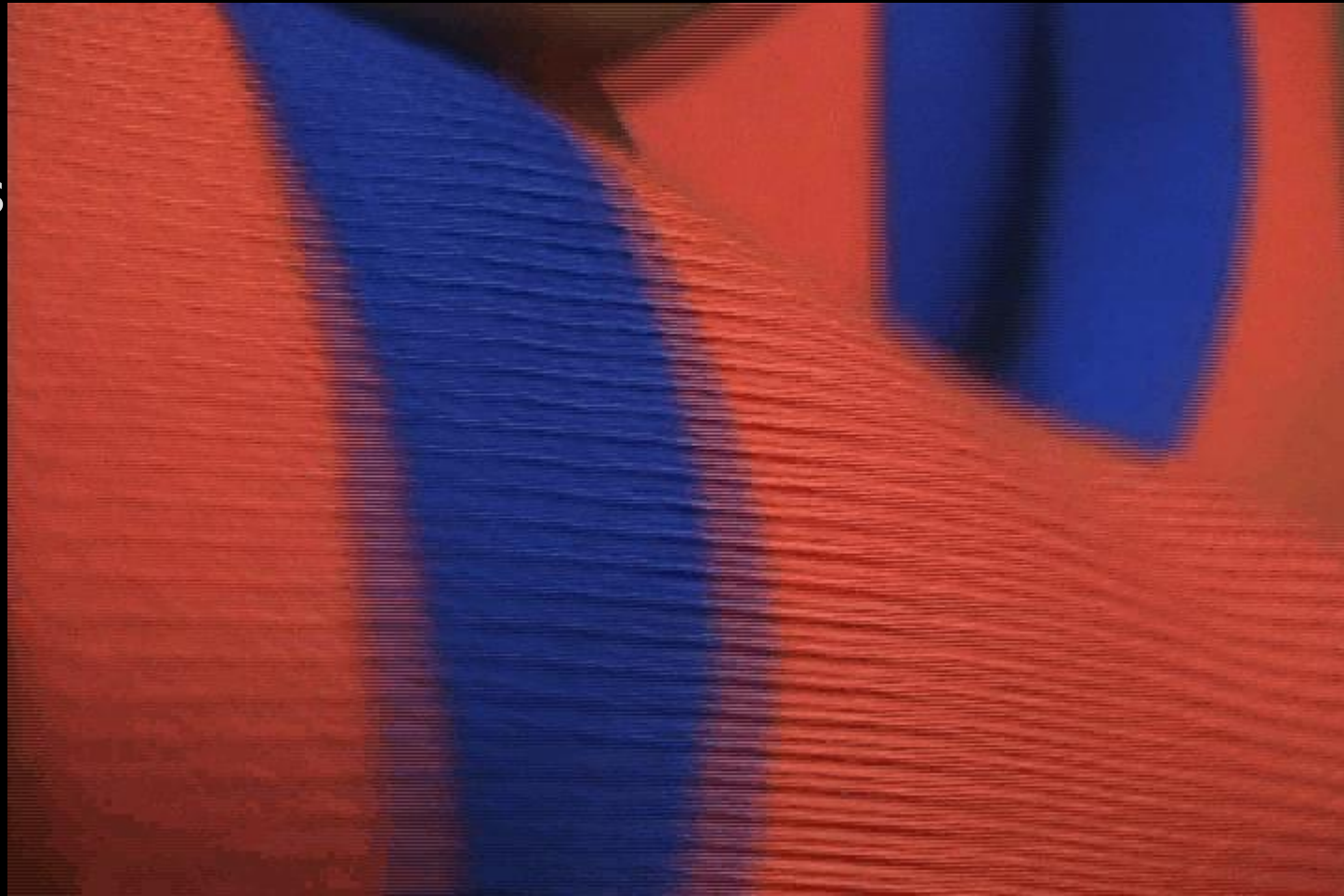


Imperceptible Tags under clothing, tracked under ambient light

Hidden
Marker Tags

Outdoors

Unique Id



Inverse Optical Mo-Cap

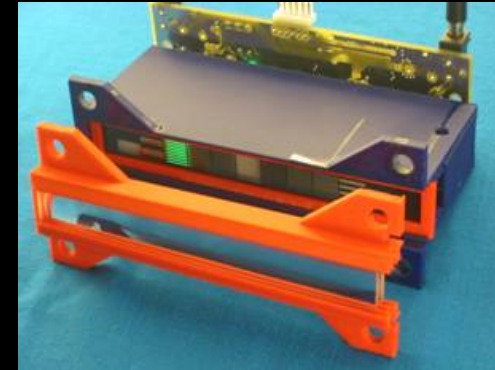
High Speed Camera

Detect blobs in each frame



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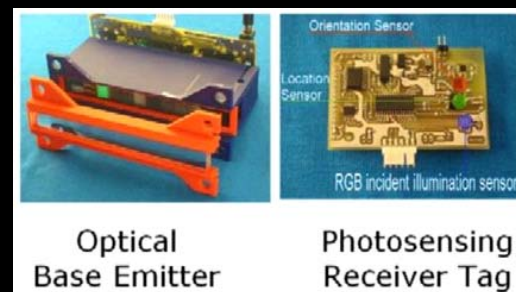
Images of Vicon motion capture camera equipment and applications removed due to copyright restrictions. See <http://www.vicon.com>



On-set MoCap:
Location + Orientation + Incident Illumination

Coded Illumination Motion Capture Clothing

- 500 Hz with Id for each Marker Tag
- Capture in Natural Environment
 - Visually imperceptible tags
 - Photosensing Tag can be hidden under clothes
 - Ambient lighting is ok
- Unlimited Number of Tags
 - Light sensitive fabric for dense sampling
- Non-imaging, complete privacy
- Base station and tags only a few 10's \$
- Full body scan + actions
 - Elderly, patients, athletes, performers
 - Breathing, small twists, multiple segments or people
 - Animation Analysis



3D Cameras

- Time of flight
 - ZCam (Shuttered Light Pulse)
- Phase Decoding of modulated illumination
 - Canesta (Phase comparison)
 - Phase difference = depth
 - Magnitude = reflectance
- Structured Light
 - Binary coded light and triangulation

MIT OpenCourseWare
<http://ocw.mit.edu>

MAS.531 Computational Camera and Photography
Fall 2009

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