



GAMES 204



Computational Imaging

Lecture 17: Computational Illumination II



Qilin Sun (孙启霖)

香港中文大学（深圳）

点昀技术 (Point Spread Technology)



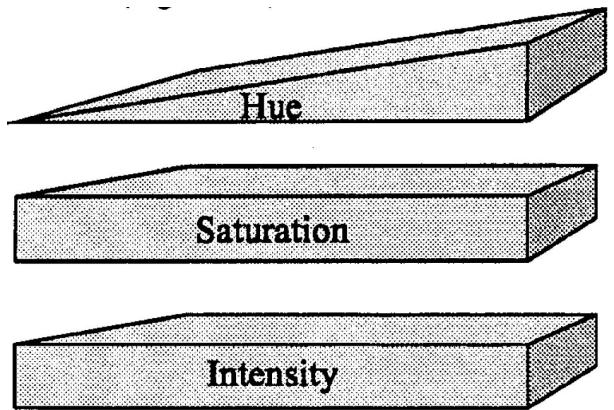
Today's Topic

- Light Color/Wavelength
- Spatial Modulation (Intra-flash 2D Modulation)
 - Synthetic Aperture Illumination
- Temporal Modulation
 - TV remote, Motion Tracking, Sony ID-cam, RFIG
- General lighting condition – Day/Night

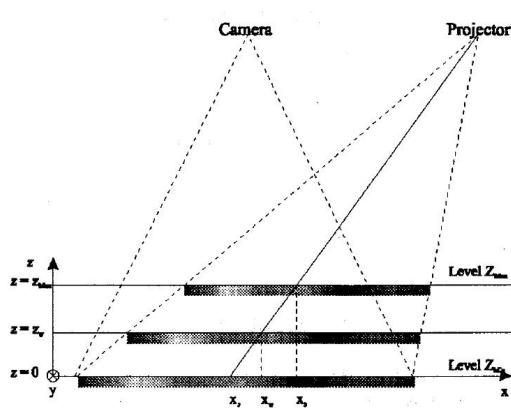
Light Color/Wavelength



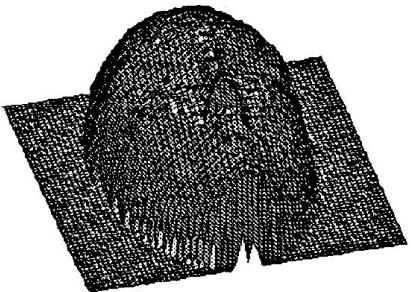
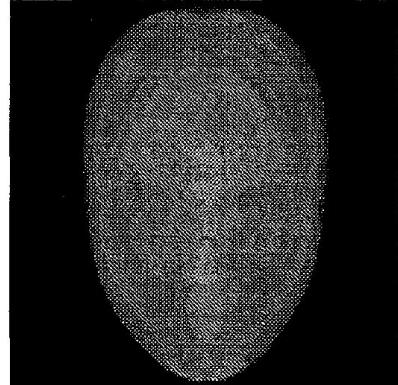
Color Coded Illumination



Hue-, saturation-, and intensity-distribution for the color-triangulation



Geometrical conditions between projector and camera



FAST 3D OBJECT RECOGNITION USING MULTIPLE COLOR CODED ILLUMINATION
Erhard Schubert, 1997



Color Coded Illumination

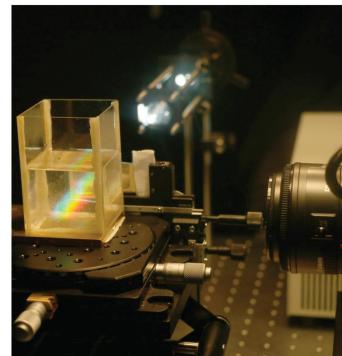
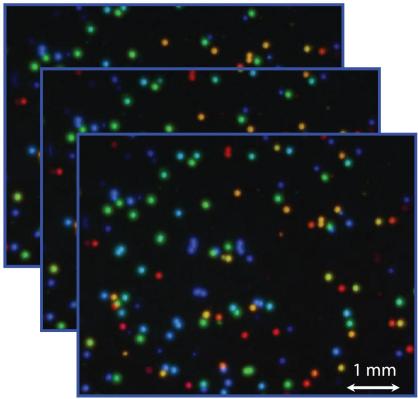
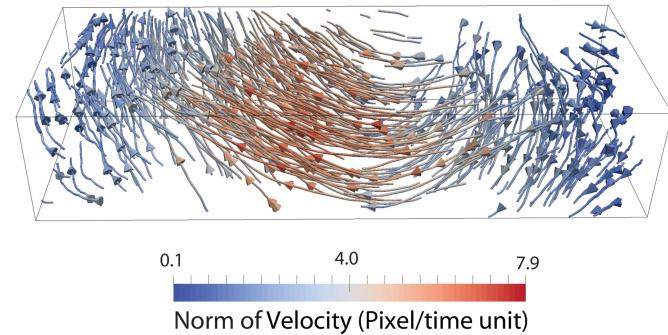


Image acquisition



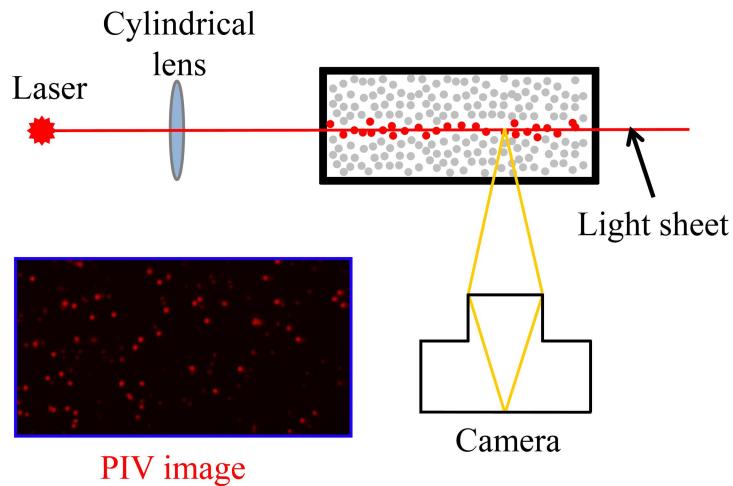
Particle distribution
reconstruction
+
Velocity vector
field estimation



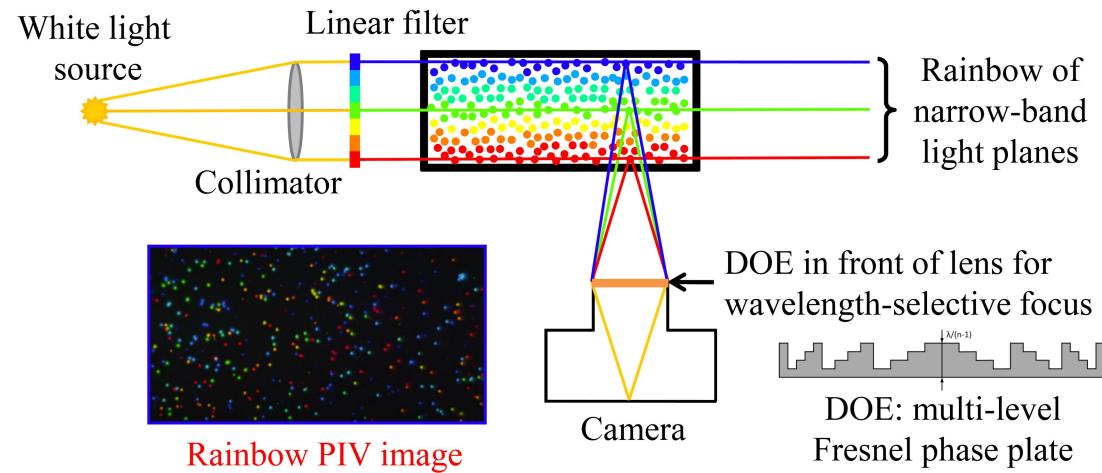
Rainbow Particle Imaging Velocimetry for Dense 3D Fluid Velocity Imaging
J. Xiong et.al, 2017

Color Coded Illumination

PIV setup



Rainbow PIV setup



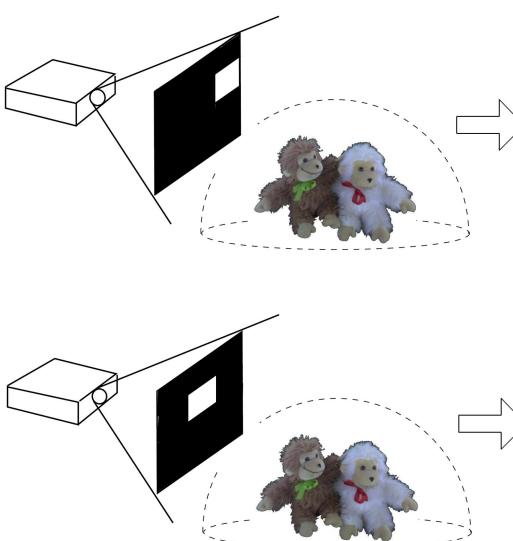
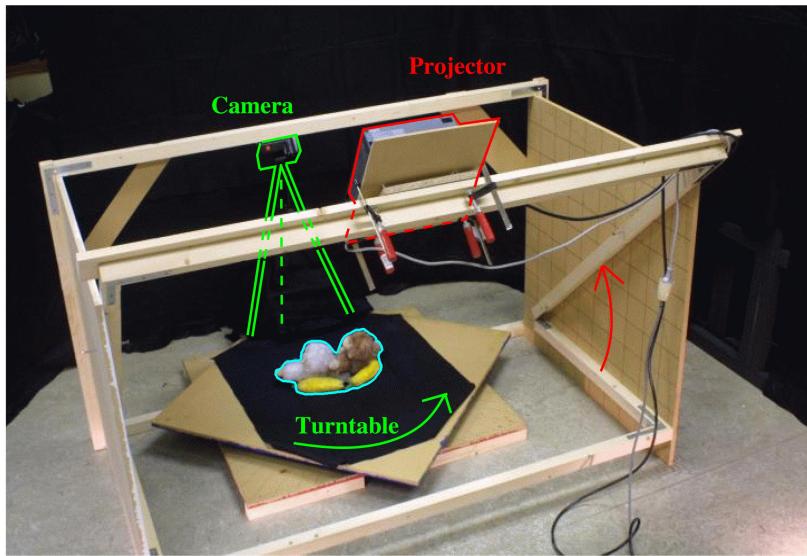
Rainbow Particle Imaging Velocimetry for Dense 3D Fluid Velocity Imaging
J. Xiong et.al, 2017

Spatial Modulation



6-D Methods and Beyond...

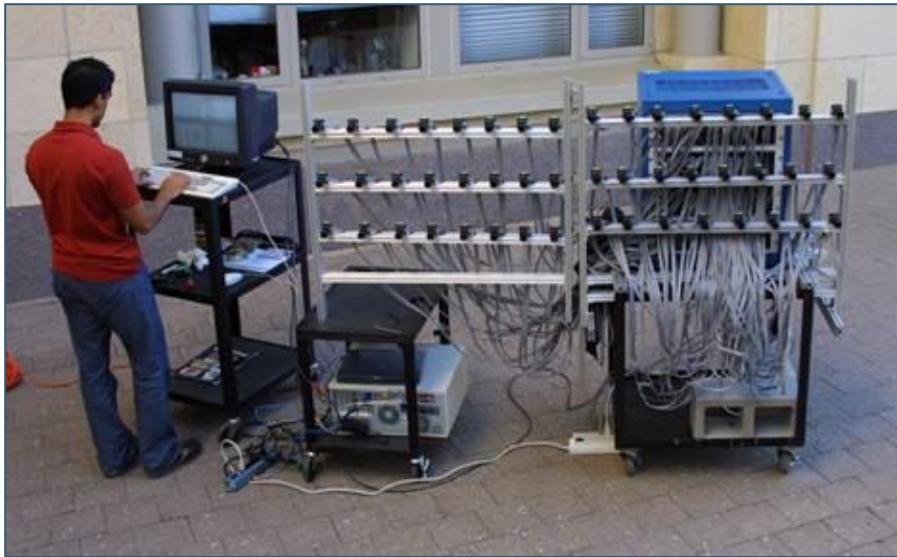
Relighting with 4D Incident Light Fields Vincent Masselus, Pieter Peers, Philip Dutre and Yves D. Willems SIGG2003





Synthetic Aperture Illumination

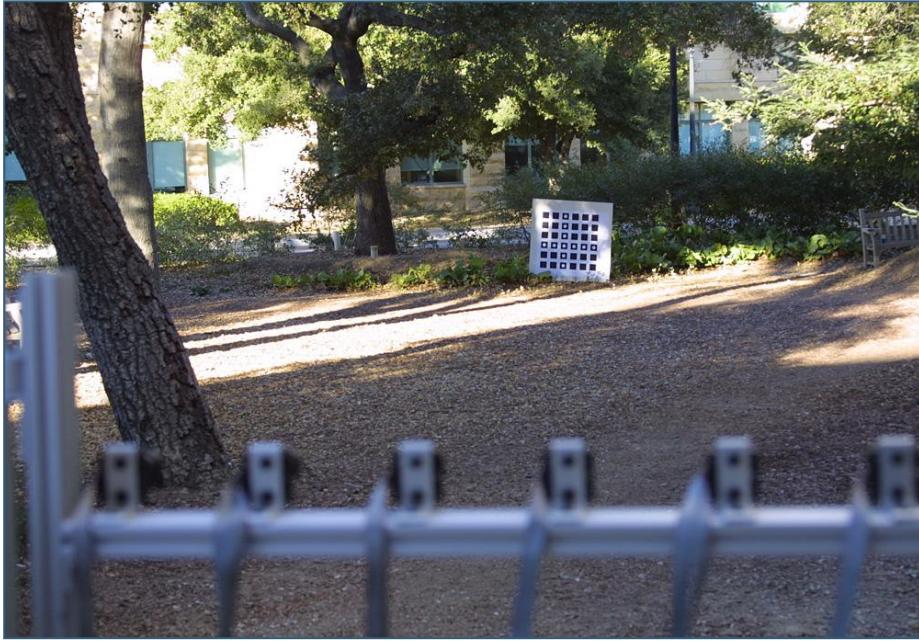
Comparison with Long-range synthetic aperture photography M.Levoy et.al



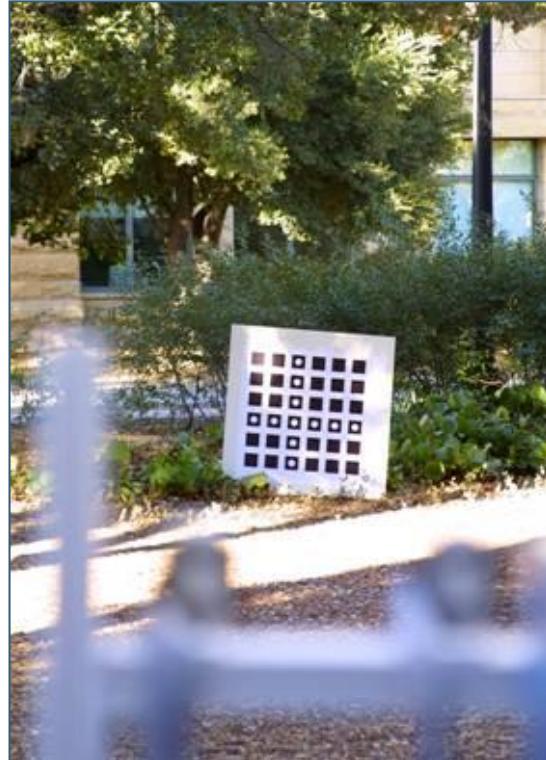
- width of aperture 6'
- number of cameras 45
- spacing between cameras 5"
- camera's field of view 4.5°



The Scene

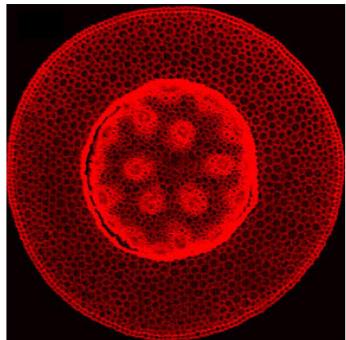


- distance to occluder 110'
- distance to targets 125'
- field of view at target 10'

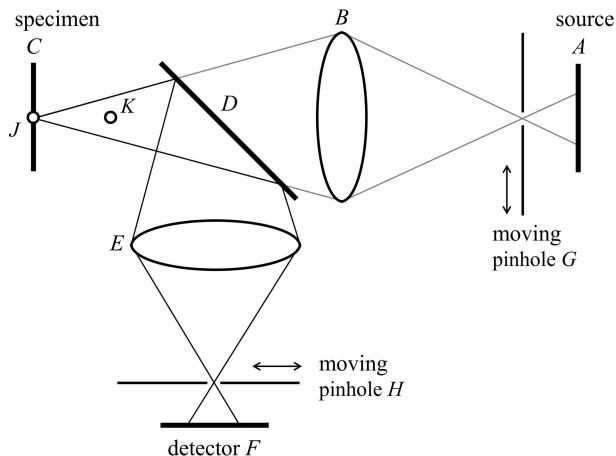


Confocal Technology

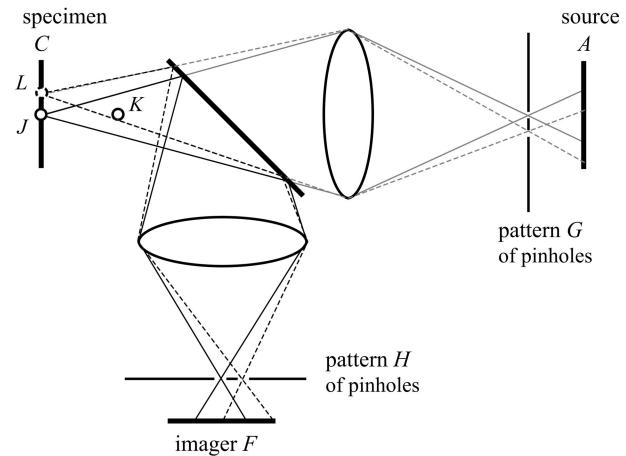
Confocal Microscopy



(a) a confocal image



(b) confocal scanning microscope



(c) aperture correlation microscope



Synthetic Aperture Photography

Synthetic aperture confocal imaging using an array of mirrors



- 11-megapixel camera (4064×2047 pixels)
- 18×12 inch effective aperture, 9 feet to scene
- 22 mirrors, tilted inwards → 22 views, each 750×500 pixels

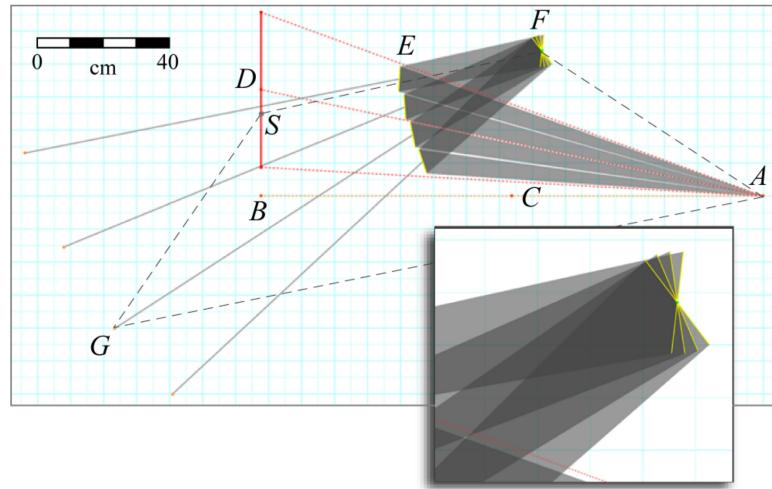
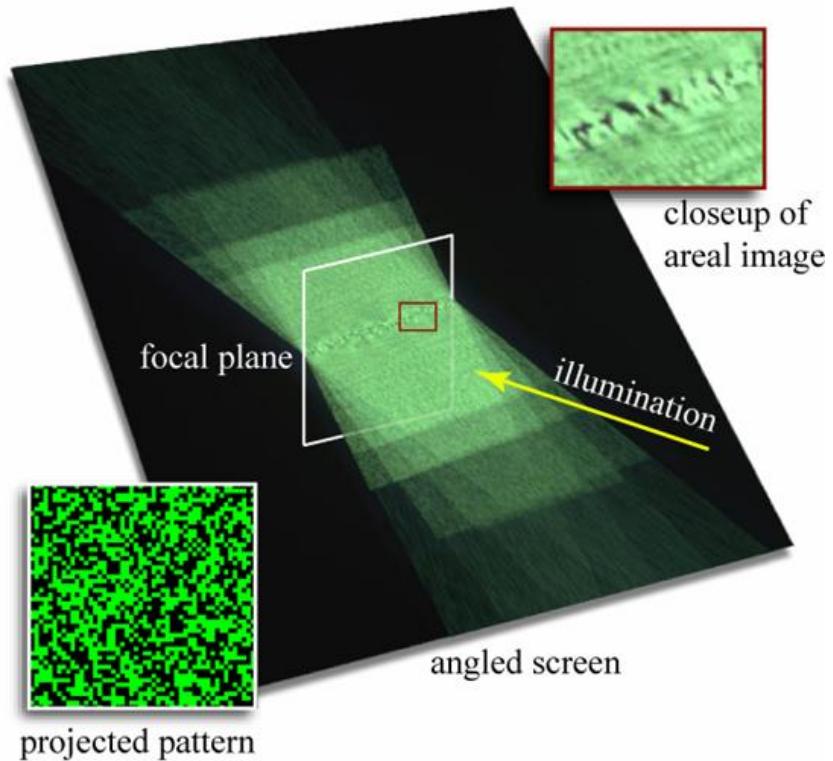
Synthetic Aperture Illumination

- Technologies
 - Array of projector
 - Array of microprojectors
 - Single projector + array of mirrors

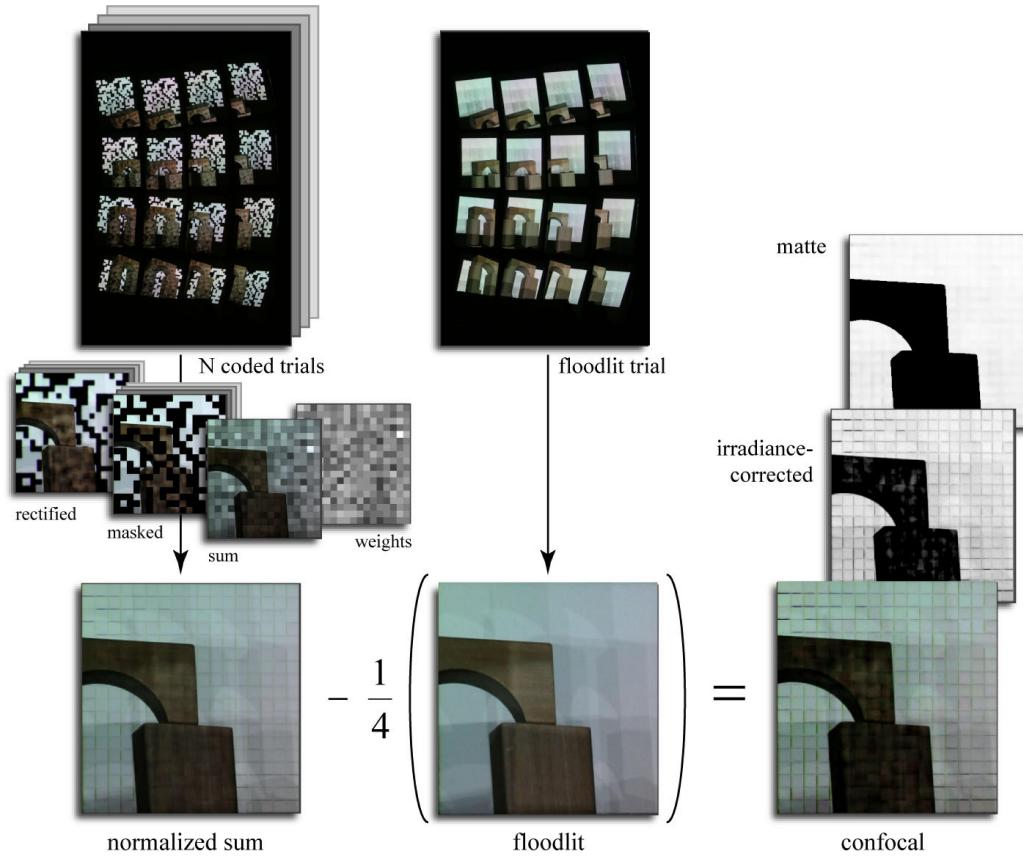


Synthetic Aperture Illumination

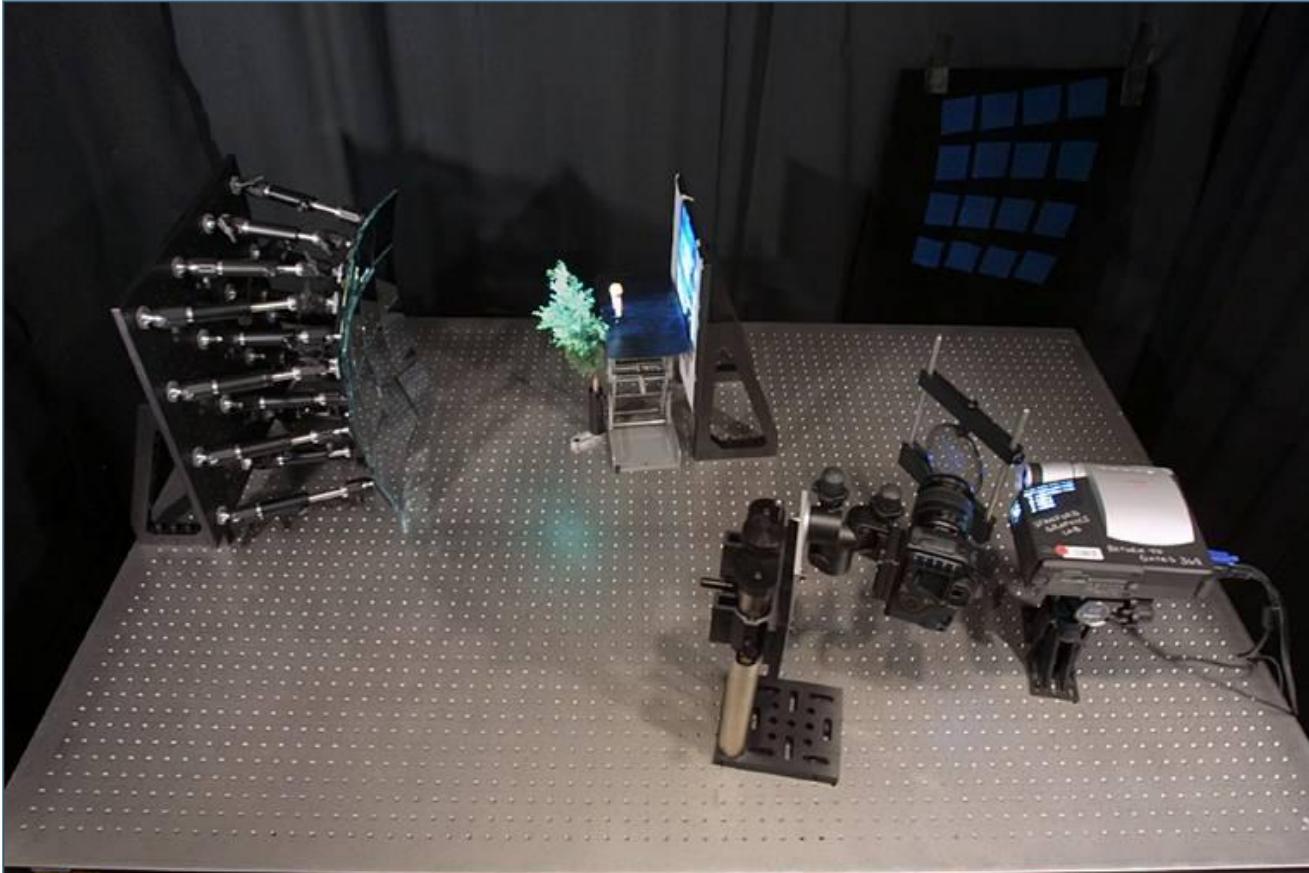
What does synthetic aperture illumination look like?



Synthetic Aperture Illumination

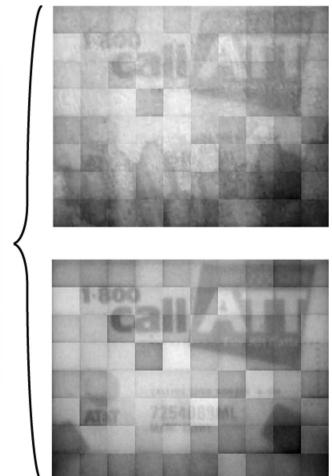
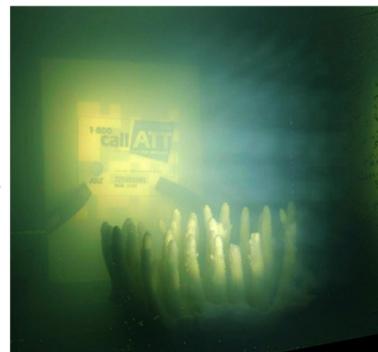
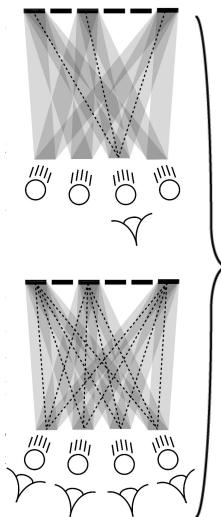
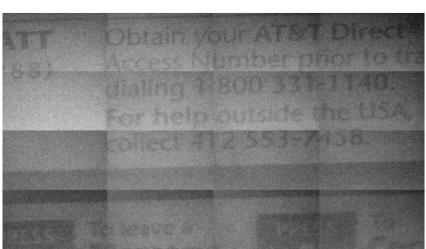
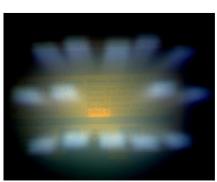
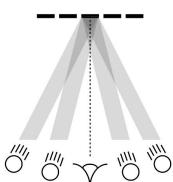
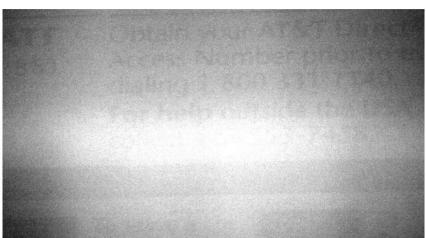
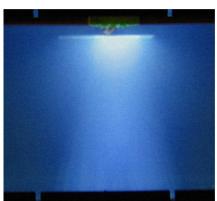
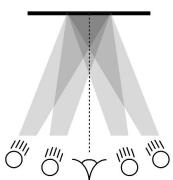
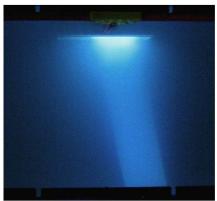
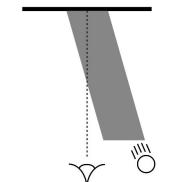


Synthetic Aperture Illumination





Underwater Confocal Imaging w/o SAP





Underwater Confocal Imaging w/o SAP



(a) single viewpoint



(b) synthetic aperture photograph



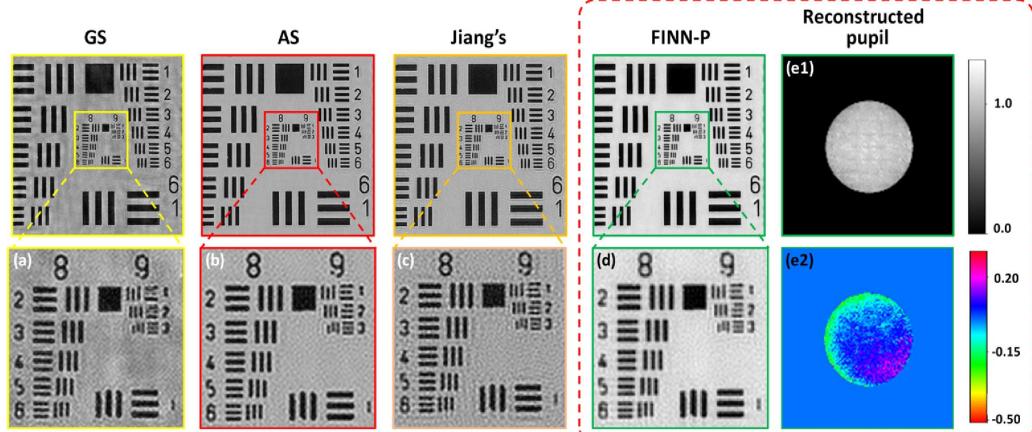
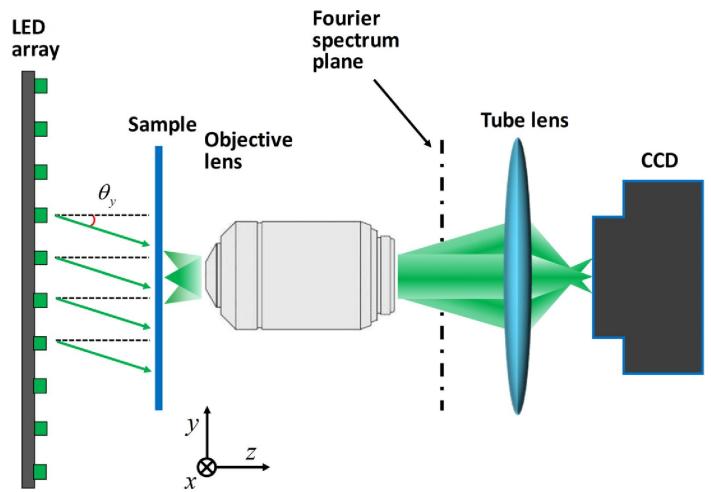
(c) confocal image



(d) combining (b) and (c)



Synthetic Aperture Illumination: Microscopy



Neural network model combined with pupil recovery for Fourier ptychographic microscopy
Sun et.al 2019

Temporal Modulation

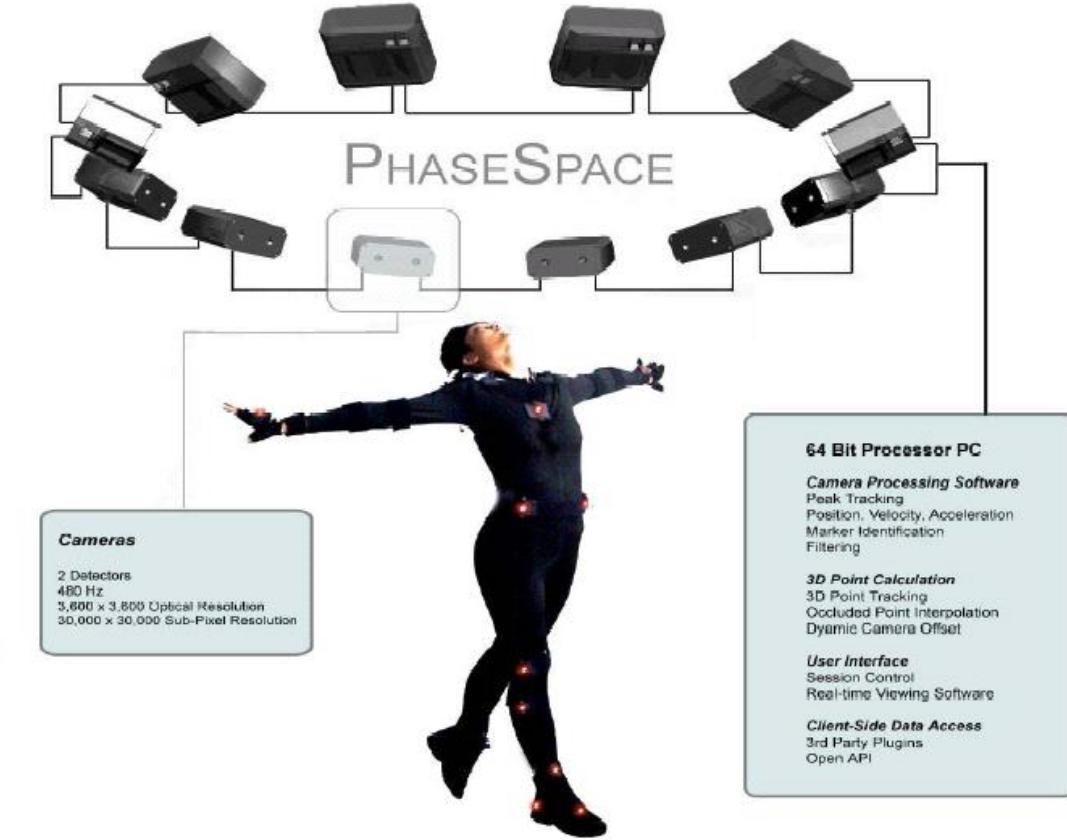


Demodulating Cameras



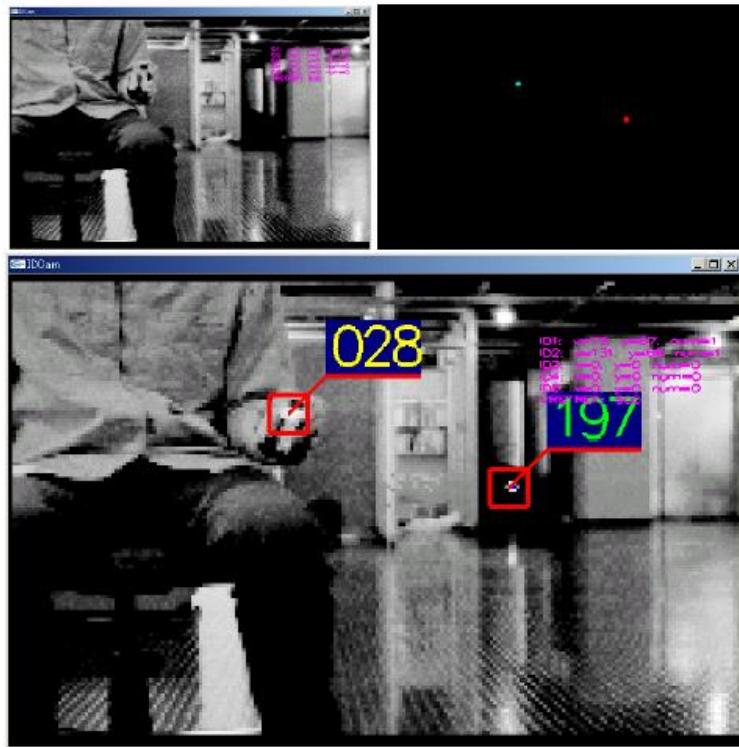
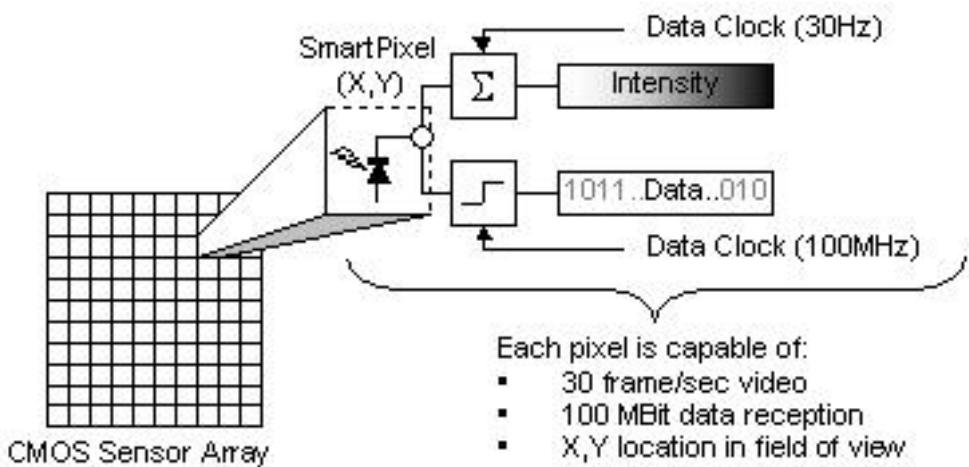
- Motion Capture Cameras
 - Visualeyez™ VZ4000 Tracking System
 - PhaseSpace motion digitizer

Demodulating Cameras



Demodulating Cameras

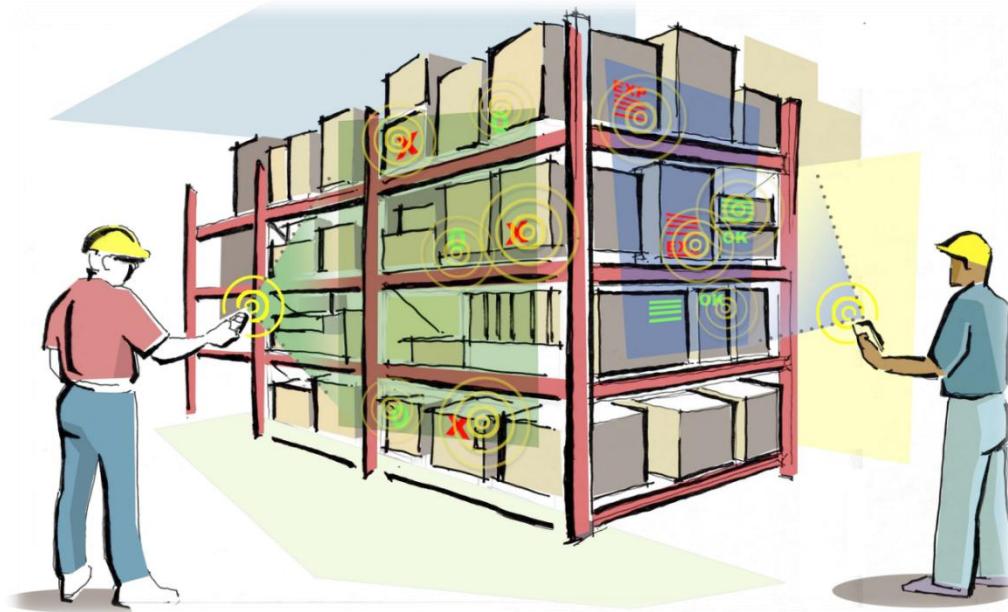
- Decode signals from blinking LEDs + image
 - Sony ID Cam
 - Phoci





RFIG Lamps

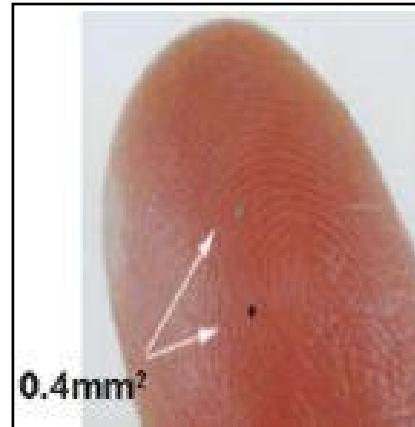
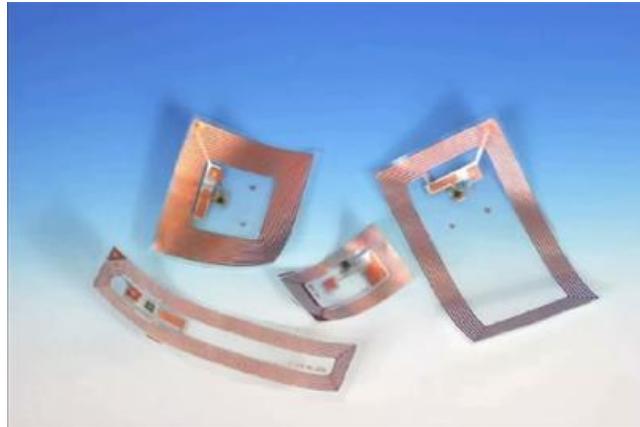
Interacting with a Self-describing World via Photosensing Wireless Tags and Projectors



Ramesh Raskar, Paul Beardsley, Jeroen van Baar, Yao Wang, Paul Dietz, Johnny Lee, Darren Leigh,
Thomas Willwacher
Mitsubishi Electric Research Labs (MERL), Cambridge, MA



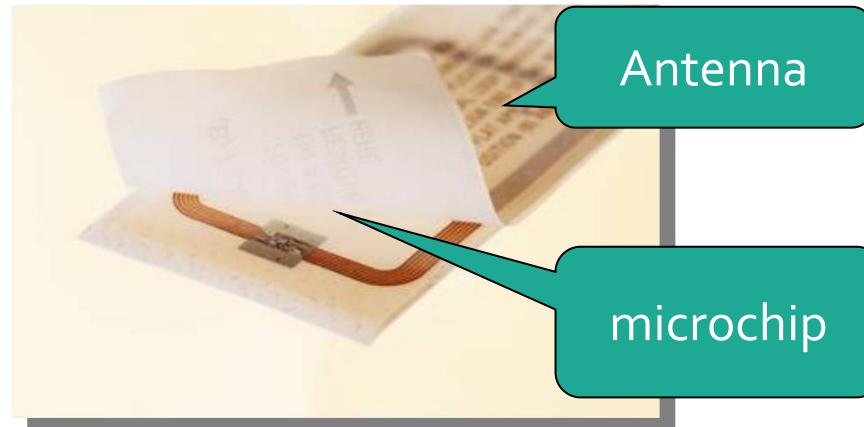
Radio Frequency Identification Tags (RFID)



No batteries,

Small size,

Cost few cents





Radio Frequency Identification Tags (RFID)

Warehousing



Routing



Livestock tracking



Library



Baggage handling

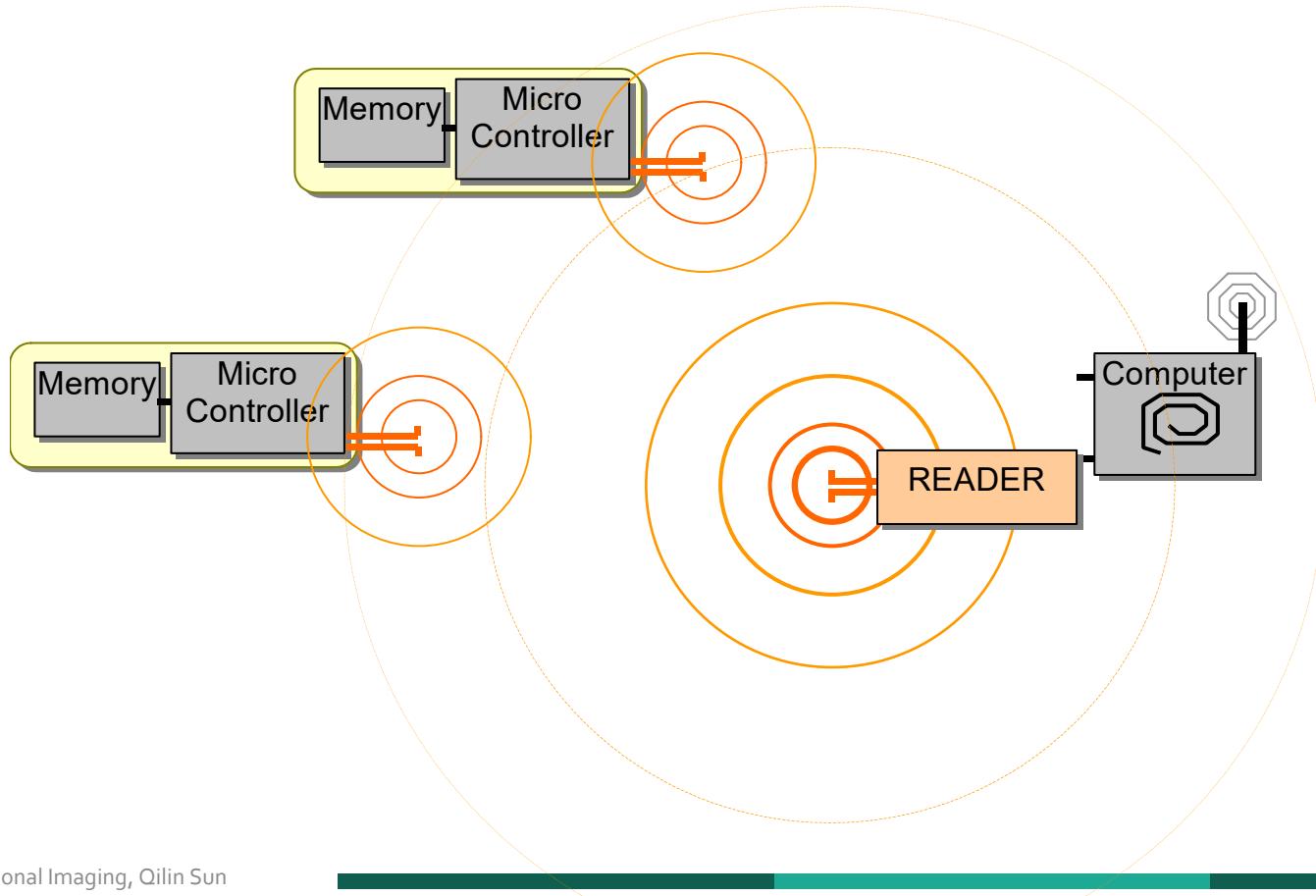


Currency





Conventional Passive RFID



Tagged Books in a Library



✓ Id

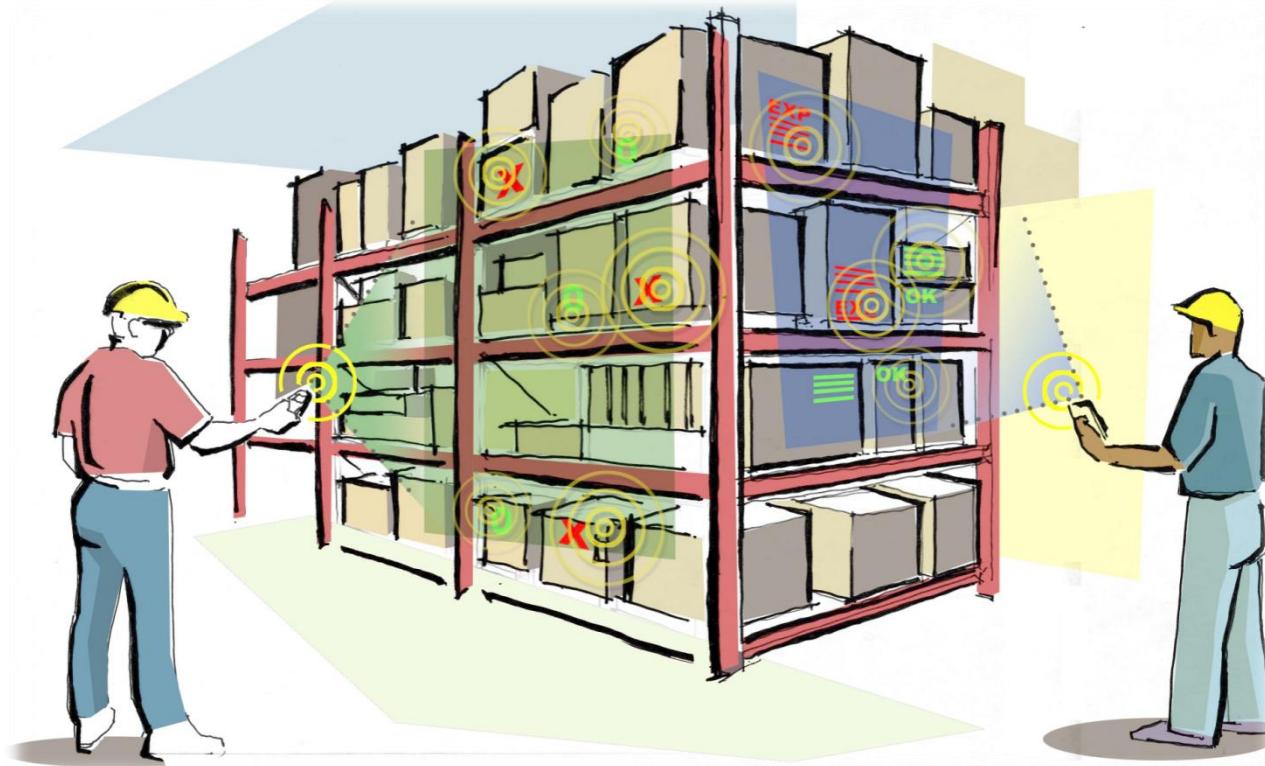
- Easy to get list of books in RF range

✗ No Precise Location Data

- Difficult to find if the books in sorted order ?
- Which book is upside down ?



Where are boxes with Products close to Expiry Date ?





Conventional RF Tag

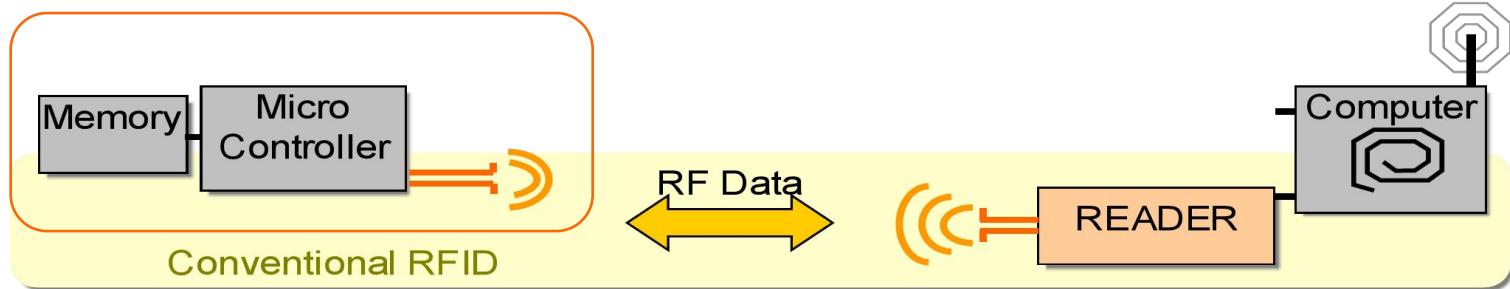


Photo-sensing RF Tag

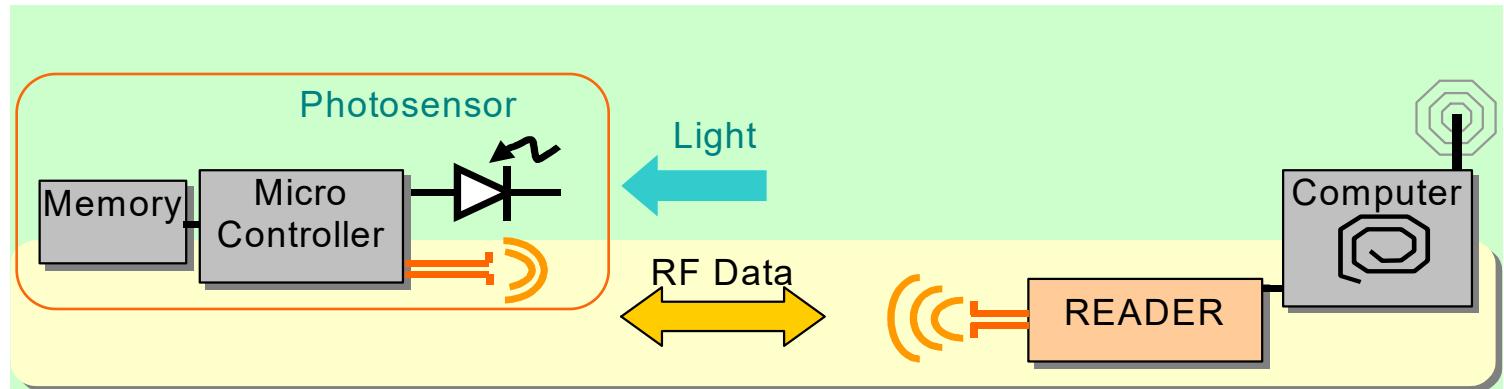
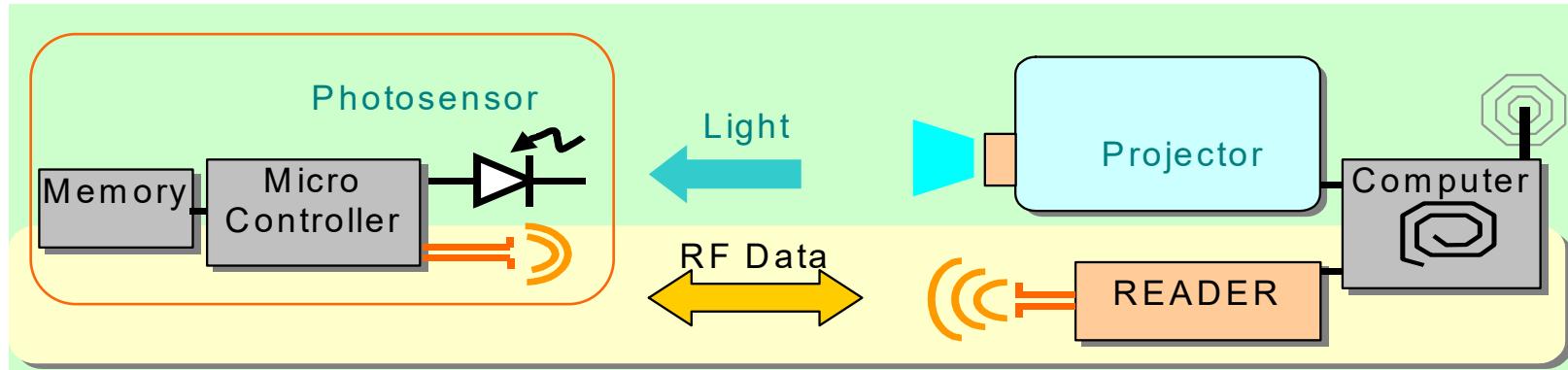




Photo-sensing RF Tag



Photosensor?

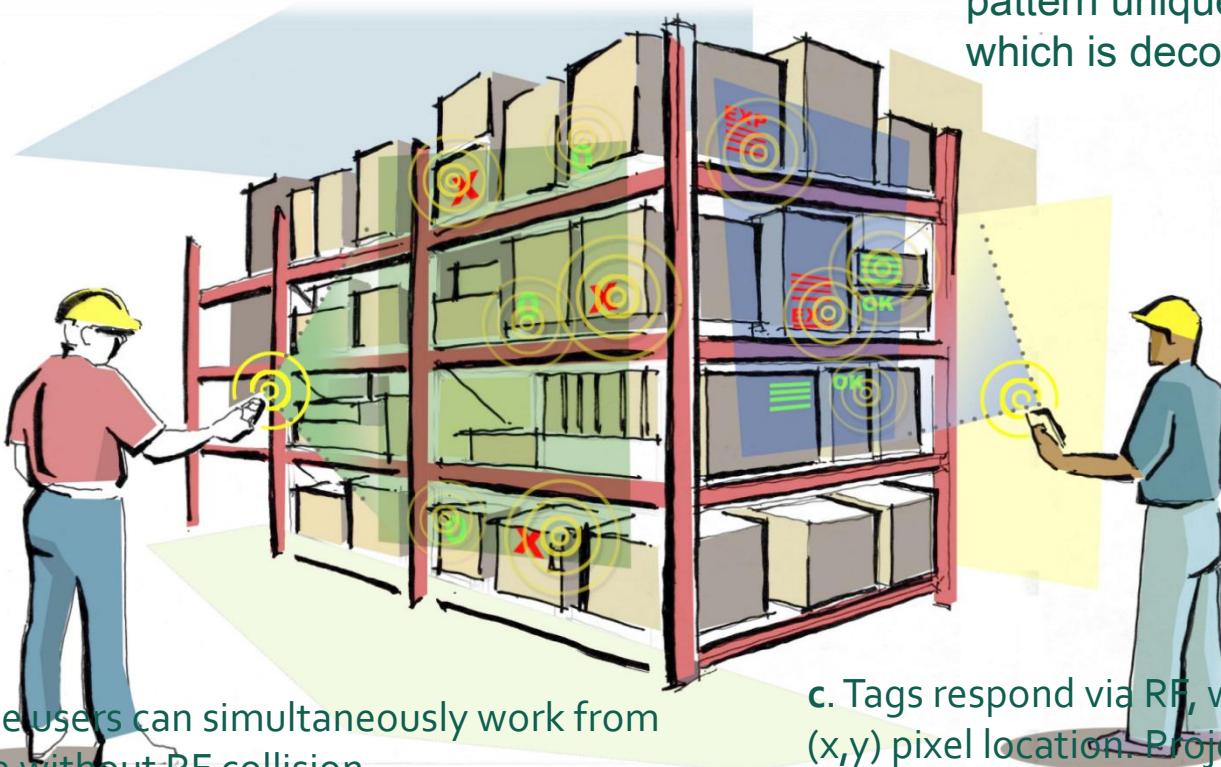
Compatible with RFID size and power needs

Projector?

Directional transfer, AR with Image overlay



a. Photosensing RFID tags
are queried via RF



d. Multiple users can simultaneously work from
a distance without RF collision

b. Projector beams a time-varying
pattern unique for each (x,y) pixel
which is decoded by tags

c. Tags respond via RF, with date and precise
(x,y) pixel location. Projector beams 'O' or
'X' at that location for visual feedback



Photo-sensing RF Tag

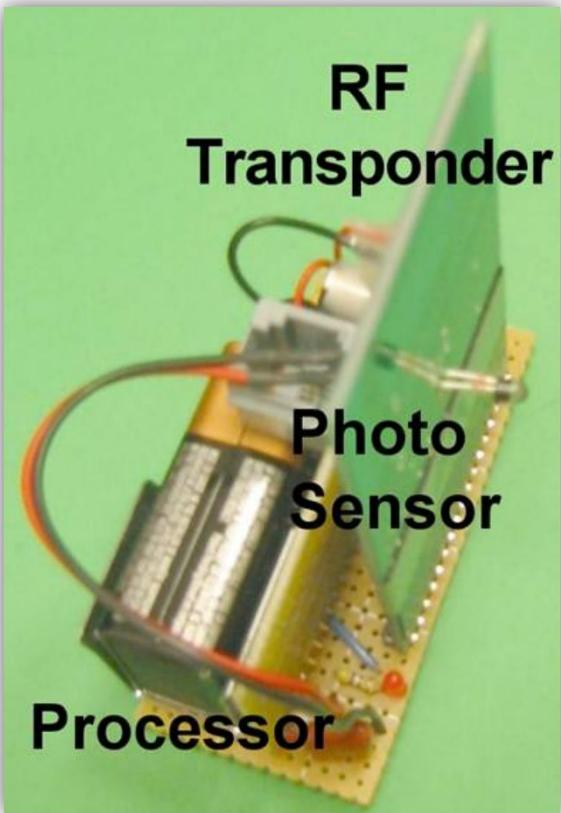
RFID
(Radio Frequency Identification)



RFIG
(Radio Frequency Id and Geometry)



Prototype Tag

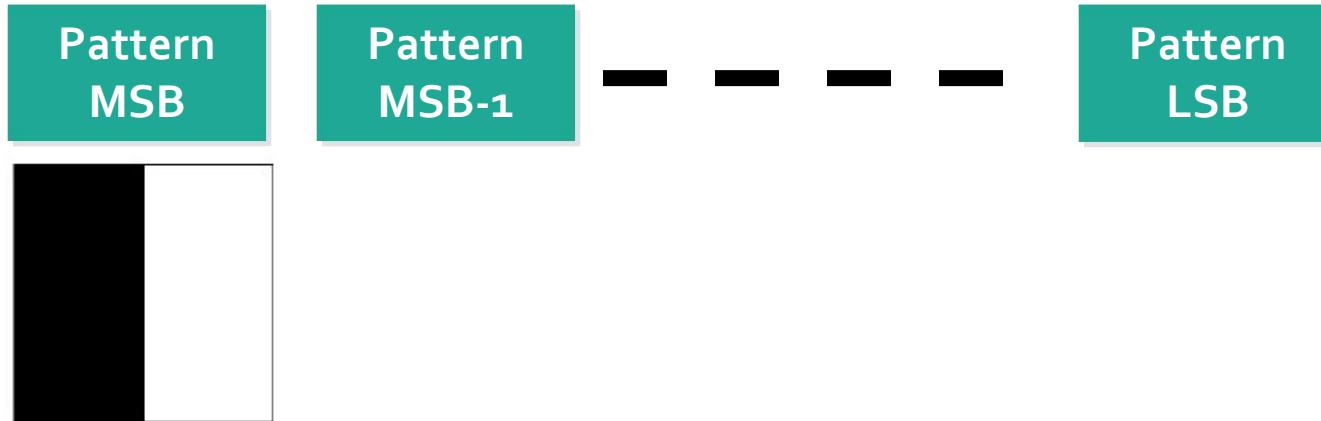


RF tag +
photosensor





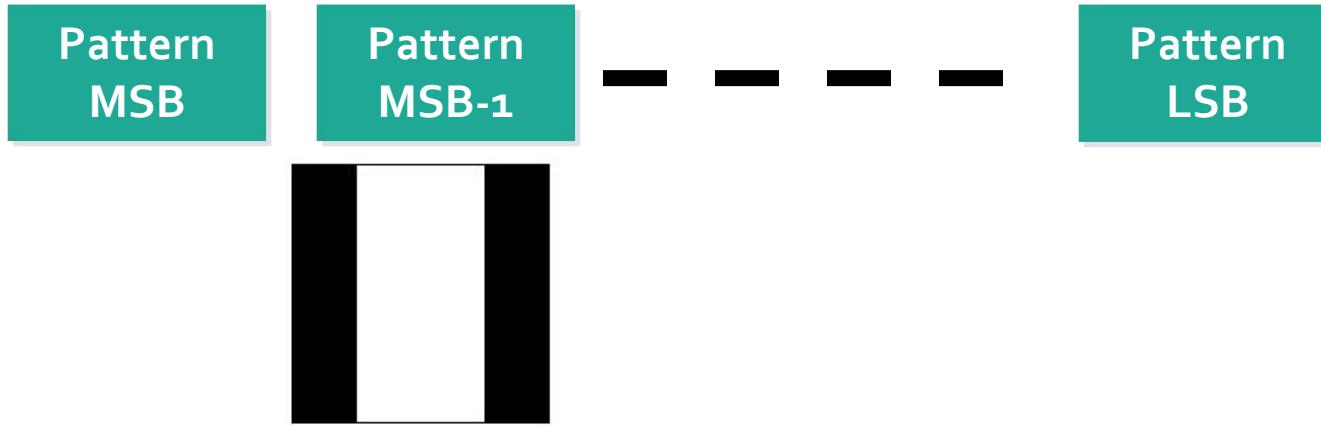
Projected Sequential Frames



- Handheld Projector beams binary coded stripes
- Tags decode temporal code

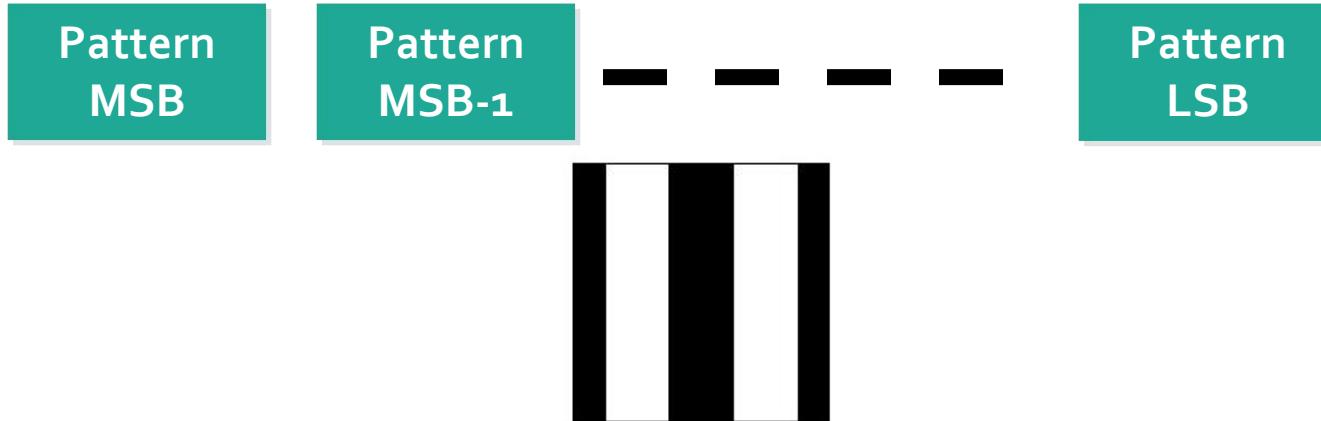


Projected Sequential Frames



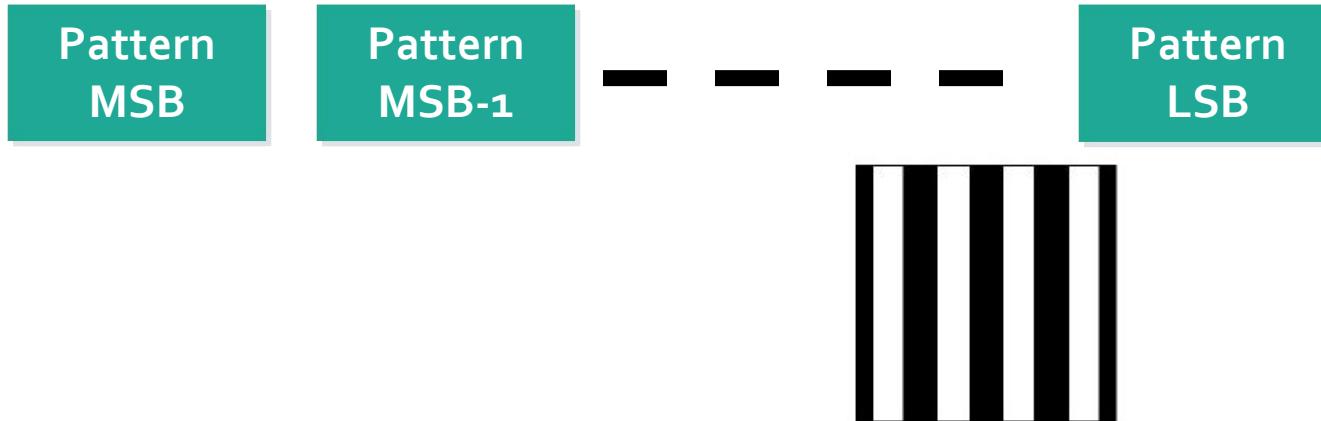
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Projected Sequential Frames



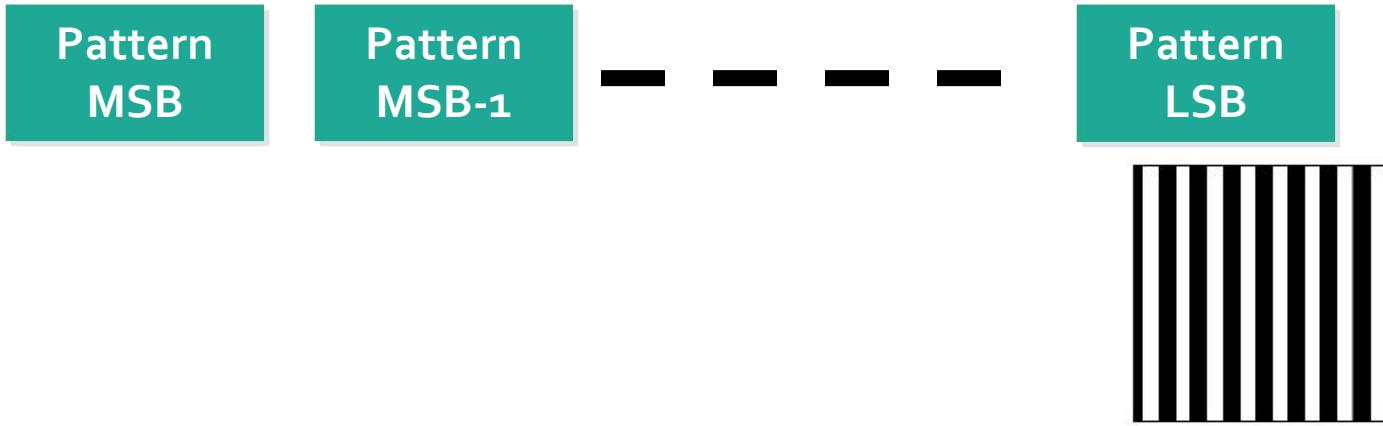
- Handheld Projector beams binary coded stripes
- Tags decode temporal code

Projected Sequential Frames



- Handheld Projector beams binary coded stripes
- Tags decode temporal code

Projected Sequential Frames



- Handheld Projector beams binary coded stripes
- Tags decode temporal code



Projected Sequential Frames



For each tag

- From light sequence, decode x and y coordinate
- Transmit back to RF reader (Id, x, y)



Visual feedback of 2D position

- a. Receive via RF $\{(x_1, y_1), (x_2, y_2), \dots\}$ pixels
- b. Illuminate those positions

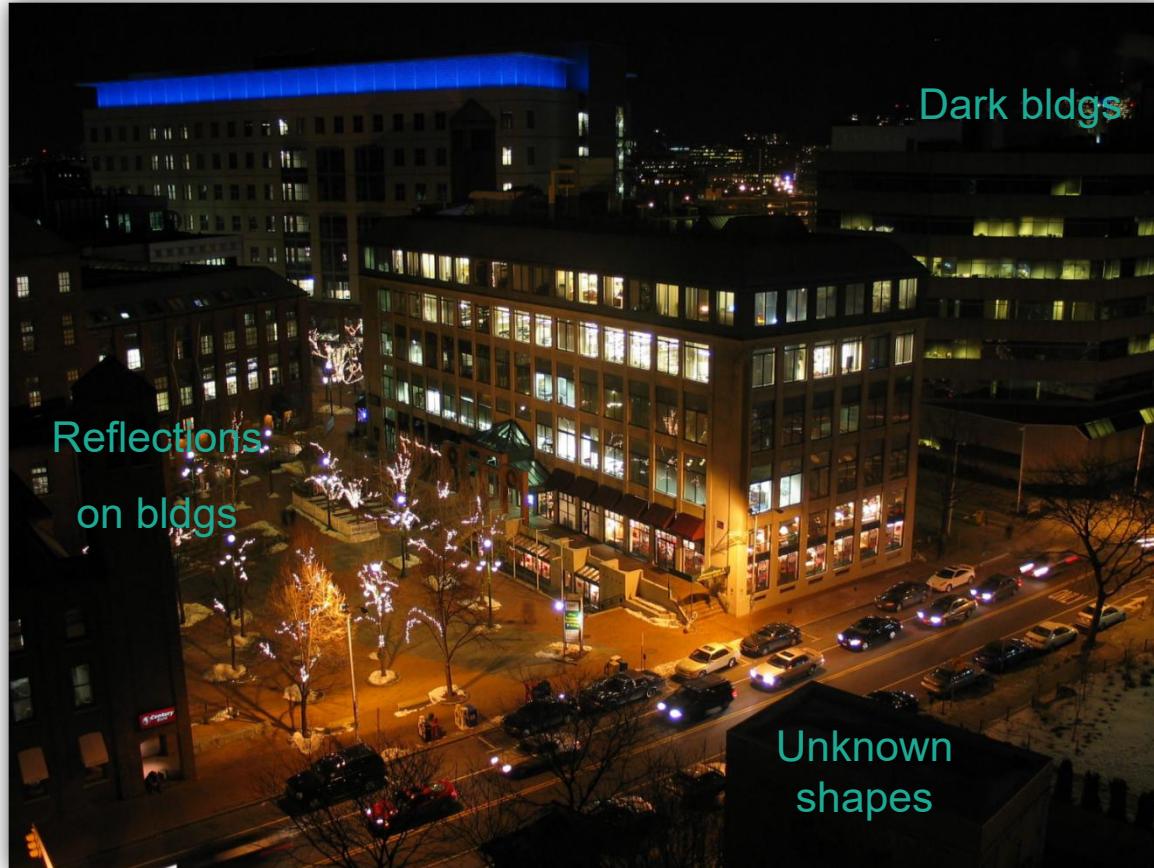


Exploiting (uncontrolled) Natural Lighting Condition



Day/Night Fusion

Objects are Difficult to Understand due to Lack of Context





Day/Night Fusion

Enhanced Context :

All features from night scene are preserved, but background in clear





Day/Night Fusion

Night Image



Day Image

Background is captured from day-time
scene using the same fixed camera



Result: Enhanced Image



Day/Night Fusion



Mask is
automatically
computed from
scene contrast



Day/Night Fusion



But, Simple Pixel
Blending Creates
Ugly Artifacts



Day/Night Fusion



Our Method:
Integration of blended Gradients

Pixel Blending





Day/Night Fusion

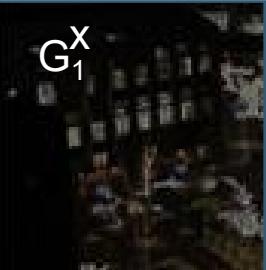
Nighttime image



Daytime image

Gradient field

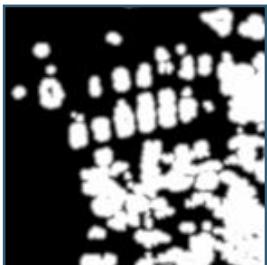
G_1^X



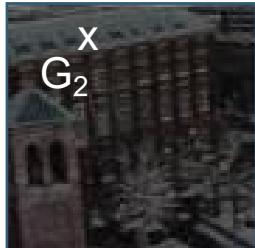
G_1^Y



Importance
image W



G_2^X



G_2^Y



Gradient field

Mixed gradient field

G^X



G^Y



Final result



Reconstruction from Gradient Field

- Problem: minimize error
- Estimate I' so that

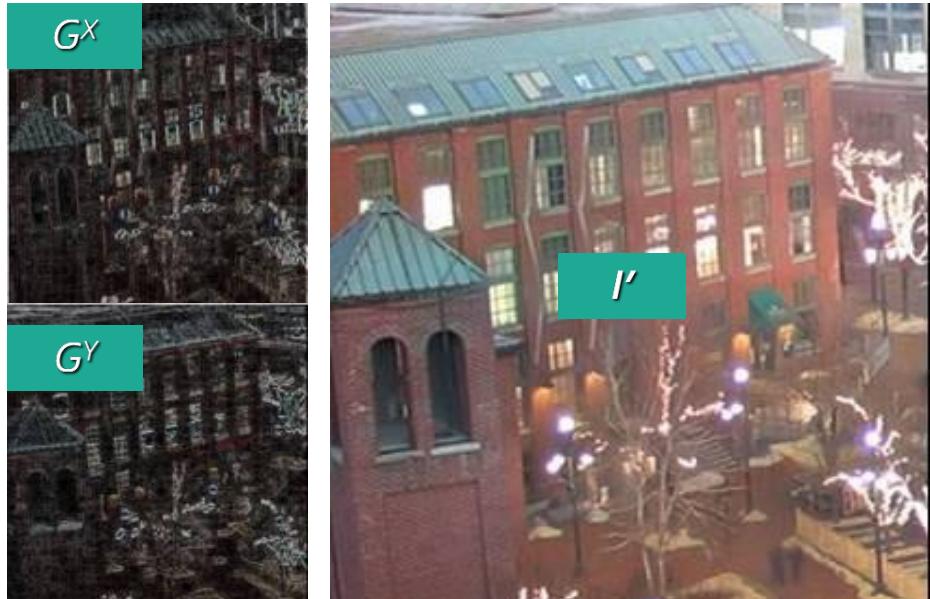
$$G = \nabla I'$$

$$|\nabla I' - G|$$

- Poisson equation

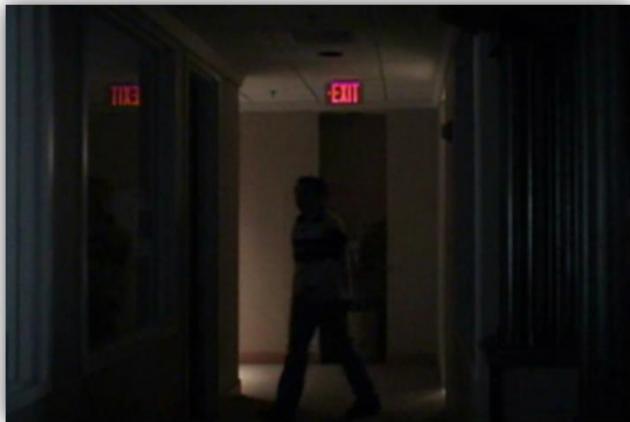
$$\nabla^2 I' = \operatorname{div} G$$

- Full multigrid solver



Video Enhancement using Fusion

- Video from fixed cameras
 - Improve low quality InfraRed video using high-quality visible video
 - Fill in dark areas, enhance change in intensity
 - Output style: better context
- Current Demo
 - Fusion of Night video and Daytime image



Original Video Frame

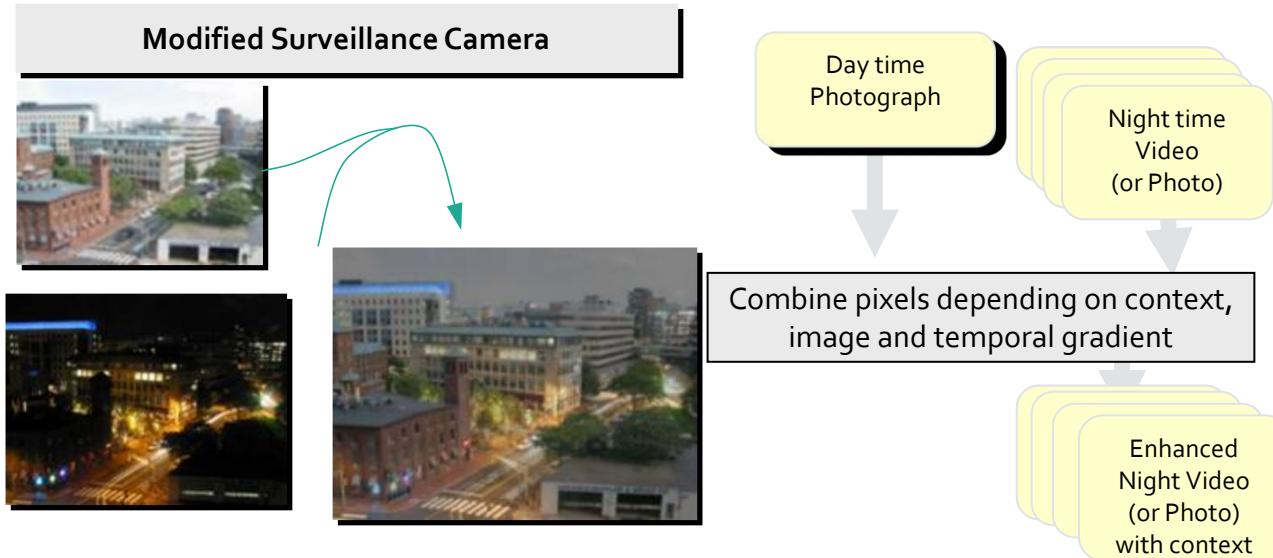


Easy-to-understand Non-photorealistic (NPR) Image or Video



Details

- Combine day and night time images
 - Night videos have low contrast, areas with no detail
 - Same camera during day can capture static information
 - Dark areas of night video are replaced to provide context
 - Moving object (from night) + Static scene (from day)





Video Enhancement using Fusion



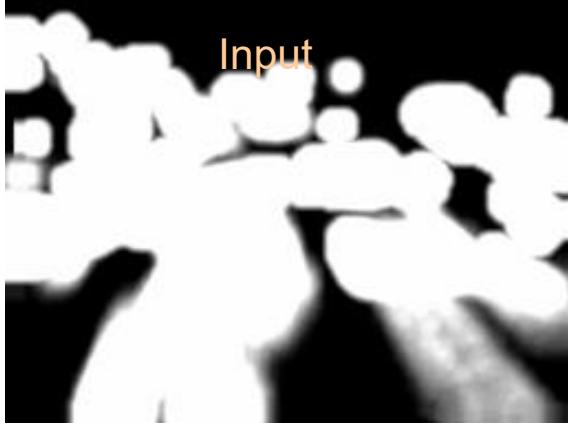


Video Enhancement using Fusion

Original night time
traffic camera
320x240 video



Mask frame (for
frame above):
Encodes pixel with
intensity change



Day time image: By
averaging 5 seconds
of day video



Enhanced video
Note: exit ramp,
lane dividers,
buildings not visible
in original night
video, but clearly
seen here.



Video Enhancement

Frame N

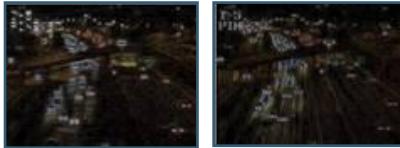


Processed binary mask

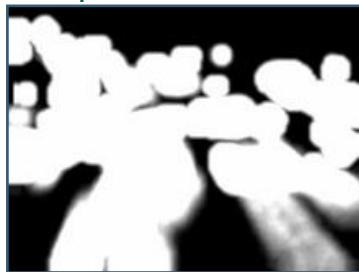


Frame $N-1$

Gradient field

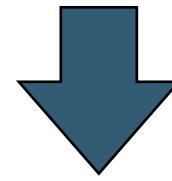


TimeAveraged
importance mask



Daytime image

Mixed gradient field



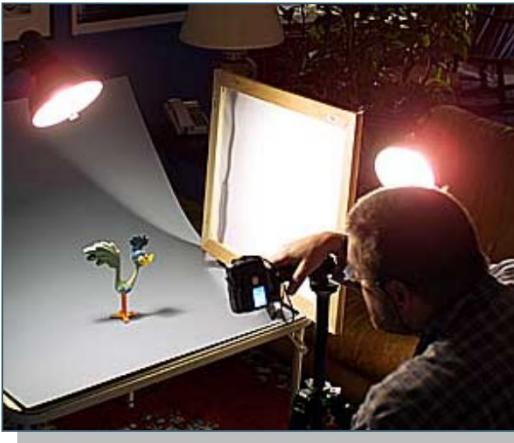
Final result



Gradient field



'Smarter' Lighting Equipment



Programmable Parameters



Today's Topic

- Light color/wavelength
- Spatial Modulation (Intra-flash 2D Modulation)
 - Synthetic Aperture Illumination
- Temporal Modulation
 - TV remote, Motion Tracking, Sony ID-cam, RFIG
- Exploiting (uncontrolled) Natural Lighting Condition
 - Day/Night



GAMES 204



Thank You!



Qilin Sun (孙启霖)

香港中文大学（深圳）
点昀技术（Point Spread Technology）