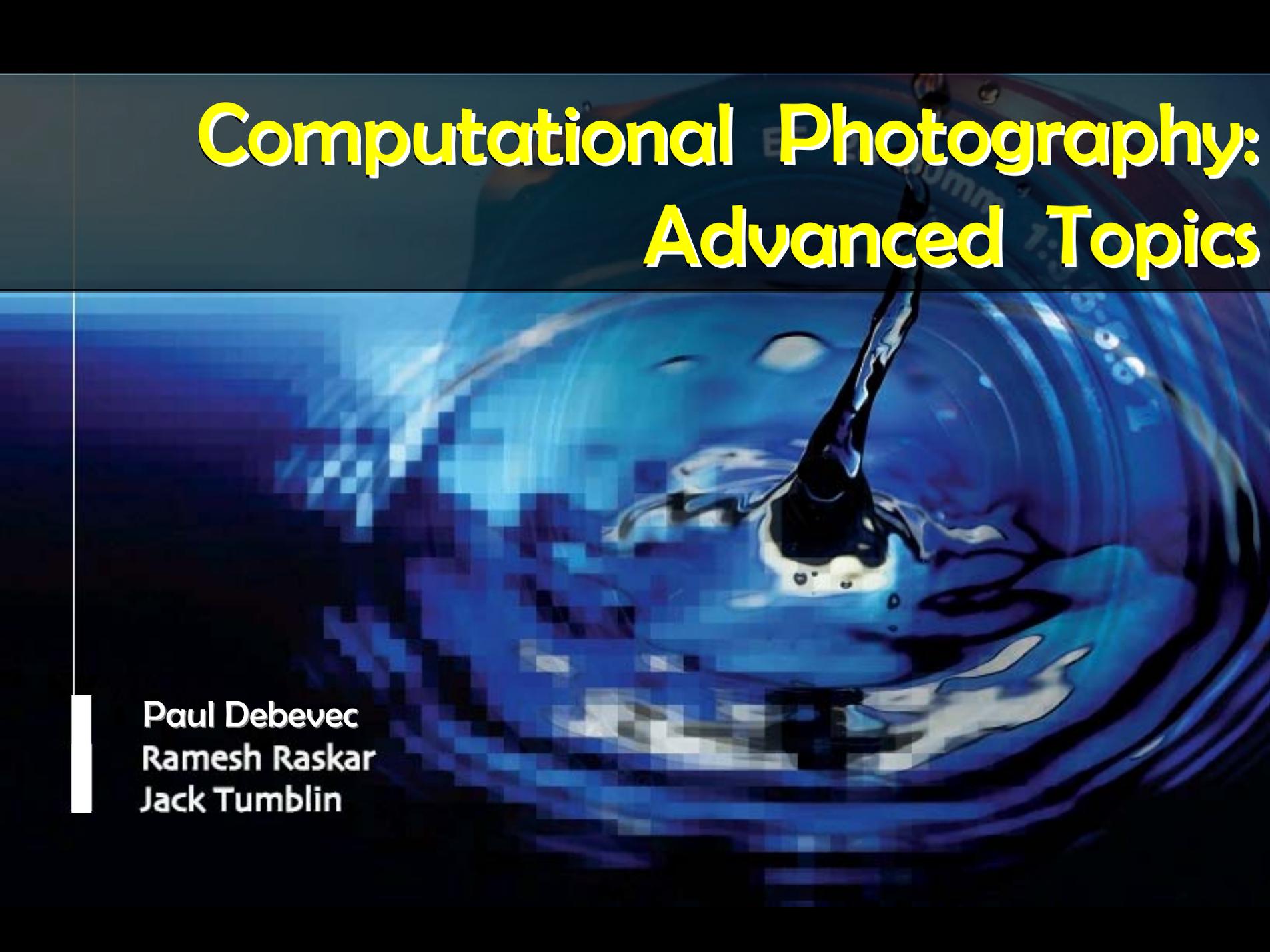




SIGGRAPH2008



Computational Photography: Advanced Topics

The background of the slide is a blue-tinted photograph of a water splash. The splash is captured in mid-air, with a central column of water falling into a pool of water below, creating ripples. The left side of the image is heavily pixelated, while the right side is smooth and clear. The overall color palette is dominated by various shades of blue, from deep navy to bright cyan.

Paul Debevec
Ramesh Raskar
Jack Tumblin

Class: Computational Photography, Advanced Topics

Debevec, Raskar and Tumblin

Module 1: 105 minutes

- 1:45: A.1 Introduction and Overview (Raskar, 15 minutes)
- 2:00: A.2 Concepts in Computational Photography (Tumblin, 15 minutes)
- 2:15: A.3 Optics: Computable Extensions (Raskar, 30 minutes)
- 2:45: A.4 Sensor Innovations (Tumblin, 30 minutes)
- 3:15: Q & A (15 minutes)

3:30: Break: 15 minutes

Module 2: 105 minutes

- 3:45: B.1 Illumination As Computing (Debevec, 25 minutes)
- 4:10: B.2 Scene and Performance Capture (Debevec, 20 minutes)
- 4:30: B.3 Image Aggregation & Sensible Extensions (Tumblin, 20 minutes)
- 4:50: B.4 Community and Social Impact (Raskar, 20 minutes)
- 5:10: B.4 Panel discussion (All, 20 minutes)

Class Page : <http://ComputationalPhotography.org>

Computational Photography: Advanced Topics

B3: Image Aggregation and Sensible Extensions (20 minutes)

Jack Tumblin

Northwestern University

Image Assembly

- Unordered images to...

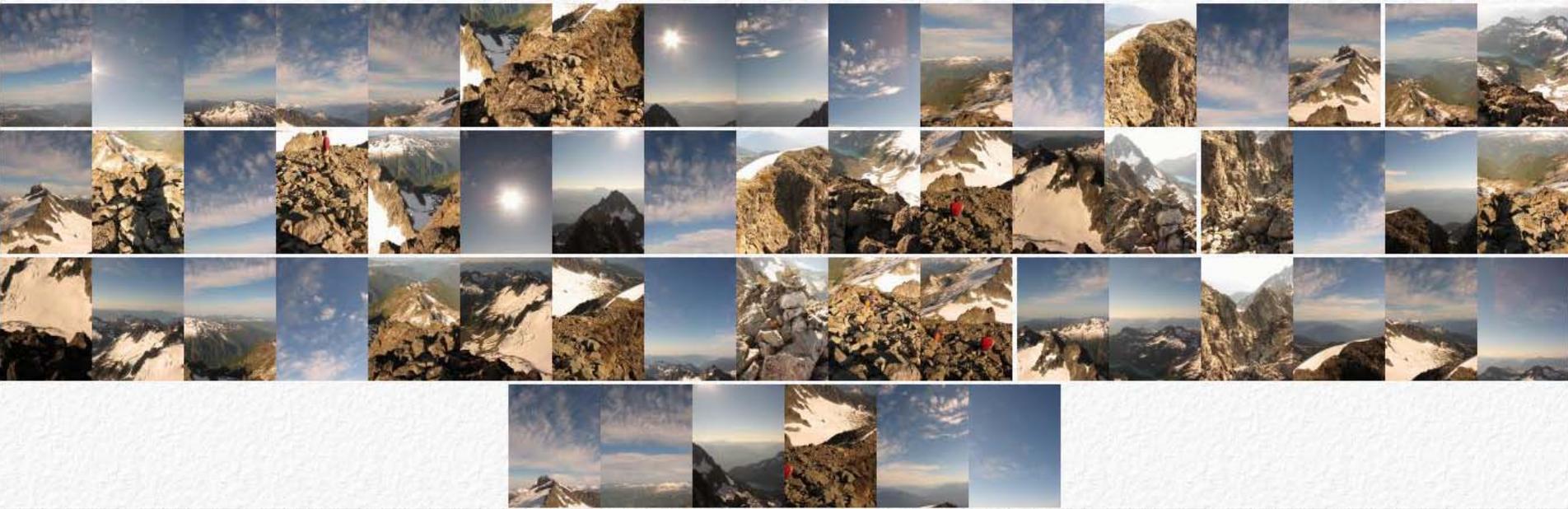


Image Assembly

- Unordered images to...



Aligned subset to...

Image Assembly

- Unordered images to...



Fully Aligned to...

Image Assembly

- Unordered images to...



Fully Aligned & matched.

- Panoramas: thousands on Flickr 'autostitch'

FUSION: Best-Focus Distance

NEAR



Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

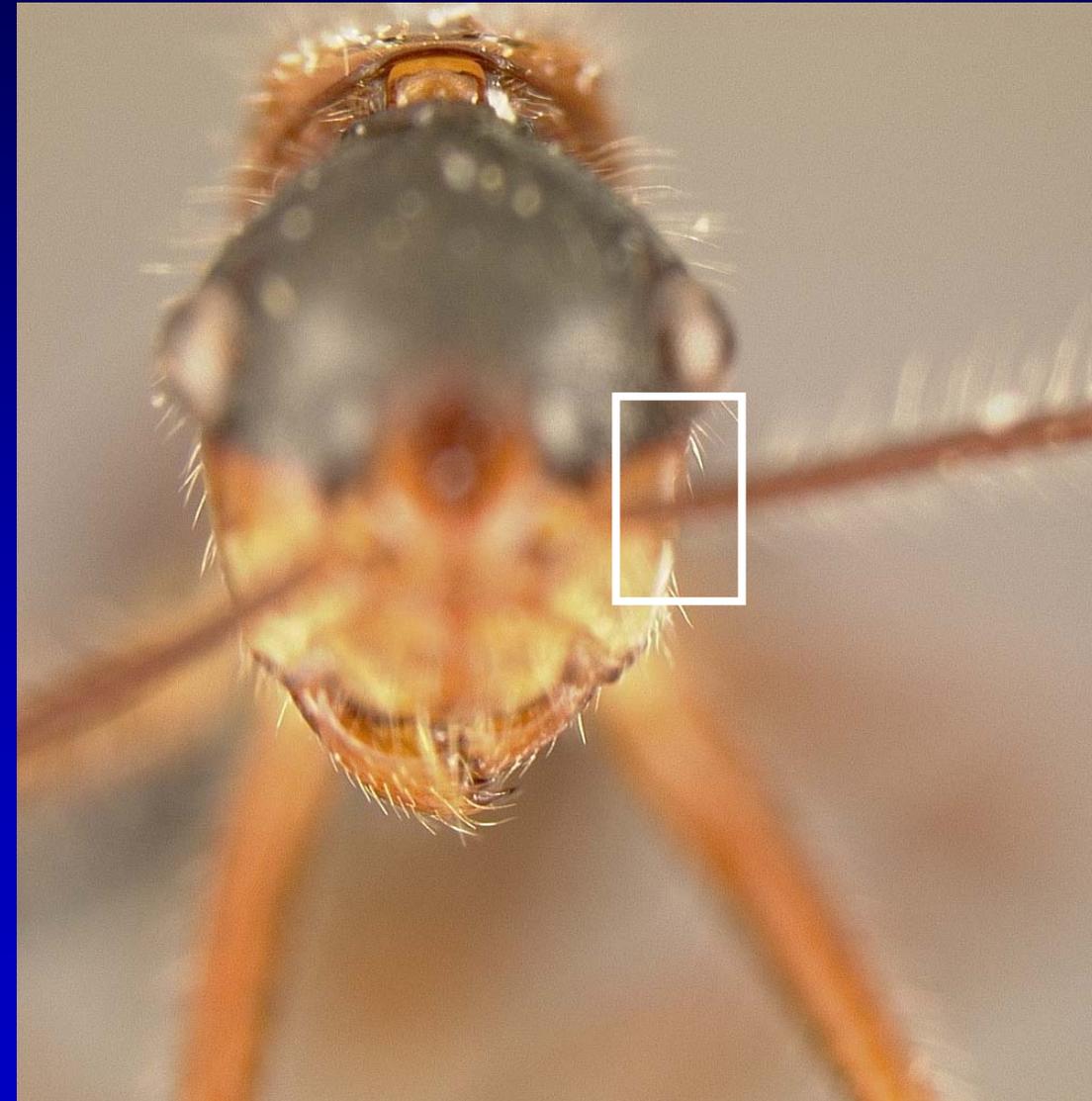
FUSION: Best-Focus Distance

FAR



Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

FUSION: Best-Focus Distance



Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

FUSION: Best-Focus Distance



Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

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Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

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Digital Photomontage
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Agrawala et al.,
Digital Photomontage
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Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

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Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

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Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

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Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

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Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

FUSION: Best-Focus Distance



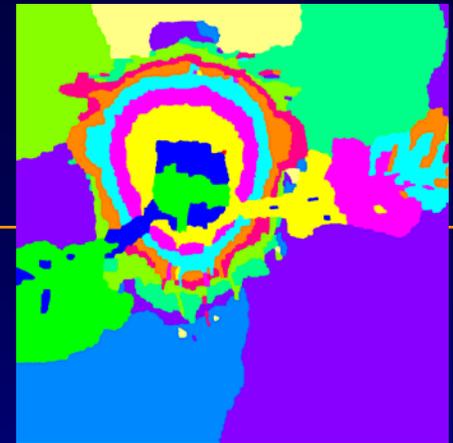
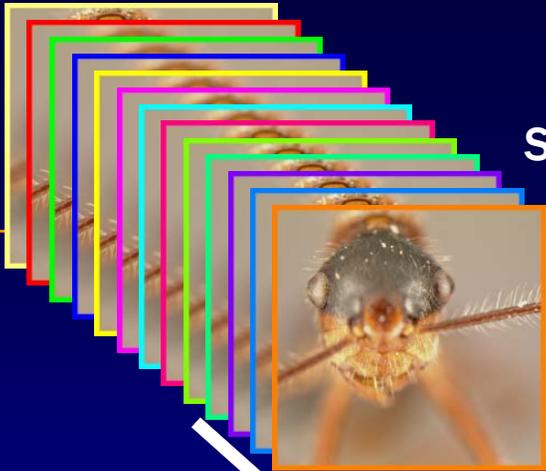
Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

FUSION: Best-Focus Distance



Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

Source images



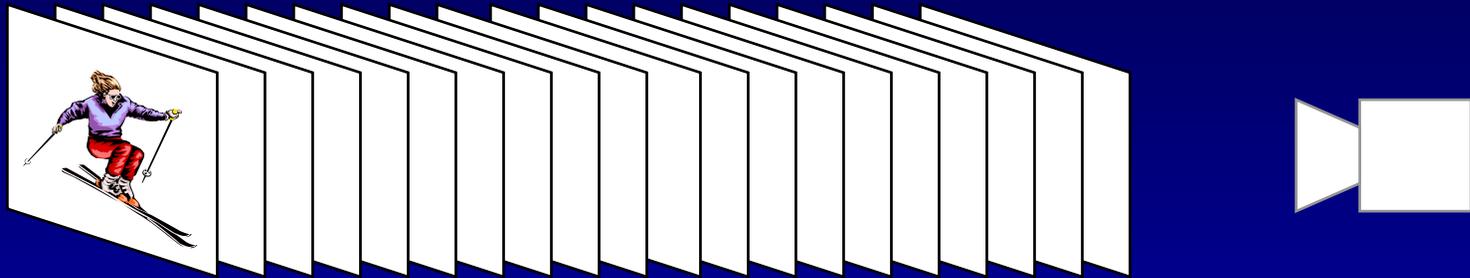
FUSION

'Graph Cuts' Solution



Agrawala et al.,
Digital Photomontage
SIGGRAPH 2004

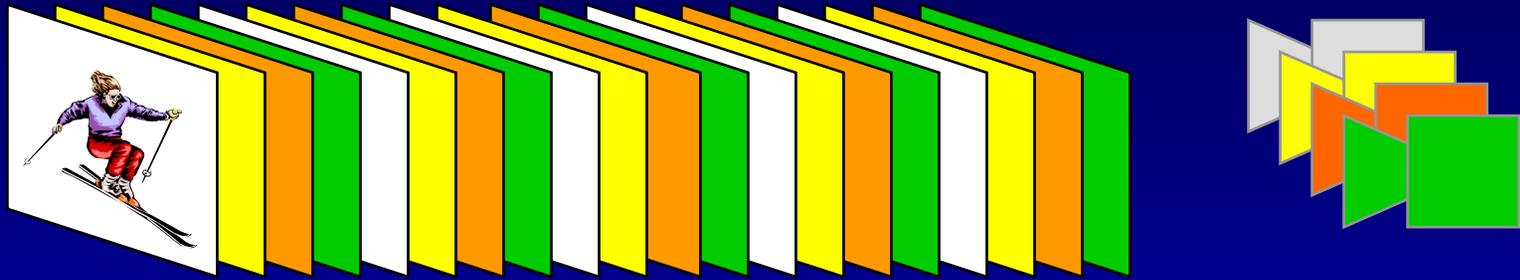
High Speed Video



Say you want 120 frame per second (fps) video.

- You could get one camera that runs at 120 fps
- Or...

High Speed Video



Say you want 120 frame per second (fps) video.

- You could get one camera that runs at 120 fps
- Or... get 4 cameras running at 30 fps.

52 Camera Cluster, 1560 FPS

Levoy et al., SIGGRAPH2005



What else can we extend?

Film-Like Camera Parameters:

- Field of View: image stitching for panoramas
- Dynamic Range: **Radiance Maps**
- Frame Rate: Interleaved Video
- Resolution: 'Super-resolution' methods

Visual Appearance & Content:

What else can we extend?

Film-Like Camera Parameters:

- Field of View: image stitching
- Dynamic Range: Radiance transfer [Lefohn]
- Frame Rate: Super-resolution video [Levoy]
- Resolution: Super-resolution methods [Nayar]

--- DONE! --- (mostly)

Visual Appearance & Available Content:

- Temporal Continuity: Space-time mixtures
- Viewpoint Constraints: Photo-Tourism, flexible collage
- Seam Carving & Resizing: least-loss deletions
- Learning from Large Datasets: day/night, scene elements
- Transfer Visible Details – Multi-Light, IR relighting...

Visually Expressive 'Time Fragments'

- Duchamp
 - Nude Descending a Staircase



FUSION: Time/Space Mixtures



Richard Hundley 2001



Strip Photography (1960s, Davidhazy)

- Time increases left-to-right;
- Girl in rotating chair





Time-Space FUSION: Shape-Time Photography



Freeman et al 2003



(b)



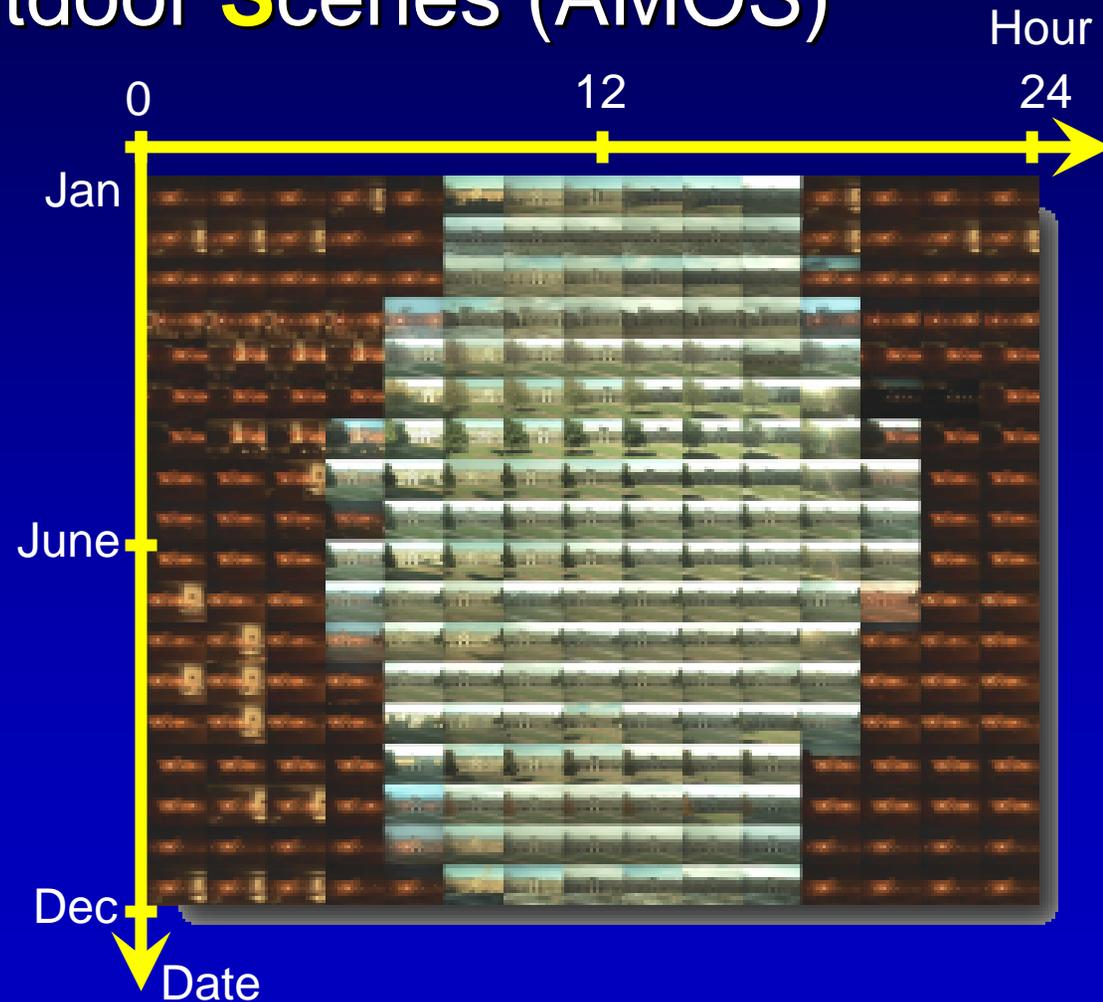
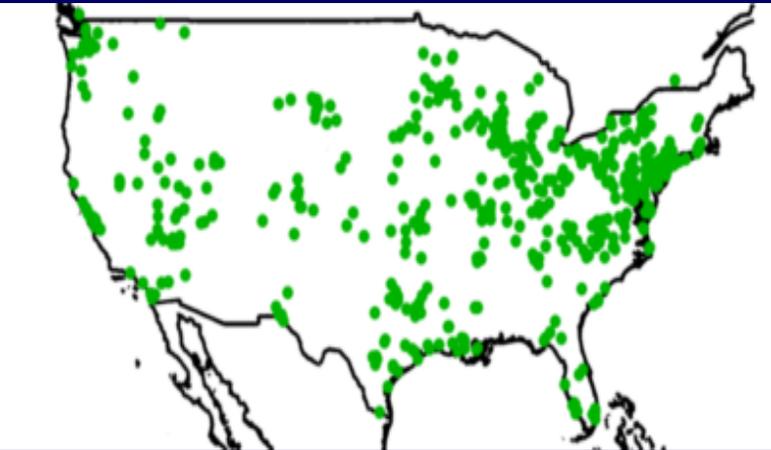
(c)



(d)

Webcam Image sets: What can we learn?

Archive of **M**any **O**utdoor **S**cenescs (AMOS)



- 2006 start
- >500 webcams
- >20 million photos

Temporal Variations: VERY consistent

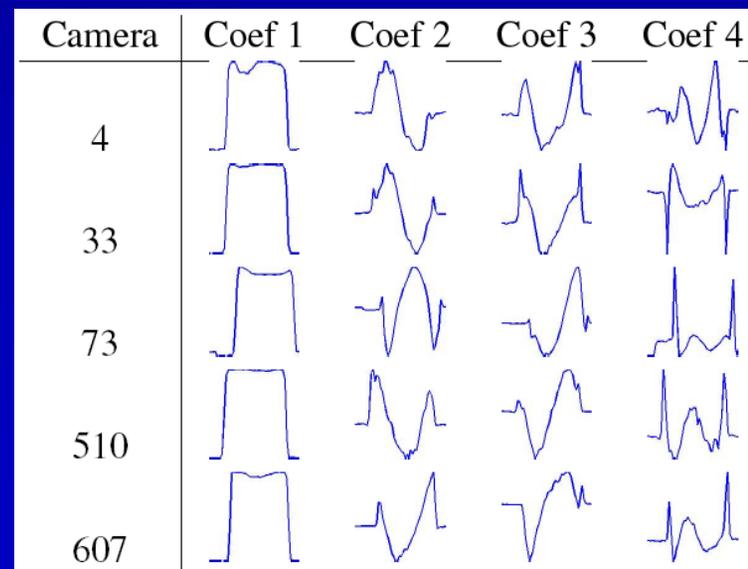
PCA on image sets

- 1st 4 components:
→ hour-of-day
- 2nd Order statistics



Annotate images for:

- Weather, Seasons,
- Surface normals,
- Geog. Orientations...



Temporal Variations: VERY consistent

From time-stamped
image sequence



Find Geographic
Location within
50 miles

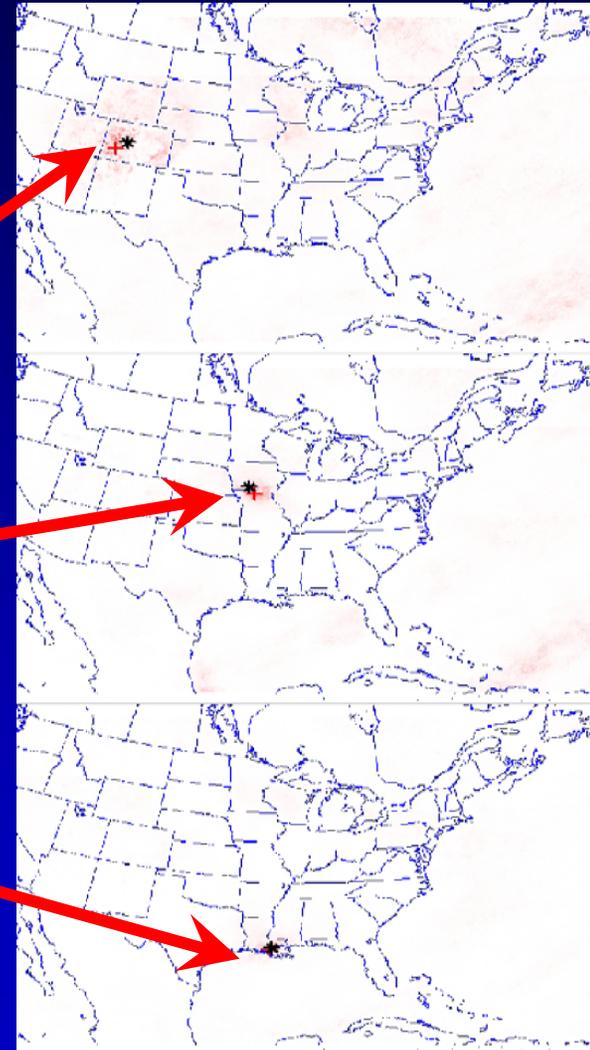


Photo Tourism

"Photo Tourism: Exploring Photo collections In in 3D" Snavely et al., SIGGRAPH 2006

- Many uncalibrated photos of popular sites
- Each have many 3D scene point-correspondences



- Find, solve for 3D scene points & each camera's 3D pose
- Reproject on 3D shapes, use view interpolation
- Friendly UI sketch-like: explore by 3D flying...

TRY IT! <http://phototour.cs.washington.edu/>

Feature matching

"Photo Tourism: Exploring Photo collections In in 3D" Snavely et al., SIGGRAPH 2006

- Find Features [SIFT, Lowe IJCV04], then
- Find pairwise matches (refined by RANSAC), then
- Find connected pairs' components, then SfM, ...

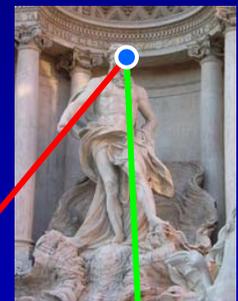
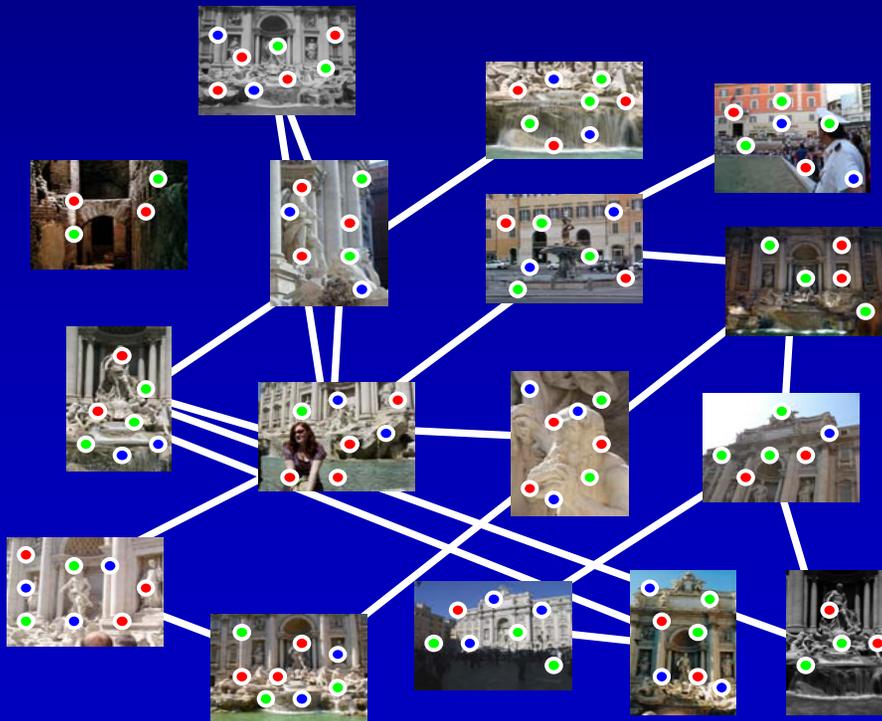


Image 2

Image 4

Photo Tourism

"Photo Tourism: Exploring Photo collections In in 3D" Snavely et al., SIGGRAPH 2006

'Structure from Motion'

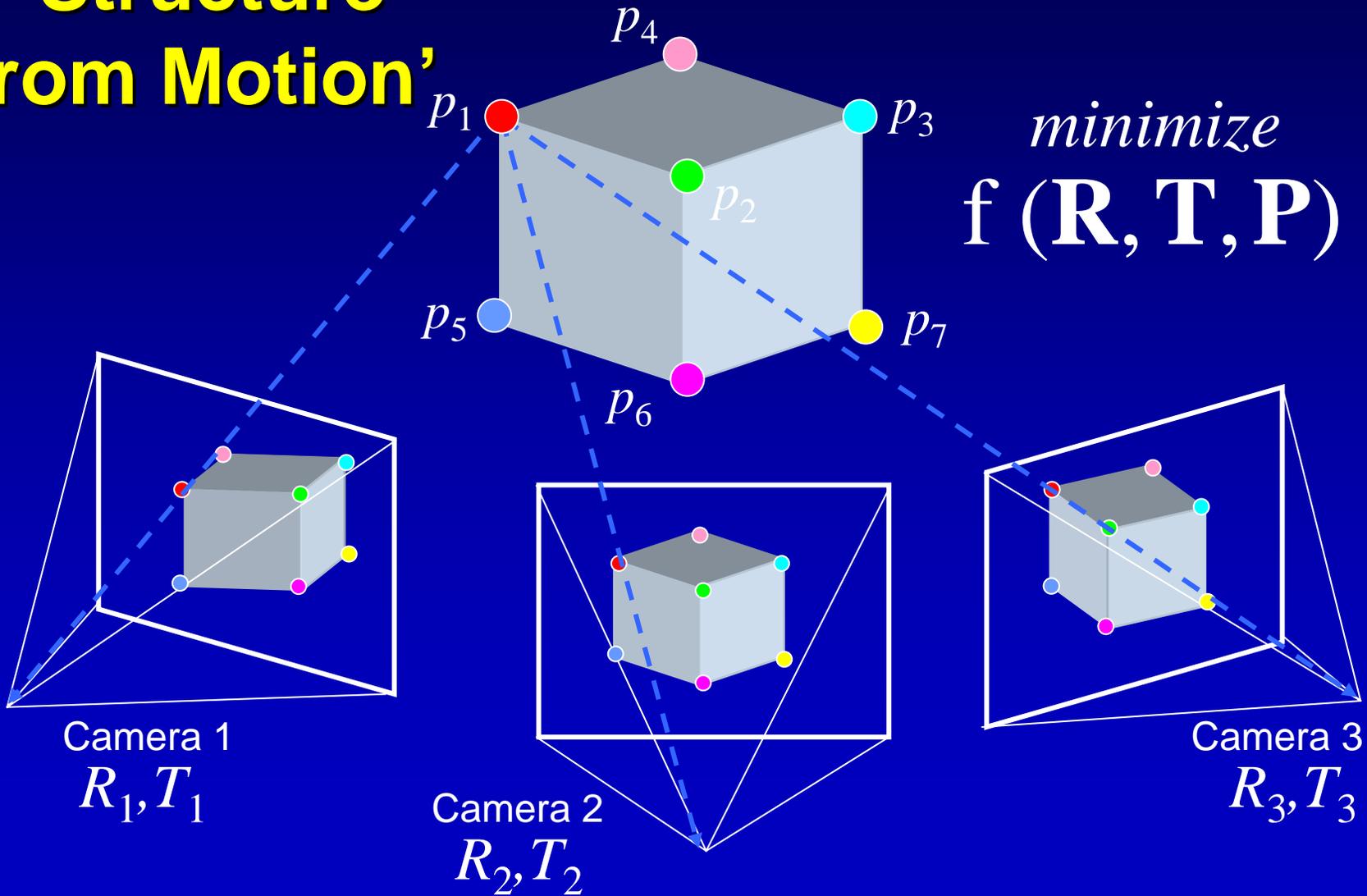


Photo Tourism

"Photo Tourism: Exploring Photo collections In in 3D" Snavely et al., SIGGRAPH 2006

sd



A tiled camera array



- 12×8 array of VGA cameras
- abutted: **7680 \times 3840 pixels**
- overlapped 50%: half of this
- total field of view = 29° wide
- (seamless mosaic: not hard)
- cameras individually metered
- **Approx same center-of-proj.**

“High performance imaging using large camera arrays”
Wilburn, Levoy et al.; SIGGRAPH 2005)

Tiled panoramic image (before)



“High performance imaging using large camera arrays” *Wilburn, Levoy SIGG'05*)

Tiled panoramic image (after)

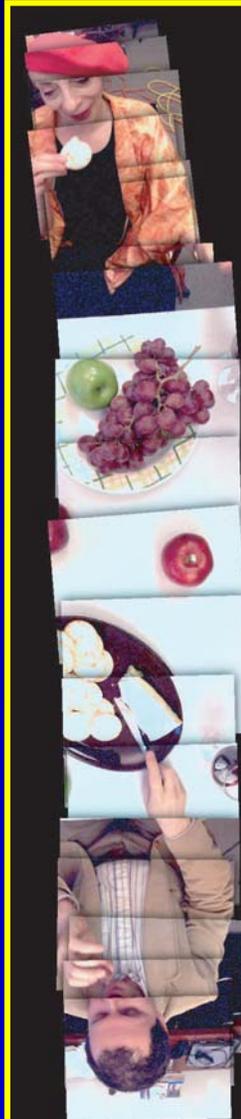
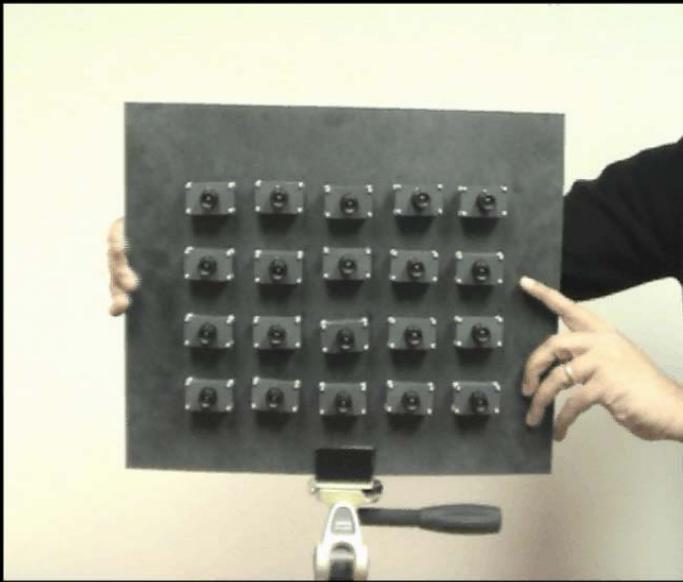


“High performance imaging using large camera arrays” *Wilburn, Levoy SIGG'05*)

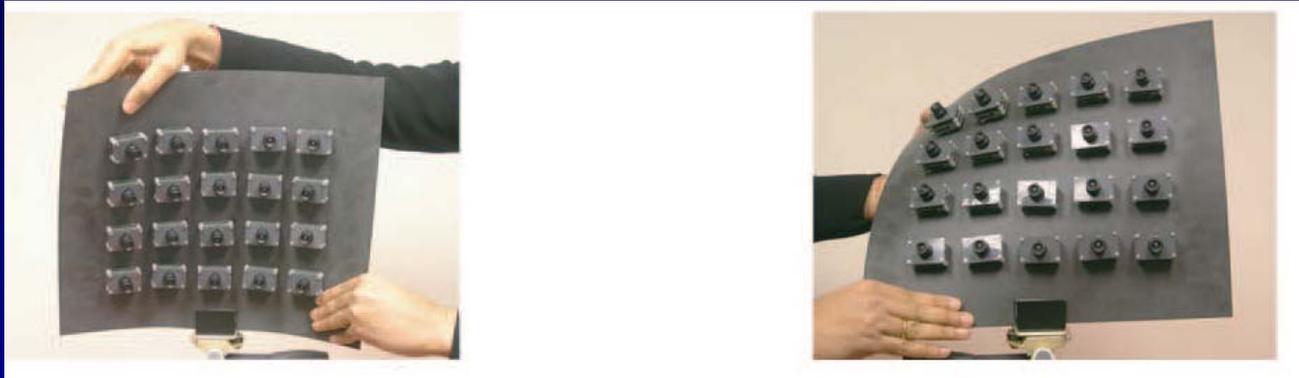
Scene Collage & Flexible Camera Arrays

"Scene Collages and Flexible Camera Arrays," Y. Nomura, L. Zhang and S.K. Nayar, EGSR 2007.

- bend the camera-sheet to fit the scene
- Align, mix, blend photos in video collage



Scene Collage & Flexible Camera Arrays



"Scene Collages and Flexible Camera Arrays," Y. Nomura, L. Zhang and S.K. Nayar, EGSR 2007.

Multi-Light Detail Transfer

SIGG2007 Fattal et al., Multiscale Shape and Detail Enhancement from Multi-light Image Collections

- Different light \rightarrow Different visible details
- Extract, Control/Enhance, Merge details



Multi-Light Detail Transfer

SIGG2007 Fattal et al., Multiscale Shape and Detail Enhancement from Multi-light Image Collections

- Different light \rightarrow Different visible details
- Extract, Control/Enhance, Merge details



Light 1

Multi-Light Detail Transfer

SIGG2007 Fattal et al., Multiscale Shape and Detail Enhancement from Multi-light Image Collections

- Different light → Different visible details
- Extract, Control/Enhance, Merge details

Light 2



Multi-Light Detail Transfer

SIGG2007 Fattal et al., Multiscale Shape and Detail Enhancement from Multi-light Image Collections

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Multi-Light Detail Transfer

SIGG2007 Fattal et al., Multiscale Shape and Detail Enhancement from Multi-light Image Collections

- Different light → Different visible details
- Extract, Control/Enhance, Merge details

- Bilateral filters
- User-set weights
- Adjust to suit...
flat, detailed or
with shadows



Multi-Light Detail Transfer

SIGG2007 Fattal et al., Multiscale Shape and Detail Enhancement from Multi-light Image Collections

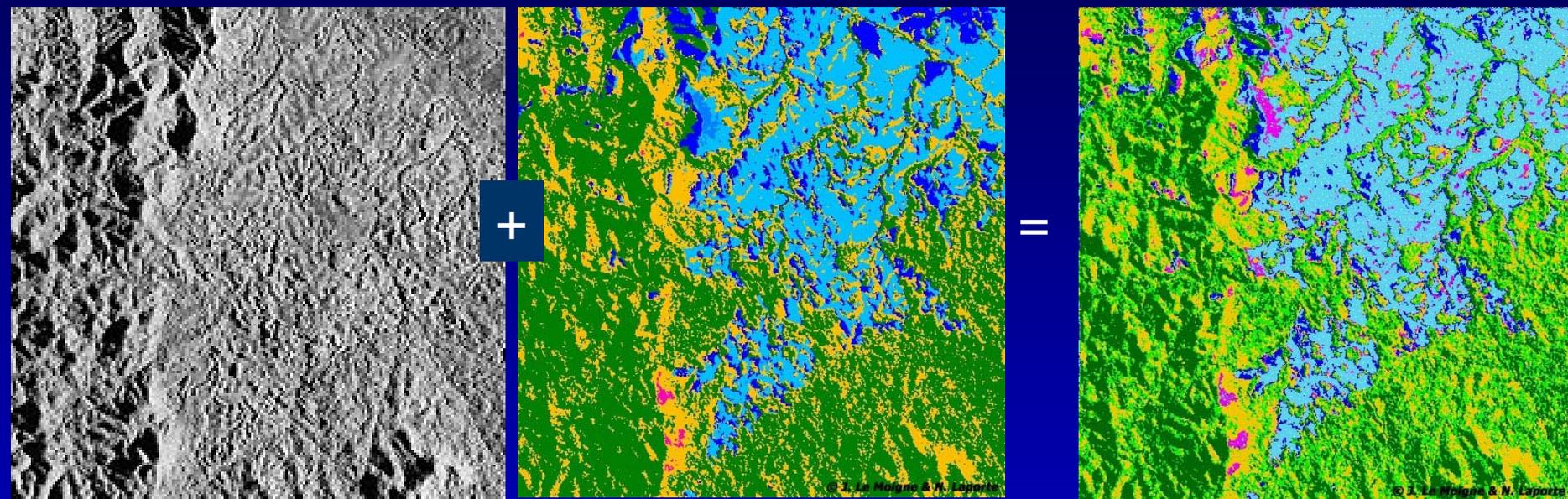
- Different light \rightarrow Different visible details
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flat, detailed or
with shadows



FUSION: Multispectral Wavelengths

Vegetation Mapping of the Forest



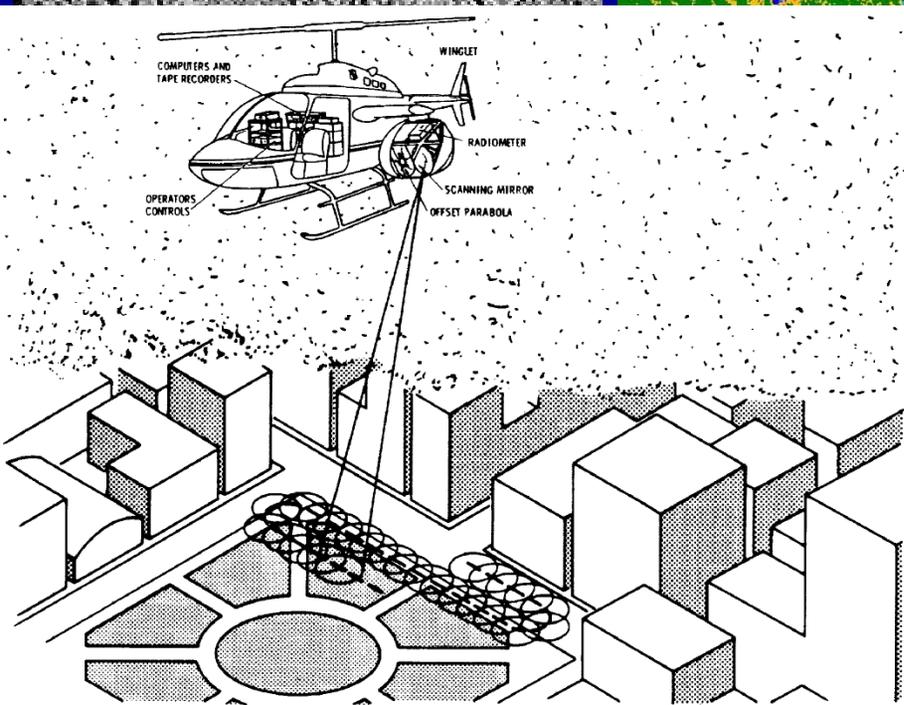
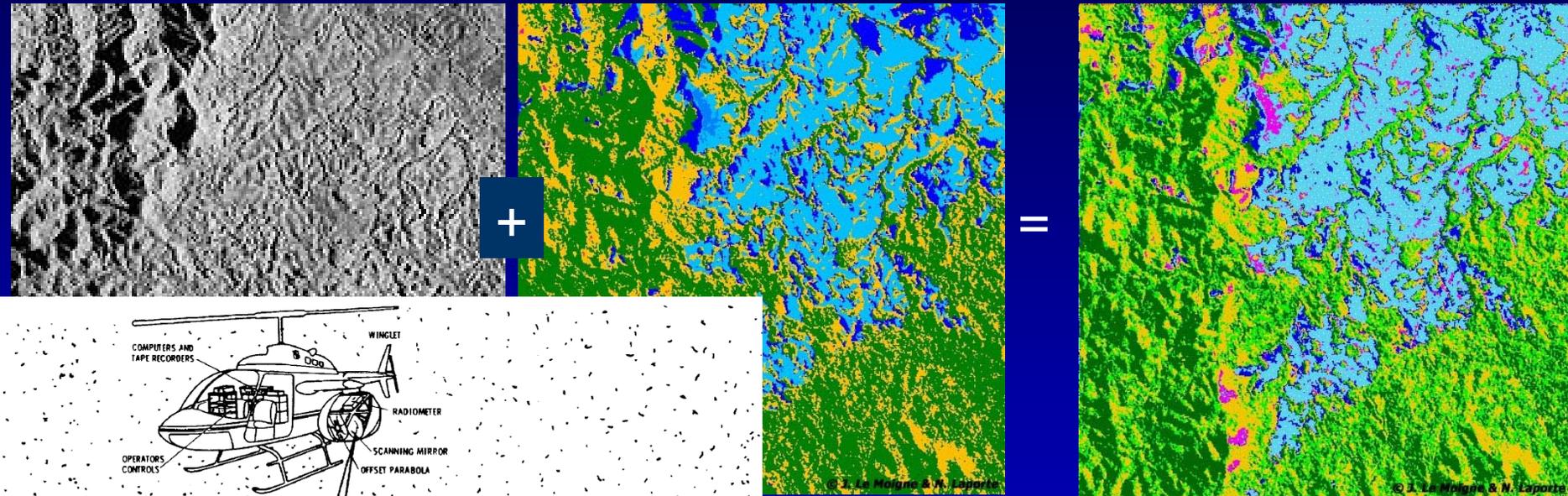
SAR

Optical Landsat

- | | |
|---------------------------------------------------------------------------------------|-------------------|
|  | Mountain forest |
|  | Mixed forest |
|  | Okoume forest |
|  | Grassland Savanna |
|  | Fern Savanna |
|  | Burnt Savanna |

FUSION: Multispectral Wavelengths

Vegetation Mapping of the Forest



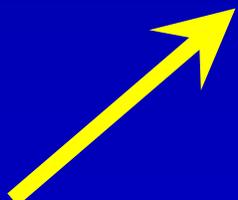
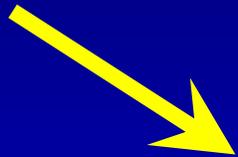
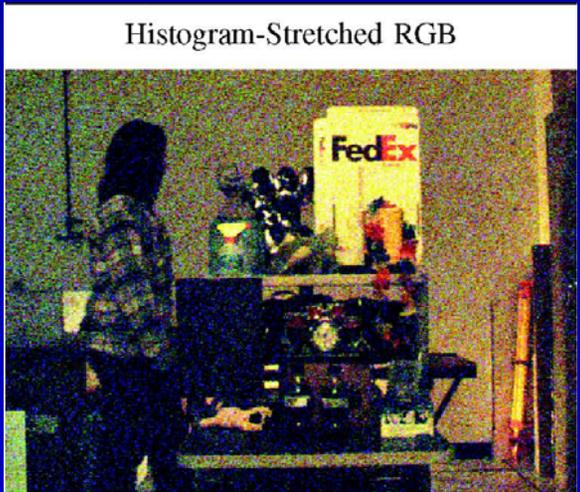
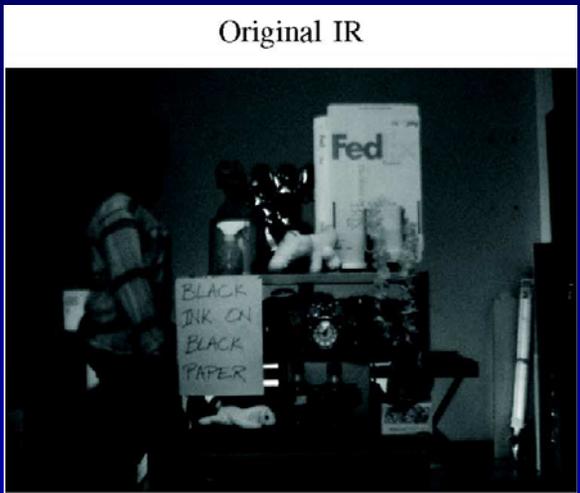
l Landsat

- Mountain forest
- Mixed forest
- Okoume forest
- Grassland Savanna
- Fern Savanna
- Burnt Savanna

Bennett2007: Multispectral Video Fusion

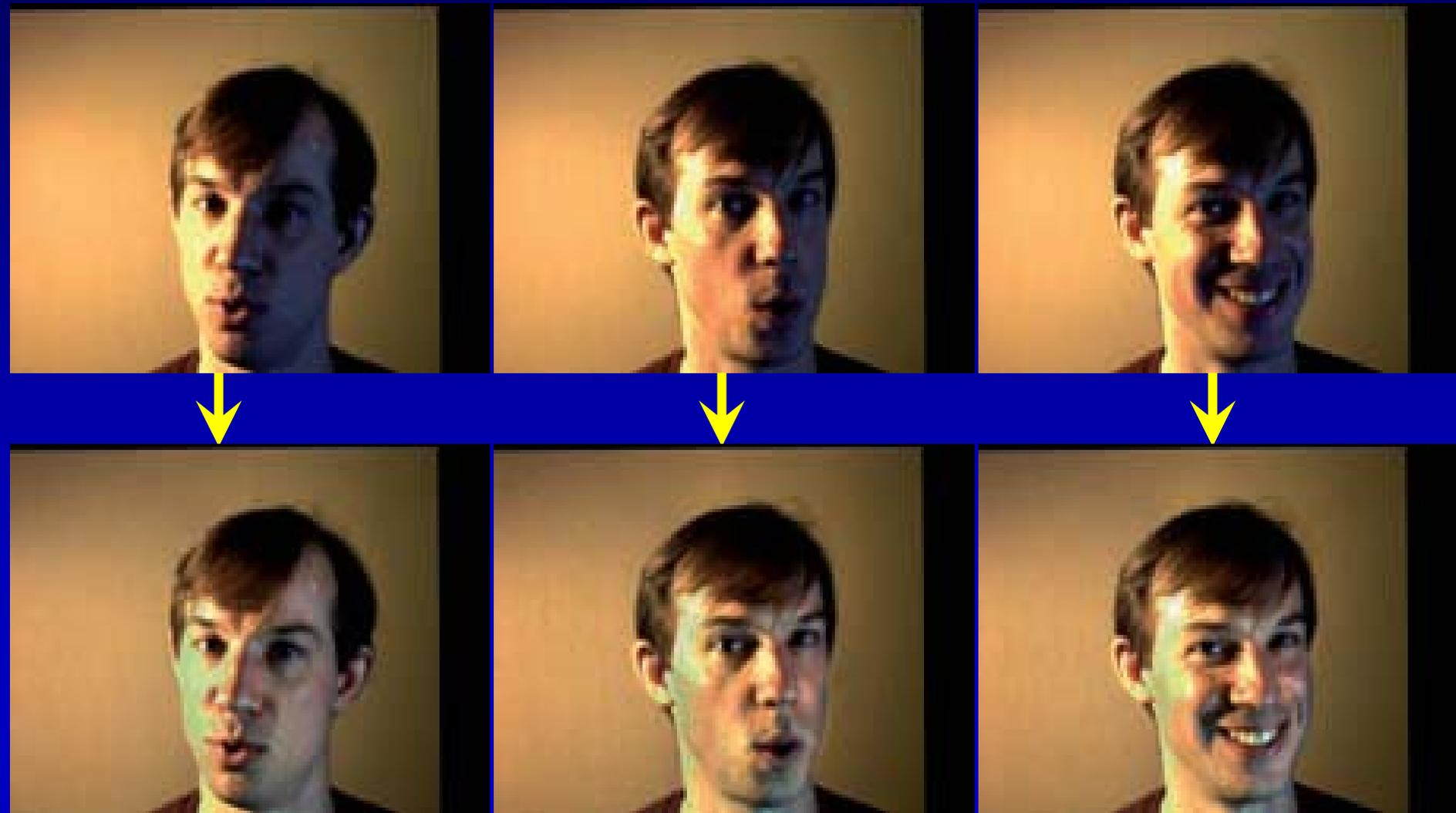
Dual-Bilateral filter:

fuses best of visible + IR



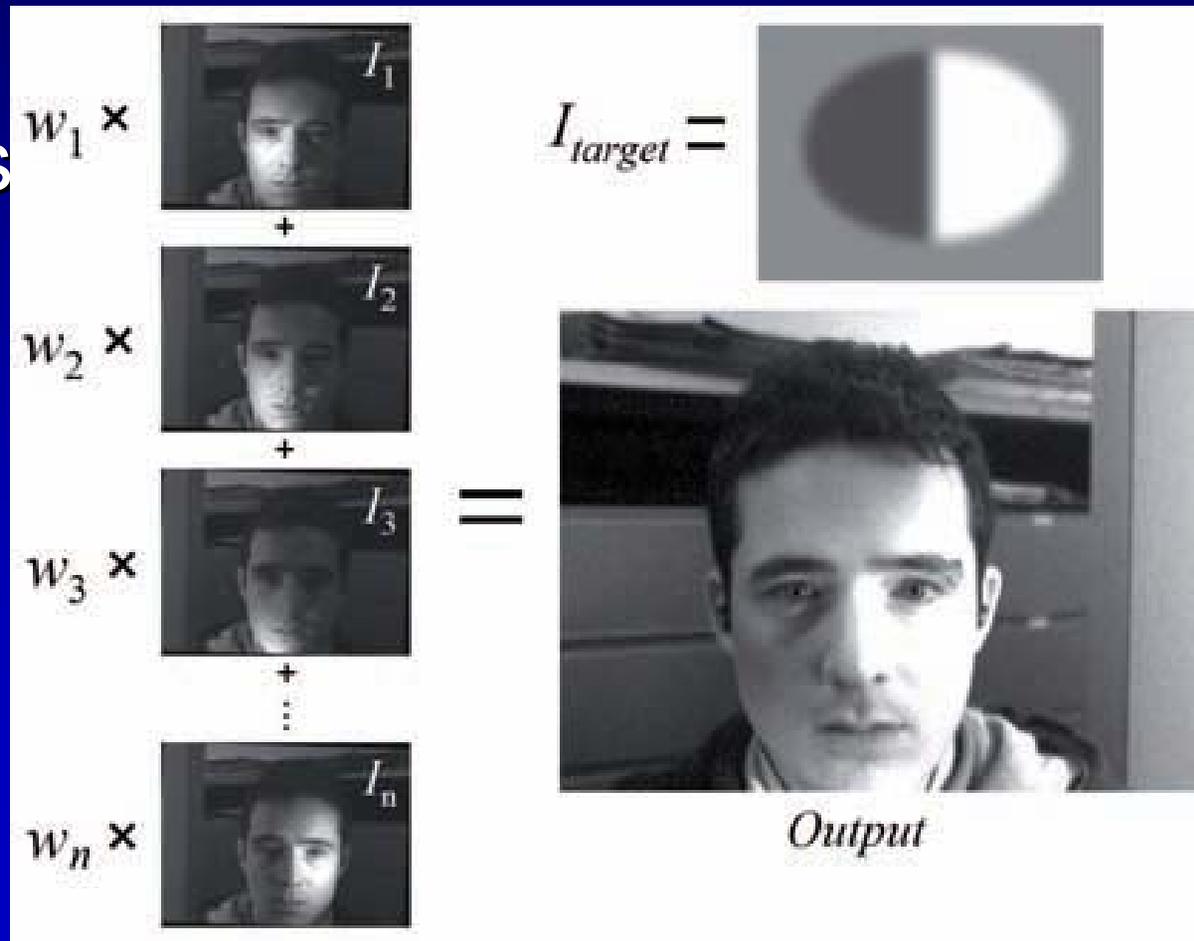
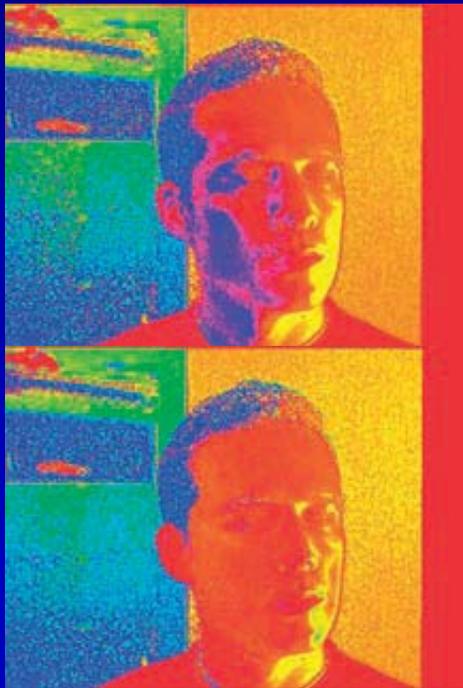
Video Relighting from IR illumination

EG2008, Wang, Davis et al. "Video Relighting Using Infrared Illumination"



Video Relighting from IR Illumination

- Switched IR illuminators, 8 photos per frame
- Ratio Images
- Hue Corrections



Seam Carving: Content-Aware Resizing

SIGG2007: "Seam Carving for Content Aware Image Resizing" Avidan, Shamir

SEE ALSO SIGG 2008: "Improved Seam Carving for Video Retargeting" Rubenstien et al.



- Find 'least-damaging' seam
(top→bottom or left→right connected path)
- Remove seam, or insert a similar one...

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- Find, remove 'least-damaging' seam (top→bottom or left→right connected path)



SEE ALSO SIGG 2008: "Improved Seam Carving for Video Retargeting" Rubenstien et al.

Perspective? Or Not?



Agrawala et al, "Long Scene Panoramas", Siggraph 2006



Rademacher et al, MCOP, Siggraph 1998

Conclusions

- Merged Multiple Measurements:
 - Multi-camera, multi-sensor,
multi-optics, multi-lighting
- Can escape obvious Optical Limits, sure...
 - lens diffraction limits, noise, available light
 - Measurement time, position, occlusion, pose
- But ALSO ‘optically impossible’ visual experiences
 - Sunless shadows, Invisible lighting, wrap-around viewpoints



SIGGRAPH2008

