Image Collections

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Outline

- Motivation
- Historical Perspective
- Conceptual Framework
- Main Mathematical Tools
- Basic Computational Techniques
- Application Examples

Teaser

- What these two images have in common?

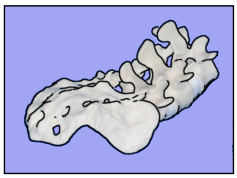
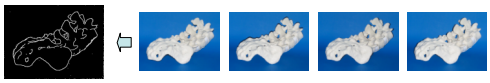


Image Collections

- Generated from many images…

Group Portrait

Medical Illustration



Recent Trend

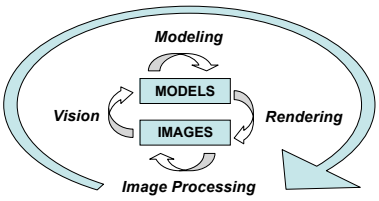
Computational Photography and Video

+

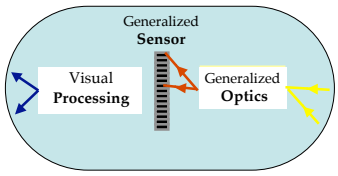
Image Based Modeling and Rendering

- Convergence of Areas

Image-Based Graphics



Computational Vision



- *Intelligent Acquisition Devices*

Events

- Pioneering Workshops
  - Stanford Workshop, 1998
  - MIT Workshop, 2005
- Dedicated Courses
  - Image-Based Modeling and Rendering
  - Computational Photography
- General Conferences
  - Graphics (SIGGRAPH, Eurographics, …)
  - Vision (ICCV, CVPR, …)

It's Already Here

- SIGGRAPH 2006
  - Session on *Image Collections*
- IMPA 2006 - Courses
  - Analysis and Synthesis from Image Collections
  - Image Processing and Computational Photography

Our Goals

- *Elaborate on Basic Concepts*
- *Discuss Related Theory*
- *Understand the Main Techniques*
- *Overview of Emerging Applications*
- *Identify Research Trends*

Image Collections

- Defining Questions
  - *What are Image Collections?*
  - *Why do We Need Them?*
  - *How to Make Interesting Things?*
- Topics for Study
  - Mathematical Tools
  - Computational Techniques
  - Areas of Applications

What are Image Collections?

- Definition:

Set of Images $\{ I_k \}$ *with the following properties:*

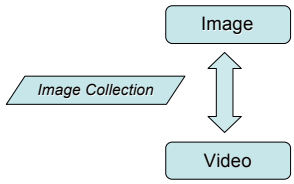
1. *Share Affinity Relation,* $\mathcal{A}$
2. *Mapped to Common Support,* U
3. *Underlying Attribute Model,* $\mathcal{M}$

Affinity

- Coherence Binding
  - Spatial (*same position*)
  - Temporal (*same time*)
  - Subject (*same object*)
  - etc…
- Guaranteed by Construction
  (*often in the acquisition setup*)

OBS: *New Kind of Object*

- Intermediate Media Type



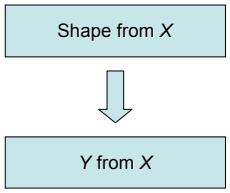
➢ *More General, Forward Looking*

Why We Need Them ?

➢ *To Create New Graphic Objects*

- Analysis / Synthesis
  - Underlying Model
  - Common Support
- *Not Necessarily an Image…*
  - Fusion (2D Image)
  - Re-synthesis (2.5 D sequence)
  - Reconstruction (3D object)

Generalization



Shape from ***X***

- Basic Vision Problem
  - Stereo (Projection)
  - Shading (Illumination)
  - Defocus (Optics)
  - Texture (Appearance)
  - etc..
- *Inference from a Known Model*

Y from ***X***

X is an Image Collection

Y is a General Graphics Object

➢ Inference from a Non-Parametric Model
(*Image-Based*)

➢ Exploit Controlled Variation

Understanding the Differences…

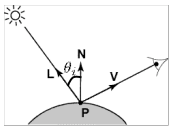
Example:
- Computation of Normals from Photographs

- Vision Approach
  - *Shape from Shading*
- Image-Based Approach
  - *Photometric Reconstruction*

Shape from Shading

Lambertian Model

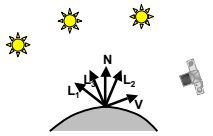
$$I = \rho \cos\theta_i$$



- Simplifying Assumptions
  - Constant Reflectance (ρ = 1)
  - Continuity / Smoothness (*integrability*)
  - Boundary Conditions (*normals at silhouette*)

- Difficult to Compute in Practice…

Photometric Reconstruction



$$\begin{aligned} I_1 &= k_d \mathbf{N} \cdot \mathbf{L}_1 \\ I_2 &= k_d \mathbf{N} \cdot \mathbf{L}_2 \\ I_3 &= k_d \mathbf{N} \cdot \mathbf{L}_3 \end{aligned}$$

$$N = \frac{1}{k_d}\left(L^{-1} I\right)$$

$$\underbrace{\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}}_{\mathbf{I}_{3\times 1}} = \underbrace{\begin{bmatrix} \mathbf{L_1}^T \\ \mathbf{L_2}^T \\ \mathbf{L_3}^T \end{bmatrix}}_{\mathbf{L}_{3\times 3}} \underbrace{k_d \mathbf{N}}_{\mathbf{G}_{3\times 1}}$$

Controlled Variation

➢ Only One Parameter is Varying

➢ All Other Parameters are Constant

Some Examples

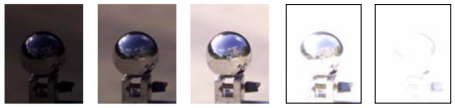
- Scene
- Exposure
- View
- Subject
- Movement

Scene

- Background + Foreground Decomposition
  - Scene without / with Objects
  - Same Scene / Different Objects


Exposure

- High Dynamic Range Imaging
  - Same Scene / Different Exposure



1/2000s 1/500s 1/125s 1/30s 1/8s

View

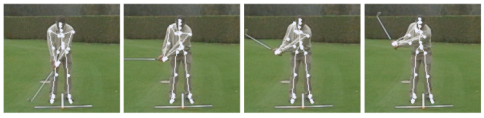
- Panoramas
  - Same Viewpoint / Different Orientation

Subject

- Faces
  - Same Person / Different Expressions

Movement

- Motion Capture / Tracking
  - Same Object / Different Poses



How to Make Interesting Things?

- Problems to Solve:
  - Registration
  - Segmentation
  - Model Estimation
  - Fusion
  - Re-Synthesis

Registration

- Coarse
  - Feature Detection
  - Matching
- Dense
  - Optical Flow

Segmentation

- Edge-Based
- Region-Based

* Mask Construction

Model Estimation

- Multi-Linear
- Bayesian
- Perceptual
- Projective

Fusion

- Blending
- Compositing
- Reconstruction

Re-Synthesis

- Stochastic (Noise)
- Spectral
- Pattern

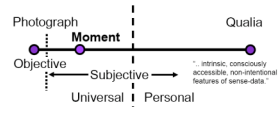
Remarks

Some operations may be Trivial (e.g. Identity*)*

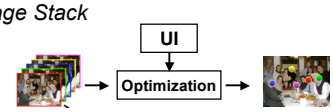
- Registration
  - Static Camera / Object
- Segmentation
  - Known Neutral Background
- Modeling
  - *Given*
- Fusion
  - Union or Superposition
- Re-Synthesis
  - Null

Related Ideas (*by Michael Cohen*)

- *the Moment…*



- *Image Stack*



Visual Computing Tools

- Image Processing
  - Data Preparation
- Computational Geometry
  - Spatial Relations
- Graph Theory
  - Structure

Mathematical Tools

- Probability
  - Common Aspects
- Statistics
  - Parameter Estimation
- Optimization
  - Best Fitting Models

Energy Functionals

- Functions for Analysis / Combination
  - Minimizers of an Energy from the Model
- Bayesian Models
  - *A priori* Knowledge
  - Good Energy Functionals

Emerging Techniques

- Graph Cuts
- Gradient-Domain Blending
- Bilateral Filters
- Multi-linear Models
- SIFT
- Epitome
- Mean Shift
- …

Recent Papers

- Panoramas
- Video Textures
- HDR
- Flash / No-Flash
- Texture Synthesis
- Hole Filling / Inpainting
- Denoising
- Color Enhancement
- Object Selection
- Photomontage

One Last Example…

- Photo Tourism

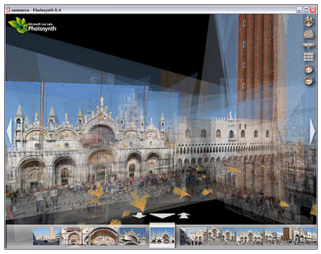



Photo Tourism
Exploring photo collections in 3D
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Steven M. Seitz
Richard Szeliski
University of Washington
Microsoft Research
SIGGRAPH 2006

Thanks !