The world in photos

- There are **billions** of photos online
- Photographic record of the surface of the earth
- Photo sharing on a massive scale

20,000 images of Rome
How can we manipulate (visualize, navigate, find) such immense numbers of images?

Photo Tourism overview

Input photographs

Relative camera positions and orientations
Point cloud
Sparse correspondence

Scene reconstruction

Photo Explorer

Photo Tourism
[Snively, Seitz, Szeliski, SIGGRAPH 2006]
Scene reconstruction

- Automatically estimate
  - position, orientation, and focal length of cameras
  - 3D positions of feature points

Feature detection

Pairwise feature matching

Correspondence estimation

Incremental structure from motion

Structure from motion

\[
\text{minimize } f(R, T, P)
\]

Incremental structure from motion

- Automatically select an initial pair of images
Navigation: Prague Old Town Square

Annotations: Notre Dame

Hierarchical annotations

Locking the camera (stabilization)
Microsoft Photosynth

- 3D reconstruction
- Multi-resolution streaming & zooming
- Quad-based exploration
- Community photo sharing

Skeletal graphs for efficient structure from motion

Noah Snavely, Steve Seitz, Richard Szeliski
CVPR’2008
Large-scale reconstruction

- Most of the models shown so far have had ~500 images

\[\text{We found 39,609 results for photos matching \textit{colosseum} and \textit{rome}.}\]

- How do we scale from 100s to 10,000s of images?

- Observation: Internet collections represent very non-uniform samplings of viewpoint

Skeletal set

- Goal: given an image graph $G_Z$, select a small set $S$ of \textit{important} images to reconstruct, bounding the loss in \textit{quality} of the reconstruction

- Reconstruct the skeletal set $S$

- Estimate the remaining images with much faster pose estimation steps

Example

<table>
<thead>
<tr>
<th>Full graph</th>
<th>Skeletal graph</th>
</tr>
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Pantheon

| Full graph | Skeletal graph (t=16) |
Skeletal reconstruction
101 images
After adding leaves
579 images
After final optimization
579 images

Pantheon

2973 images registered (277 in skeletal set)

Trafalgar Square

Building Rome in a Day

Sameer Agarwal, Noah Snavely, Ian Simon, Steven M. Seitz, Richard Szeliski
ICCV’2009
Results: Dubrovnik

Reconstructing Rome on a Cloudless Day

Results: Rome

Reconstructing Rome on a Cloudless Day

[J.M. Frahm et al., ECCV 2010]
Applications

Community photo collections

- “Wikipedia for photos” – visual record of world through community of photographers
  - Geograph British Isles
    - http://www.geograph.org.uk/
- Users can tag and comment on photos, link to other content
  - World-wide telescope
- “Where should I take a photo?”
  - http://photocitygame.com/

Community photo collections

- Leveraging large databases of photos, large number of users
  - Annotations / augmented reality

Virtual tour guide scenario

St. Peter’s Basilica
- Built: 1506 - 1626
- http://en.wikipedia.org/wiki/St._Peter's_Basilica
Rephotography

Summary

- Large (Internet) photo collections: the next frontier in computer vision
- Efficient algorithms for large-scale 3D matching and reconstruction
- New challenges for 3D recognition

Internet Computer Vision

Computer Vision and the Internet (09w5126)

Achong Sunday, August 30 and despising Friday, September 4, 2009

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INTERNET VISION

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By B. Savva, J. Zhou, M. Gonsalves, B. Sturtevant, and D. H. Salesin

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By R. Roes, A. Gru, A. Zivkovic, E. Arakon, and N. T. Herman

Efficient

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Phenomenal

POV

Computer

Internet

Network

Security

The

World

To

0.00

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Phenomenal

POV

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