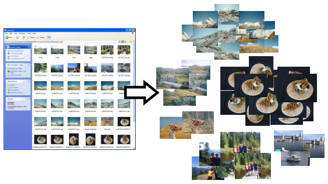
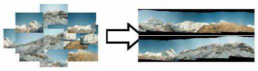
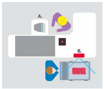
Panorama Stitching and Augmented Reality



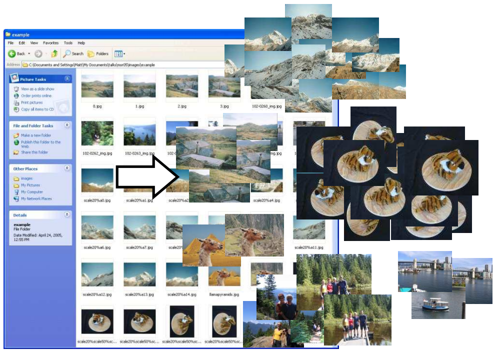
Local feature matching with large datasets

- **Examples:**
  - Identify all panoramas and objects in an image set
  - Identify all products in a supermarket
  - Identify any location for robot localization or augmented reality





Matching in large unordered datasets



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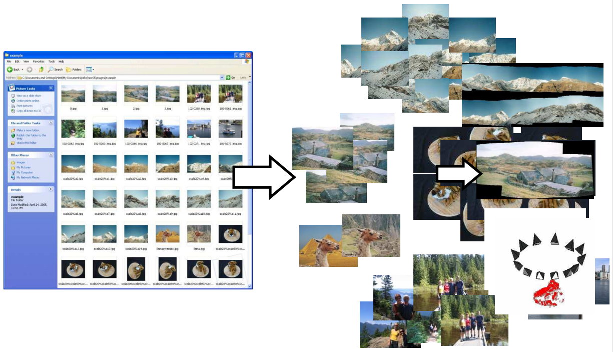


Nearest-neighbor matching

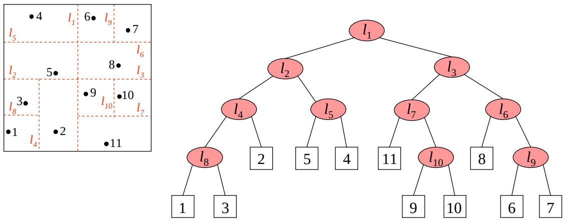
- Solve following problem for all feature vectors, $\mathbf{x}$:

$$\forall j \; NN(j) = \arg\min_i ||\mathbf{x}_i - \mathbf{x}_j||, \; i \neq j$$

- Nearest-neighbour matching is the major computational bottleneck
  - Linear search performs dn^2 operations for n features and d dimensions
  - No exact methods are faster than linear search for d>10
  - Approximate methods can be much faster, but at the cost of missing some correct matches. Failure rate gets worse for large datasets.

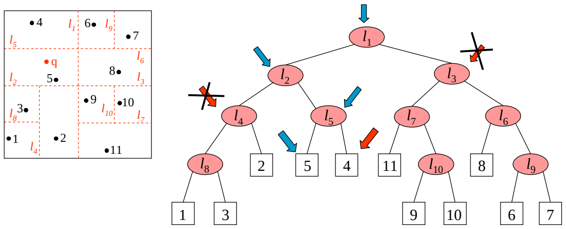
K-d tree construction

Simple 2D example



Slide credit: Anna Atramentov

K-d tree query

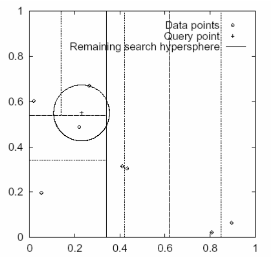


Slide credit: Anna Atramentov

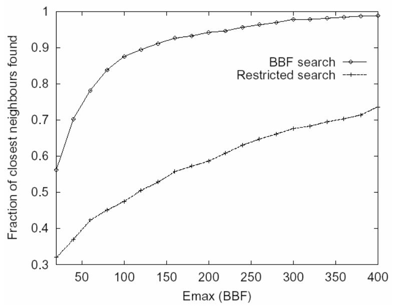
Approximate k-d tree matching

Key idea:

- Search k-d tree bins in order of distance from query
- Requires use of a priority queue



Fraction of nearest neighbors found

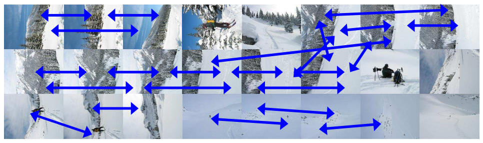


- 100,000 uniform points in 12 dimensions.

Results:

- Speedup by several orders of magnitude over linear search

Panorama stitching (with Matthew Brown)



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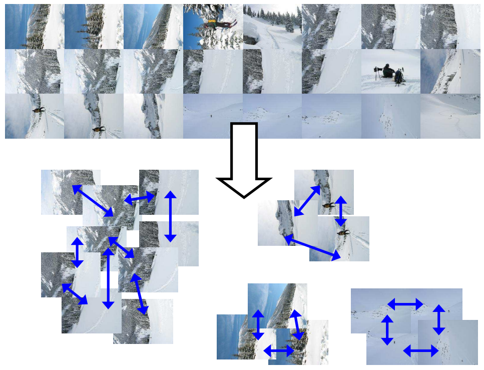

Bundle Adjustment

- New images initialised with rotation, focal length of best matching image

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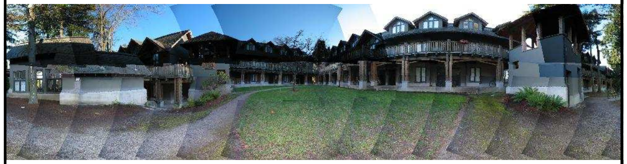
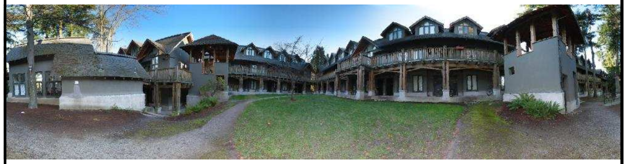
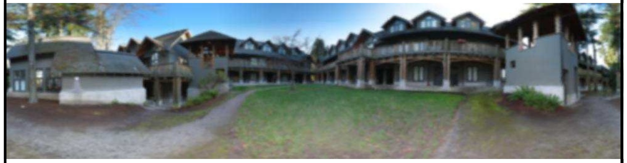


Multi-band Blending

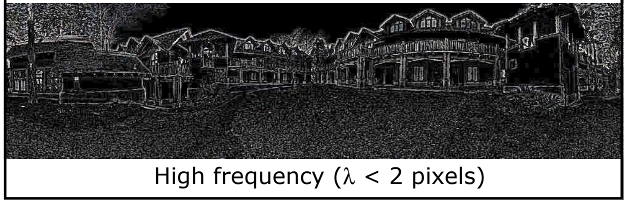
- Burt & Adelson 1983
  - Blend frequency bands over range ∝ λ



2-band Blending



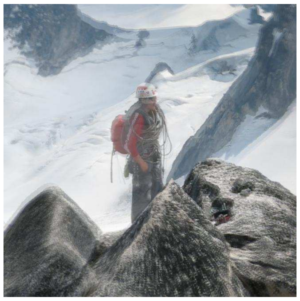
Low frequency (λ > 2 pixels)



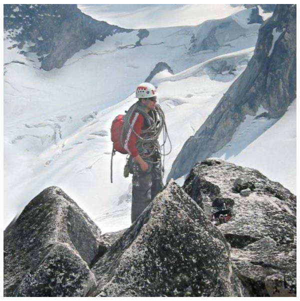
High frequency (λ < 2 pixels)

Multi-band Blending

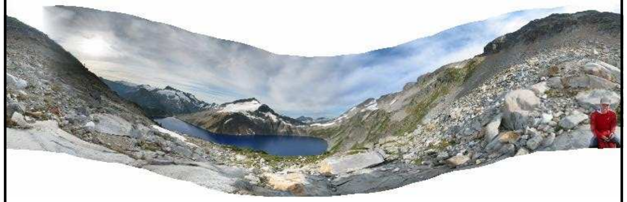
- Linear blending



- Multi-band blending

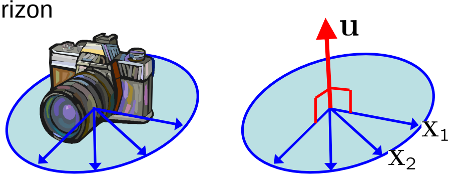


Automatic Straightening



Automatic Straightening

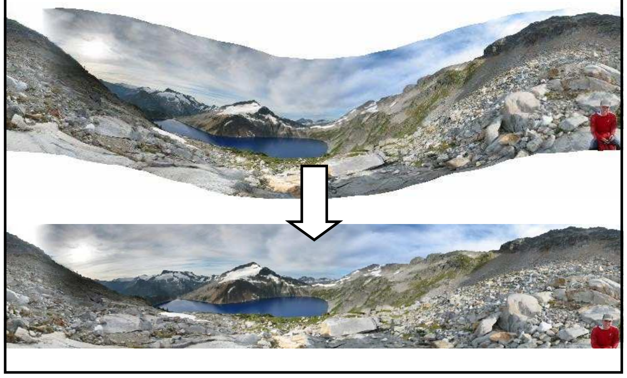
- Heuristic: user does not *twist* camera relative to horizon



- Up-vector perpendicular to plane of camera x vectors

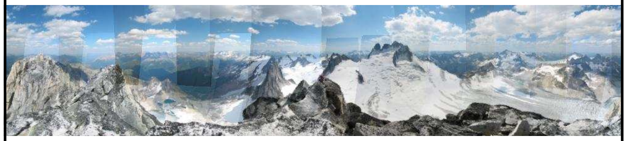
$$\left(\sum_i \mathbf{X}_i \mathbf{X}_i^T\right)\mathbf{u} = 0$$

Automatic Straightening



Gain Compensation

- No gain compensation



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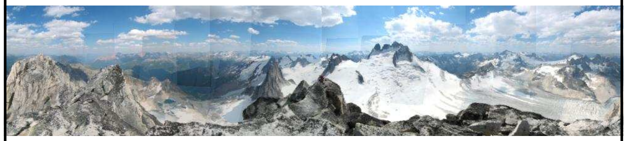


– Single gain parameter g_i for each image

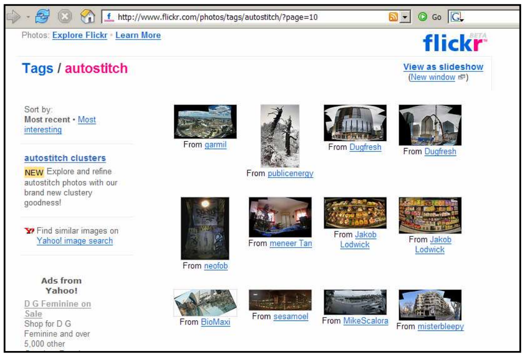
$$e = \sum_i \sum_j \sum_{\mathbf{u}_i \epsilon \mathcal{R}(i,j)} (g_i I_i(\mathbf{u}_i) - g_j I_j(\mathbf{u}_j))^2$$

Panoramas from handheld consumer cameras

- Free working demo available: *Autostitch*
- Commercial products: Serif, Kolor, others coming

- Show in Java applet: Browser demo

Autostitch usage in www.flickr.com



http://www.flickr.com/photos/tags/autostitch/?page=10

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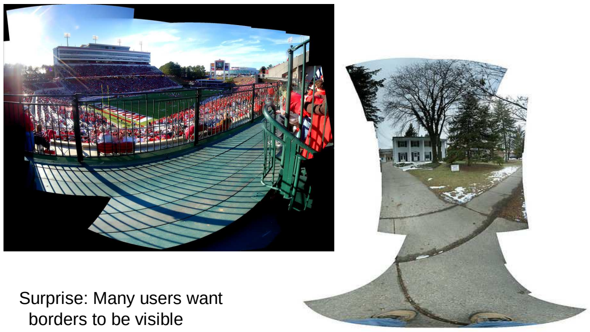
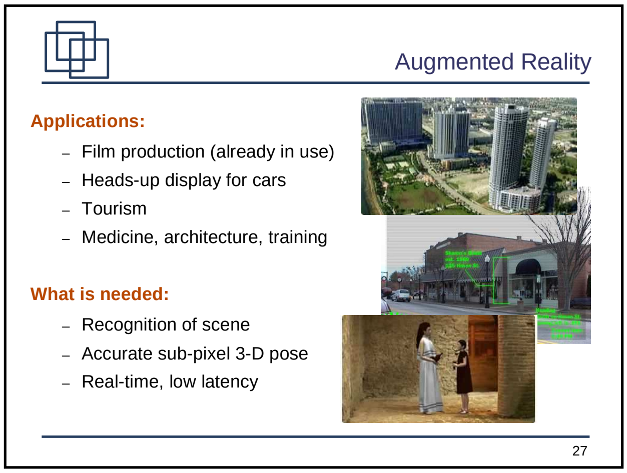
Public images from Flickr



Surprise: Many users want borders to be visible



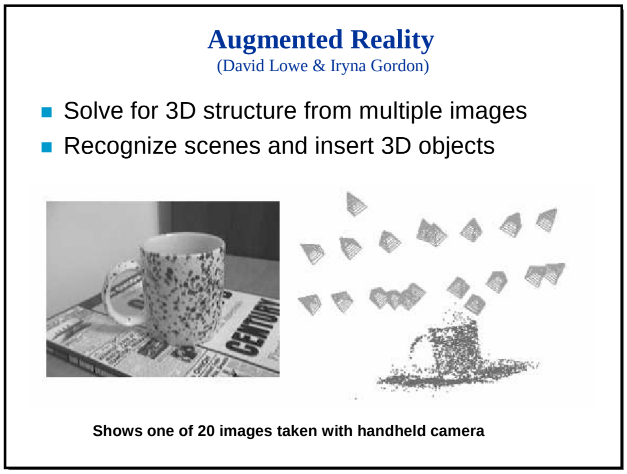
Augmented Reality

Applications:

- Film production (already in use)
- Heads-up display for cars
- Tourism
- Medicine, architecture, training

What is needed:

- Recognition of scene
- Accurate sub-pixel 3-D pose
- Real-time, low latency

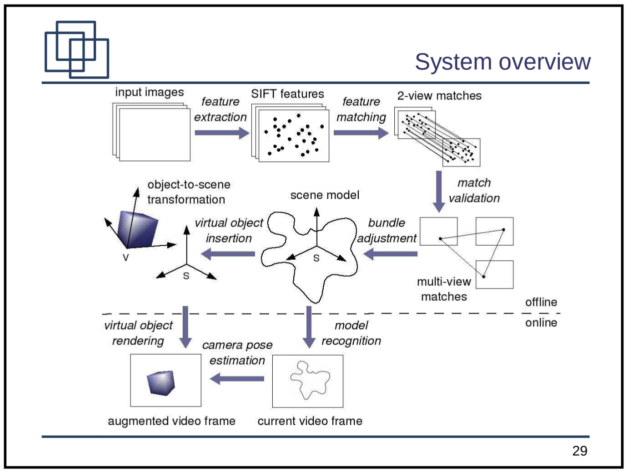


Augmented Reality

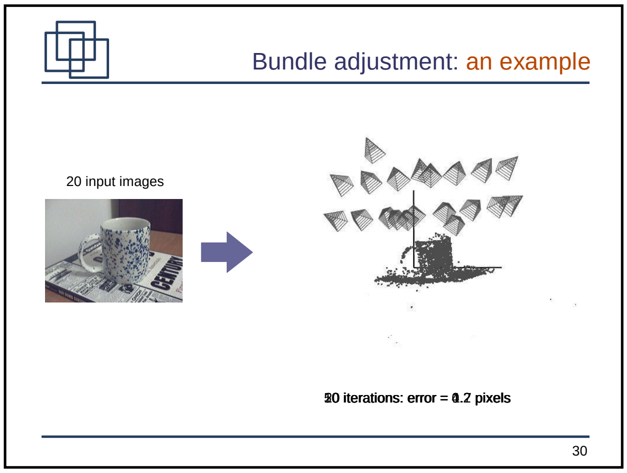
(David Lowe & Iryna Gordon)

- Solve for 3D structure from multiple images
- Recognize scenes and insert 3D objects

Shows one of 20 images taken with handheld camera

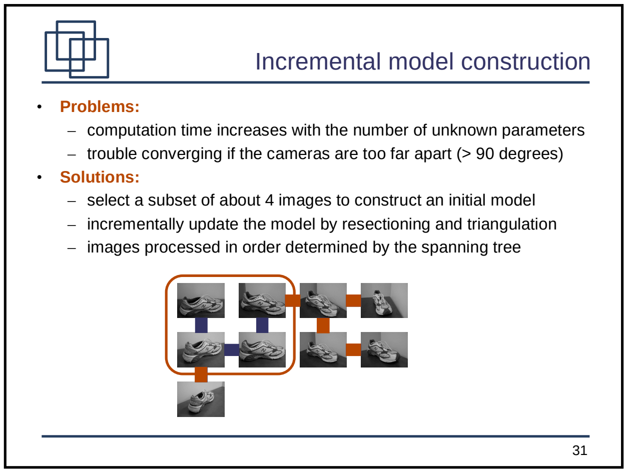


System overview



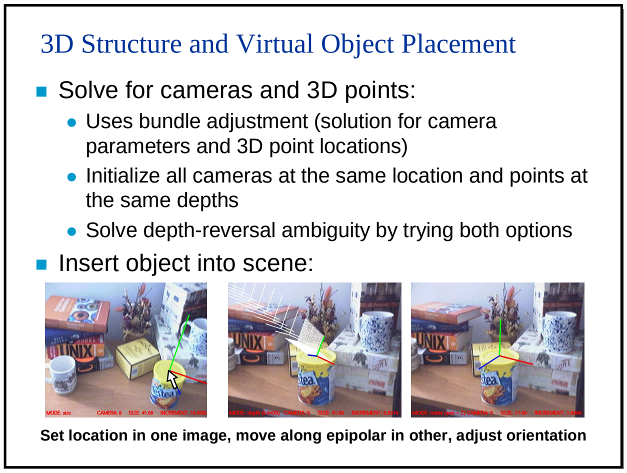
Bundle adjustment: an example

20 iterations: error = 0.2 pixels



Incremental model construction

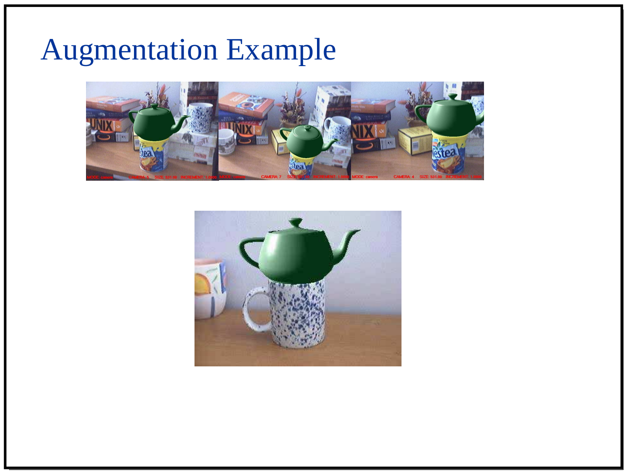
- **Problems:**
  - computation time increases with the number of unknown parameters
  - trouble converging if the cameras are too far apart (> 90 degrees)
- **Solutions:**
  - select a subset of about 4 images to construct an initial model
  - incrementally update the model by resectioning and triangulation
  - images processed in order determined by the spanning tree



3D Structure and Virtual Object Placement

- Solve for cameras and 3D points:
  - Uses bundle adjustment (solution for camera parameters and 3D point locations)
  - Initialize all cameras at the same location and points at the same depths
  - Solve depth-reversal ambiguity by trying both options
- Insert object into scene:

Set location in one image, move along epipolar in other, adjust orientation



Augmentation Example