Announcements

• Assignment 2 is due today, 11:59 PM
• Assignment 3 will be released today
  – Due Apr 22, 11:59 PM
Burst photography

• Hyperspectral image (HSI) set to RGB image
Burst photography

• Set of standard dynamic range (SDR) images to a high dynamic range (HDR) image
• Super resolution
Super resolution

• Camera motion (e.g., hand shake) causes pixel-level differences over each image in the burst
• Requires subpixel alignment of all images
• Can be used to compute a super resolution image
Super resolution

Figure 10. (Left) A small section of one of 15 low-resolution input images. (Right) An estimate of the texture at 2.0 times higher resolution using the MAP estimator.

Camera and image motion

- Mosaic construction from video or a set of images
- Video stabilization
Camera and image motion

• Image motion is 2D projective transformation
  – Rotating camera
    • Same camera center
  – Imaging a plane
    • Camera center can move
Camera and image motion

Camera motion

Image motion

\[ \mathbf{x} = \mathbf{K}\mathbf{R}[\mathbf{I} - \mathbf{\tilde{C}}]\mathbf{X} \]

\[ \mathbf{x}' = \mathbf{K}'\mathbf{R}'[\mathbf{I} - \mathbf{\tilde{C}}]\mathbf{X} \]

\[ \mathbf{x}' = \mathbf{H}\mathbf{x} \]

\[ \mathbf{K}'\mathbf{R}'[\mathbf{I} - \mathbf{\tilde{C}}]\mathbf{X} = \mathbf{H}\mathbf{K}\mathbf{R}[\mathbf{I} - \mathbf{\tilde{C}}]\mathbf{X} \]

\[ \mathbf{K}'\mathbf{R}' = \mathbf{H}\mathbf{K}\mathbf{R} \]

\[ \mathbf{K}'\mathbf{R}'\mathbf{R}^{-1}\mathbf{K}^{-1} = \mathbf{H} \quad \text{2D projective transformation} \]
Camera and image motion

• Imaging a plane

\[ x' = Hx \]

2D projective transformation
Camera and image motion

• Camera motion measurement may be inaccurate or imprecise
  – Initial estimate of image motion
  – Guided feature matching

• Camera motion may be unknown
  – Estimate camera and/or image motion from images directly
    • Direct methods
    • Feature based methods
Camera and image motion

- Mosaic construction from video or a set of images
Mosaic construction from images

• Select one of the images as a reference image $\text{ref}$
• For the remaining images
  – Calculate or estimate the 2D projective transformation $H_{n,\text{ref}}$ from image $n$ to $\text{ref}$
    • Compose 2D projective transformations
  – Transform image under $H_{n,\text{ref}}$
Mosaic construction from images

Rotating camera
Mosaic construction from video

- Set image 1 as the reference image
- For the remaining images
  - Sequentially estimate the 2D projective transformation $H_{n,n-1}$ from the current image $n$ to the previous image $n-1$
  - Compose 2D projective transformations $H_{n,1} = H_{n-1,1}H_{n,n-1}$
  - Transform the image under $H_{n,1}$
Mosaic construction from video

Example
2D projective transform estimation

• Direct methods
  – Estimate directly from spatial derivatives and difference of image intensities using all pixels

• Feature based methods
  – Estimate from a set of feature correspondences
Direct methods

• Given two images $J$ and $I$, estimate the transform from $J$ to $I$

• Assumptions
  – Intensity constancy
    \[ J(x, y) = I(x + u(x, y), y + v(x, y)) \]
  – Small displacement $(u, v)$
    \[ I_x u + I_y v + I_t = 0 \]

• Requires pyramidal implementation
  – Coarse-to-fine iterative estimation refinement
Feature based methods

• Given a set of feature correspondences between two images $J$ and $I$, estimate the transform from $J$ to $I$
Feature based methods

• Establish feature correspondences
  – Feature detection
    • Feature descriptors
  – Putative feature correspondences
    • Feature matching (images) or tracking (video)
  – Outlier rejection
    • Random sample consensus (RANSAC) or M-estimator sample consensus (MSAC)
      – Minimal solution of model (e.g., 2D projective transformation)

• Model estimation
  • Linear and/or nonlinear solution
Feature based methods

• Feature detection
Feature based methods

- Putative feature correspondences
Feature based methods

• Outlier rejection
Outlier rejection

Putative feature correspondences

Inliers

Outliers
Mosaic construction

Composition of transformations accumulates error of each transformation estimate

Registration Errors
Optimization

• Minimization of all errors
  – Simultaneous adjustment of all parameters
  – Cannot be performed sequentially

• Direct

• Feature based
  – 2D block adjustment
Optimization
Limitations

• 2D projective transformation is only valid for rotating camera or planar scene
• Nonplanar scene and translating camera requires 3D model
Camera and image motion

• Video stabilization
Video stabilization

• Estimate frame to frame motion (e.g., similarity transformation)
  – Parameterize motion (e.g., scale, rotation, translation)
  – Over time window centered at current frame
    • Compose transformations such that current frame is reference frame
    • Low pass filter (i.e., smooth) parameters
    • Apply transformation comprised of filtered parameters
Issue: dynamic scene

- Static scene is aligned, not moving objects
- Burst photography
  - Hyperspectral image to RGB image
  - High dynamic range imaging
- Camera and image motion
  - Mosaic construction from images
High dynamic range imaging

Figure 10.16  Merging multiple exposures to create a high dynamic range composite (Kang, Uyttendaele, Winder et al. 2003): (a–c) three different exposures; (d) merging the exposures using classic algorithms (note the ghosting due to the horse’s head movement); (e) merging the exposures with motion compensation.
Mosaic construction from images

Figure 9.14  Final composites computed by a variety of algorithms (Szeliski 2006a): (a) average, (b) median, (c) feathered average, (d) $p$-norm $p = 10$, (e) Voronoi, (f) weighted ROD vertex cover with feathering, (g) graph cut seams with Poisson blending and (h) with pyramid blending.