SAIR

Spatial AI & Robotics Lab

CSE 473/573-A

L13: STITCHING (BLENDING)

Chen Wang

Spatial AI & Robotics Lab

Department of Computer Science and Engineering

University at Buffalo The State University of New York

Content

- Stitching
  - Panorama, Blending, Deghosting
  - Feathering, Pyramid Blending
  - Laplacian Blending

Image Stitching

1. Align the images over each other
   - camera pan ↔ translation on cylinder
2. Blend the images together

Assembling the panorama

- Stitch pairs together, blend, then crop

Problem: Drift

- Error accumulation
  - small (vertical) errors accumulate over time
  - apply correction so that sum = 0 (for 360° pan.)

Problem: Drift

- Solution
  - add another copy of first image at the end
  - this gives a constraint: $y_n = y_1$
  - there are a bunch of ways to solve this problem
    - add displacement of $(y_1 - y_n)/(n - 1)$ to each image after the first
    - compute a global warp: $y' = y + ax$
    - run a big optimization problem, incorporating this constraint
      - best solution, but more complicated.

Full-view (360° spherical) panoramas

Full-view Panorama

Texture Mapped Model

Image Blending

- How do we put images together so there is no obvious divisions?

Alpha Blending / Feathering

$$I_{blend} = \alpha I_{left} + (1-\alpha) I_{right}$$

Setting alpha: simple averaging

- Alpha = 0.5 in the overlap region

Setting alpha: center seam

- Alpha = logical(dtrans1>dtrans2)

Setting alpha: blurred seam

- Alpha = blurred

Setting alpha: center weighting

- Alpha = dtrans1 / (dtrans1+dtrans2)

Feathering

Effect of window size

Effect of window size

Good Window Size

- “Optimal” Window: smooth but not ghosted.
- To avoid seams
  - window = size of largest prominent feature
- To avoid ghosting
  - window <= 2*size of smallest prominent feature

Pyramid Blending

Burt, P. J. and Adelson, E. H., A multiresolution spline with applications to image mosaics, ACM Transactions on Graphics, 42(4), October 1983, 217-236.

Laplacian Pyramid (Recap)

- **Difference between up-sampled Gaussian pyramid and Gaussian pyramid**.
- **Band pass filter** - each level represents spatial frequencies (largely) unrepresented at other level.

Laplacian pyramid (Recap)

Laplacian Pyramid (Recap)

- Reconstruction: recover x_1 from L_1, L_2, L_3 and g_3

Laplacian Pyramid (Recap)

- Information captured at each level of a Gaussian (top) and Laplacian (bottom) pyramid
  - showing full resolution.

Fig 5. First four levels of the Gaussian and Laplacian pyramid. Gaussian images, upper row, were obtained by expanding pyramid arrays (Fig. 4) through Gaussian interpolation. Each level of the Laplacian pyramid is the difference between the corresponding and next higher levels of the Gaussian pyramid.

Pyramid Blending

Left pyramid

blend

Right pyramid

Laplacian level 4

Laplacian level 2

Laplacian level 0

left pyramid

right pyramid

blended pyramid

Laplacian Pyramid: Blending

- 1. Build Laplacian pyramids LA and LB from images A and B
- 2. Build a Gaussian pyramid GR from selected region R
- 3. Combined pyramid LS from LA / LB using GR as weights:
  - $LS(i, j) = GR(i, j) * LA(i, j) + (1 - GR(i, j)) * LB(i, j)$
- 4. Collapse the LS pyramid to get the final blended image

Blending Regions

Season Blending

Don’t blend, CUT!

- So far we only tried to blend between two images.
- What about finding an optimal seam?

Don’t blend, CUT!

- Segment the mosaic
  - Single source image per segment
- Avoid artifacts along boundaries
  - Dijkstra’s algorithm

Minimal error boundary

Gradient Domain Blending

- Blend the gradients of the two images, then integrate.

sources | destinations | cloning | seamless cloning

Perez et al, SIGGRAPH 2003

Gradient Domain Blending

- Blend the gradients of the two images, then integrate.

sources/destinations

cloning

seamless cloning

Watch a video

https://youtu.be/Rp7uDRdQRFc

Final thought: What is a “panorama”?

- Tracking a subject
- Repeated (best) shots
- Multiple exposures
- “Infer” what photographer wants?
- Also referred to as “Computational Photography”

Stitching

- Feature Detection
- Feature Matching
- Homography
- RANSAC
- Global alignment
- Warping
- Blending

(a) (b)