Seamless Image Stitching in the Gradient Domain

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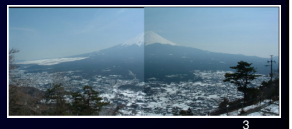
Outline

- Introduction
  - Related Work
- GIST: Gradient-domain Image Stitching
  - GIST1
  - GIST2
- Implementation details
  - Iterative Optimization
- Experiments & Discussion
  - Panoramic View
  - Object Parts

Image Stitching

- Combine individual images having some overlap into a composite image
- Commonly used for generating panoramic images

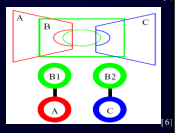
- Visual artificial edges at the seam due to the differences in
  - Camera gain
  - Scene illumination
  - Geometrical misalignment



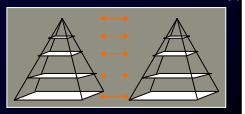
Related Approaches

- Optimal seam algorithm
  - Optimal seam[3,2,4]
    - Optimal seam curve that fits to the minimal difference
- Transition smoothing
  - Feathering[6] or alpha blending
    - Weighted combination with coefficient functions of distance
  - Pyramid Blending[7]
    - Different alpha masks in different frequency bands
- Optimization process
  - Poisson Image Editing[10]
    - Optimization over the gradient domain
  - Gradient-domain Image Stitching(GIST)

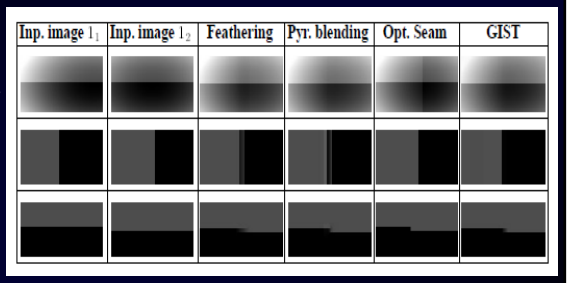
[2]



[6]

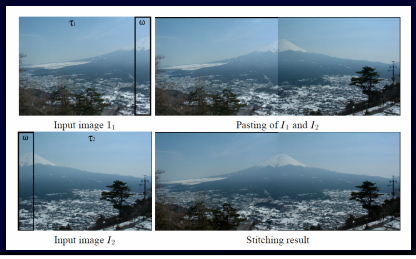


Comparison of Stitching Methods



Requirement

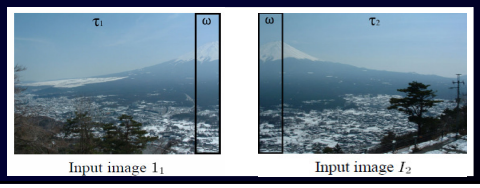
- Good stitching (seamless)
  - The mosaic should be as *similar* as possible to the input images, both geometrically and photo-metrically.
  - The seam between the stitched images should be *invisible*.
- Quality measurement is operated in gradient domain.



GIST: Gradient Image STitching

- GIST1: Optimizing a cost function over Image Derivatives
  - $E_p(\hat{I}; I_1, I_2, W) = d_p(\nabla\hat{I}, \nabla I_1, \tau_1 \cup \omega, W) + d_p(\nabla\hat{I}, \nabla I_2, \tau_2 \cup \omega, U - W),$

    where $d_p(J_1, J_2, \phi, W) = \sum_{q \in \phi} W(q) \left\| J_1(q) - J_2(q) \right\|_p^p$



GIST: Gradient Image STitching

- GIST2: Stitching Derivative Images
  - Compute deriatives: $\frac{\partial I_1}{\partial x}, \frac{\partial I_1}{\partial y}, \frac{\partial I_2}{\partial x}, \frac{\partial I_2}{\partial y}$
  - Form a field $F = (F_x, F_y)$, where
  - F_x, F_y are formed with stitching $\frac{\partial I_1}{\partial x}, \frac{\partial I_2}{\partial x}$ and $\frac{\partial I_1}{\partial y}, \frac{\partial I_2}{\partial y}$

    (Feathering, Pyramid blending, or optimal seam)
  - minimize $d_p(\nabla I, F, \pi, U) = \sum_{q \in \pi} U(q) \left\| \nabla I(q) - F(q) \right\|_p^p$

GIST Properties

- Which method to use?
  GIST1 under ℓ_1 is recommended
- GIST1 under ℓ_1 V.S optimal seam
  - Same results in geometric misalignments condition
  - GIST1 > optimal seam if no perfect seam, e.g. photometric inconsistencies
- GIST1 under ℓ_1 V.S GIST1 under ℓ_2
  - GIST1 under ℓ_2 ≡ Feathering of the gradient images (GIST2) under ℓ_2 (solution of Poisson Equation)
  - ℓ_2: tending to mix the derivatives and hence blurring in the overlap region.
  - ℓ_1: tending to behave similarly to the optimal seam methods.

9

Implementation

- GIST1 under ℓ_2
  - Solving through FFT

$$d_2(J_1, J_2, \phi, W) = \sum_{q \in \phi} W(q) \|J_1(q) - J_2(q)\|^2$$

- GIST1 under ℓ_1
  - Solving through Linear Programming
  - Uniform intensity shift (input image, mosaic image)

$$d_1(J_1, J_2, \phi, W) = \sum_{q \in \phi} W(q) \|J_1(q) - J_2(q)\|$$

$$Min : \sum_i (z_i^+ + z_i^-)$$
$$Subject\ to : Ax + (z_i^+ + z_i^-) = b,$$
$$x \geq 0,\ z_i^+ \geq 0,\ z_i^- \geq 0$$

- Iterative ℓ_1 optimization
  - Initial the solution image I
  - Iterate until convergence:
    - For all x,y in the image,

$$I(x,y) \leftarrow 2 * median(\cup_j \{ \begin{matrix} I(x+1,y) - Dx_j(x,y), & I(x-1,y) + Dx_j(x-1,y), \\ I(x,y+1) - Dy_j(x,y), & I(x,y-1) + Dy_j(x,y-1) \end{matrix} \})$$

10

Differences with Poisson Editing

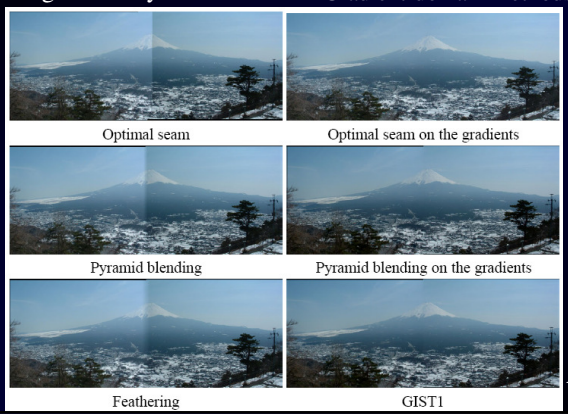
- GIST use the gradients of both images in the overlap region.
- The optimization is done under different norms

Performance

+ Overcome global inconsistencies
+ Overcome Misalignments
- Speed
- Convergence

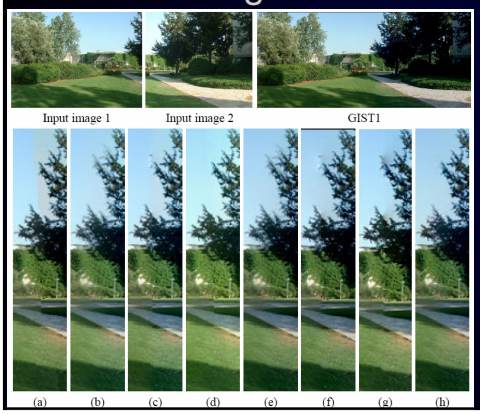
11

Image-intensity methods V.S. Gradient-domain methods



12

Stitching Panoramic View



(a) Optimal seam
(b) Feathering
(c) Pyramid blending
(d) Optimal seam (gradient)
(e) Feathering (gradient)
(f) Pyramid blending (gradient)
(g) Poisson editing
(h) GIST1 under ℓ_1

13

Stitching Panoramic View

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14

Stitching Panoramic View

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15

Stitching Panoramic View

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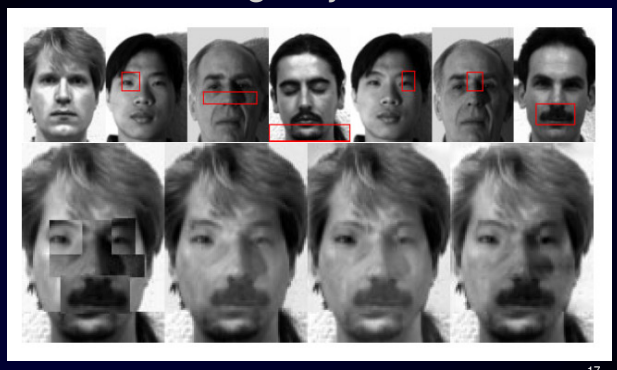
(h) GIST1 under ℓ_1

16

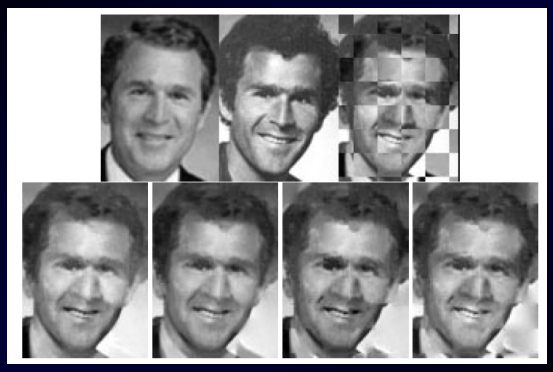
Stitching Object Parts



Original composition GIST1 under ℓ_1 GIST1 under ℓ_2 Pyramid (gradient)

17

Stitching Object Parts



GIST1 under ℓ_1 GIST1 under ℓ_2 Pyramid (gradient) Pyramid (image)

18