Drag and Drop Pasting

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Outline

- Introduction
- Related Work
- Optimal Boundary
  - Poisson Image Editing
  - Boundary Energy Minimization
  - Shortest Closed Path Algorithm
- Fractional Boundary
  - Blended Guidance Field
- Results
- Conclusions
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Introduction

- Problem
  - For Poisson Image Editing to work well user must carefully draw boundary on source image
  - Poisson Image Editing may generate unnatural blurring artifacts
Introduction

- Proposed
  - A new objective function to compute an optimized boundary
  - A blend guidance field to integrate an alpha matte into the Poisson equation to preserve fractional boundary
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Related Work

- Poisson Image Editing [Perez et al. 2003]
- Image Stitching in the Gradient Domain [Levin et al. 2004]
- Interactive Digital Photomontage [Agarwala et al. 2004]
- Multi-resolution spline technique [Burt & Adelson 1983]
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Poisson Image Editing

• Minimizing Problem [Perez et al. 2003]
  
  \[
  \min_\mathcal{F} \int_{p \in \Omega_0} | \nabla f - v|^2 dp \quad \text{with} \quad f|_{\partial \Omega_0} = f_t|_{\partial \Omega_0}, \quad (1)
  \]

  where \( v = \nabla f_s \)

  • Denote \( f' = f - f_s \), equation (1) becomes

  \[
  \min_{f'} \int_{p \in \Omega_0} | \nabla f'|^2 dp \quad \text{with} \quad f'|_{\partial \Omega_0} = (f_t - f_s)|_{\partial \Omega_0}. \quad (2)
  \]

  • The associated Laplace equation is:

  \[
  \Delta f' = 0 \quad \text{with} \quad f'|_{\partial \Omega_0} = (f_t - f_s)|_{\partial \Omega_0}, \quad (3)
  \]

  where \( \Delta = \left( \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \right) \) is the Laplacian operator
Poison Image Editing

\[
\min_{f'} \int_{p \in \Omega_0} |\nabla f'|^2 dp \text{ with } f'|_{\partial \Omega_0} = (f_t - f_s)|_{\partial \Omega_0}. \quad (2)
\]

- **Important Property of equation 2**
  - Variational energy \( \Omega_0 |\nabla f|^2 \) will approach zero if and only if all boundary pixels satisfy \((f_t - f_s)|_{\partial \Omega_0} = k\), where k is some constant value [Zwillinger 1997]
  - Important as less variation in color along the boundary produces better results in the compositing operation
Poisson Image Editing

\[
\min_{f'} \int_{p \in \Omega_0} |\nabla f'|^2 dp \quad \text{with} \quad f'|_{\partial \Omega_0} = (f_t - f_s)|_{\partial \Omega_0}.
\]
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Before Boundary Energy Minimization

- **Optimal Boundary**
  - Where is this optimal boundary $\partial \Omega$?
  - Has to be inside the region of interest $\Omega_0$
  - It also has to be outside the object of interest $\Omega_{\text{obj}}$
  - Use GrabCut [Rother et al. 2004] to automatically compute $\Omega_{\text{obj}}$

![Diagram showing the regions $\Omega$, $\Omega_0$, $\Omega_{\text{obj}}$, and the boundary $\partial \Omega$.]
Boundary Energy Minimization

- To reduce the color variance along the boundary the following objective function is minimized:

\[ E(\partial \Omega, k) = \sum_{p \in \partial \Omega} ((f_t(p) - f_s(p)) - k)^2, \text{ s.t. } \Omega_{obj} \subset \Omega \subset \Omega_0, \] (4)

- Where
  - \( f(p) \) is a ternary set in \{r,g,b\} space
  - \( f(p) - f(q) \) is computed as L2 Norm
Boundary Energy Minimization

- Iterative Optimization

1. Initialize $\Omega$ as $\Omega_0$

2. Take derivative of equation 4 and equate to zero. Solve for $K$.

$$ \frac{\partial E(\partial \Omega, k)}{\partial k} = 0 $$

$$ \iff k = \frac{1}{|\partial \Omega|} \sum_{p \in \partial \Omega} (f_i(p) - f_s(p)),$$ (5)

where $|\partial \Omega|$ is length of the boundary $\partial \Omega$

3. Given the current $K$, optimize the boundary $\partial \Omega$.

4. Repeat steps 2 and 3 until the energy does not decrease in successive iterations
Boundary Energy Minimization

- Iterative Optimization

1. Initialize $\Omega$ as $\Omega_0$

2. Take derivative of equation 4 and equate to zero. Solve for $K$

$$\Leftrightarrow k = \frac{\|f_s(p)\|}{|\partial \Omega|}$$

where $|\partial \Omega|$ is the length of the boundary $\partial \Omega$

3. Given the current $K$, optimize the boundary $\partial \Omega$.

4. Repeat steps 2 and 3 until the energy does not decrease in successive iterations.
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Shortest Closed Path

- Assume a graph $G$
  - Nodes in $G$ are pixels within the band $\Omega - \Omega_{obj}$
  - Edges represent 4-connectivity relationships between neighboring pixels
  - Cost on each node is defined as $((f_t(p) - f_s(p)) - K)^2$
  - Region $\Omega_{obj}$ can be considered as genus 0
  - Region $\Omega_0 \setminus \Omega_{obj}$ can be considered as genus 1
Finding Shortest path is difficult as $\partial \Omega$ is a closed curve enclosing $\Omega_{\text{obj}}$

We therefore change region $\Omega_0 \setminus \Omega_{\text{obj}}$ from genus 1 to genus 0 by introducing cut $C$. 
Shortest Closed Path

• Cut C
  • Compute shortest straight line segment among all pixel pairs for $\partial\Omega_{\text{obj}}$ and $\partial\Omega_0$.

• Benefits of this approach
  • Short length reduces probability that optimal boundary passes the cut more than once
  • Speeds up computation.
Shortest Closed Path

- Shortest Closed Path Algorithm
  - For each pixel $P$ on one side of the cut (Marked Yellow) compute Shortest paths to all adjacent pixels on the other side (Shown in Blue).
    - Use 2D Dynamic programming [Dijkstra 1959; Mortensen and Barrent 1995] to compute paths.
    - $O(N)$ where $N$ is the number of pixels in the band.
  - Repeat process for all pixels on yellow side of cut $C$.
    - We obtain a set of Paths.
    - Optimized boundary $\partial \Omega$ is assigned to the path with globally minimum cost.
    - Assuming there are $M$ yellow pixels, overall complexity is $O(MN)$.
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Fractional Boundary

- Problem is optimized boundary may intersect with an object with fractional boundary and break up subtle and fine details.

![Diagram showing fractional boundary interactions](image)
Blended Guidance Field

• Solution is to incorporate an alpha matt into the guidance field for Poisson equations

• To do this we must detect regions in which alpha blending should be computed

• Define binary coverage mask $M$ to indicate where alpha blending should be applied.
Blended Guidance Field

- Denote $\Phi = \{ p | 0 < \alpha(p) < 1 \}$ as the fractional object boundary.
- $\alpha$ is computed automatically within a few pixels surrounding $\Omega_{obj}$ using coherence matting [Shum et al. 2004].

$\Phi$ is the shape of the narrow blue belt.
Blended Guidance Field

- Now the blended guidance field $v' = (v'_x, v'_y)$

- For each pixel $p = (x,y)$, $v'_x(x,y)$ is defined as

$$v'_x(x,y) = \begin{cases} 
\nabla_x f_s(x,y) & M(x,y) = M(x + 1, y) = 0 \\
\n\nabla_x (\alpha f_s + (1 - \alpha) f_t) & M(x,y) = M(x + 1, y) = 1 \\
0 & M(x,y) \neq M(x + 1, y)
\end{cases}$$

- To construct $M$
  - Compute head and tail intersections b/w $\partial \Omega$ and belt $\Phi$ (Red Dots)
  - Compute the nearest point on the other side of belt $\Phi$. This gives us the green region in which blending must be applied.
  - Set $\{p|M(p) = 1\}$ in green region and $M(p) = 0$ in remaining pixels of $p$ in $\Omega \cup \Phi$
**Blended Guidance Field**

- Now the blended guidance field $v' = (v'_x, v'_y)$

- For each pixel $p = (x, y)$, $v'_x(x, y)$ is defined as:

$$v'_x(x, y) = \begin{cases} \nabla_x \text{grad} & \\ \text{if } x \notin \partial \Omega \text{ and } x \notin \Phi (\text{Red Dots}) & \\ 0 & \text{otherwise} \end{cases}$$

- To construct $M$:
  - Compute head and tail intersections between $\partial \Omega$ and belt $\Phi$. (Red Dots)
  - Compute the nearest point on the other side of belt $\Phi$. This gives us the green region in which blending must be applied.
  - Set $\{p | M(p) = 1\}$ in green region and $M(p) = 0$ in remaining pixels of $p$ in $\Omega \cup \Phi$
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Figure 2: Example of results. (a) shows the original image, (b) shows the detected object, (c) shows the refined detection, (d) shows the final result, and (e) shows the comparison with the ground truth.
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- Proposed a user friendly approach to achieve seamless image composition without requiring careful initialization by user.
- A system which is more practical and easy to use.
- The approach preserves fractional boundary by introducing blended guidance field.
- User interaction is only required if there is a large error in computing $\Omega_{\text{obj}}$. 