Improved Seam Carving for Video Resizing

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Media Size Change

- Water Ski
Previous Work (Size Change)

- Cropping & Scaling:
  - [Wang et al. 2004]
  - [Fan et al. 2003]
  - [Liu and Gleicher 2006]
  - [Deselaers et al. 2008]

- Segment & Recombine
  - [Tao et al. 2007]

- Non linear scaling (Warping)
  - [Wolf et al. 2007]

- Time manipulations:
  - [Pritch et al. 2008] – Object based video
  - [Chen and Sen 2008] – Graph cut

Overview

1. Extending Seam Carving Operator to Video
2. Defining a New Energy Measure

[Wolf et al. 2007]
Finding the Seam?

The Optimal Seam

\[ E(I) = |\frac{\partial}{\partial x} I| + |\frac{\partial}{\partial y} I| \Rightarrow s^* = \arg \min_s E(s) \]
Pixel Attribute $\rightarrow$ Dynamic Programming

$$M(i, j) = E(i, j) + \min(M(i-1, j-1), M(i-1, j), M(i-1, j+1))$$

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Video?

- Naive… frame by frame independently
Jittery Results

Naïve (2): Global Projection

- Reduction of the video problem to image seam carving by using projection of maximum energy through time:
Naïve (2): Global Projection

- Reduction of the video problem to image seam carving by using projection of maximum energy through time:

Results

Rescale

Retarget
Results

Rescale

Retarget

Problems?

• More complex scenes:
  – Object movement
  – Camera movement

Global Seams
More Complex Scenes

• More complex scenes:
  – Object movement
  – Camera movement

Global Seams

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More Complex Scenes

• Seams should adapt and change through time!

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Global Solution

Video Cube

One 3D Seam
What is the challenge?

• Dynamic Programming no longer works in 3D!
• Video Cubes:
  – Schodl et al. Siggraph 2000, Video Textures
  – Kwatra et al. Siggraph 2003, Graph cut textures
  – Rav-Acha et al. CVPR 2005, Video Mosaics
  – Wang et al. Siggraph 2005, Interactive video cutout
  – Chen and Sen EG 2008 (short papers), Video Carving

What is the challenge?

• Dynamic Programming no longer works in 3D!
• Use Graph Cut:
  – Chen and Sen EG 2008 (short papers), Video Carving
What is the challenge?

- How to Define a Seam from a Cut?

Kwatra et al. Siggraph 2003, *Graph cut textures*

Constraints

1. Seams should be monotonic!
   - i.e. one pixel in each row
Constraints

1. Seams should be monotonic!
2. Seams should be connected!

Piecewise vs. Connected
Standard Construction

New Construction

- This construction guarantees monotonic and connected seams
- This construction creates seams that are equivalent to the dynamic programming approach
  (Proofs in the paper)
3D Graph Construction

Video Cube

3D Graph Cut

Video Cube
Not Enough!

Also on Images!
Also on Images!

Changes in Image
Changes in Image

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Changes in Image

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Energy Inserted (not only removed)

Energy Reduced
Energy Increased

Changes in Energy

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• Three possibilities When Removing Pixel $P_{i,j}$

\[
C_L(i, j) = |I(i, j + 1) - I(i, j - 1)| + |I(i - 1, j) - I(i, j - 1)|
\]
Pixel $P_{i,j}$: Right Seam

\[ C_R(i, j) = |I(i, j+1) - I(i, j-1)| + |I(i-1, j) - I(i, j+1)| \]

Pixel $P_{i,j}$: Vertical Seam

\[ C_V(i, j) = |I(i, j+1) - I(i, j-1)| \]
Energy Function

\[ M(i, j) = E(i, j) + \min \left\{ M(i-1, j-1), M(i-1, j), M(i-1, j+1) \right\} \]

New Forward Looking Energy Function

\[ M(i, j) = \min \left\{ M(i-1, j-1), M(i-1, j), M(i-1, j+1) \right\} \]
Backward (SIG 07)

Forward (SIG 08)
Backward Expand

Forward Expand
Graph Cut Formulation

Results
Results

Rescale

Retarget

Results

Rescale

Retarget
Timing

• Typical video sequences have a resolution of 400 x 300 and 400 frames.
• 2 Seconds per seam using multi-resolutions of three levels (details in the paper)
• Total preprocessing time to enable between 50% to 150% change in aspect ratio takes around 10 minutes.
• Resizing can be performed in real time (multi-size videos)
Multi-size Video

Limitations

- Nature Scene
...Object Removal

Summary

1. Graph Cut
2. Forward Energy
**Contributions**

- Extend the seam carving operator from images to video while maintaining its simplicity.
- Formulate using graph cut
- Allowing vertical and horizontal content aware size change and define multi-size video
- A novel forward energy for better content preservation with

**Future**

- Quality improvements (Energy, Smoothing)
- Faster (recent GPU-based graph-cut optimizations)
- Use of multiple operators
- Automatic
- Other applications (domains?)…
Thank you!

XT Plane

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Monotonic: One Cut in Each Row

Defining a Seam from a Cut

1. Seams should be monotonic
2. Seams should be connected!
Defining a Seam from a Cut

1. Seams should be monotonic
2. Seams should be connected!

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