Chapter 5

Seam Carving

Michael Rubinstein, MIT
Shai Avidan, Mitsubishi Electric Research Labs
Ariel Shamir, The Interdisciplinary Center & MERL

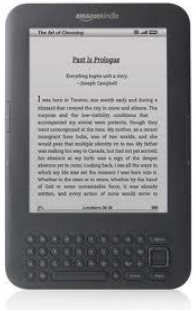
Department of Mechatronics

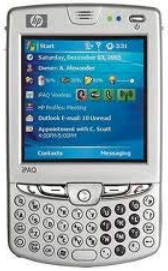
Contents

Image resizing

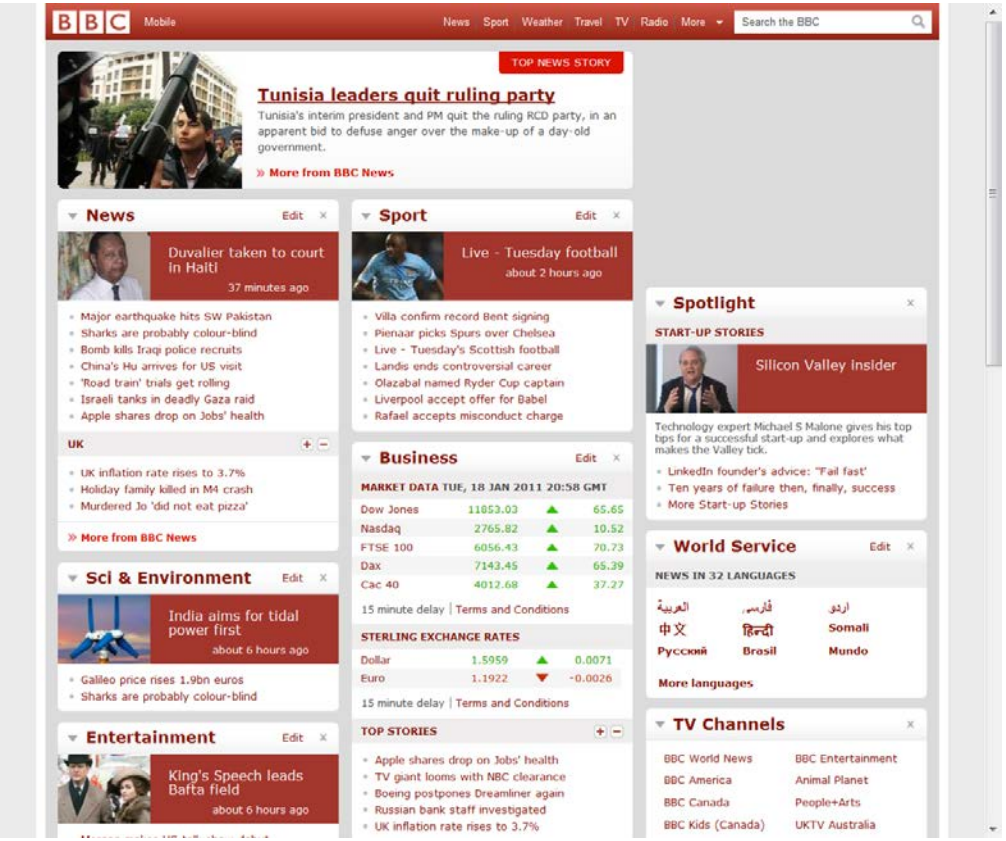
- **Seam Carving algorithm**

Display Devices





Content Retargeting



PC

iPhone

Page Layout


Page layout - Wikipedia, the free encyclopedia - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://en.wikipedia.org/wiki/Page_layout
Page Layout
Page layout - Wikipedia, the ...
Log in / create account
Article Discussion
Read Edit View history
Search
WIKIPEDIA
The Free Encyclopedia
Page layout
From Wikipedia, the free encyclopedia
For the Wikipedia guideline on an articles' layout, see Wikipedia:Manual of Style (layout).
This article does not cite any references or sources.
Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed. (June 2007)
Page layout is the part of graphic design that deals in the arrangement and style treatment of elements (content) on a page.
Contents [hide]
1 History and development
2 Grids versus templates
3 Front-end versus back-end
4 See also
Consumer magazine sponsored advertisements and covers rely heavily on professional page layout skills to compete for visual attention.
History and development [edit]
Beginning from early illuminated pages in hand-copied books of the Middle Ages and proceeding down to intricate modern magazine and catalog layouts, proper page design has long been a consideration in printed material. With print media, elements usually consist of type (text), images (pictures), and occasionally place-holder graphics for elements that are not printed with ink such as die/laser cutting, foil stamping or blind embossing.
Since the advent of personal computing, page layout skills have expanded to electronic media as well as print media. The electronic page is better known as a graphical user interface (GUI) when interactive elements are included. Page layout for interactive media overlaps with (and is often called) interface design. This usually includes interactive elements and multimedia in addition to text and still images. Interactivity takes page layout skills from planning attraction and eye flow to the next level of planning user experience in collaboration with software engineers and creative directors. [citation needed]
A page layout may be designed in a rough paper and pencil sketch before producing, or produced during the design process to the final form. Both design and production may be achieved using hand tools or page layout software. Producing a web page may require knowledge of markup languages along with WYSIWYG editors to compensate for incompatibility between platforms. Special considerations must be made for how the layout of an HTML page will change (reflow) when resized by the end-user. Cascading style sheets are often required to keep the page layout consistent between web browsers.
Grids versus templates [edit]
Grids and templates are page layout design patterns used in advertising campaigns and multiple-page publications, including websites.
Main page
Contents
Featured content
Current events
Random article
Donate to Wikipedia
Interaction
Help
About Wikipedia
Community portal
Recent changes
Contact Wikipedia
Toolbox
Print/export
Languages
Česky
Dansk
Deutsch
Ελληνικά
Esperanto
فارسی
Français
Italiano
Nederlands
日本語
Polski
Português
Suomi
Done
F110%

Simple Media Retargeting Operators

Letterboxing *Cropping* *Scaling*

Content-aware Retargeting Operators

"Important" content

Content-aware

Content-oblivious

Content-aware Retargeting

Input

Scale

Crop

Content-aware

“less-Important” content

Image Retargeting

- **Problem statement:**
  - **Input Image I with size n × m, and new size n' × m'**
  - **Output Image I' of size n' × m' which will be "good representative" of the original image I**

- **To date, no agreed definition, or measure, as to what a good representative is in this context!**

Image/Video Retargeting

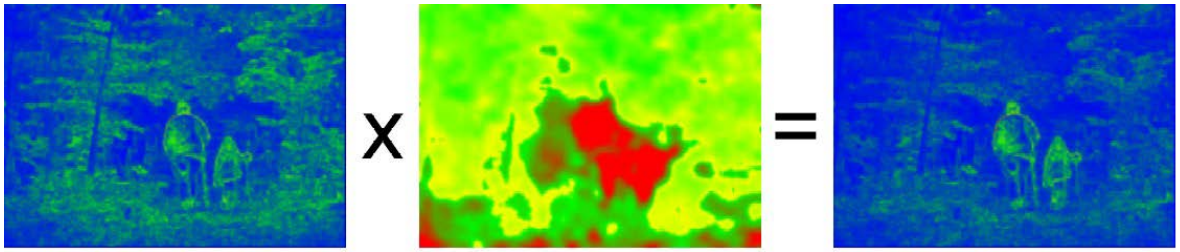
- **In large, we would expect:**

1. **Adhere to the *geometric constraints* (display/aspect ratio)**
2. **Preserve the important *content* and *structures***
3. **Limit *artifacts***
4. **Perhaps a new representation that will support different sizes?**

- **Very ill-posed!**
  - **How do we define important? Is there a universal ground truth?**
  - **Would different viewers think the same about a retargeted image?**
  - **What about artistic impression in the original content?**

Importance (Saliency) Measures

- **A function S: p → [0,1]**



Wang et al. 2008

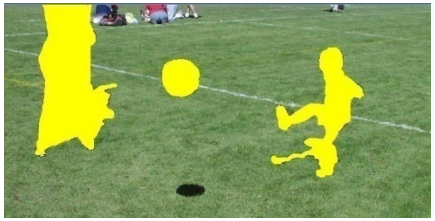
- **More sophisticated: attention models, eye tracking (gazing studies), face detectors, …**

Judd et al. ICCV09 Learning to predict where people look

General Retargeting Framework

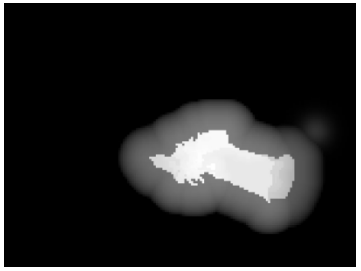
1. Define an energy function $E(I)$ (interest, importance, saliency)

2. Use some operator(s) to change the image I



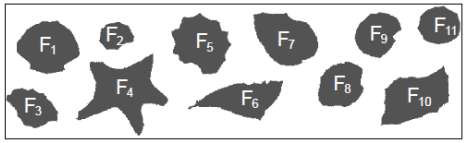
Recompose

Setlur et al. [2005]



Crop

Santella et al. [2005]

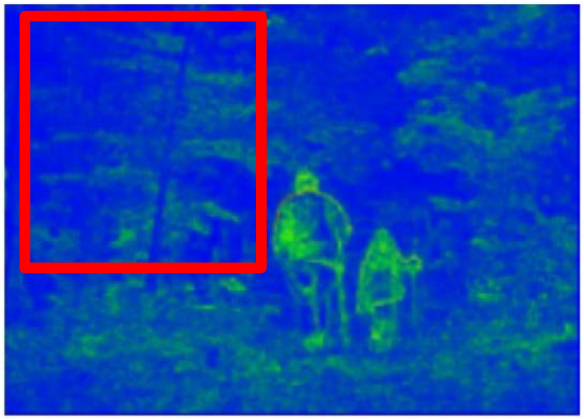


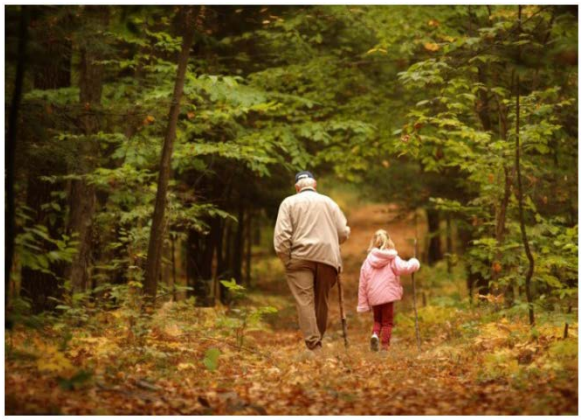
Warp

Gal et al. [2006]

Previous Retargeting Approaches

- **Optimal Cropping Window**





- **For videos: “Pan and scan”**

  Still done manually in the movie industry

Liu and Gleicher, Video Retargeting: Automating Pan and Scan (2006)

Cropping

Seam Carving

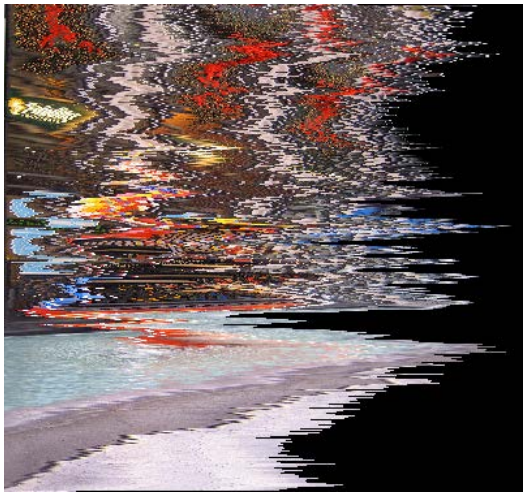
- **Assume m × n → m × n', n' < n**

- **Basic Idea: remove unimportant pixels from the image**
  - **Unimportant = pixels with less "energy"**

$$E_1(\mathbf{I}) = |\frac{\partial}{\partial x}\mathbf{I}| + |\frac{\partial}{\partial y}\mathbf{I}|.$$

- **Intuition for gradient-based energy:**
  - **Preserve strong contours**
  - **Human vision more sensitive to edges – so try remove content from smoother areas**
  - **Simple, enough for producing some nice results**
  - **See their paper for more measures they have used**

Pixel Removal



Optimal

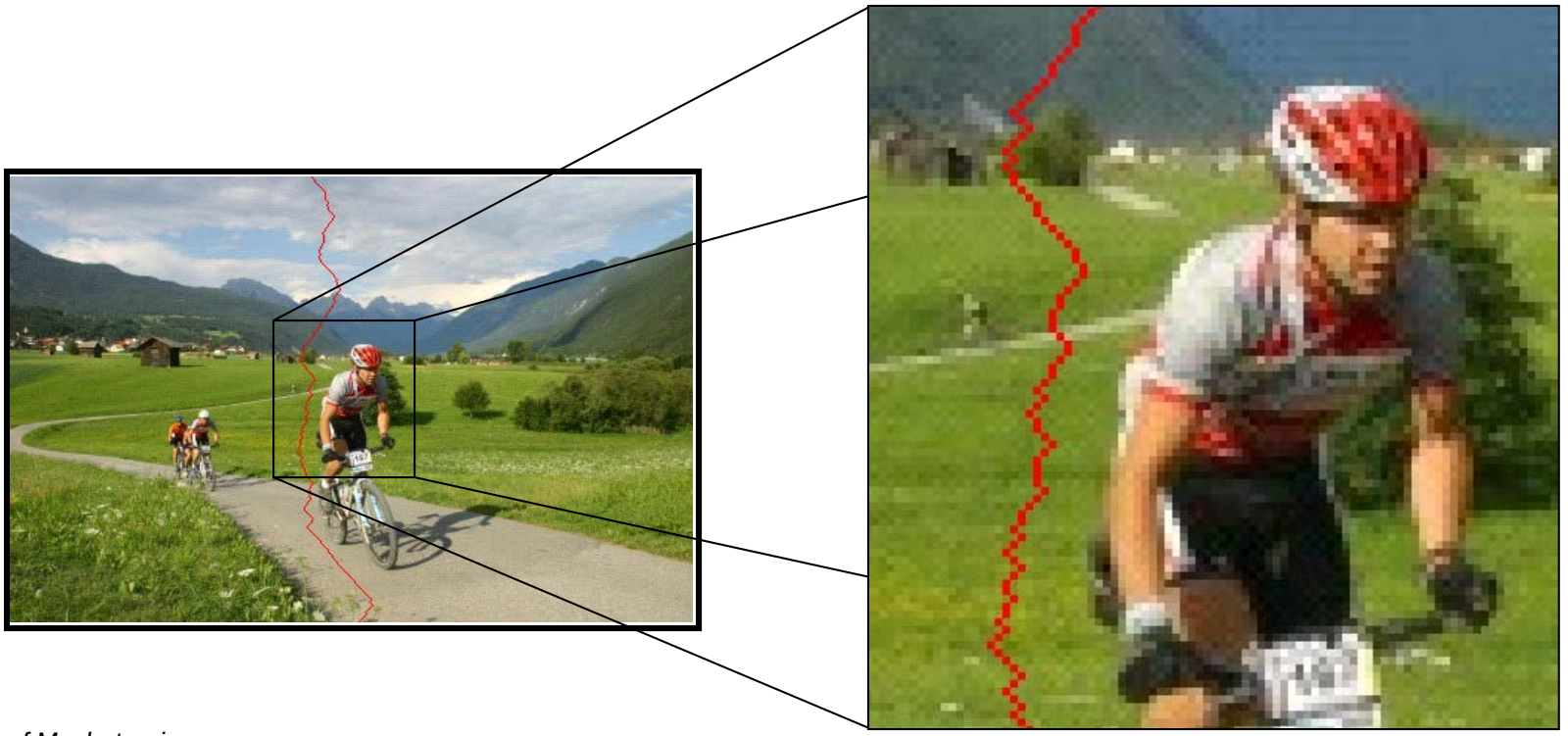
Least-energy pixels (per row)

Least-energy columns

A Seam

- **A connected path of pixels from top to bottom (or left to right). Exactly one in each row**

$$\mathbf{s^x} = \{s_i^x\}_{i=1}^n = \{(x(i), i)\}_{i=1}^n, \text{ s.t. } \forall i, |x(i) - x(i-1)| \leq 1$$
$$\mathbf{s^y} = \{s_j^y\}_{j=1}^m = \{(j, y(j))\}_{j=1}^m, \text{ s.t. } \forall j |y(j) - y(j-1)| \leq 1$$



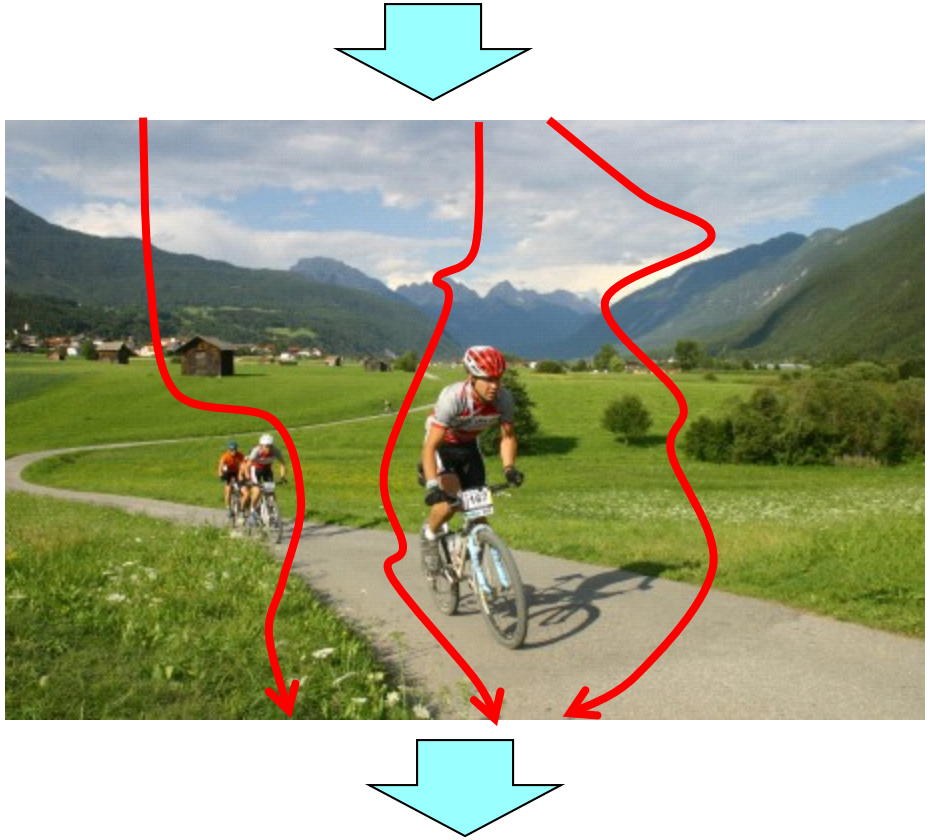
Seams in Images

- Efros & Freeman [2001] – Texture synthesis
- Kwatra et al. [2003] – Image and video synthesis
- Agarwala et al. [2004] – Digital Photomontage
- Perez et al. [2
- Jia et al. [200
- Rother et al. [2006] – Auto-Collage
- Wang and Cohen [2006] – simultaneous matting and compositing

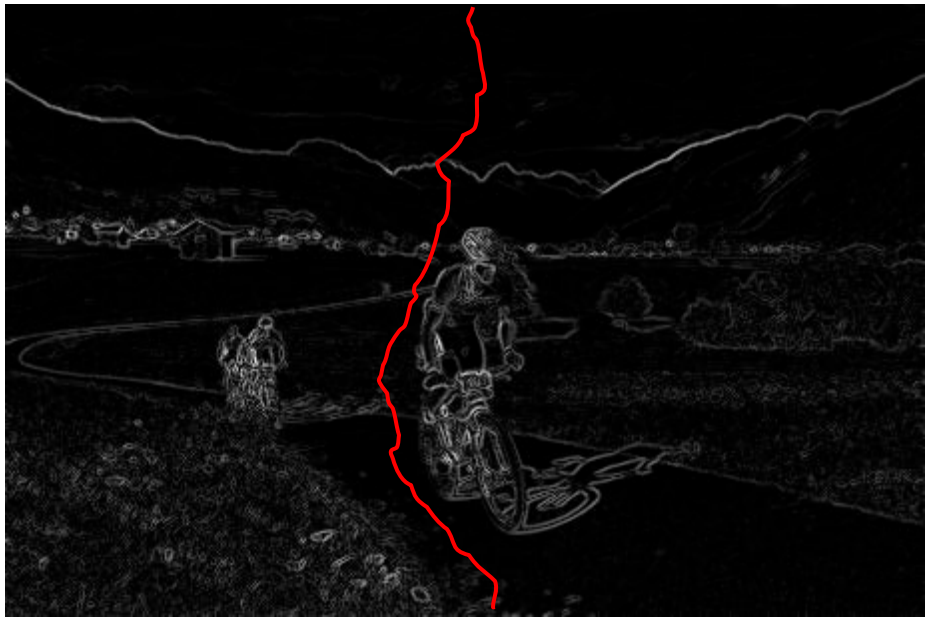
Mostly used for composition of two (or more) images or patches…

Agarwala et al., Interactive Digital Photomontage

Finding the Seam?



The Optimal Seam



$$E(\mathbf{I}) = \left|\frac{\partial}{\partial x}\mathbf{I}\right| + \left|\frac{\partial}{\partial y}\mathbf{I}\right| \Rightarrow s^* = \arg\min_s E(s)$$

$$\frac{\partial \boldsymbol{I}(\boldsymbol{x},\boldsymbol{y})}{\partial \boldsymbol{x}} = \frac{\boldsymbol{I}(\boldsymbol{x}+\boldsymbol{1},\boldsymbol{y}) - \boldsymbol{I}(\boldsymbol{x}-\boldsymbol{1},\boldsymbol{y})}{\partial \boldsymbol{x}} \qquad \frac{\partial \boldsymbol{I}(\boldsymbol{x},\boldsymbol{y})}{\partial \boldsymbol{y}} = \frac{\boldsymbol{I}(\boldsymbol{x},\boldsymbol{y}+\boldsymbol{1}) - \boldsymbol{I}(\boldsymbol{x},\boldsymbol{y}-\boldsymbol{1})}{\partial \boldsymbol{y}}$$

The Optimal Seam

- **The recursion relation**

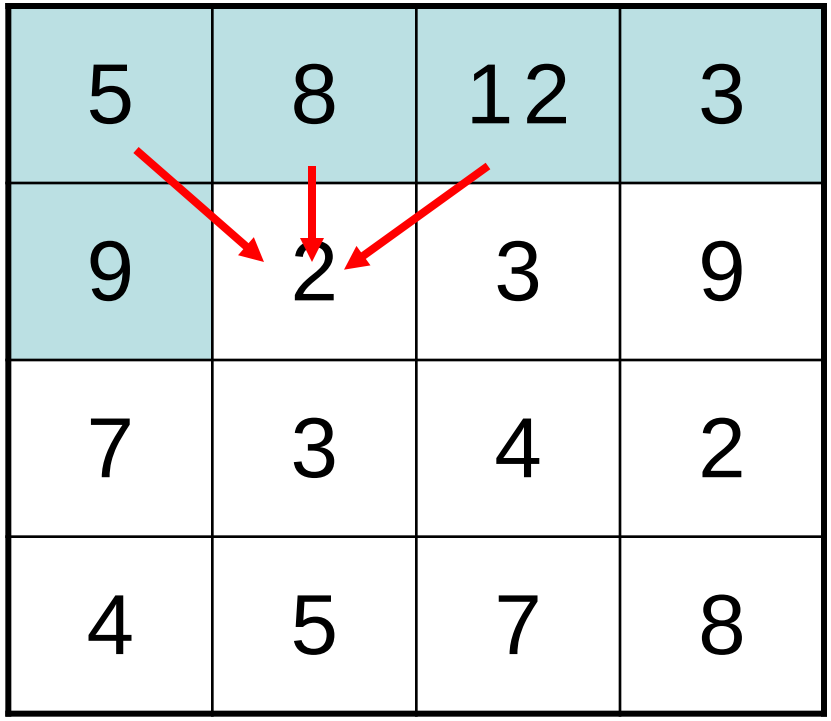
$$\mathbf{M}(i, j) = E(i, j) + \min\left(\mathbf{M}(i-1, j-1), \mathbf{M}(i-1, j), \mathbf{M}(i-1, j+1)\right)$$

- **Can be solved efficiently using dynamic programming in** $O(s \cdot n \cdot m)$

  (s=3 in the original algorithm)

Dynamic Programming

- **Invariant property:**
  - **M(i,j) = minimal cost of a seam going through (i,j) (satisfying the seam properties)**



Dynamic Programming

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

5	8	12	3
9	2+5	3	9
7	3	4	2
4	5	7	8

Dynamic Programming

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

5	8	12	3
9	7	3+3	9
7	3	4	2
4	5	7	8

Dynamic Programming

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

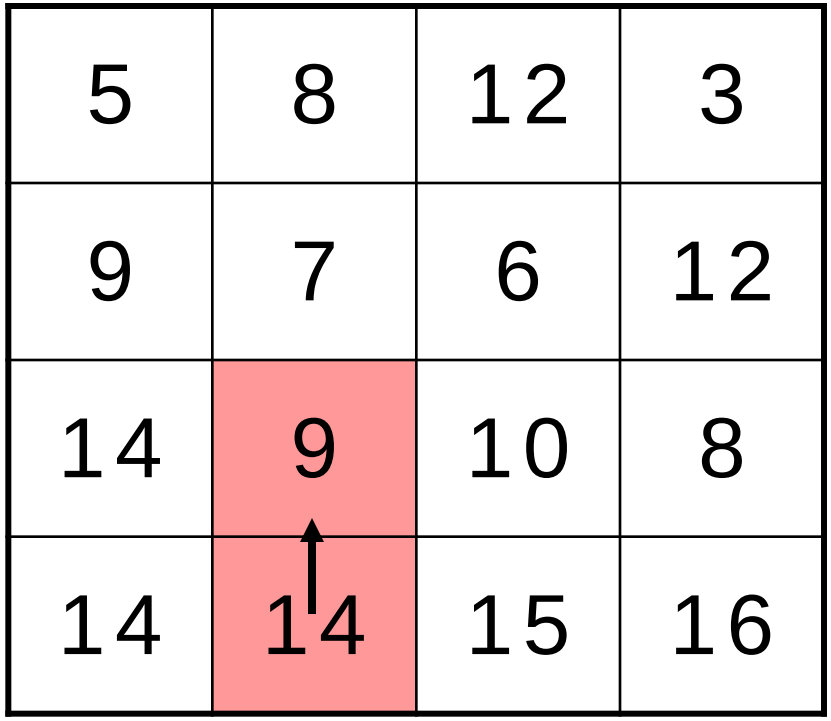
5	8	12	3
9	7	6	12
14	9	10	8
14	14	15	8+8

Searching for Minimum

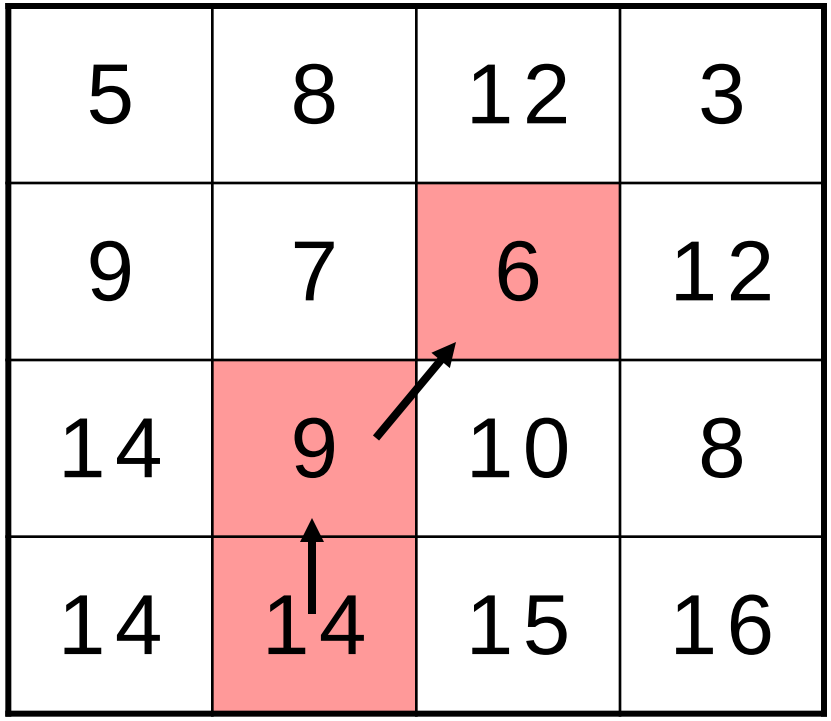
- **Backtrack (can store choices along the path, but do not have to)**

5	8	12	3
9	7	6	12
14	9	10	8
14	14	15	16

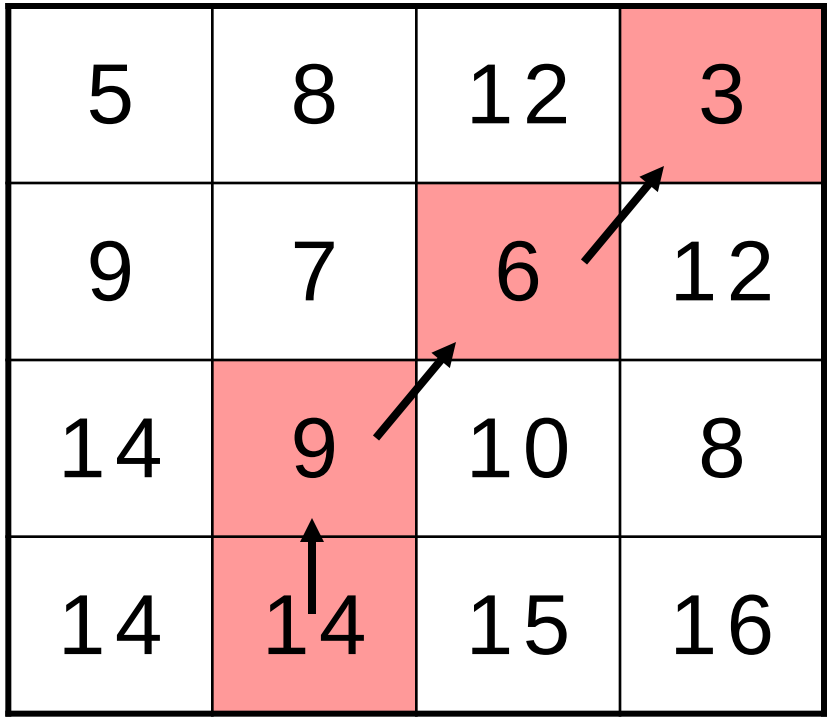
Backtracking the Seam



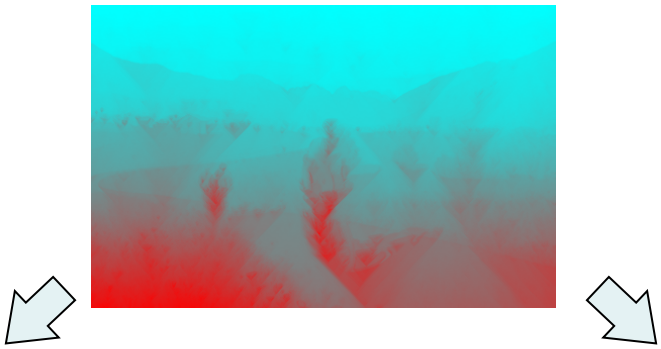
Backtracking the Seam

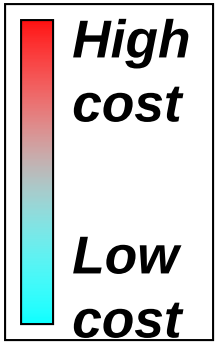


Backtracking the Seam



H & V Cost Maps





Horizontal Cost

Vertical Cost

Seam Carving

The Seam-Carving Algorithm

SEAM-CARVING(im,n') // size(im) = mxn

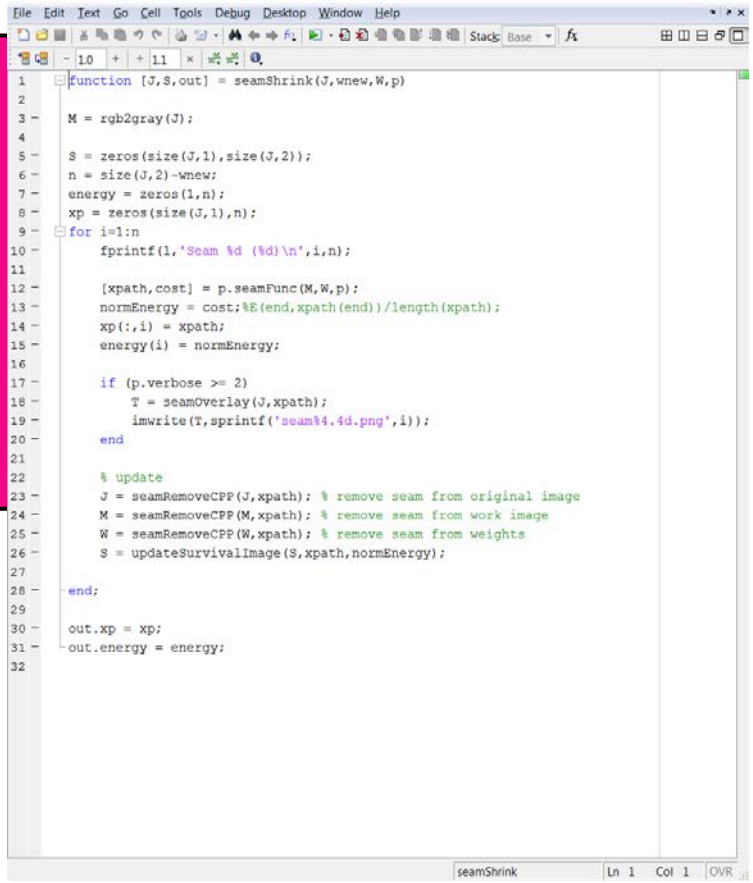
Do (n-n') times

2.1. E ← Compute energy map on im

2.2. s ← Find optimal seam in E

2.3. im ← Remove s from im

Return im



- ***For vertical resize: transpose the image***
- ***Running time:***

  2.1 O(mn) 2.2 O(mn) 2.3 O(mn)

  ➔O(dmn) d=n-n'

Changing Aspect Ratio

Changing Aspect Ratio

Original

Seam Carving

Scaling

Changing Aspect Ratio

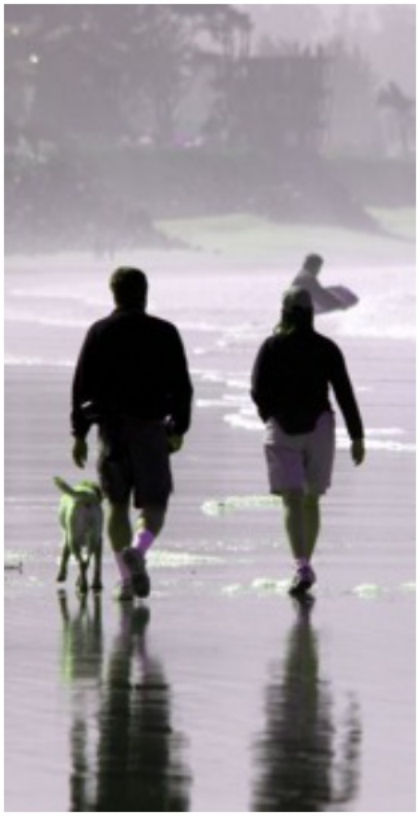
Cropping

Seams

Scaling

Changing Aspect Ratio

Original



Retarget

Resize
Scale

Changing Aspect Ratio

Original

Retarget

Resize /Scale

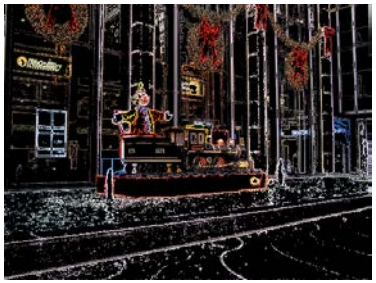
Content Enhancement

Seam Carving in the Gradient Domain

Preserved Energy

Energy

10%



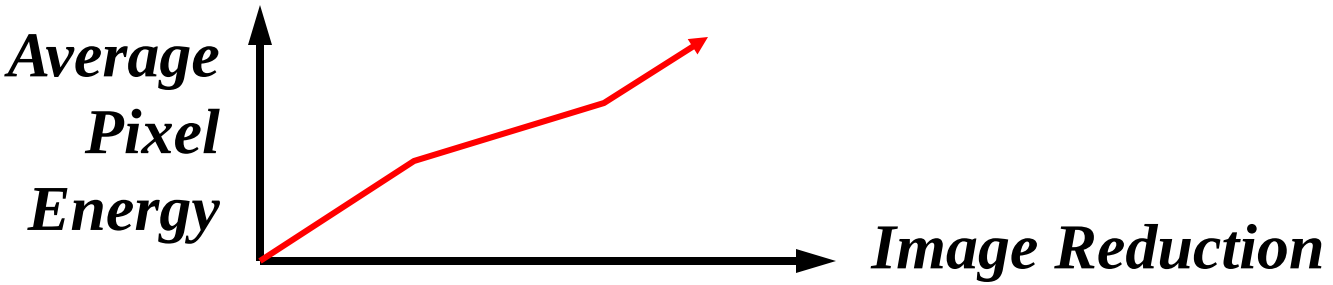
30%

40%

75%

While resizing: remove as many low energy pixels and as few high energy pixels!

Preserved Energy



If we measure the average energy of pixels in the image after applying a resizing operator…

…the average should increase!

While resizing: remove as many low energy pixels and as few high energy pixels!

Preserved Energy

Average Pixel Energy ↑

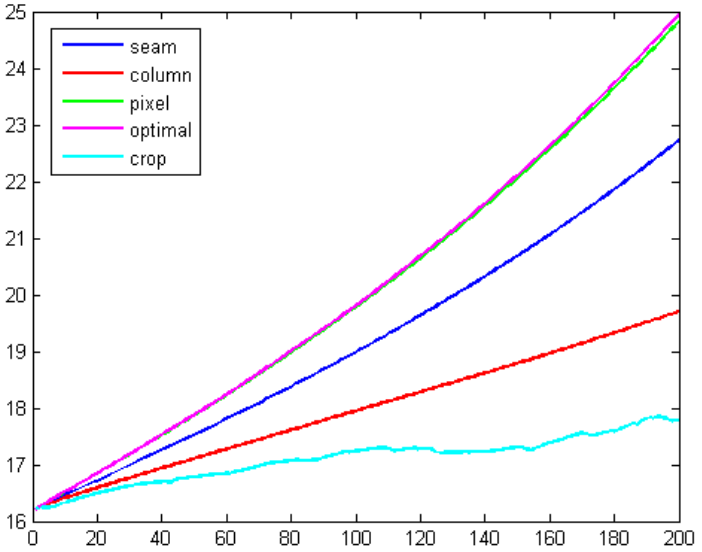


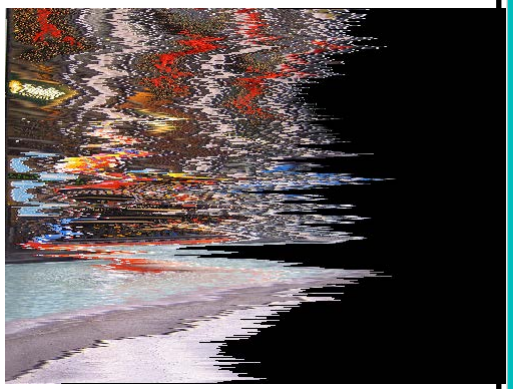
Image Reduction →

crop

column

seam

pixel

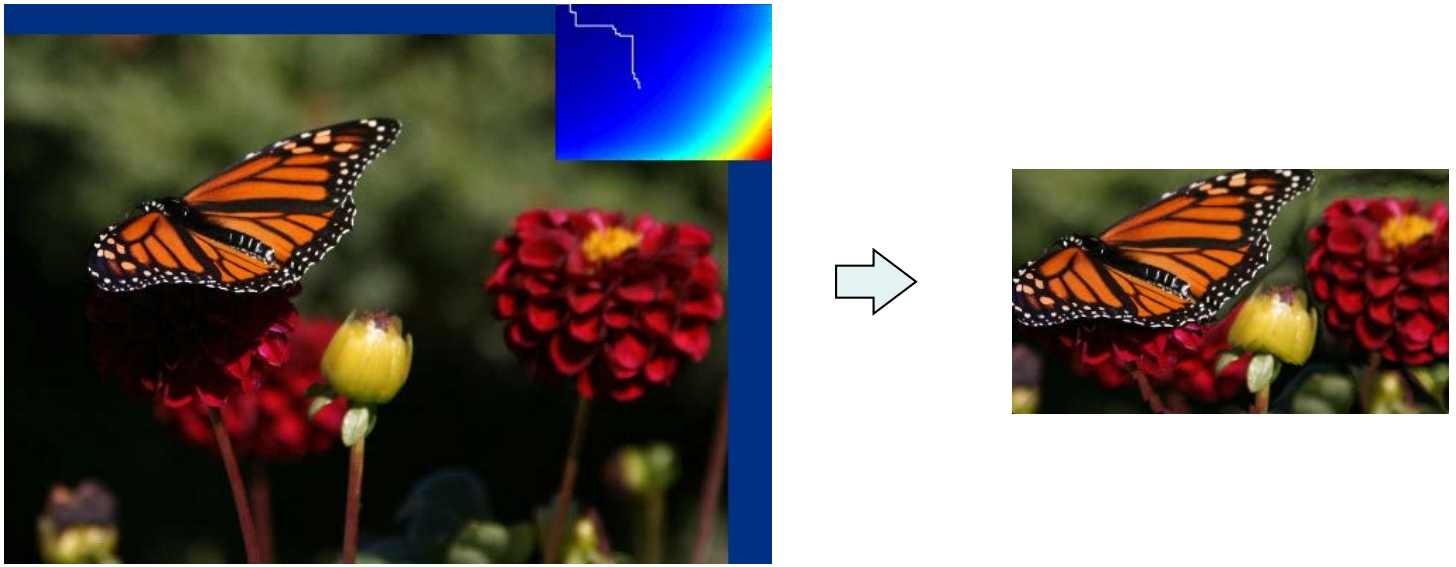


optimal

Both Dimensions?

- $m \times n \rightarrow m' \times n'$

- Remove horizontal seam first?
- Remove vertical seams first?
- Alternate between the two?
- The optimal order can be found! → Dynamic Prog (again)

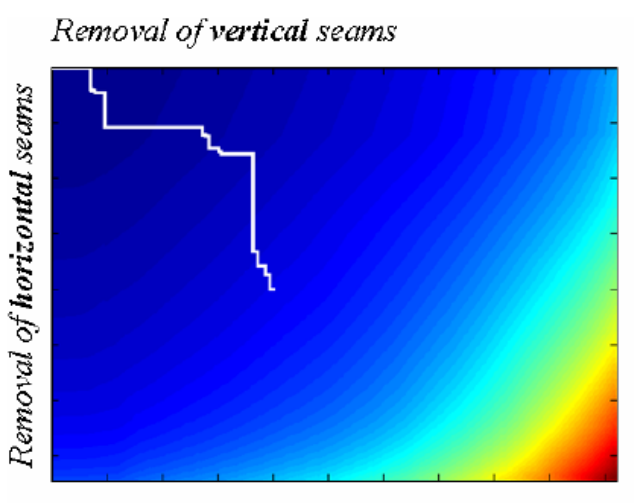


Retargeting in Both Dimensions

- **The recursion relation:**

$$\mathbf{T}(r,c) = min(\mathbf{T}(r-1,c) + E(\mathbf{s^x}(\mathbf{I_{n-r-1\times m-c}})), \mathbf{T}(r,c-1) + E(\mathbf{s^y}(\mathbf{I_{n-r\times m-c-1}})))$$

Optimal Order Map



Removal of vertical seams

Removal of horizontal seams

0	13	16	19		
16	17	22	28		
19	31	25	35		
24	28	29	???		
32	35	33			
41	38	35			

Optimal?

- **In a greedy sense…**
- **Seam costs are not absolute**
  - **Consider HVV (how many possibly orderings?)**
  - **Cost(V) on HV not necessarily equal Cost(V) on VH**
  - **But we keep track of only one: min(HV,VH) …**

Horizontal Seams \ *Vertical Seams*	V	VV
0	V	VV
H	min(HV,VH)	?

Image Expansion (Synthesis)

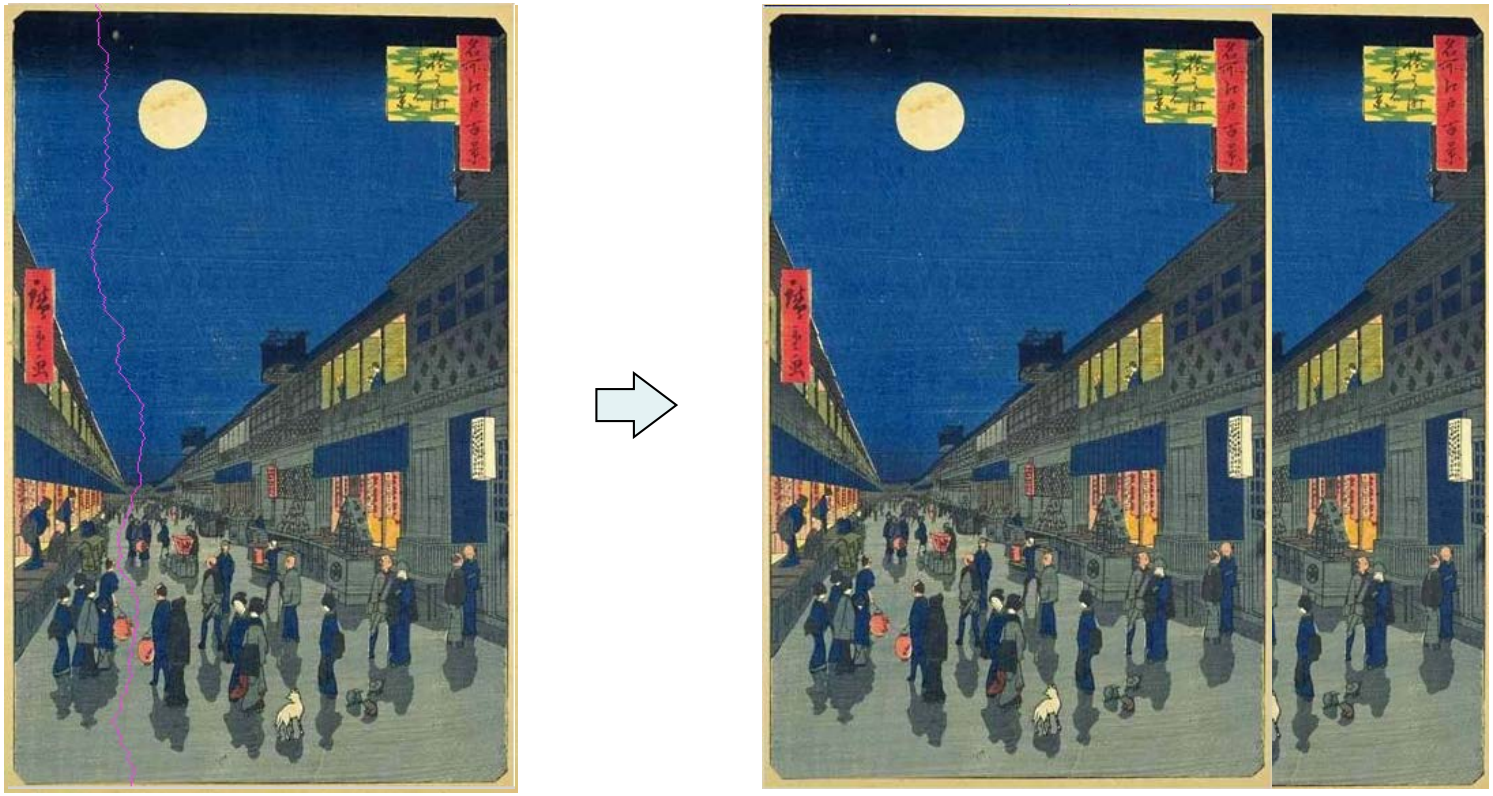


Image Expansion – take 2

Scaling

Enlarged or Reduced?

Combined Insert and Remove

Insert & remove seams

Scaling