

Chapter 5

Seam Carving

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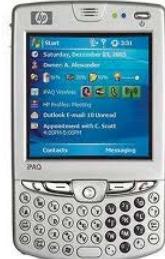
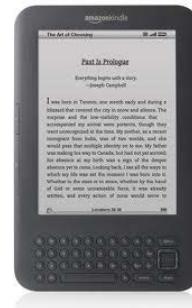
Contents

Image resizing

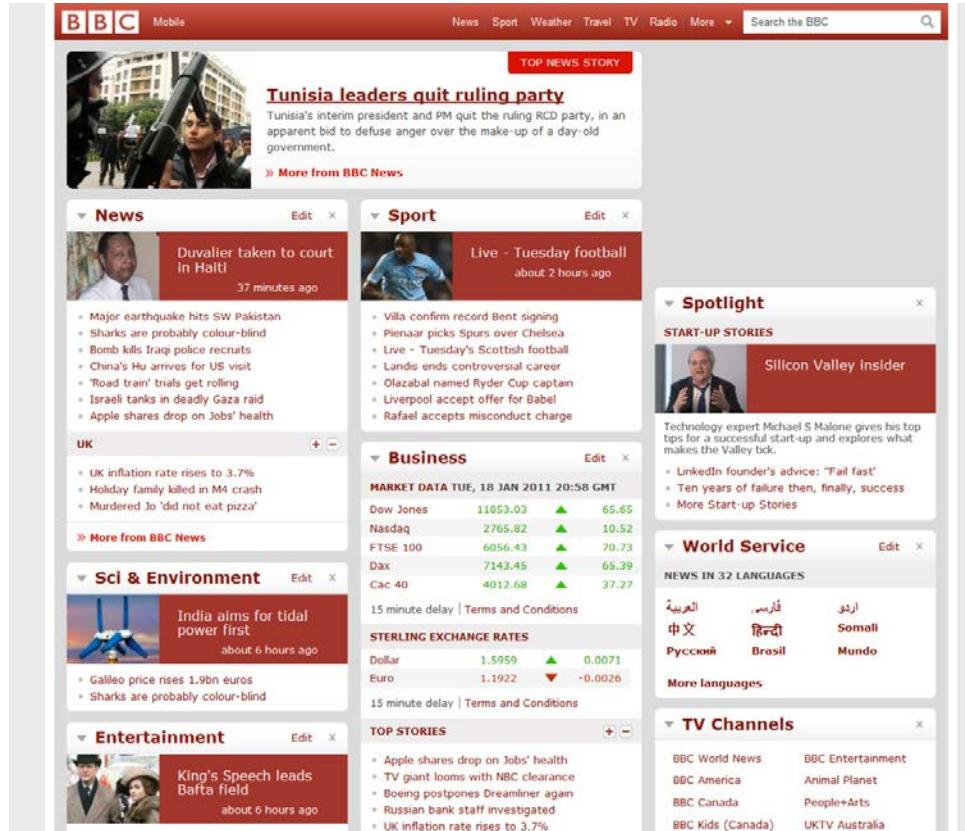
- Seam Carving algorithm



Display Devices



Content Retargeting



PC

BBC Mobile

TOP NEWS STORY

Tunisia leaders quit ruling party

Tunisia's interim president and PM quit the ruling RCD party, in an apparent bid to defuse anger over the make-up of a day-old government.

» More from BBC News

News

Duvalier taken to court in Haiti 37 minutes ago

- Major earthquake hits SW Pakistan
- Sharks are probably colour-blind
- Bomb kills Iraqi police recruits
- China's Hu arrives for US visit
- 'Road train' trials get rolling
- Israeli tanks in deadly Gaza raid
- Apple shares drop on Jobs' health

UK

- UK inflation rate rises to 3.7%
- Holiday killer in M4 crash
- Murdered Jo 'did not eat pizza'

» More from BBC News

Sport

Live - Tuesday football about 2 hours ago

Villa confirm record Bent signing
Pienna picks Spurs over Chelsea
Live - Tuesday's Scottish football
Larrieu ends controversial career
Olazabal named Ryder Cup captain
Liverpool accept offer for Babel
Rafael accepts misconduct charge

Business

MARKET DATA TUE, 18 JAN 2011 20:58 GMT

	Dow Jones	Nasdaq	FTSE 100	Dax	Cac 40
	11853.03	2765.82	6056.43	7143.45	4012.68
	▲ 65.65	▲ 10.52	▲ 70.73	▲ 65.29	▲ 37.27

STERLING EXCHANGE RATES

	Dollar	Euro
	1.5959	1.1922
	▲ 0.0071	▼ -0.0026

Entertainment

King's Speech leads Bafta field about 6 hours ago

- Apple shares drop on Jobs' health
- TV giant looms with NBC clearance
- Boeing postpones Dreamliner again
- Russian bank staff investigated
- UK inflation rate rises to 3.7%

Spotlight

START-UP STORIES

Silicon Valley Insider

Technology expert Michael S Malone gives his top tips for a successful start-up and explores what makes the Valley tick.

- LinkedIn founder's advice: "Fail fast"
- Ten years of failure, then, finally, success
- More Start-up Stories

World Service

NEWS IN 32 LANGUAGES

العربية	فارسی	اردو
中文	हिन्दी	Somali
Русский	Brasil	Mundo

More languages

TV Channels

BBC World News	BBC Entertainment
BBC America	Animal Planet
BBC Canada	People+Arts
BBC Kids (Canada)	UKTV Australia

BBC News

China's Hu arrives for US visit
Duvalier taken to court in Haiti
Tunisia leaders quit ruling party

More from BBC News

BBC Sport

Live - Tuesday football
Villa confirm record Bent signing
More from BBC Sport

BBC World Service

Inside the IMF
The King's Speech: A stammerer's perspective
Hourly news bulletin
More audio from BBC World Service

Weather

Find 5 day forecast

Languages

Spanish
News in more languages

From BBC Mobile UK

- Television
- Radio & Music
- Entertainment
- BBC Children
- Learning
- Lifestyle
- Food

FAQ

iPhone

Page Layout



The screenshot shows a Mozilla Firefox browser window displaying the Wikipedia article "Page layout". The page title is "Page layout" and it is categorized under "Article". The main content discusses the history and development of page layout, mentioning its transition from illuminated manuscripts to modern magazine layouts. It highlights the role of type, images, and graphics in layout design. A sidebar on the left provides navigation links for the Wikipedia site, including "Main page", "Contents", and "Languages". A right-hand sidebar features a photograph of a magazine rack and a caption about consumer magazine sponsored advertisements.

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

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](#).

Simple Media Retargeting Operators

Letterboxing



Content-aware Retargeting Operators

Content-aware



*“Important”
content*



Content-oblivious



Content-aware Retargeting

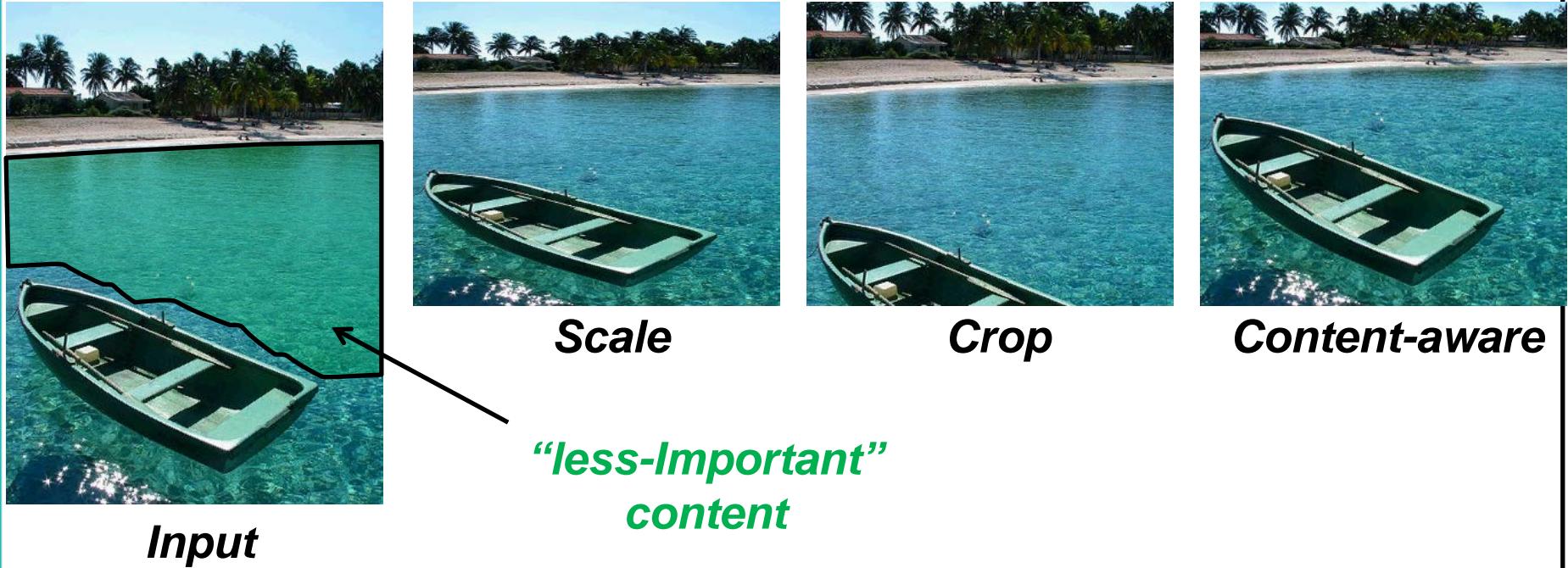


Image Retargeting

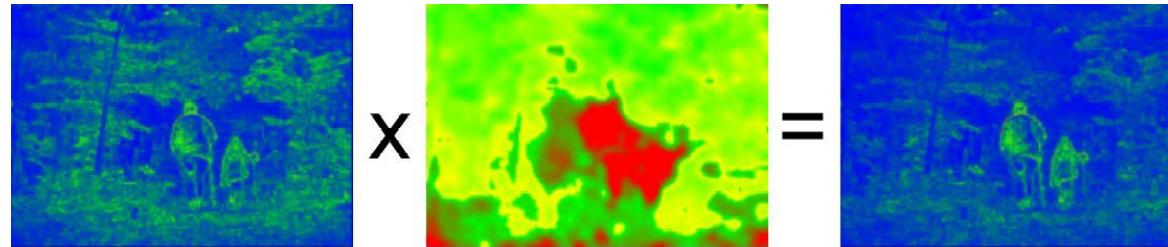
- Problem statement:
 - Input Image I with size $n \times m$, and new size $n' \times m'$
 - Output Image I' of size $n' \times m'$ which will be “**good representative**” of the original image I
- To date, **no agreed definition**, or **measure**, as to what a good representative is in this context!

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 $S: p \rightarrow [0,1]$



Wang et al. 2008

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

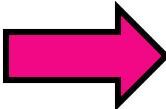


Judd et al. ICCV09 Learning to predict where people look

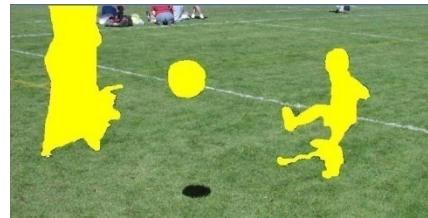


General Retargeting Framework

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



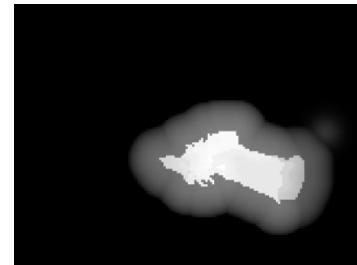
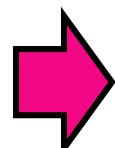
2. Use some operator(s) to change the image I



Recompose



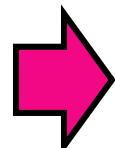
**Setlur et al.
[2005]**



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)

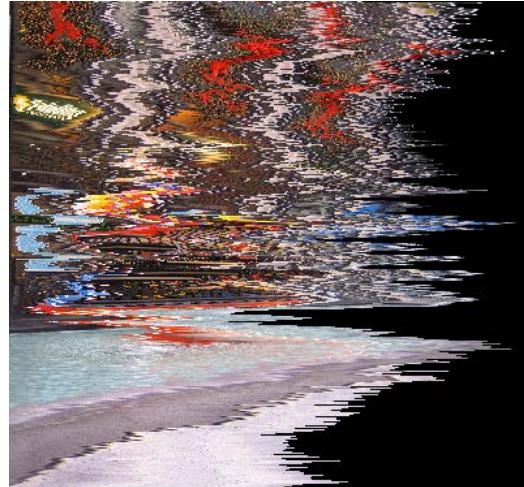
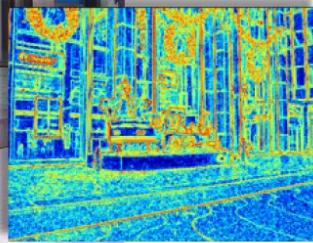
Cropping



Seam Carving

- Assume $m \times n \rightarrow m \times n'$, $n' < n$
- Basic Idea: remove unimportant pixels from the image
 - Unimportant = pixels with less “energy”
$$E_1(\mathbf{I}) = \left| \frac{\partial}{\partial x} \mathbf{I} \right| + \left| \frac{\partial}{\partial y} \mathbf{I} \right|.$$
- 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

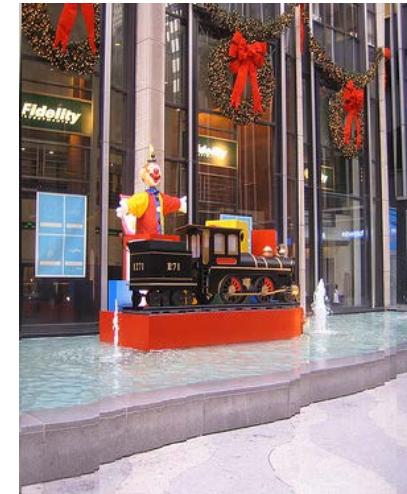


Optimal

Department of Mechatronics



*Least-energy pixels
(per row)*



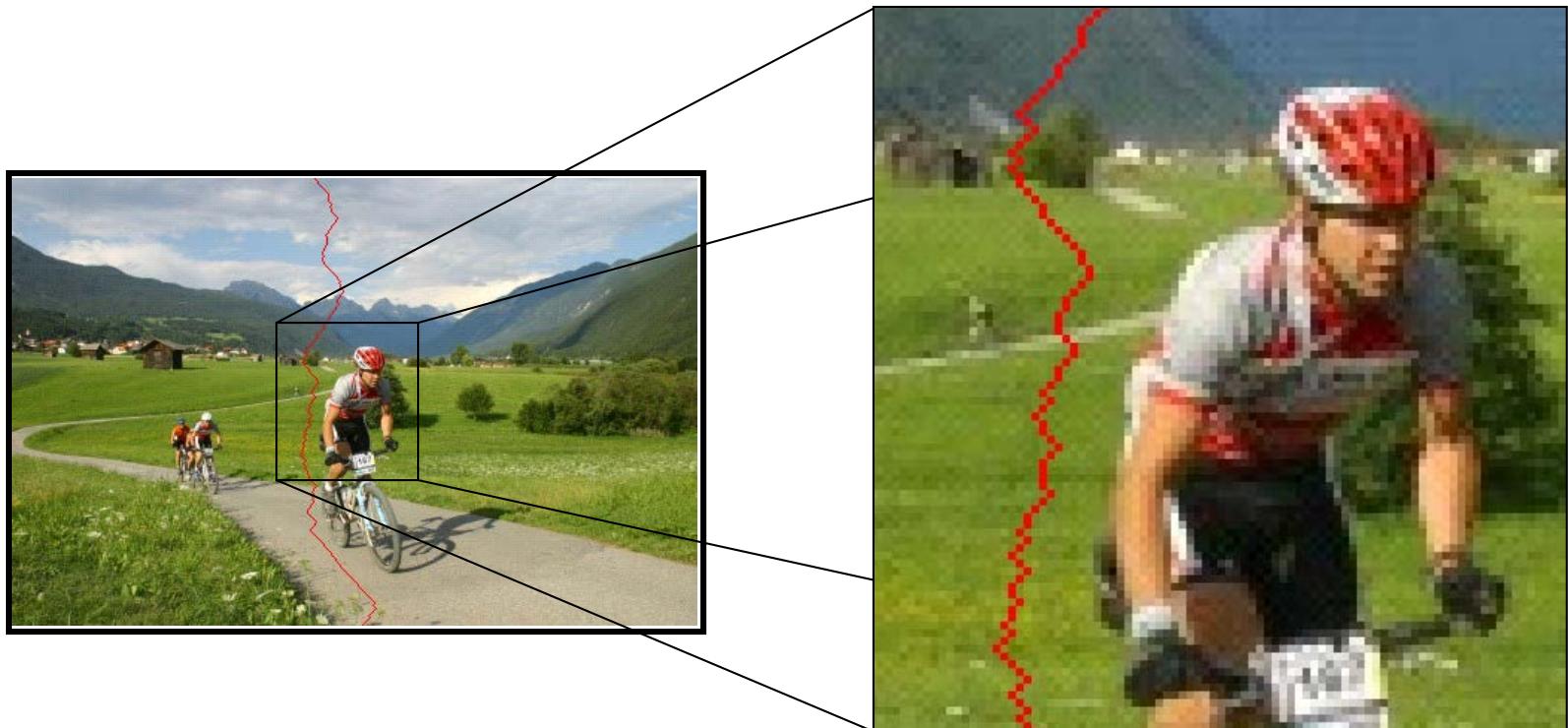
Least-energy columns

A Seam

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

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

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



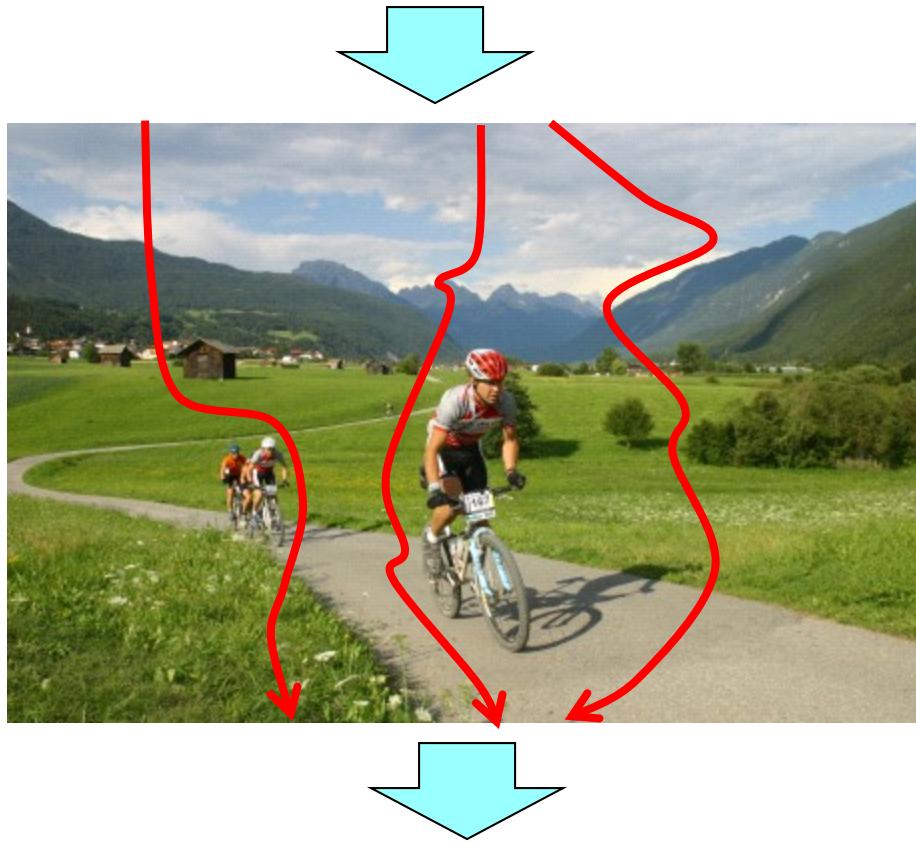
Seams in Images

- Efros & Freeman [2001] – Texture synthesis
- Kwatra et al. [2003] – Image and video synthesis
- Agarwala et al. [2004] – Digital Photomontage
- Perez et al. [2003] *Mostly used for composition of two (or more) images or patches...*
- Jia et al. [2004] – Multi-Image Matting
- Rother et al. [2006] – Auto-Collage
- Wang and Cohen [2006] – simultaneous matting and compositing

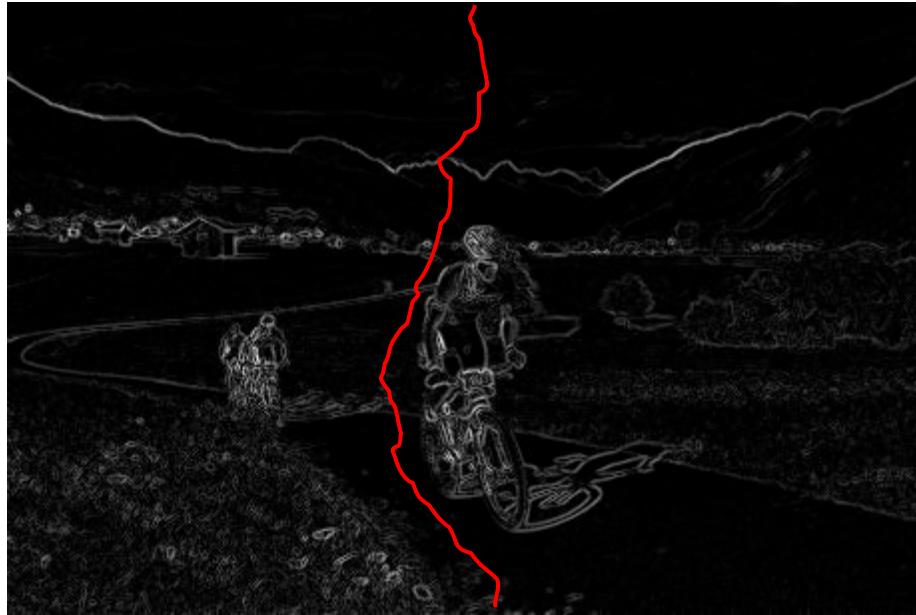


Agarwala et al., Interactive Digital Photomontage

Finding the Seam?



The Optimal Seam



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

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

The Optimal Seam

- The recursion relation

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

- 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)

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

A 4x4 grid of numbers representing costs for a seam. Red arrows point from the top-left cell (5) to the second column of the second row (2), indicating the path of the minimum-cost seam.

Dynamic Programming

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

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

A 4x4 grid illustrating dynamic programming. The top row contains values 5, 8, 12, 3. The second row contains 9, 2+5, 3, 9. The third row contains 7, 3, 4, 2. The bottom row contains 4, 5, 7, 8. Red arrows point from the value 2 in the second row to the value 5 in the first row, and from the value 5 in the first row to the value 2+5 in the second row.

Dynamic Programming

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

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

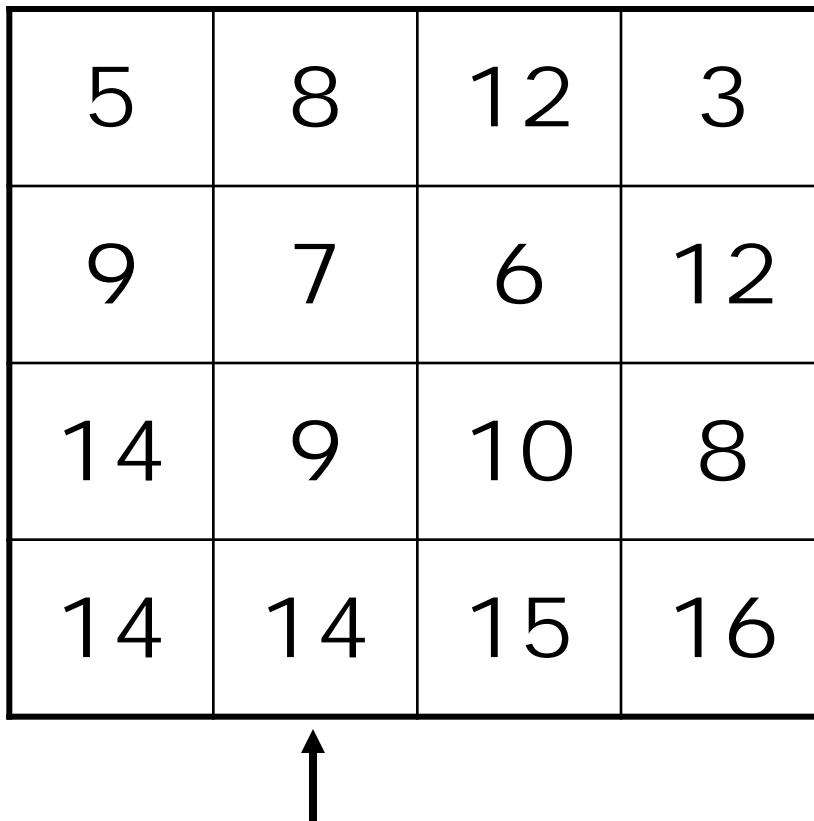
Dynamic Programming

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

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

Searching for Minimum

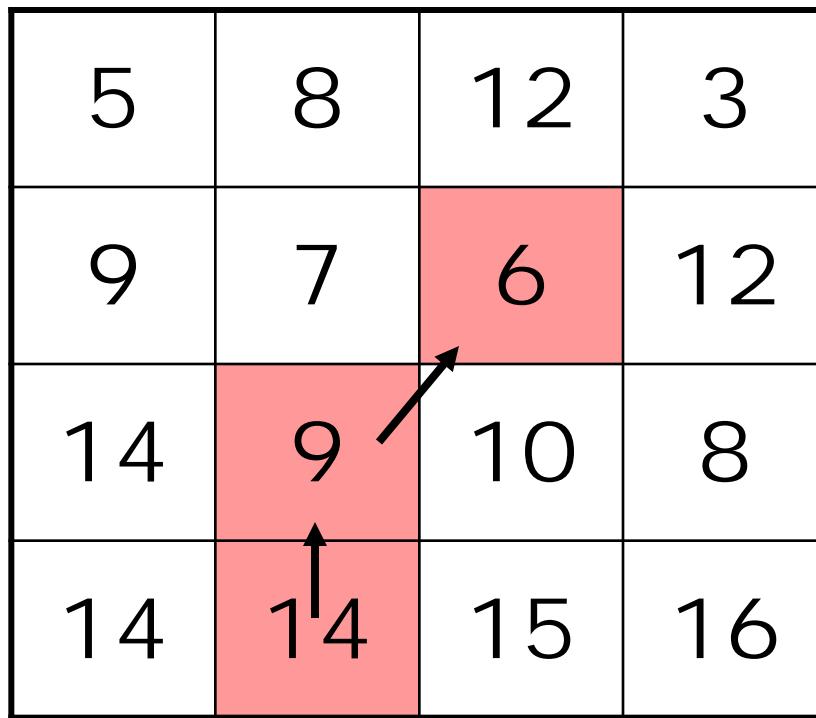
- Backtrack (can store choices along the path, but do not have to)



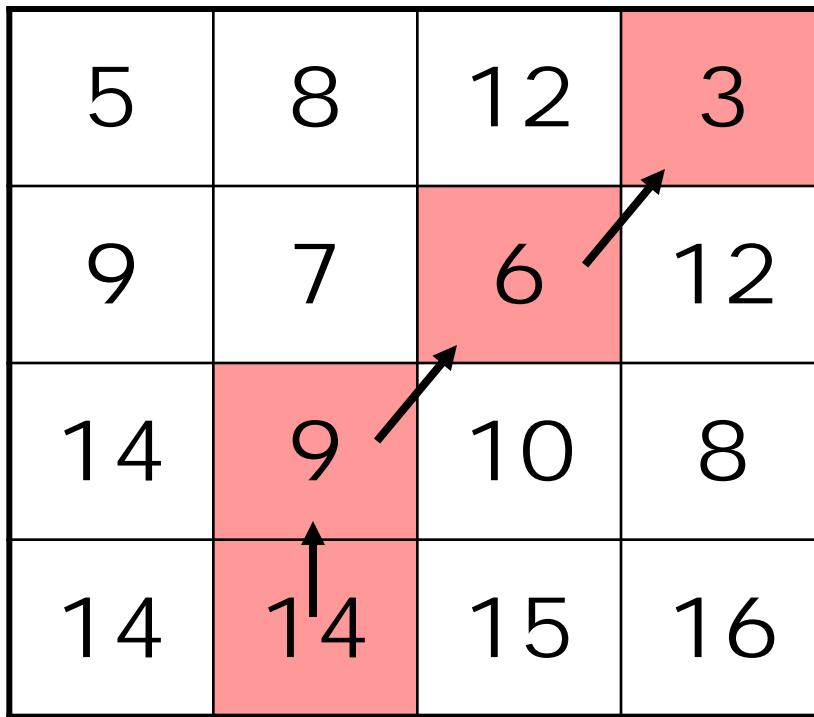
Backtracking the Seam

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

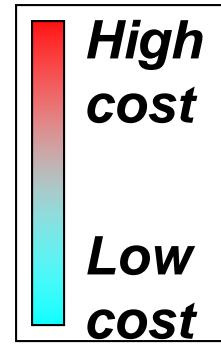
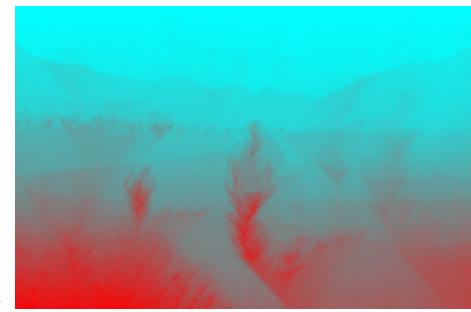
Backtracking the Seam



Backtracking the Seam

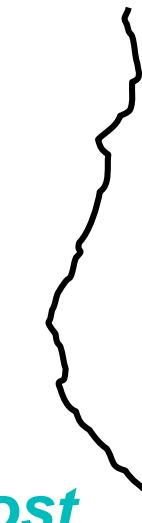


H & V Cost Maps



Horizontal Cost

Vertical Cost



Seam Carving



The Seam-Carving Algorithm

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

Do ($n-n'$) times

- 2.1. $E \leftarrow$ Compute energy map on im
- 2.2. $s \leftarrow$ Find optimal seam in E
- 2.3. $im \leftarrow$ Remove s from im

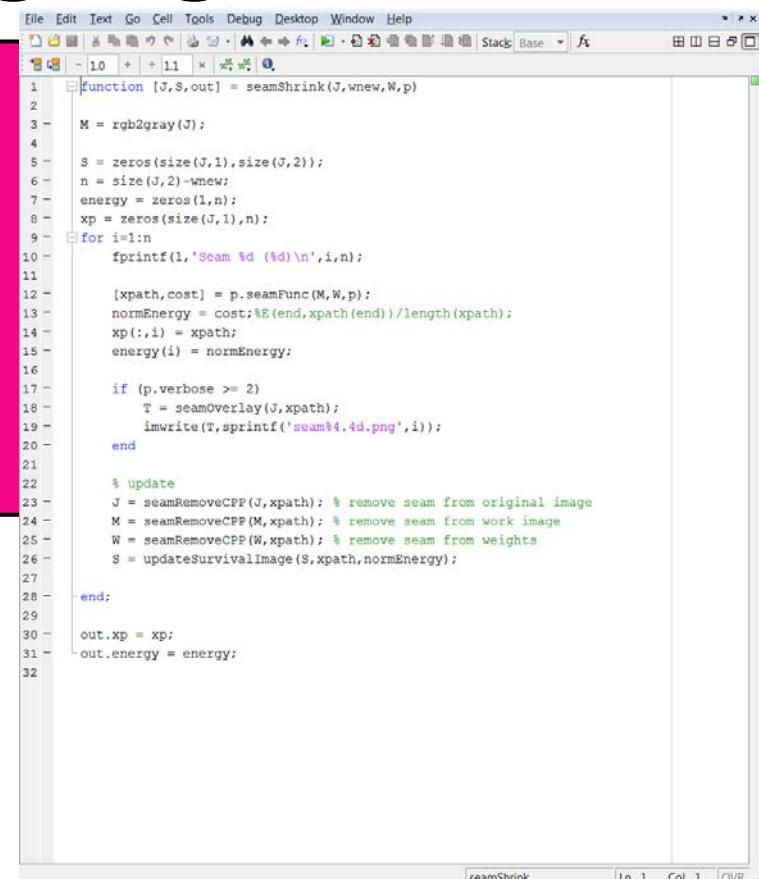
Return im

- *For vertical resize: transpose the image*

- *Running time:*

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

$\rightarrow O(dmn)$ $d=n-n'$



```

File Edit Text Go Cell Tools Debug Desktop Window Help
File Edit Text Go Cell Tools Debug Desktop Window Help
1 function [J,S,out] = seamShrink(J,wnew,W,p)
2
3 M = rgb2gray(J);
4
5 S = zeros(size(J,1),size(J,2));
6 n = size(J,2)-wnew;
7 energy = zeros(1,n);
8 xp = zeros(size(J,1),n);
9 for i=1:n
10    fprintf(1,'Seam %d (%d)\n',i,n);
11
12    [xpath,cost] = p.seamFunc(M,W,p);
13    normEnergy = cost;%E(end,xpath(end))/length(xpath);
14    xp(:,i) = xpath;
15    energy(i) = normEnergy;
16
17 if (p.verbose >= 2)
18    T = seamOverlay(J,xpath);
19    imwrite(T,sprintf('seam%d4d.png',i));
20 end
21
22 % update
23 J = seamRemoveCPP(J,xpath); % remove seam from original image
24 M = seamRemoveCPP(M,xpath); % remove seam from work image
25 W = seamRemoveCPP(W,xpath); % remove seam from weights
26 S = updateSurvivalImage(S,xpath,normEnergy);
27
28 end;
29
30 out.xp = xp;
31 out.energy = energy;
32

```

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



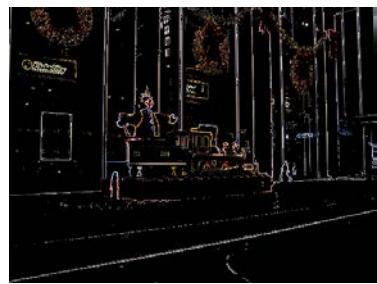
Seam Carving in the Gradient Domain



Preserved Energy



Energy



10%



30%



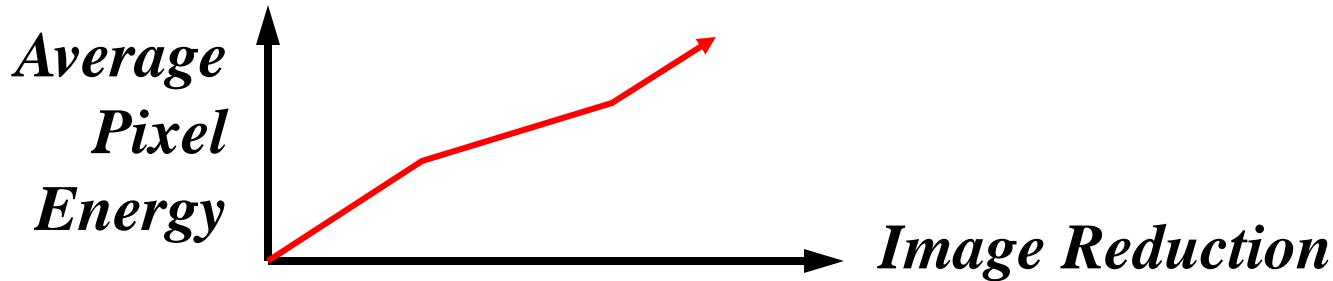
40%



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

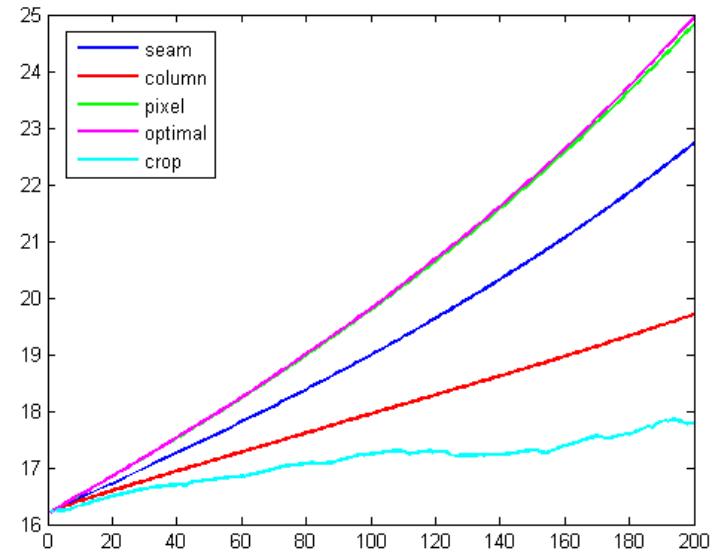


Image Reduction →



crop



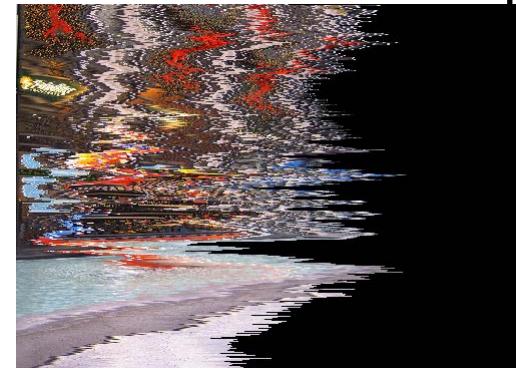
column



seam



pixel



optimal

Both Dimensions?

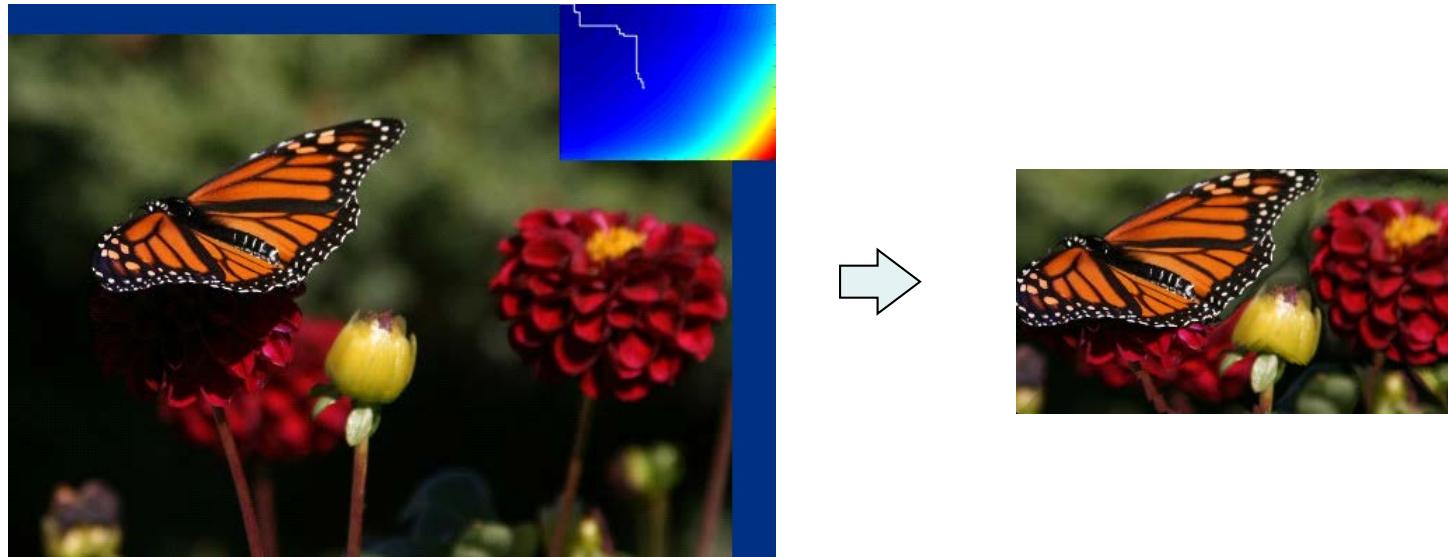
- $m \times n \rightarrow m' \times n'$
- Remove horizontal seam first?
- Remove vertical seams first?
- Alternate between the two?
- The optimal order can be found! → Dynamic Prog (again)



Retargeting in Both Dimensions

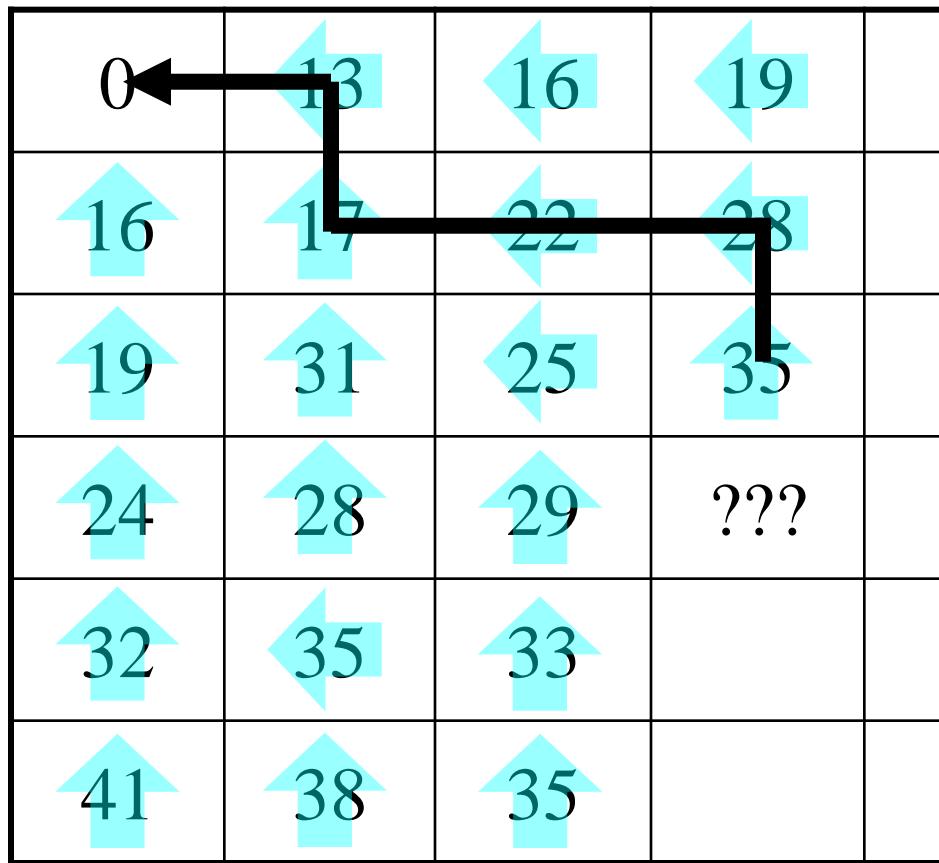
- The recursion relation:

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



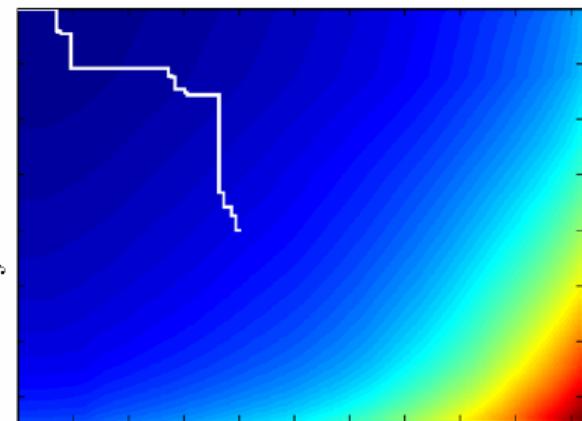
Optimal Order Map

Removal of horizontal seams



Removal of vertical seams

Removal of horizontal seams



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

0	V	VV
H	$\min(HV, VH)$?

Image Expansion (Synthesis)

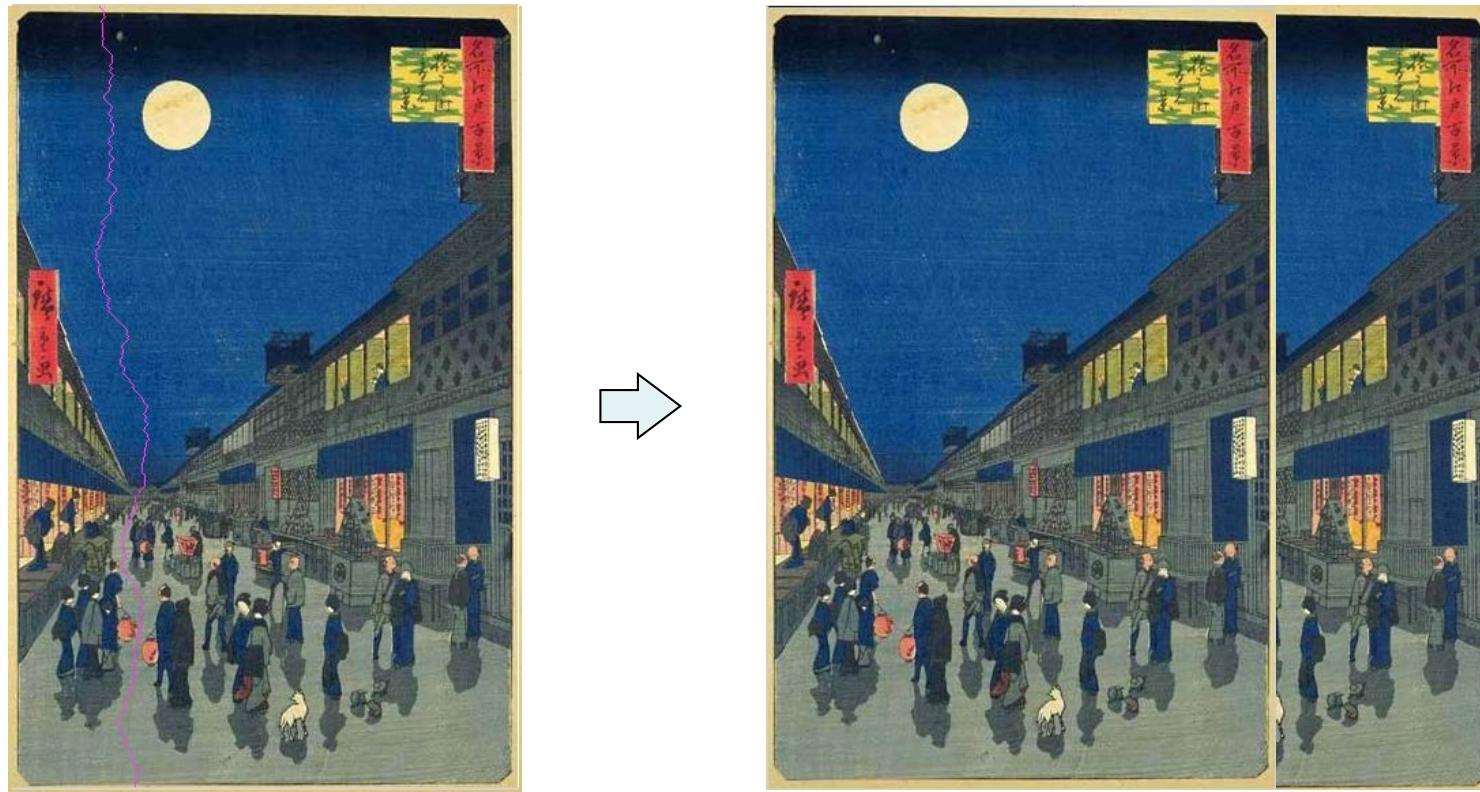
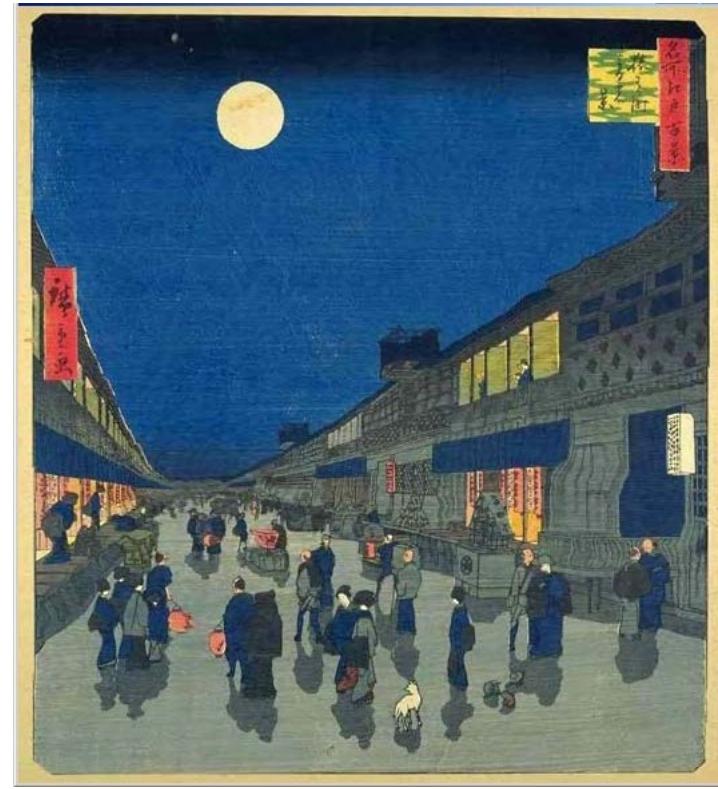
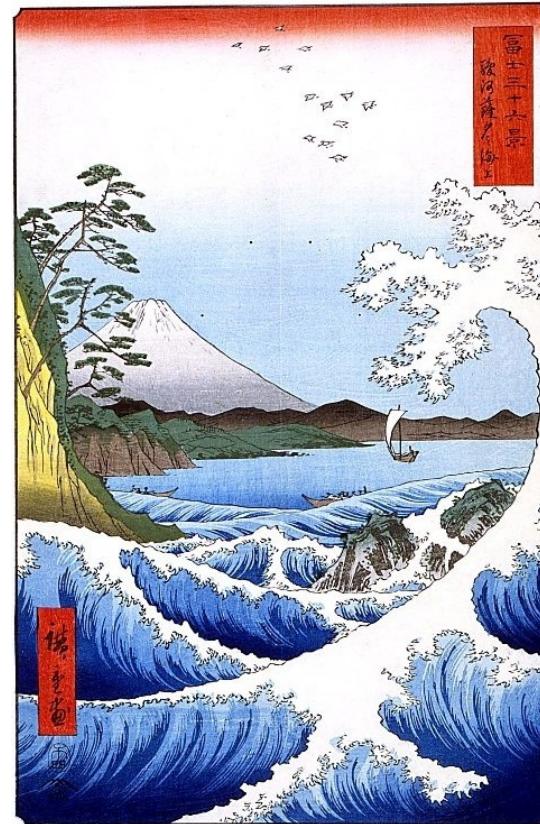


Image Expansion – take 2



Scaling

Enlarged or Reduced?



Combined Insert and Remove



Insert & remove seams



Scaling