



Lecture: Image Resizing

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CS 131 Roadmap

Image Resizing

15-Oct-2019

2





Today's agenda

- Image resizing
 - Seam carving
 - Dynamic programming
- Applications



Display Devices





Content Retargeting

Image Resizing

15-Oct-2019

BBC Mobile

News | Sport | Weather | Travel | TV | Radio | More | Search the BBC

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 family killed in M4 crash
- Murdered Jo 'did not eat pizza'

» More from BBC News

Sci & Environment

India aims for tidal power first about 6 hours ago

- Galileo price rises 1.9bn euros
- Sharks are probably colour-blind

Entertainment

King's Speech leads Bafta field about 6 hours ago

TOP NEWS STORY

Sport

Live - Tuesday football about 2 hours ago

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
▲ 65.65	▲ 10.52	▲ 70.73	▲ 65.39	▲ 37.27	

15 minute delay | Terms and Conditions

STERLING EXCHANGE RATES

	Dollar	Euro
1.5959	▲ 0.0071	
1.1922	▼ -0.0026	

15 minute delay | Terms and Conditions

TOP STORIES

- 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%

TOP NEWS STORY

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

PC

BBC

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

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

FAQ

iPhone



Image Resizing

15-Oct-2019

Dribble - Show and tell f... X +

working on? Dribble is show and tell for designers. Learn more. Sign up

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Send to Slack

InVision

Vladimir Marchukov

Brian Steely

Justas Galaburda

UN BRIN DE FORÊT POUR TOUS

Lionel Durimel

Szende Brassai / Adline

Dustin Wallace

Vladimir Babic

seanwes

GIF

CHOOSING COLOURS

1,442 7 132

504 5 118

868 2 114

1,553 8 126

2,120 12 266

1,709 8 175

1,002 7 157

796 5 135



Simple Media Retargeting Operators

Left Scaling





Content-aware Retargeting Operators

Content-aware



"Important" content



Content-oblivious





Content-aware Retargeting

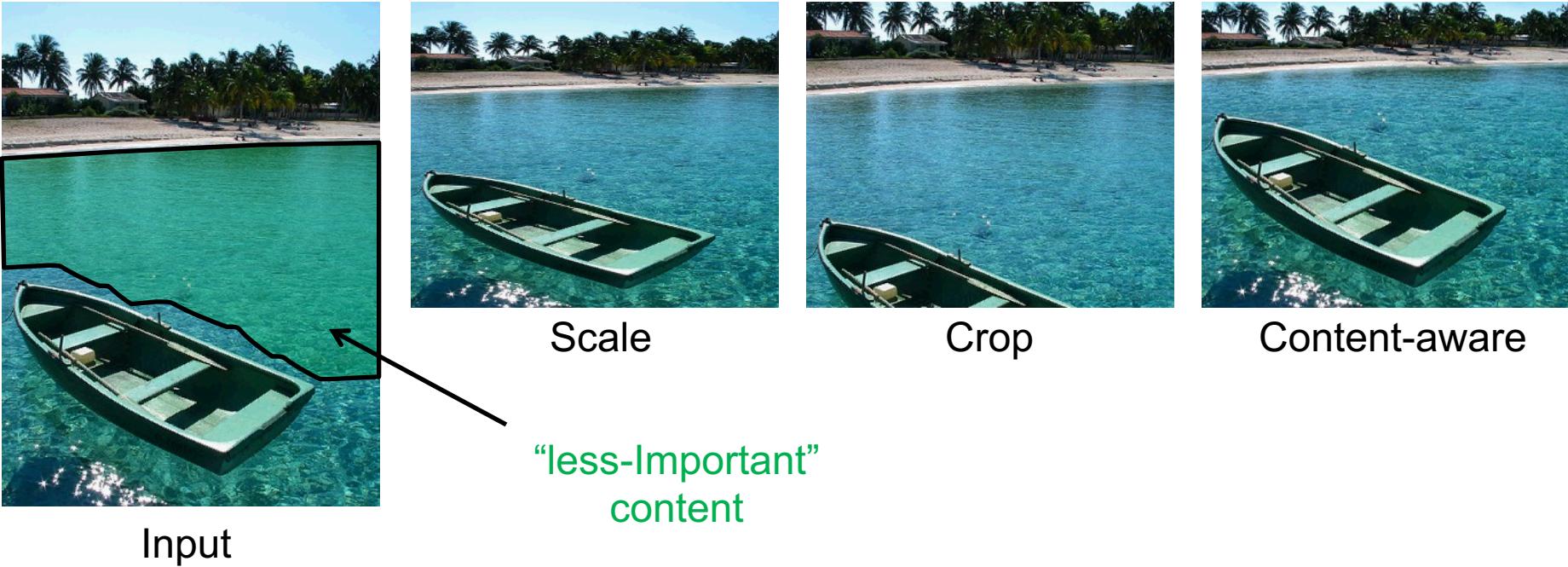




Image Retargeting

- Problem statement:
 - Input Image I $n \times m$, 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!



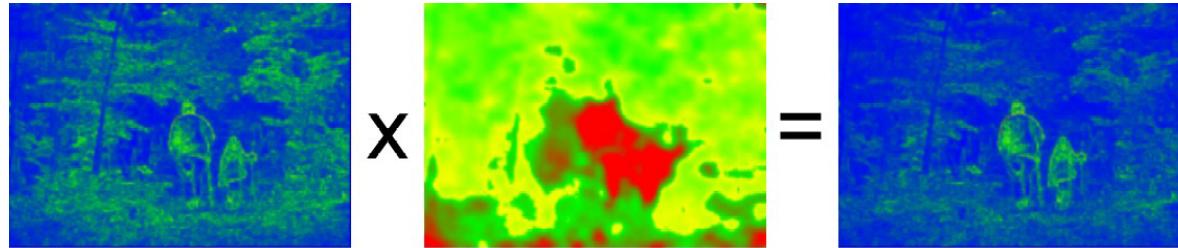
Image/Video Retargeting

- In large, we would expect retargeting to:
 1. Adhere to the geometric constraints (display/aspect ratio)
 2. Preserve the important *content* and *structures*
 3. Limit *artifacts*
- 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*

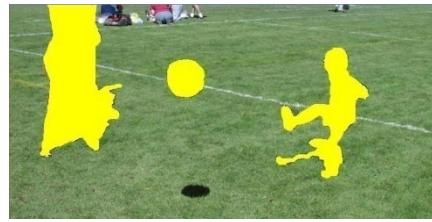
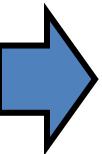


General Retargeting Framework

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



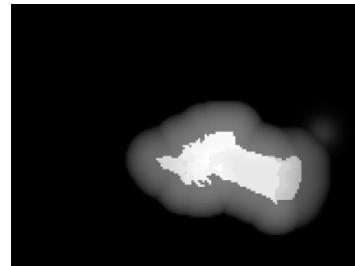
2. Use some operator(s) to change the image I



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

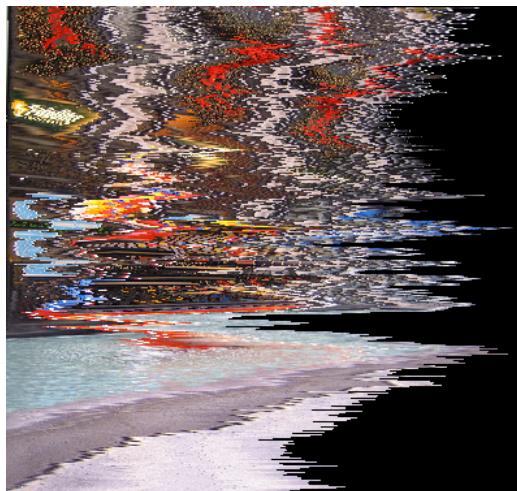
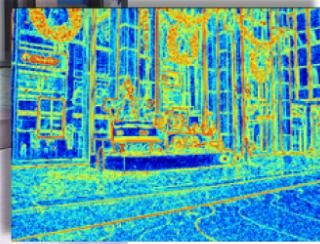
- Assume $m \times n \rightarrow m \times n'$, $n' < n$ (summarization)
- Basic Idea: remove unimportant pixels from the image
 - Unimportant = pixels with less “energy”

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

- 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



Pixel Removal



Optimal



Least-energy pixels
(per row)



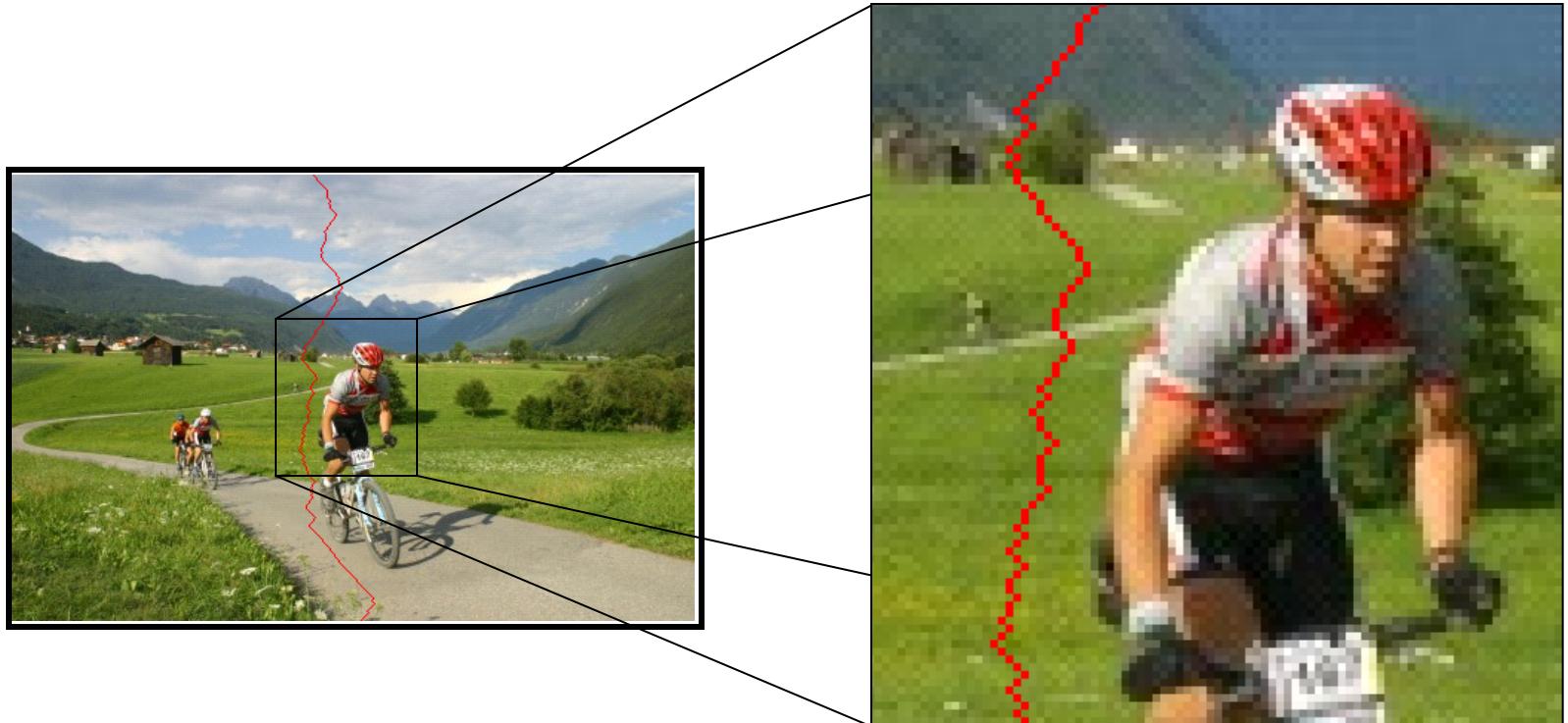
Least-energy columns



A Seam

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

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



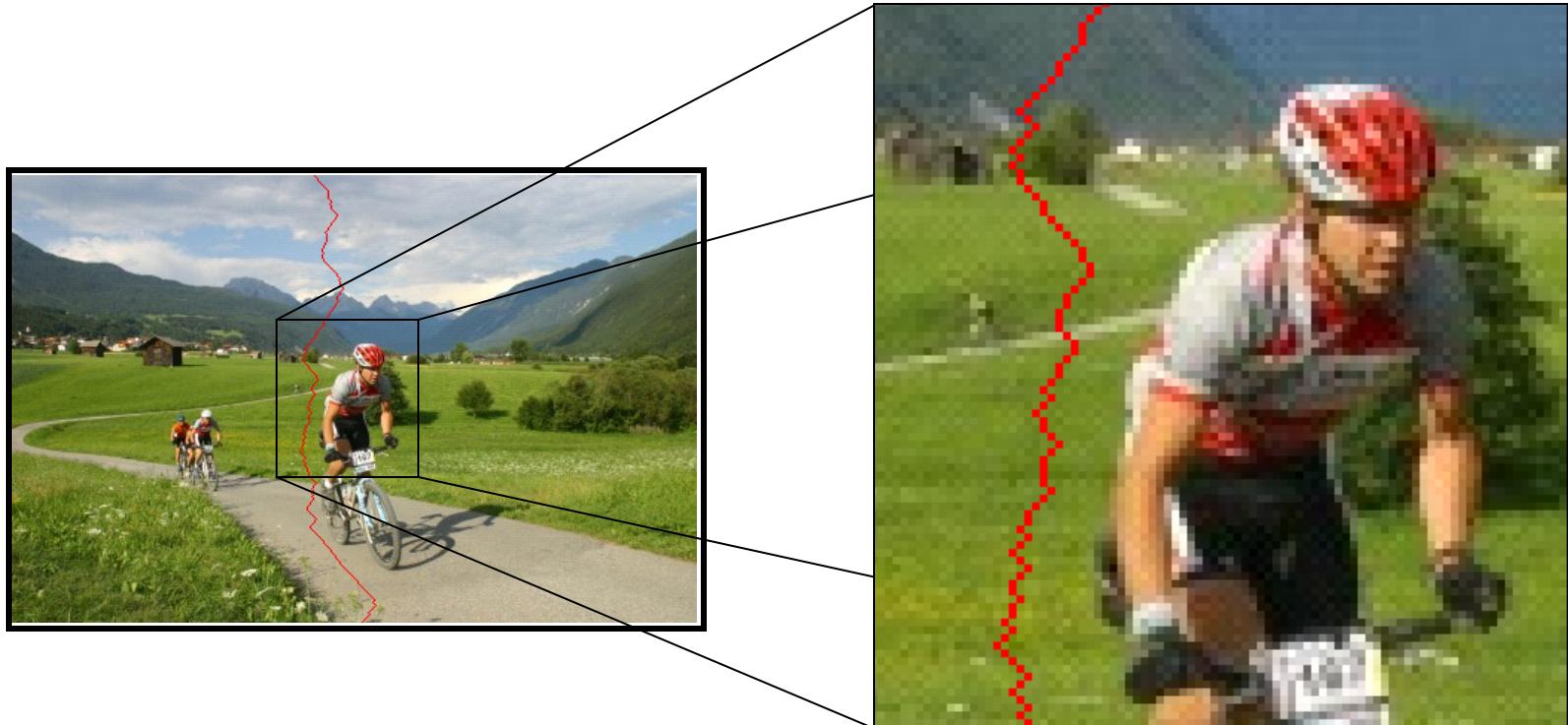


A Seam

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

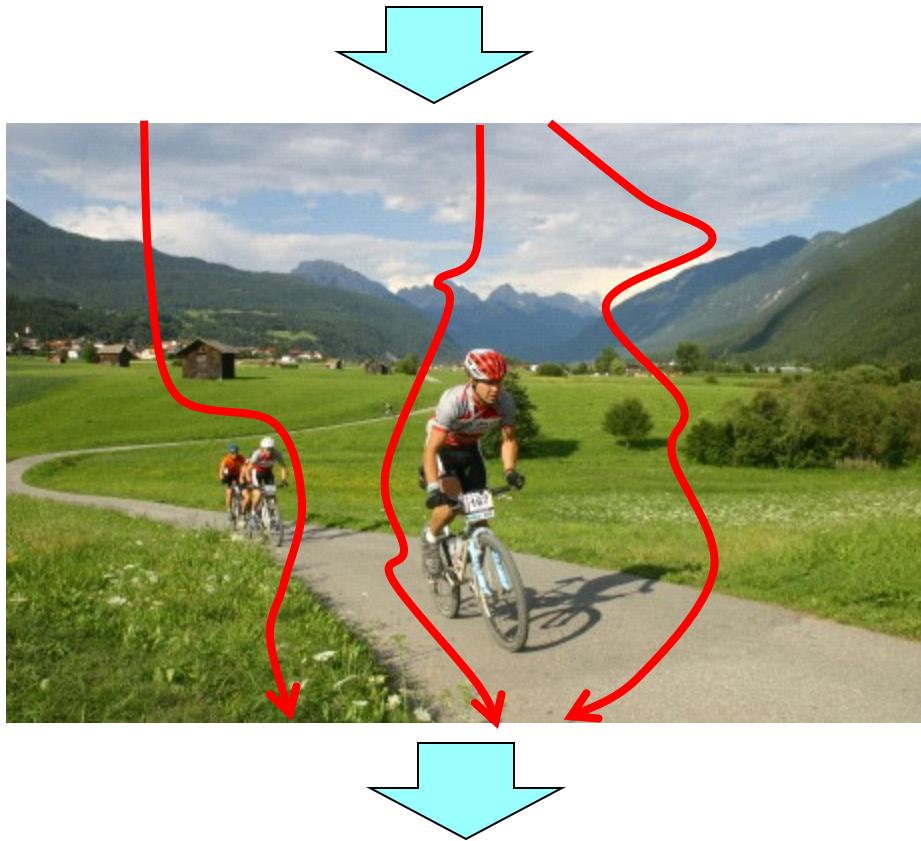
$$\mathbf{s}^x = \{s_i^x\}_{i=1}^n = \{(x(i), i)\}_{i=1}^n, \text{ s.t. } \forall i, |x(i) - x(i-1)| \leq 1$$

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



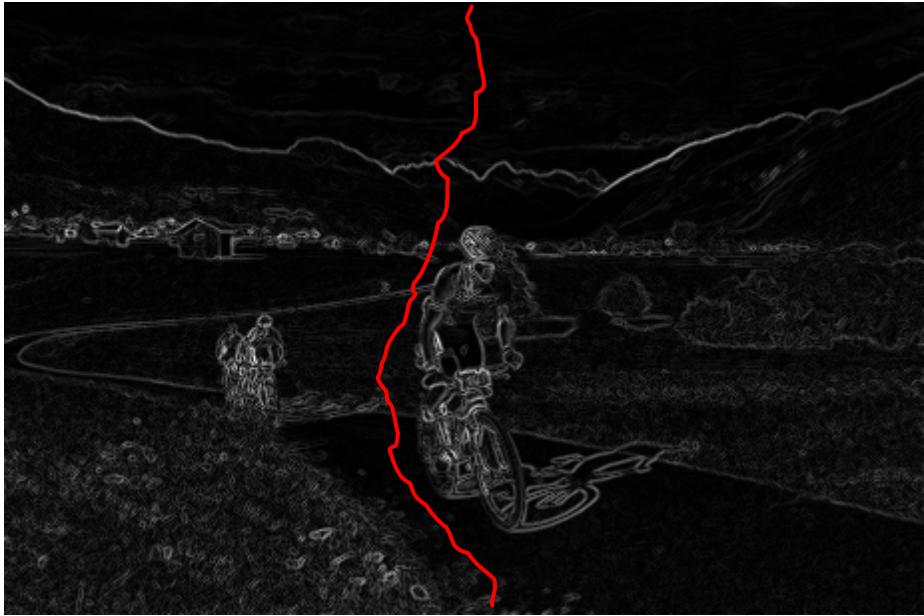


Finding the Seam?





The Optimal Seam



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



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		

Diagram illustrating a seam in a 4x4 grid. The grid contains the following values:

5	8	12	3
9	2		

Red arrows point from the value 5 to the value 2, indicating the path of the seam.

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

Energy - $E(i,j)$



Dynamic Programming

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

5	8	12	3
9	2+5		

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

Energy - $E(i,j)$



Dynamic Programming

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

5	8	12	3
9	7	3+3	

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

Energy - $E(i,j)$



Dynamic Programming

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

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

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

Energy - $E(i,j)$



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

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

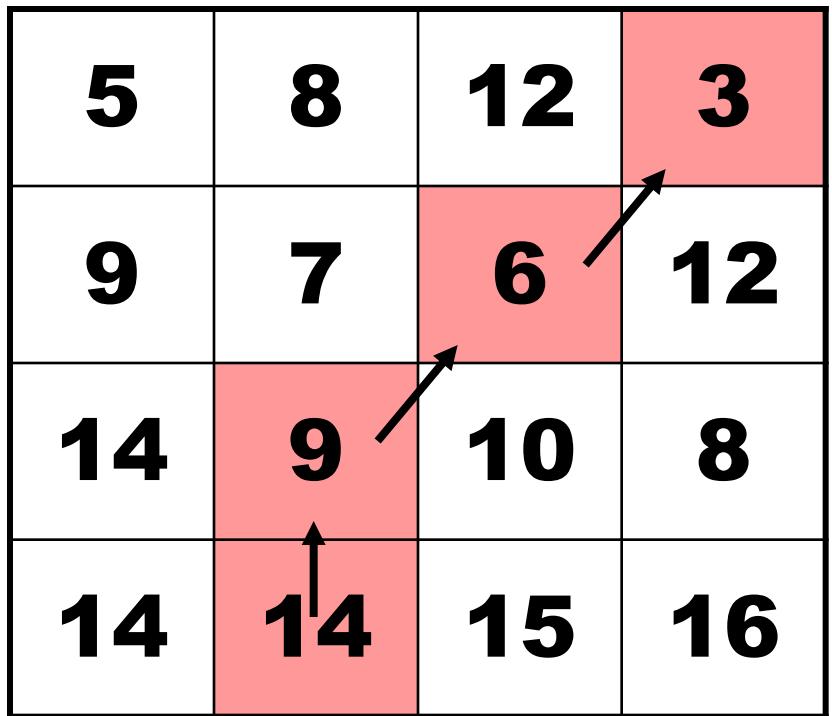


Backtracking the Seam

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

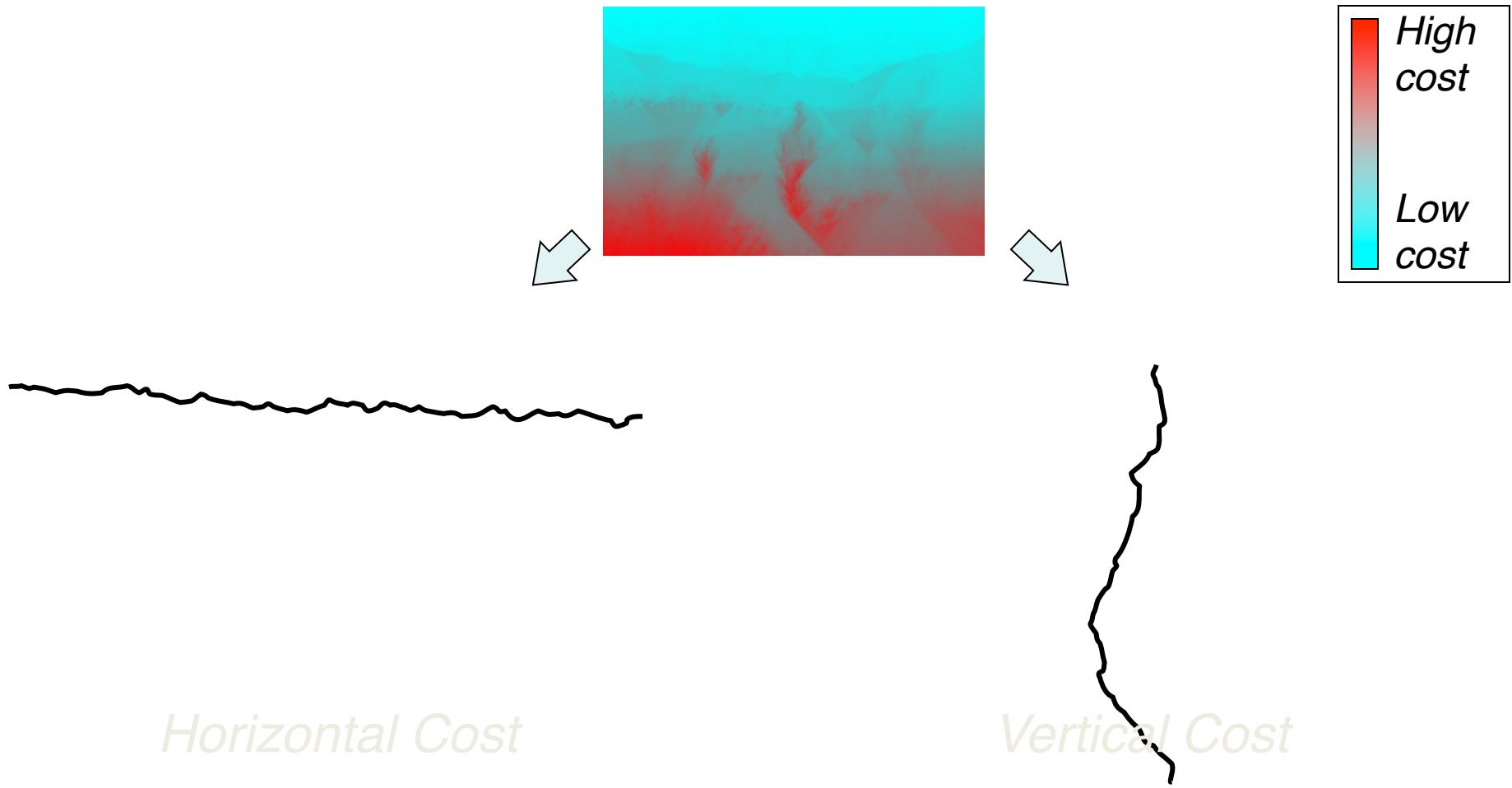


Backtracking the Seam





H & V Cost Maps



Seam Carving

Sandipan Dey (UMBC)

Removing V-Seam, image shape = (413x627), size = 5.93 MB





The Seam-Carving Algorithm

```
SEAM-CARVING(im, n') // size(im) = m x n
```

1. 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
2. Return im

- For vertical resize: transpose the image
- Running time:
 - 2.1 $O(mn)$
 - 2.2 $O(mn)$
 - 2.3 $O(mn)$

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



Changing Aspect Ratio



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Changing Aspect Ratio



Original



Seam Carving



Scaling



Changing Aspect ratio



Cropping



Seams



Scaling



Changing Aspect Ratio



Original



Retarget



Scaling



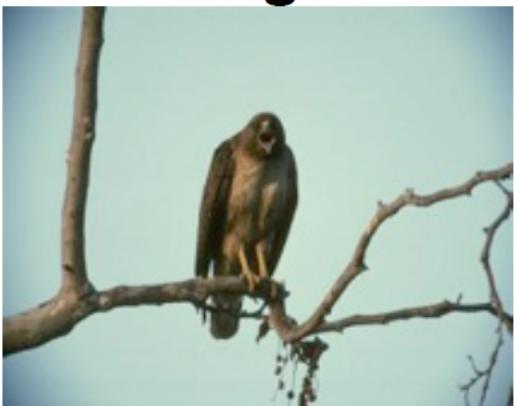
Changing Aspect Ratio



Original



Retarget



Scaling

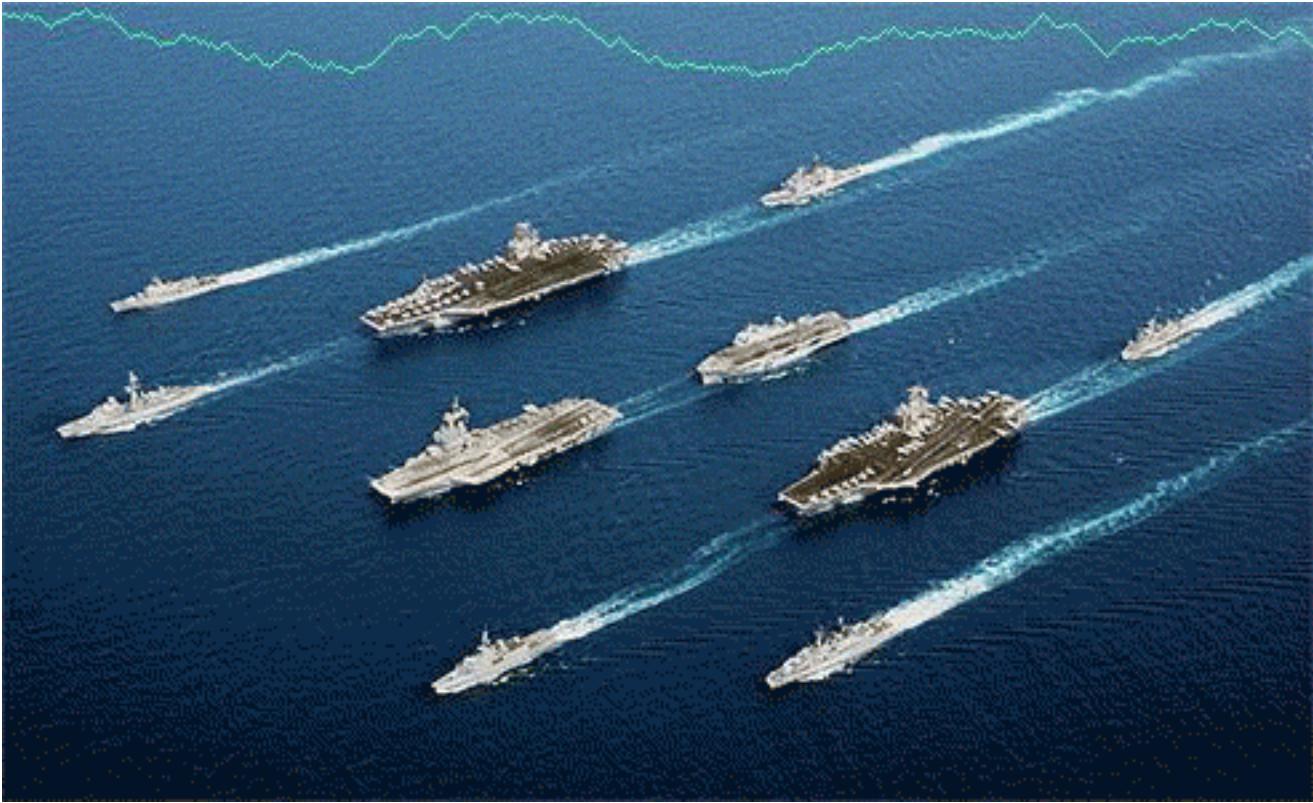


Example seam carving





Another example





Questions?

- Q: Will the result be the same if the image is flipped upside down?
- A: Yes (up to numerical stability)

- Q: Can we improve the running time?
- A: Yes, by accounting for locality of operations



A Local Operator



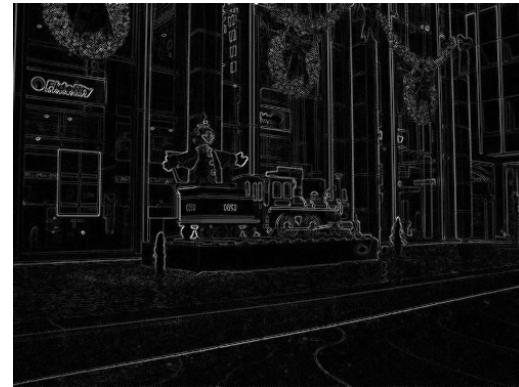


Questions?

- Q: Will the result be the same if the image is flipped upside down?
• A: Yes (up to numerical stability)
- Q: Can we improve the running time?
• A: Yes, by accounting for locality of operations
- Q: What happens to the overall energy in the image during seam carving?



Preserved Energy



Energy



10%



30%



40%



75%

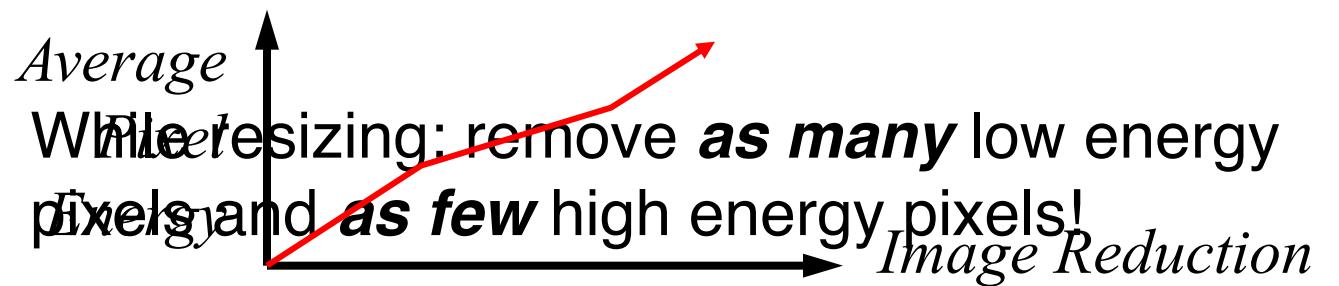
While resizing: remove ***as many*** low energy pixels and ***as few*** high energy pixels!



Preserved Energy

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

...the average should increase!





Preserved Energy



Average
Pixel
Energy

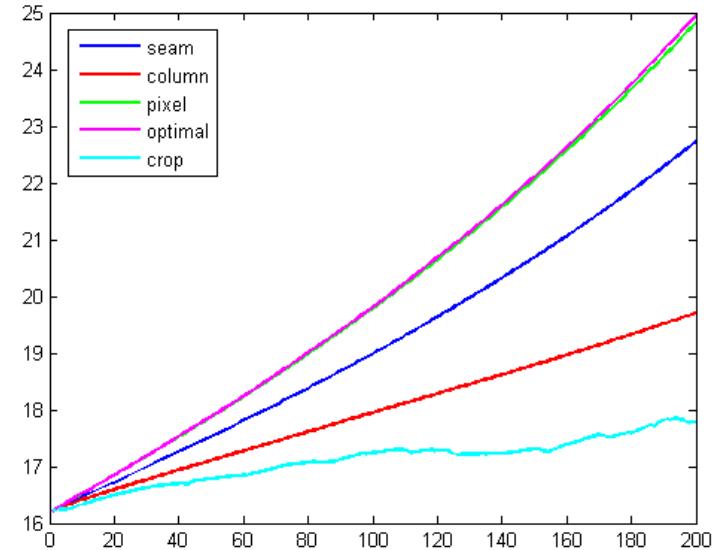


Image Reduction →



crop



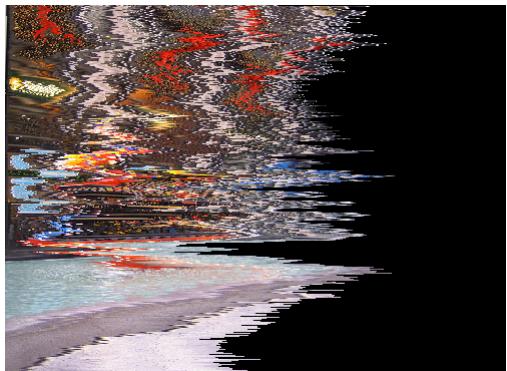
column



seam



pixel



optimal



Extension to 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)





Image Expansion (Synthesis)

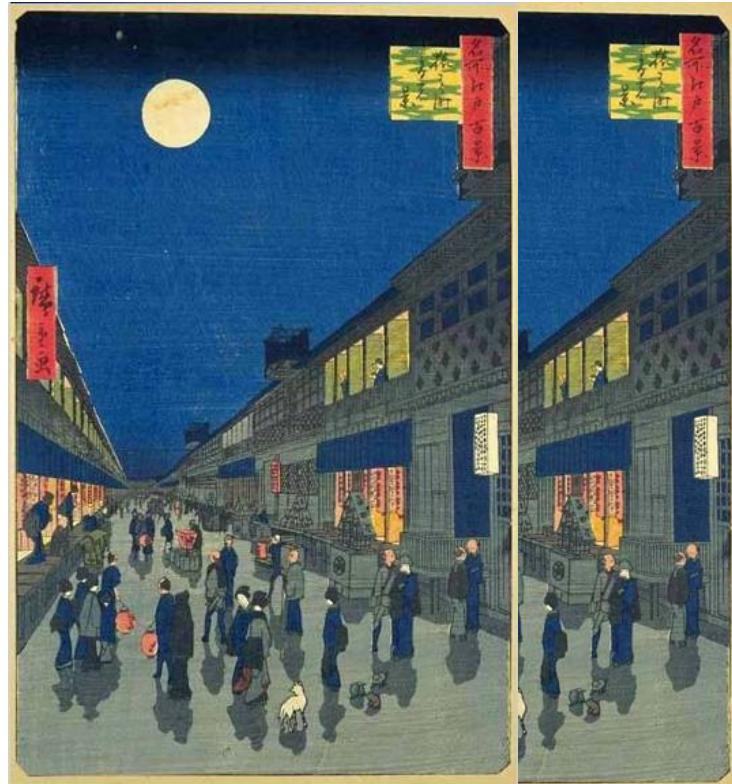
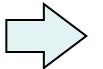
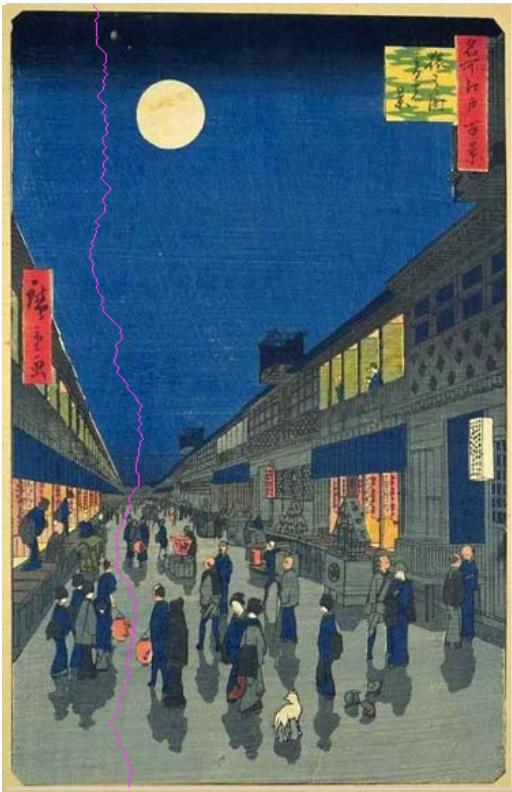


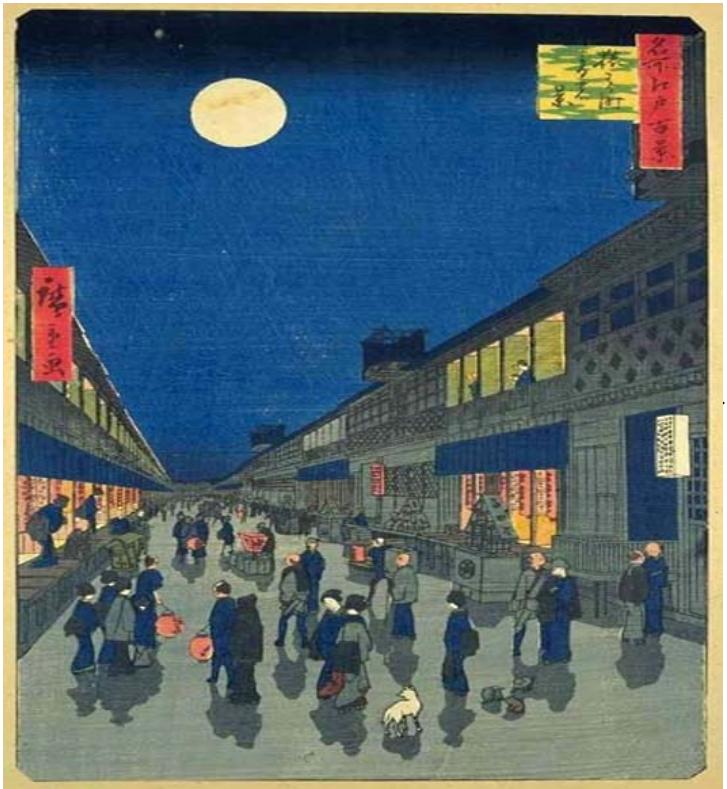


Image Expansion – take 2

Image Resizing

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Scaling





Combined Insert and Remove



Insert & remove seams



Scaling



Questions?



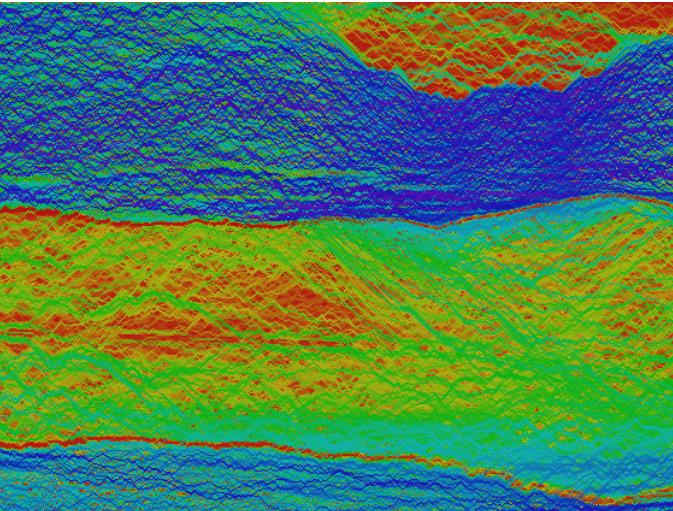
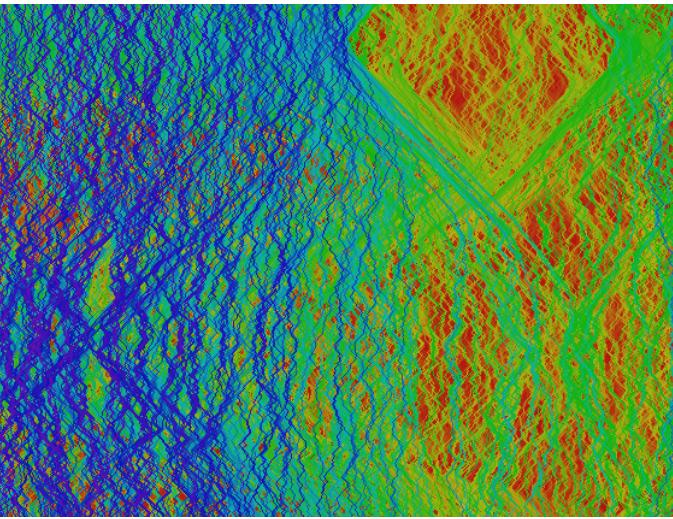
Multi-Size Images

- We can create a new representation of an image that will allow adapting it to different sizes!
 1. Precompute all seams once
 2. Realtime resizing / transmit with content



Multi-Size Images

- █ *First to be removed*
- █ *•*
- █ *•*
- █ *•*
- █ *•*
- █ *Last to be removed*

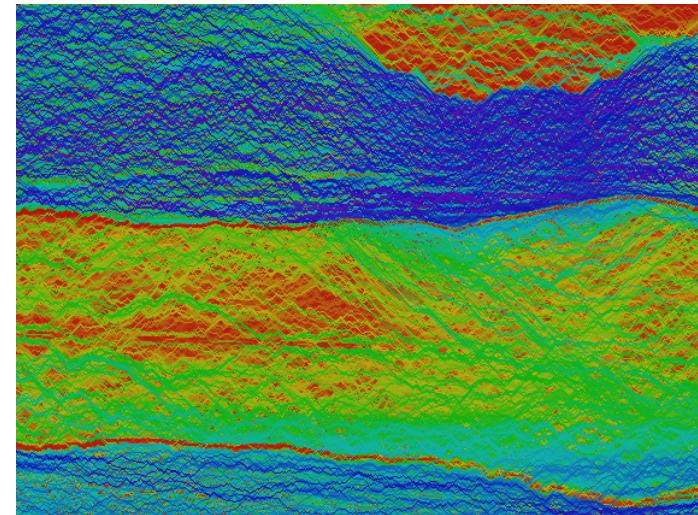




Multi-Size Image Representation



+





Multi-Size Image Representation





Object Removal





Auxiliary Energy

- Recall our seam equation

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



Object Removal



Input

Retargeted

Pigeon Removed

Girl Removed

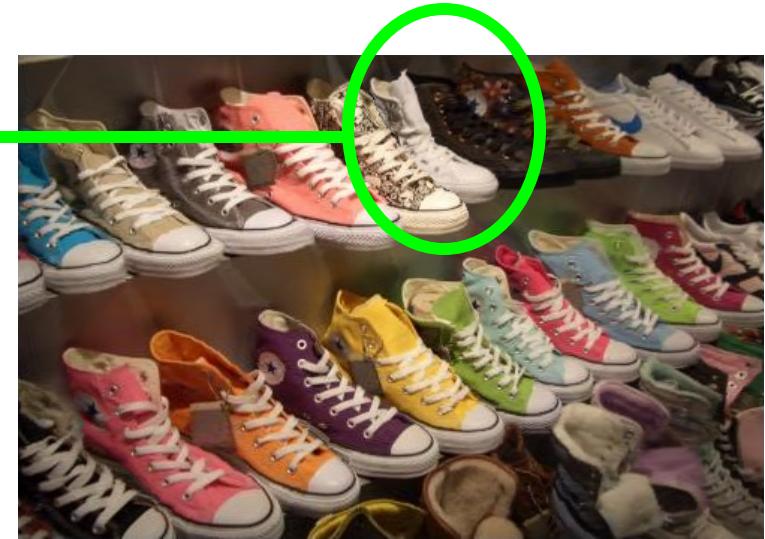


Find the Missing Shoe!





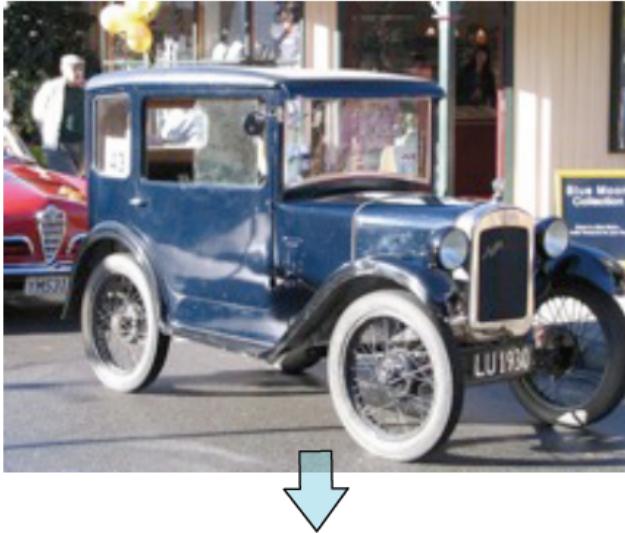
Solution



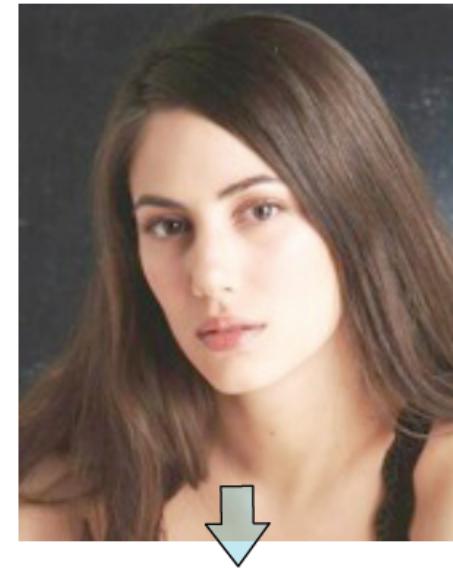


Limitations

Content



Structure





With face detector





With User Constraints





Preserved Energy - Revisited



Average
Pixel
Energy

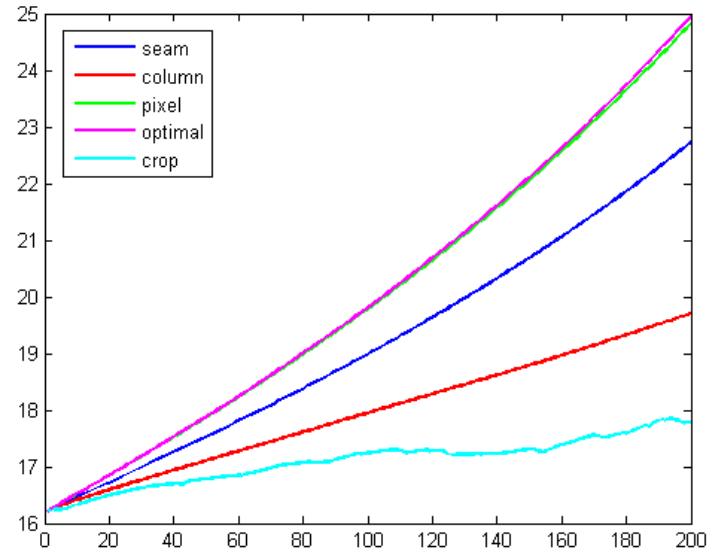


Image Reduction →



crop



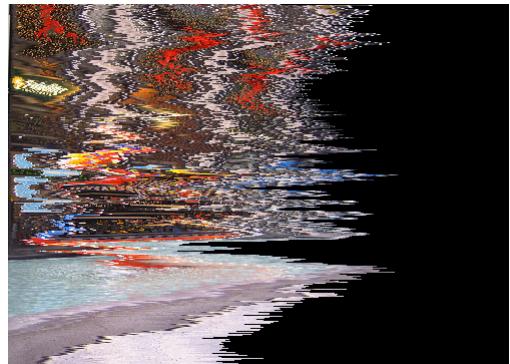
column



seam



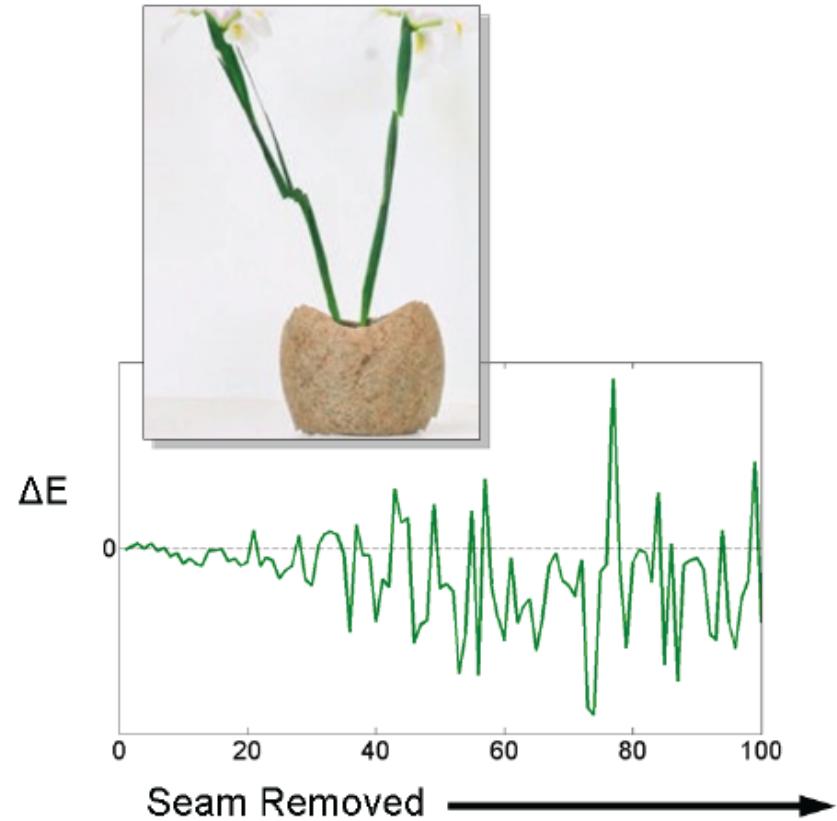
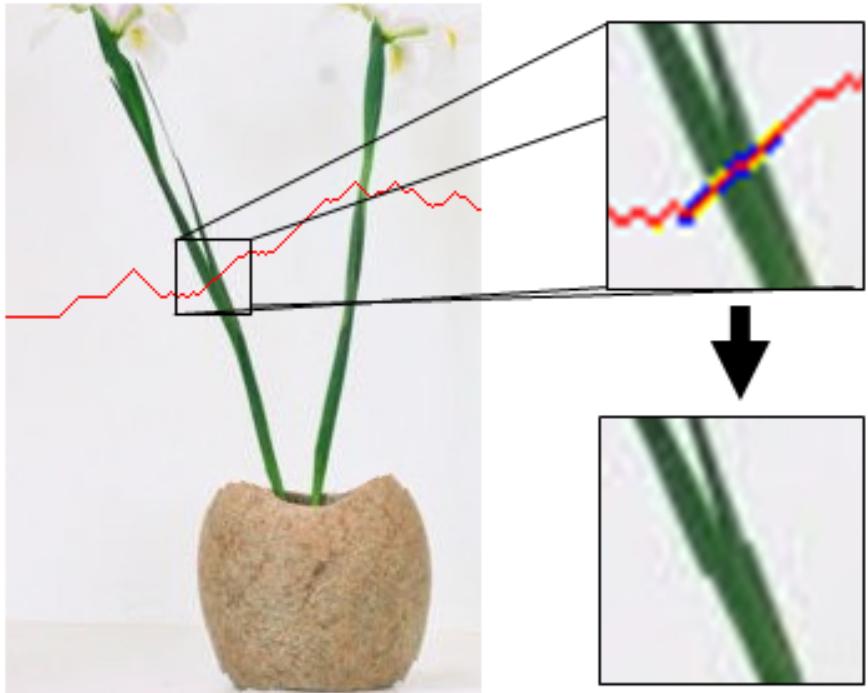
pixel



optimal



Inserted Energy



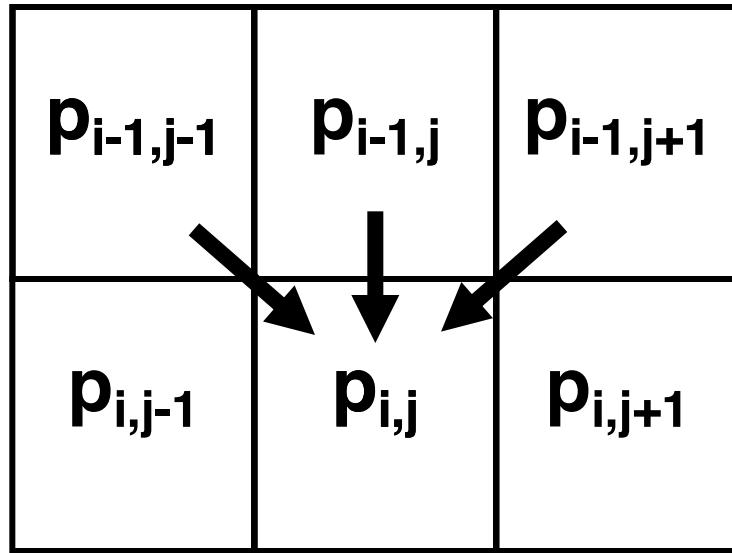


Minimize Inserted Energy

- Instead of removing the seam of least energy, remove the seam that inserts the least energy to the image !



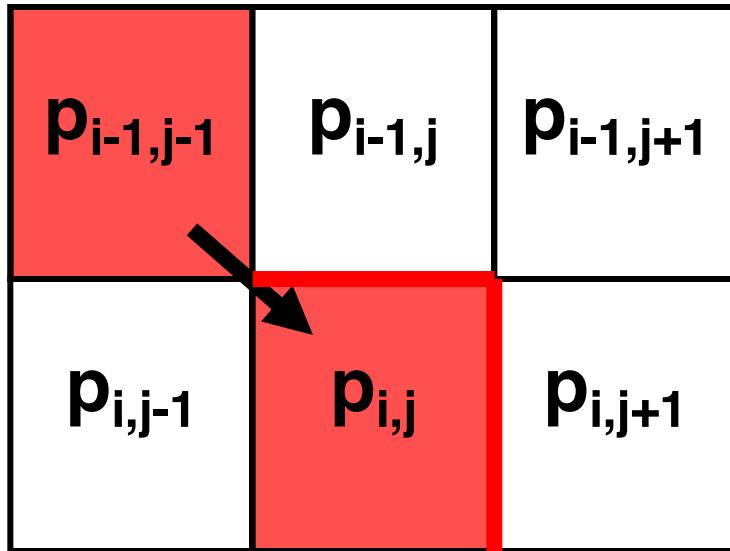
Tracking Inserted Energy



- Three possibilities when removing pixel $P_{i,j}$



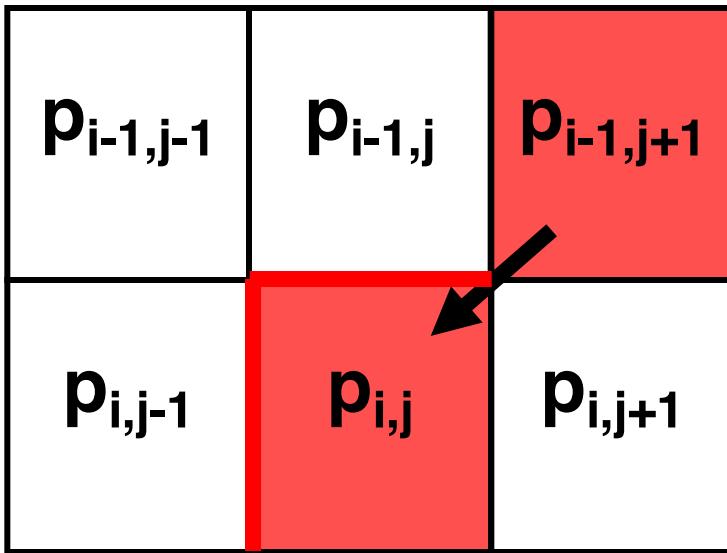
Pixel $P_{i,j}$: Left Seam



$$C_L(i, j) = \|I(i, j + 1) - I(i, j - 1)\| + |I(i - 1, j) - I(i, j - 1)|$$



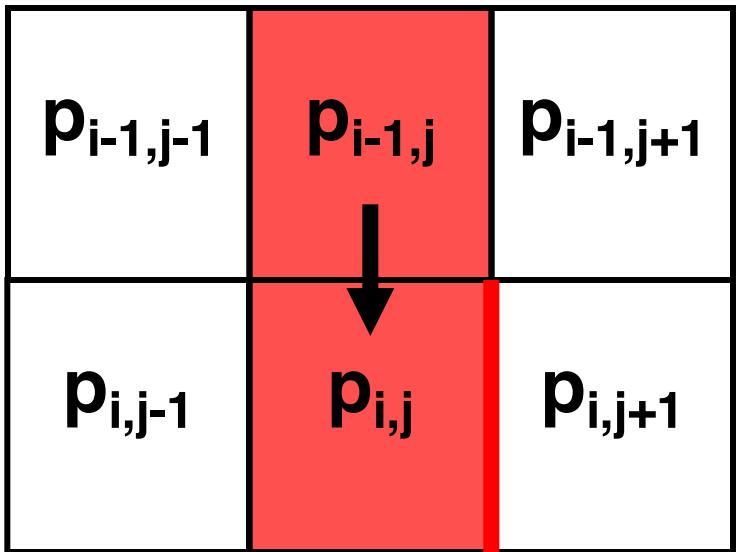
Pixel $P_{i,j}$: Right Seam



$$C_R(i, j) = |I(i, j + 1) - I(i, j - 1)| + |I(i - 1, j) - I(i, j + 1)|$$



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



$$C_V(i, j) = |I(i, j + 1) - I(i, j - 1)|$$



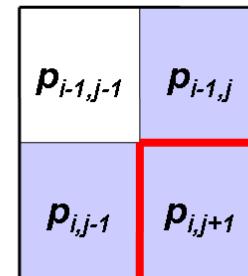
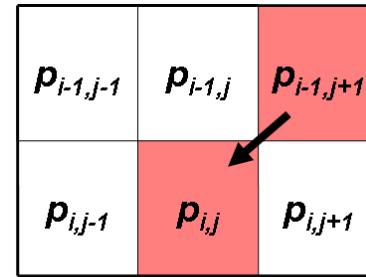
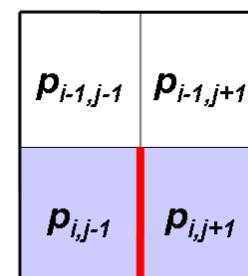
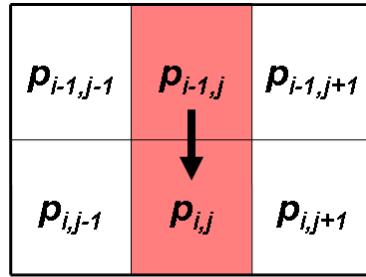
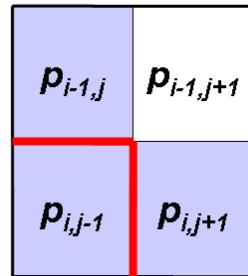
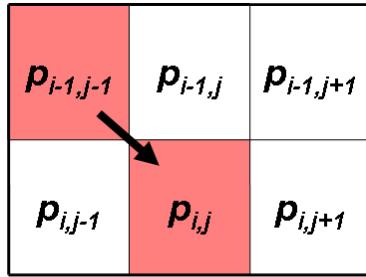
Old “Backward” Energy

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



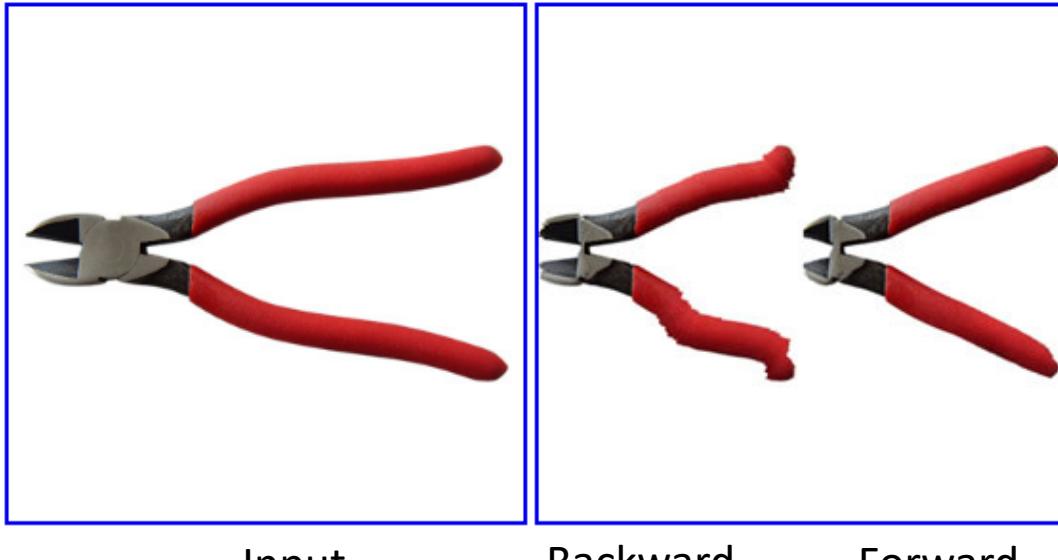
New Forward Looking Energy

$$M(i, j) = \min \begin{cases} M(i - 1, j - 1) + C_L(i, j) \\ M(i - 1, j) + C_U(i, j), \\ M(i - 1, j + 1) + C_R(i, j) \end{cases}$$



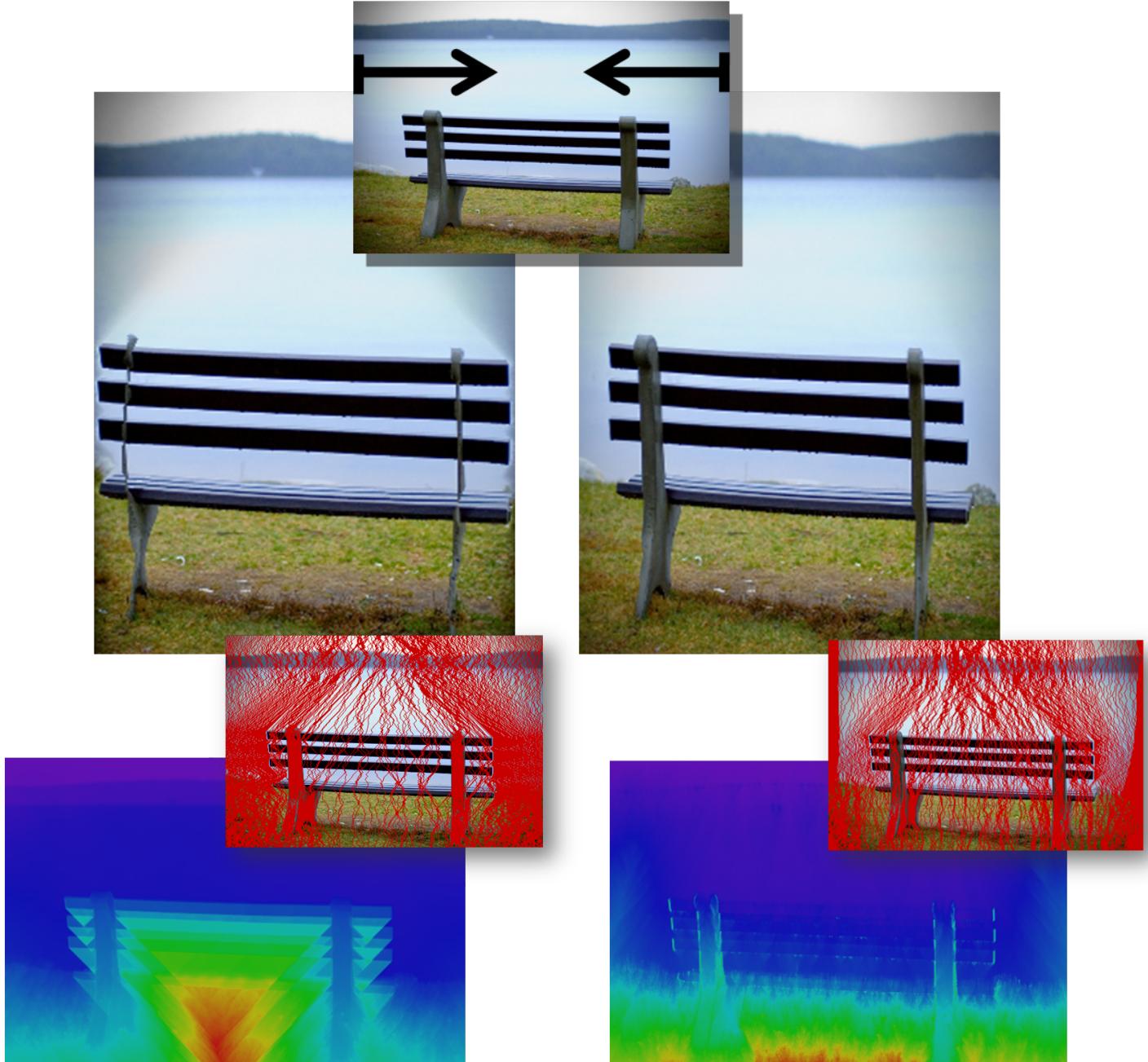


Results





Results





Backward vs. Forward



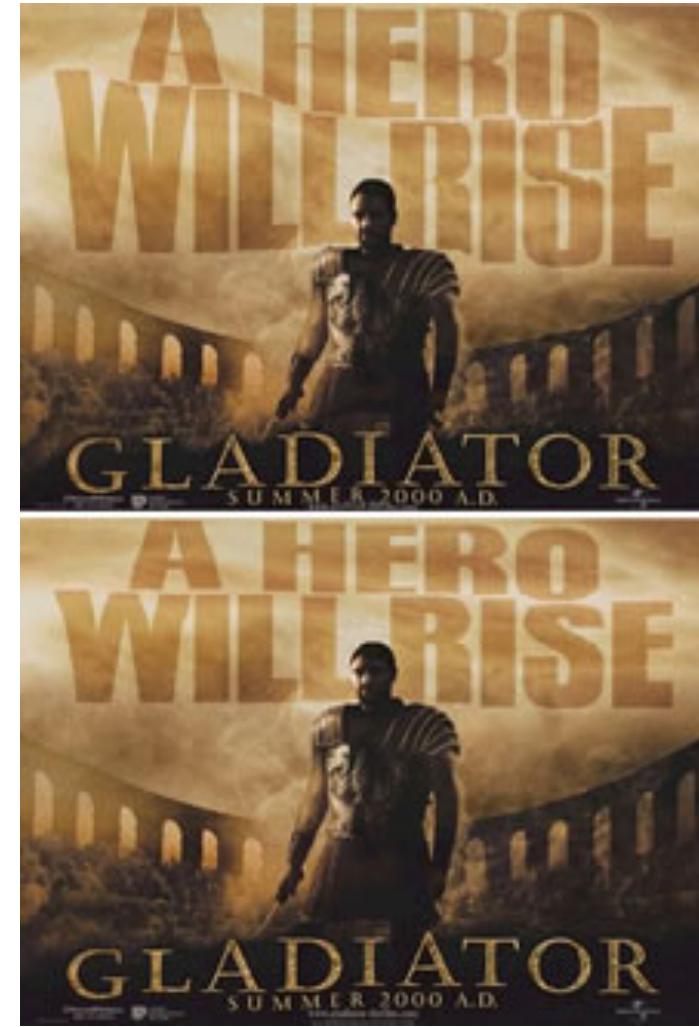
Backward



Forward



Results





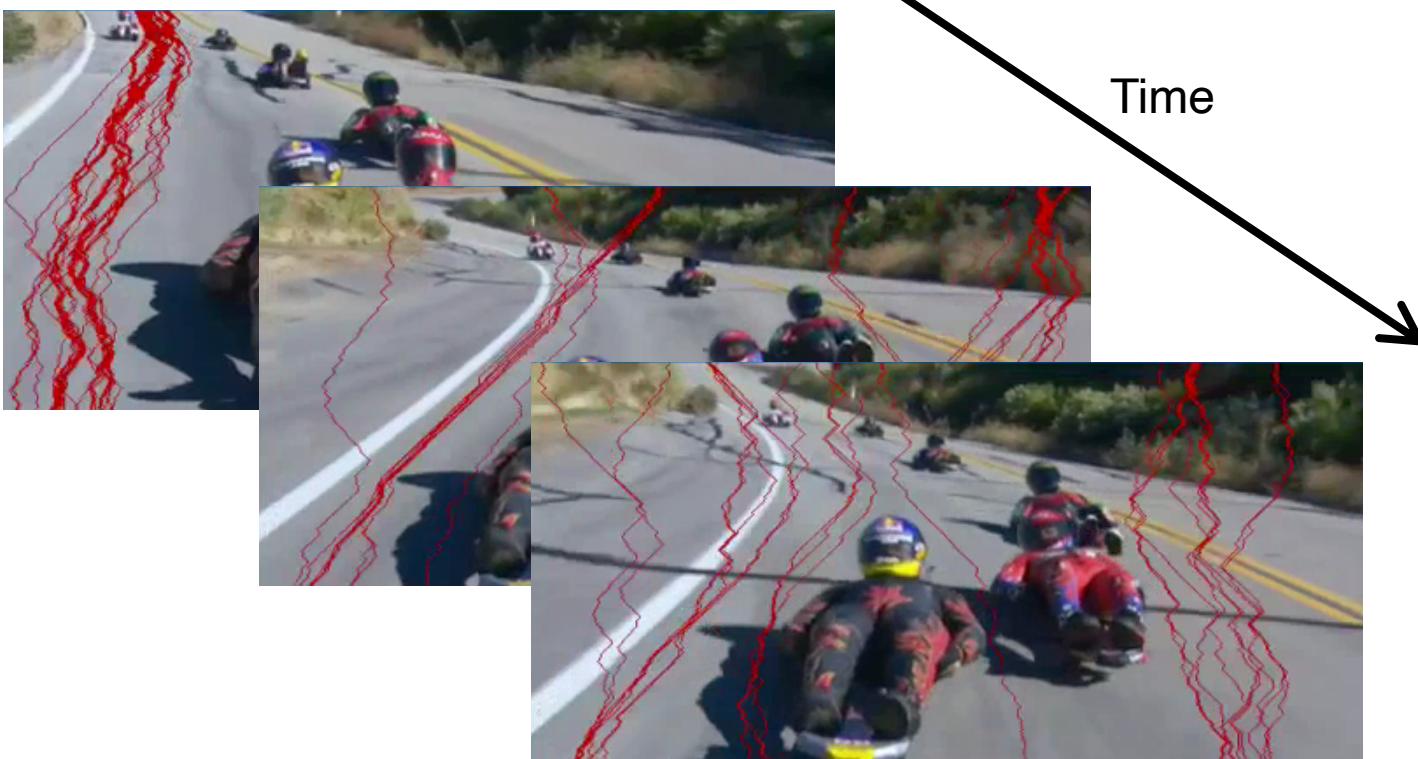
From Images to Videos

- In general, video processing is a much (much!) harder problem
1. Cardinality
 - Suppose 1min of video x 30 fps = 1800 frames
 - Say your algorithm processes an image in 1 minute → **30 hours !!**
 2. Dimensionality/algorithmic
 - Temporal coherency: human visual system is highly sensitive to motion!



Seam-Carving Video?

- Naive... frame by frame independently





Frame-by-frame Seam-Carving



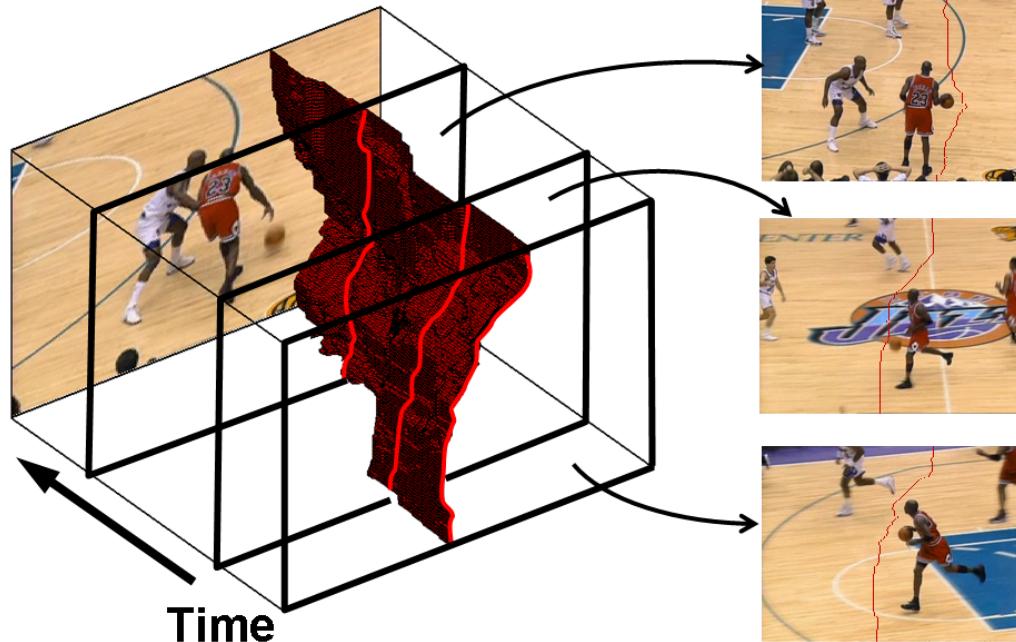
[Let's check out
this video](#)



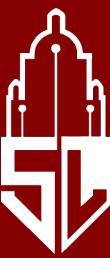
From 2D to 3D



1D paths in images



2D manifolds in video cubes



Example video retargeting





Object Remove



Image Resizing

15-Oct-2019

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Object detection + seam carving





References

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- Content-driven Video Retargeting – Wolf et al. 2007
- Improved Seam Carving for Video Retargeting – Rubinstein et al. 2008
- *Optimized Scale-and-Stretch* for Image Resizing – Wang et al. 2008
- Summarizing Visual Data Using Bidirectional Similarity – Simakov et al. 2008
- Multi-operator Media Retargeting – Rubinstein et al. 2009
- Shift-Map Image Editing – Pritch et al. 2009
- Energy-Based Image Deformation – Karni et al. 2009
- Seam carving in Photoshop CS4:
http://help.adobe.com/en_US/Photoshop/11.0/WS6F81C45F-2AC0-4685-8FFD-DBA374BF21CD.html