

Computational Photography



Dr. Irfan Essa

Professor

School of Interactive Computing

Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.

Digital Images: Cutting Images for Merging

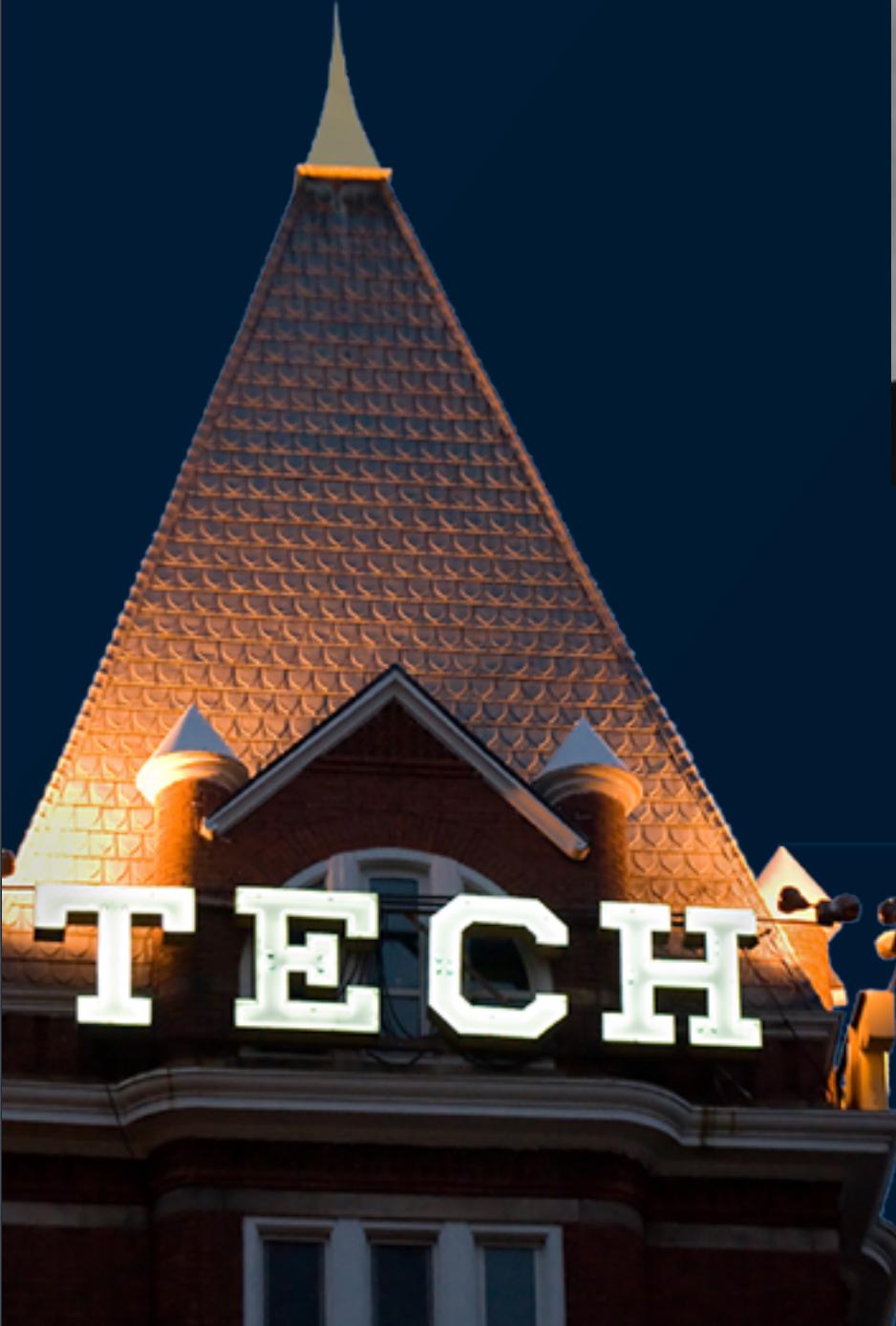


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Methods for Combing Multiple Images by
Cutting to Generate a Novel Image



Lesson Objectives

- ★ Describe in your own words an additional method for merging images besides blending.
- ★ Describe in your own words how seams are found in images.
- ★ Describe the benefits of cutting images over blending images.



REVIEW: Combine, Merge, Blend

Images



REVIEW: Combine, Merge, Blend Images

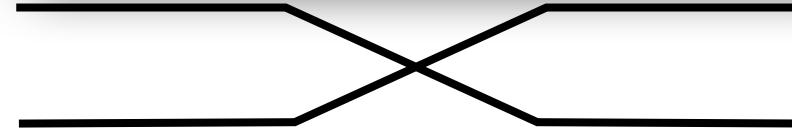
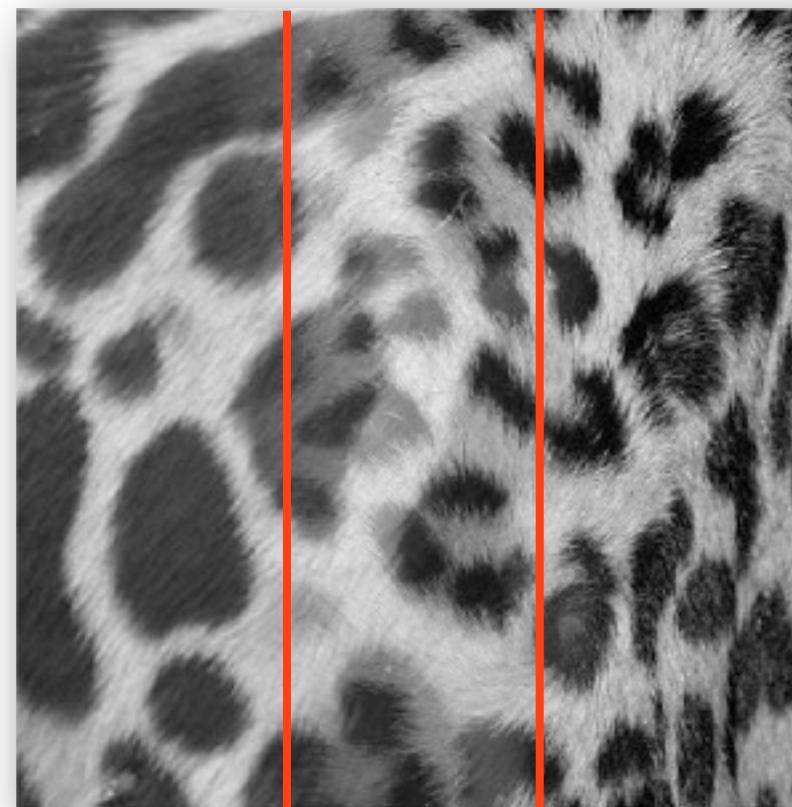
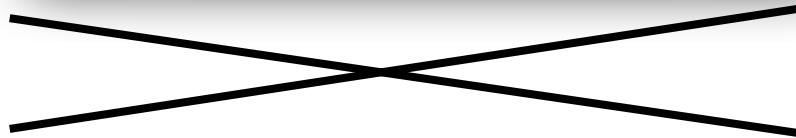


REVIEW: Combine, Merge, Blend Images

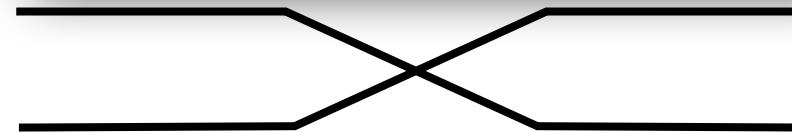
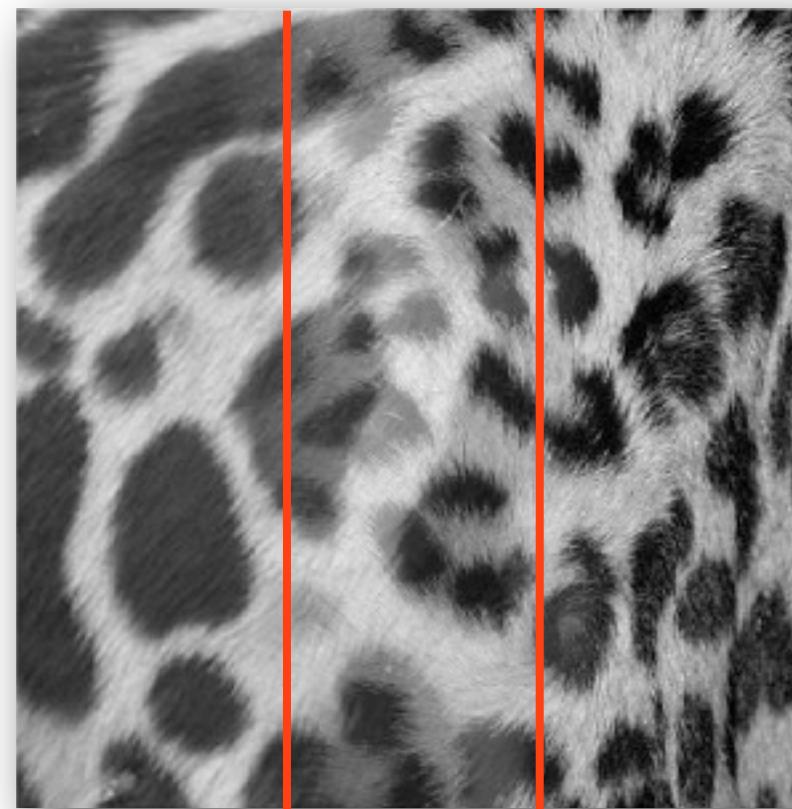
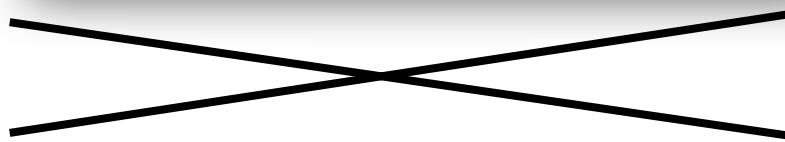


REVIEW: Combine, Merge, Blend

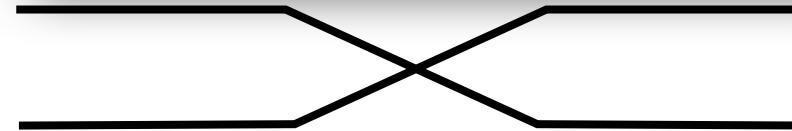
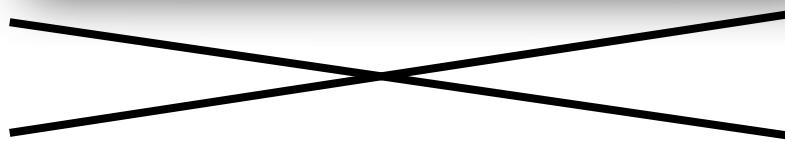
Images



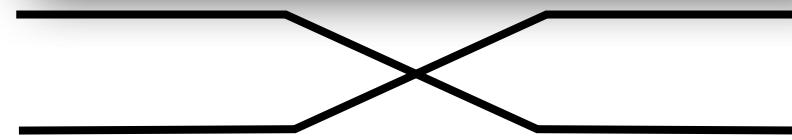
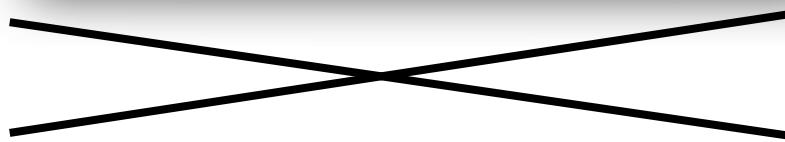
Cross-Fading Window Size



Cross-Fading Window Size



Cross-Fading Window Size



Cross-Fading Window Size



Cut, Don't Blend!



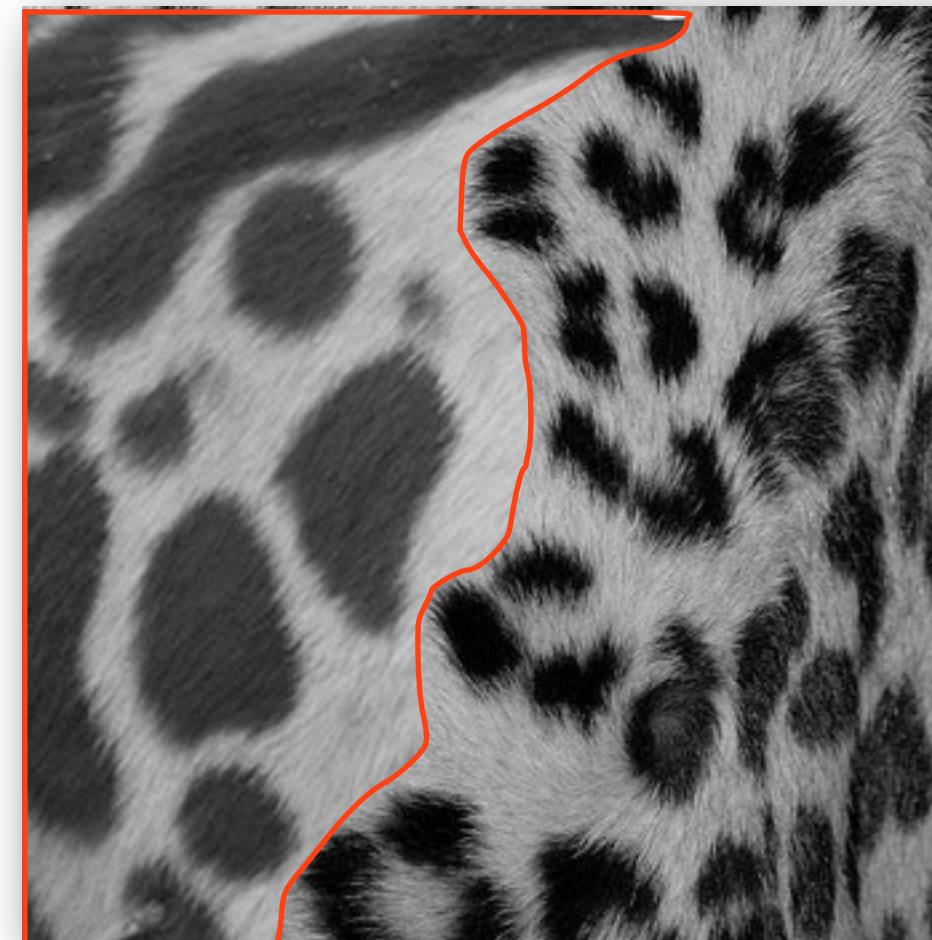
Cut, Don't Blend!



Cut, Don't Blend!



Cut, Don't Blend!



Cut, Don't Blend!



Cut, Don't Blend!

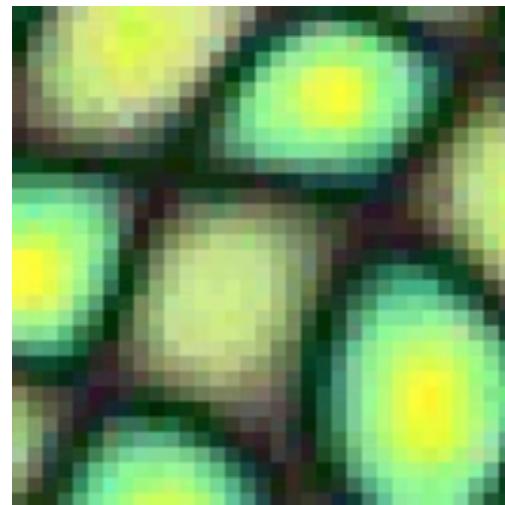
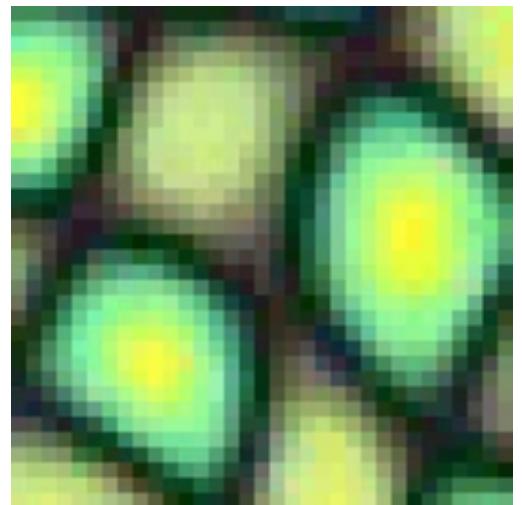
Cut, Don't Blend



- ★ Moving objects cause “ghosting”
- ★ Find an optimal seam as opposed to blend between images.
- ★ Final has exact pixels from an Image
- ★ Davis (1998)



overlapping blocks



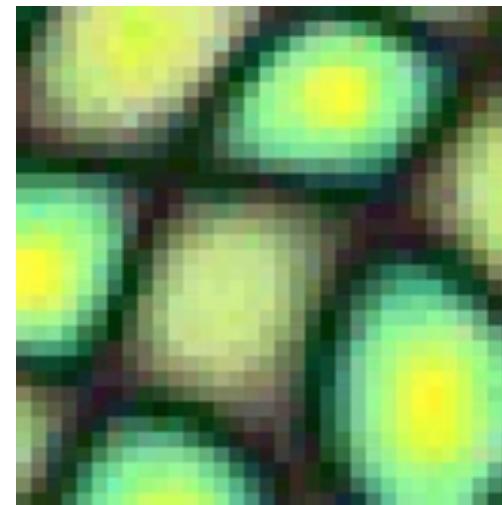
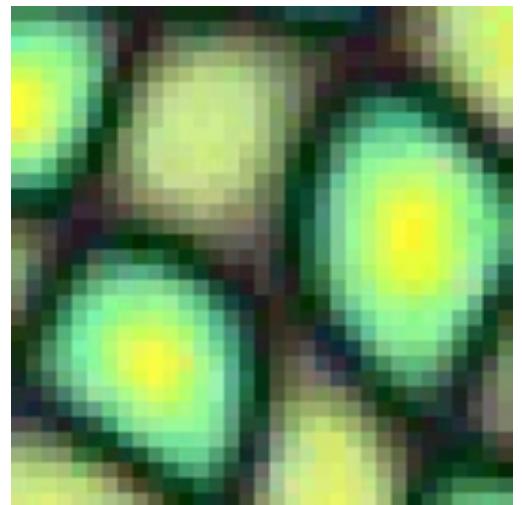
overlap error

min. error boundary

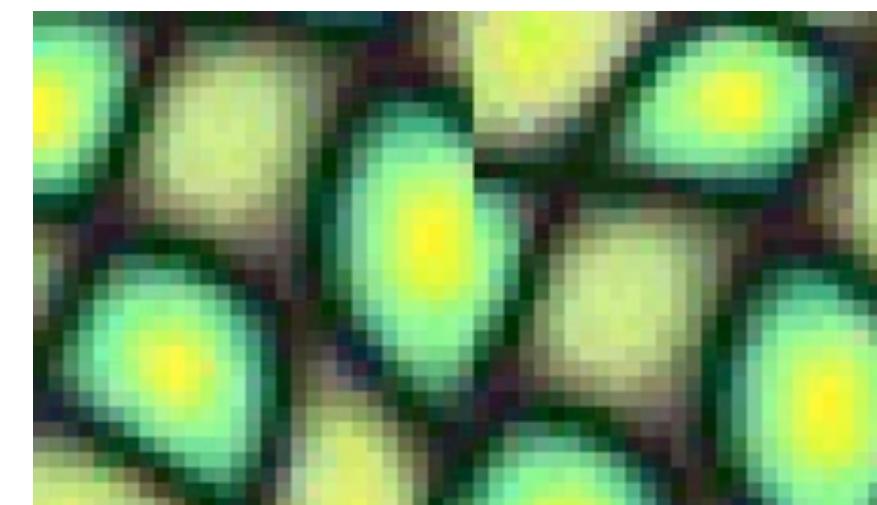
Finding the Seams

Efros and Freeman (2001)

overlapping blocks



vertical boundary



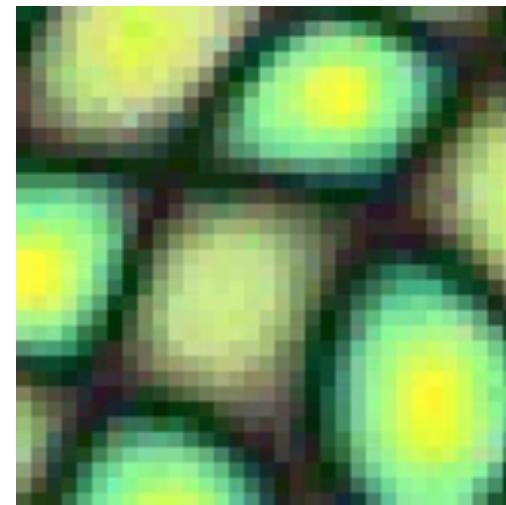
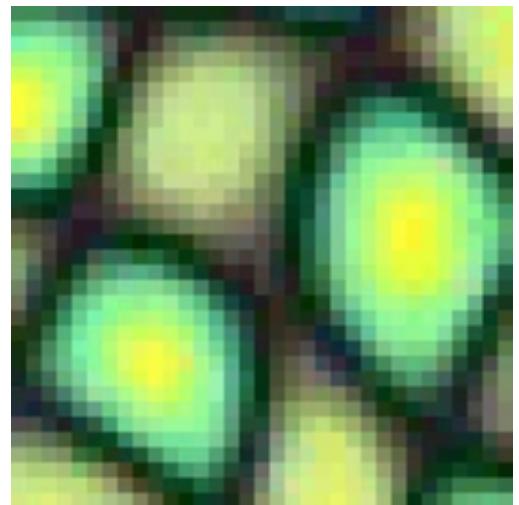
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Efros and Freeman (2001)

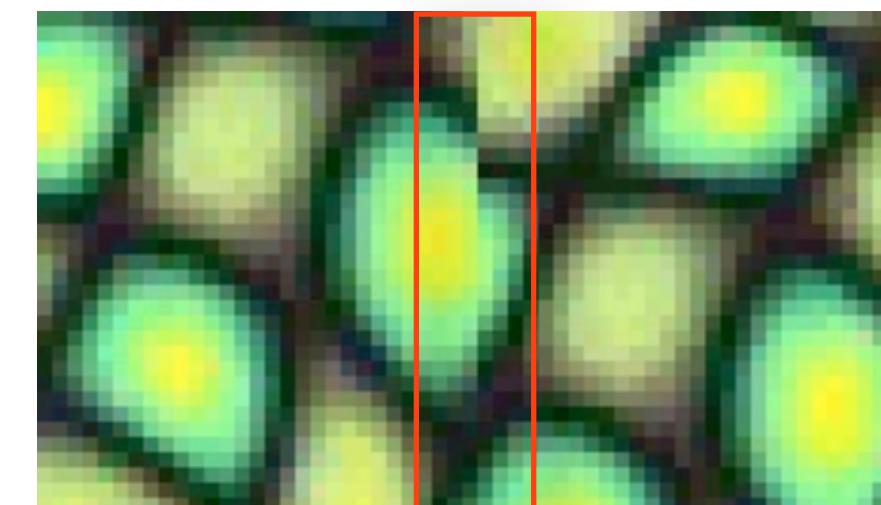
overlap error

min. error boundary

overlapping blocks



vertical boundary



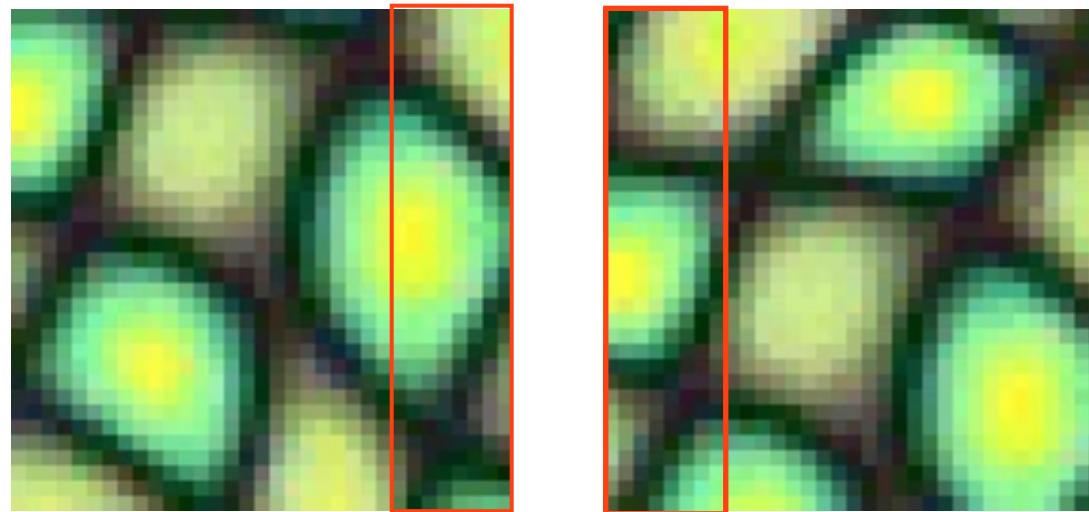
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Efros and Freeman (2001)

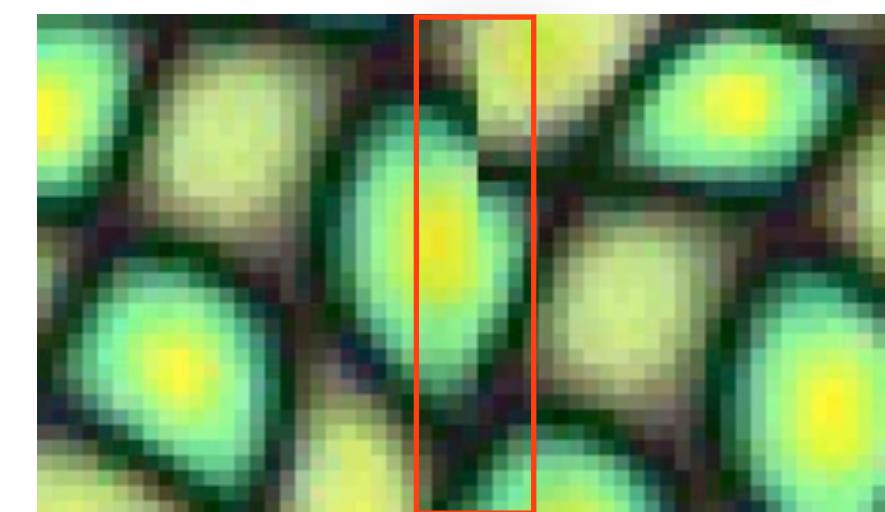
overlap error

min. error boundary

overlapping blocks



vertical boundary



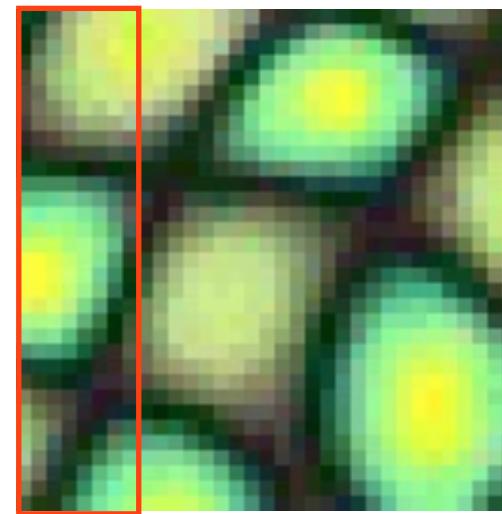
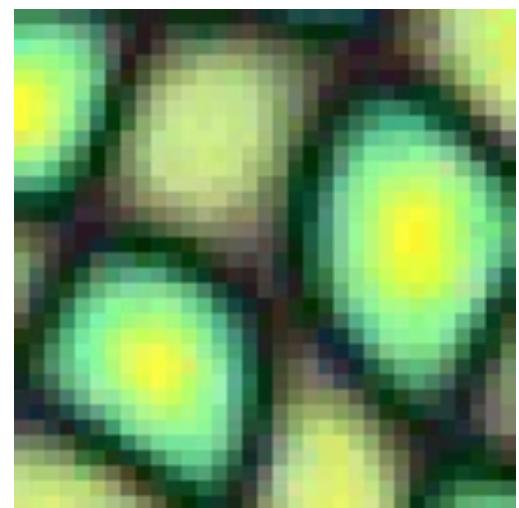
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Efros and Freeman (2001)

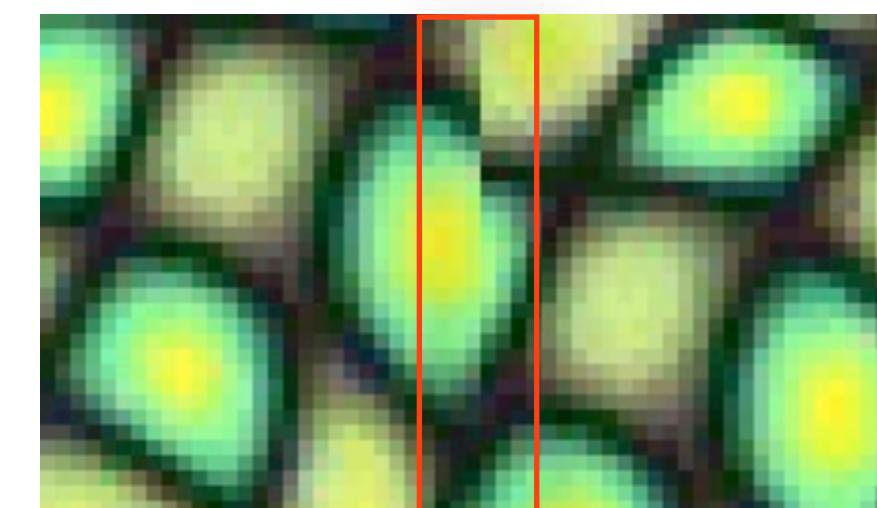
overlap error

min. error boundary

overlapping blocks

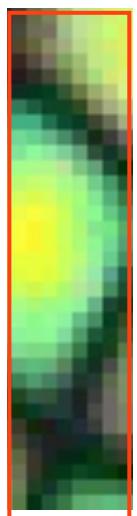


vertical boundary



Finding the **Seams**

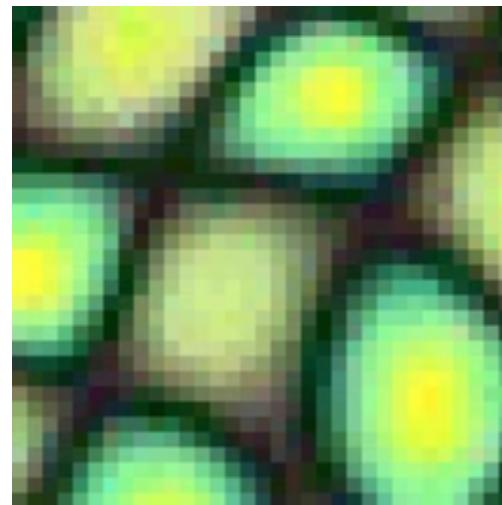
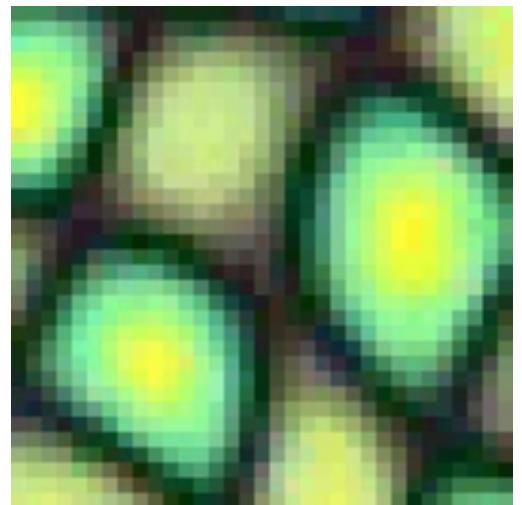
Efros and Freeman (2001)



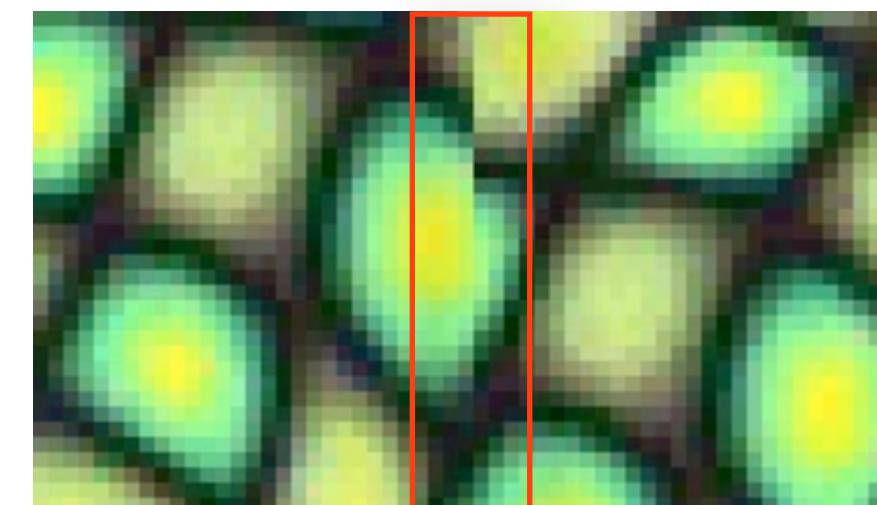
overlap error

min. error boundary

overlapping blocks

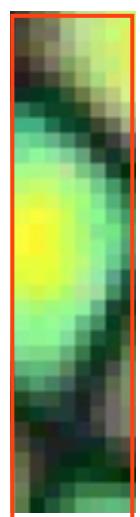


vertical boundary

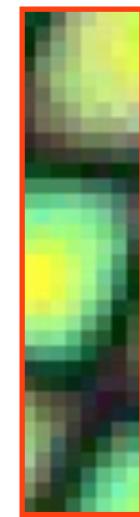


Finding the **Seams**

Efros and Freeman (2001)

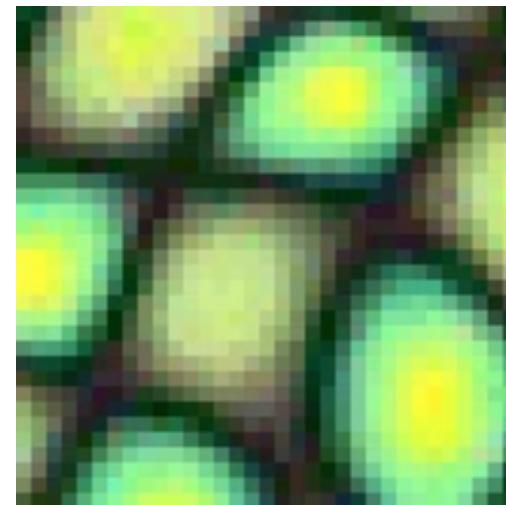
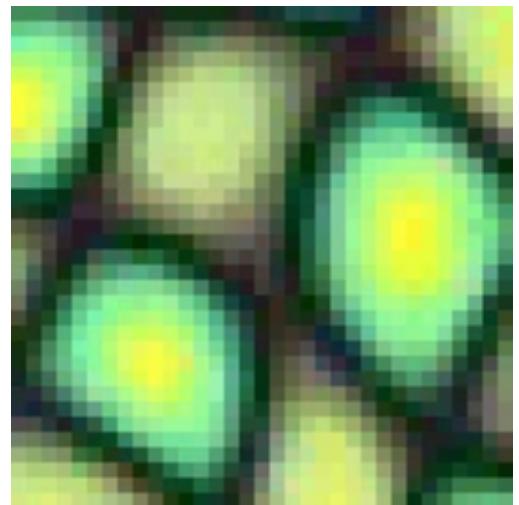


overlap error

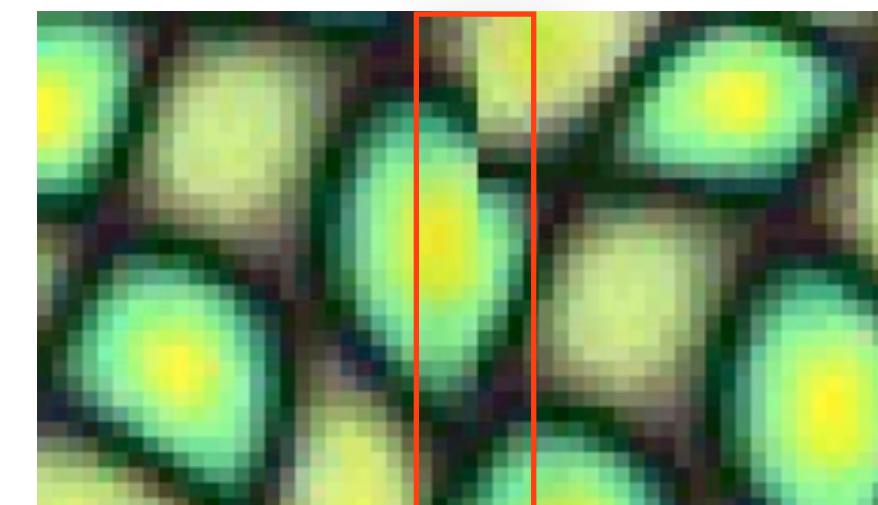


min. error boundary

overlapping blocks



vertical boundary



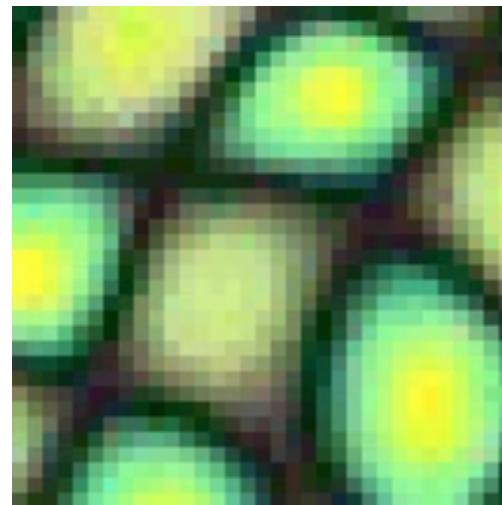
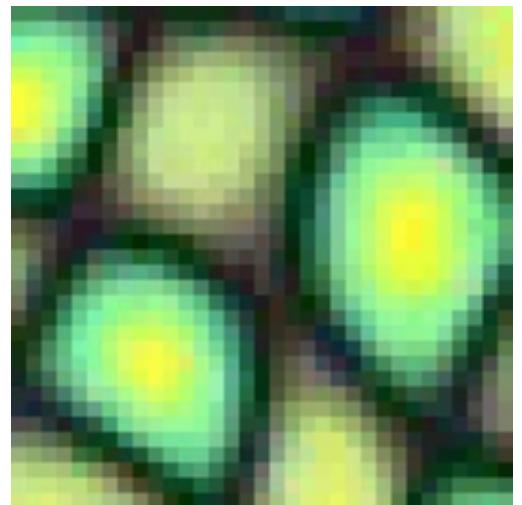
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Efros and Freeman (2001)

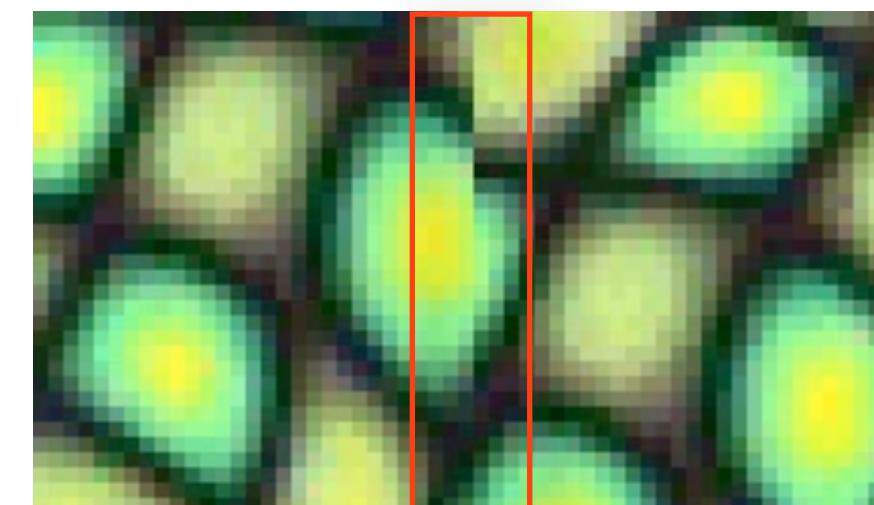
$$\left(\begin{array}{c} \text{[block]} \\ - \\ \text{[block]} \end{array} \right)^2 = \text{overlap error}$$

min. error boundary

overlapping blocks



vertical boundary



Finding the Seams

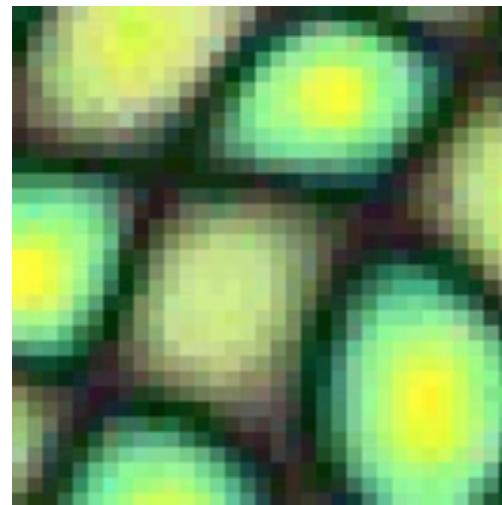
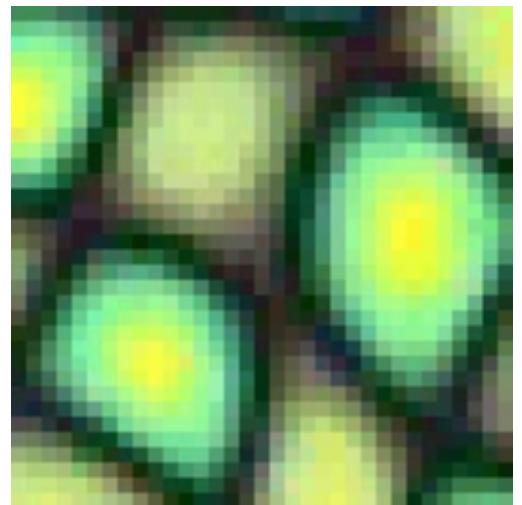
Efros and Freeman (2001)

$$\left(\begin{array}{c} \text{[red box]} \\ - \\ \text{[red box]} \end{array} \right)^2 = \text{[min. error boundary}}$$

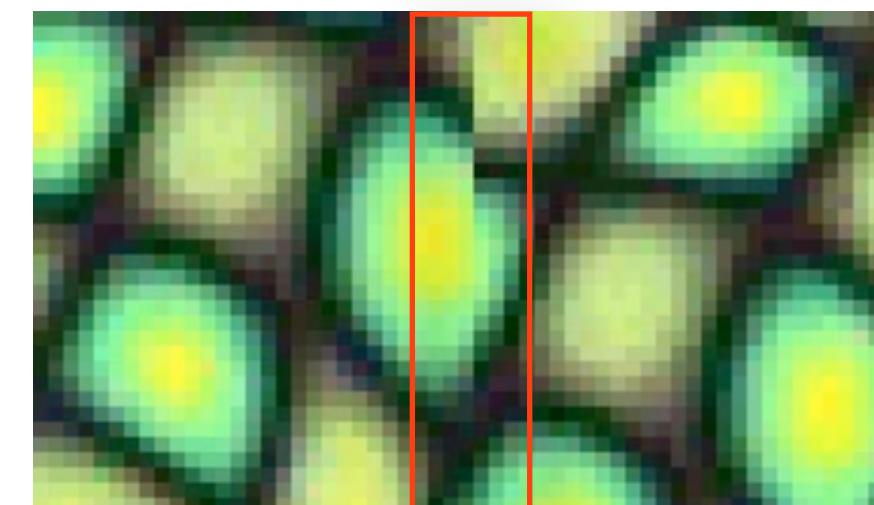
overlap error

min. error boundary

overlapping blocks



vertical boundary



Finding the Seams

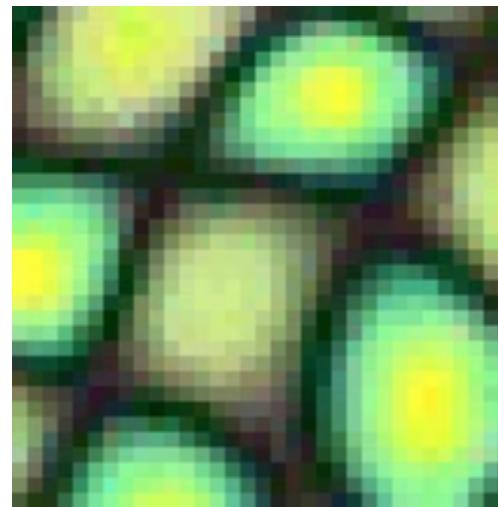
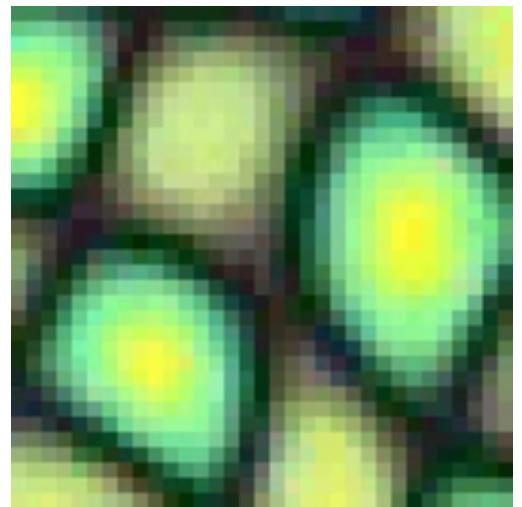
Efros and Freeman (2001)

$$\left(\begin{array}{c} \text{[red box]} \\ - \\ \text{[red box]} \end{array} \right)^2 = \text{[min. error boundary]}$$

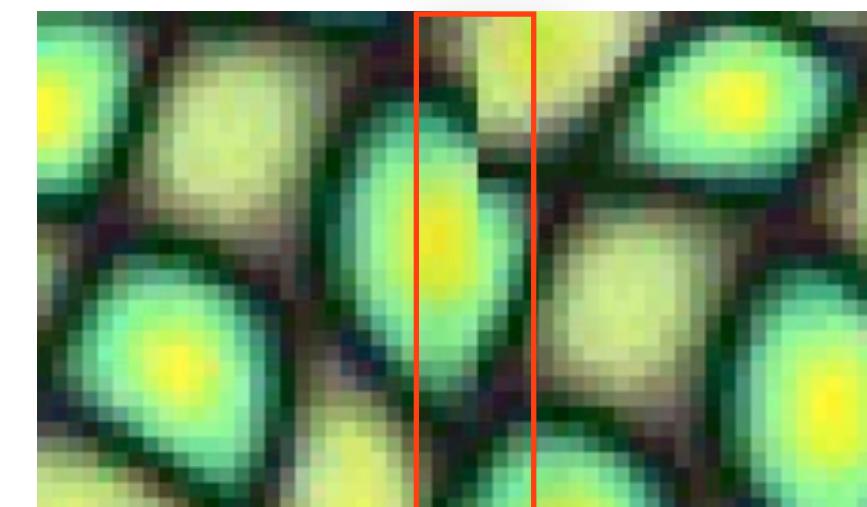
overlap error

min. error boundary

overlapping blocks

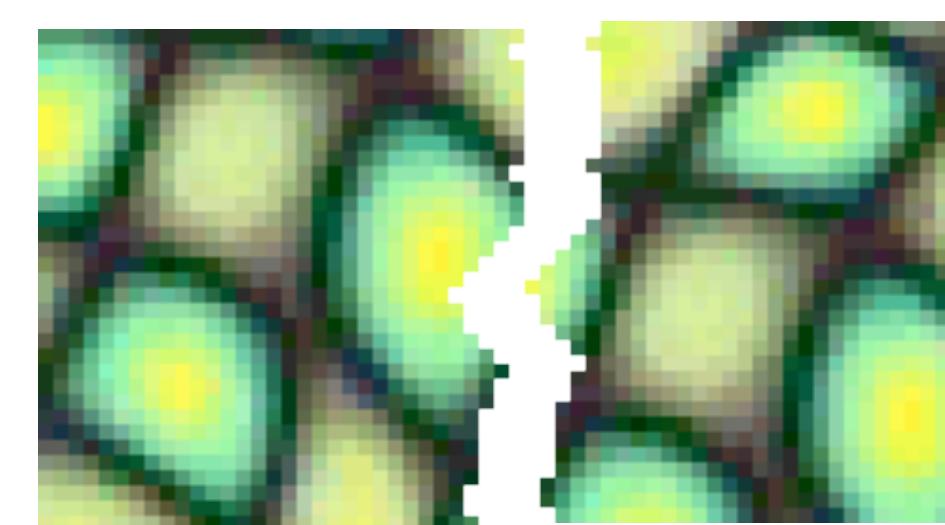


vertical boundary



Finding the Seams

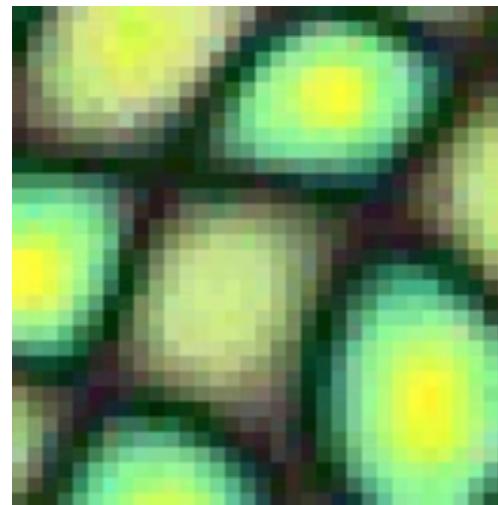
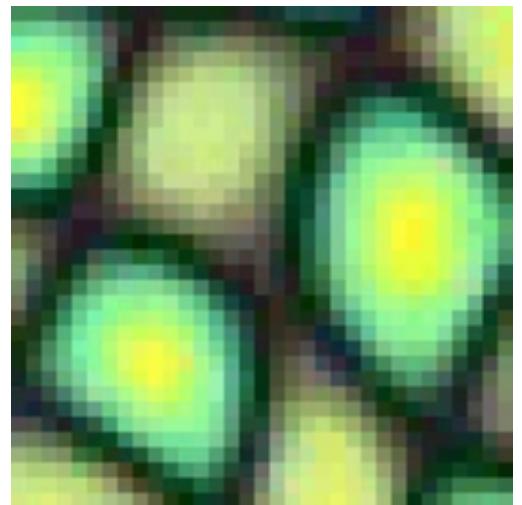
$$\left(\begin{array}{c|c} \text{block 1} & \text{block 2} \\ \hline \end{array} \right) - \left(\begin{array}{c|c} \text{block 1}' & \text{block 2}' \\ \hline \end{array} \right)^2 = \text{overlap error}$$



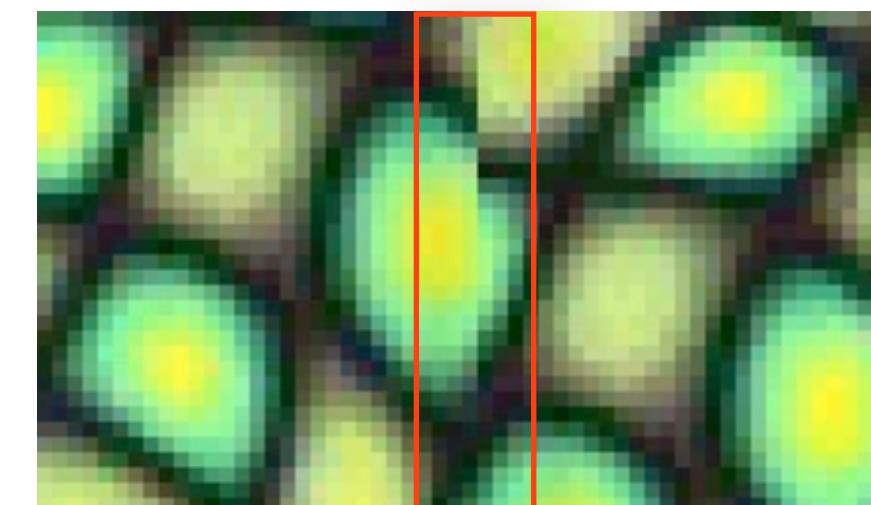
min. error boundary

Efros and Freeman (2001)

overlapping blocks



vertical boundary

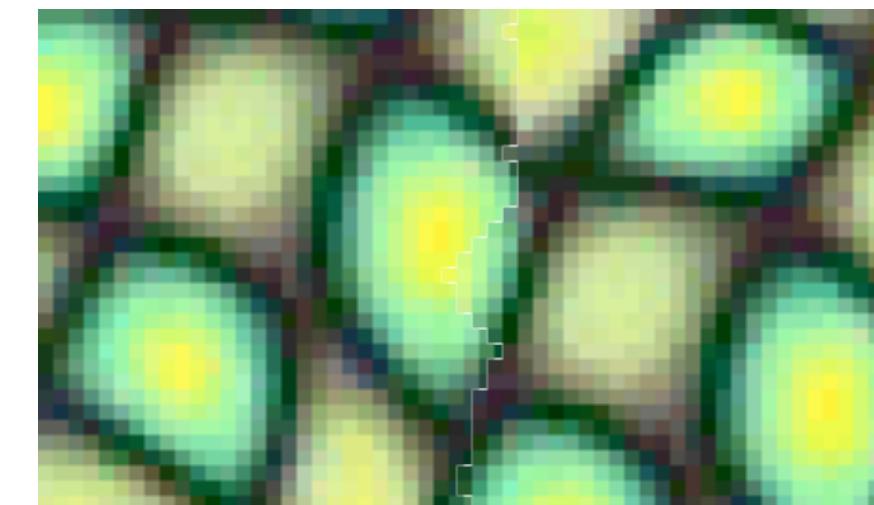


Finding the Seams

Efros and Freeman (2001)

$$\left(\begin{array}{c} \text{[red box]} \\ - \\ \text{[red box]} \end{array} \right)^2 = \text{[red line]}$$

overlap error

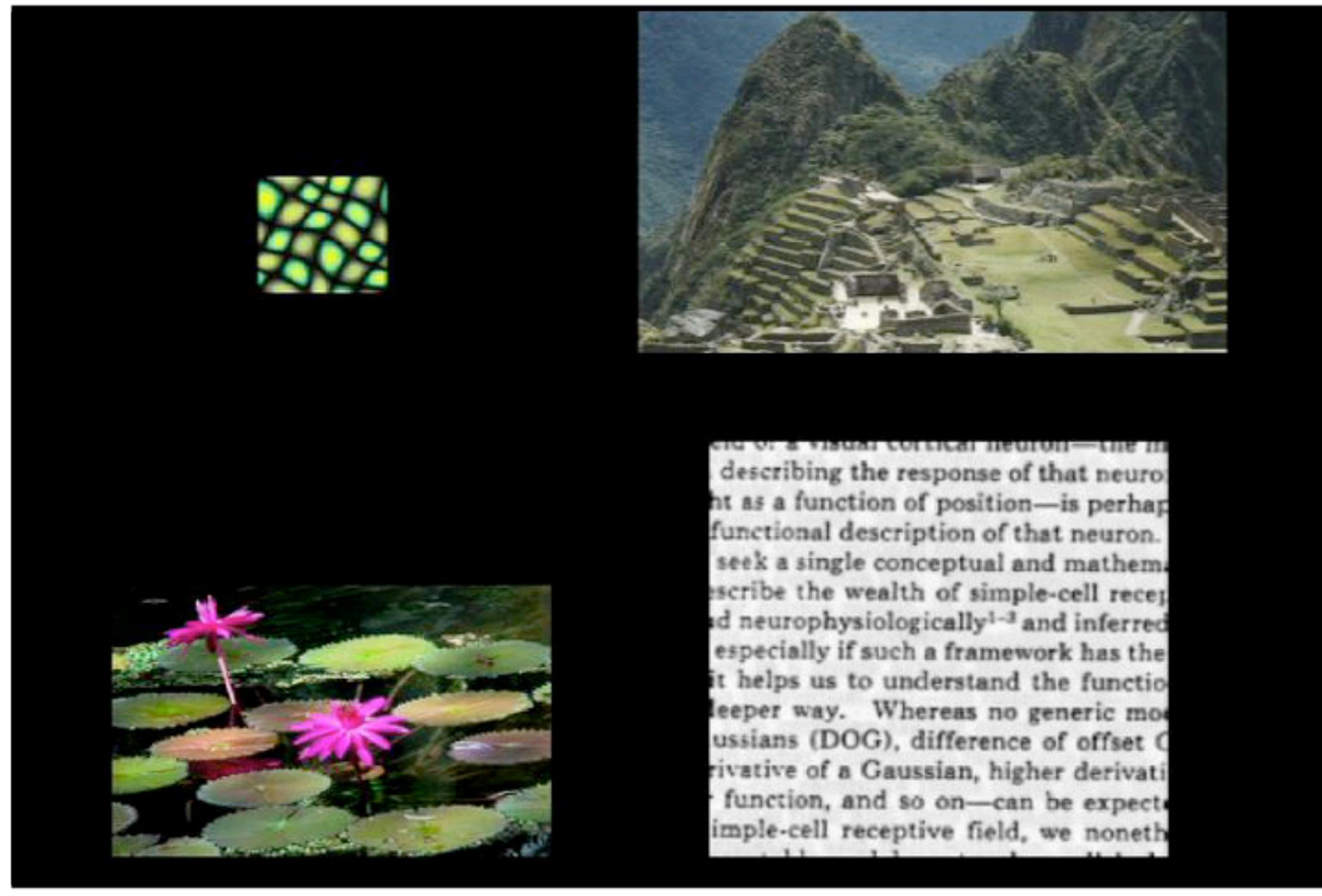


min. error boundary



Finding Seams

Kwatra et al. (2003)



Generating Novel Image

Kwatra et al. (2003)

eld of a visual cortical neuron—the receptive field—describing the response of that neuron as a function of position—is perhaps the most functional description of that neuron. We seek a single conceptual and mathematical framework to describe the wealth of simple-cell receptive fields found neurophysiologically^{1–3} and inferred^{4–6}, especially if such a framework has the potential to help us to understand the function in a deeper way. Whereas no generic model exists, Gaußians (DOG), difference of offset Gaussians (DOG), derivative of a Gaussian, higher derivatives of a Gaussian, higher derivative functions, and so on—can be expected to provide a good approximation to the simple-cell receptive field, we nonetheless lack a general framework to relate all these models to each other.

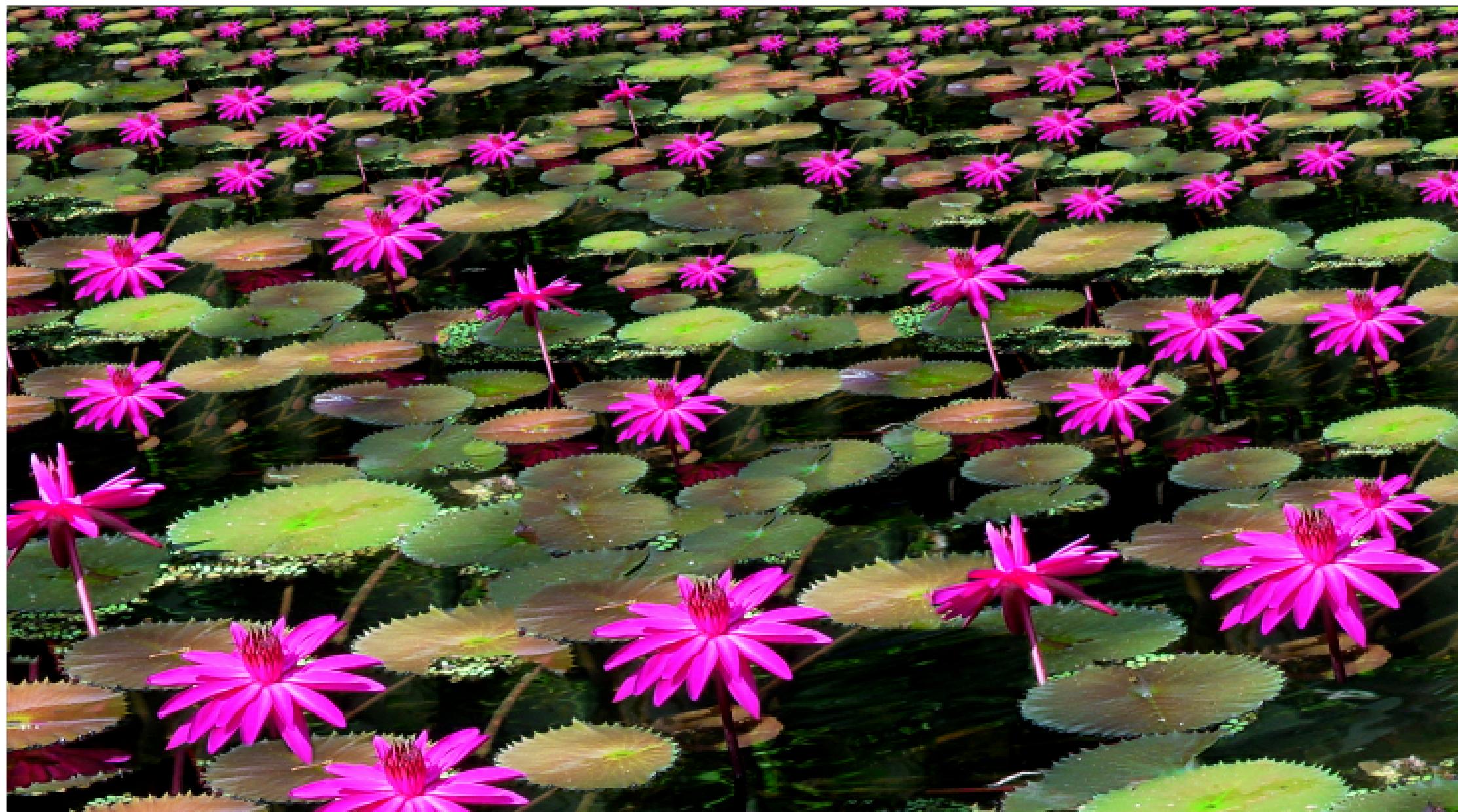
Kwatra et al. (2003)

Extending Images



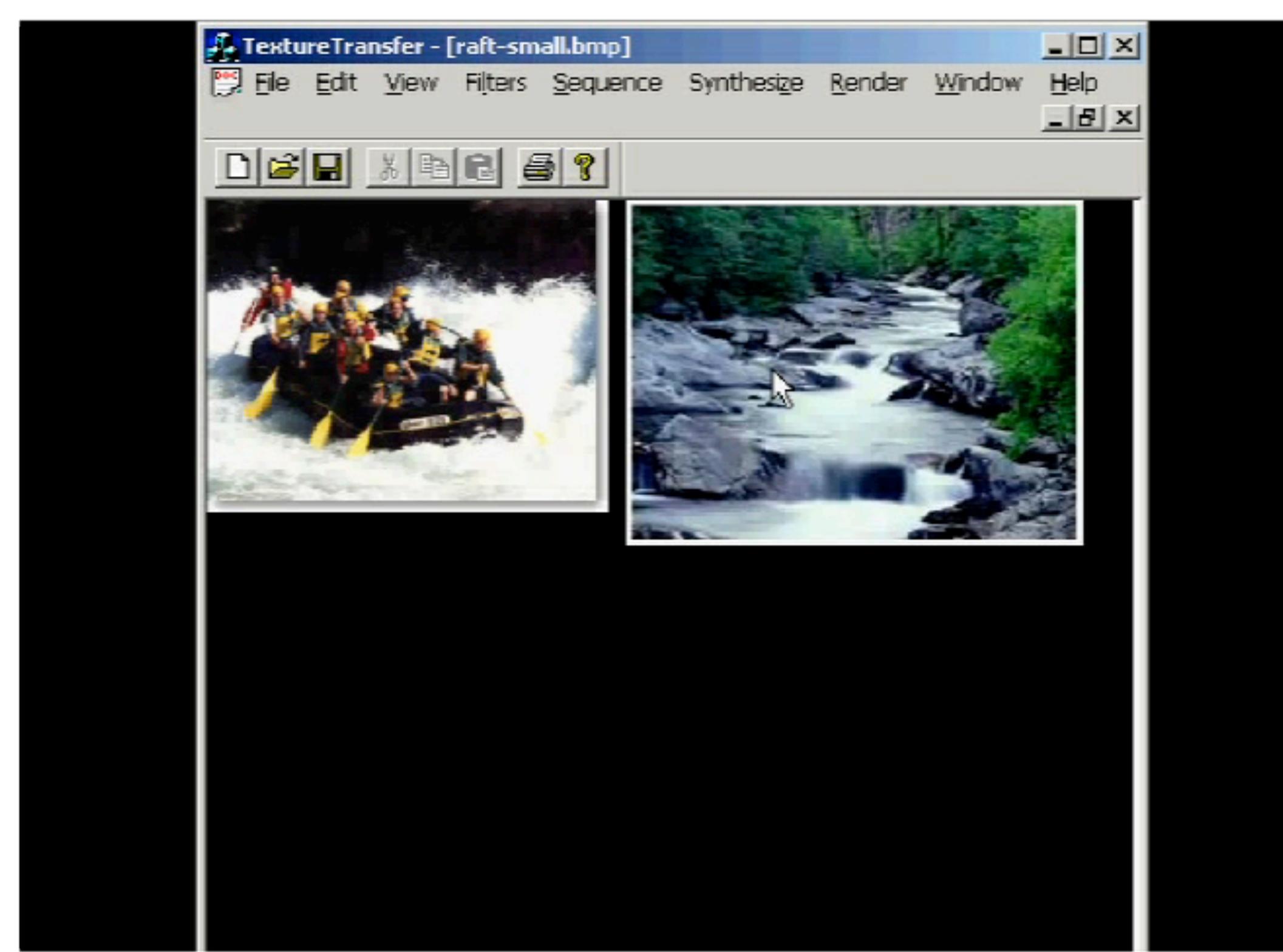
Kwatra et al. (2003)

Extending Images



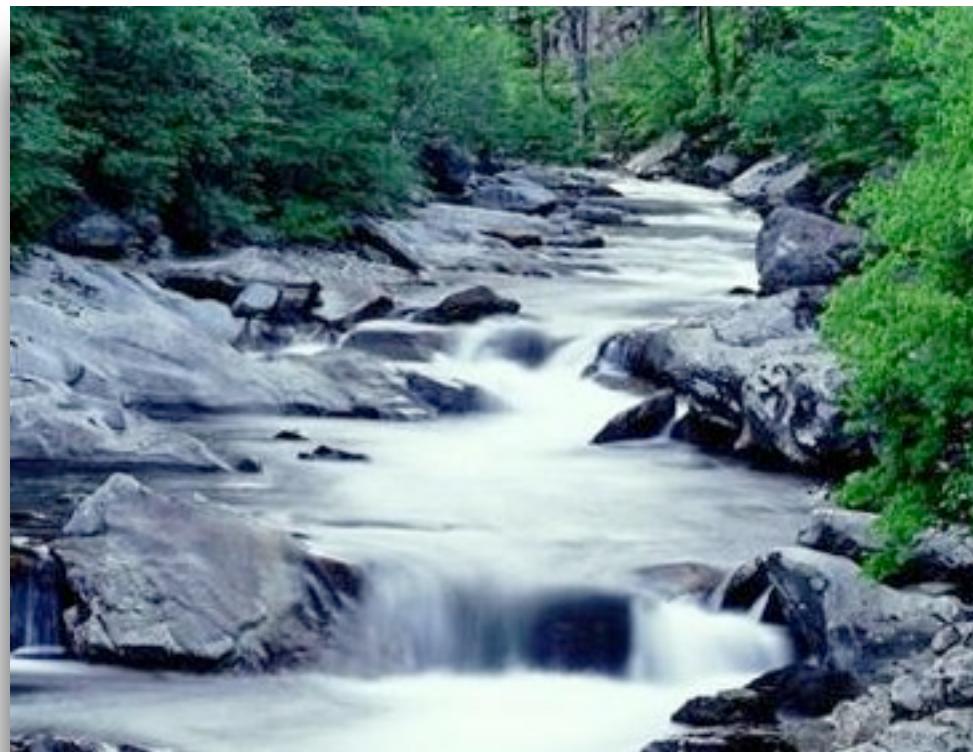
Kwatra et al. (2003)

Extending Images



Editing Images

Kwatra et al. (2003)



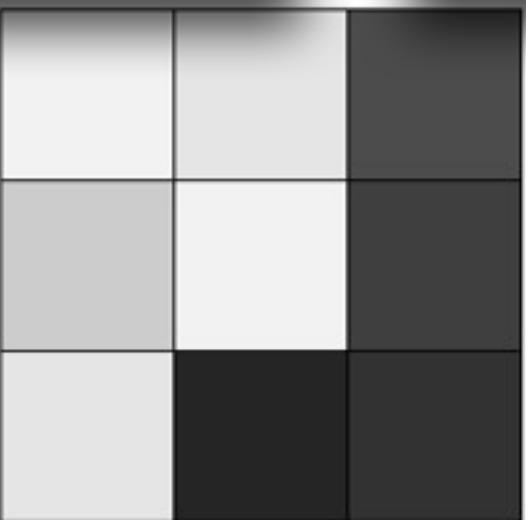
Editing Images



Kwatra et al. (2003)



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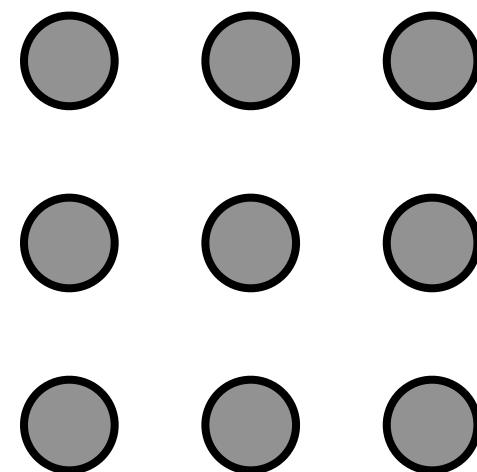
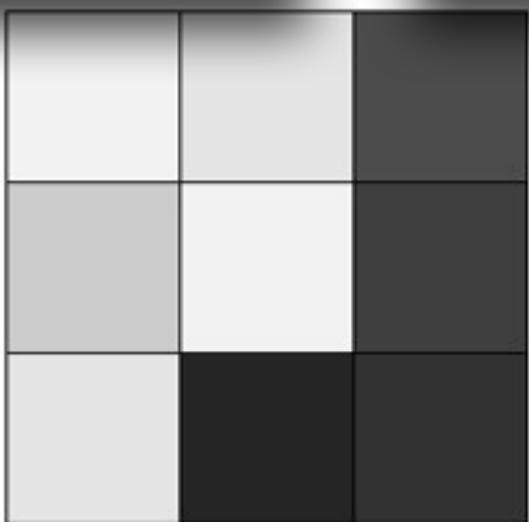


Seam Finding using Graph-cuts

Boykov and Jolly (2001)
Kwatra et al. (2003)



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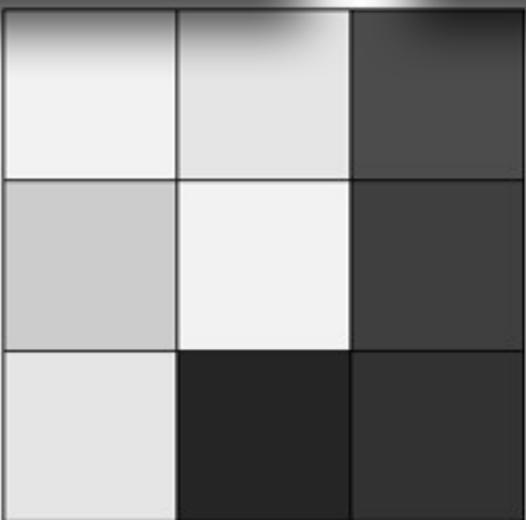


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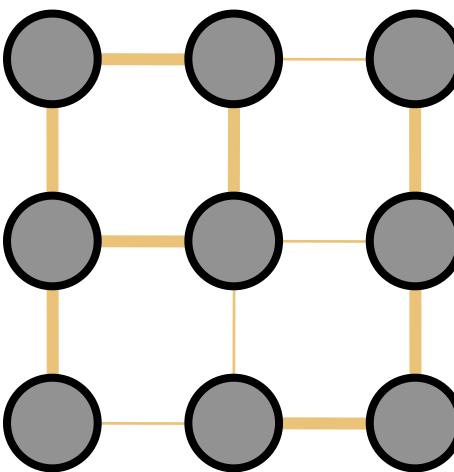
t



s



n-links

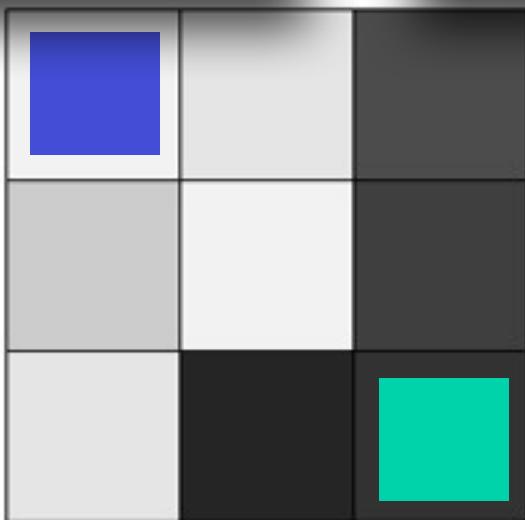


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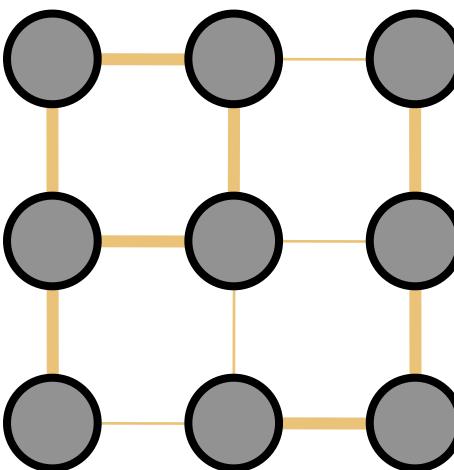
t



s



n-links

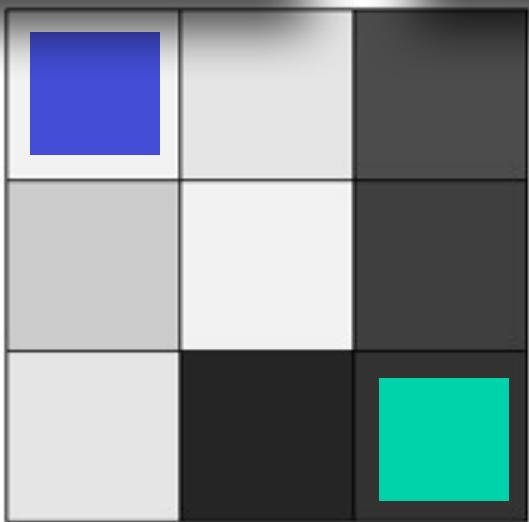


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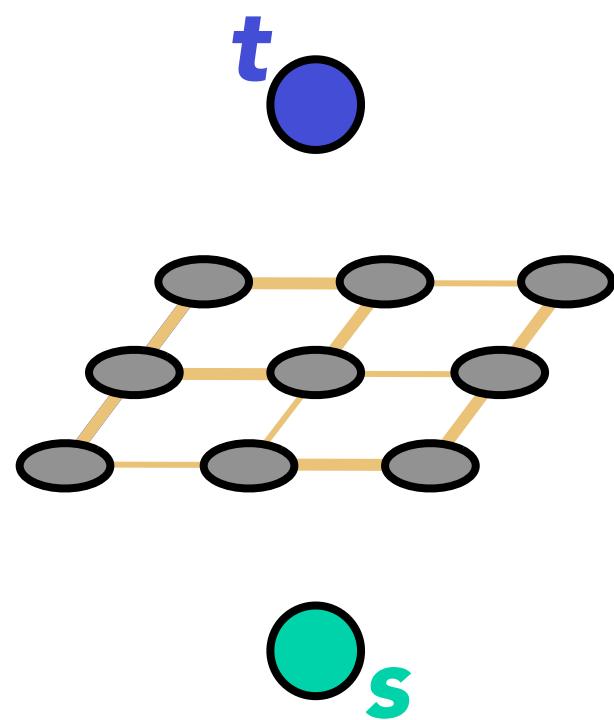
Boykov and Jolly (2001)
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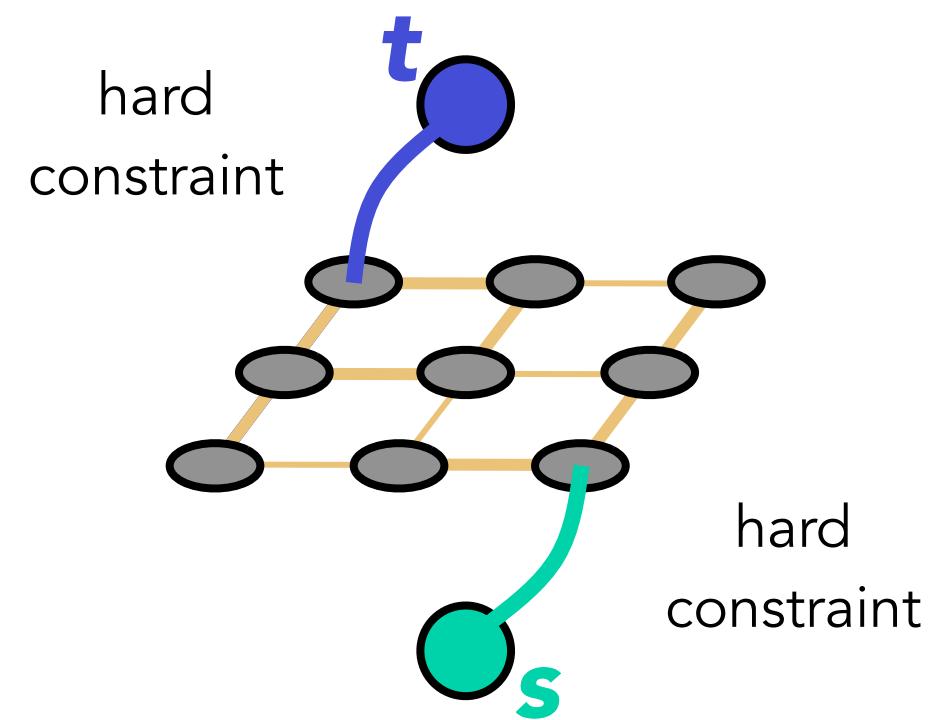
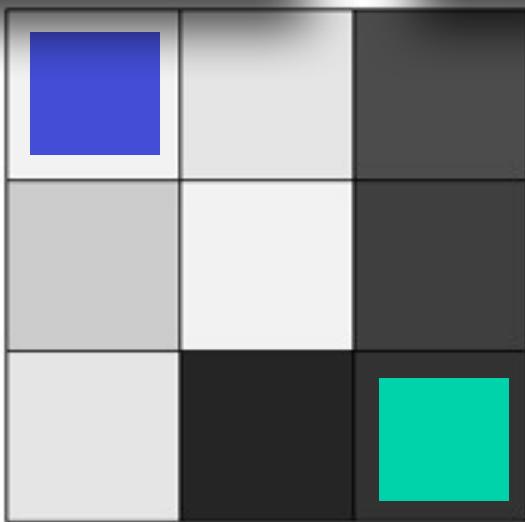


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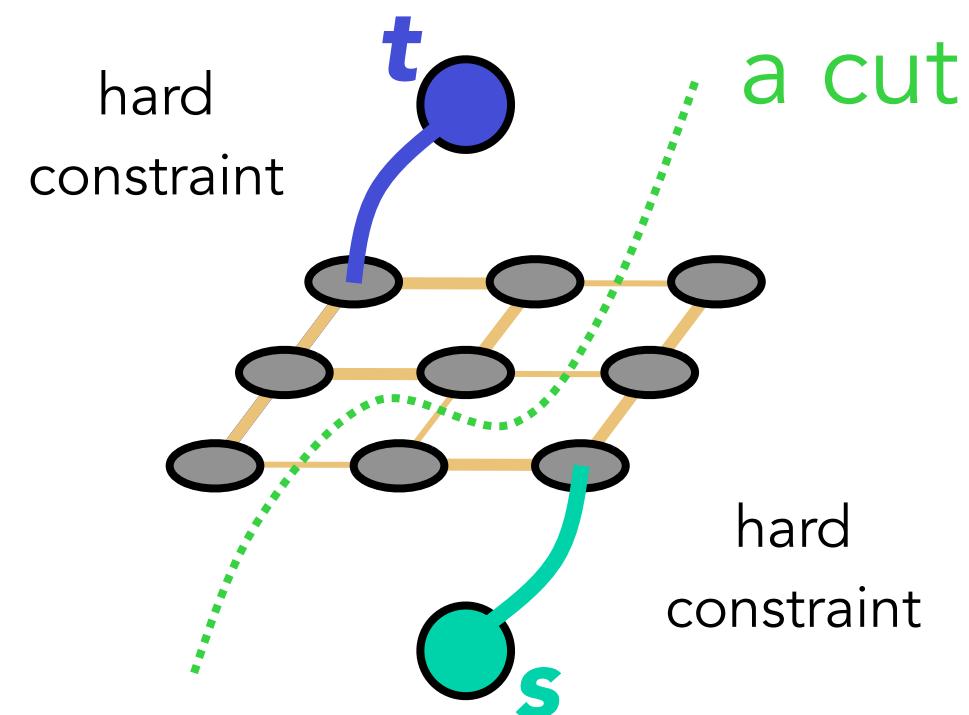
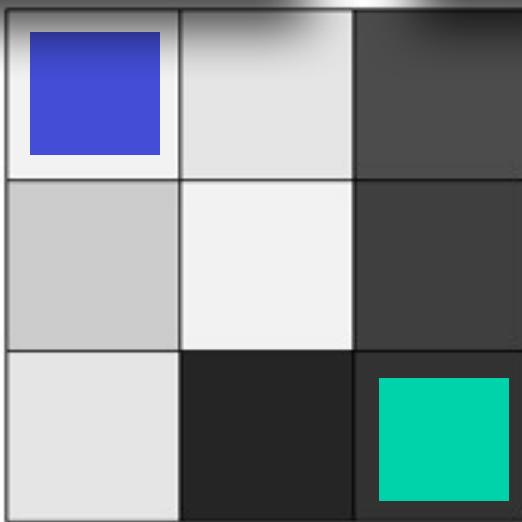


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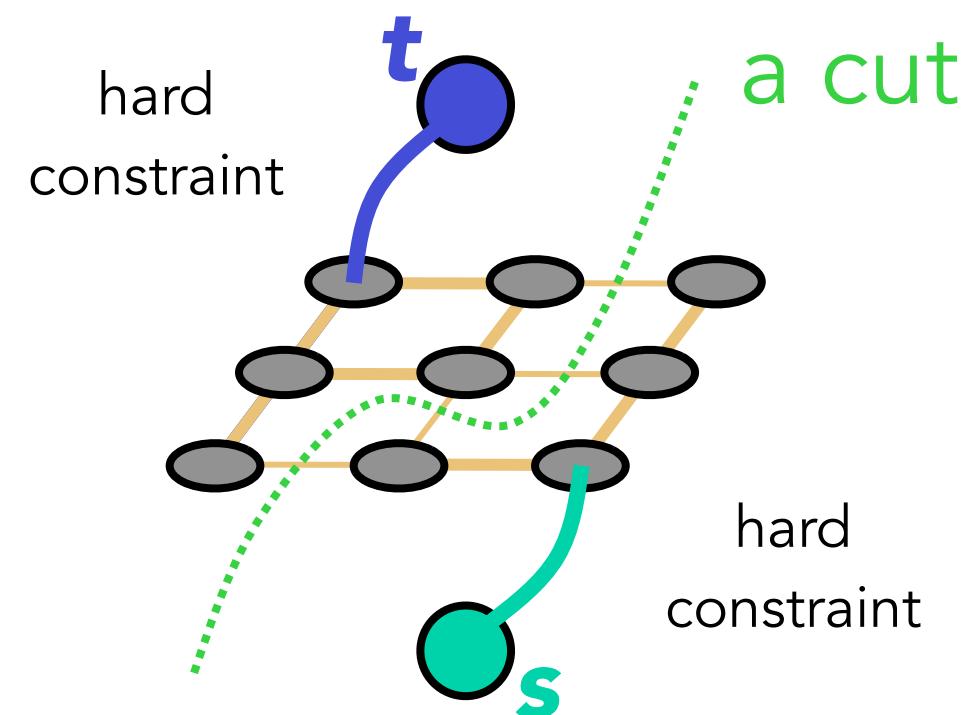
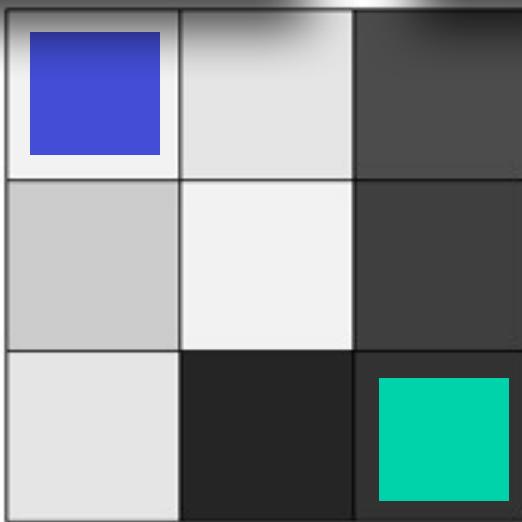


Seam Finding using Graph-cuts

Boykov and Jolly (2001)
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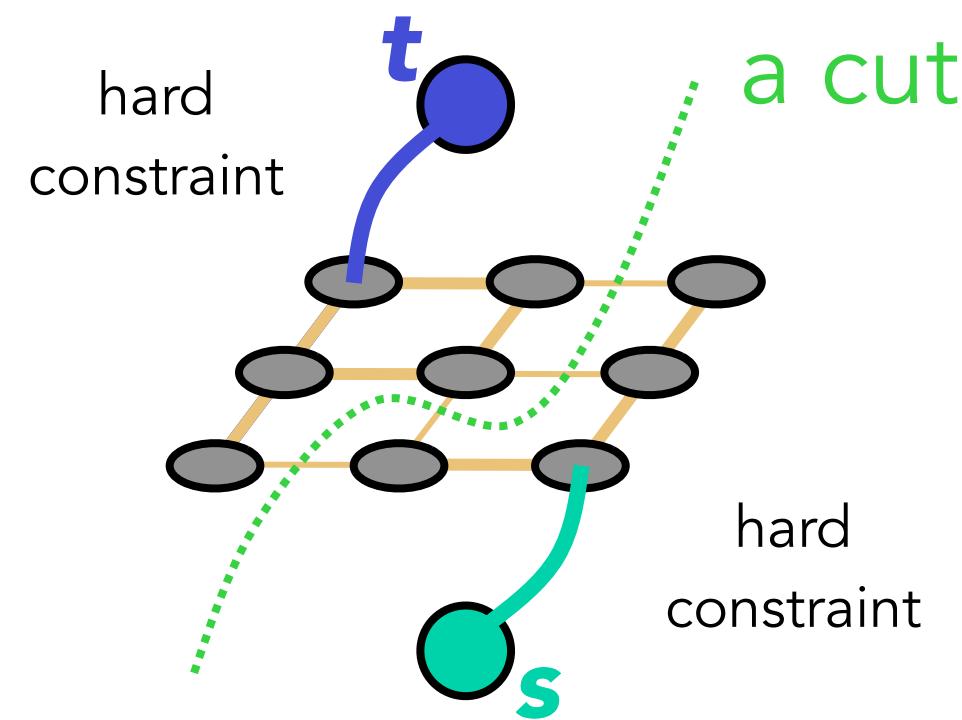
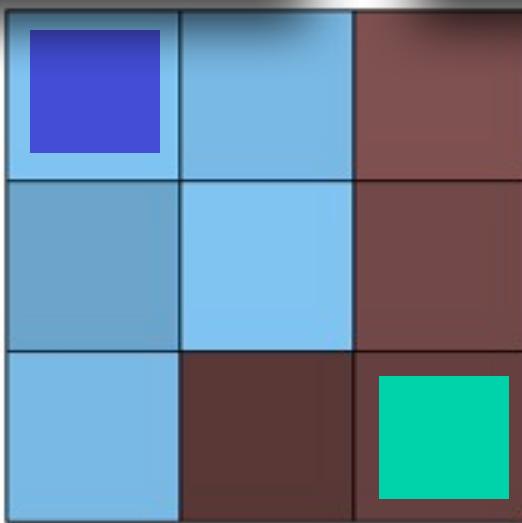
Seam Finding using Graph-cuts

Minimum cost cut can be computed
in polynomial time (max-flow/min-
cut algorithms)

Boykov and Jolly (2001)
Kwatra et al. (2003)



t ***s***



Seam Finding using **Graph-cuts**

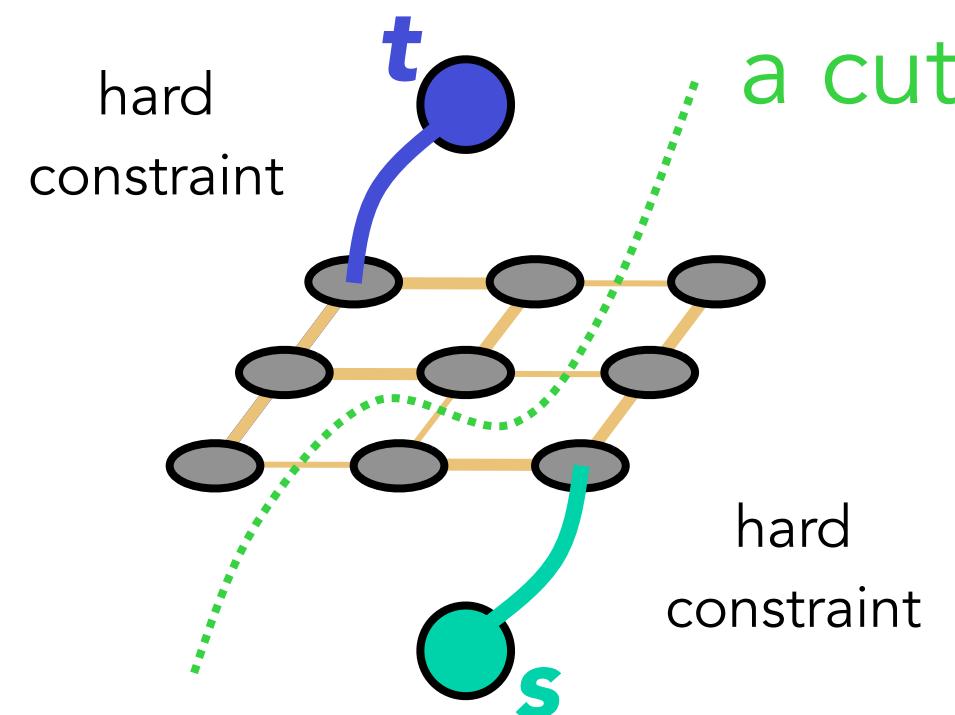
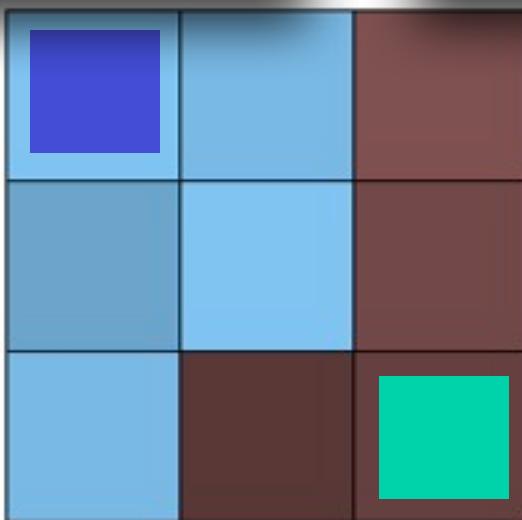
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t ***s***



Boykov and Jolly (2001)

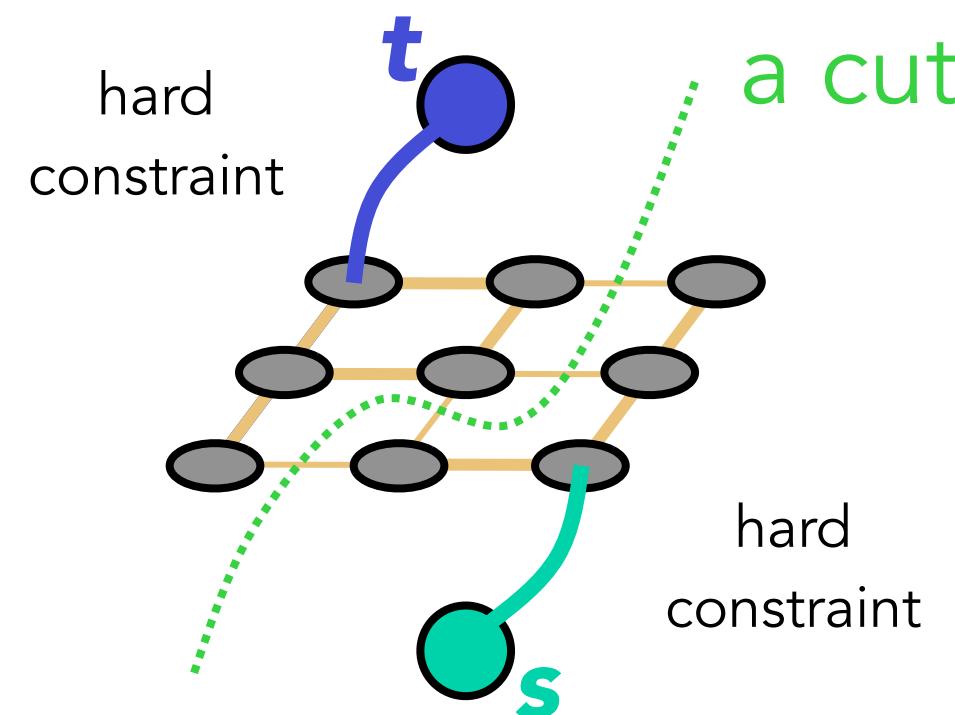
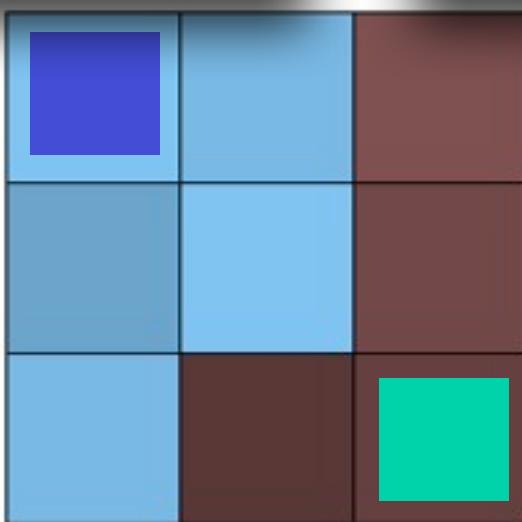
Kwatra et al. (2003)

Seam Finding using Graph-cuts

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t ***s***



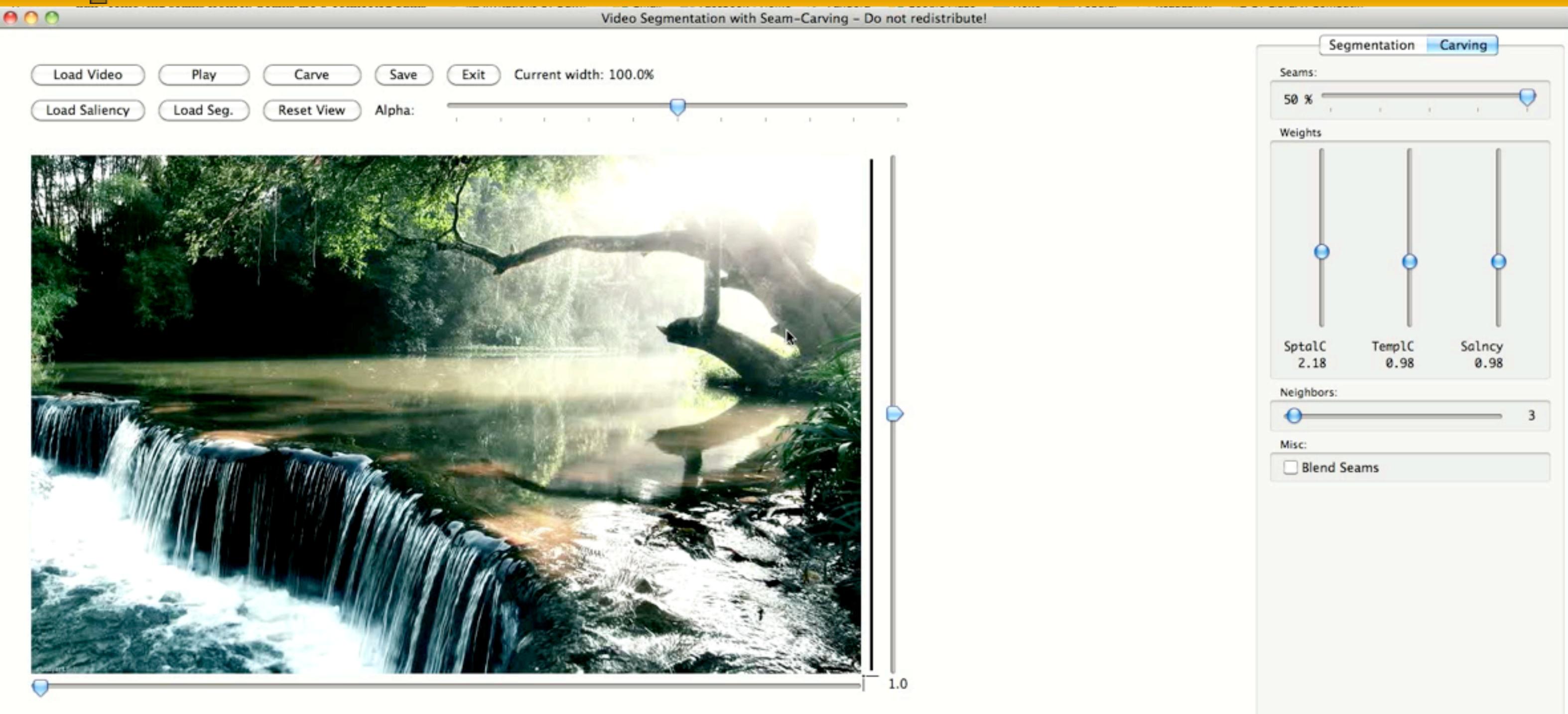
Boykov and Jolly (2001)

Kwatra et al. (2003)

Minimum cost cut can be computed
in polynomial time (max-flow/min-
cut algorithms)

Another approach is to use
Dynamic Programming to find Seams

Seam Finding using Graph-cuts



Seam Carving

Grundmann et al. (2010), Avidan and Shamir (2007)

Summary

- ★ Introduced an additional method for merging images besides blending.
- ★ Described how seams are found in images.
- ★ Discussed the benefits of cutting images over blending images.



Further Reading

- ★ Davis (1998), "Mosaics of Scenes with Moving Objects" IEEE Computer Vision and Pattern Recognition (CVPR), 1998.
- ★ Efros and Freeman (2001), "Image Quilting for Texture Synthesis and Transfer" SIGGRAPH 2001 [DOI]
- ★ Kwatra, Schödl, Essa, Turk, Bobick (2003), "Graphcut textures: image and video synthesis using graph cuts" SIGGRAPH 2003 [DOI].
- ★ Boykov and Jolly (2001), "Interactive Graph Cuts for Optimal Boundary & Region Segmentation of Objects in N-D images. ICCV 2001.
- ★ Avidan and Shamir (2007), "Seam carving for content-aware image resizing", SIGGRAPH 2007.
- ★ Agarwala, Dontcheva, Agrawala, Drucker, Colburn, Curless, Salesin, Cohen (2004), "Interactive Digital Photomontage." SIGGRAPH 2004.



commons.wikimedia.org/

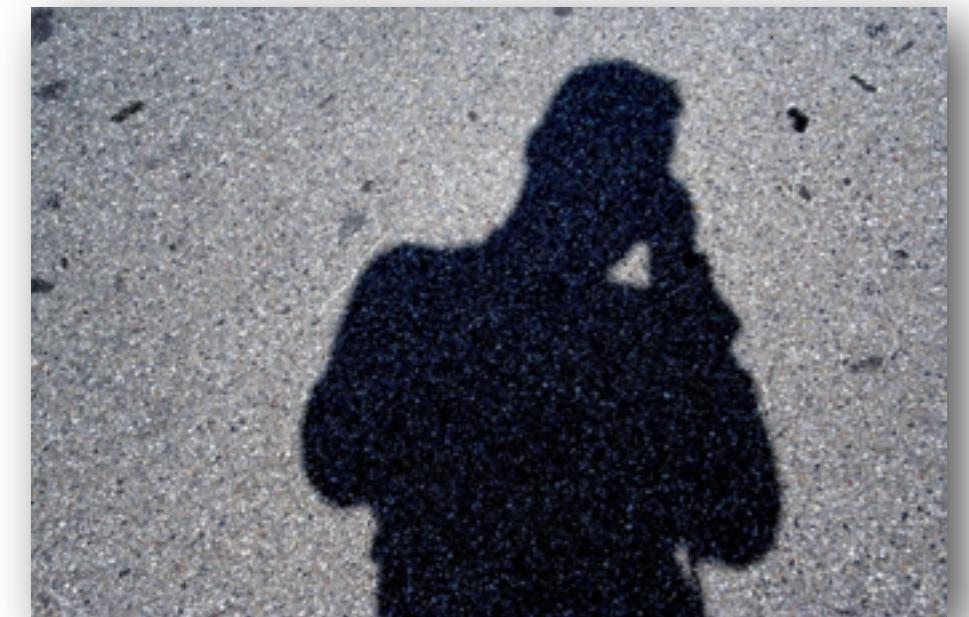
Next Class

★ Feature Detection and Matching



Credits

- ★ For more information, see
 - Richard Szeliski (2010) Computer Vision: Algorithms and Applications, Springer.
- ★ Some concepts in slides motivated by similar slides by A. Efros and J. Hays.
- ★ Some images retrieved from
 - <http://commons.wikimedia.org/>.
 - List will be available on website.



www.flickr.com/photos/neneonline/231886965/



Computational Photography



Dr. Irfan Essa

Professor

School of Interactive Computing

Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.