

Transformation Guided Image Completion



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Research

My lab mate's picture from his honeymoon



Can we get rid of those annoying tourists?



Can we get rid of those annoying tourists?



Photoshop Content-Aware Fill

[[Wexler et al., PAMI 07](#)]

[[Barnes et al. SIG 09](#)]



Photoshop Content-Aware Fill

[[Wexler et al., PAMI 07](#)]

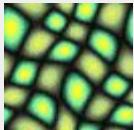
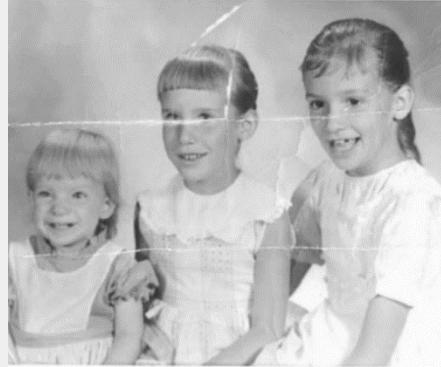
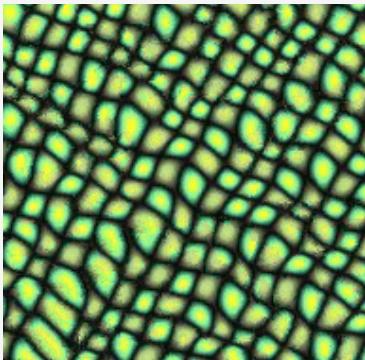
[[Barnes et al. SIG 09](#)]



Our result

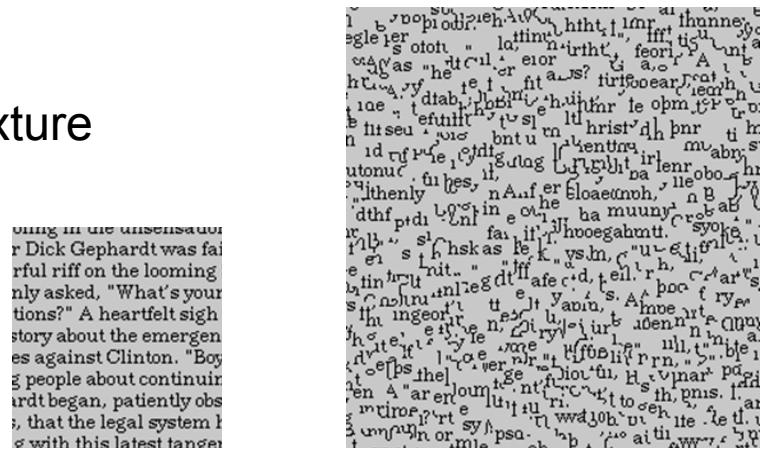


Related Problems

	Texture Synthesis	Image Inpainting	Image Completion
Stationarity	Yes	No	No
Hole size	Large	Small	Large
Example input			
Example output			

Related Work

- Statistical methods
 - Good at synthesizing pure stochastic texture
 - Don't work well for structured texture
- Diffusion-based methods
 - Good at filling small holes
 - Don't work well for large holes

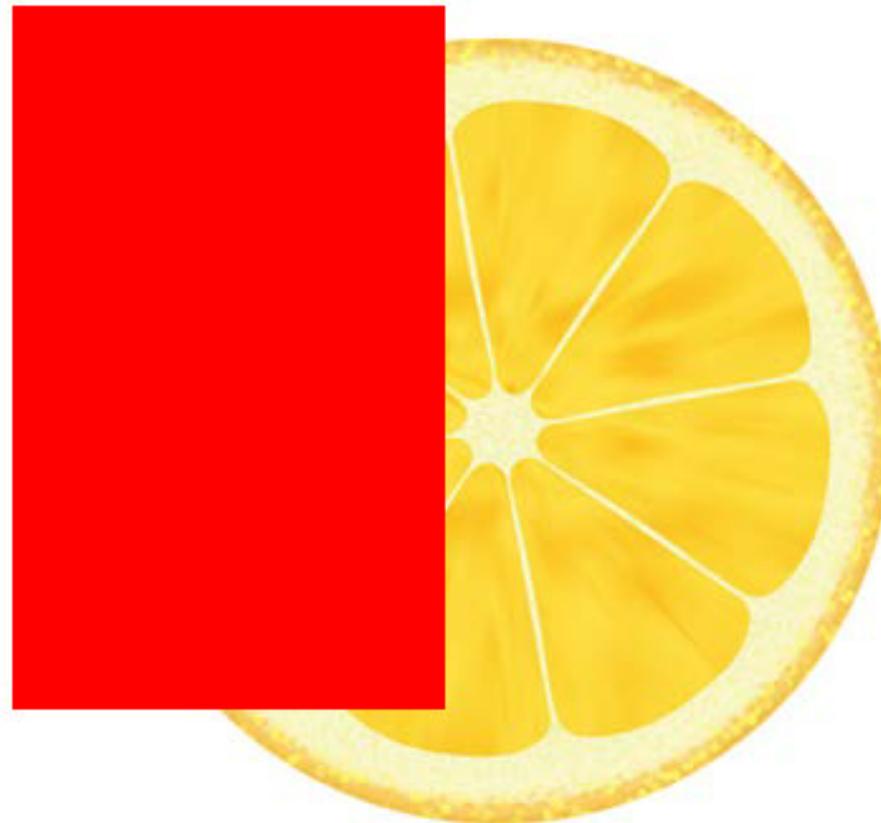


Example-based methods

- Idea: exploit redundancy in natural images
- Previous work:
 - Unit of synthesis (pixels, patches or regions)
 - [[Efros and Leung, ICCV 99](#)] [[Efros and Freeman, SIG 01](#)] [[Kwatra et al. SIG 03](#)]
 - Filling ordering
 - [[Criminisi et al., TIP 04](#)] [[Drori et al., SIG 03](#)] [[Xu et al., TIP 10](#)]
 - Global optimization
 - [[Wexler et al., PAMI 07](#)] [[Kwatra et al., SIG 05](#)] [[Komodakis and Tziritas, TIP 07](#)]
 - Transformations beyond translation
 - [[Mansfield et al., BMVC 11](#)] [[HaCohen et al. SIG 11](#)] [[Darabi et al. SIG 12](#)]
 - Semi-automatic approaches
 - [[Hertzmann et al. SIG 01](#)] [[Sun et al., SIG 05](#)] [[Pavic et al., VC 06](#)]
[[Barnes et al. SIG 09](#)]

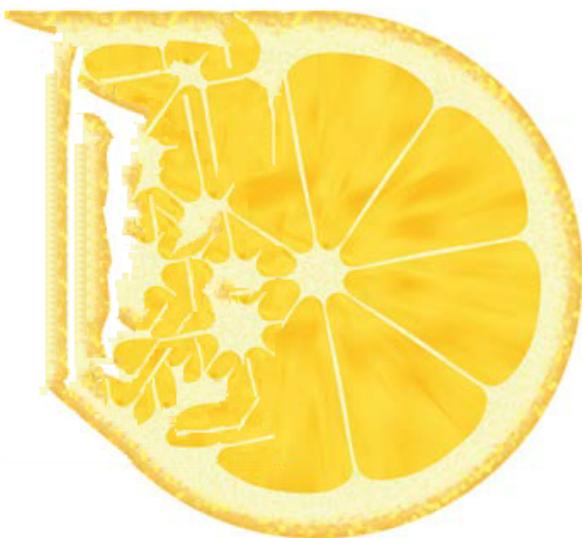
The Key Challenge

- Geometric and photometric transformation are often required.

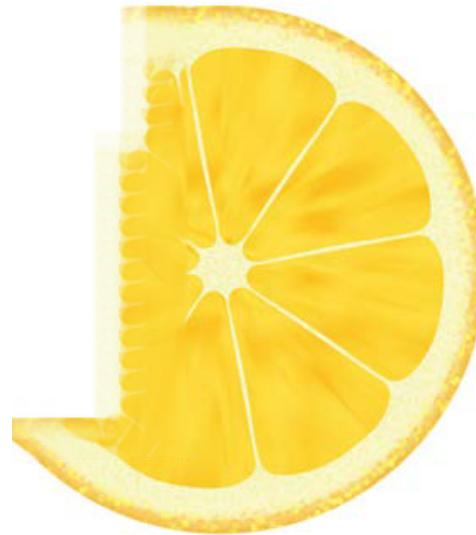


Completion using only translational patches

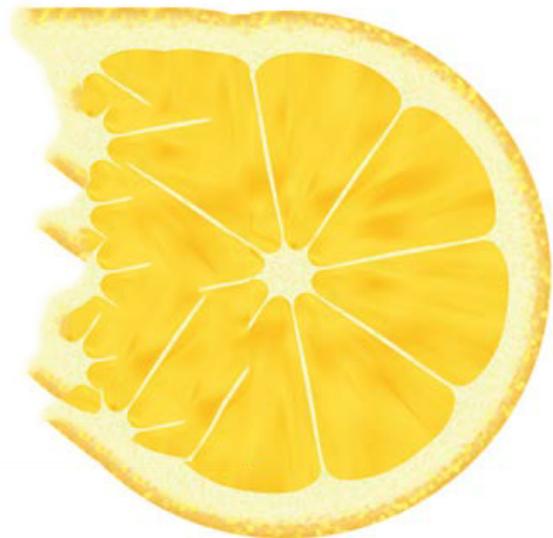
Translational patches are not sufficient!



Examplar-based inpainting
[Criminisi et al., TIP 04]



Priority-BP
[Komodakis and Tziritas, TIP 07]



Photoshop Content-aware fill
[Wexler et al., PAMI 07]
[Barnes et al. SIG 09]

Completion using transformed patches

Difficult to optimize!

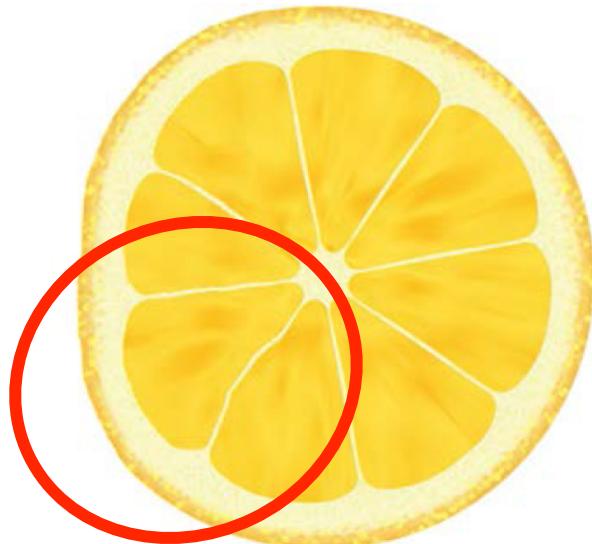
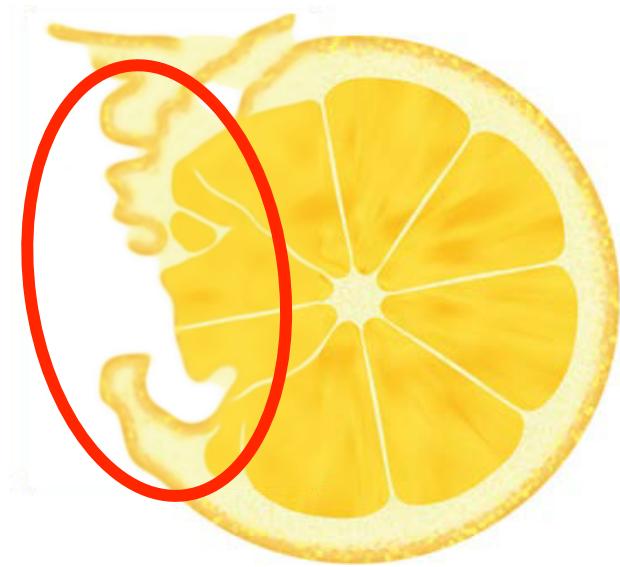


Image melding
[\[Darabi et al. SIG 12\]](#)



Transforming image completion
[\[Mansfield et al., BMVC 11\]](#)

What if the computer could understand the underlying structure?

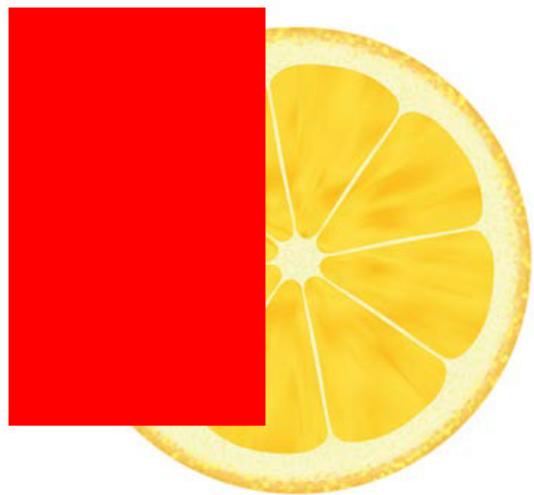
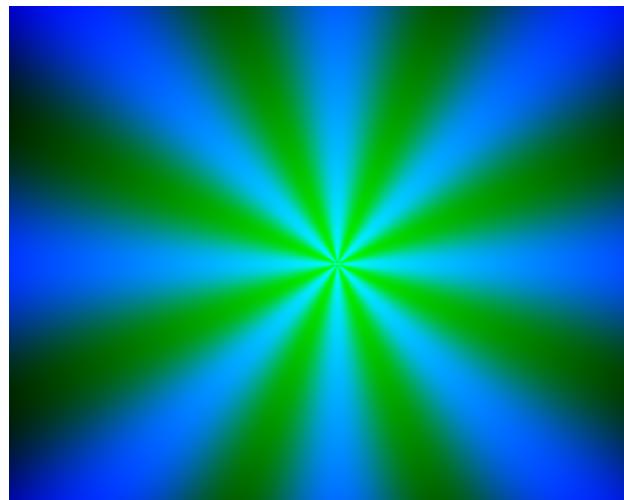
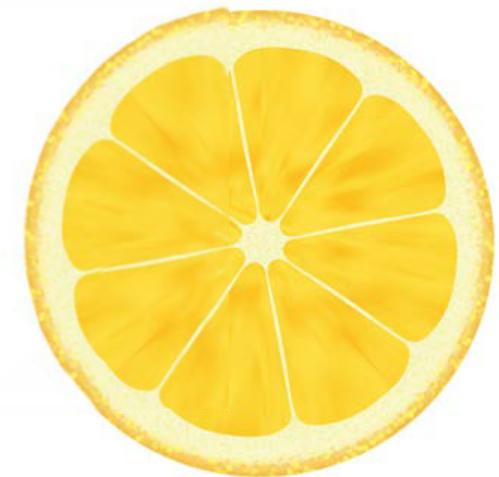


Image with hole

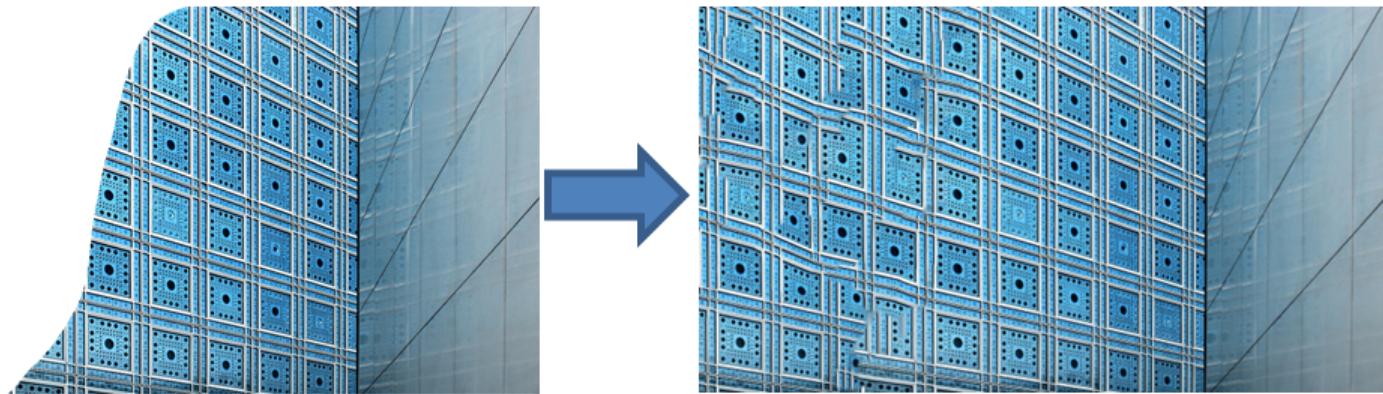


Positional guidance map

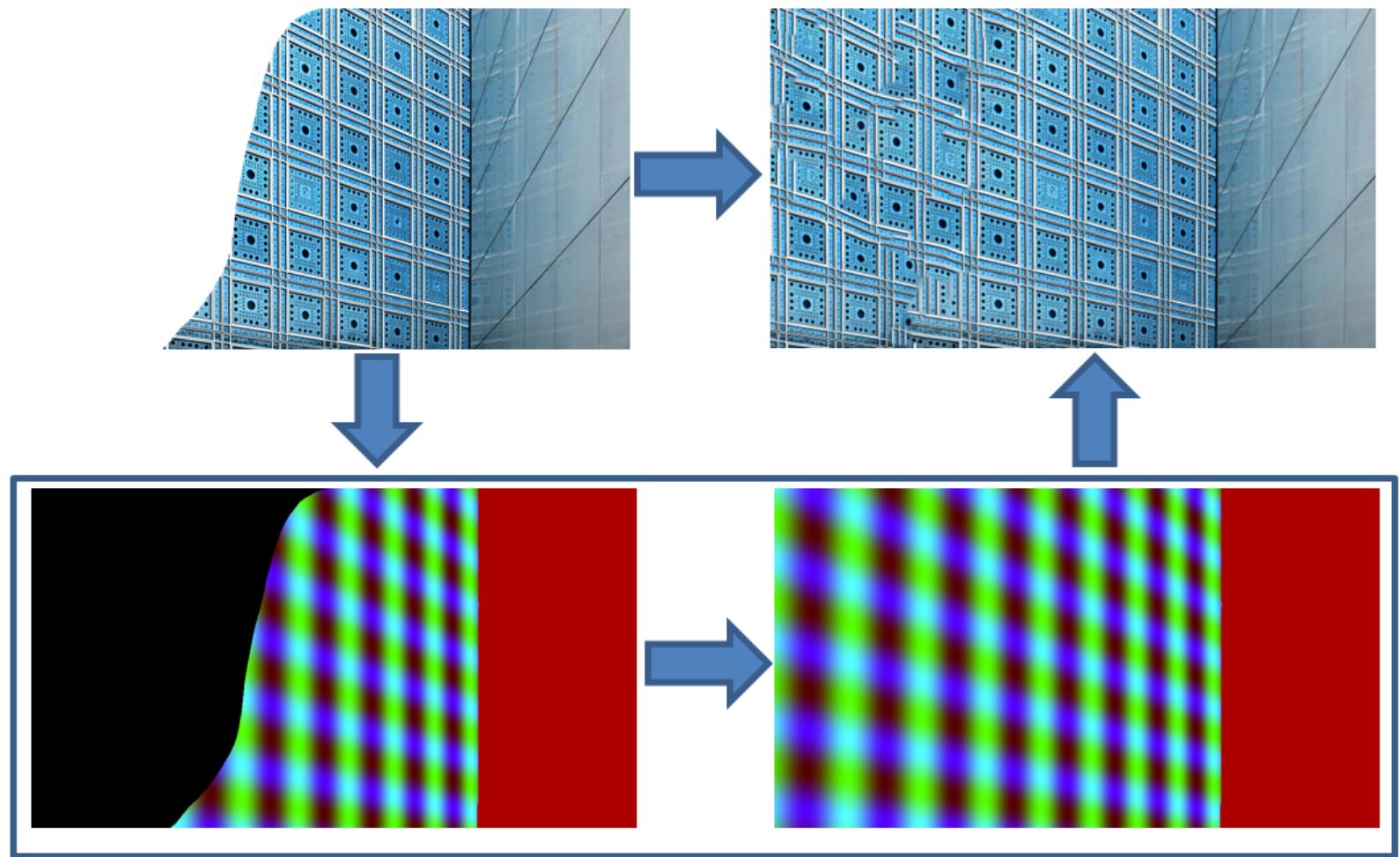


Our result

General Framework



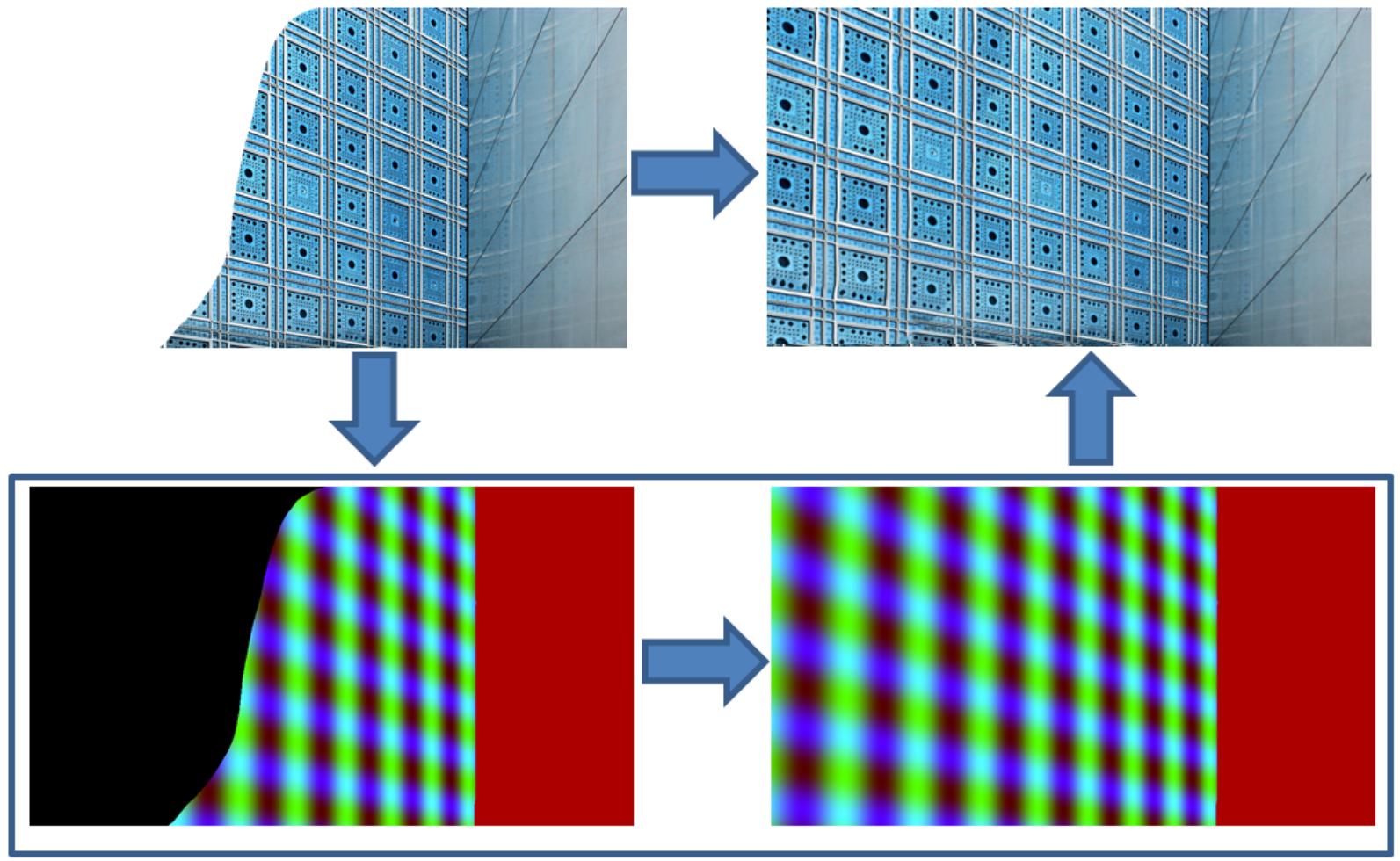
General Framework



Structure in known regions

Extrapolation to unknown regions

General Framework

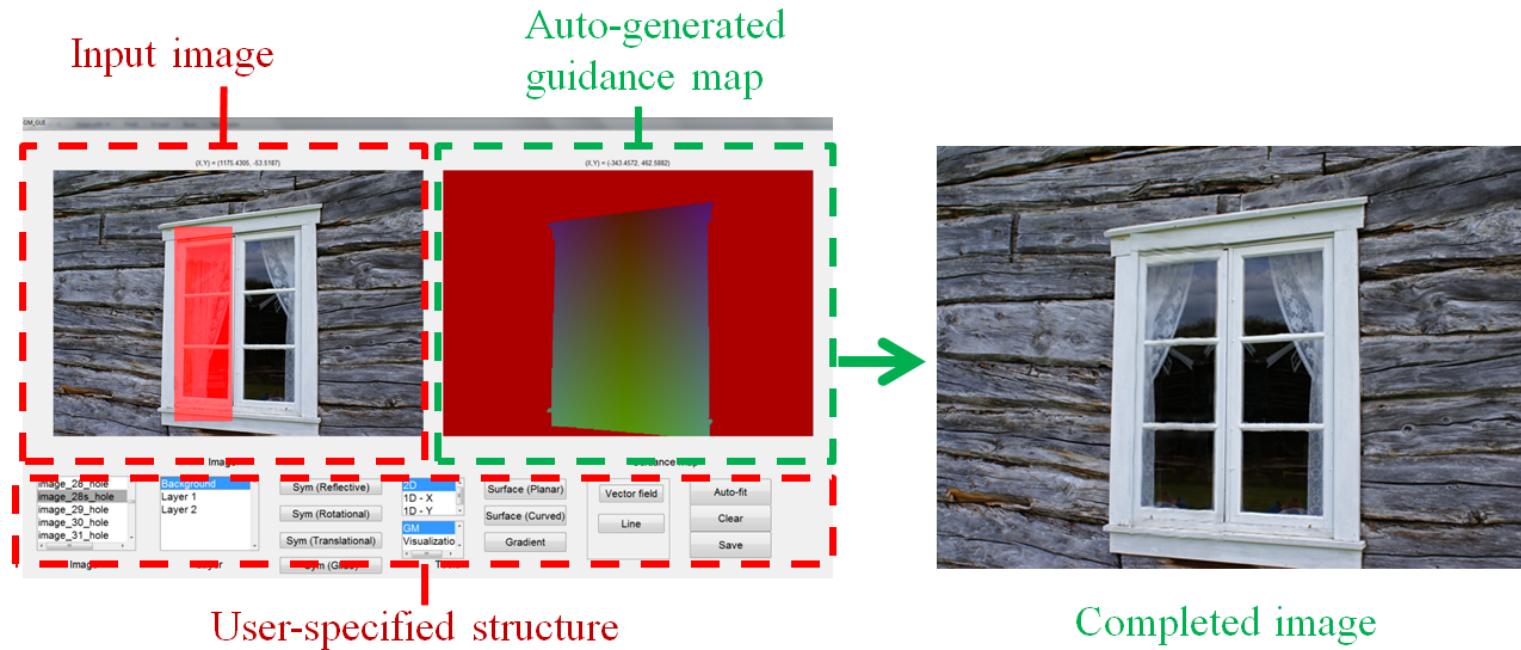


Structure in known regions

Extrapolation to unknown regions

Specifying Image Structure

- How?
 - Specify structure whenever possible.



- Why?
 - Easy for human, but difficult for computer
 - Allow humans to provide high-level expertise while the system performs low- and mid-level processing

Exploiting Structures in Images

- Label maps [\[Hertzmann et al. SIG 01\]](#) [\[Sun et al., SIG 05\]](#) [\[Barnes et al. SIG 09\]](#)
 - Search sources patches only from patches with the same label (Texture-by-numbers)

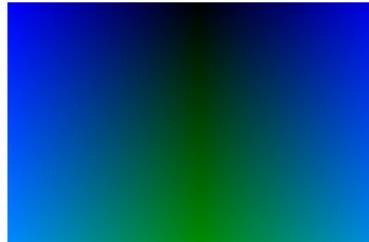


- Ramp gradient
 - Constraint searching along a certain direction

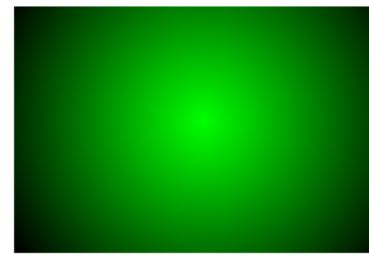
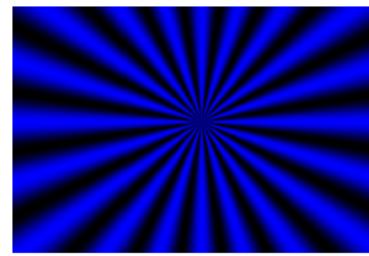
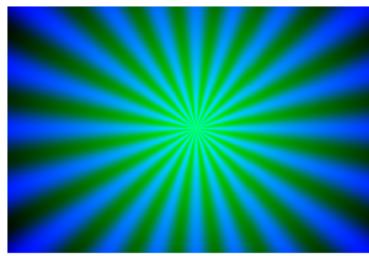


Symmetry

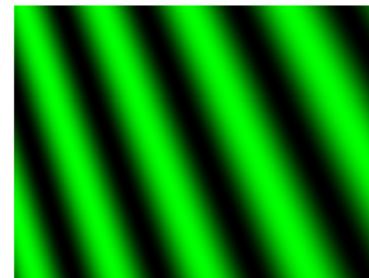
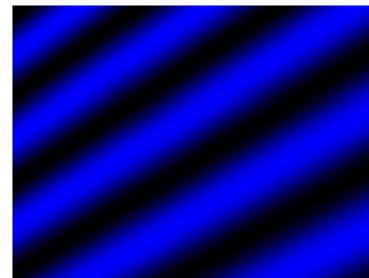
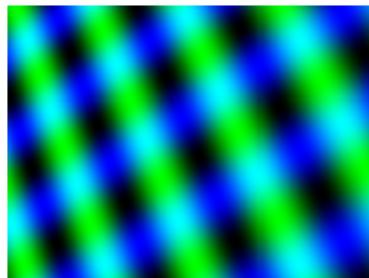
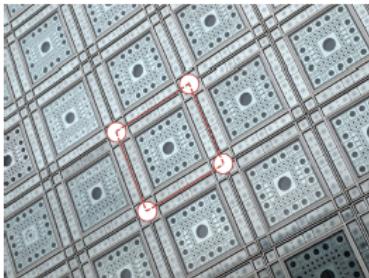
Reflection



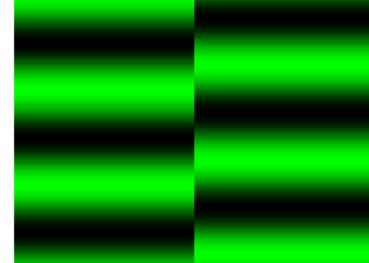
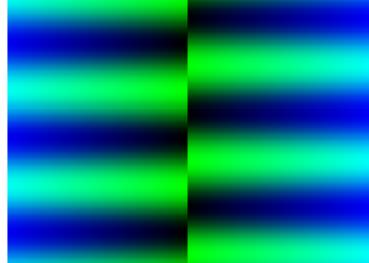
Rotation



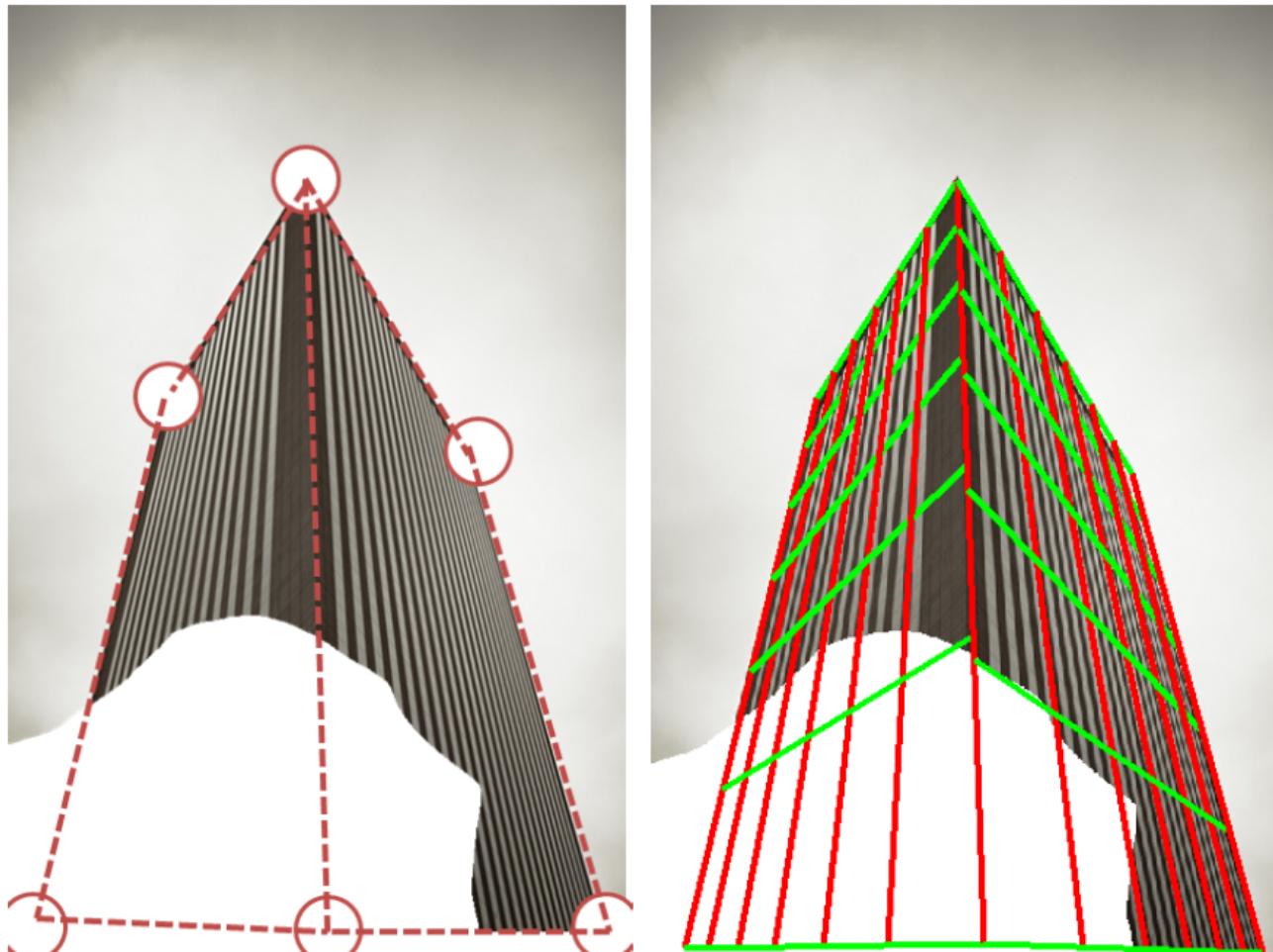
Translation



Glide



Piecewise planar geometry



Translate user inputs to constraints

- Objective function

$$E = \sum_{i \in \overline{K}} E_{\text{color}}(\mathbf{s}_i, \mathbf{t}_i) + \lambda E_{\text{guide}}(\mathbf{s}_i, \mathbf{t}_i)$$

- Color matching cost

$$E_{\text{color}}(\mathbf{s}_i, \mathbf{t}_i) = \|p(\mathbf{s}_i) - p(\mathbf{t}_i)\|$$

- Guidance cost: positional and non-positional

$$E_{\text{guide}}(\mathbf{s}_i, \mathbf{t}_i) = E_{\text{pos}}(\mathbf{s}_i, \mathbf{t}_i) + E_{\text{non-pos}}(\mathbf{s}_i, \mathbf{t}_i)$$

Positional guidance

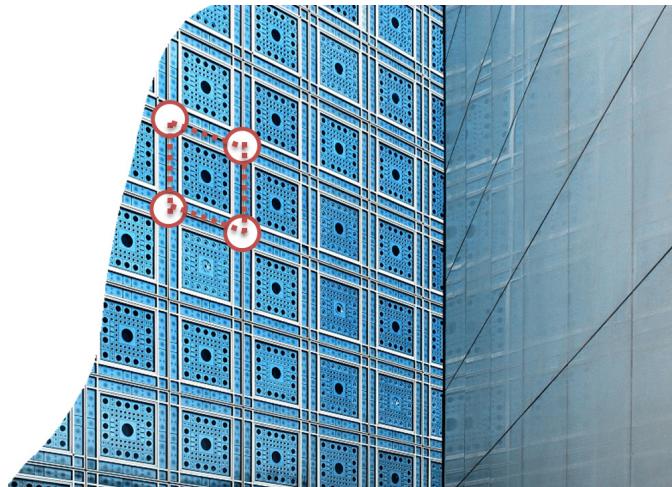
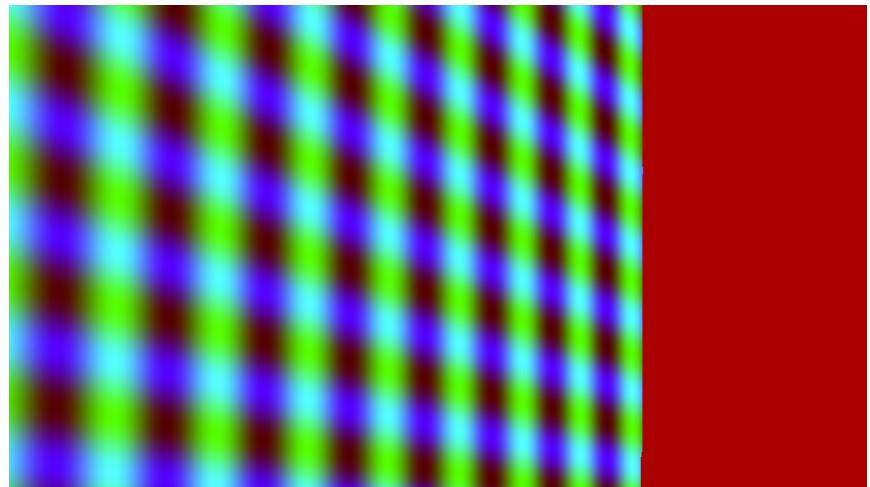
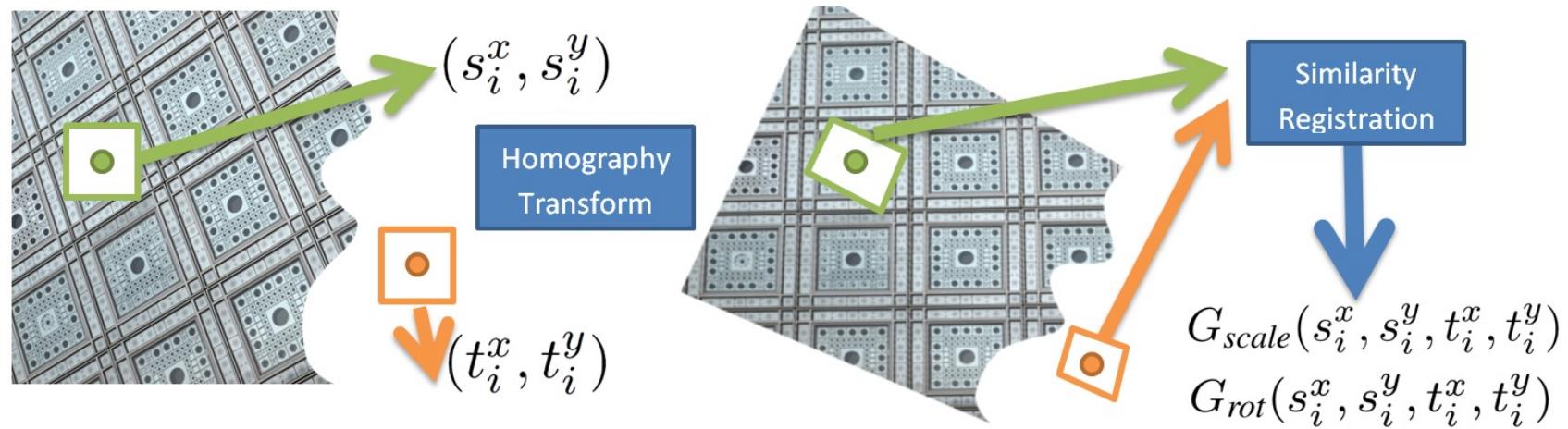
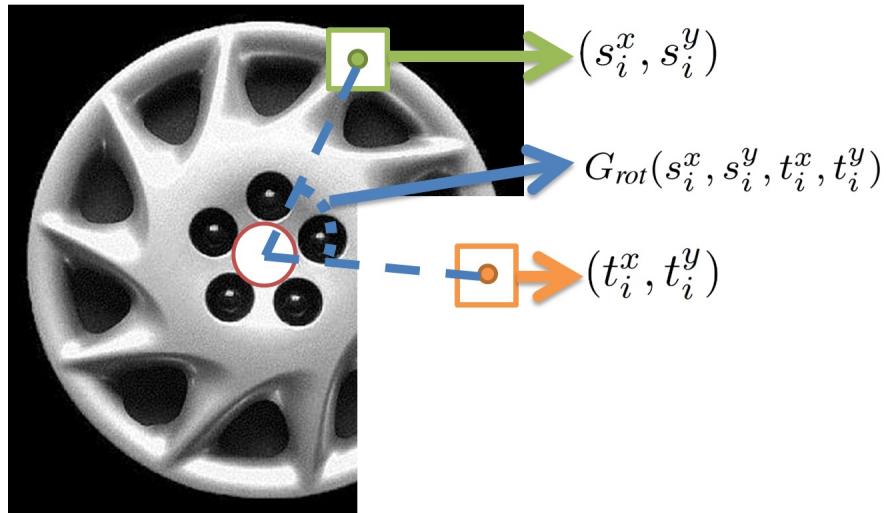


Image with missing region



Positional guidance map

Non-positional guidance



Probabilistic Interpretation

- Probability factorization given user input \mathbf{u}

$$\begin{aligned} P_{\mathbf{u}}(\mathbf{s}_i | \mathbf{t}_i) &= P_{\mathbf{u}}(s_i^x, s_i^y, s_i^r, s_i^s | \mathbf{t}_i) \\ &= P_{\mathbf{u}}(s_i^x, s_i^y | \mathbf{t}_i) P_{\mathbf{u}}(s_i^r | s_i^x, s_i^y, \mathbf{t}_i) P_{\mathbf{u}}(s_i^s | s_i^x, s_i^y, \mathbf{t}_i) \end{aligned}$$

- Guidance cost

$$E_{\text{pos}}(\mathbf{s}_i, \mathbf{t}_i) = -\log(P_{\mathbf{u}}(s_i^x, s_i^y | \mathbf{t}_i))$$

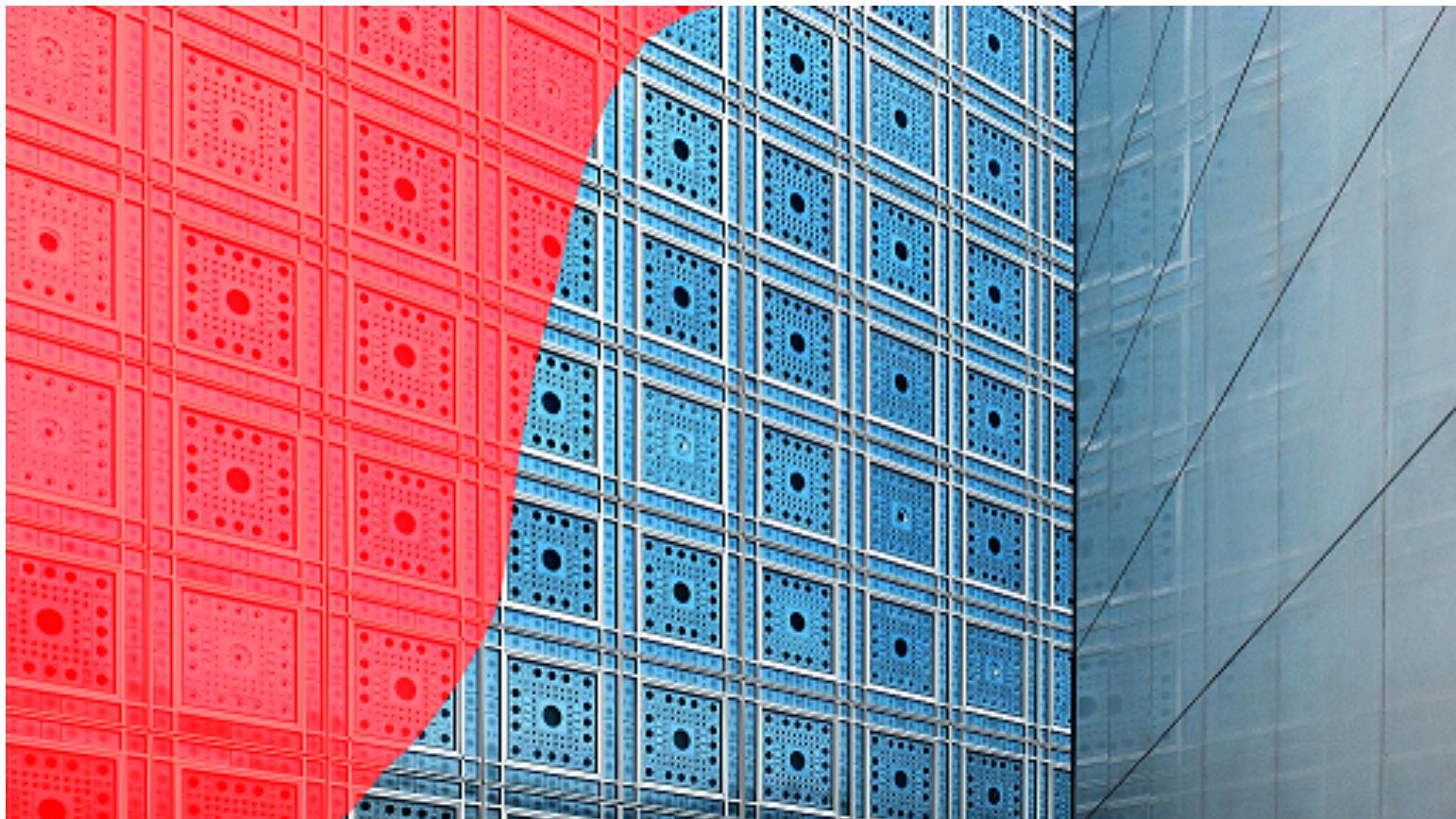
$$E_{\text{rot}}(\mathbf{s}_i, \mathbf{t}_i) = -\log(P_{\mathbf{u}}(s_i^r | s_i^x, s_i^y, \mathbf{t}_i))$$

$$E_{\text{scale}}(\mathbf{s}_i, \mathbf{t}_i) = -\log(P_{\mathbf{u}}(s_i^s | s_i^x, s_i^y, \mathbf{t}_i))$$

Probabilistic interpretation for interactive image completion methods

	Positional prior $P_{\mathbf{u}}(s_i^x, s_i^y \mathbf{t}_i)$	Non-positional prior $P_{\mathbf{u}}(s_i^r s_i^x, s_i^y, \mathbf{t}_i)$ $P_{\mathbf{u}}(s_i^s s_i^x, s_i^y, \mathbf{t}_i)$
Label map [Hertzmann et al. SIG 01] [Barnes et al. SIG 09]	uniform distribution with finite support	N/A
Line/contour-based constraints [Sun et al., SIG 05]	degenerate distribution along the curve	N/A
Perspective [Pavic et al., VC 06]	N/A	constant, no uncertainty modeled
Ours	distribution corresponds to eps-insensitive loss	Laplacian distribution

An image with missing region



Photoshop content-aware fill



Our result (unguided)



Our result (positional guide only)



Our result (non-positional guide only)



Our result (positional *and* non-positional)



Comparison with the-state-of-the-art

- Example-based Inpainting [[Criminisi et al., TIP 04](#)]
 - Smart filling order selection
- Priority-BP [[Komodakis and Tziritas, TIP 07](#)]
 - Global optimization with MRF model
- Photoshop content-aware fill (CS 5)
 - Nonparametric formulation [[Wexler et al., PAMI 07](#)] + PatchMatch [[Barnes et al. SIG 09](#)]
- Image melding [[Darabi et al. SIG 12](#)]
 - geometric and photometric transformations for patch + image gradients representation
- Transforming image completion [[Mansfield et al., BMVC 11](#)]
 - Search transformed patches using generalized PatchMatch
- Ours (unguided)
 - Our completion algorithm without using guidance map

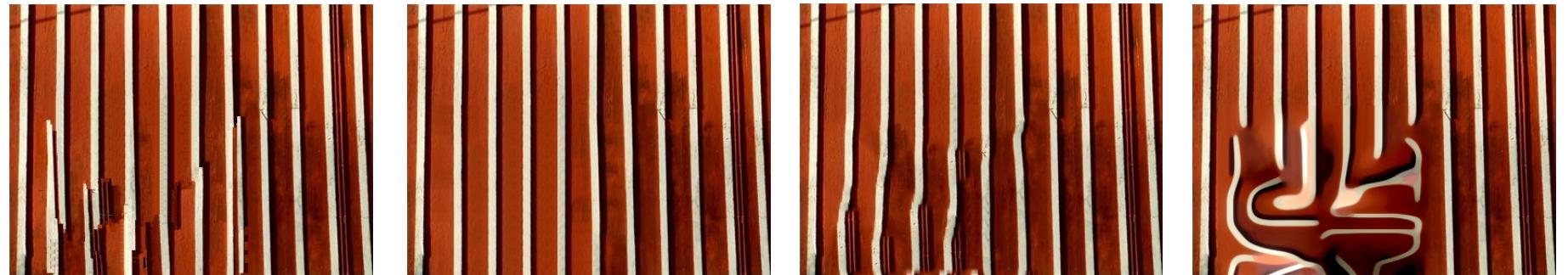


Image with hole

Ours

Ours (unguided)

Image melding
[\[Darabi et al. SIG 12\]](#)



Exampler-based inpainting
[\[Criminisi et al., TIP 04\]](#)

Priority-BP
[\[Komodakis and Tziritas, TIP 07\]](#)

Photoshop content-aware fill
[\[Wexler et al., PAMI 07\]](#)
[\[Barnes et al. SIG 09\]](#)

Transforming
image completion
[\[Mansfield et al., BMVC 11\]](#)



Guidance map

Ours

Ours (unguided)

Image melding
[\[Darabi et al. SIG 12\]](#)



Exemplar-based inpainting
[\[Criminisi et al., TIP 04\]](#)

Priority-BP
[\[Komodakis and Tziritas, TIP 07\]](#)

Photoshop content-aware fill
[\[Wexler et al., PAMI 07\]](#)
[\[Barnes et al. SIG 09\]](#)

Transforming
image completion
[\[Mansfield et al., BMVC 11\]](#)



Image with hole



Ours



Photoshop content-aware fill
[\[Wexler et al., PAMI 07\]](#)
[\[Barnes et al. SIG 09\]](#)



Image melding
[\[Darabi et al. SIG 12\]](#)



Guidance map



Examplar-based inpainting
[\[Criminisi et al., TIP 04\]](#)



Priority-BP
[\[Komodakis and Tziritas, TIP 07\]](#)



Transforming
image completion
[\[Mansfield et al., BMVC 11\]](#)



Image with hole



Ours



Ours (unguided)



Image melding
[Darabi et al. SIG 12]



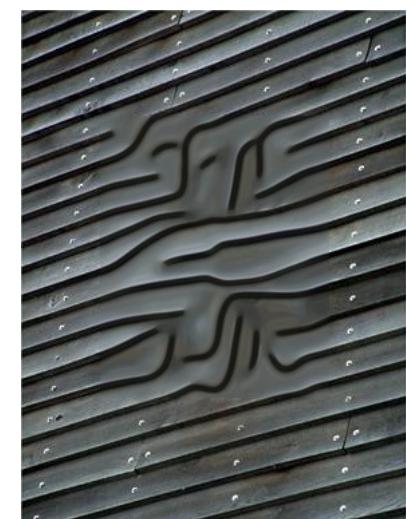
Examplar-based inpainting
[Criminisi et al., TIP 04]



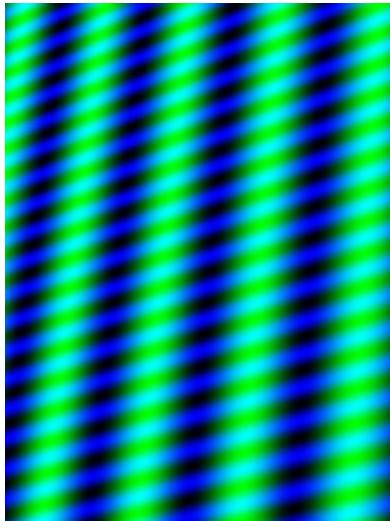
Priority-BP
[Komodakis and Tziritas,
TIP 07]



Photoshop content-aware fill
[Wexler et al., PAMI 07]
[Barnes et al. SIG 09]



Transforming
image completion
[Mansfield et al., BMVC 11]



Guidance map



Ours



Ours (unguided)



Image melding
[Darabi et al. SIG 12]



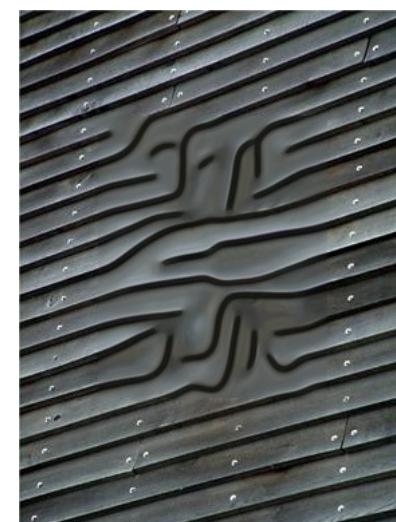
Exemplar-based inpainting
[Criminisi et al., TIP 04]



Priority-BP
[Komodakis and Tziritas, TIP 07]



Photoshop content-aware fill
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[Barnes et al. SIG 09]



Transforming image completion
[Mansfield et al., BMVC 11]

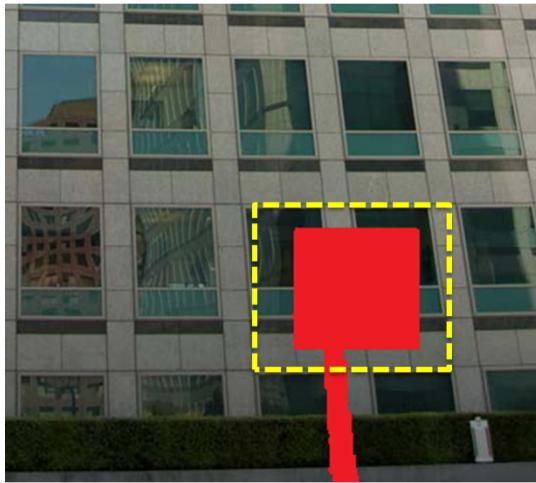


Image with mask



Our result



Image melding
[\[Darabi et al. SIG 12\]](#)



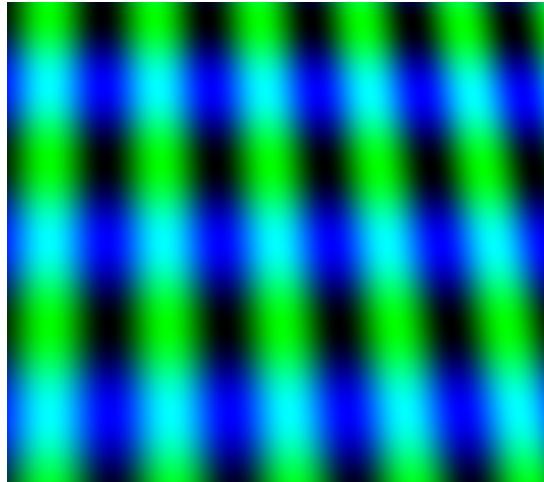
Photoshop content-aware fill
[\[Wexler et al., PAMI 07\]](#)
[\[Barnes et al. SIG 09\]](#)



Priority-BP
[\[Komodakis and Tziritas, TIP 07\]](#)



Transforming image completion
[\[Mansfield et al., BMVC 11\]](#)



Guidance map



Our result



Image melding
[\[Darabi et al. SIG 12\]](#)



Photoshop content-aware fill
[\[Wexler et al., PAMI 07\]](#)
[\[Barnes et al. SIG 09\]](#)



Priority-BP
[\[Komodakis and Tziritas, TIP 07\]](#)



Transforming image completion
[\[Mansfield et al., BMVC 11\]](#)



Image with hole



Ours

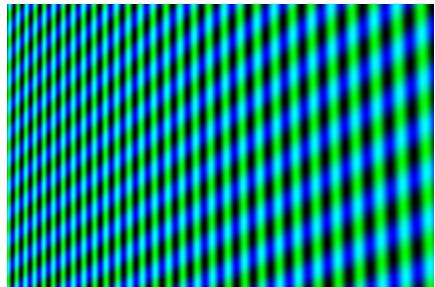


Photoshop content-aware fill

[\[Wexler et al., PAMI 07\]](#)
[\[Barnes et al. SIG 09\]](#)



Image melding
[\[Darabi et al. SIG 12\]](#)



Guidance map



Examplar-based inpainting
[\[Criminisi et al., TIP 04\]](#)



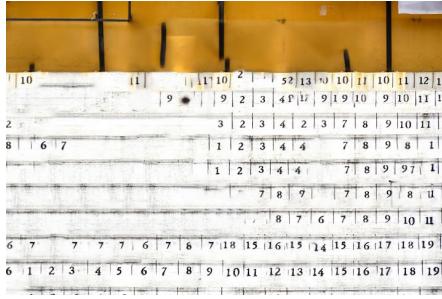
Priority-BP
[
[Komodakis and Tziritas, TIP 07](#)
]



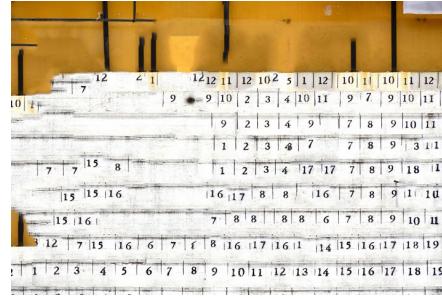
Transforming
image completion
[\[Mansfield et al., BMVC 11\]](#)



Image with hole



Ours



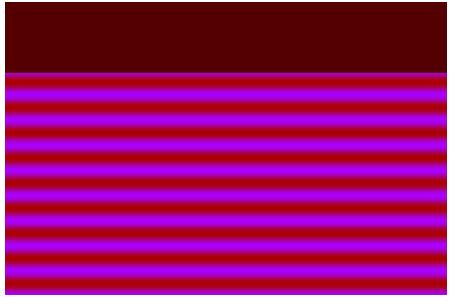
Photoshop content-aware fill

[Wexler et al., PAMI 07](#)
[Barnes et al. SIG 09](#)



Image melding

[Darabi et al. SIG 12](#)



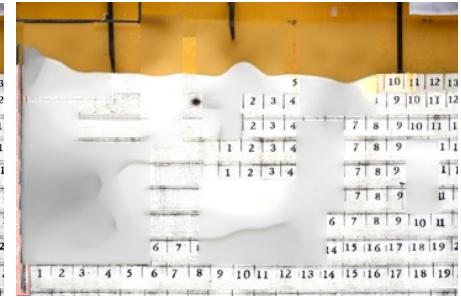
Guidance map



Exemplar-based inpainting
[Criminisi et al., TIP 04](#)



Priority-BP
[Komodakis and Tziritas, TIP 07](#)



Transforming image completion
[Mansfield et al., BMVC 11](#)

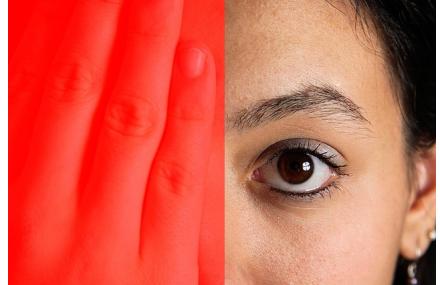


Image with hole



Ours



Ours (unguided)



Image melding
[[Darabi et al. SIG 12](#)]



Examplar-based inpainting
[[Criminisi et al., TIP 04](#)]



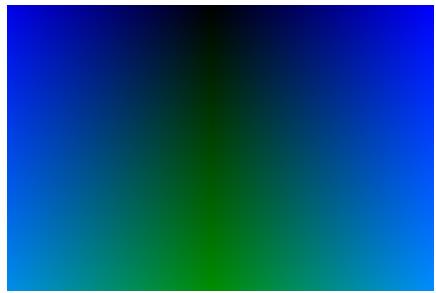
Priority-BP
[[Komodakis and Tziritas, TIP 07](#)]



Photoshop content-aware fill
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Transforming
image completion
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Guidance map



Ours



Ours (unguided)



Image melding
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Priority-BP
[
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image completion
[\[Mansfield et al., BMVC 11\]](#)



Image with hole



Ours



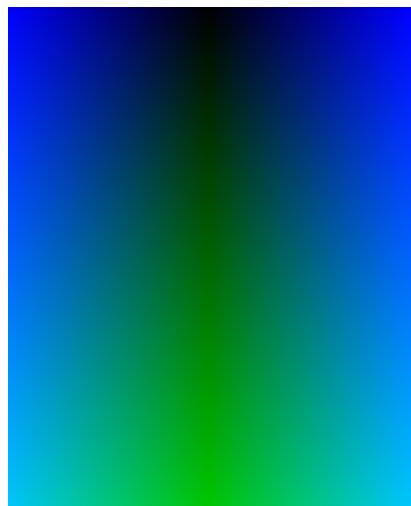
Photoshop content-aware fill

[Wexler et al., PAMI 07](#)
[Barnes et al. SIG 09](#)

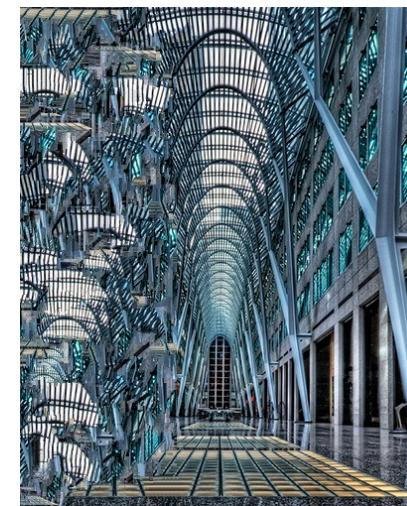


Image melding

[\[Darabi et al. SIG 12\]](#)



Guidance map



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image completion
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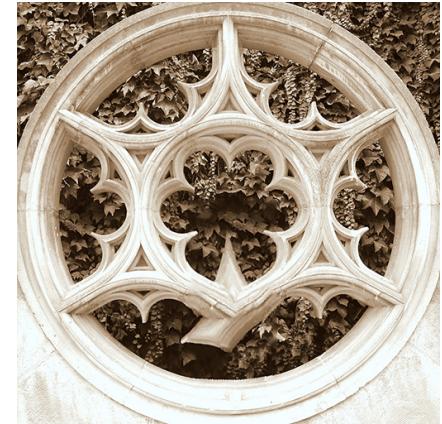
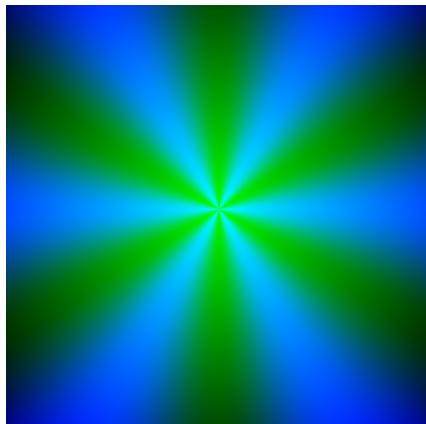
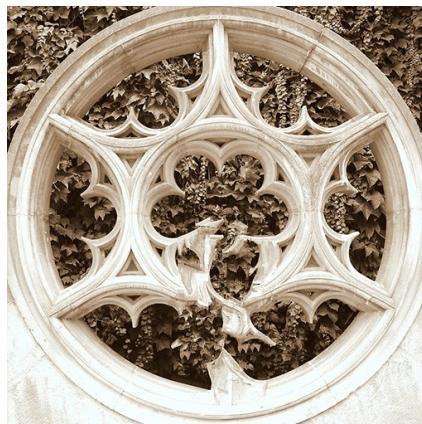


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[Mansfield et al., BMVC 11](#)



Image with hole



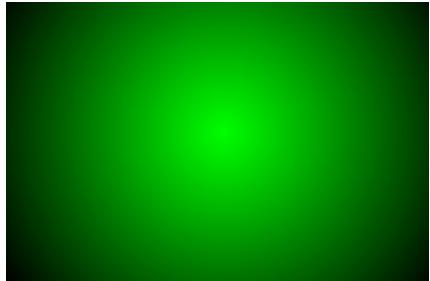
Ours



Photoshop content-aware fill
[Wexler et al., PAMI 07]
[Barnes et al. SIG 09]



Image melding
[Darabi et al. SIG 12]



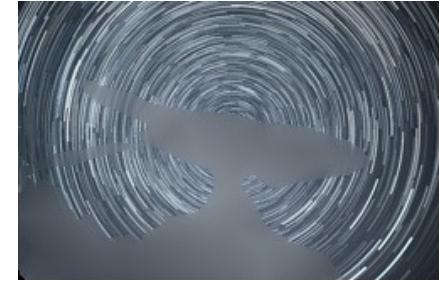
Guidance map



Exemplar-based inpainting
[Criminisi et al., TIP 04]



Priority-BP
[
Komodakis and Tziritas,
TIP 07]



Transforming
image completion
[Mansfield et al., BMVC 11]



Image with hole



Ours



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Image with hole



Photoshop content-aware fill
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Exemplar-based inpainting
[\[Criminisi et al., TIP 04\]](#)



Priority-BP
[\[Komodakis and Tziritas, TIP 07\]](#)



Image with hole



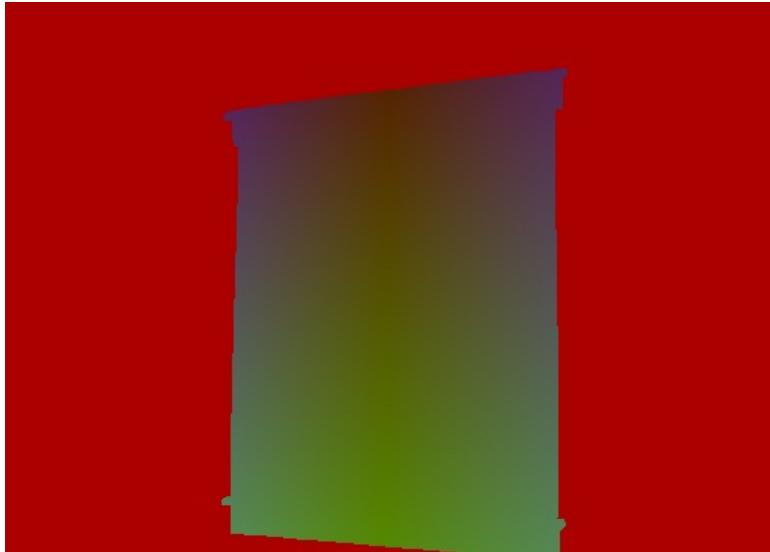
Our result



Image melding
[\[Darabi et al. SIG 12\]](#)



Transforming image completion
[\[Mansfield et al., BMVC 11\]](#)



Guidance Map



Our result



Image melding
[\[Darabi et al. SIG 12\]](#)



Transforming image completion
[\[Mansfield et al., BMVC 11\]](#)



Image with hole



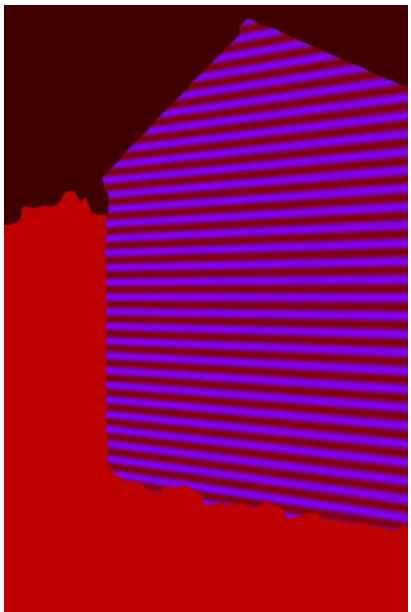
Ours



Photoshop content-aware fill
[\[Wexler et al., PAMI 07\]](#) [\[Barnes et al. SIG 09\]](#)



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[\[Mansfield et al., BMVC 11\]](#)

Failure cases

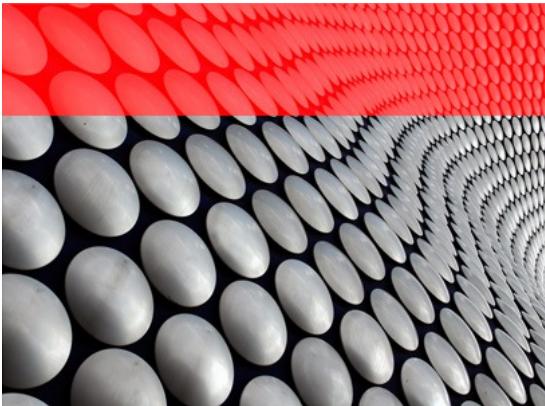
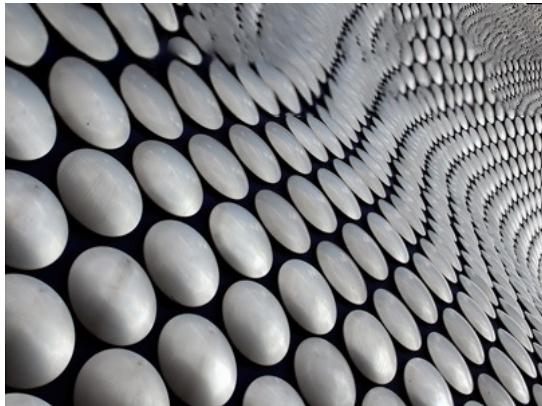
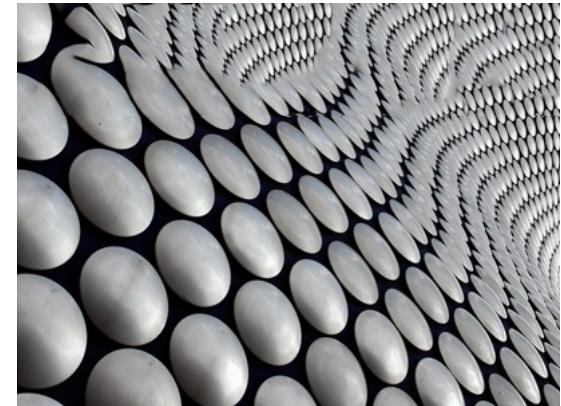


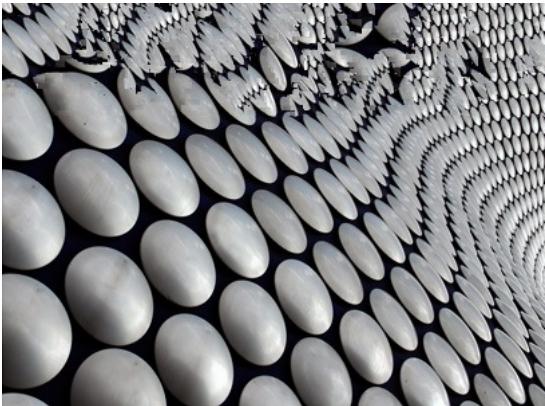
Image with hole



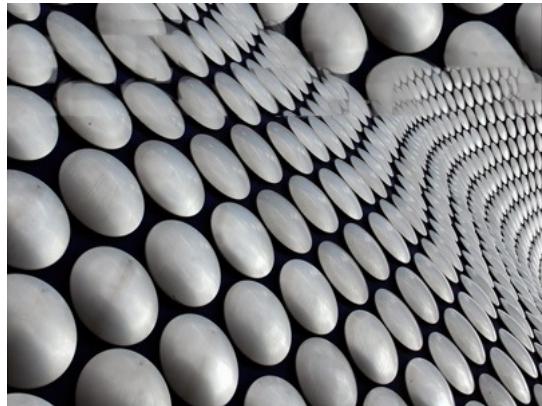
Our result



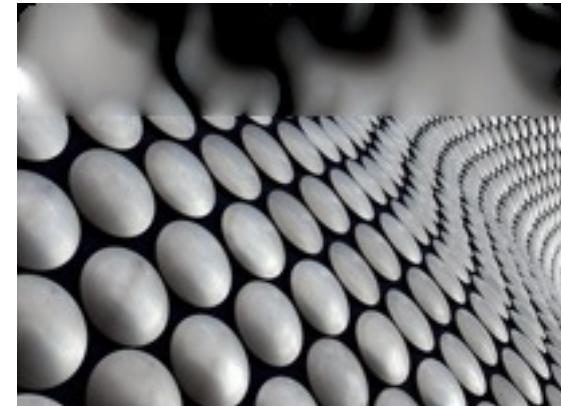
Photoshop content-aware fill
[\[Wexler et al., PAMI 07\]](#)
[\[Barnes et al. SIG 09\]](#)



Examplar-based inpainting
[\[Criminisi et al., TIP 04\]](#)



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Transforming image completion
[\[Mansfield et al., BMVC 11\]](#)

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Summary

- A simple user interface
 - allow users to directly control the desired image completion results by specifying various image structures
- Automatically generate the transformation guidance maps
 - serve as soft constraints in guiding the completion process
- An optimization framework with probabilistic interpretation
 - generalize existing work using interactive techniques for image completion

Thank you!

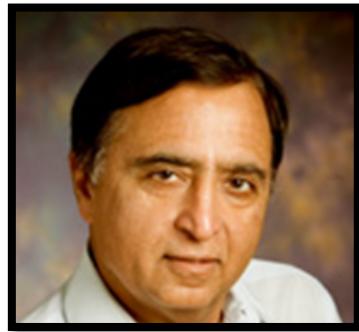
- Comments or questions?



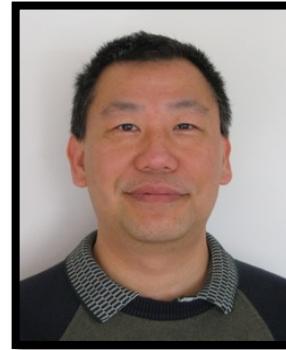
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