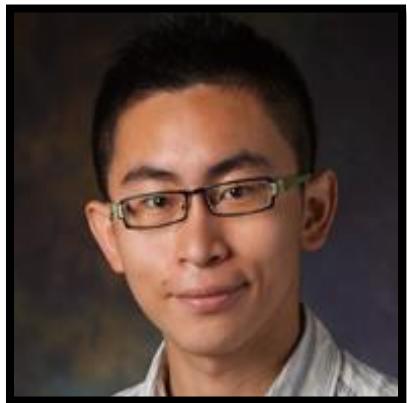
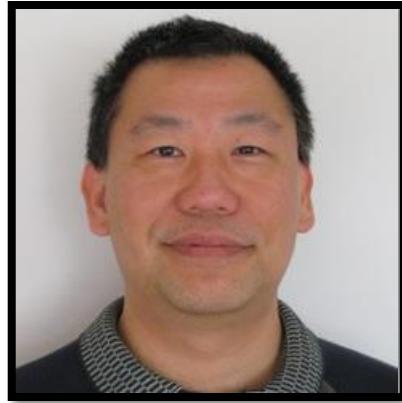


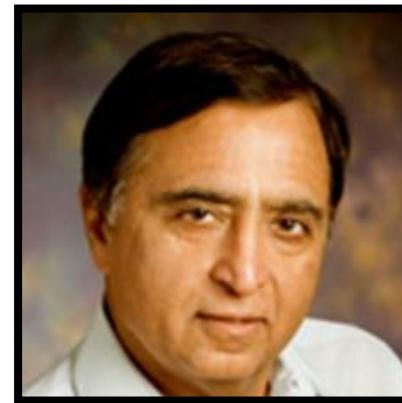
# Image Completion using Planar Structure Guidance



Jia-Bin Huang



Sing Bing Kang



Narendra Ahuja



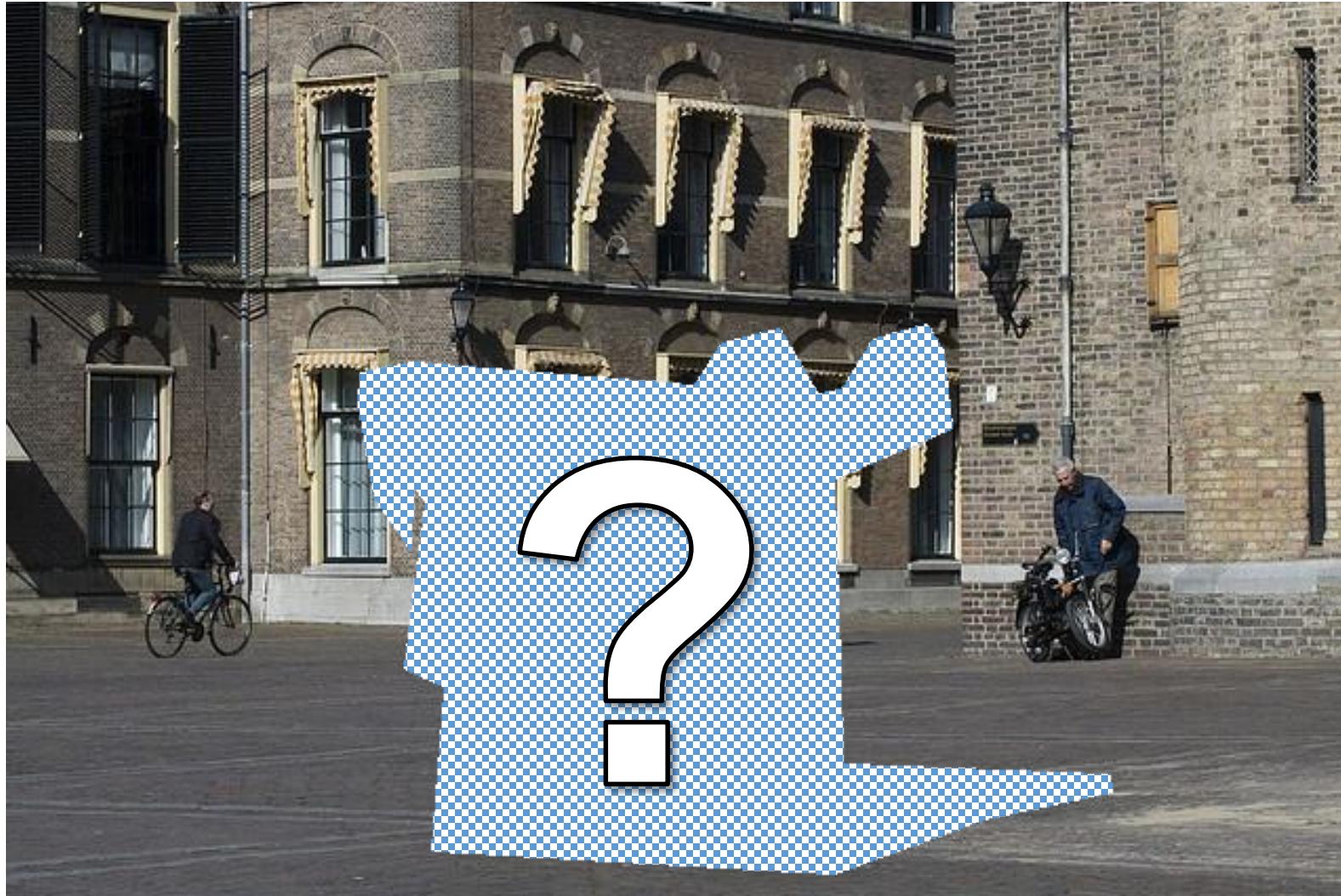
Johannes Kopf

# The image completion problem



Credit: ©Flickr user  
remonrijper

# The image completion problem



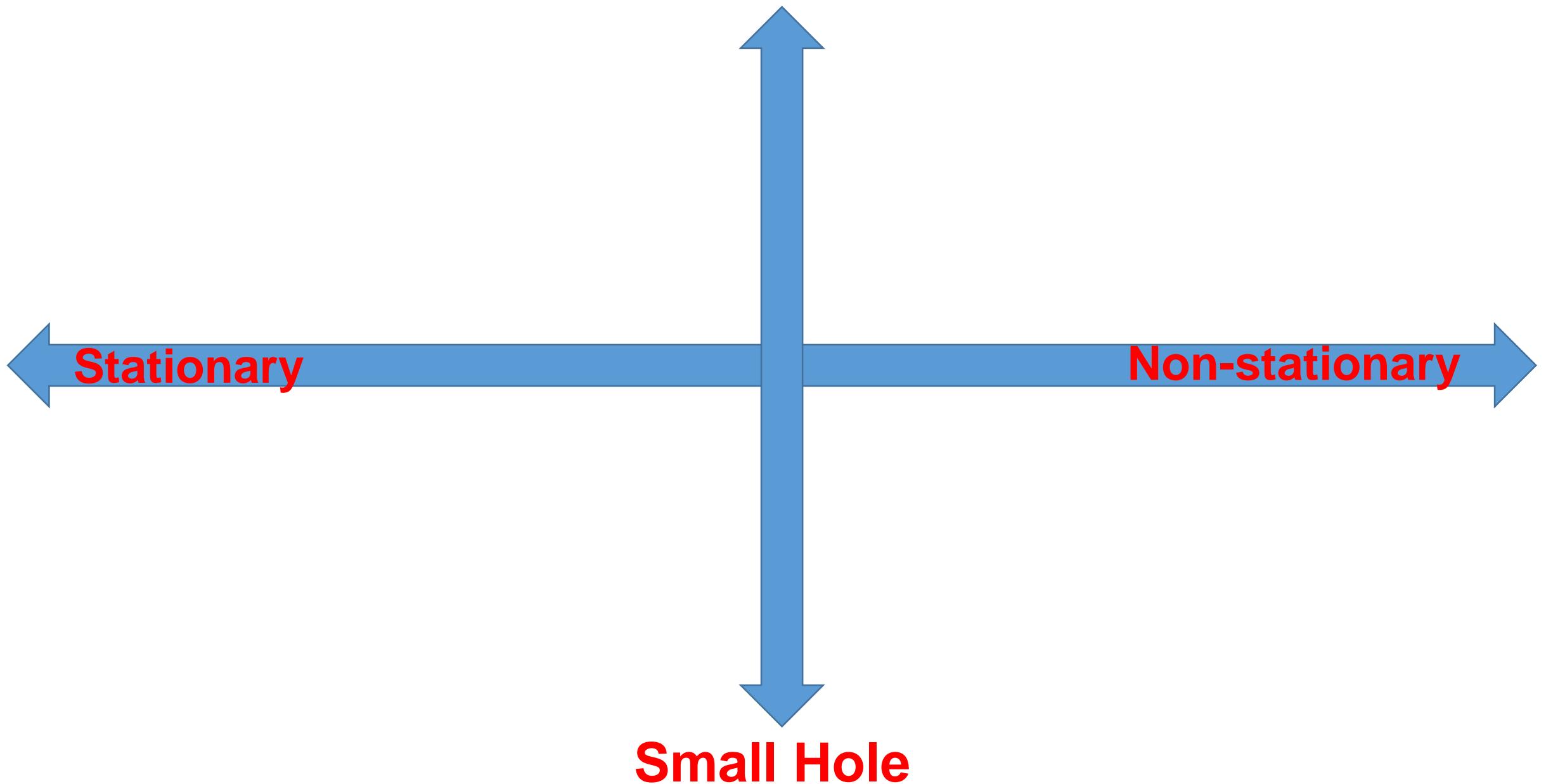
Credit: ©Flickr user  
remonrijper

# The image completion problem



Credit: ©Flickr user  
remonrijper

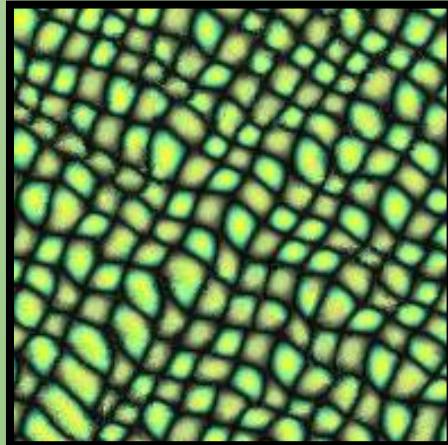
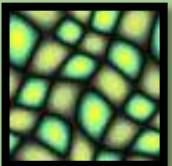
**Large Hole**



**Large Hole**

Texture Synthesis

**Stationary**



**Small Hole**

**Non-stationary**

# Large Hole

Texture Synthesis

Stationary

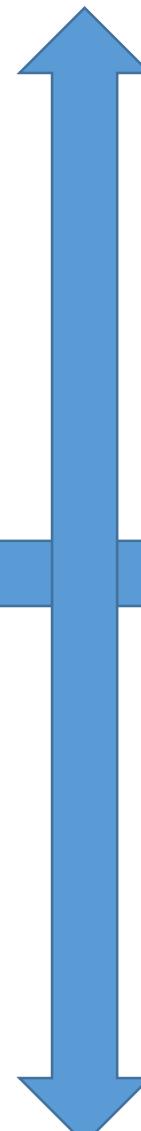
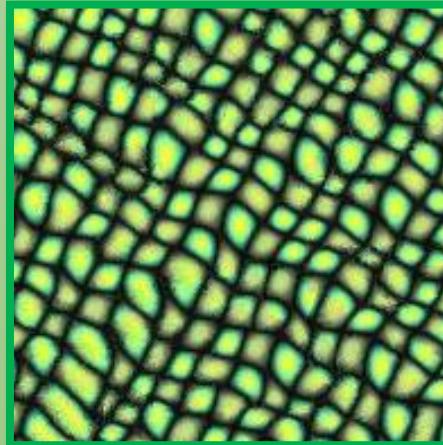
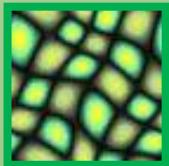


Image Inpainting



Small Hole

# Large Hole

Texture Synthesis

Stationary

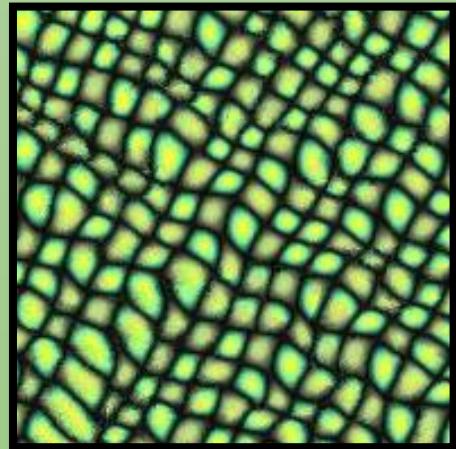
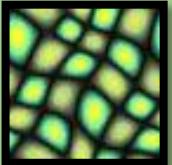
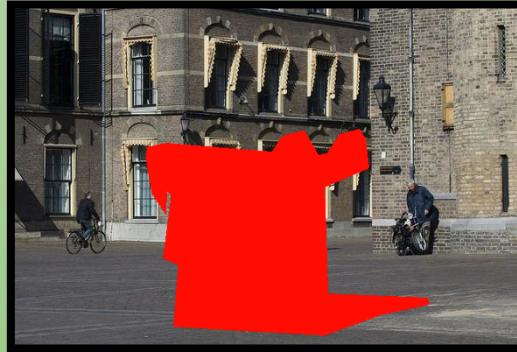
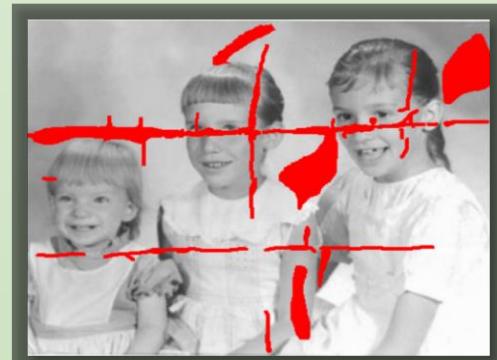


Image Completion



Non-stationary

Image Inpainting



Small Hole



# Input Image

Credit: ©Flickr user  
remonrijper



Region to fill



Photoshop Content Aware Fill  
[Wexler et al. 2007] [Barnes et al. 2009]



Statistics of Patch Offsets      Translational patches  
[He and Sun ECCV 2012]      are not sufficient!



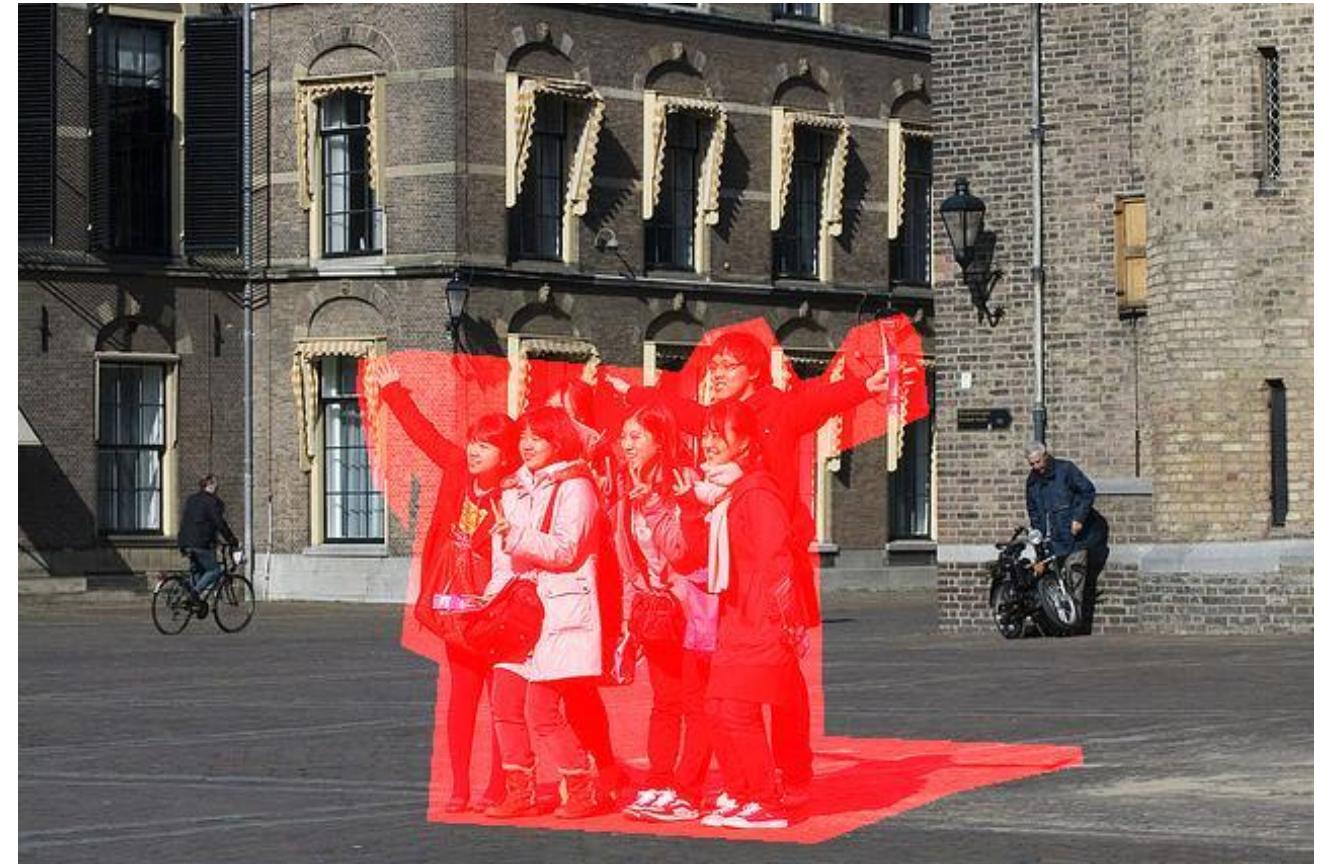
Image Melding    Searching patch transformation  
[Darabi et al. 2012] space is HARD!



Our Result

We use mid-level  
information

- Based on non-parametric framework of [Wexler et al. 2007]



- Based on non-parametric framework of [Wexler et al. 2007]
- The basic form

$$\min_{\{\mathbf{t}_i, \mathbf{s}_i\}} \sum E_{\text{color}}(\mathbf{t}_i, \mathbf{s}_i)$$



- Based on non-parametric framework of [Wexler et al. 2007]

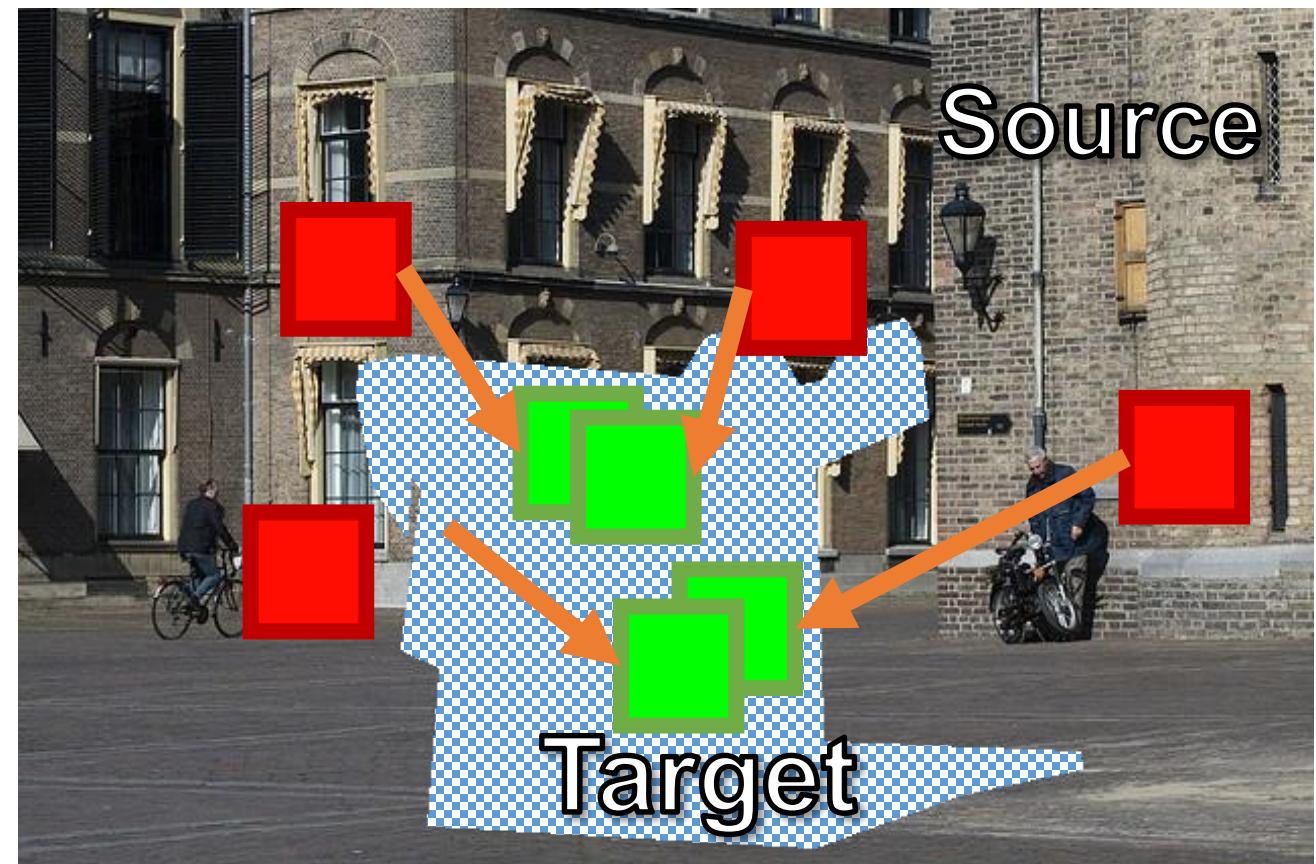
- The basic form

$$\min_{\{\mathbf{t}_i, \mathbf{s}_i\}} \sum E_{color}(\mathbf{t}_i, \mathbf{s}_i)$$

- Patch matching cost

$$E_{color}(\mathbf{t}_i, \mathbf{s}_i) = || \boxed{\text{green patch}} - \boxed{\text{red patch}} ||_1$$

- PatchMatch [Barnes et al. 2009] for efficient nearest neighbor field search.



- Low-level processing is not sufficient

$$\min_{\{t_i, s_i\}} \sum E_{color}(t_i, s_i)$$



- Low-level processing is not sufficient
- Idea: guide the completion using **mid-level** information!

$$\min_{\{\mathbf{t}_i, \mathbf{s}_i\}} \sum E_{color}(\mathbf{t}_i, \mathbf{s}_i) + E_{guide}(\mathbf{t}_i, \mathbf{s}_i)$$

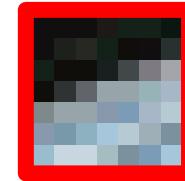


- Low-level processing is not sufficient
- Idea: guide the completion using **mid-level** information!
- Transformation of source patches



- Low-level processing is not sufficient
- Idea: guide the completion using **mid-level** information!
- Transformation of source patches

- *Translational*  
(Photoshop CAF)

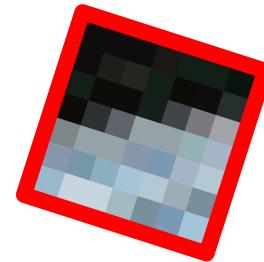


- Low-level processing is not sufficient
- Idea: guide the completion using **mid-level** information!
- Transformation of source patches

- *Translational*  
(Photoshop CAF)



- *Rotation and scale*  
(Image Melding)



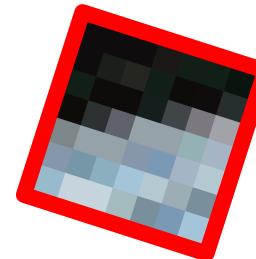
Our Result

- Low-level processing is not sufficient
- Idea: guide the completion using **mid-level** information!
- Transformation of source patches

- *Translational*  
(Photoshop CAF)



- *Rotation and scale*  
(Image Melding)



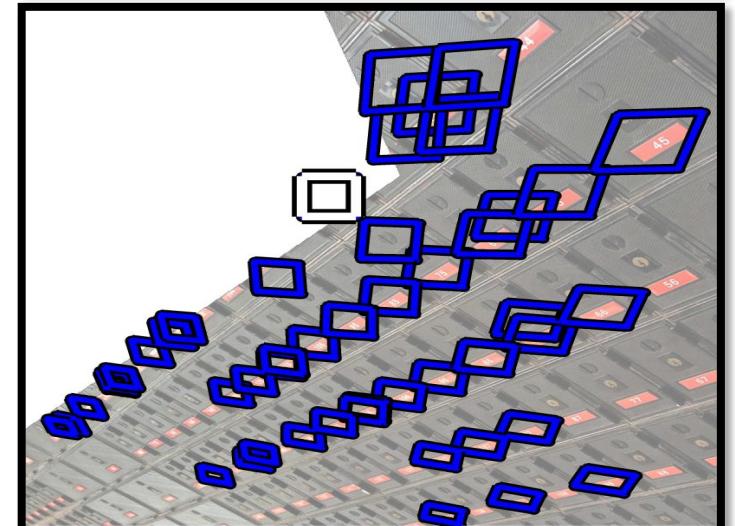
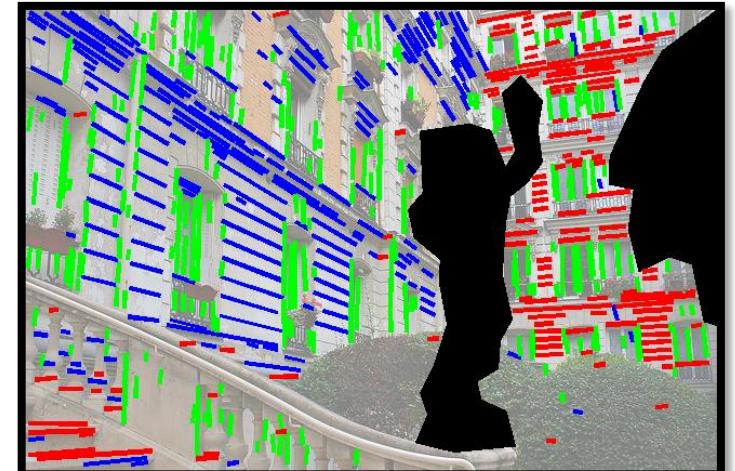
- *Projective transform*  
(Ours)



Our Result

# Mid-Level cues for guidance

- Planes:  
Cues for **how to deform** patches
- Regularity:  
Cues for **where to sample** patches



# Mid-level cues – planes

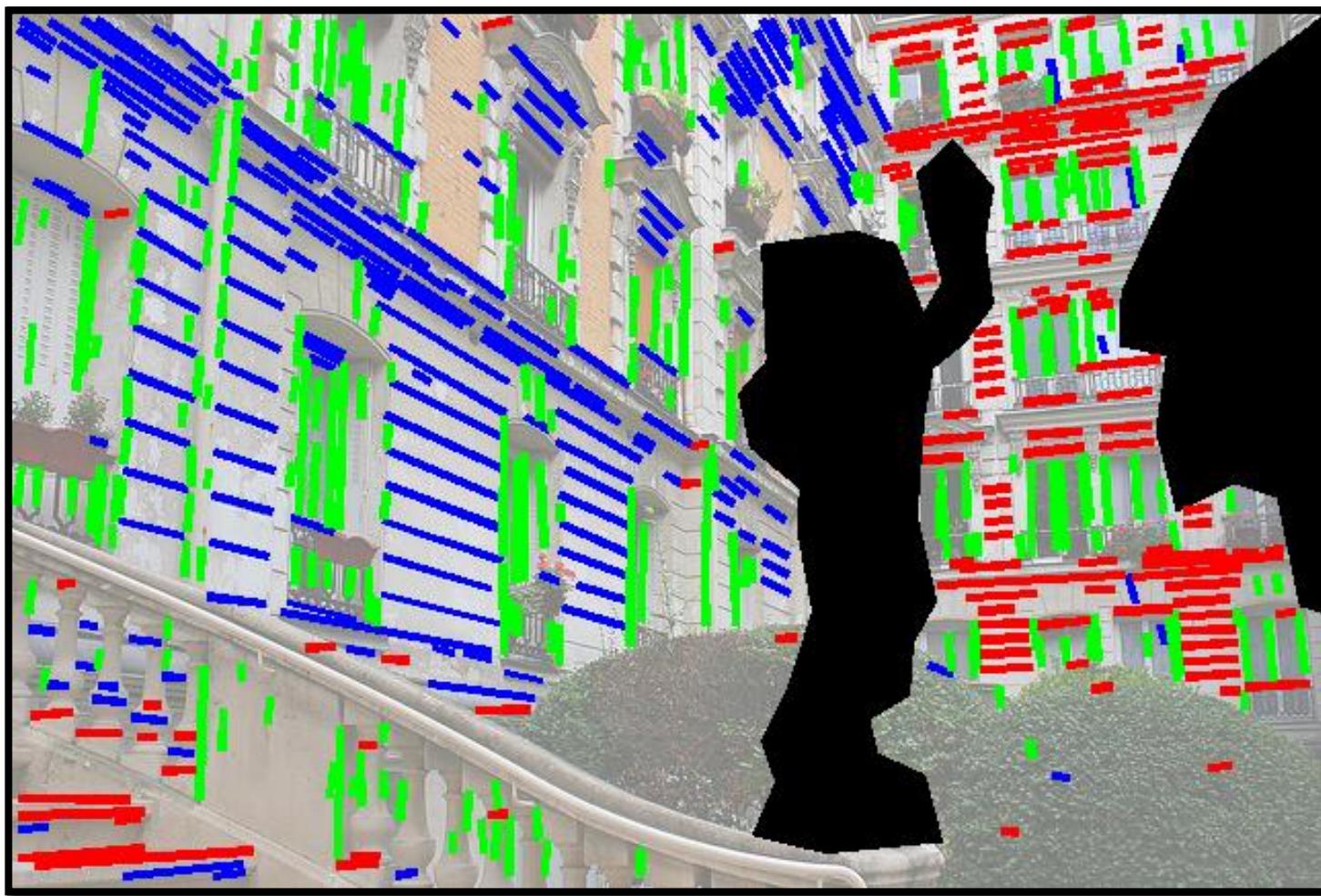


Credit: ©Flickr user  
micromegas

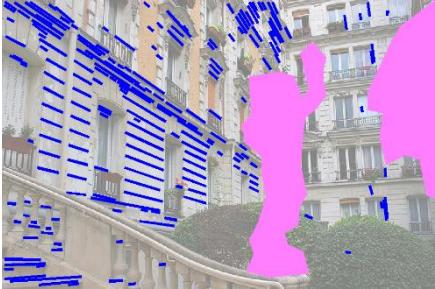
# Plane detection – vanishing point detection



# Plane detection – vanishing point detection

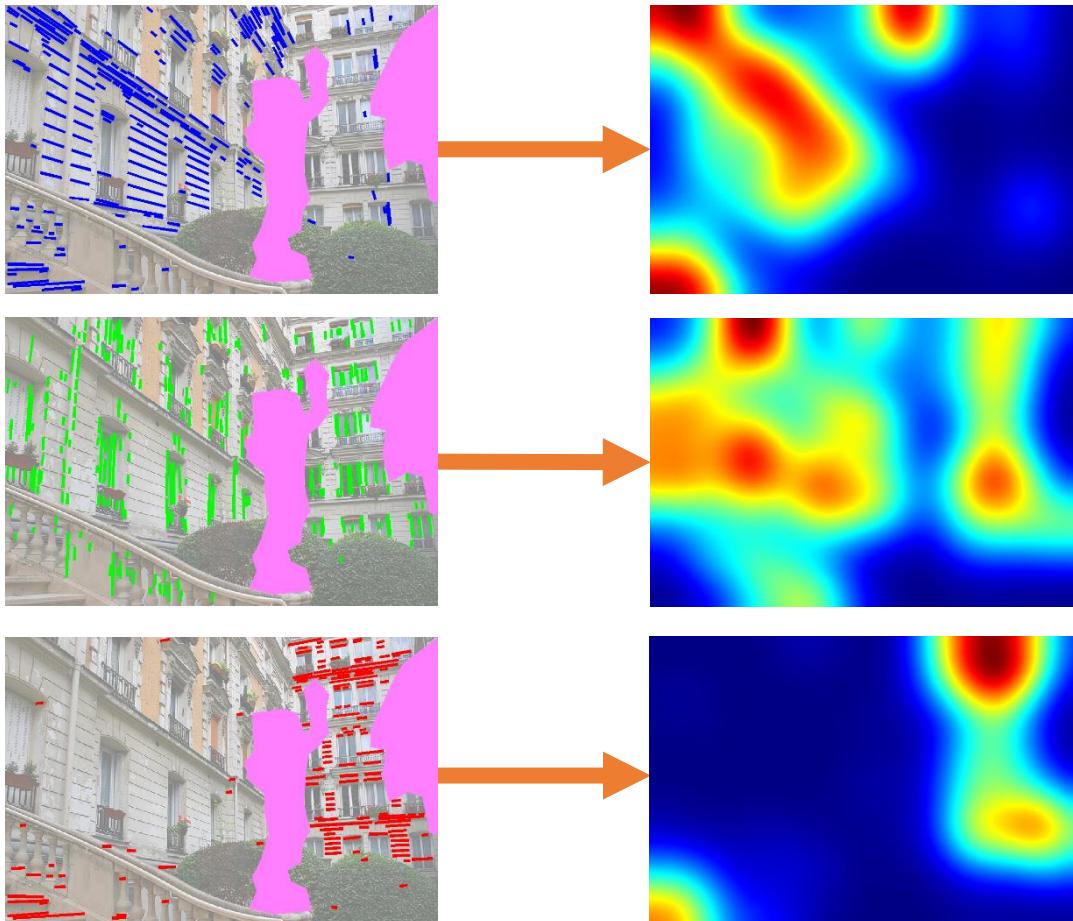


# Plane detection – localization



Support lines for VPs

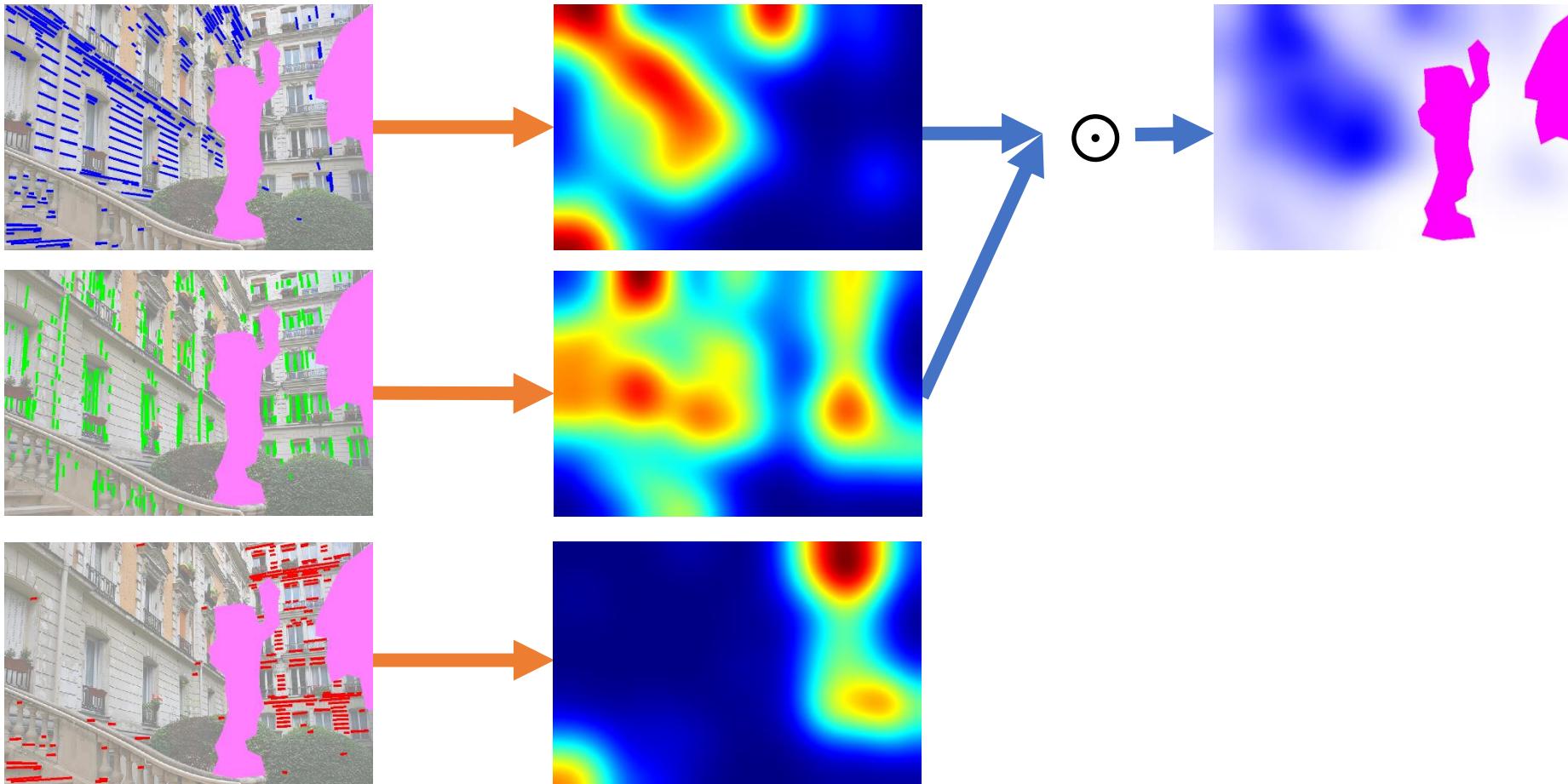
# Plane detection – localization



Support lines for VPs

Support line density

# Plane detection – localization

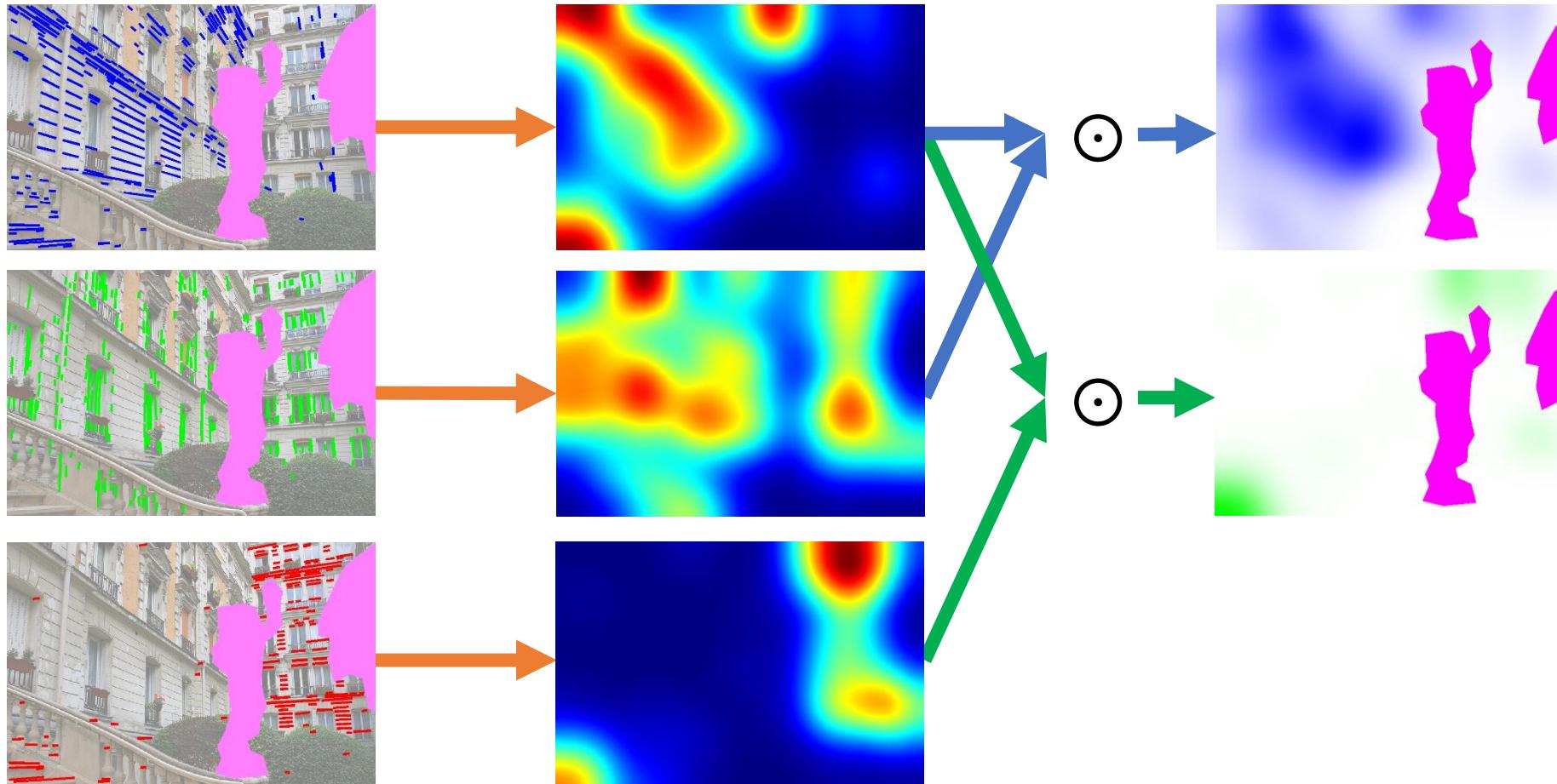


Support lines for VPs

Support line density

Plane location density

# Plane detection – localization

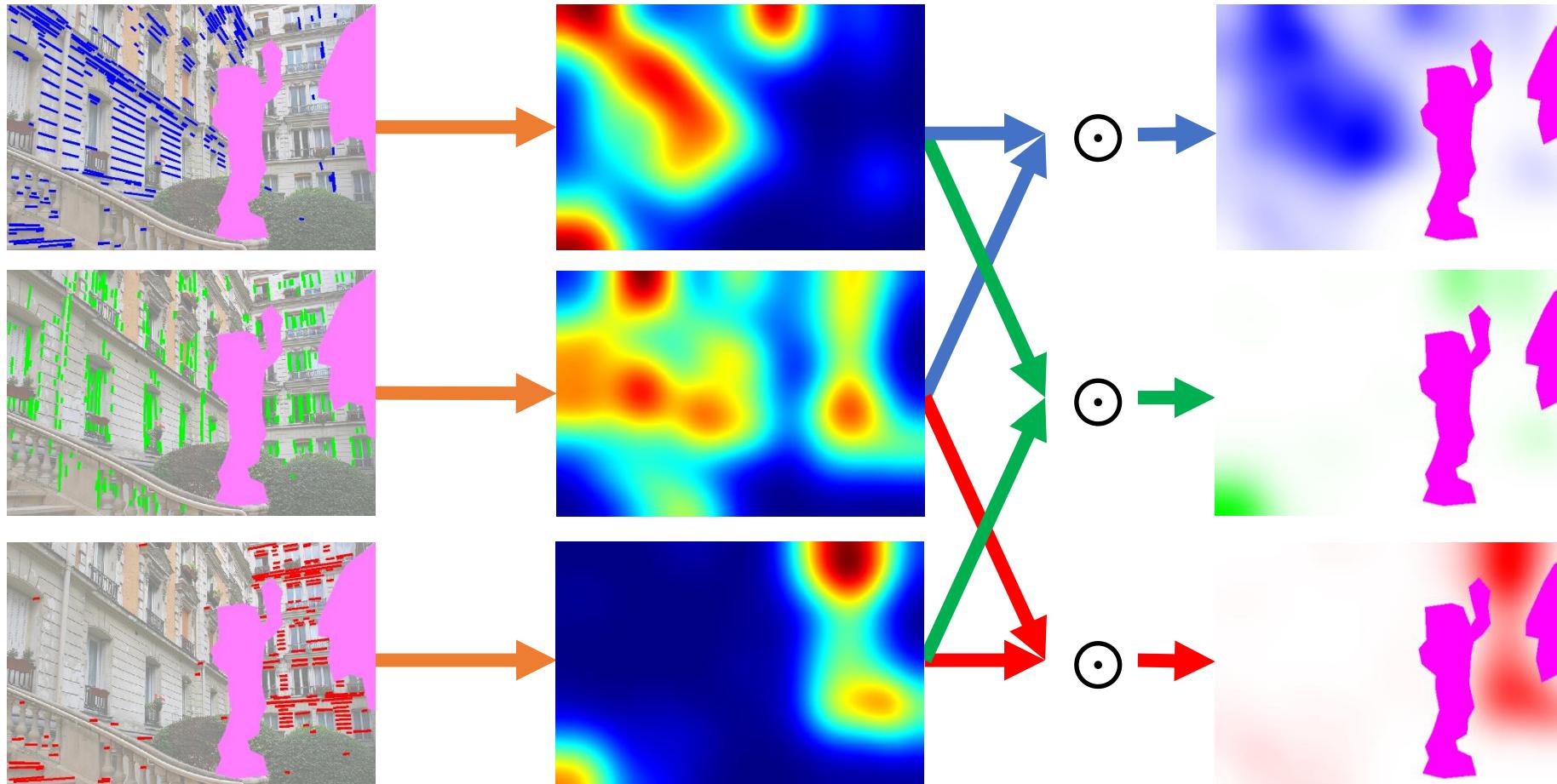


Support lines for VPs

Support line density

Plane location density

# Plane detection – localization

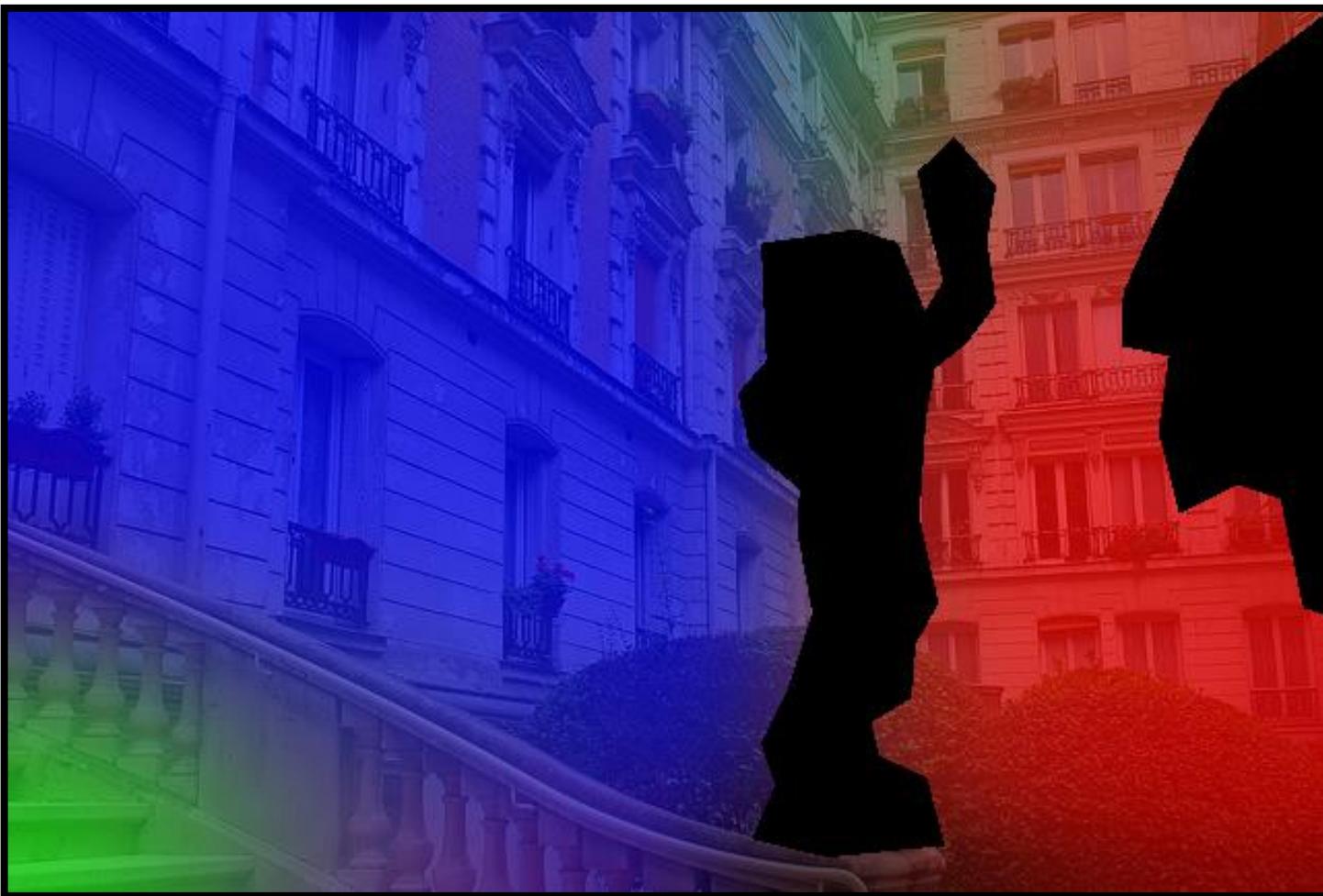


Support lines for VPs

Support line density

Plane location density

# Plane detection – posterior probability





Our Result



Photoshop Content Aware Fill



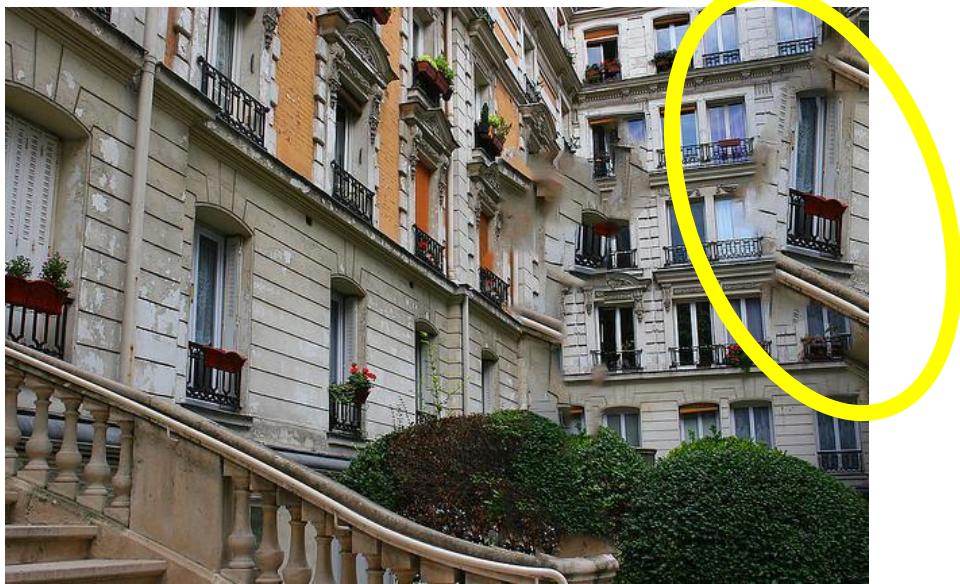
Image Melding



Statistics of Patch Offsets



Our Result



Photoshop Content Aware Fill



Image Melding



Statistics of Patch Offsets



Our Result



# Input and Hole

Credit: ©Flickr user  
theenmoy



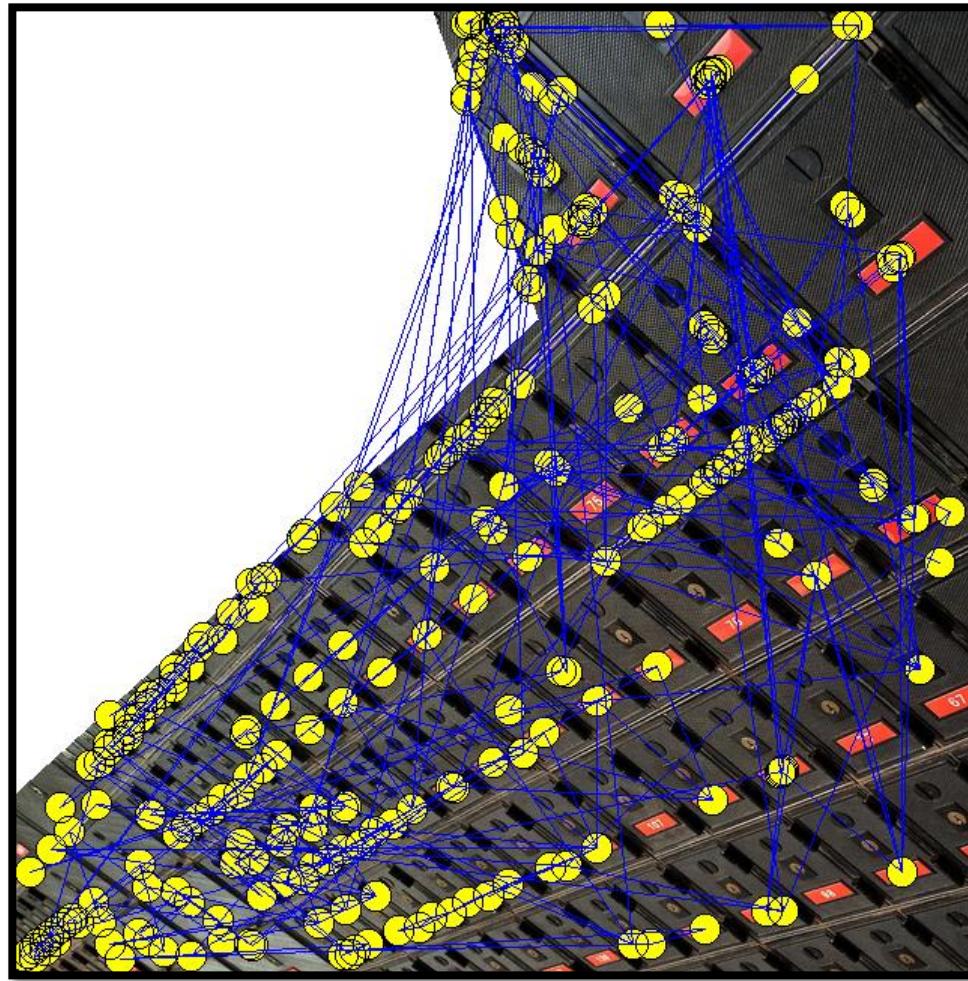
# Need regularity guidance!

# Our Result (with planar guidance only)

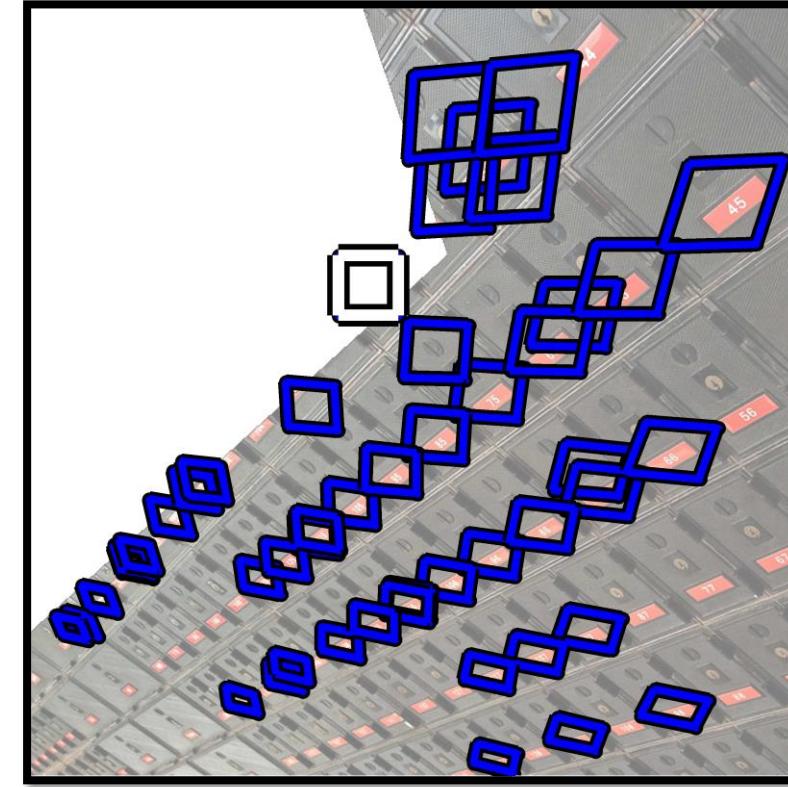
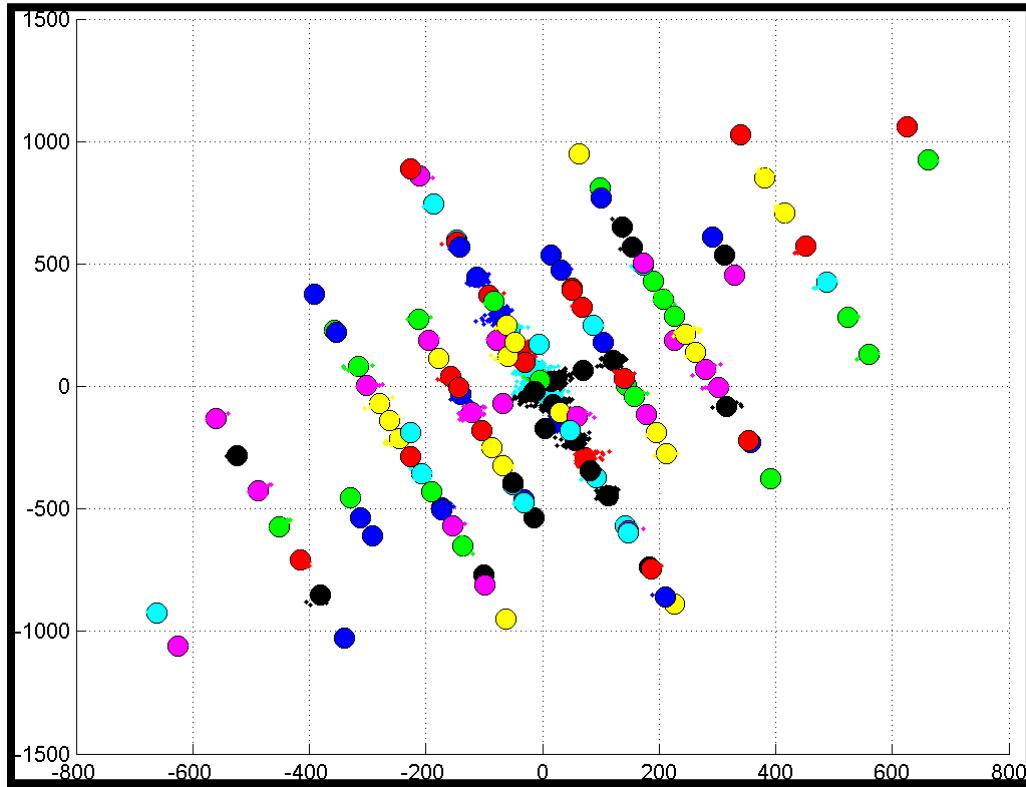
# Extracting mid-level cues - regularity detection



# Regularity detection – feature detection and matching

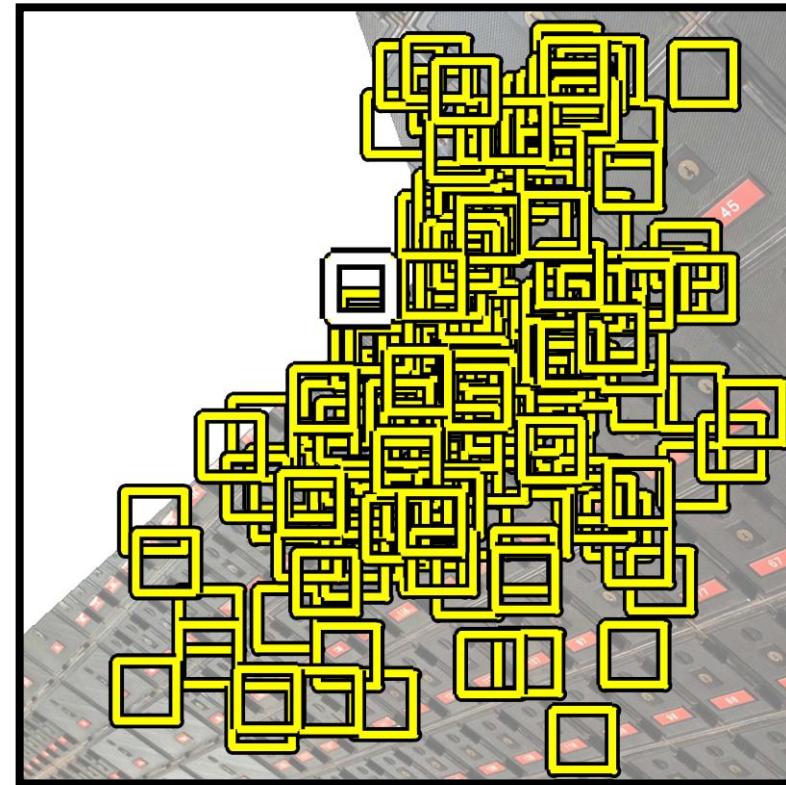
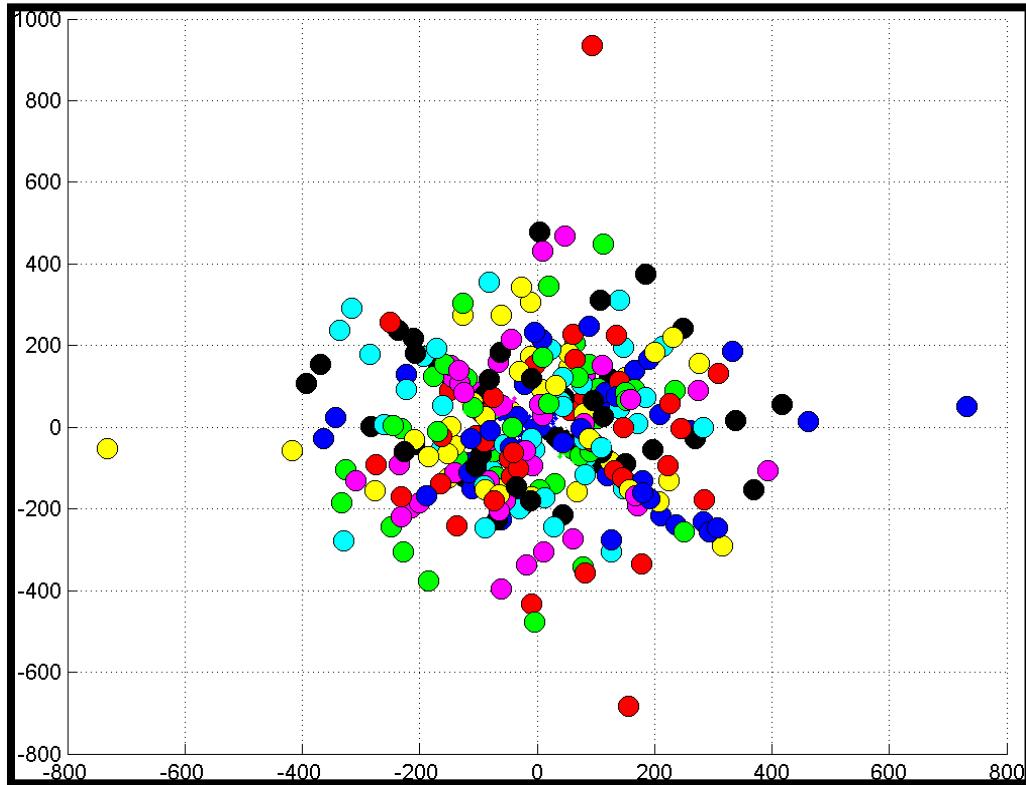


# Regularity detection – mode detection



- For fronto-parallel scenes, similar to [He and Sun ECCV 2012]
- Can handle perspectively distorted planes and multiple surfaces

# Regularity detection without rectification





# With planar guidance only



# Plane and regularity

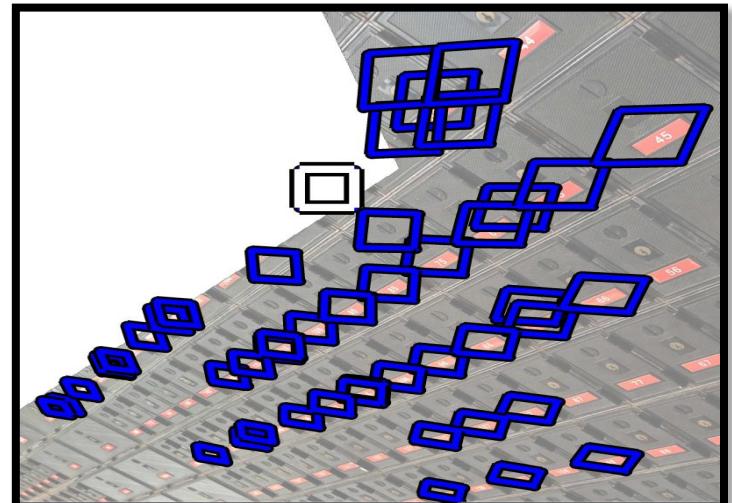
# Guided sampling and propagation

- Slight modification of PatchMatch algorithm
- Plane guided sampling and propagation
  - Draw a plane index based on posterior probability
  - Draw random samples using rejection-based sampling



# Guided sampling and propagation

- Slight modification of PatchMatch algorithm
- Plane guided sampling and propagation
  - Draw a plane index based on posterior probability
  - Draw random samples using rejection-based sampling
- Regularity guided sampling
  - Randomly draw a offset vector in rectified space

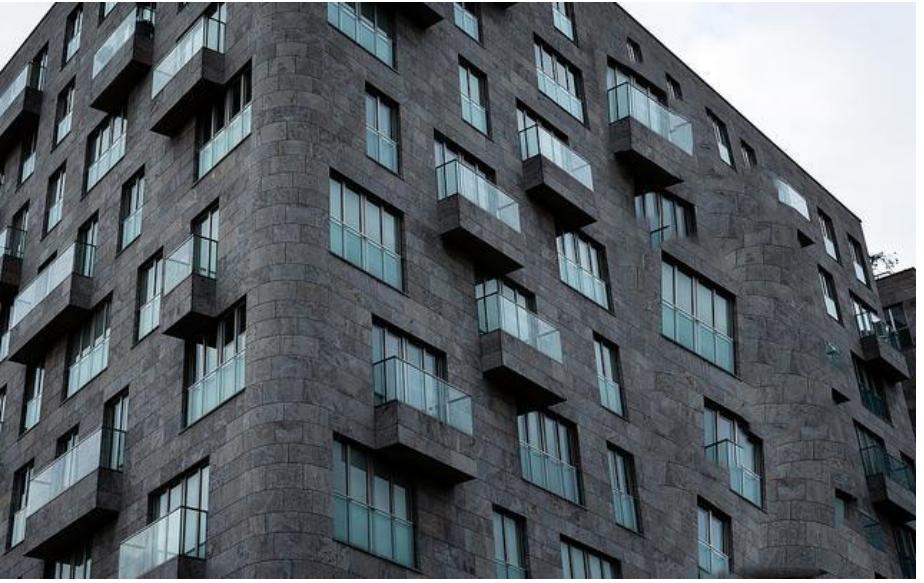


# Results



# Input and Hole

Credit: ©Flickr user  
danielfoster



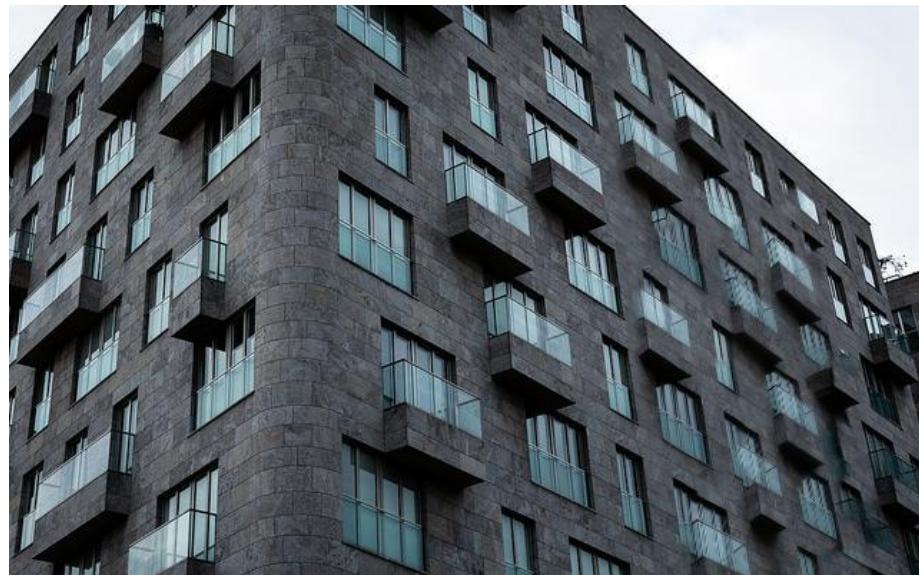
Photoshop Content Aware Fill



Image Melding



Statistics of Patch Offsets

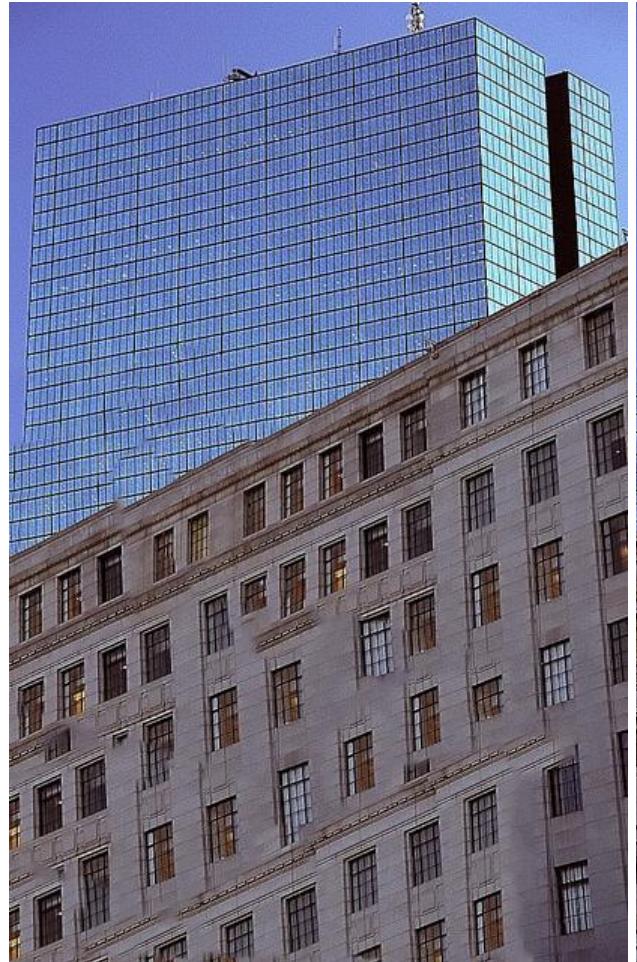


Our Result

# Input and hole

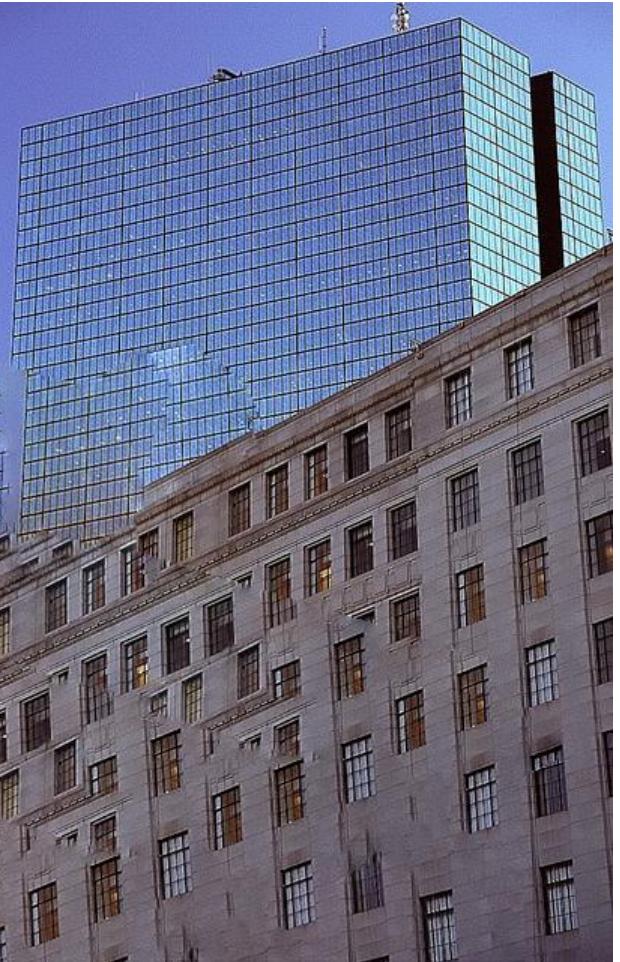


Credit: ©Flickr user  
the-o



Photoshop CAF

[Wexler et al. 2007]  
[Barnes et al. 2009]



Statistics of Patch Offsets

[He and Sun 2012]

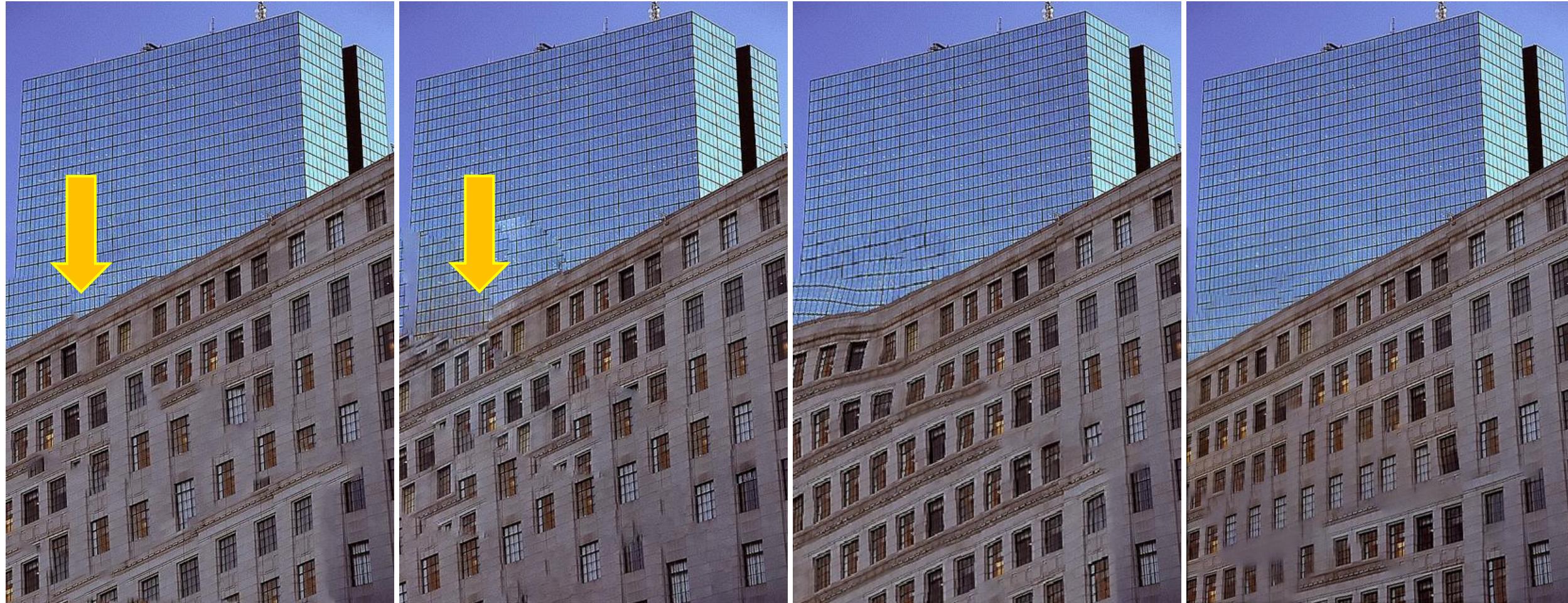


Image Melding

[Darabi et al. 2012]



Our Result



Photoshop CAF

[Wexler et al. 2007]  
[Barnes et al. 2009]

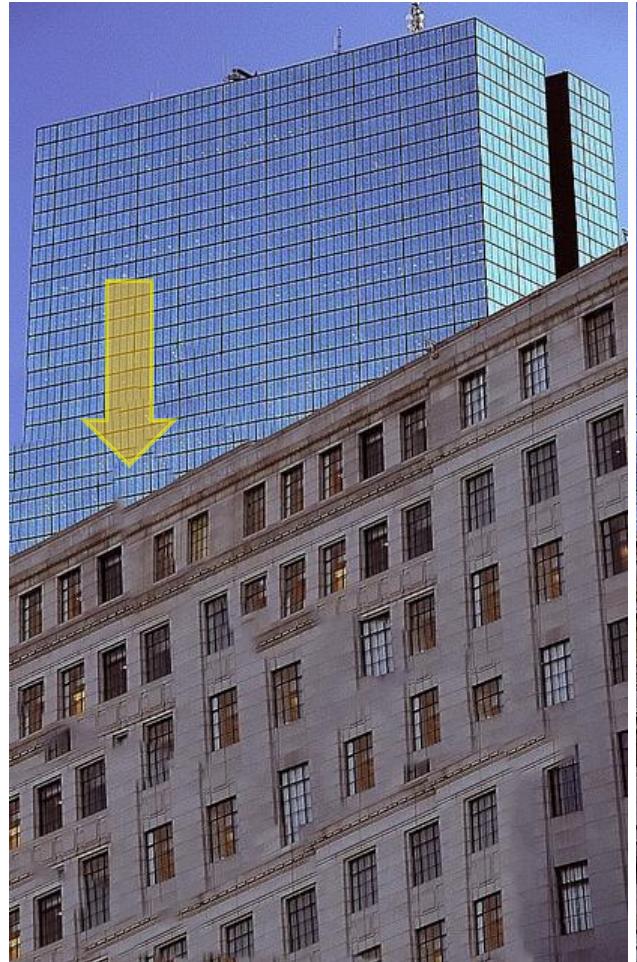
Statistics of Patch Offsets

[He and Sun 2012]

Image Melding

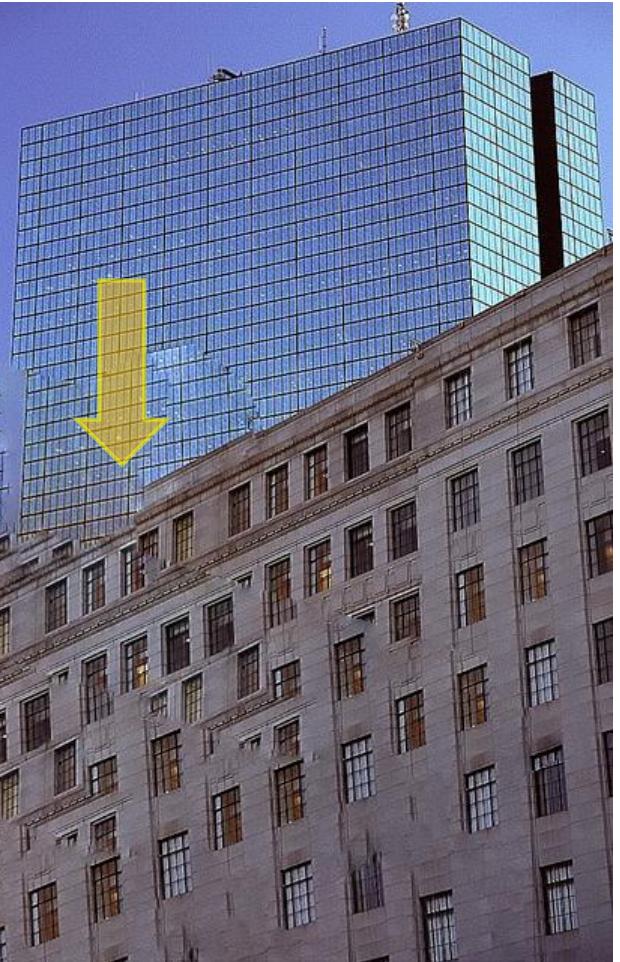
[Darabi et al. 2012]

Our Result



Photoshop CAF

[Wexler et al. 2007]  
[Barnes et al. 2009]



Statistics of Patch Offsets

[He and Sun 2012]

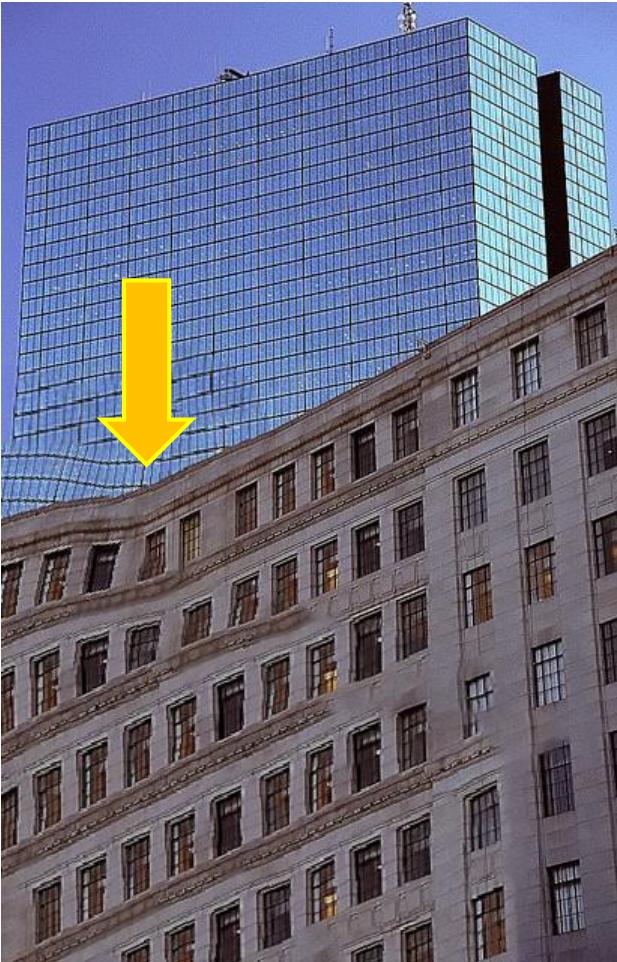


Image Melding

[Darabi et al. 2012]



Our Result



# Input and Hole

Credit: ©Flickr user  
chrisschoenbohm



Photoshop Content Aware Fill



Image Melding



Statistics of Patch Offsets



Our Result



# Input and Hole

Credit: ©Flickr user  
99667320@N06



Photoshop Content Aware Fill



Image Melding



Statistics of Patch Offsets

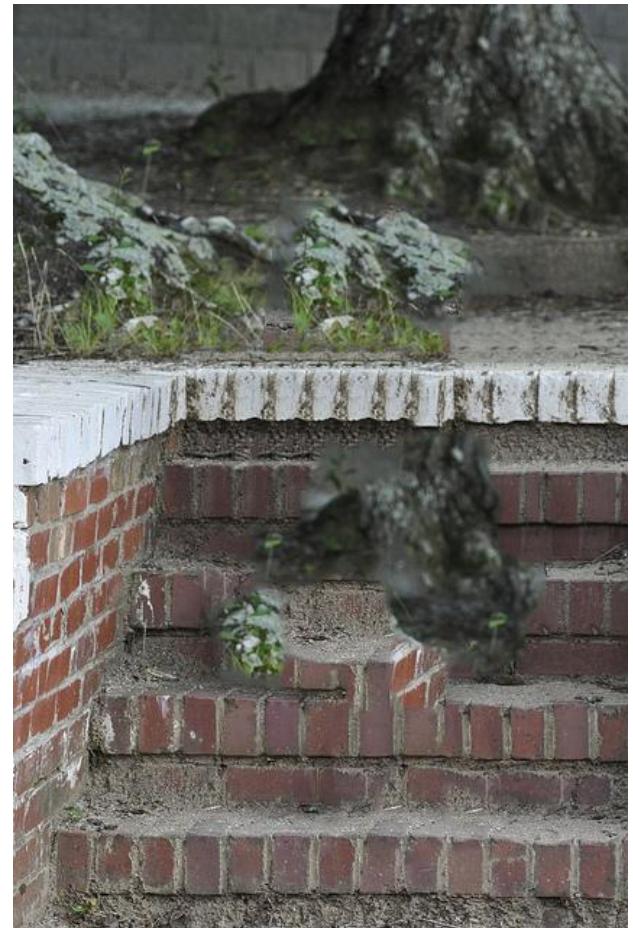


Our Result

Input and hole



Credit: ©Flickr user  
sunshinepictures



Photoshop CAF

[Wexler et al. 2007]  
[Barnes et al. 2009]



Statistics of Patch Offsets

[He and Sun 2012]



Image Melding

[Darabi et al. 2012]



Our Result

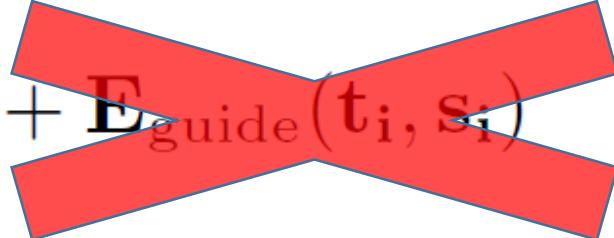
# What if there are no structures?

- Reduces to baseline image completion algorithms which use translational patches (same as Photoshop content-aware fill)

$$\min_{\{t_i, s_i\}} \sum E_{color}(t_i, s_i) + E_{guide}(t_i, s_i)$$

# What if there are no structures?

- Reduces to baseline image completion algorithms which use translational patches (same as Photoshop content-aware fill)

$$\min_{\{t_i, s_i\}} \sum E_{color}(t_i, s_i) + E_{guide}(t_i, s_i)$$


- Works well with man-made scenes
- *Backward-compatible* with natural scenes
- Tested on 25 natural images from [Kopf et al. 2012]



Input and Mask



Completion



Input and Mask



Completion



Input and Mask

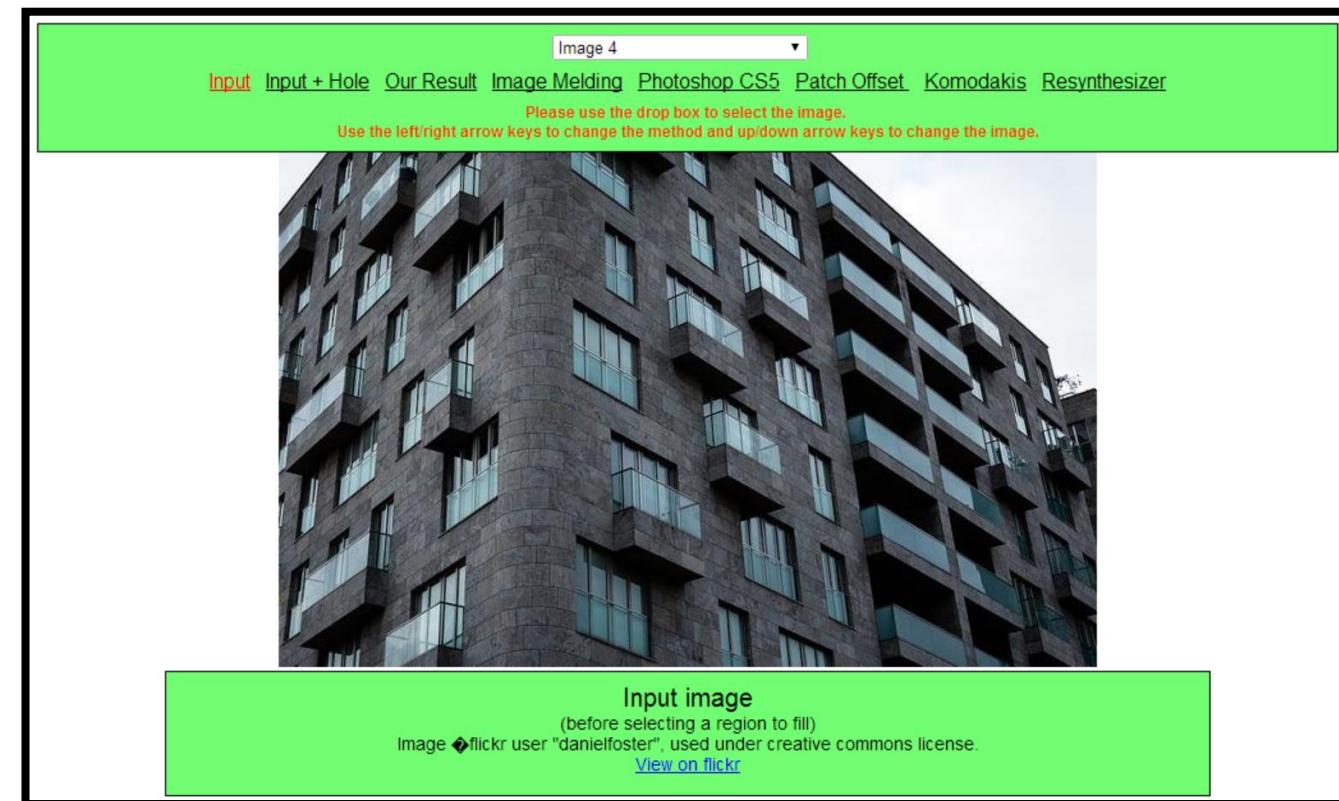


Completion

# Check out our project website!

- <http://bit.ly/planarcompletion>

- Full comparison of 110 images
  - 85 urban scenes + 25 natural
- Code will be released soon!



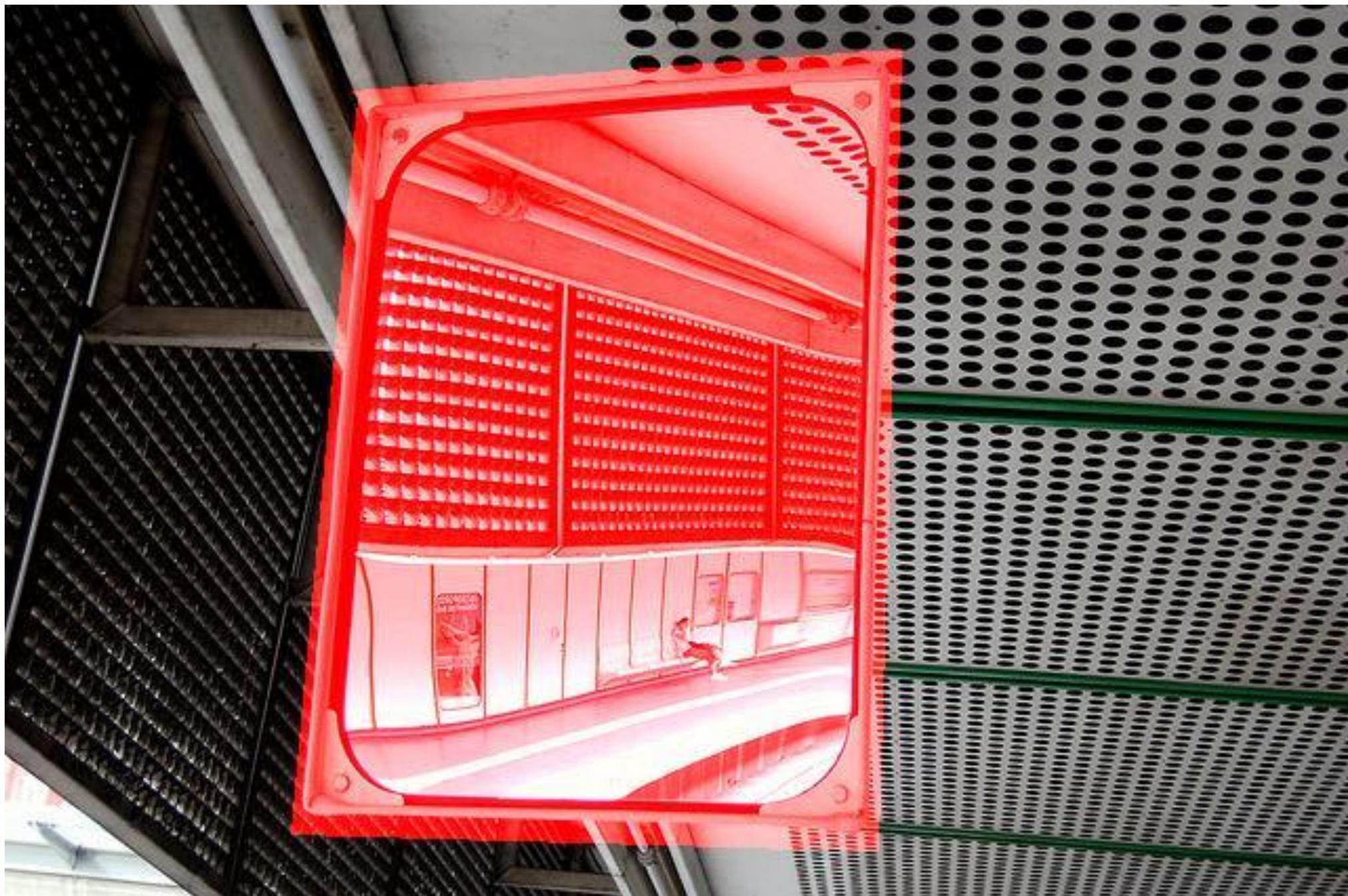
# Failure modes

- Difficult to find correct demarcation lines (boundary between regions)
  - Need higher-level information
- Missed, false, or inaccurate detection of plane parameters or regularity
  - Computer vision algorithms are not perfect

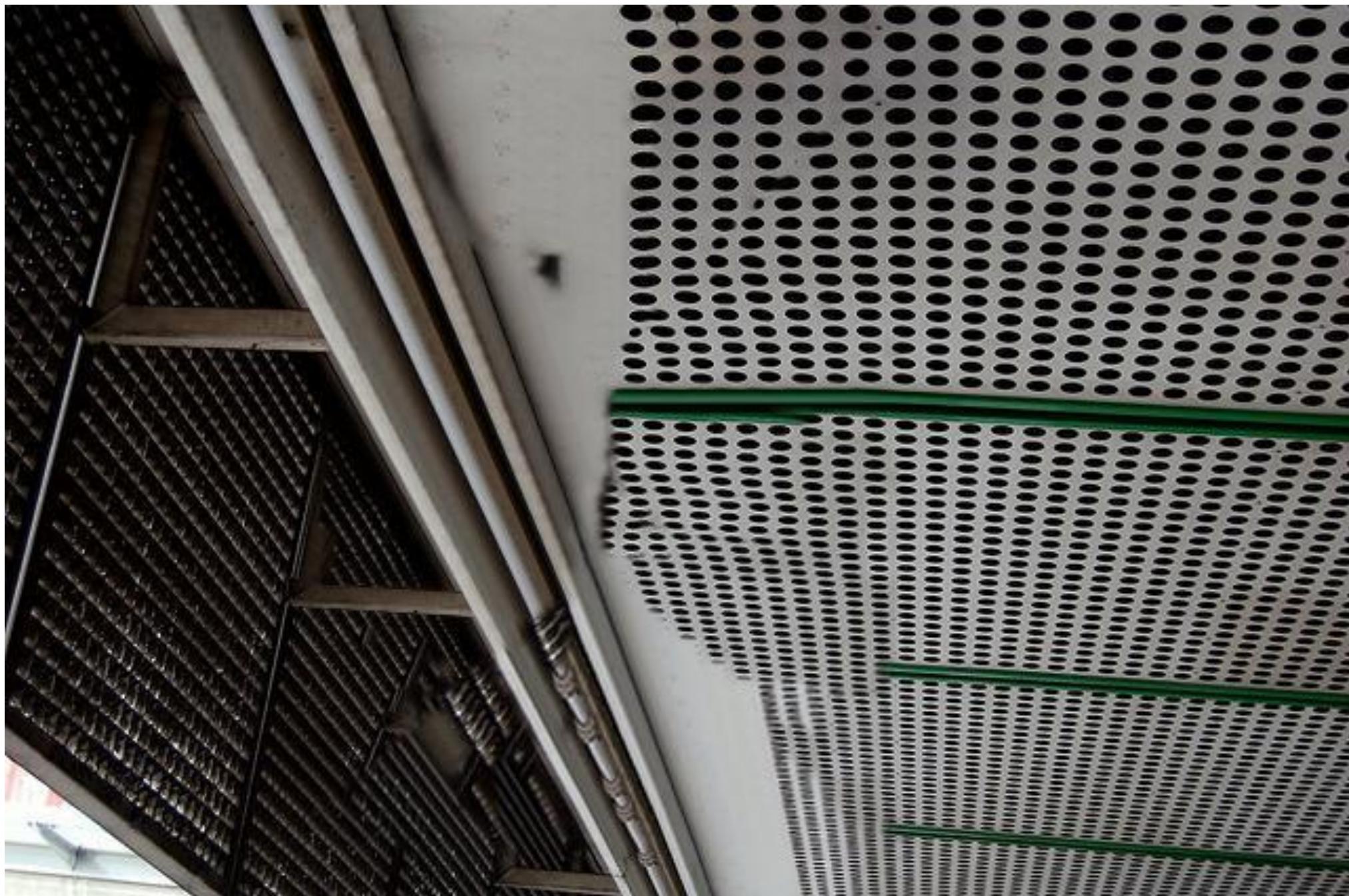


Input

Credit: ©Flickr user  
loungerie



Mask



Our result



Photoshop



Statistics of Patch Offset

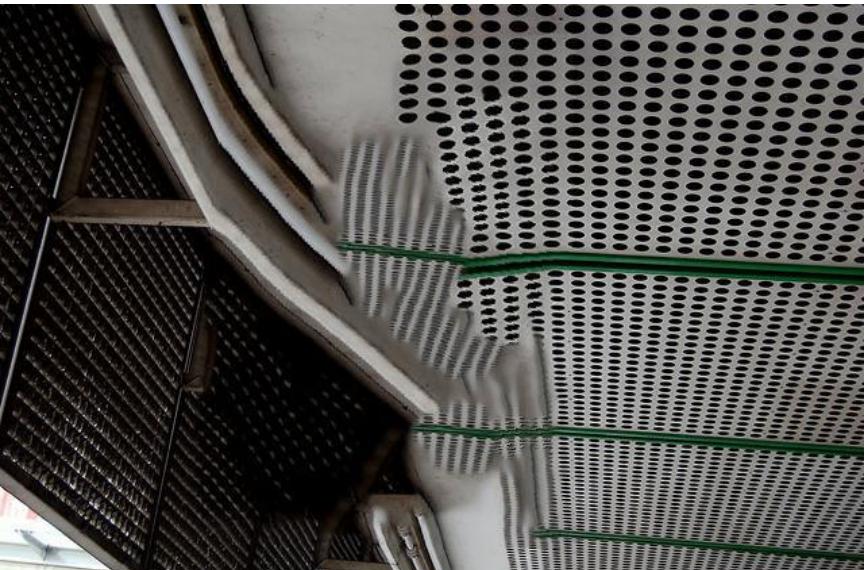
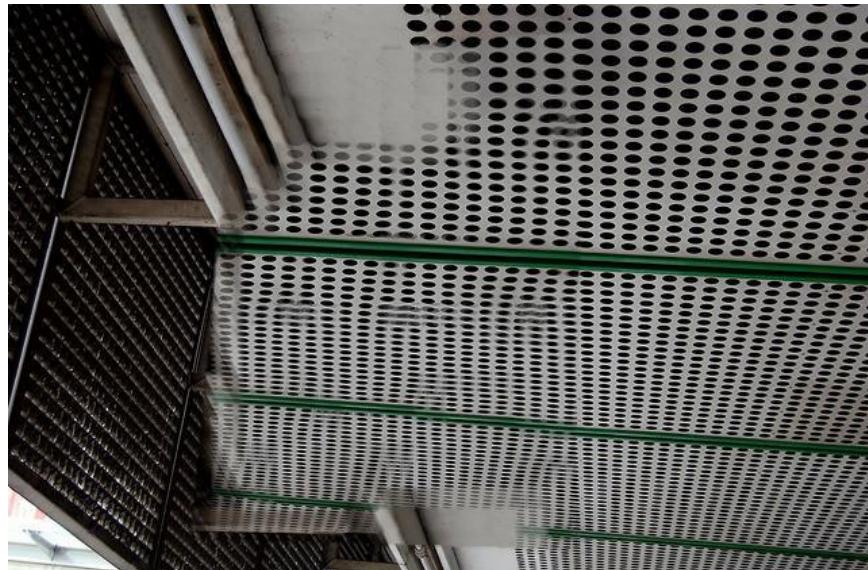


Image Melding



Priority BP

# Input



Credit: ©Flickr user  
addictive\_picasso

Mask





Our result



Photoshop CAF

[Wexler et al. 2007]  
[Barnes et al. 2009]



Statistics of Patch Offset  
[He and Sun 2012]



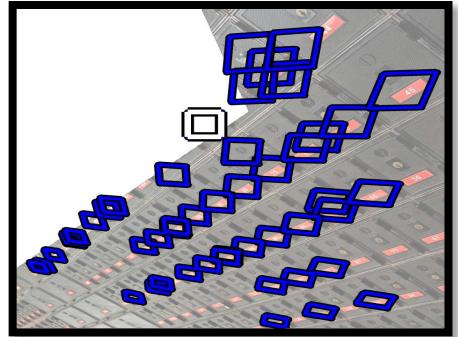
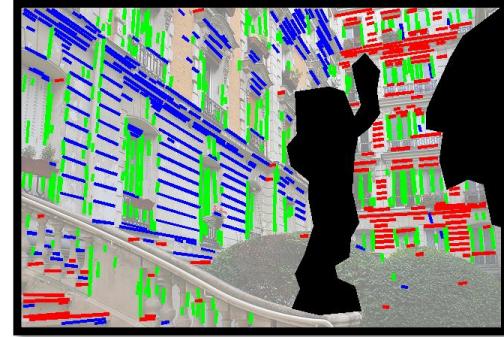
Image Melding  
[Darabi et al. 2012]

# Conclusions

- Mid-level constraints for the win!

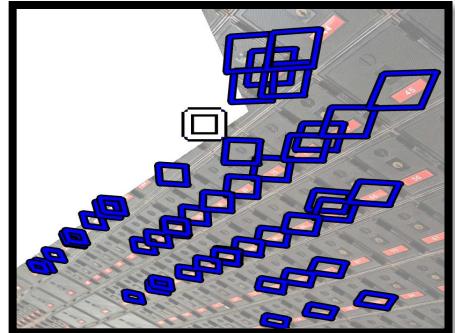
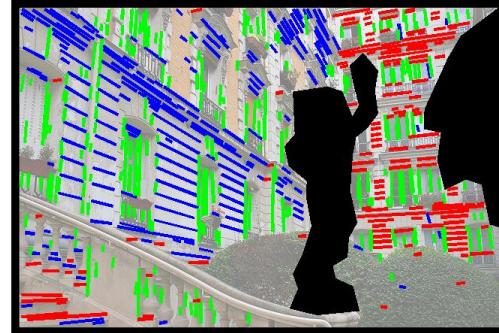
# Conclusions

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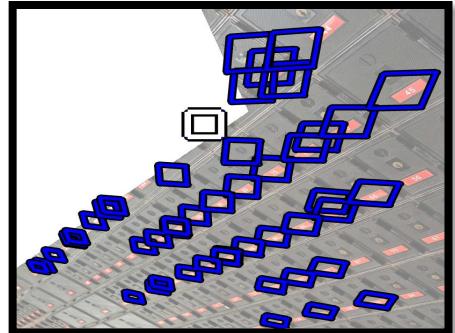
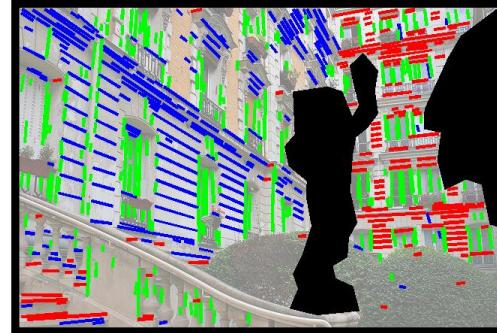
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# Conclusions

- Mid-level constraints for the win!
  - Our work: planes and regularity
- Great for man-made scenes
- Backward-compatible with natural scenes





# Thank You!