Hierarchical Diffusion Curves for Accurate Automatic Image Vectorization

Guofu Xie[1,3] Xin Sun[2] Xin Tong[2] Derek Nowrouzezahrai[1]

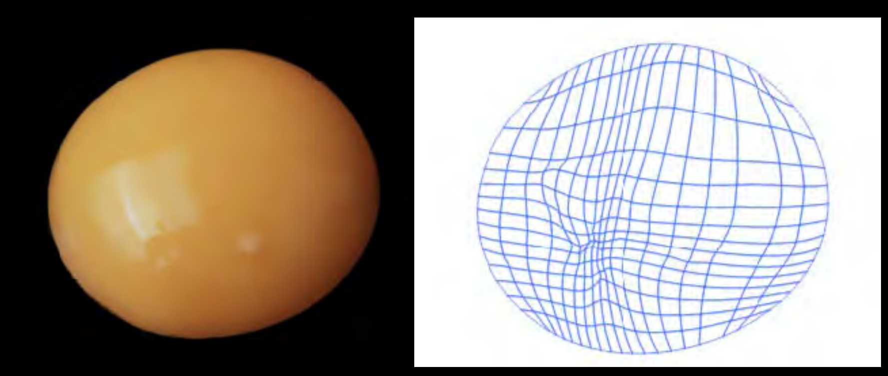
[1]University of Montreal

[2]Microsoft Research

[3]State Key Laboratory of Computer Sciences, ISCAS

Image Vectorization

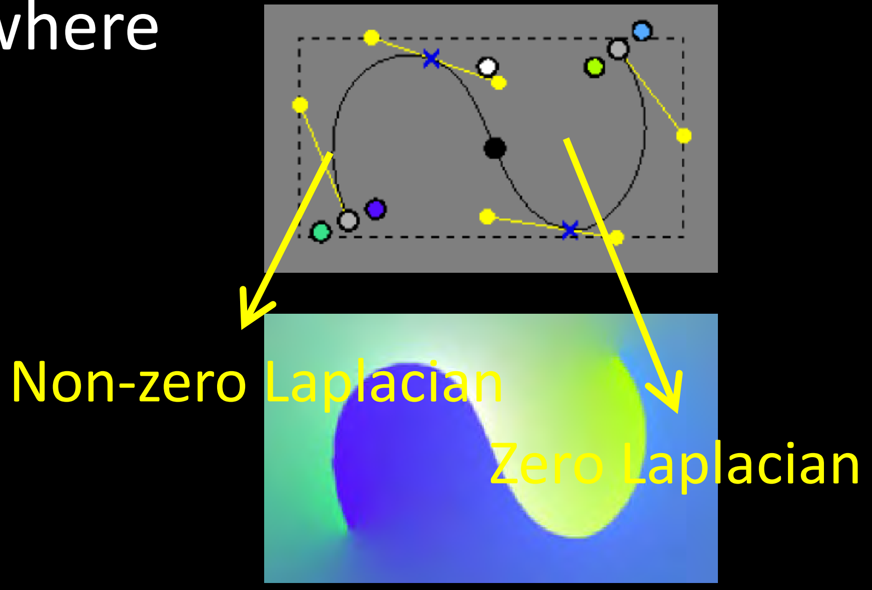
- Convert a raster image into a vector graphics
  - Vector primitives: points, curves, meshes
  - Compact, resolution-independent



Input and vector primitives [Sun et al. 07;Orzan et al. 08]

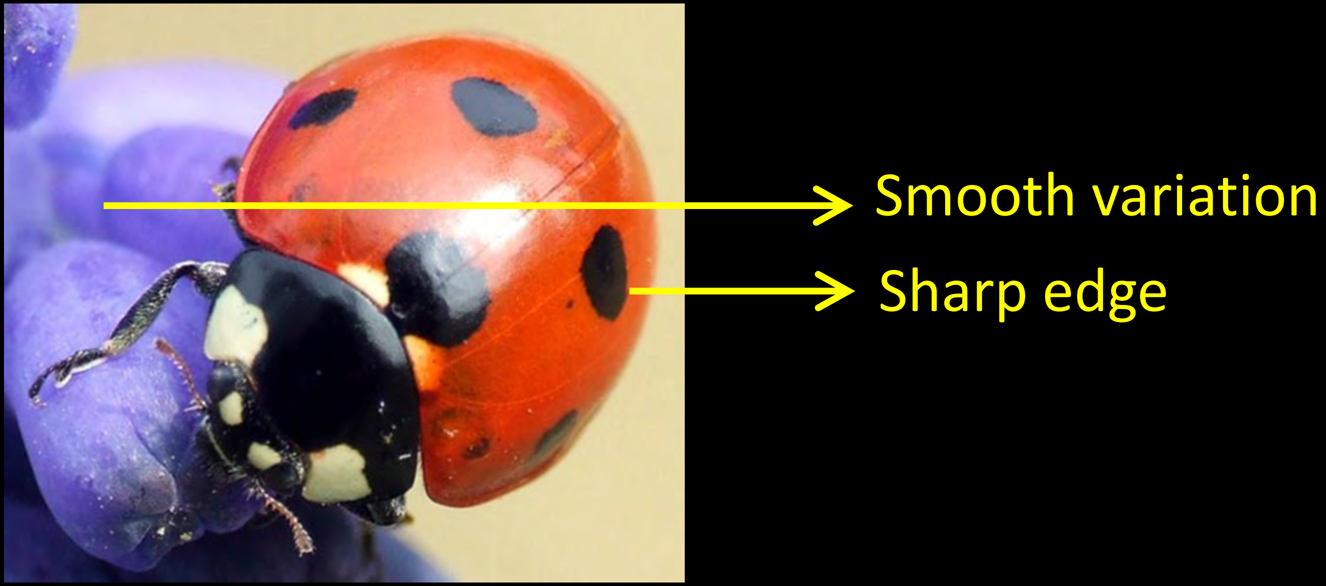
Diffusion Curves

- Definition [Orzan et al. 08]
  - Color defined on control curves
  - Non-zero Laplacian on the curves and zero Laplacian elsewhere
  - Smooth shading
- Advantage
  - Sparse control curves
  - Rich shading variations



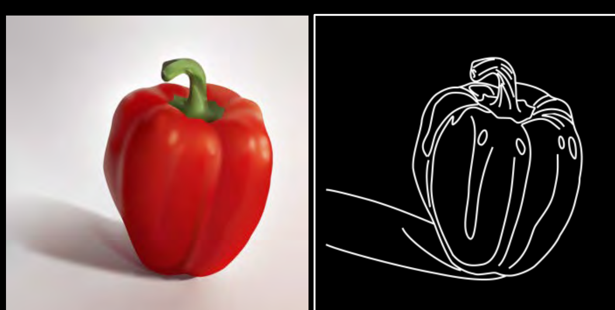
Vectorization with Diffusion Curves

- High quality reconstruction
  - Sharp edges
  - Smooth variations
- Automatic extraction



Previous Work

- Manual extraction
  - [Orzan et al. 08; Jeschke et al. 11; Finch et al. 11; Sun et al. 12; Ilbery et al. 13; Sun et al. 14]
- Automatic extraction in the gradient domain
  - [Orzan et al. 07; Orzan et al. 08; Jeschke et al. 11]
  - Hard to extract curves for smooth variations



Manual extraction

Automatic extraction

Our Contribution

- Accurate automatic image vectorization
  - Hierarchical diffusion curve representation
  - Laplacian and bilaplacian diffusion curves

Key Idea

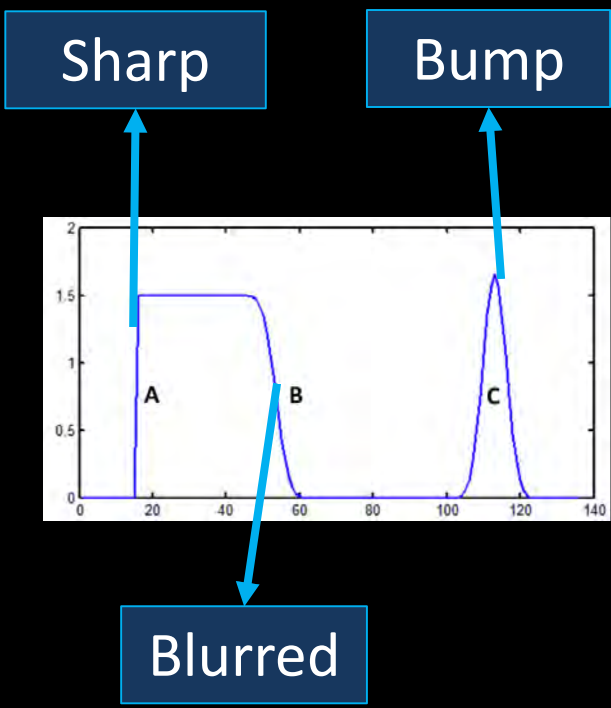
- Trace curves in the Laplacian domain instead of gradient domain
  - Capture both sharp and smooth image features

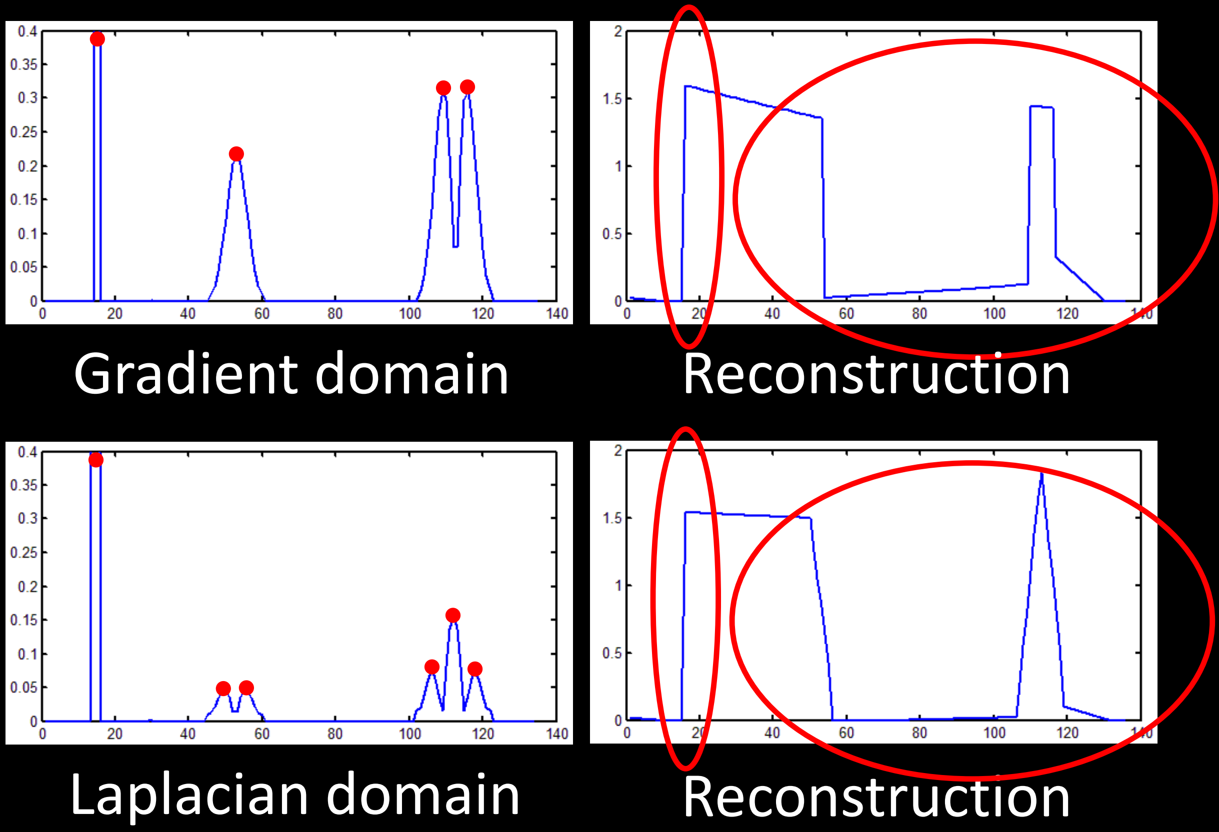
Input

Gradient domain

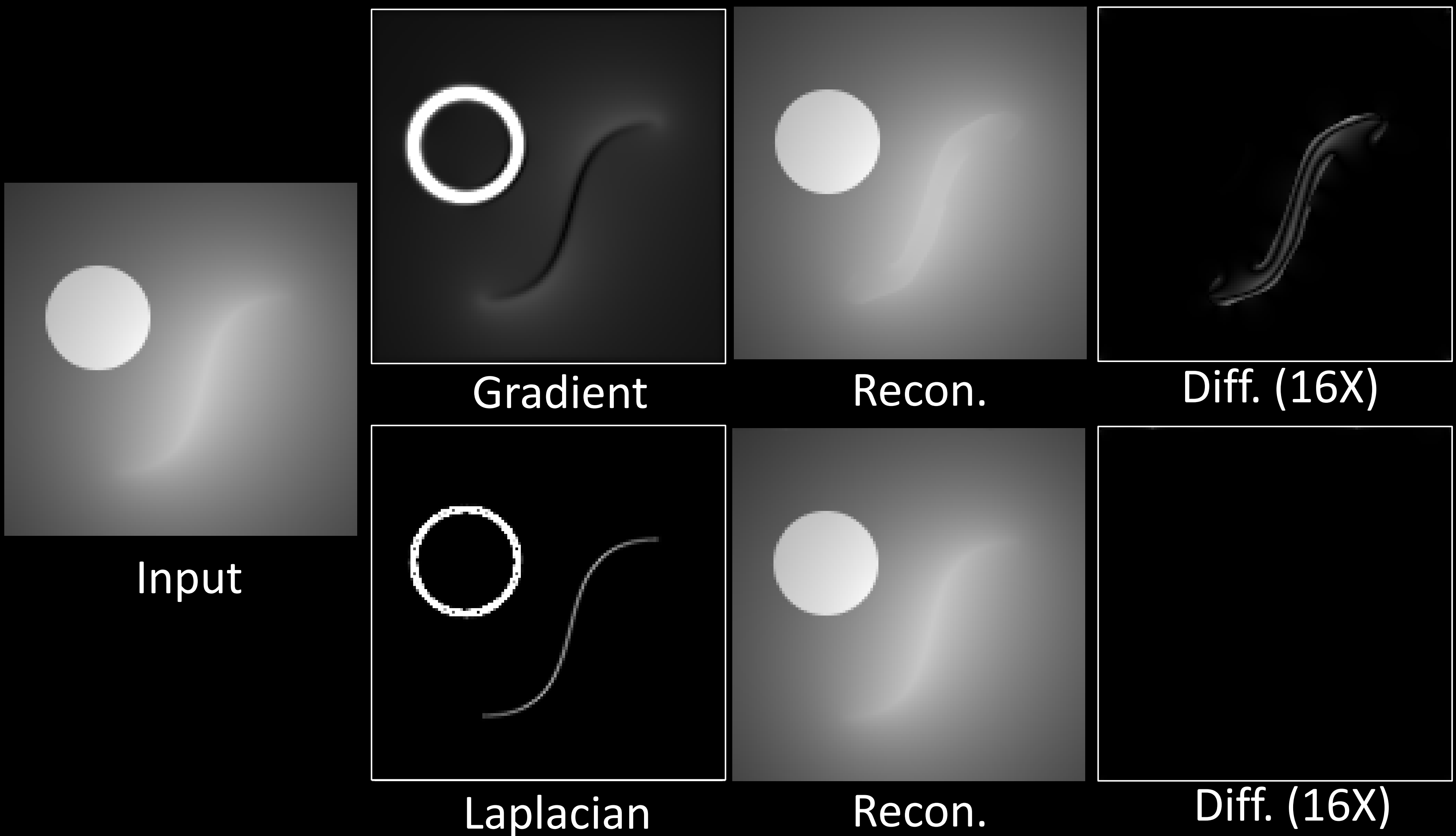
Laplacian domain

Curve Extraction (1D)



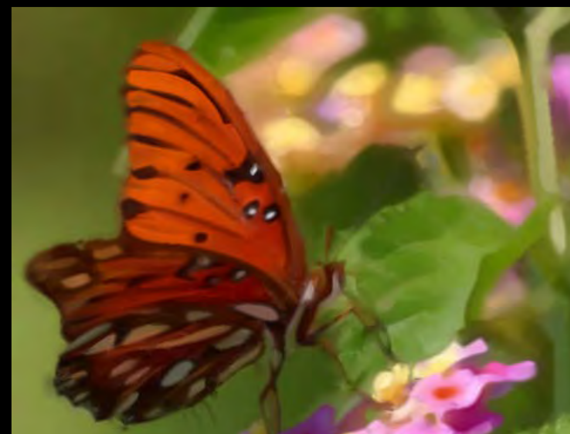


Curve Extraction (2D)



One Result

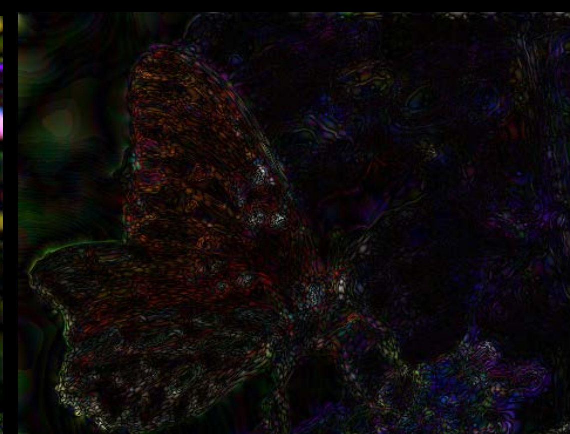
Input



Gradient recon.

Laplacian recon.

Diff. (8X)

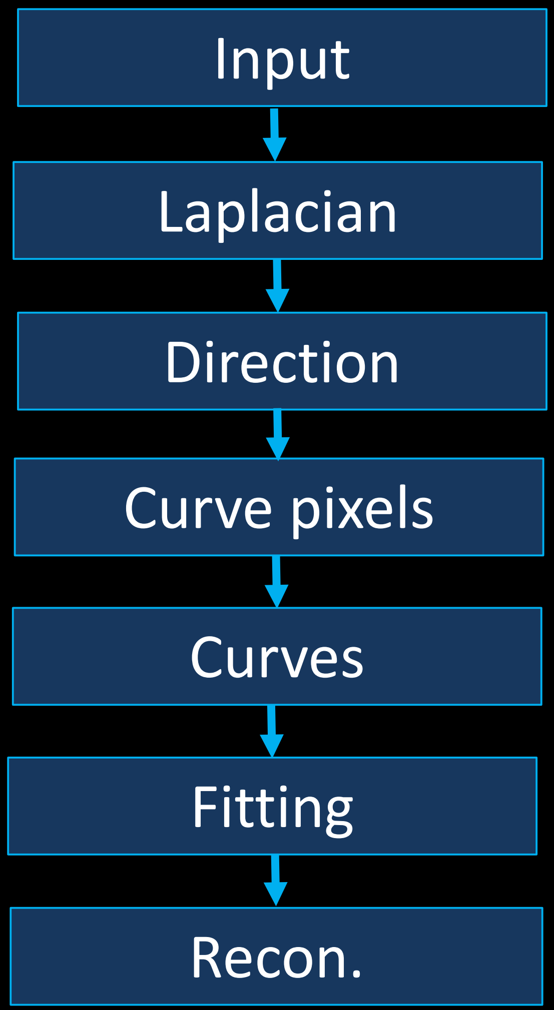


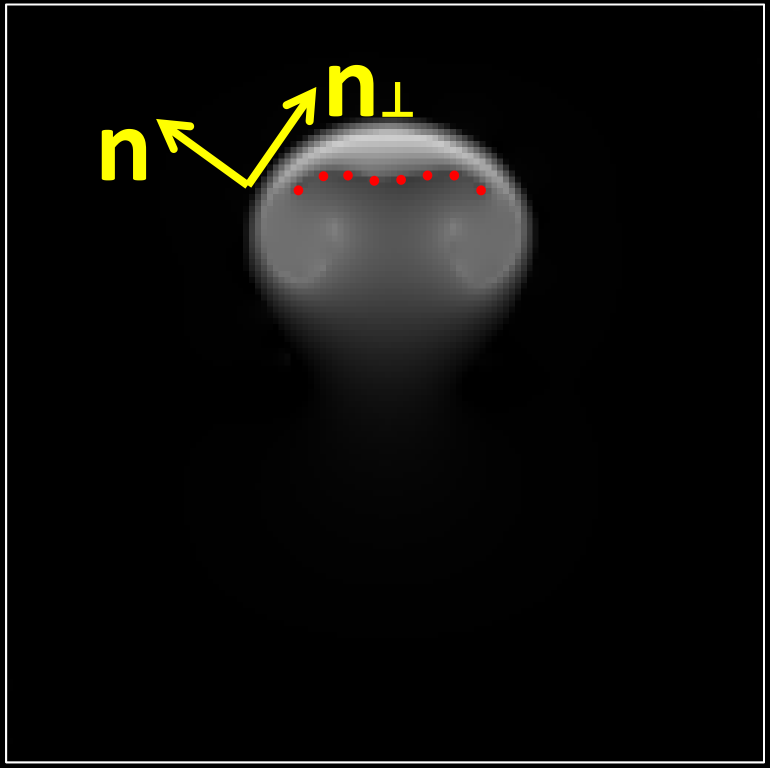
Diff. (8X)

Outline

- Curve extraction in the Laplacian domain
- Hierarchical curve construction
- Laplacian/bilaplacian diffusion curves

Curve Extraction in the Laplacian Domain





[Sun et al. 12; Ilbery et al. 13]

Approximate normal partial derivatives of the image Laplacian

Nonmaximal suppression

$$u(x) = \oint_{\partial D} \left(\frac{\partial u(x')}{\partial n(x')} G^L(x,x') - u(x') \frac{\partial G^L(x,x')}{\partial n(x')} \right) \mathrm{d}x' + \oint_{\partial D} \left(\frac{\partial v(x')}{\partial n(x')} G^B(x,x') - v(x') \frac{\partial G^B(x,x')}{\partial n(x')} \right) \mathrm{d}x'$$

Hierarchical Representation

- Multi-scale features
- Long curves represent large scale features, while shorter curves represent smaller details

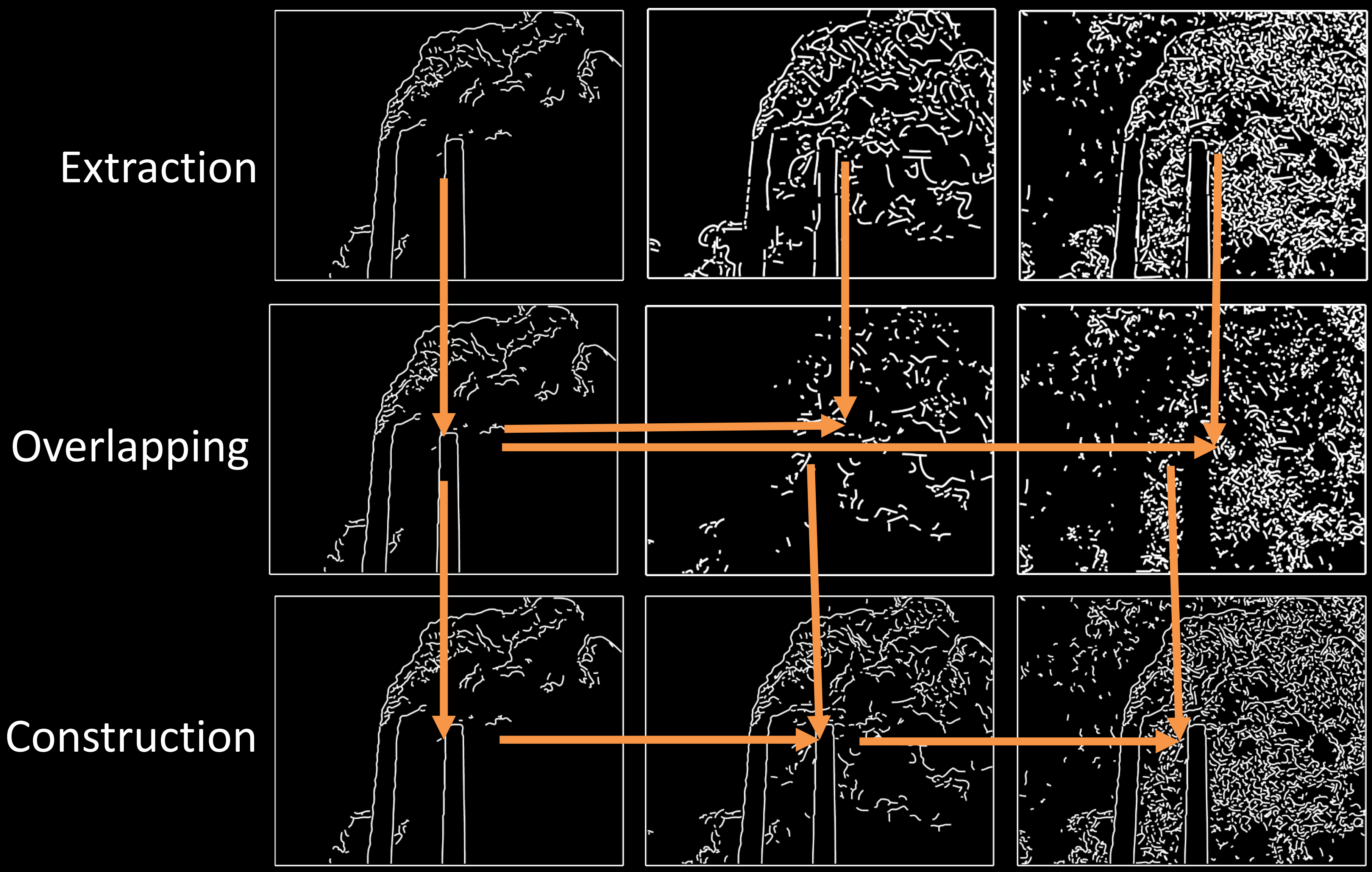
Hierarchical Curve Construction

- Multi-scale bilateral decomposition
  - Structure-preserving

$$u^{j+1}[p] = 1/k \sum_{q\in\Omega_j} g_{\sigma_{s,j}}(\|q\|)\, g_{\sigma_{r,j}}(u^j[p+q]-u^j[p])\, u^j[p+q]$$

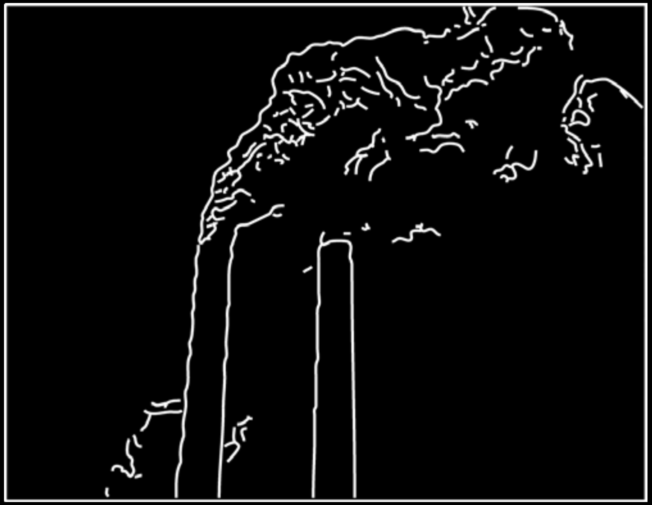
Input Scale 0 Scale 1 Scale 2

Hierarchical Curve Construction



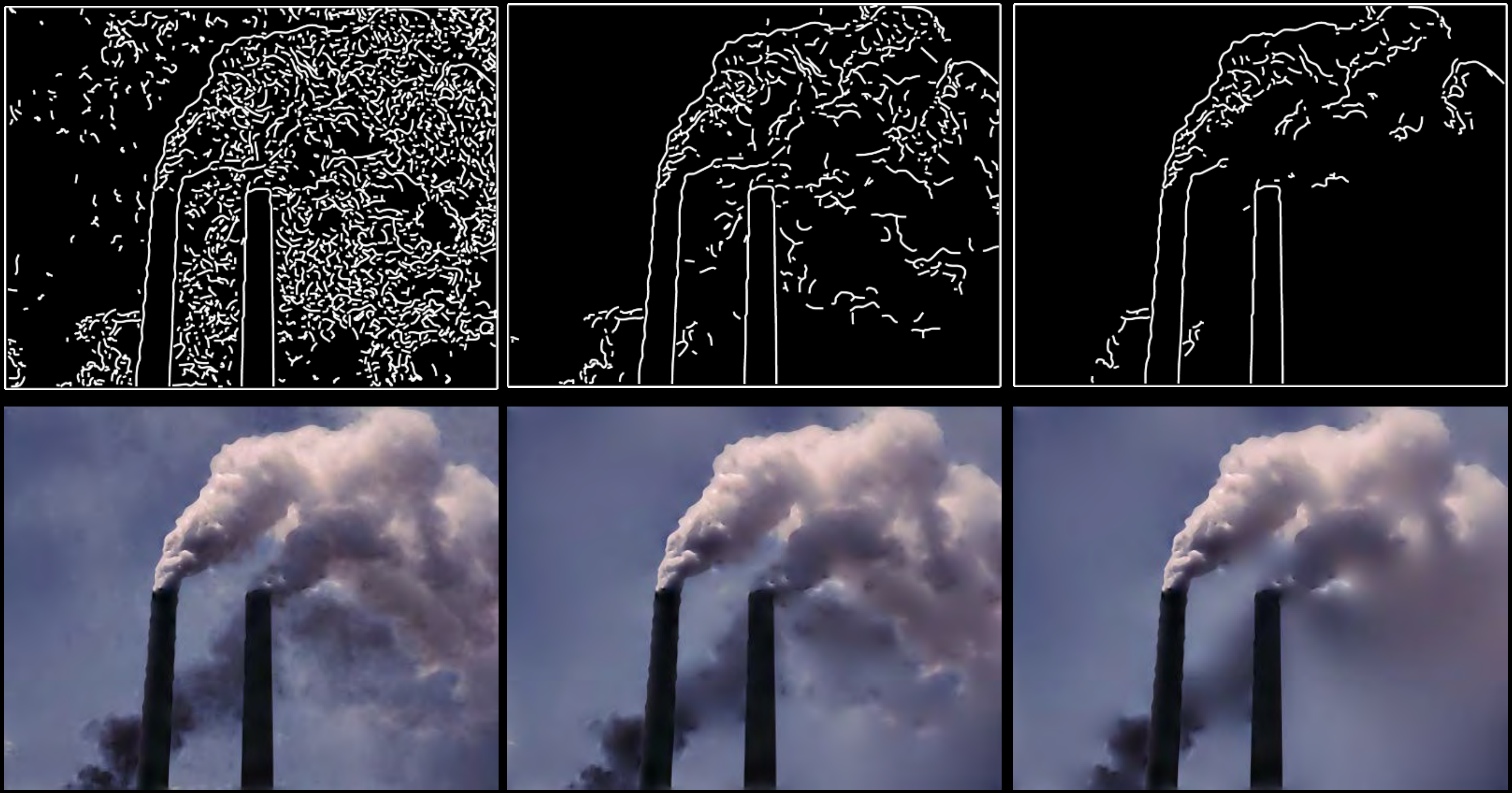
Application – Multi-scale Abstraction

Curves 0-1-2



Scale 0-1-2

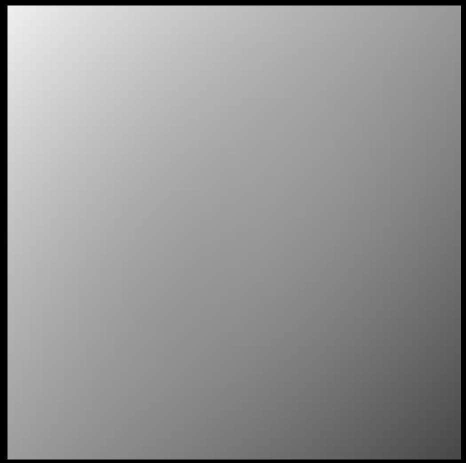
Application – Multi-scale Abstraction



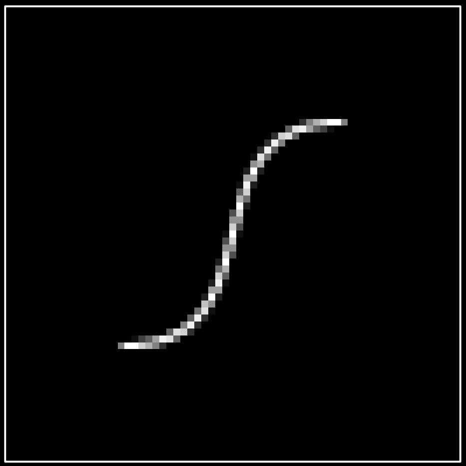
Scale 0+1+2 Scale 1+2 Scale 2

Bilaplacian Diffusion Curves

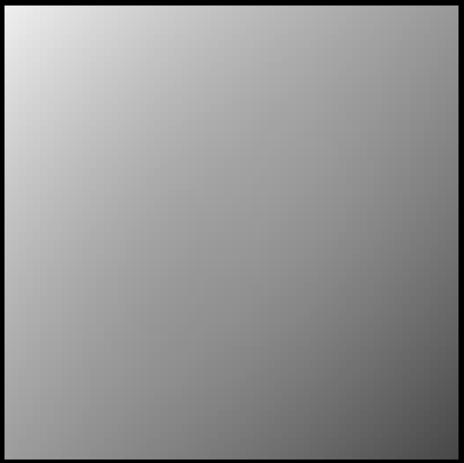
- Curves in the image bilaplacian domain
- Bilaplacian: higher order smooth variations [Ilbery et al. 13]



Input

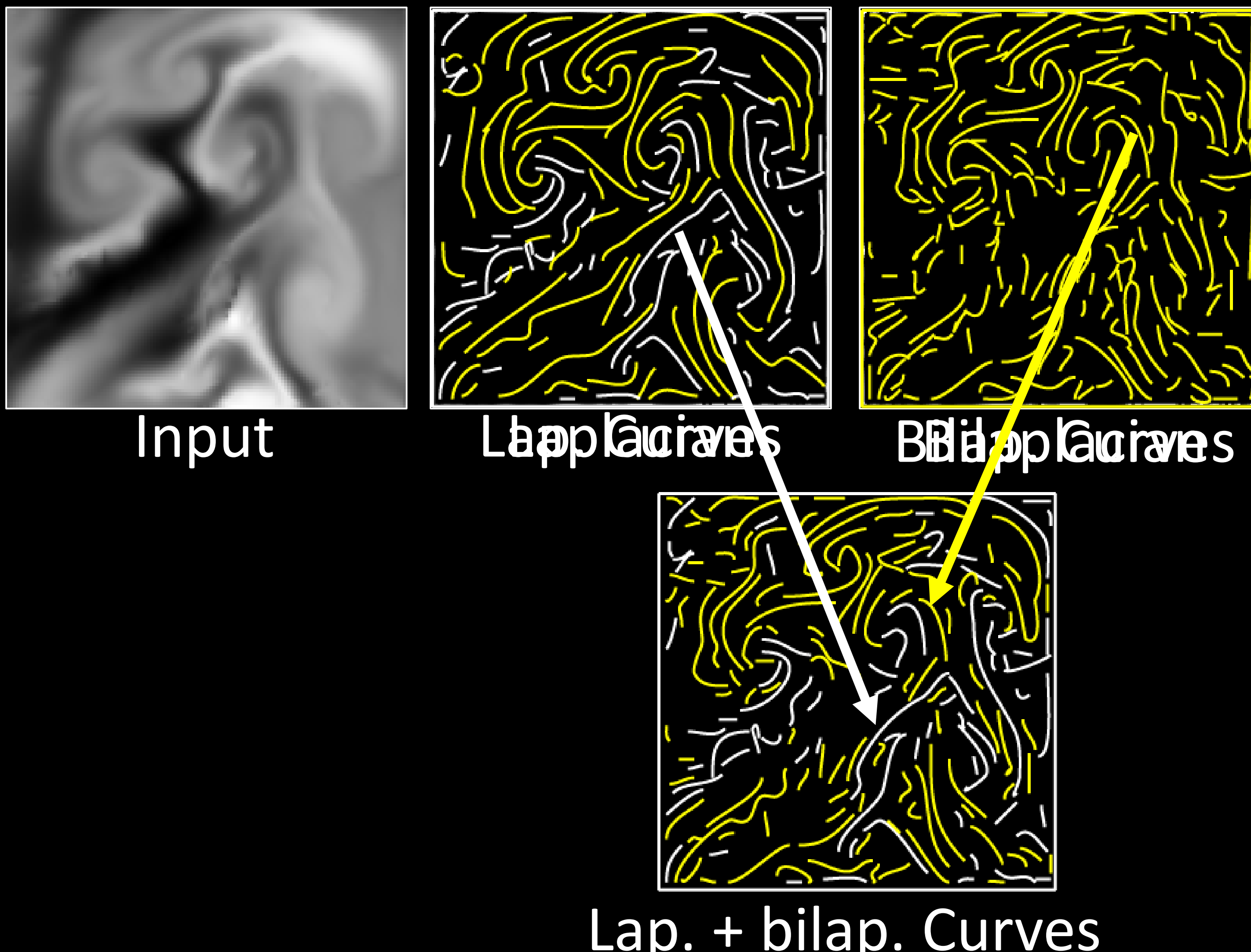


Curves

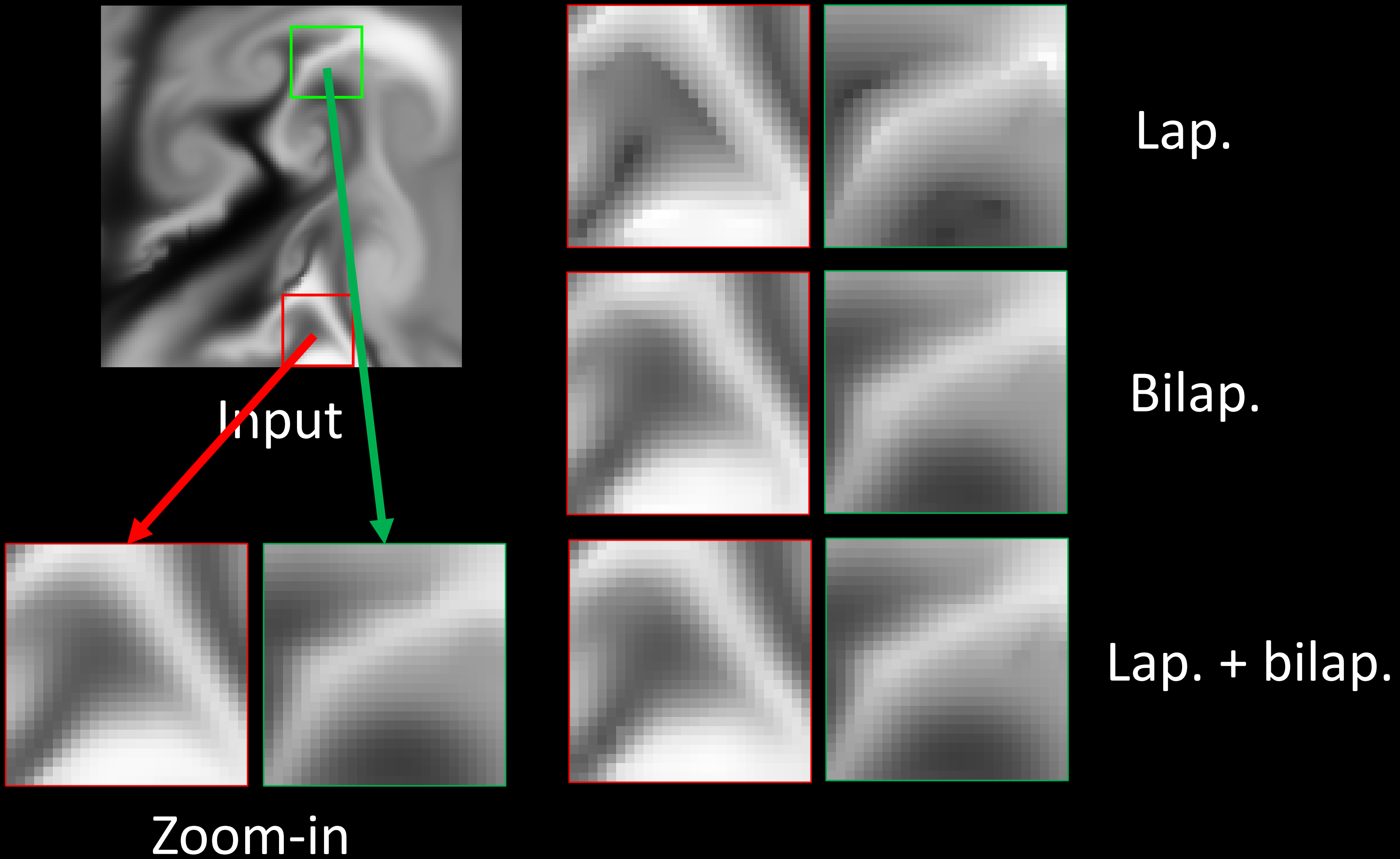


Recon.

Lap./bilap. Diffusion Curves



Lap./bilap. Diffusion Curves



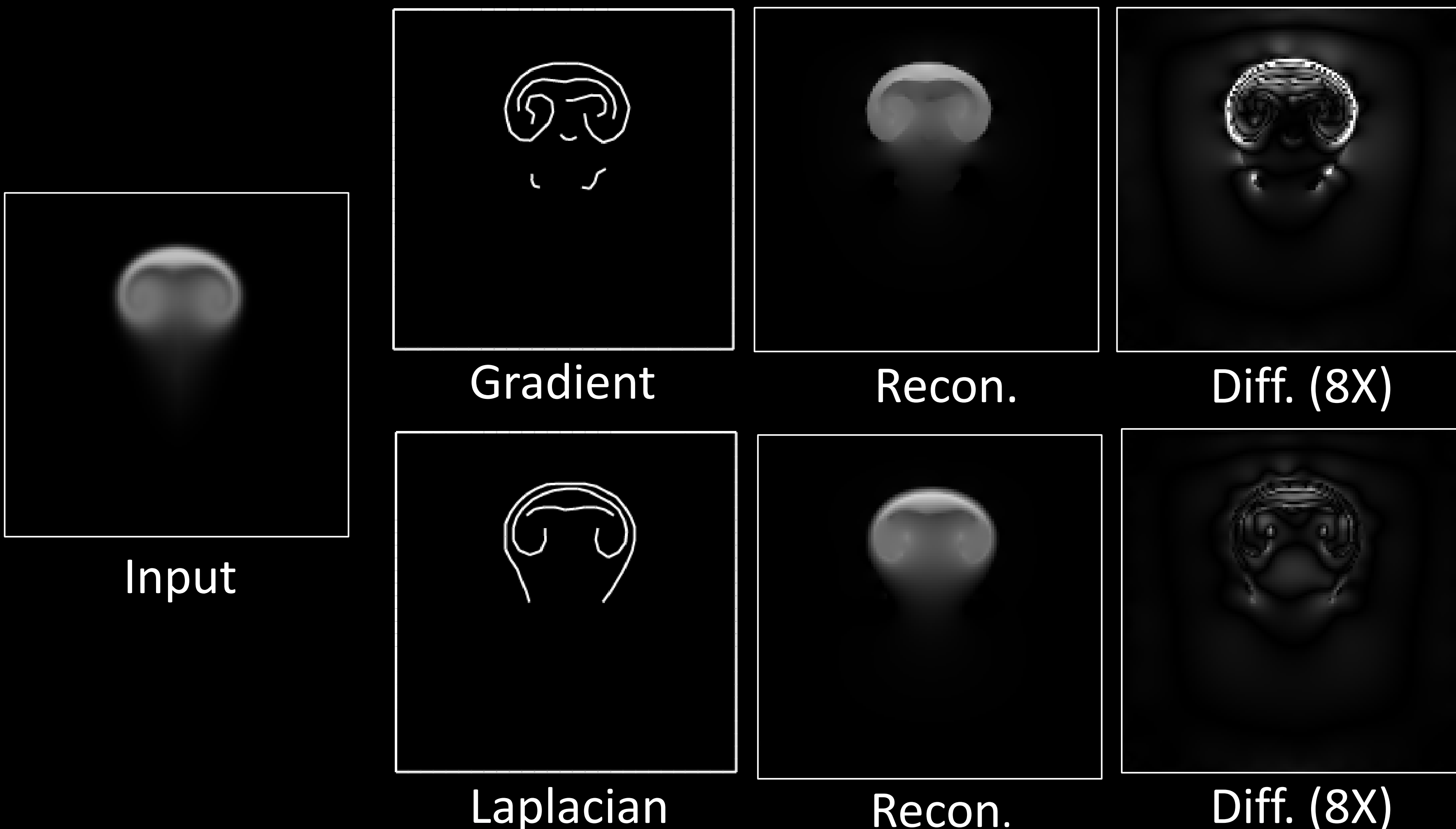
Implementation Details

- An Intel Core i7-3770K 3.5 GHz CPU and an Nvidia Quadro 6000
- Number of Bezier curves: 42 ~ 45K
- Storage: 36KBytes ~ 363KBytes
- Fitting: 21.9s ~ 660s
- Performance: 40.8ms ~ 591ms

Results

Results

Comparison: Gradient vs. Laplacian



Comparison with [Orzan et al. 08]


Input


Gradient curves

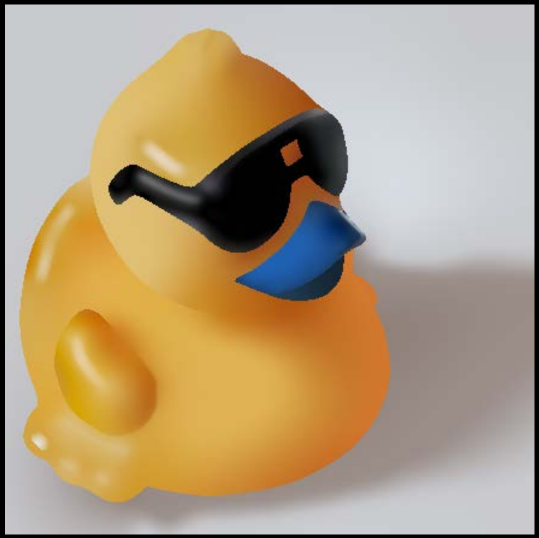

Our curves

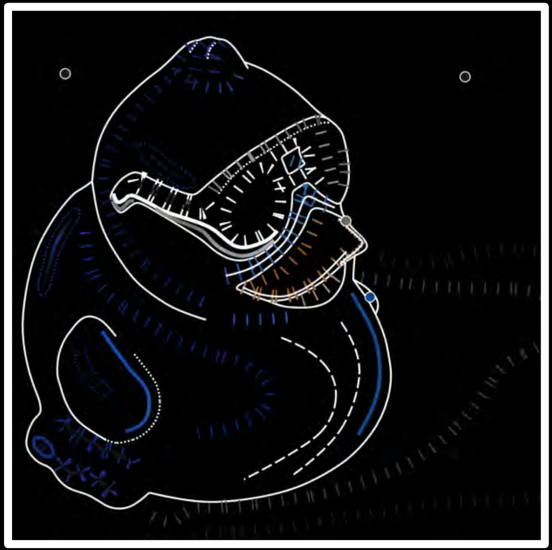

Without blur


With blur


Our result

Comparison: FFG

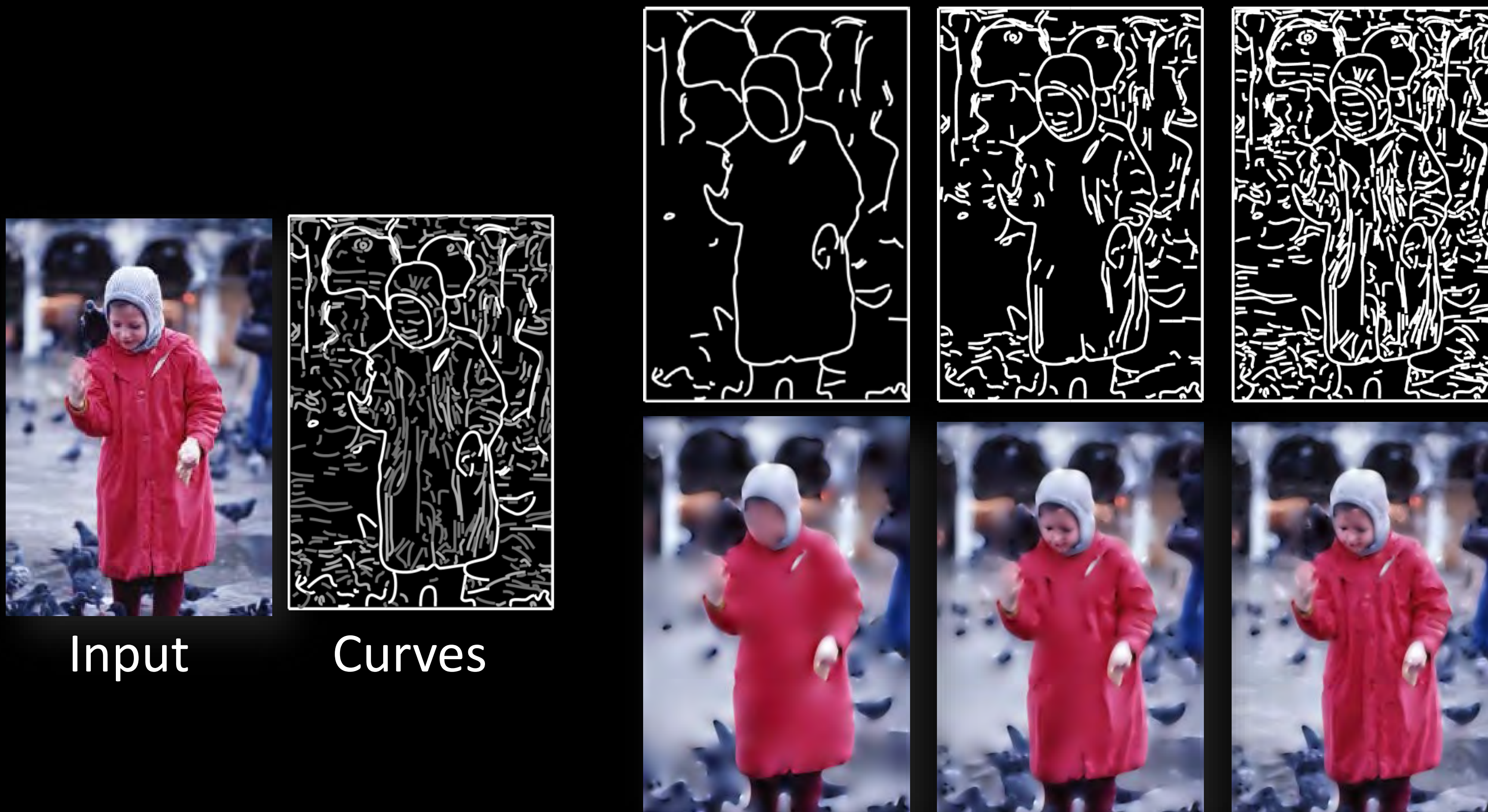




Freeform vector graphics

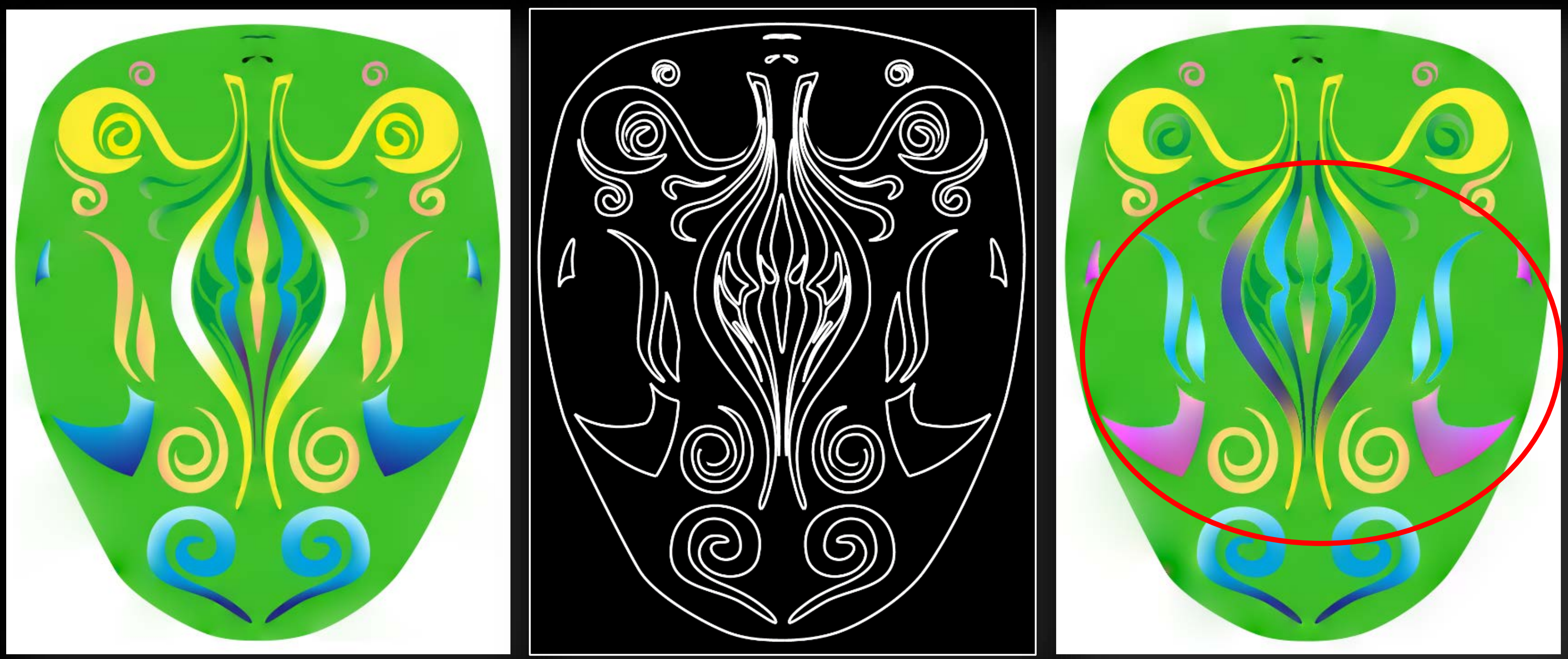
Ours

Hierarchical Representation and Abstraction



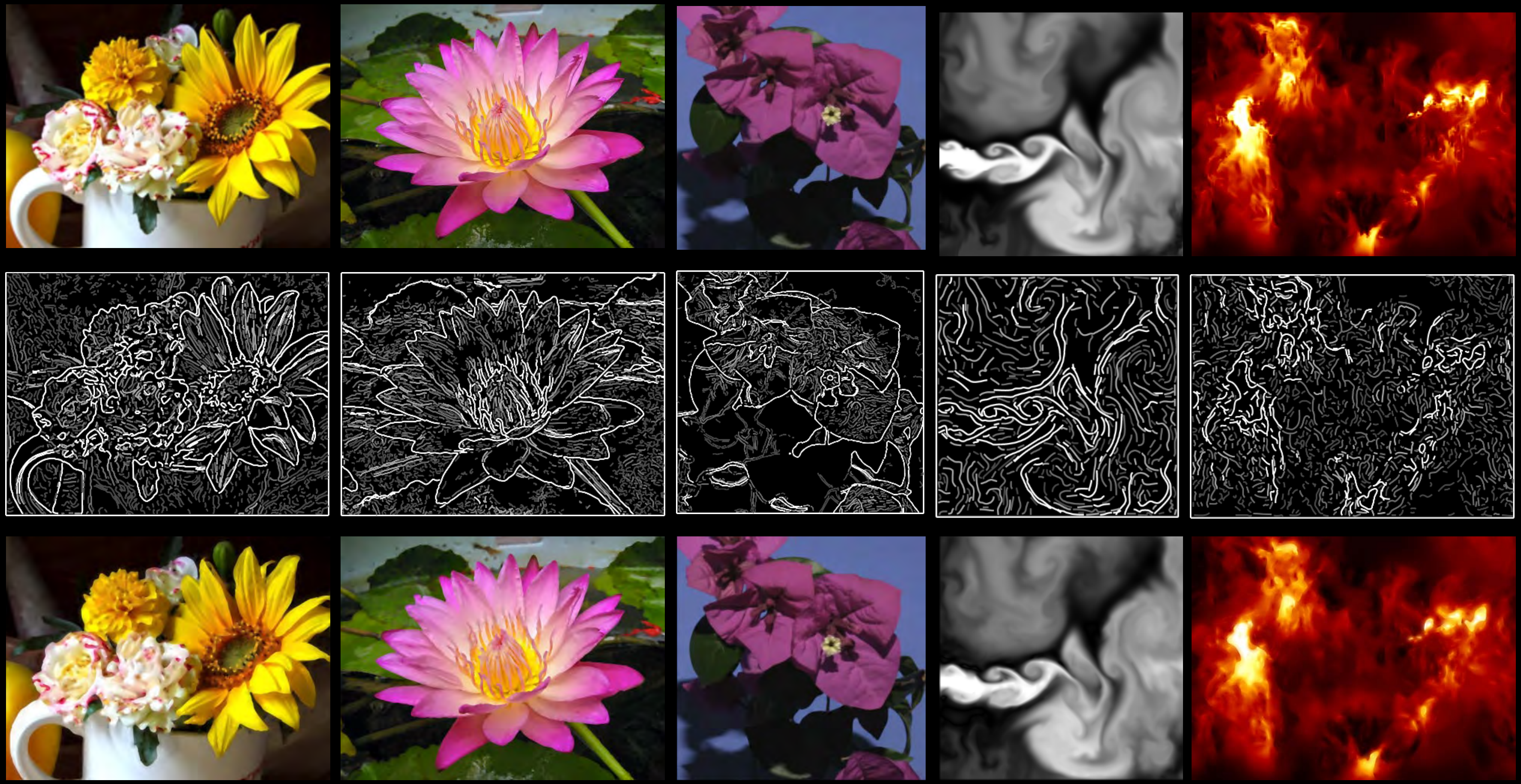
Input Curves Scale 2 Scale 1 Scale 0

Editing



Input　Curves　Reconstruction / Edit

More Results



Conclusion

- Accurate and fully automatic method
- Vectorize images using diffusion curve representation
  - Extract curves in the Laplacian/bilaplacian domain
  - Propose hierarchical fitting and multi-scale representation

Limitations and Future Work

- Limitations
  - Remove image features with low contrast
  - Generate many short curves for noisy images
- Future work
  - 3D volume vectorization
  - Animation sequences

Acknowledgements

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  - Valuable suggestions and comments
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Thank you!