SIGGRAPH2013

Dynamic Element Textures

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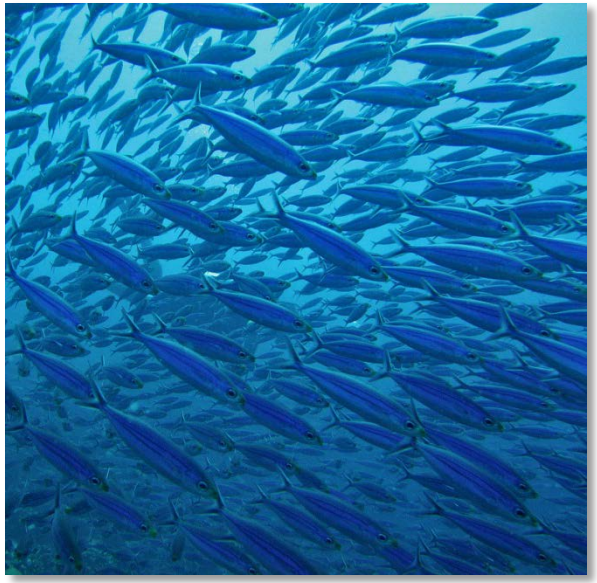
Sylvain Lefebvre Xin Tong

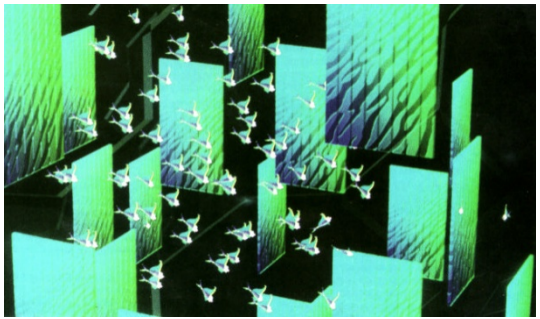
Aggregated elements



Computer animation

- Physics based simulation
  - ✔ Visual realism
  - ✘ Lack of artistic control
  - ✘ Application-specific

- Manual edit
  - ✔ Intuitive control
  - ✘ Tedious for complex scenes



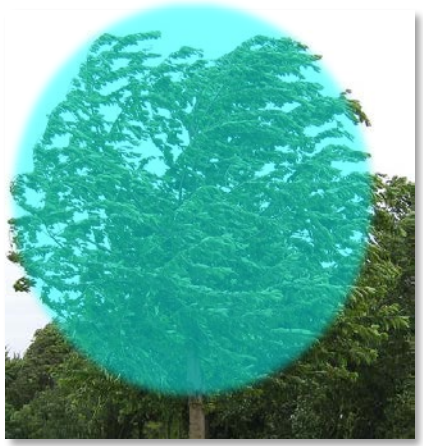
[Reynolds 1987]

[Hsu and Keyser 2012]

Key observations

Many natural phenomena

- Large scale structures



Key observations

Many natural phenomena

- Large scale structures

- Small scale details
  - Spatial-temporal repetitions
  - Random variations

Our approach

Many natural phenomena

- Large scale structures
- Small scale details
  - Spatial-temporal repetitions
  - Random variations

Dynamic element textures

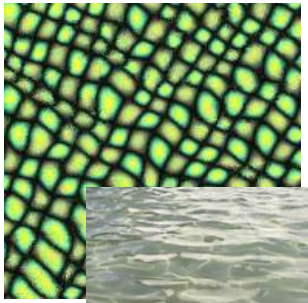
- Output constraints
  - Constrained optimization
- Input exemplars
  - Data-driven computation

Technical challenges

- Representation
  - Diversity of natural phenomena
- Input analysis
  - Coupled global structure and local details
- Output synthesis
  - Different controls
  - High dimensional state space

Related work: texture

- Neighborhood-base texture synthesis
- Time-varying textures
- Element-based textures



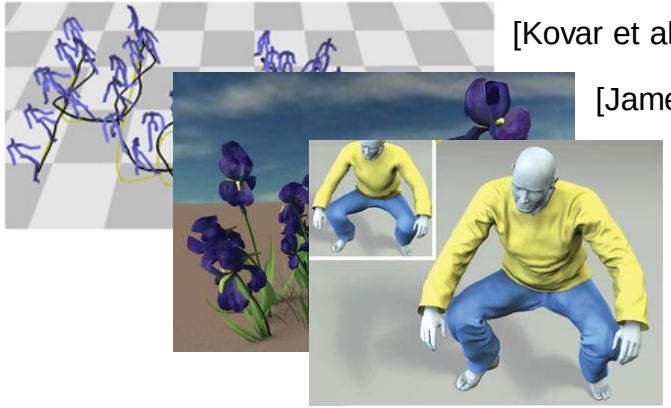
[Efros and Leung 1999]

[Kwatra et al. 2003]

[Ma et al. 2011]

Related work: animation

- Data-driven synthesis
  - Character
  - Mesh ensemble
  - Cloth wrinkles

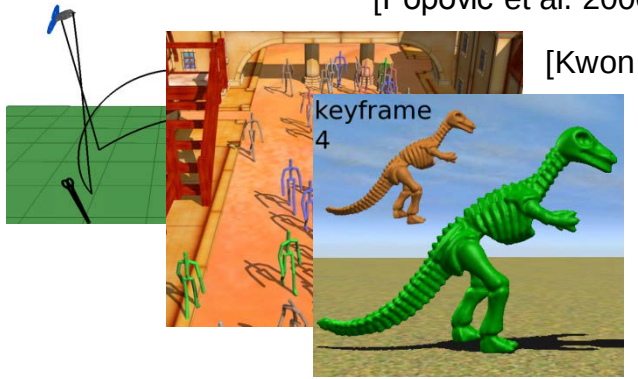


[Kovar et al. 2002]

[James et al. 2007]

[Wang et al. 2008]

- Controllable synthesis
  - Rigid body
  - Crowd formation
  - Deformable objects



[Popović et al. 2000]

[Kwon et al. 2008]

[Barbič et al. 2009]

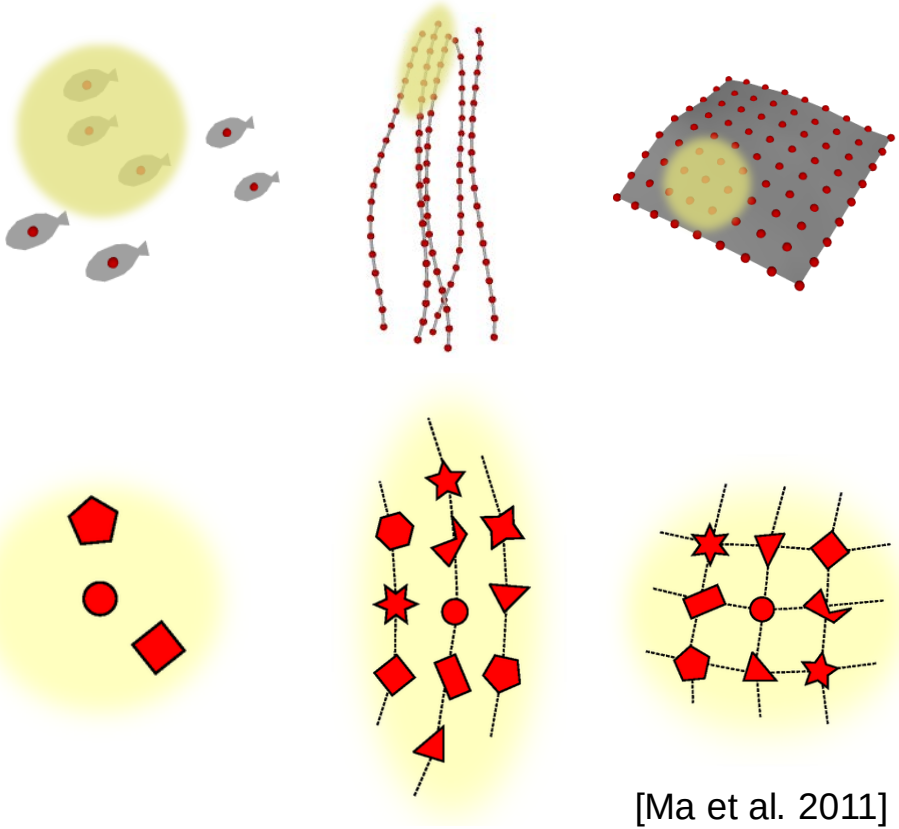
Core ideas

- Spatial-temporal samples

$$\mathbf{u}(s) = \big(\mathbf{p}(s), t(s)\big)$$

- Neighborhood

$$\mathbf{n}(s) = \{\hat{\mathbf{u}}(s', s)\}$$
$$= \{\mathbf{u}(s') - \mathbf{u}(s)\}$$



[Ma et al. 2011]

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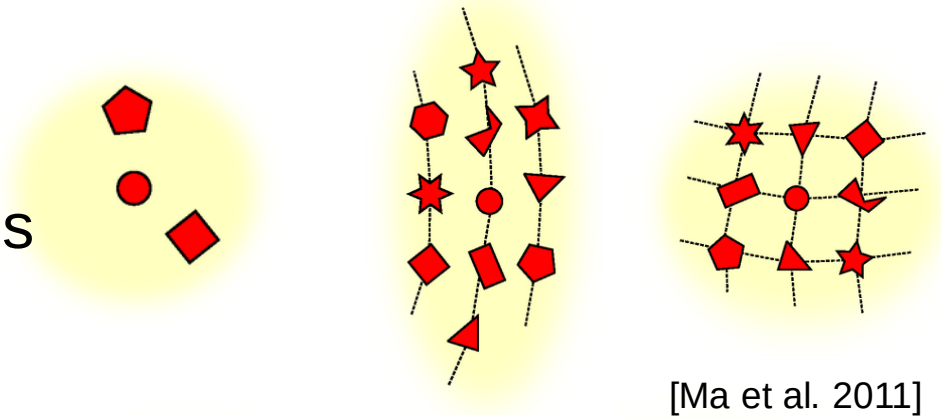


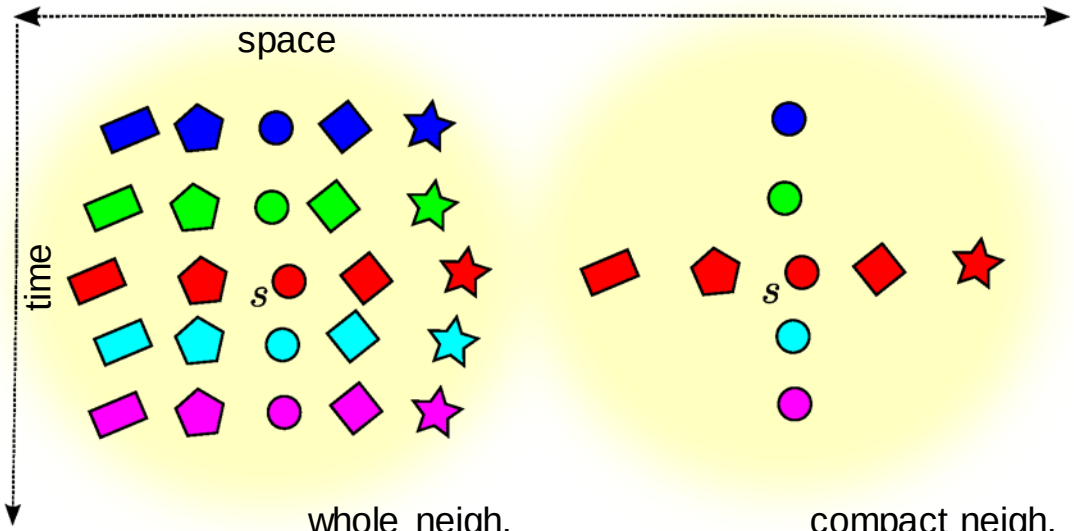
[Ma et al. 2011]

- Neighborhood

$$\mathbf{n}(s) = \{\hat{\mathbf{u}}(s', s)\}$$
$$= \{\mathbf{u}(s') - \mathbf{u}(s)\}$$

- Distance measure

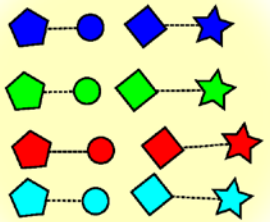
$$|\mathbf{n}(s_o) - \mathbf{n}(s_i)|^2$$



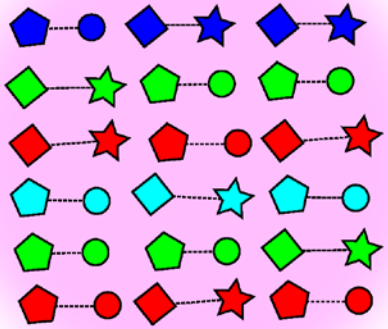
Algorithm: basic synthesis

- Initialization
  - Random patch copy

input



output



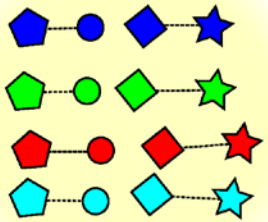
Algorithm: basic synthesis

- Initialization
  - Random patch copy

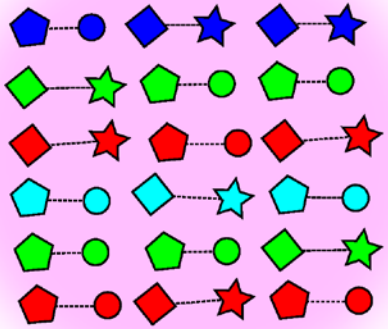
⇩

- Iterative optimization
  - [Kwatra et al. 2003]

input



output



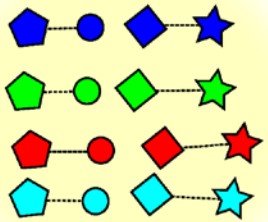
Algorithm: basic synthesis

- Initialization
  - Random patch copy

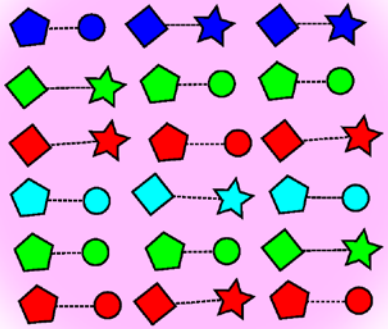
- Search step

- Assignment step

input

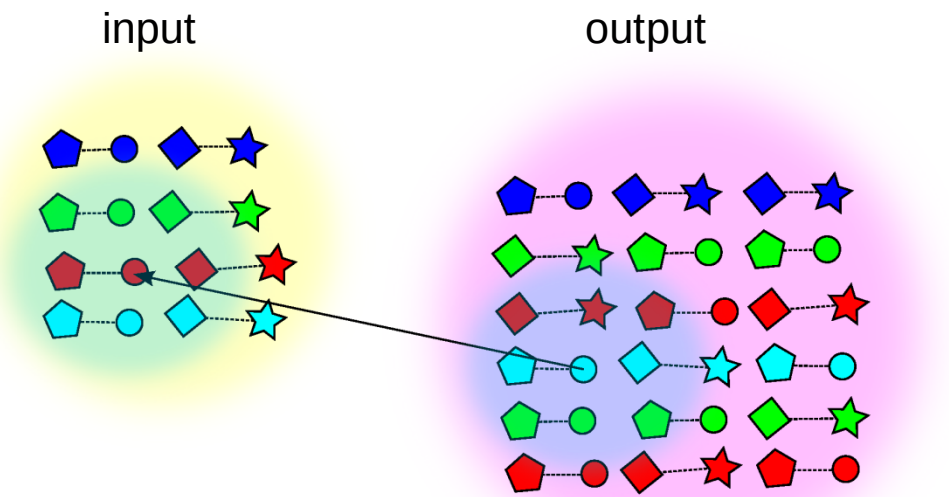


output



Algorithm: basic synthesis

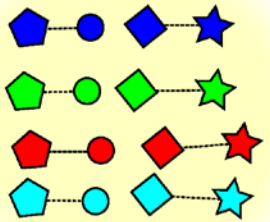
- Initialization
  - Random patch copy
- Search step
  - Nearest neighbor
- Assignment step



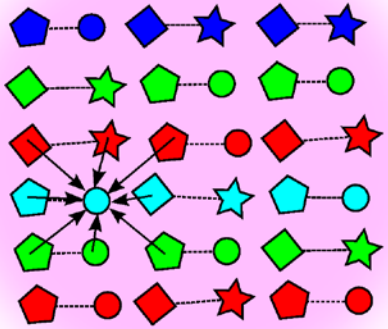
Algorithm: basic synthesis

- Initialization
  - Random patch copy
- Search step
  - Nearest neighbor
- Assignment step
  - Least squares

input



output



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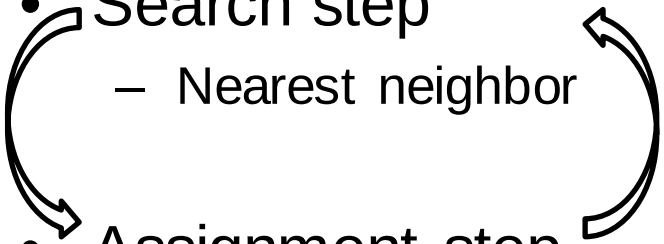
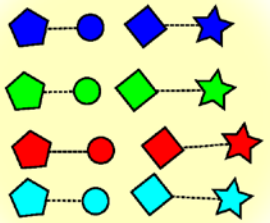
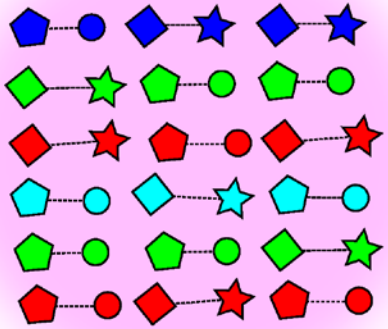


input



output



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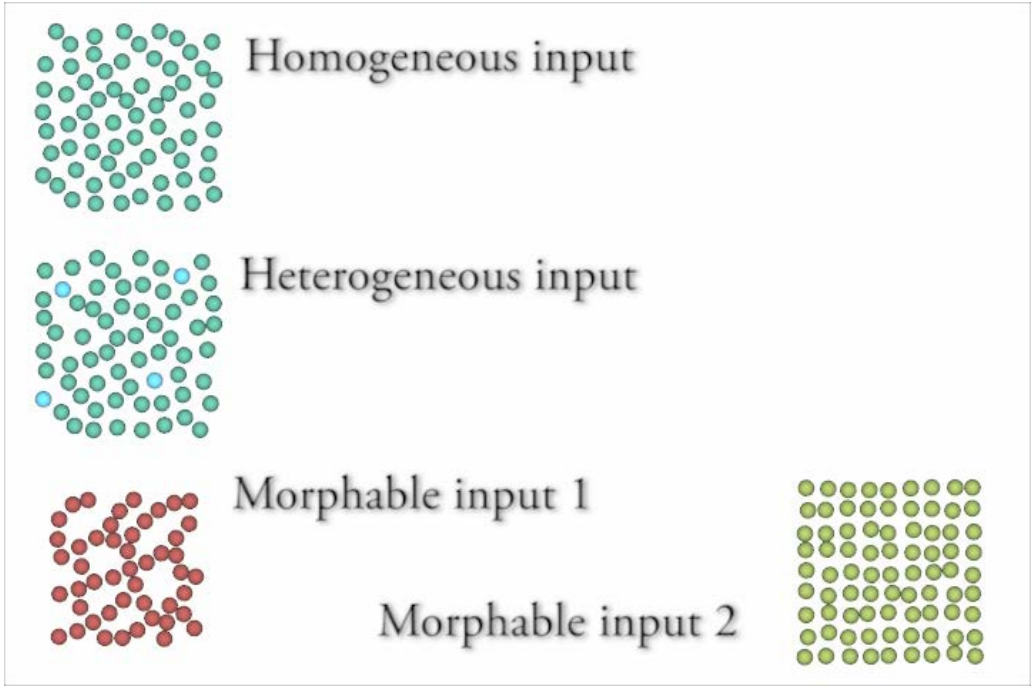
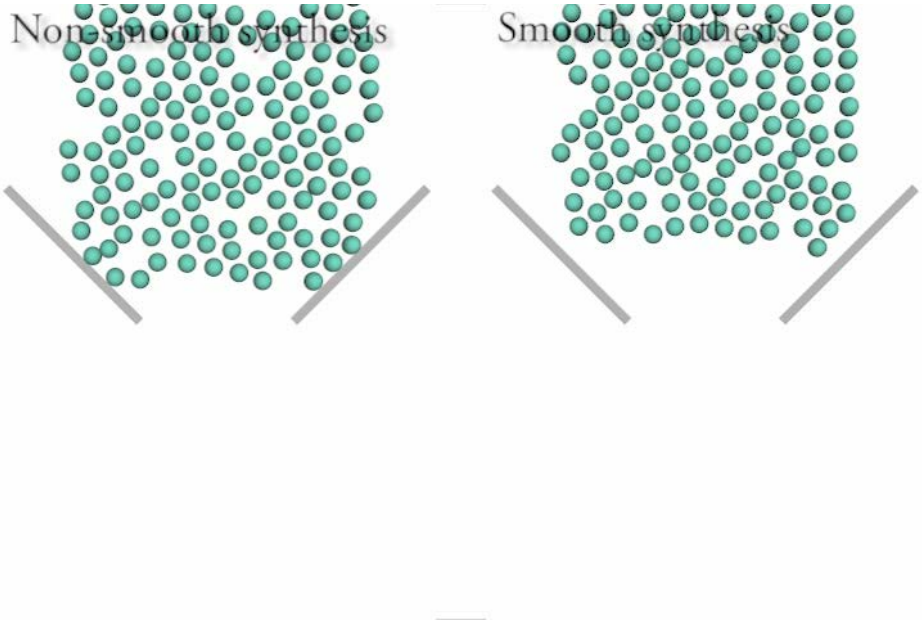


Algorithm: smooth synthesis

- Goal: reduce jittering artifact
- Approach
  - Gaussian falloff
  - Multiple nearest neighbors
  - Adaptive interpolation

Algorithm: smooth synthesis

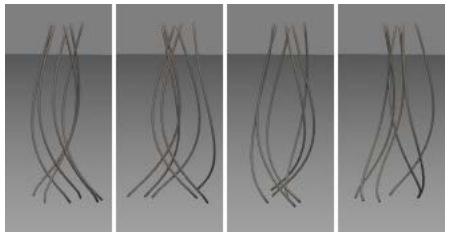
- Goal: reduce jittering artifact

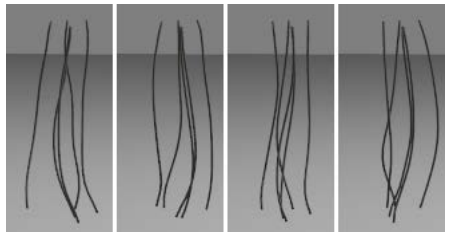


- Approach
  - Gaussian falloff
  - Multiple nearest neighbors
  - Adaptive interpolation

Algorithm: graph synthesis

- Goal: animate output from static input

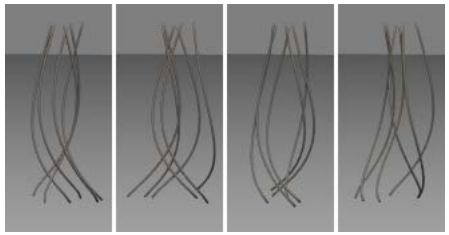


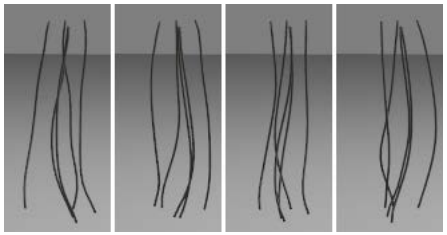


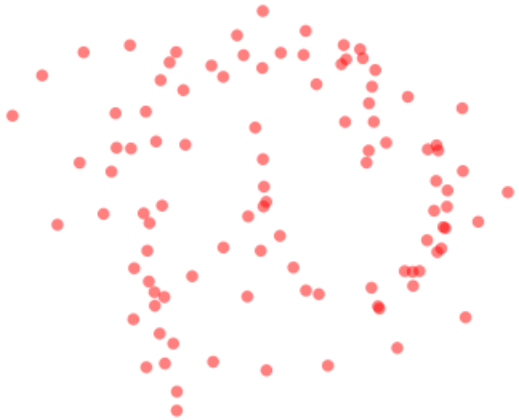
Algorithm: graph synthesis

- Goal: animate output from static input

- Approach
  - Graph construction







Algorithm: graph synthesis

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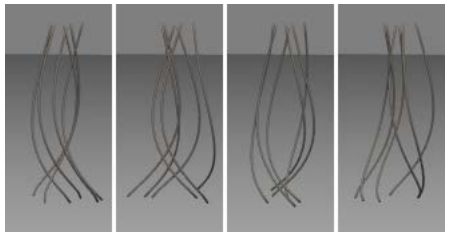
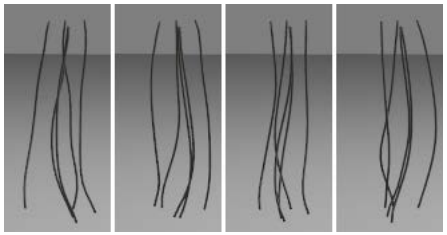
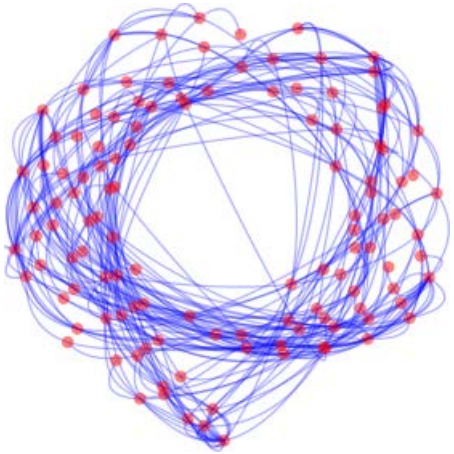
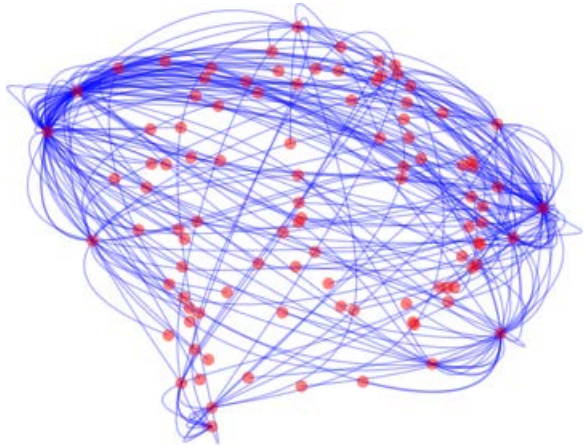
  - Path computation









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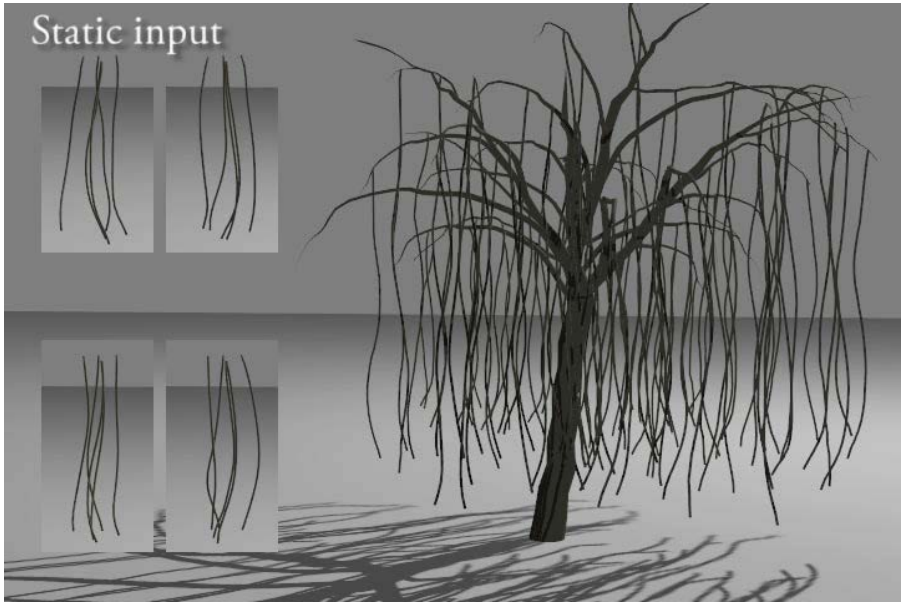

Algorithm: analysis

- Goal: decompose general inputs
  - Global structure
  - Local details

- Approach
  - Low-pass filtering

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Original input

Analysis result
(small kernel)

Algorithm: analysis

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Original input

Analysis result
(large kernel)

Algorithm: analysis

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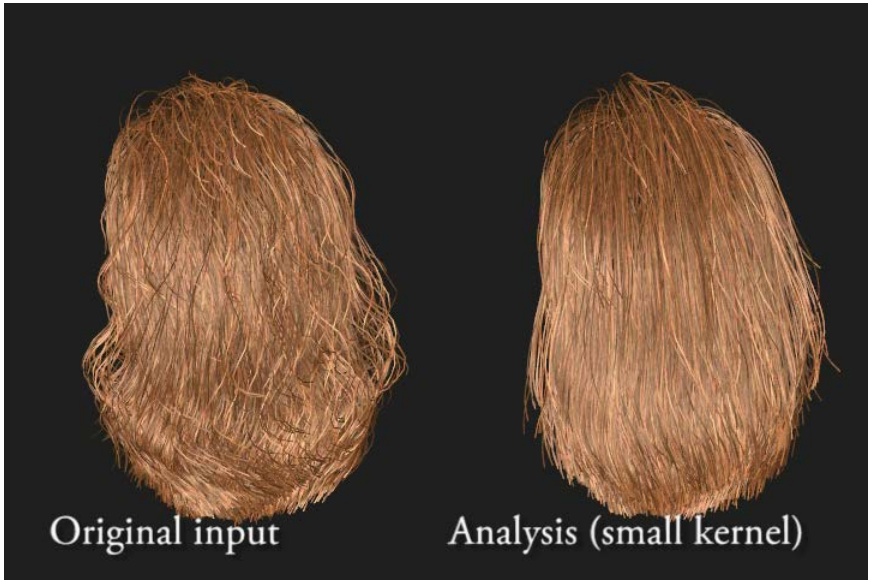
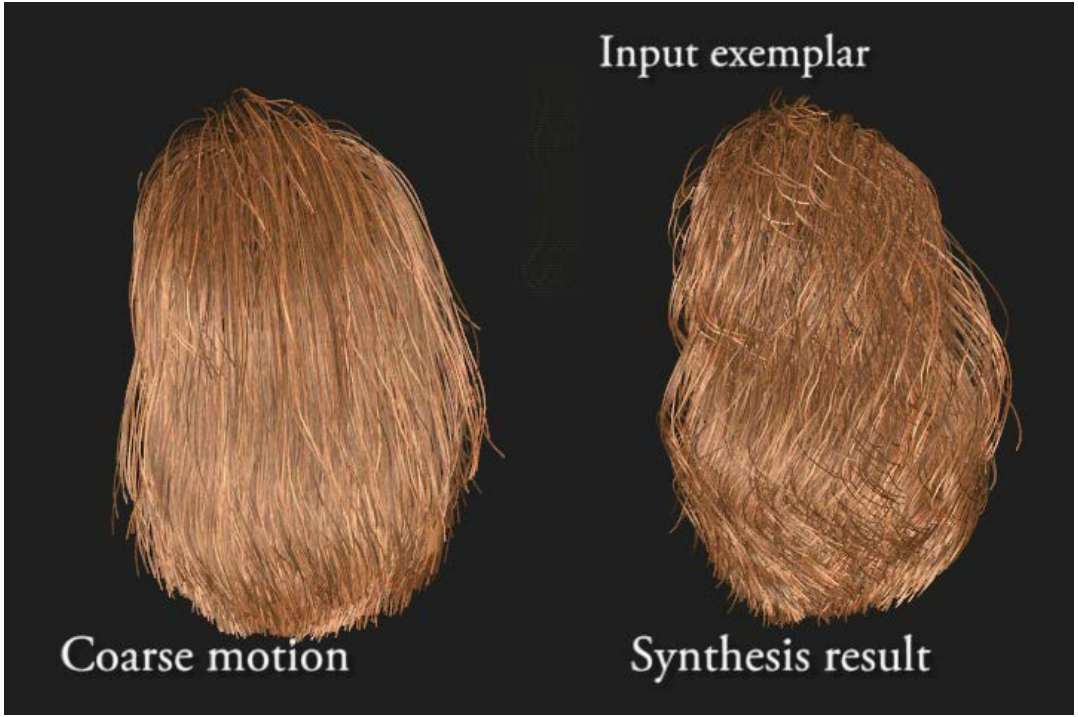
  - Low-pass filtering

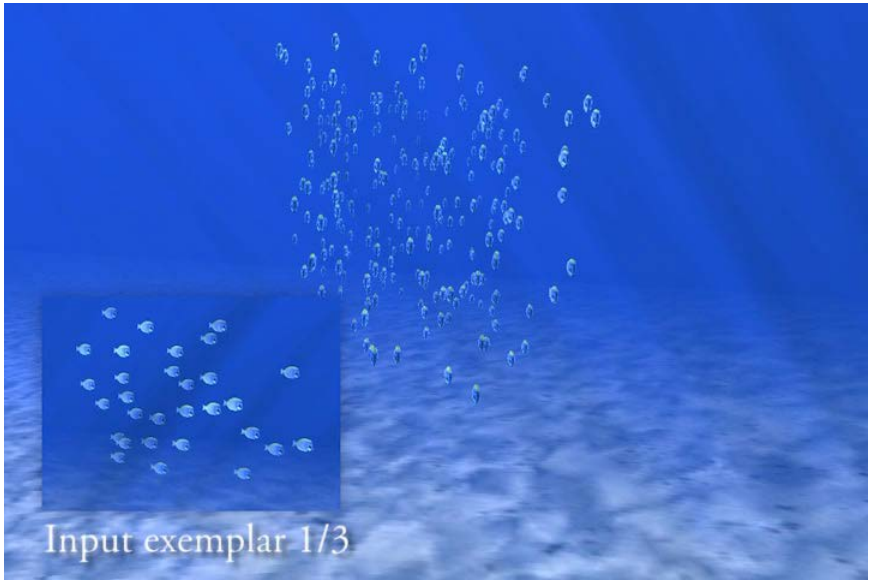


Results: hair synthesis



Results: fish

- Homogeneous
- Temporally-heterogeneous
- Spatially-heterogeneous



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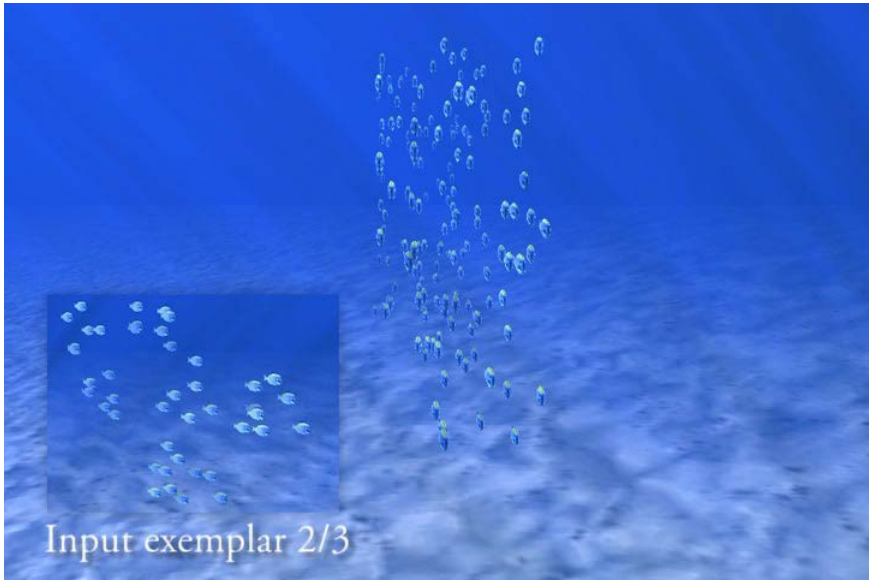

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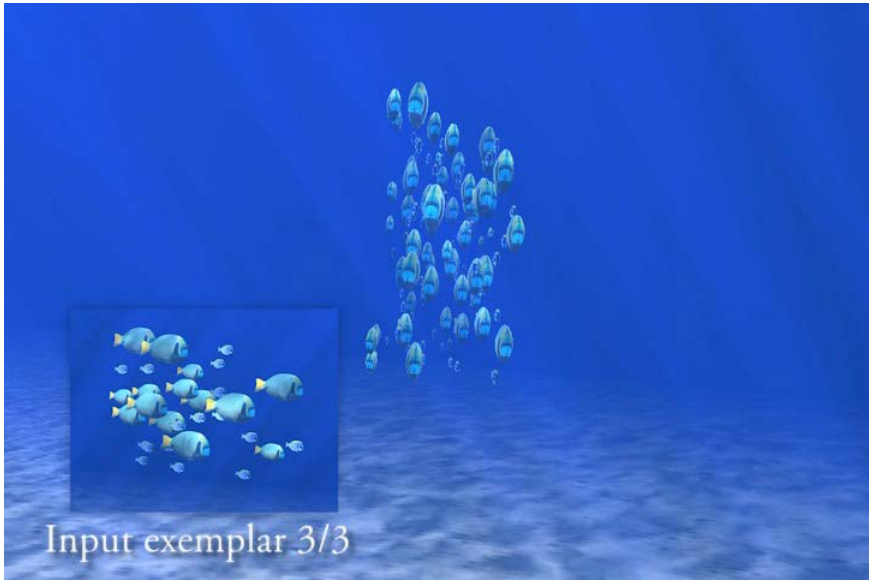
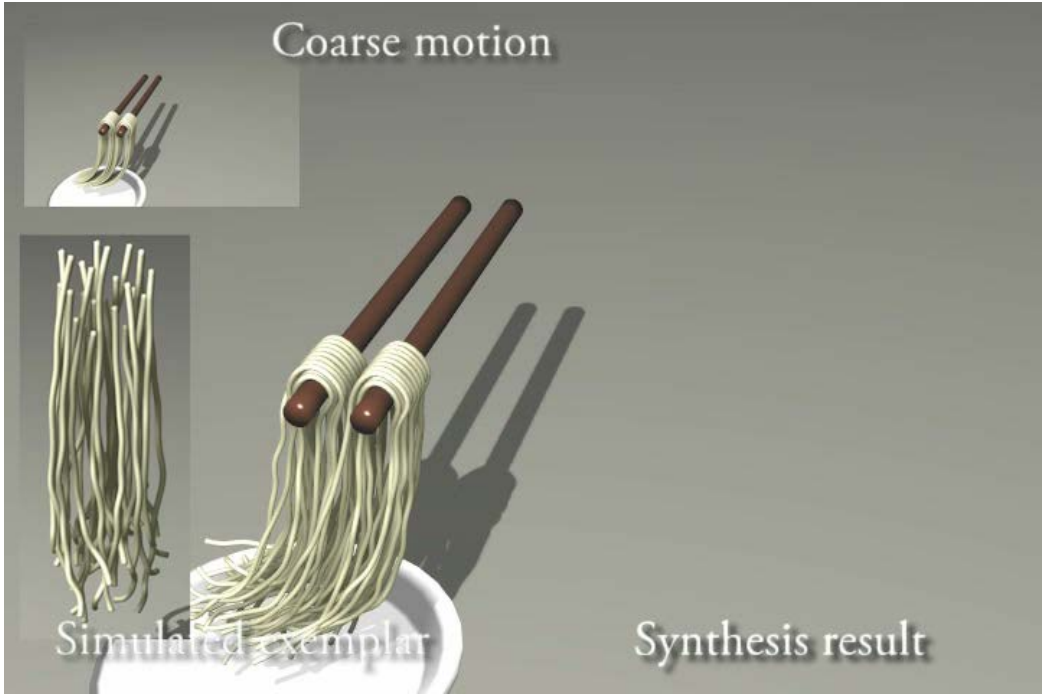


Results: noodles

- Realistic
- Artistic



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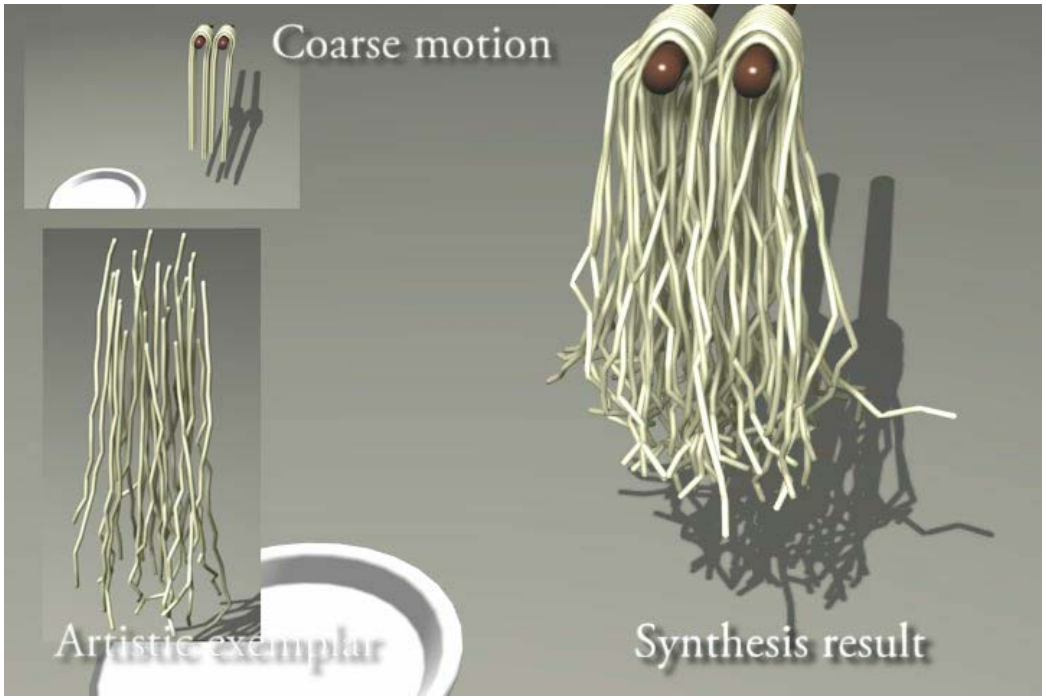
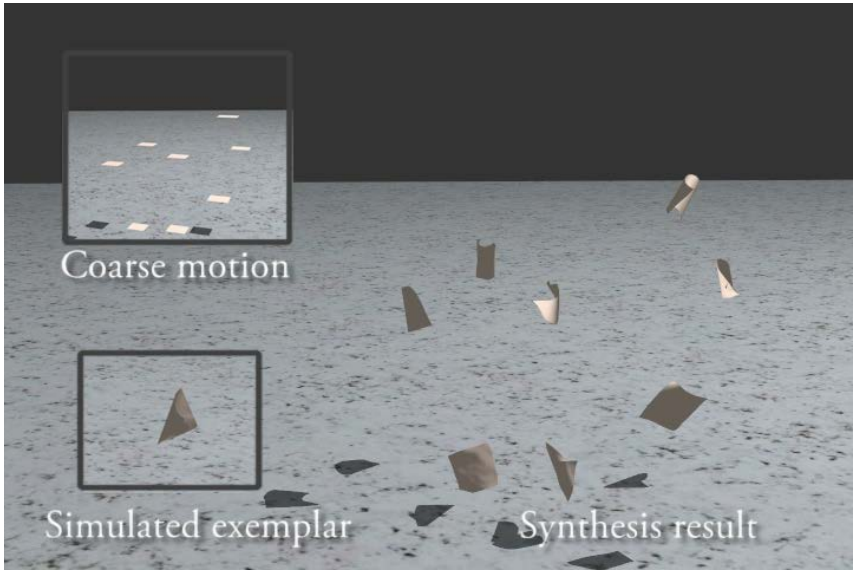
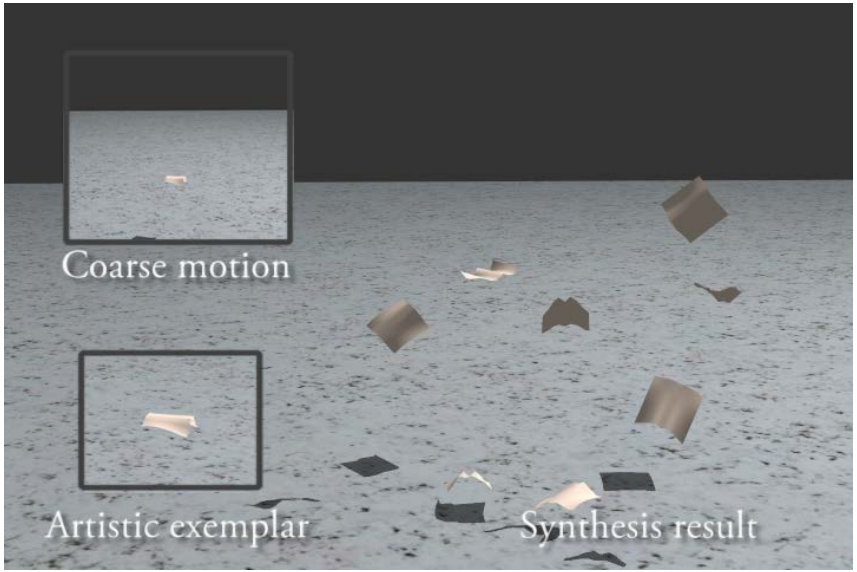


Results: scraps

Realistic

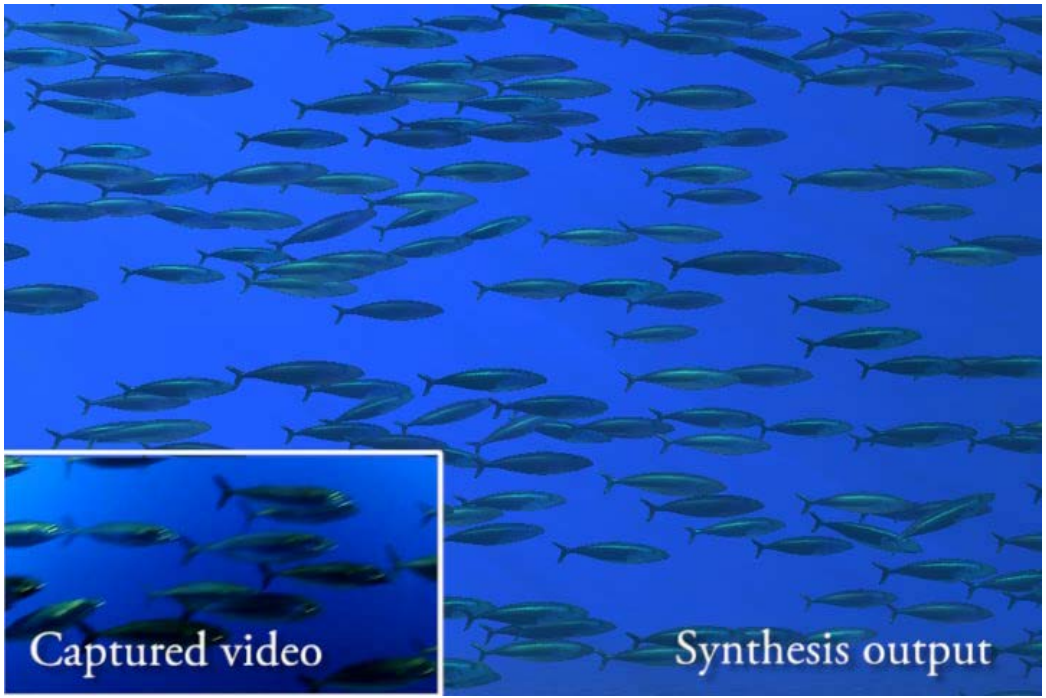


Artistic



Results: captured input

- Video input
- Image input



Results: captured input

- Video input

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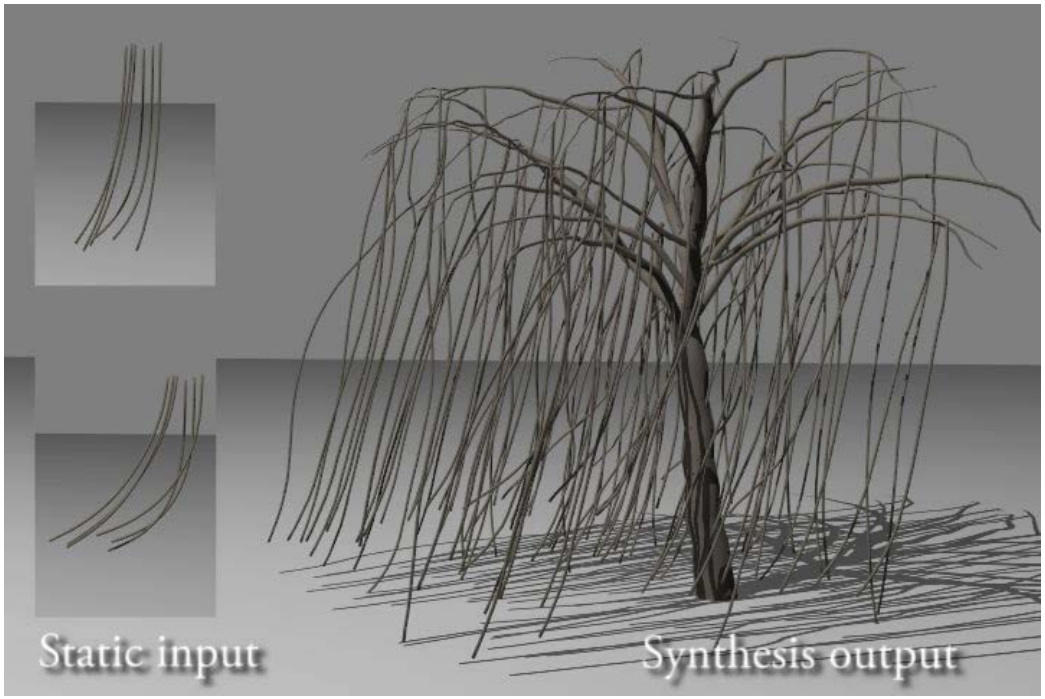

Conclusion

- A general representation for spatial-temporal repetitions
- A synthesis framework with both coarse scale and fine scale control
- An analysis algorithm to decompose general inputs into local and global components

Future work

- Order-independent synthesis for efficiency
  - [Lefebvre and Hoppe SIGGRAPH 2005]
- Domain-specific metrics for accurate evaluation
  - [Guy et al. SIGGRAPH Asia 2012; Zheng SCA 2013]
- Authoring UI for human intervention
  - [Kazi et al. SIGCHI 2012]

Acknowledgements

- Anonymous reviewers
- Florence Bertails-Descoubes
  - Hair animation data
- Shuitian Yan and Weiwei Xu
  - Input preparation
- Lvdi Wang, Xin Sun and Weikai Chen
  - Final rendering
- Steve Lin and David Brown
  - Video dubbing
- Will Chang
  - Proofreading
- Funding
  - ERC grant *ShapeForge* (StG-2012-307877)
  - General research fund *Dynamic Element Textures* (HKU 717112E)

Thank you!

Project page (source code available):
www.cs.ubc.ca/~chyma/publications/dt/