SIGGRAPH2006

Appearance Manifolds for Modeling Time-Variant Appearance of Materials

Jiaping Wang	Institute of Computing Technology, CAS
Xin Tong	Microsoft Research Asia
Stephen Lin	
Baining Guo	
Heung-Yeung Shum	
Minghao Pan	Zhejiang University
Hujun Bao	
Chao Wang	Tsinghua University

Motivation

Modeling and editing of time-variant surface appearance

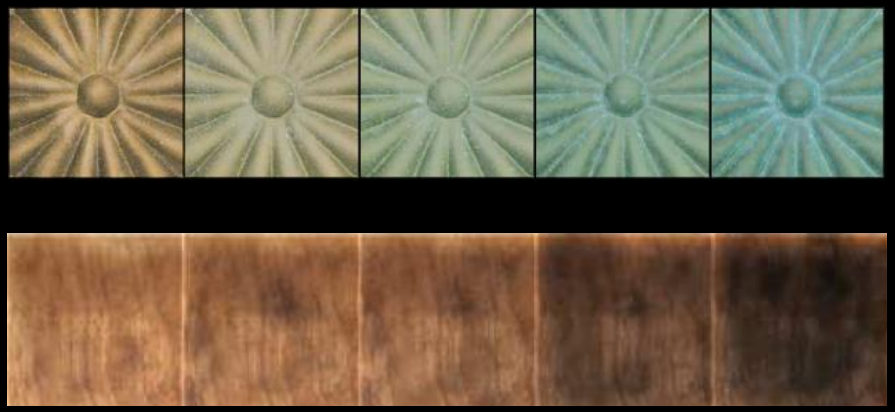
Related Work

- Visual simulation of weathering distribution
  - [Miller94, Hsu95, Wong97, Chen05]
  - Focus on global distribution
- Physically-based simulation
  - [Dorsey96, Dorsey99, Merillou01, Paquette02, Lu05]
  - Only for some specific materials
- Directly capture images of real samples
  - [Georghiades05, Gu06]

Related Work: Image Capture

Georghiades05:
Observing and Transferring Material Histories

Gu06:
Time-Varying Surface Appearance: Acquisition, Modeling, and Rendering



Frame-by-frame capture over time

- ☺ Realistic appearance from real samples
- ☹ Laborious capture of full time sequences

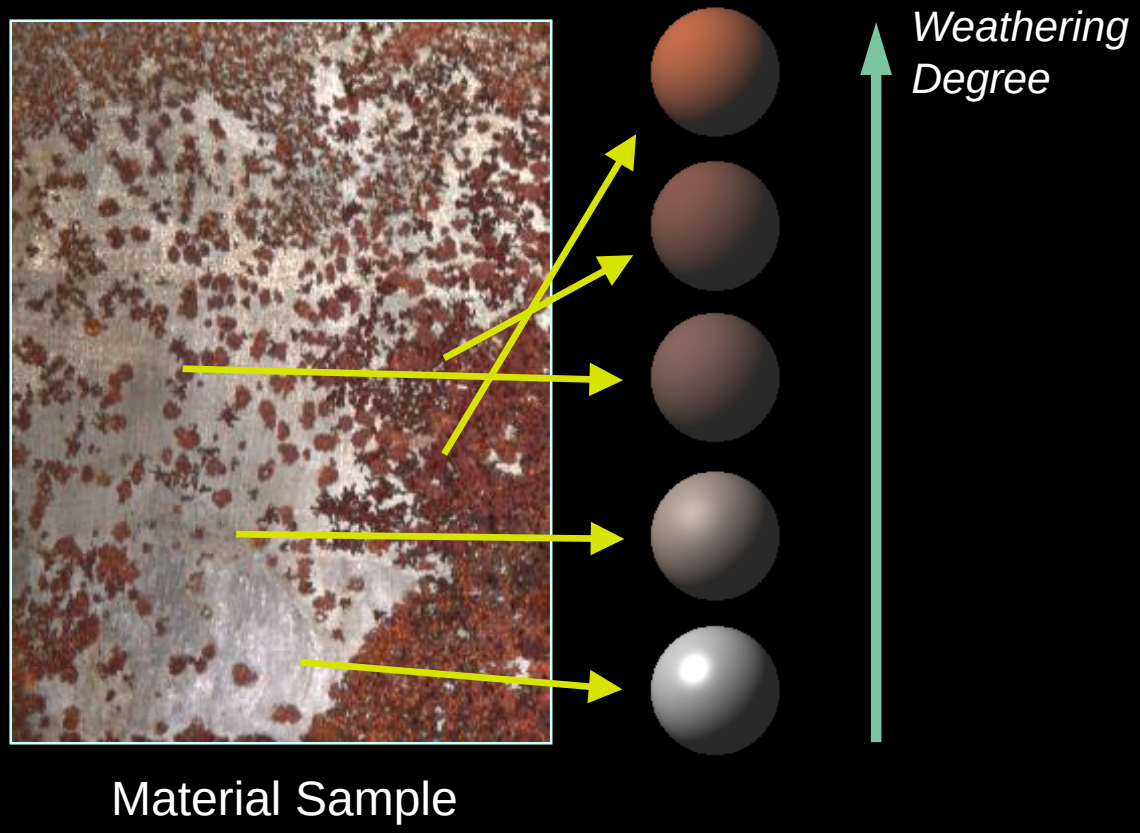
Our Contributions

An easy-to-use technique for modeling time-variant appearance of materials

- Capture at a single time instant
- Generate realistic appearance
  - spatially-variant BRDFs
  - surface texture patterns evolve over time
- Visual simulation technique
  - not necessarily physically accurate

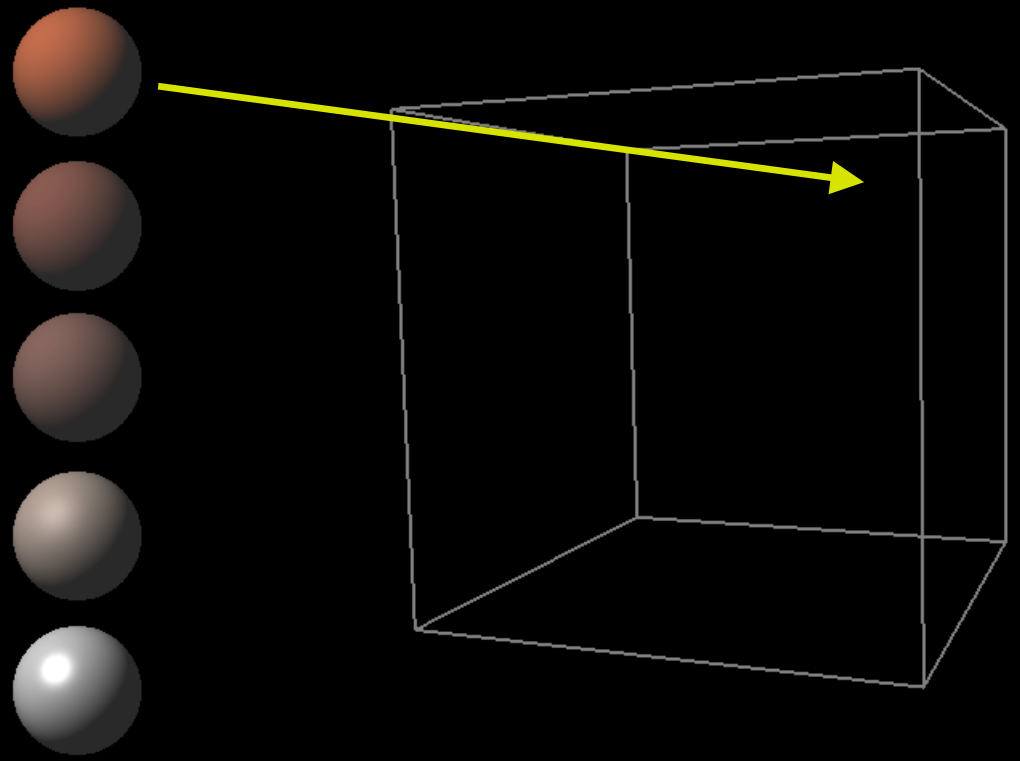
An Example

Key Observation



Key Observation

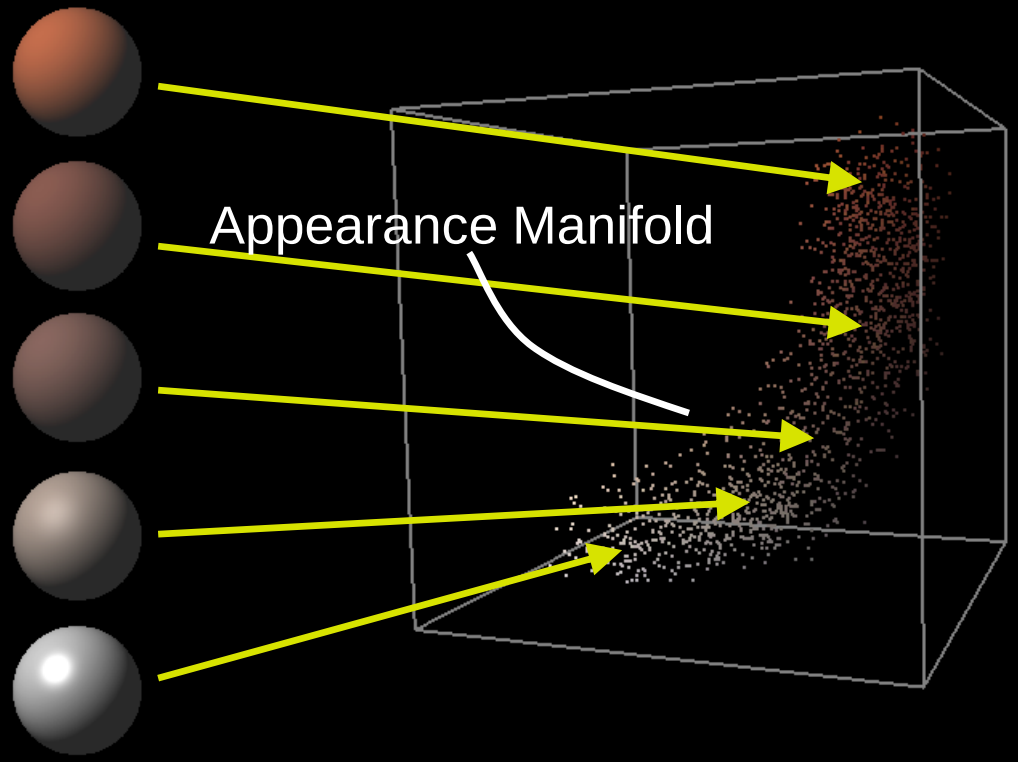
Material Sample



High-dimensional Appearance Space

Key Observation

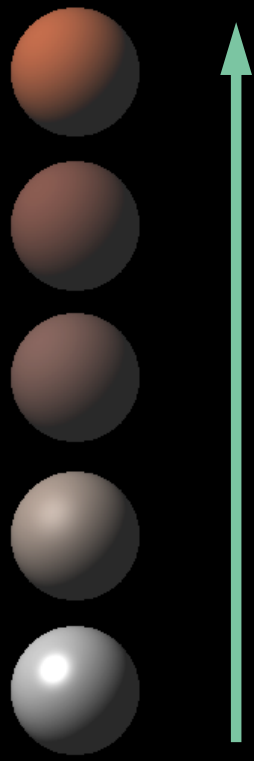
Material Sample

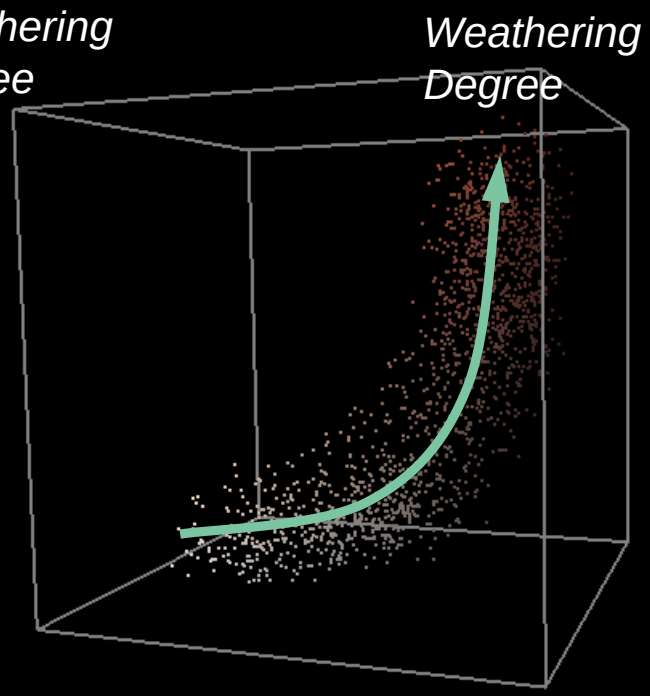


High-dimensional Appearance Space

Key Observation

Material Sample

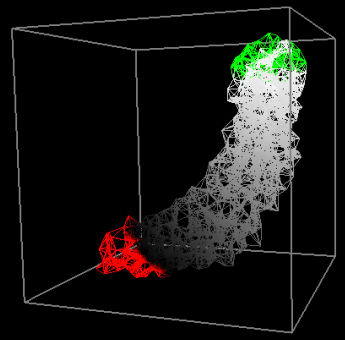




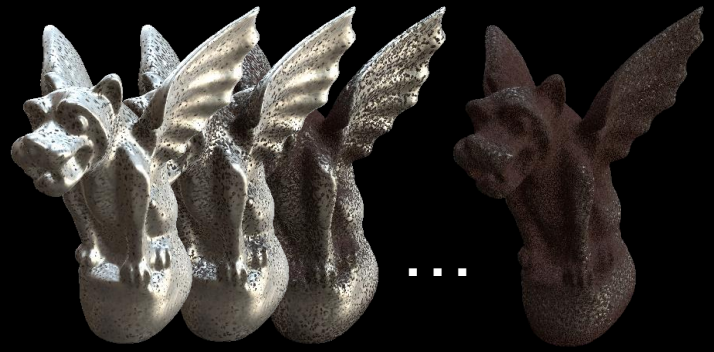
Appearance Manifold

System Overview

Material Sample

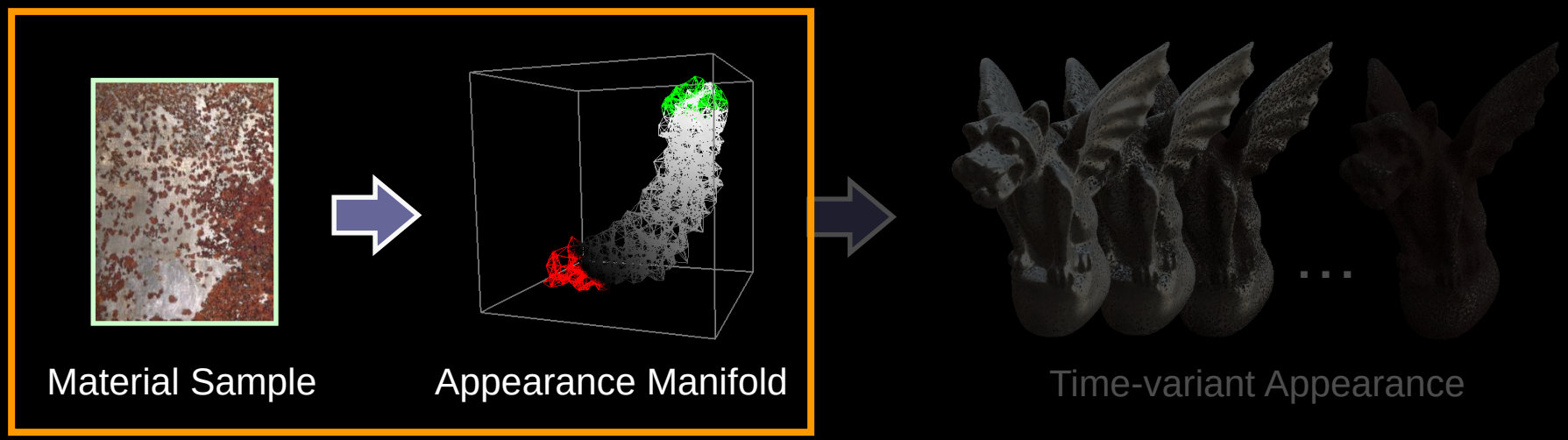


Appearance Manifold



Time-variant Appearance

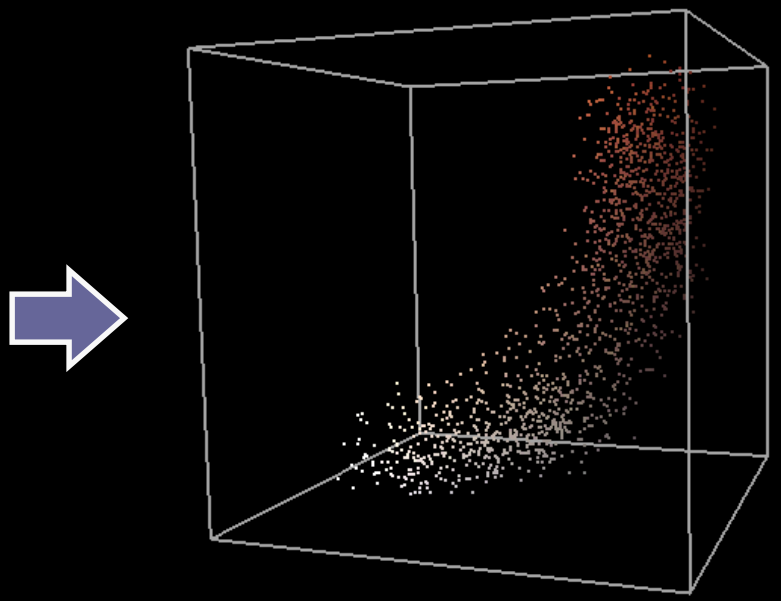
System Overview



Construct Appearance Manifold

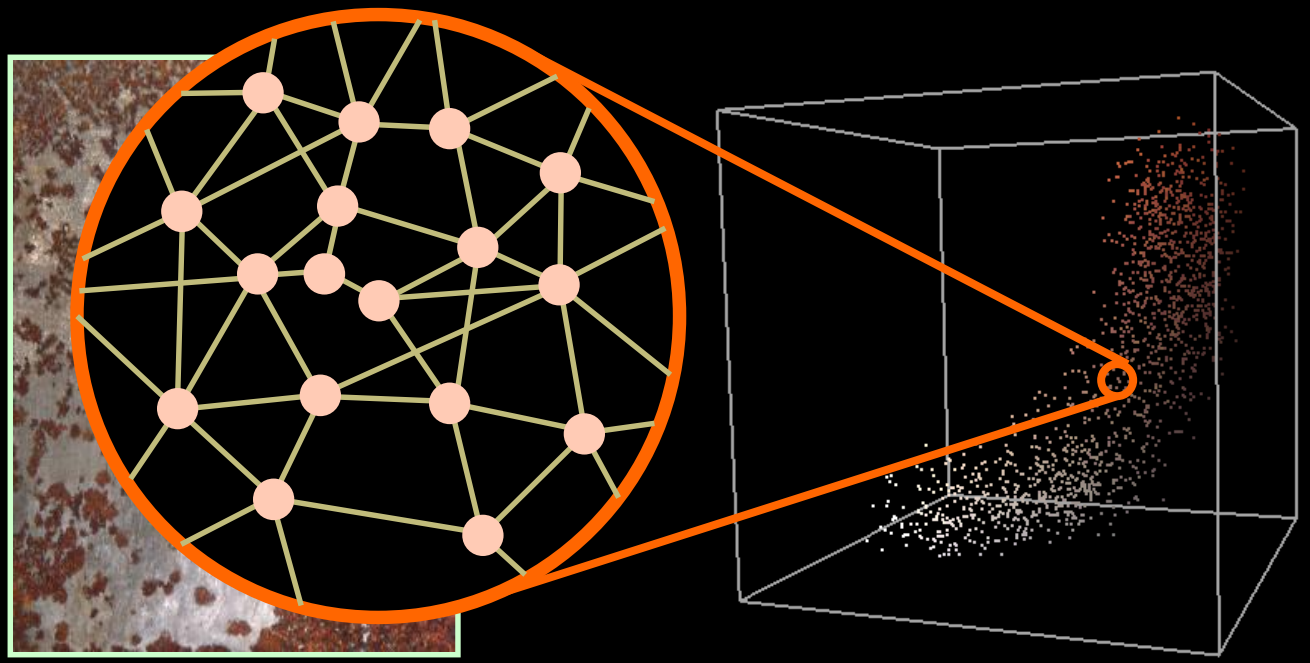
Appearance Space Projection

Material Sample



Appearance Space

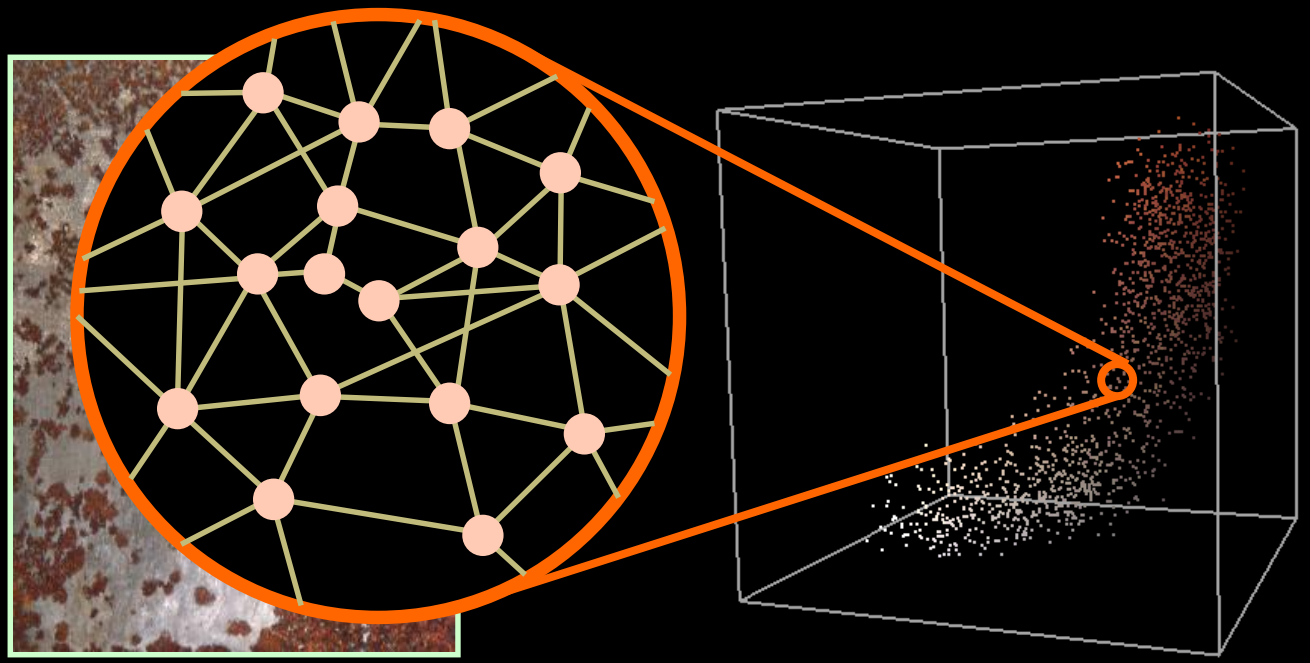
Construct Appearance Manifold



Material Sample

Appearance Space

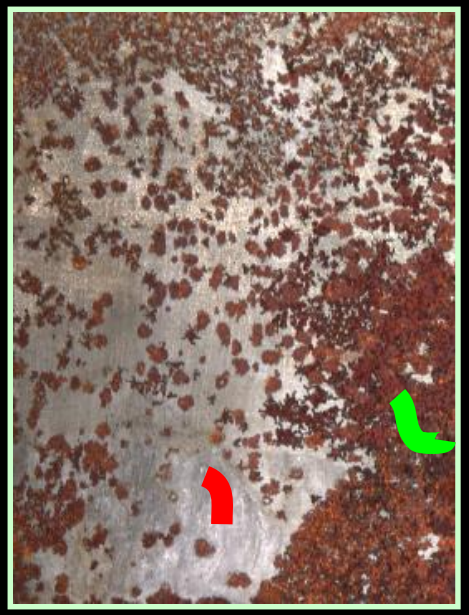
Construct Appearance Manifold



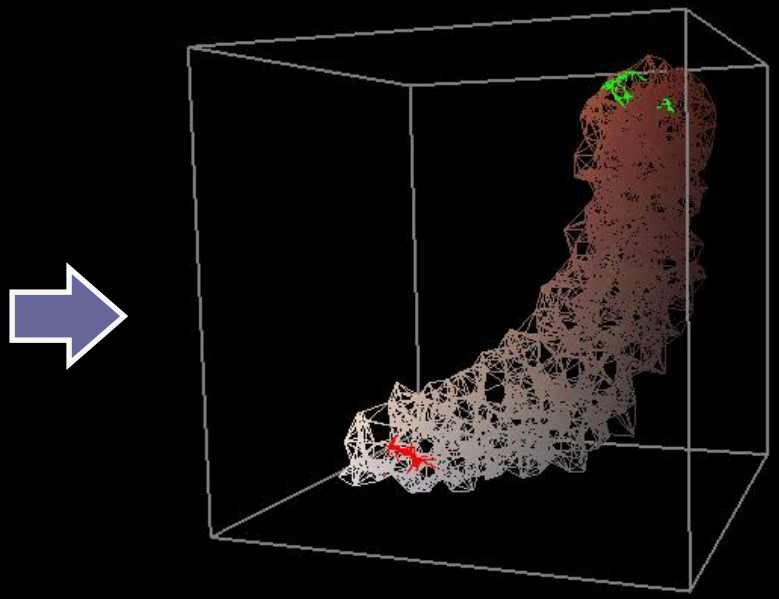
Material Sample

Appearance Space

Determine Weathering Degree

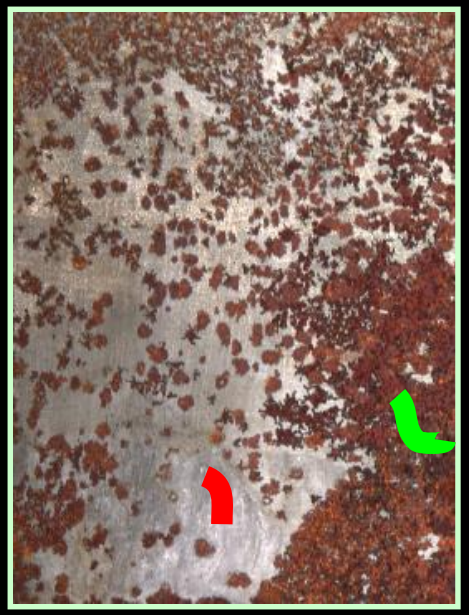


Material Sample

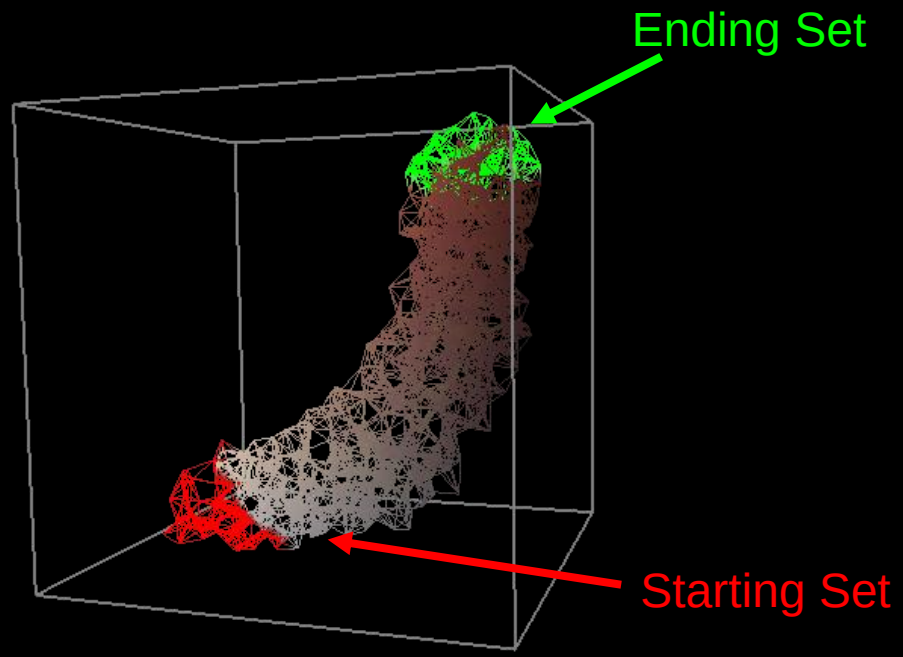


Appearance Space

Determine Weathering Degree



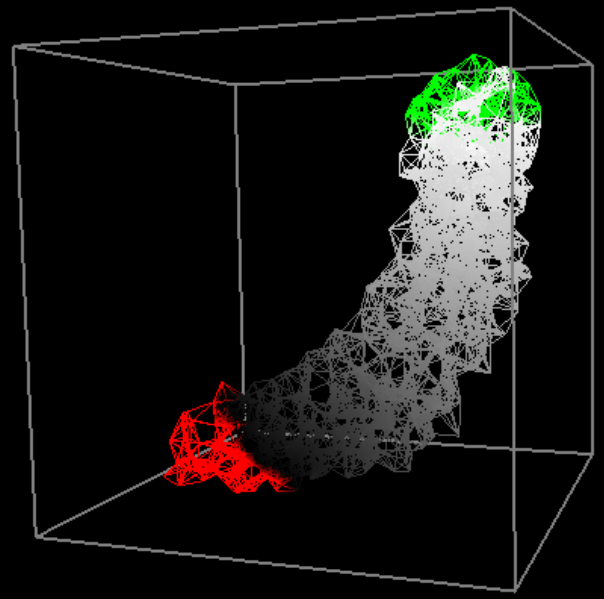
Material Sample



Appearance Space

Determine Weathering Degree

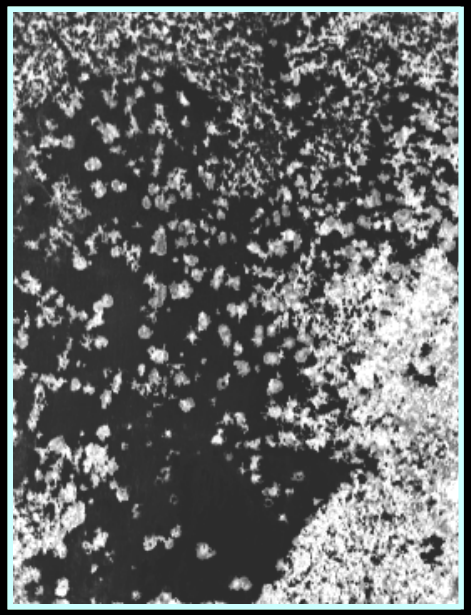
Material Sample



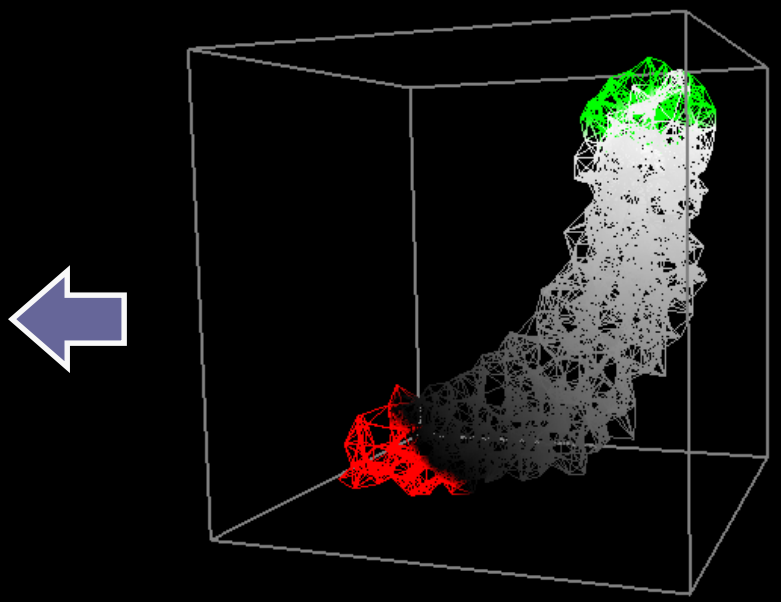
Appearance Space

- Weathering degree of x is $\frac{L_0}{L_0 + L_1}$

Determine Weathering Degree

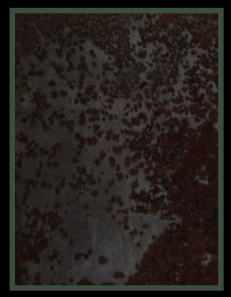


Weathering Degree Map

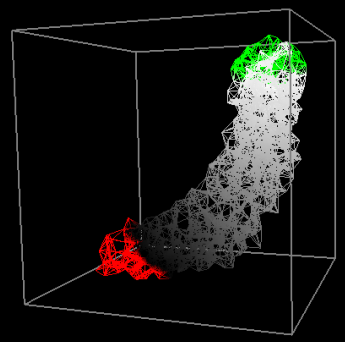


Appearance Space

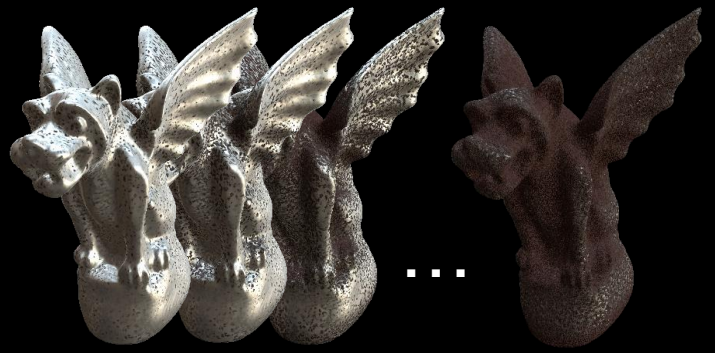
System Overview



Material Sample



Appearance Manifold



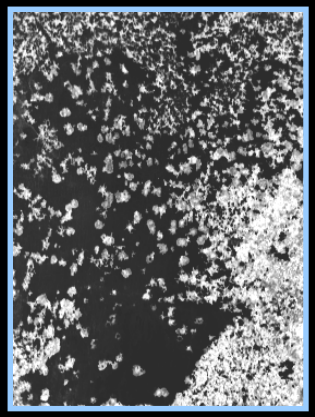
Time-variant Appearance

Synthesize Time-variant Appearance

Synthesize Time-Variant Appearance

SIGGRAPH2006

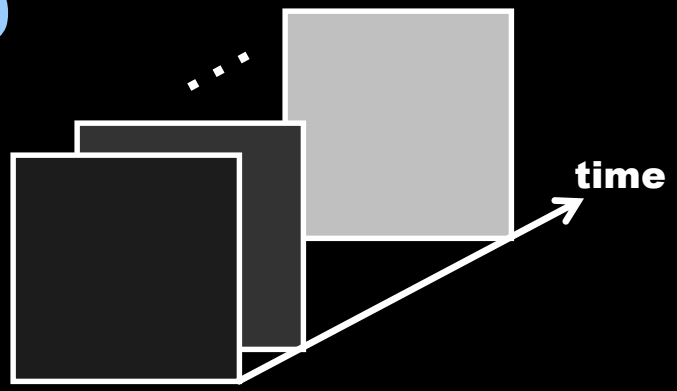
2D



Source Degree Map

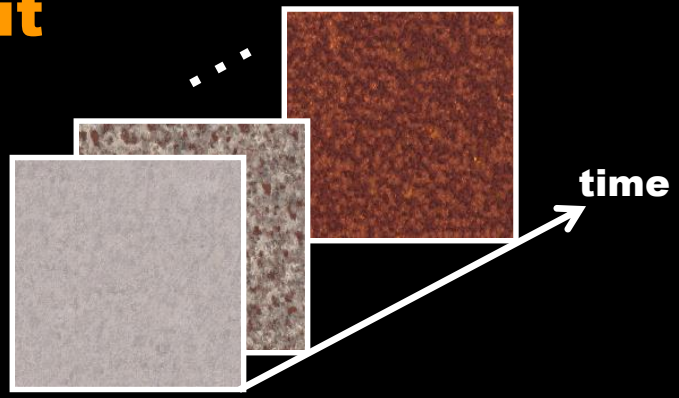
Source Texture Sample

Input 3D



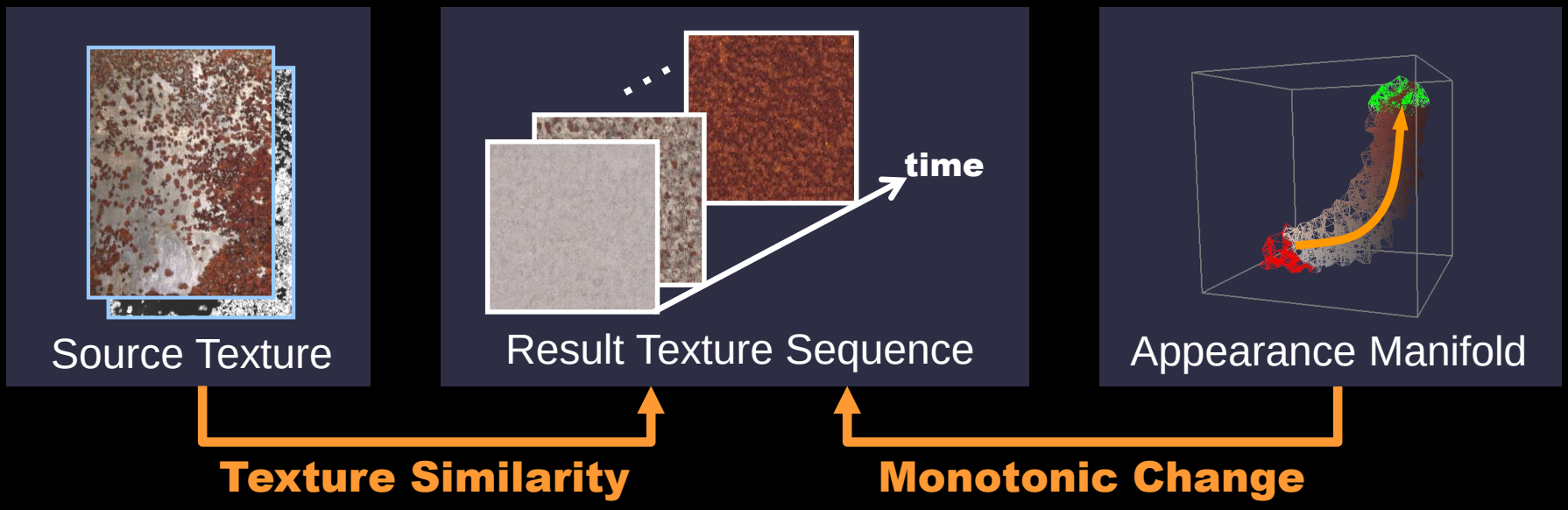
Target Weathering Degree Sequence

Output



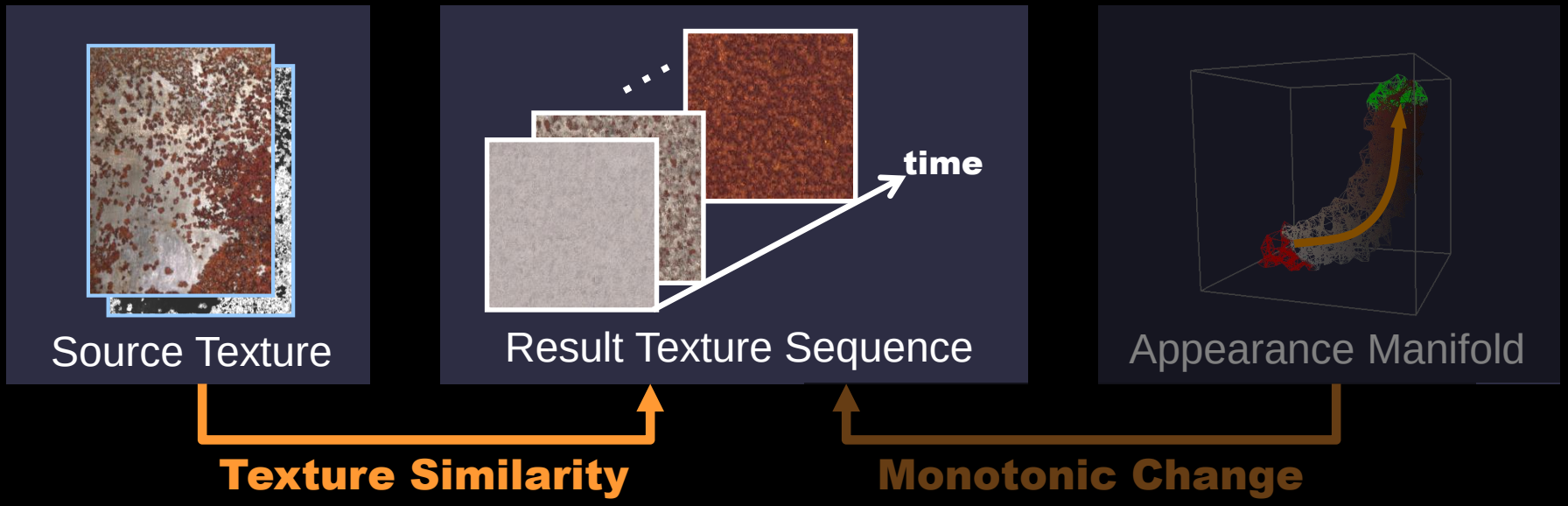
Result Texture Appearance Sequence

Frame-Coherent Texture Synthesis



- Similarity: texture elements similar to source
- Monotonic: monotonic change of appearance

Naïve Approach I



✓ Similarity: texture elements similar to source

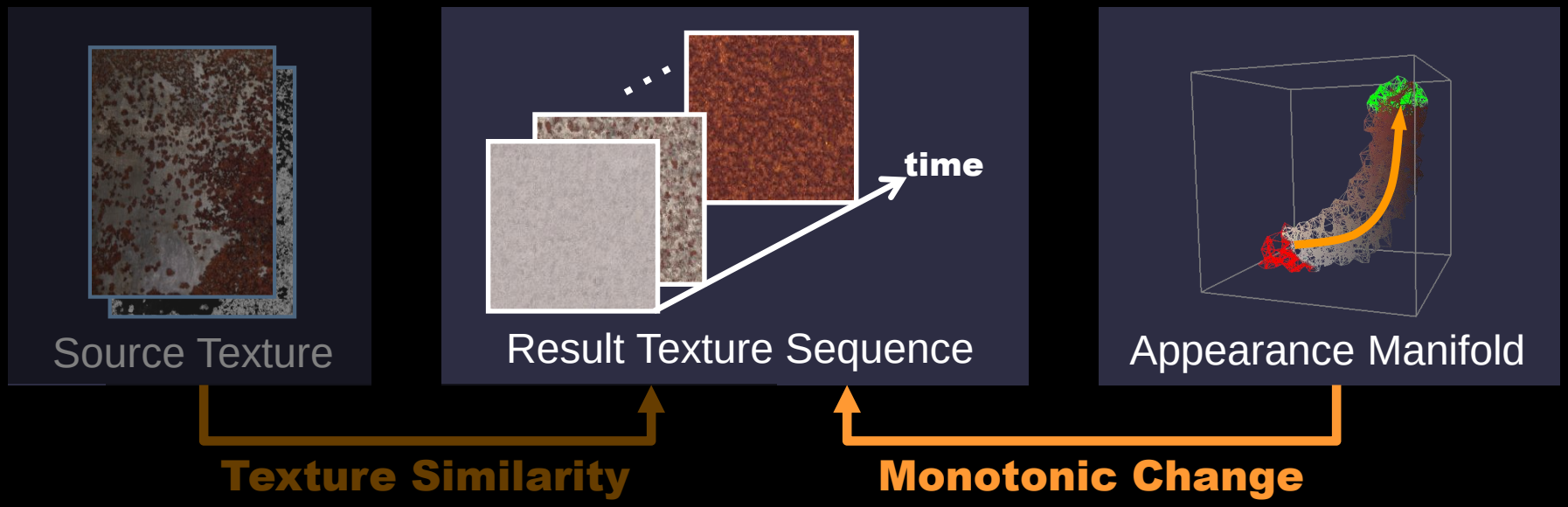
✗ Monotonic: monotonic change of appearance

Naïve Approach I

- Ignore monotonic change of appearance
- Independently synthesize each frame

Result Sequence

Naïve Approach II

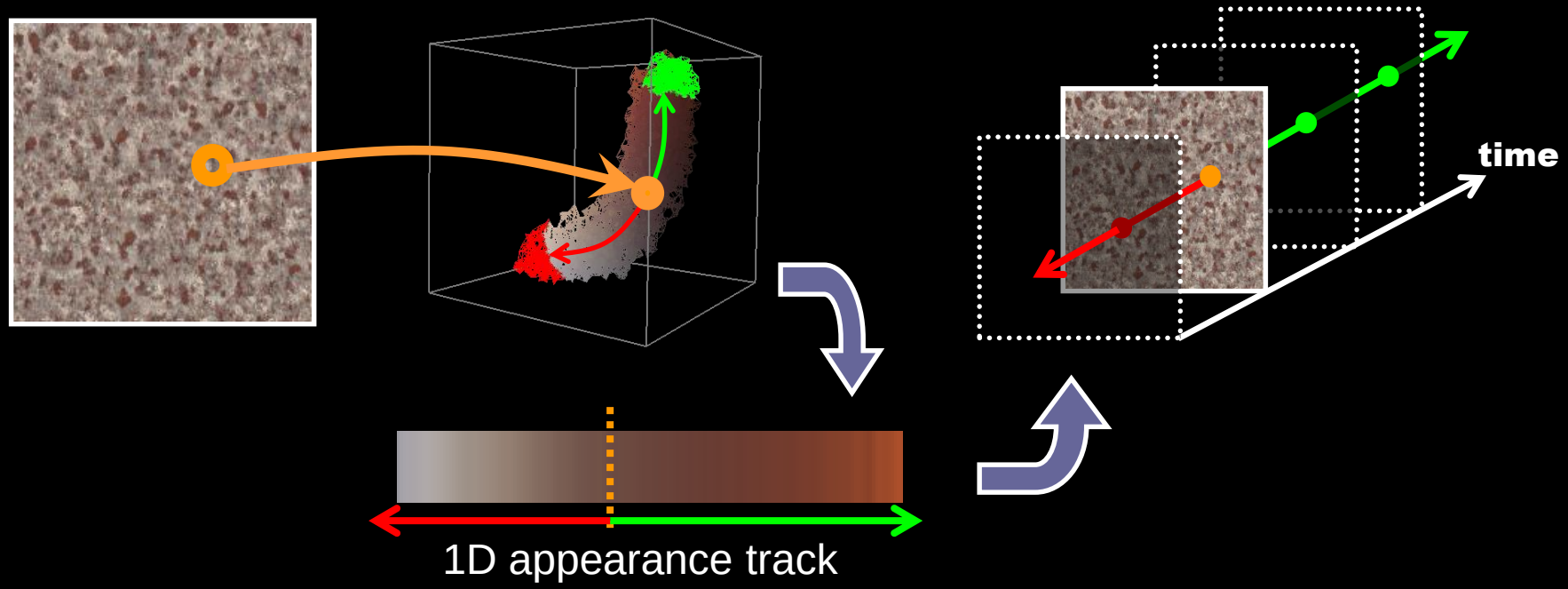


✗ Similarity: texture elements similar to source

✓ Monotonic: monotonic change of appearance

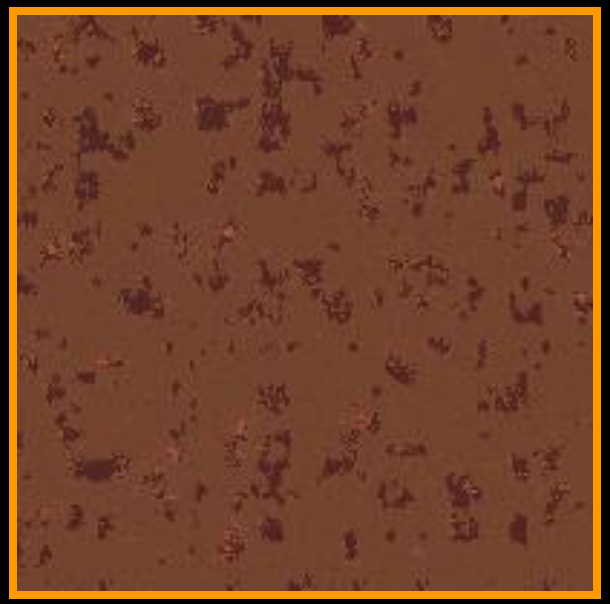
Naïve Approach II

- Ignores patterns in texture
- Pixel-wise extrapolation of one frame



Naïve Approach II

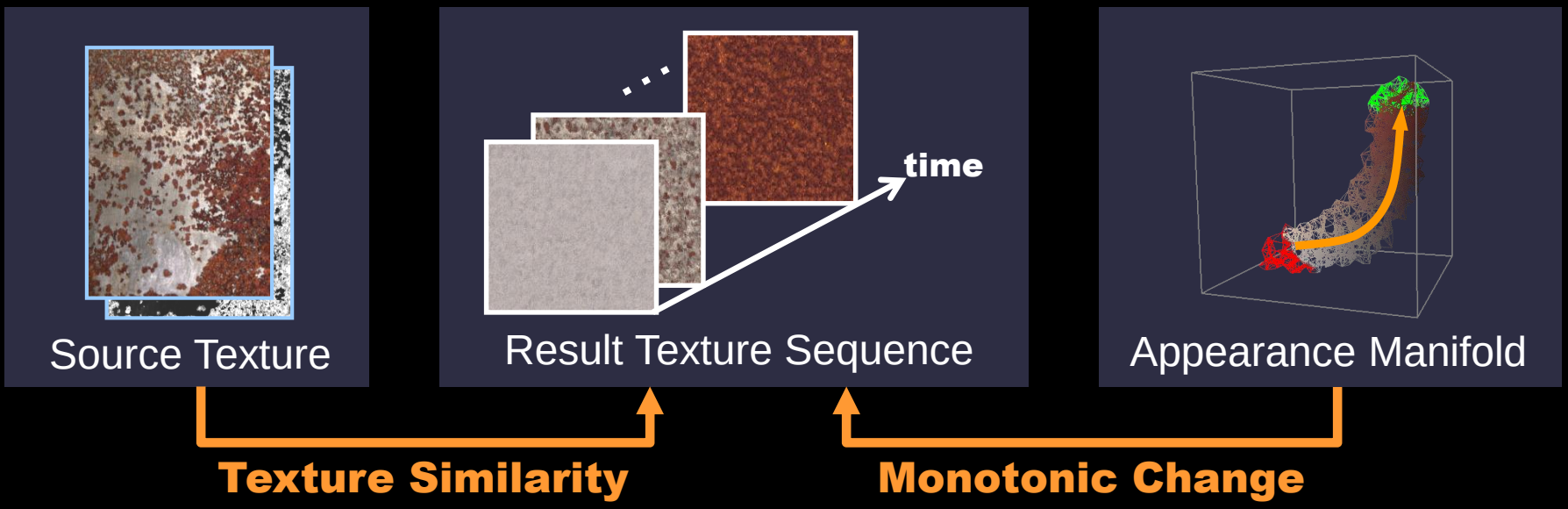
- Ignores patterns in texture
- Pixel-wise extrapolation of one frame



Pixel-wise Extrapolation

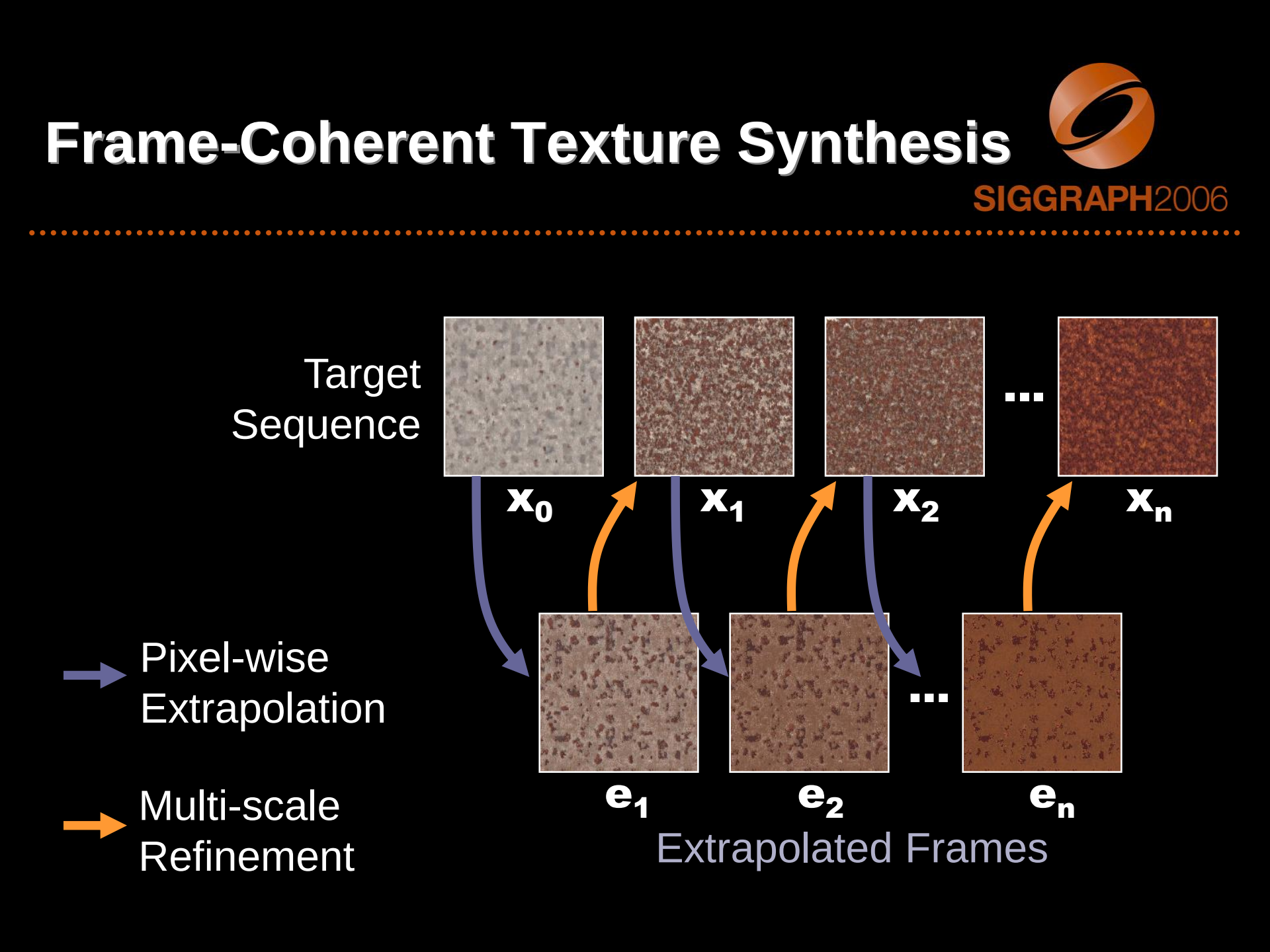
Ground Truth

Frame-Coherent Texture Synthesis

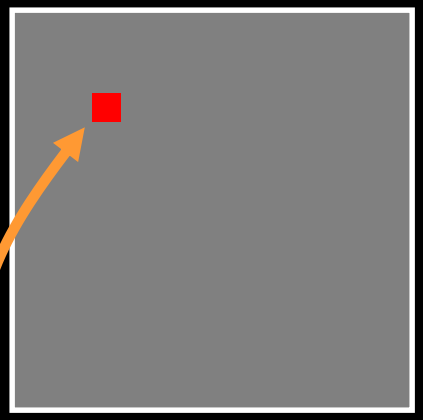


- ✓ Similarity: texture elements similar to source
- ✓ Monotonic: monotonic change of appearance

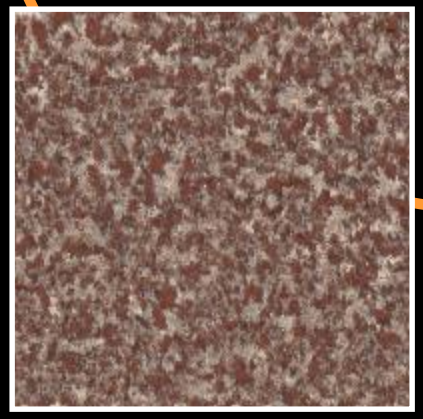
Frame-Coherent Texture Synthesis



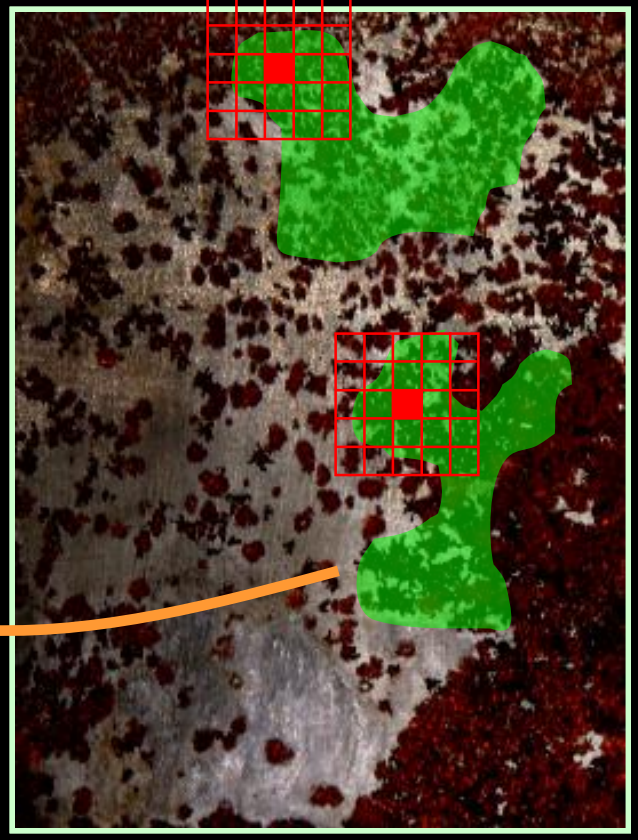
Consistency Constraint



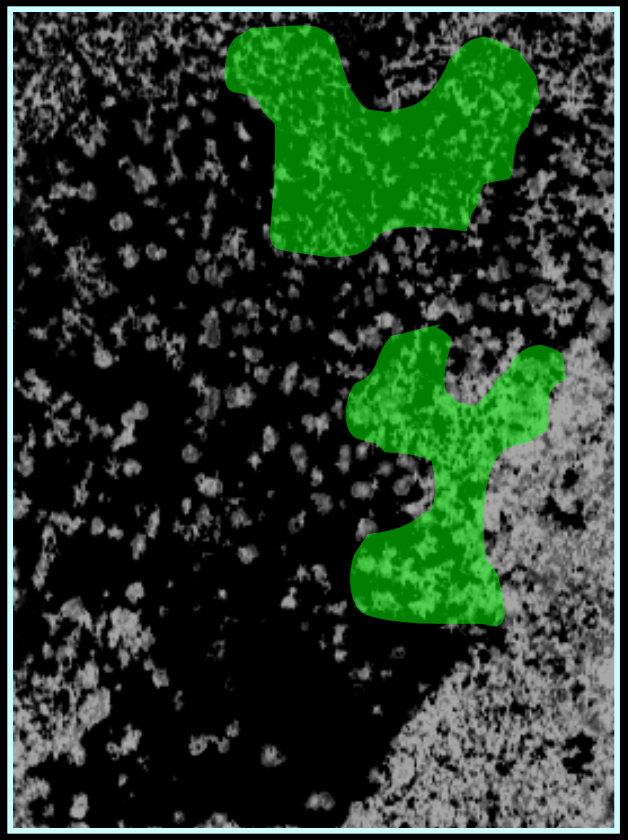
Target Degree Map



Target Frame $\mathbf{x}_t$

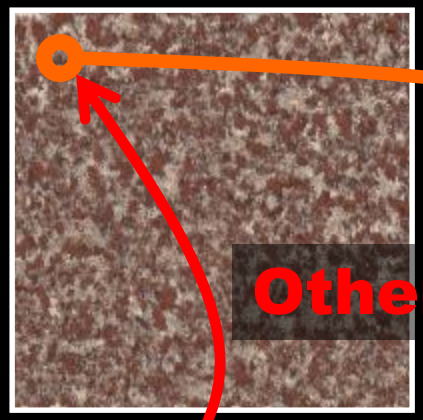


Source Texture

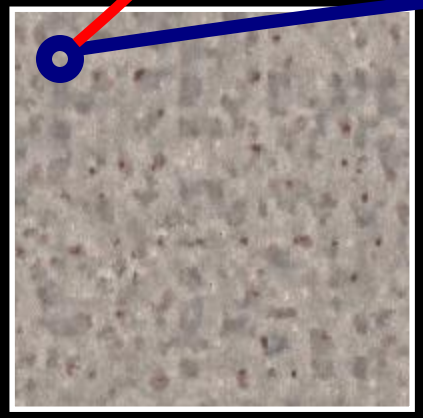


Source Degree Map

Monotonicity Constraint

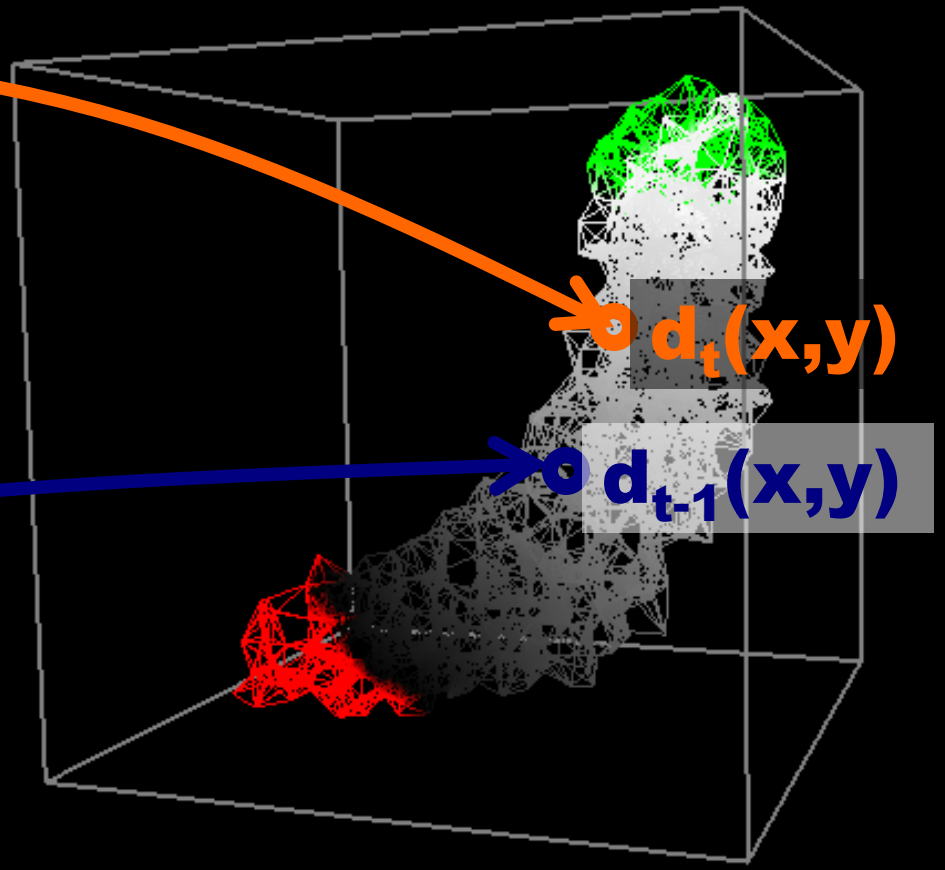


Target Frame $\mathbf{x_t}$



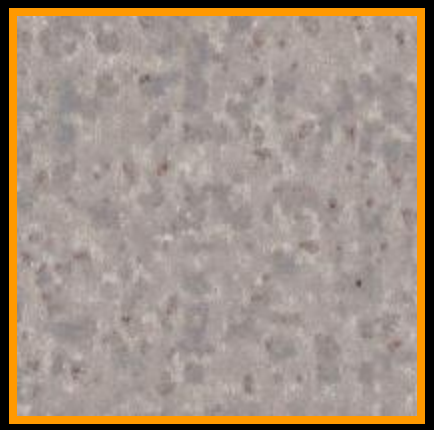
Target Frame $\mathbf{x_{t-1}}$

Otherwise

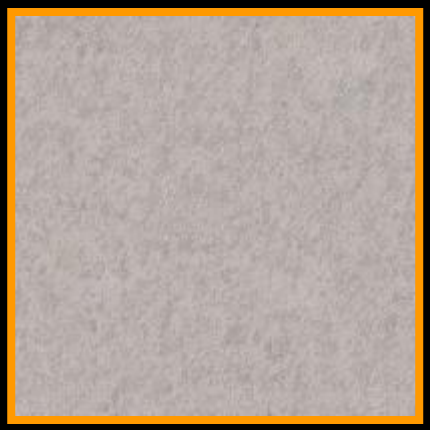


$$d_t(x,y) \geq d_{t-1}(x,y)$$

Comparison to Naïve Approaches



Only
Monotonicity



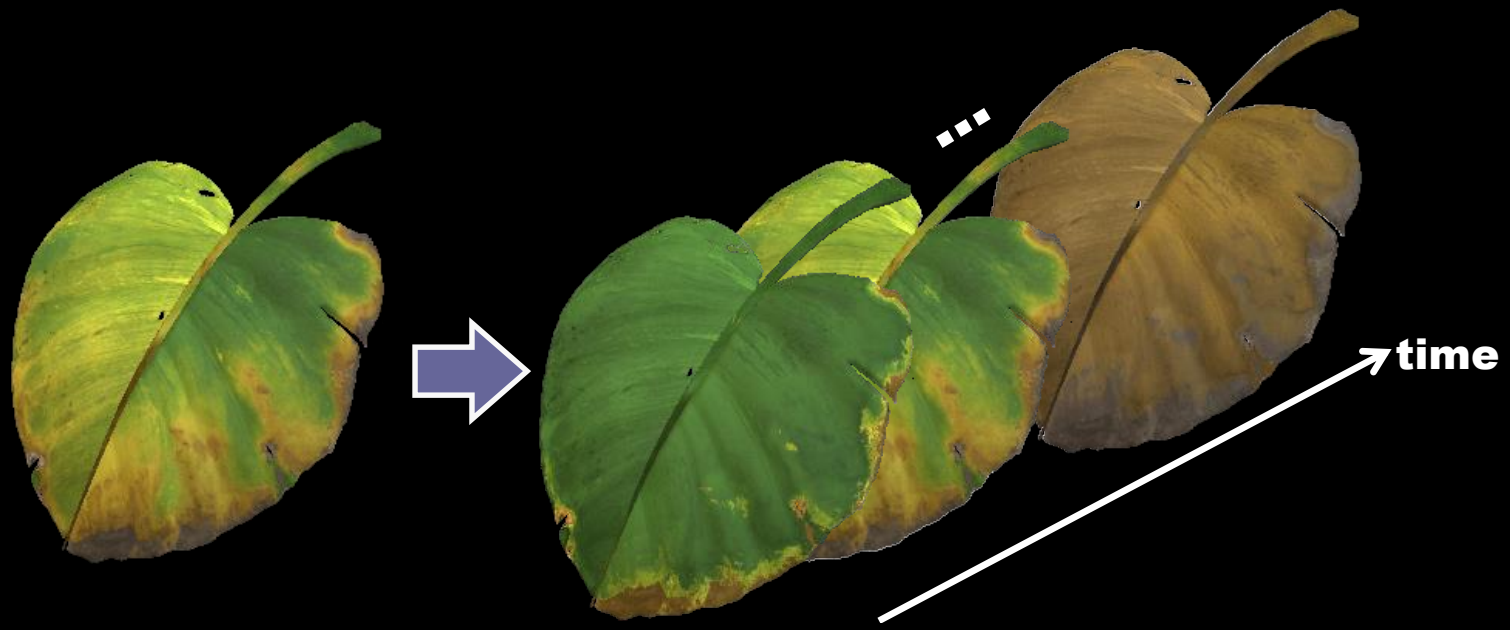
Frame-Coherent
Synthesis

Only
Texture Consistency

Synthesis Result on 3D Surface

Weathered Bananas

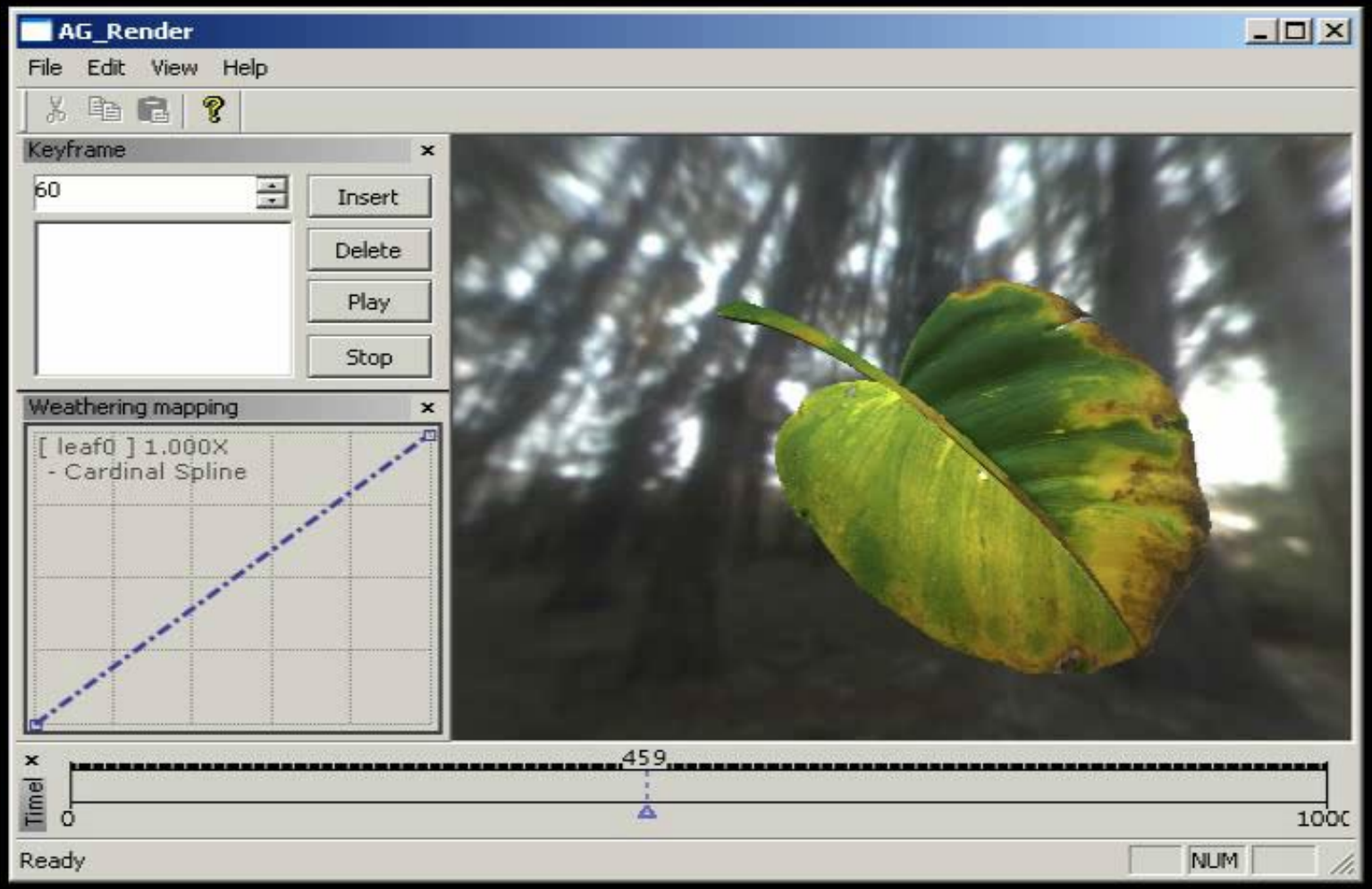
Weathering/Deweathering



Material Sample

Time-variant Appearance

Weathering/Deweathering

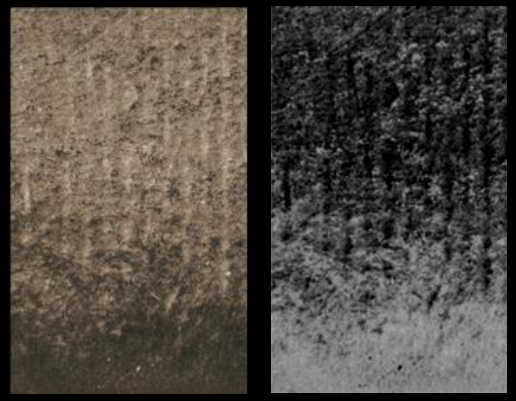


Weathered Leaf

Weathering Transfer

Input Weathered Object

Transferred Object



Another Time-variant Appearance

Rendering Results

Conclusion

- An easy-to-use tool for modeling time-variant appearance of materials
  - Acquisition at a single point in time
  - Realistic spatially-variant BRDFs
  - Plausible temporal variations
- Frame-coherent texture synthesis
- Tool for editing weathered appearance of existing objects

Acknowledgements

- Kun Zhou , Dong Xu
  - Helpful discussions
- Yuan Tian , Rui Jin
  - Geometry models and photography
- Paul Debevec
  - Linear light source reflectometry
  - HDR environment maps

Thanks