Modeling and Rendering of Outdoor Scans

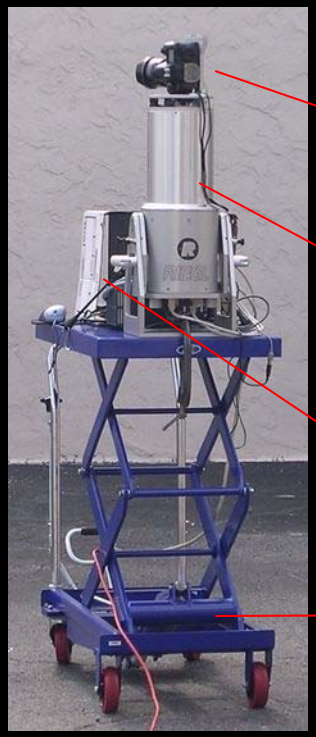
Baoquan Chen (陳寶權)
University of Minnesota Twin Cities
http://www.cs.umn.edu/~baoquan

Ayia Napa, June 30th, 2006

Minnesota Scanning Project

- Long range outdoor scanning

Outdoor Scanning



Riegl LMSZ360 3D Scanner

- Range: 200m
- Precision: 12mm
- FOV: 360° x 90°
- Speed: 10,000 pts/sec

Scanning Activities

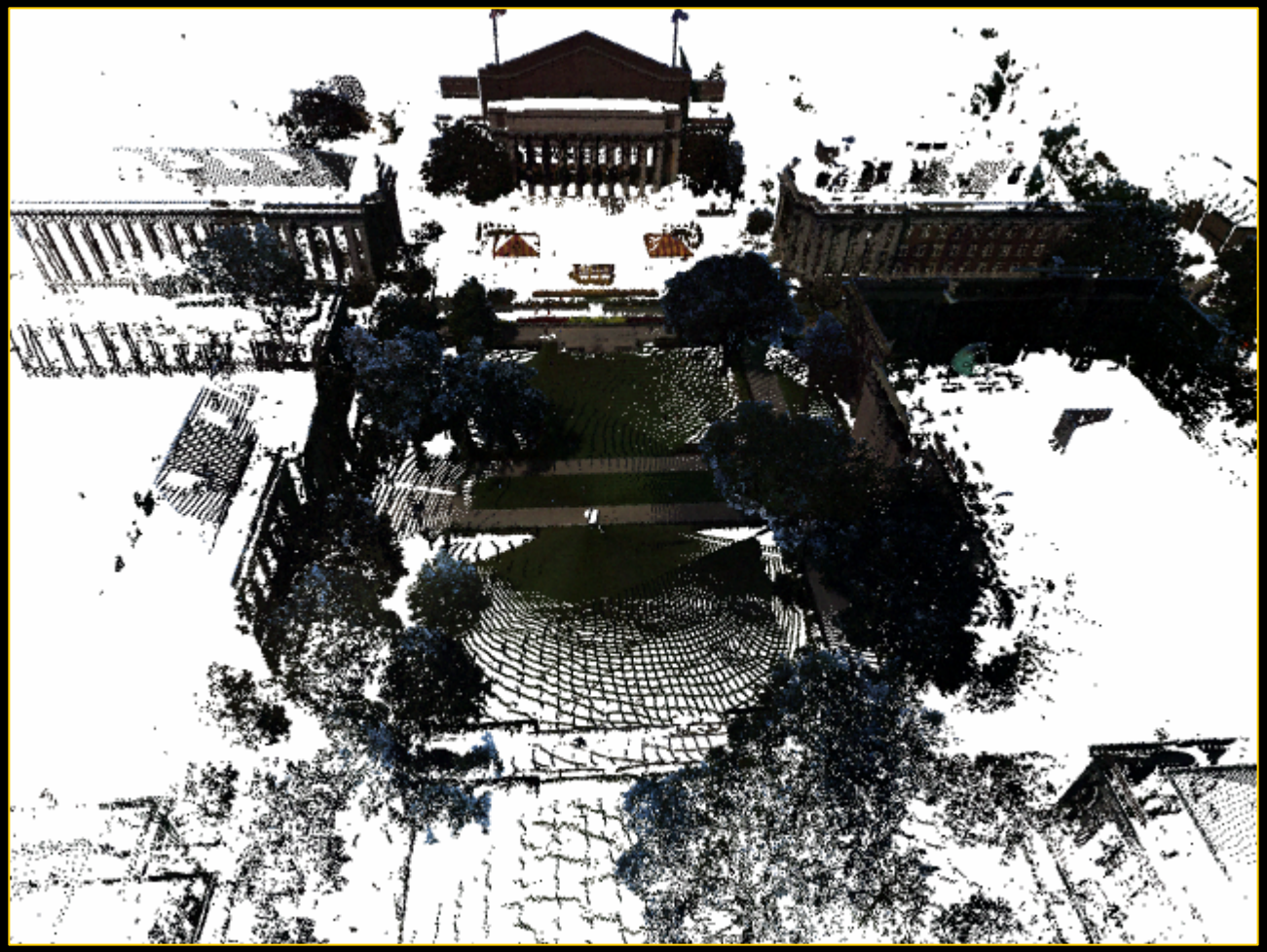
Mount Rushmore [Jul 4 03]

Stone Arch Bridge [Aug 03]

Mill City Ruins [Aug 03]

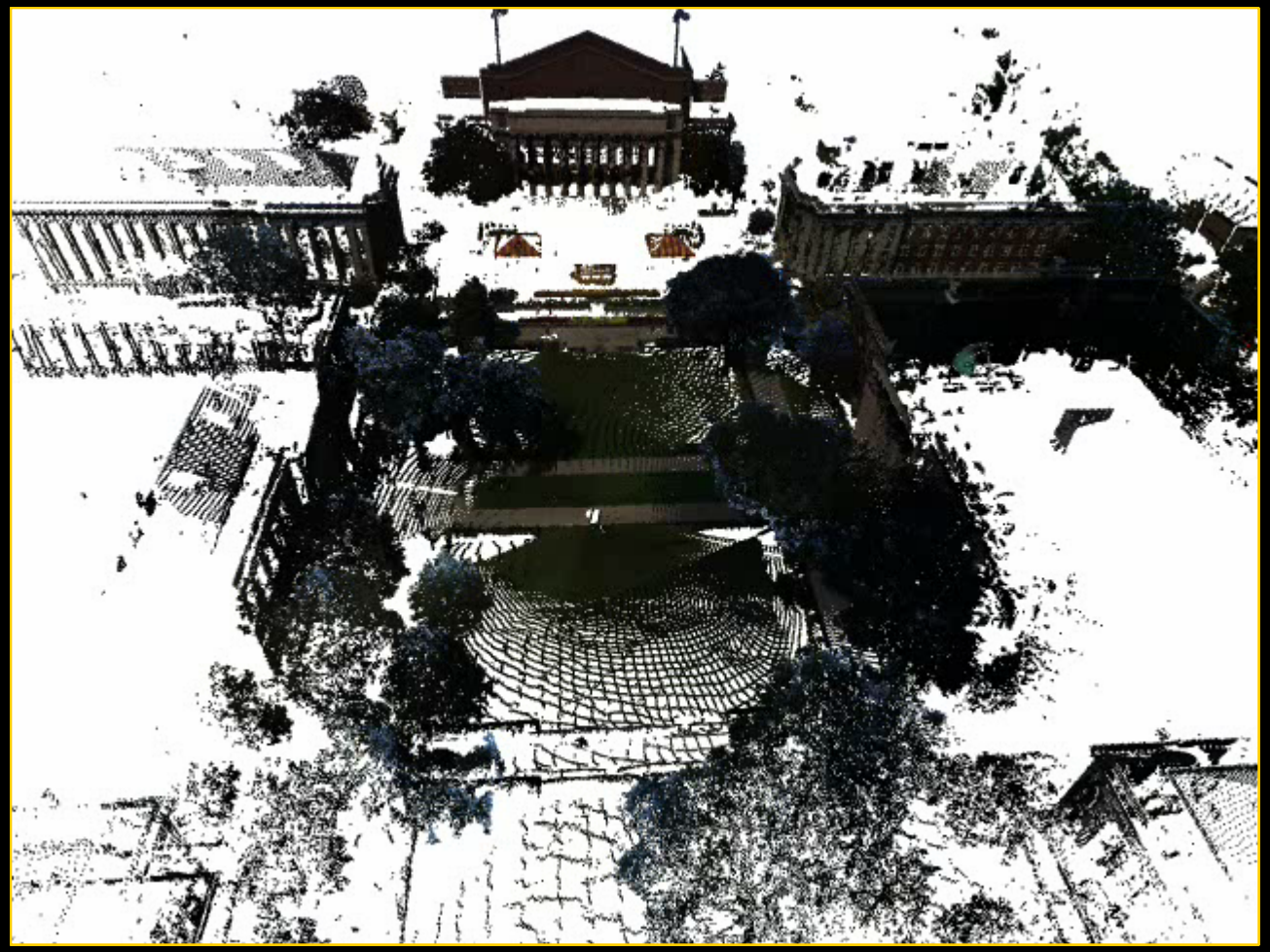
Ephesos excavation site [Wimmer 04, Vienna]

Data Properties/Challenges



Northrop Mall, University of Minnesota

Range Image Registration: Consistency

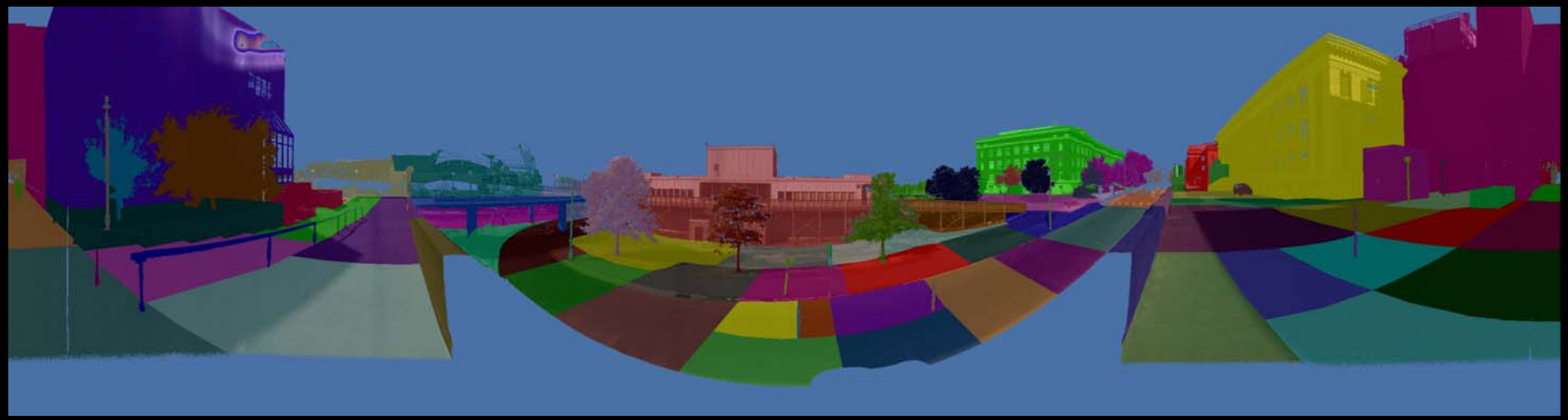


10,892,004 points from six scans

Multiple Scan Registration

Object Segmentation

- Purposes: **[Yuan, Xu, Nguyen, Shesh, Chen, SBM 05]**
  - Apply *modeling* methods individually
  - Apply *rendering* methods individually
- Sketch-Based Segmentation
  - Allow sketching on arbitrary viewing direction
  - Extend Max-flow Min-cut [Boykov & Kolmogorov 04] to 3D



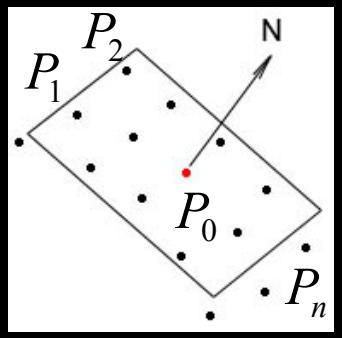
Geometry Representation and Rendering

1. Avoid constructing polygonal meshes:
   point-based representation and rendering
   - Feasibility: "raw" and complex geometry
   - Flexibility: neglecting connectivity
   - Deal with uncertainty

2. Develop novel ways of constructing
   polygonal meshes from sparse scans:
   Knowledge-based geometry construction

Point Geometry Estimation

- Point Size
  - $r \times \theta$. r : range; θ : pixel azimuth/altitude angle
- Point Normal
  - Fit a plane to neighboring points and use the normal of the plane
  - Construct a matrix



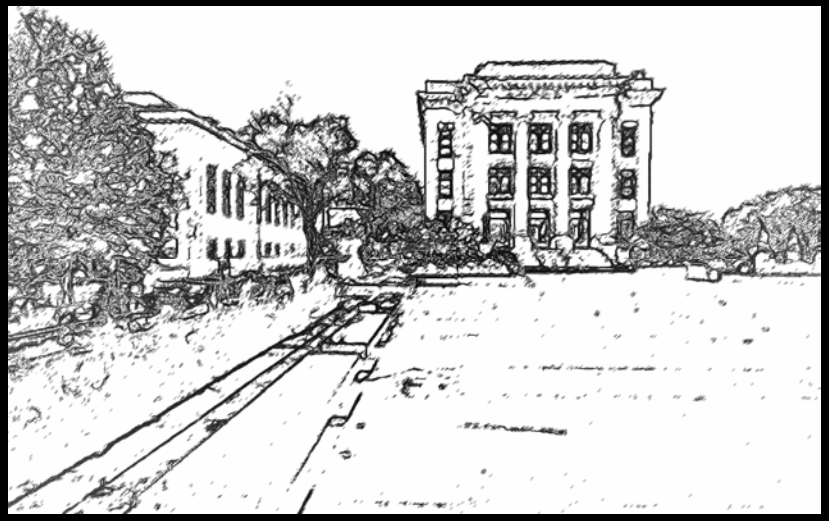
$$M = \sum_{i=0}^{n} (P_i - \overline{P})(P_i - \overline{P})^T, \text{ where } \overline{P} = \frac{1}{n+1} \sum_{i=0}^{n} P_i$$

  - N is the eigenvector corresponding to the smallest eigenvalue of M

Photorealistic Rendering

- Ephesos excavation site, data provided by Wimmer, Vienna
- Rendered by PointWorks software developed at Minnesota

Artistic Rendering



Sketchy

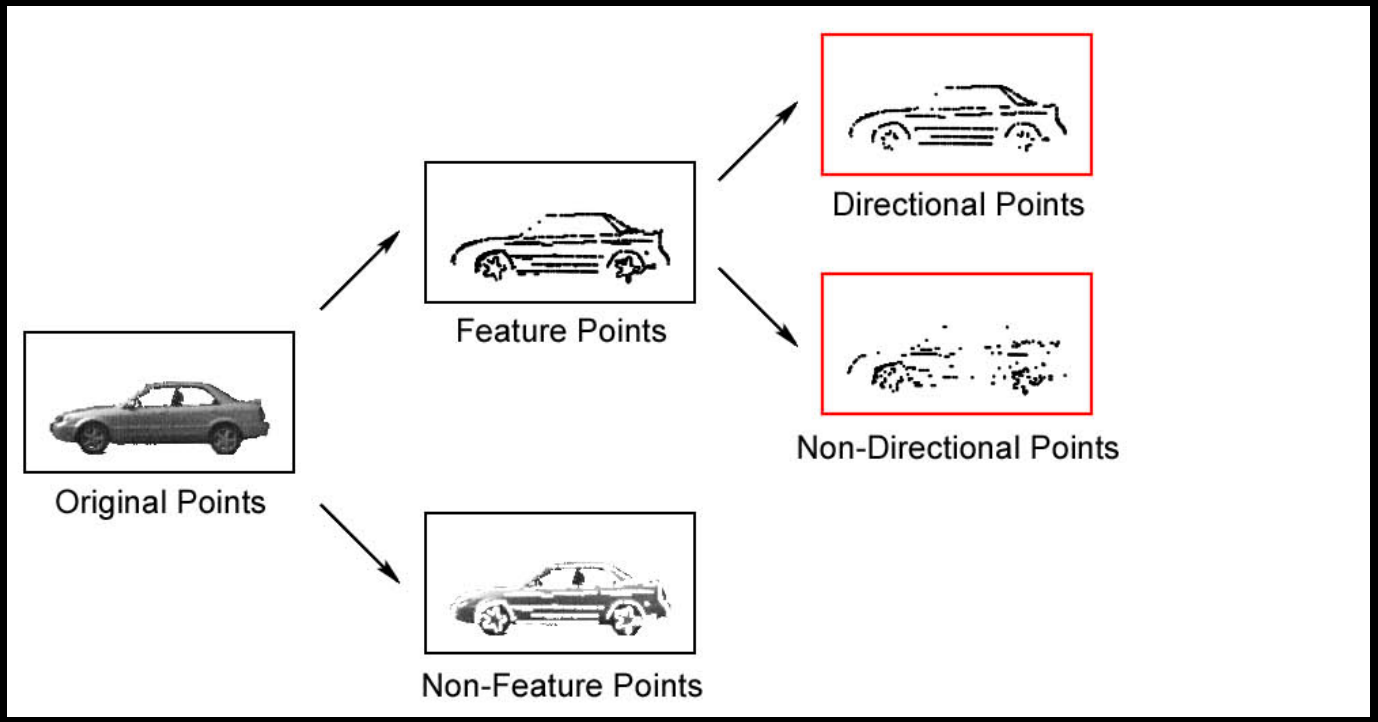
Painterly

Cartoon

Intermingled

Feature Extraction & Point Classification

- Feature
  - Significant geometric and photometric change
  - View dependent and independent



Sketchy Rendering [Xu & Chen, NPAR 04]

Directional Points:

Walter Library, U of M

Sketchy Rendering

Directional Points:

Non-directional points:

Walter Library, U of M

Sketchy Rendering

Directional Points:

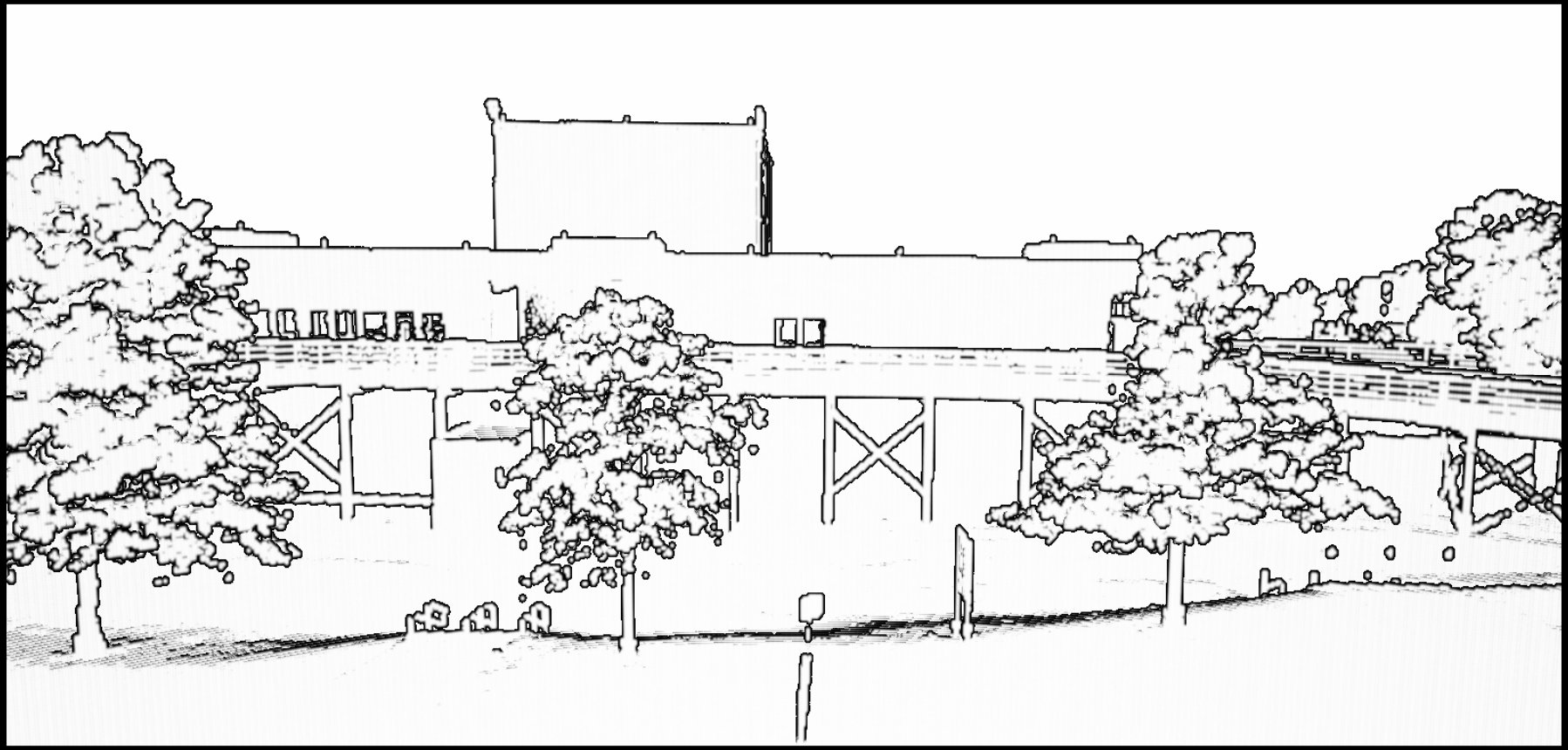
Non-directional points:

Dithering points:

Walter Library, U of M

Silhouette Rendering

[Xu, Nguyen, Yuan, Chen, PBG2004]



Mississippi River Bank, U of M

Profiling Lines

Northrop Mall, U of M

Cartoon Rendering

Silhouettes + Segmentation + Mean color

Mississippi River Bank, U of M

Cartoon Rendering

Back of Walter Library, U of M

Painterly Rendering [Xu, Gossett & Chen, EGSR 04]

Painterly Rendering

Painterly Rendering

Stone Arch Bridge, Minneapolis

Painterly Rendering

Northrop Mall, U of M

Painterly Rendering

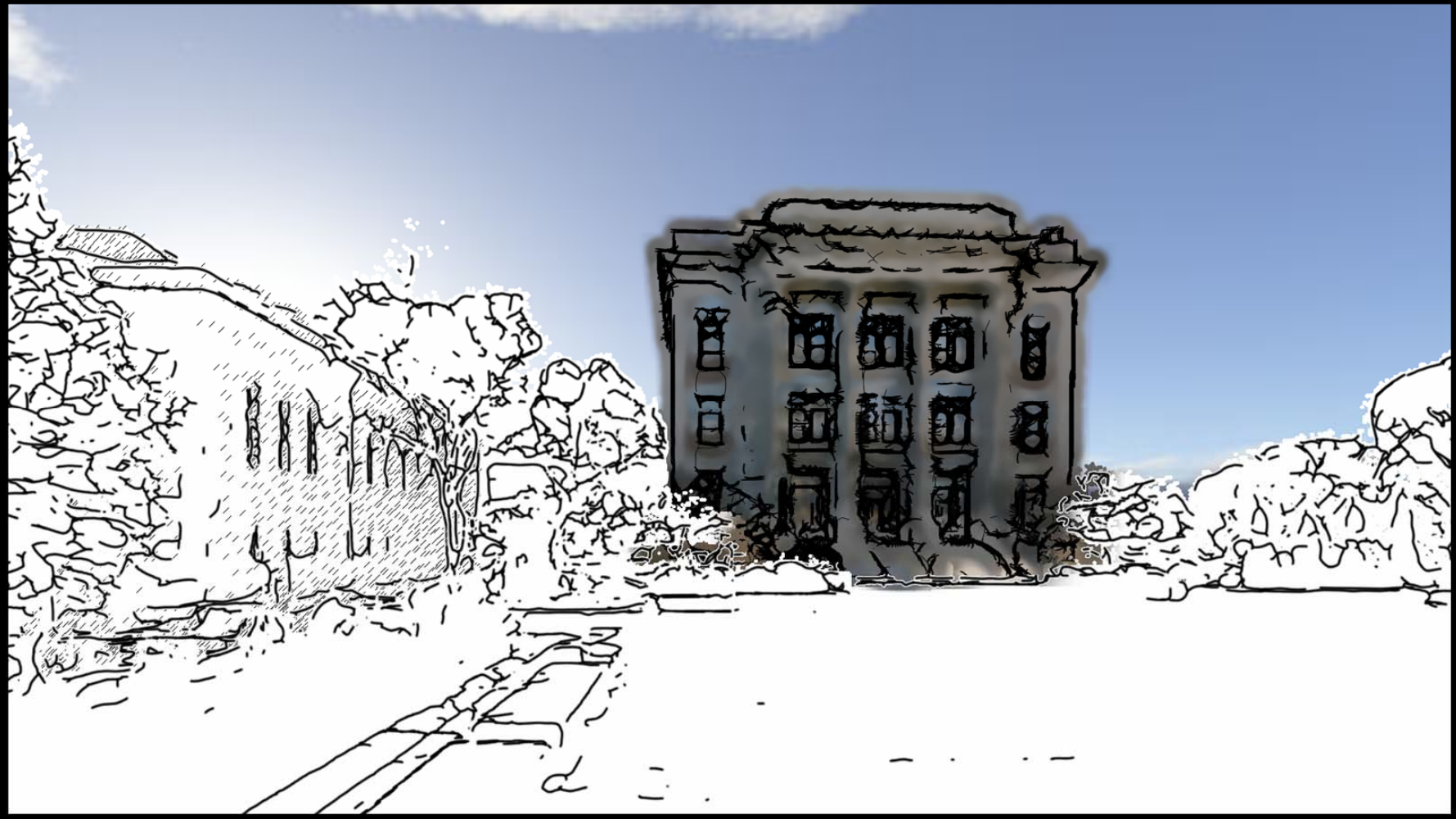
Northrop Mall, U of M

Intermingled Styles

Silhouettes + Painterly

Mississippi River Bank, U of M

Intermingled Styles



Northrop Mall, U of M

"What Dreams May Come"

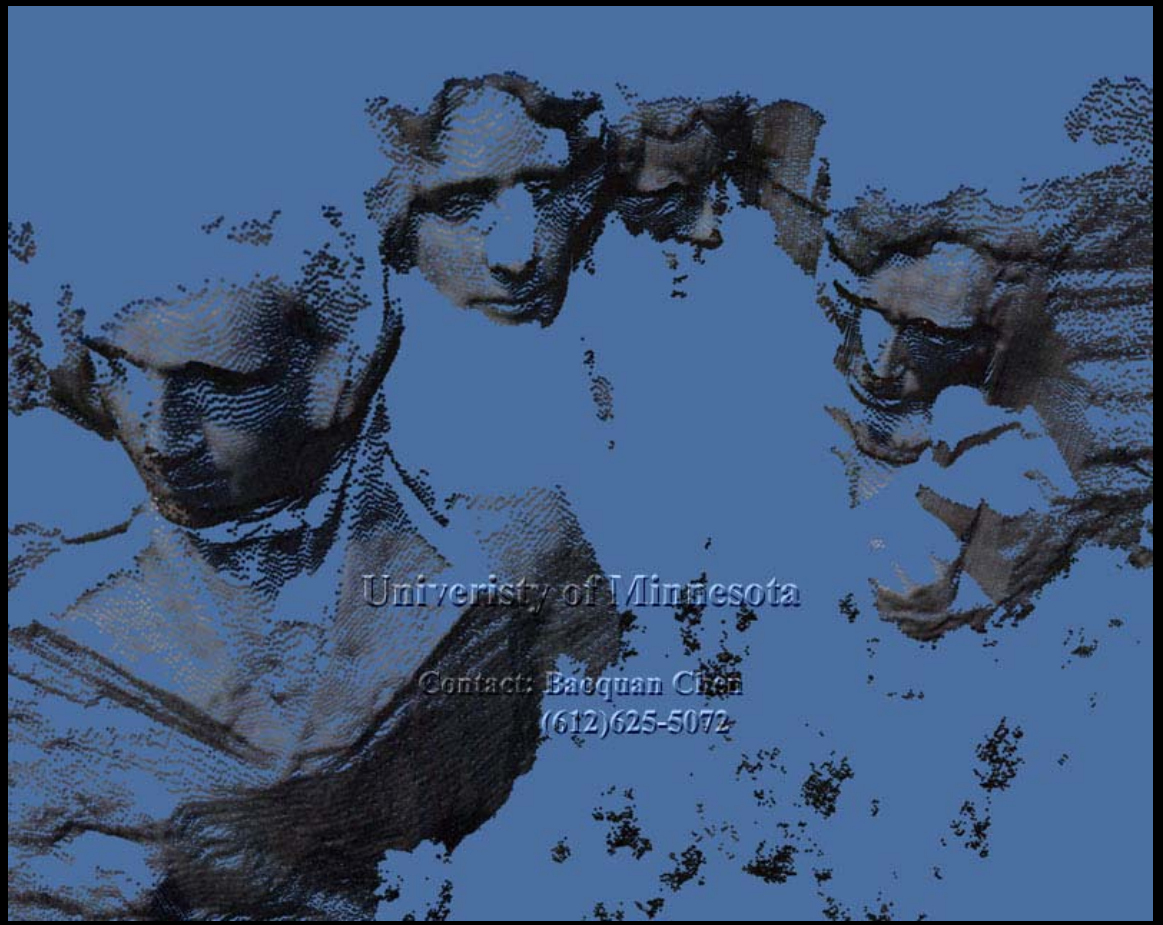
Head Mounted Display with 32'x32' Tracker

Physical world

animation coherence

Virtual world

Geometry Completion / Reconstruction



Knowledge-based Tree Modeling

[Xu, Gossett & Chen, ACM TOG 06, under review]

Prior Work

- L-System (Lindenmayer 1968)
- Billboard (Ervin and Hasbrouck 2001)
- Modeling from images (Shlyakhter et al. 2001, Long et al. 2006)
- Volumetric method from photographs (Reche et al. 2004)
- Forestry & Ecology (Gorte and Pfeifer 2004)

Our Approach

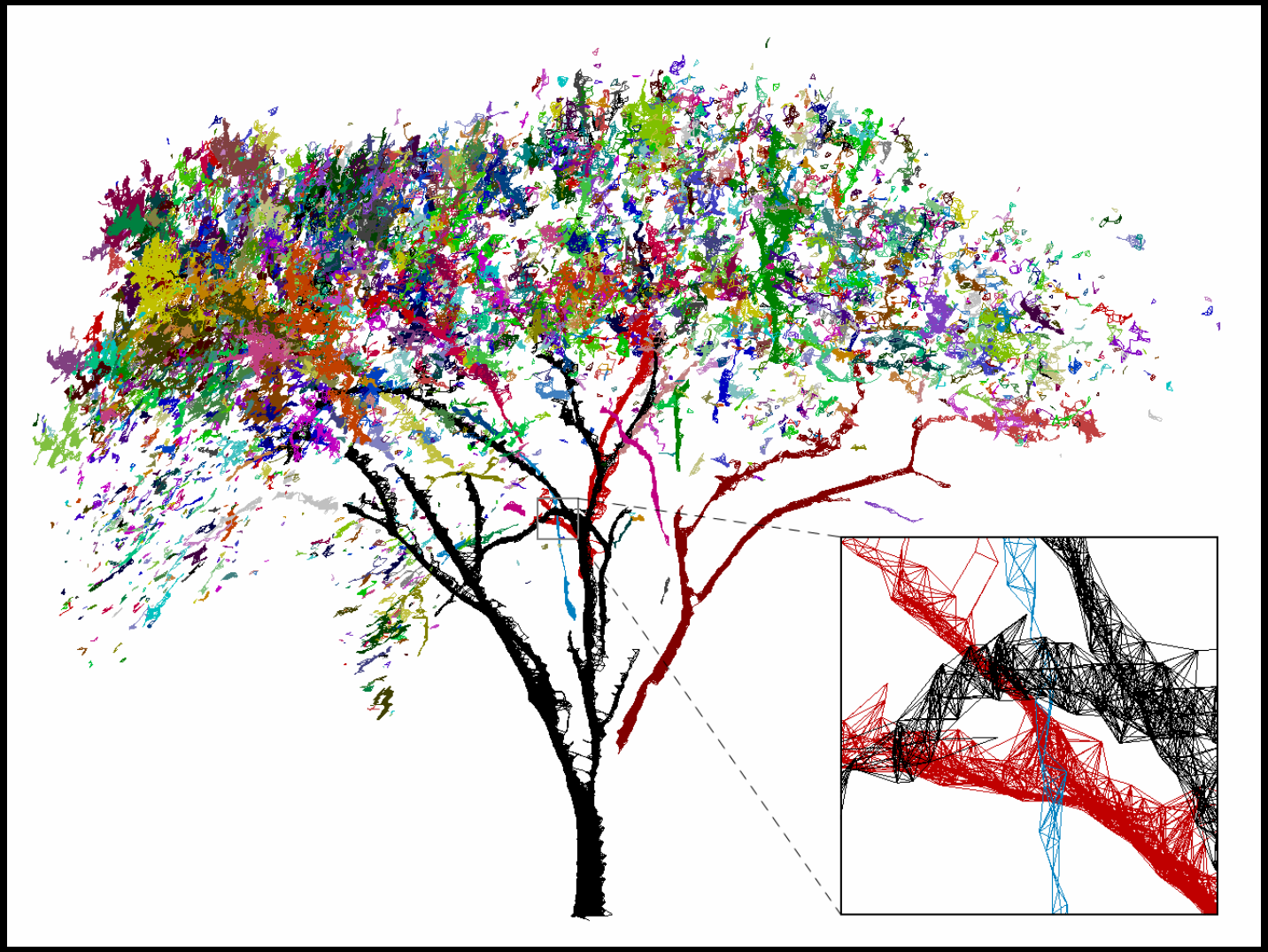
Point Cloud

Knowledge:

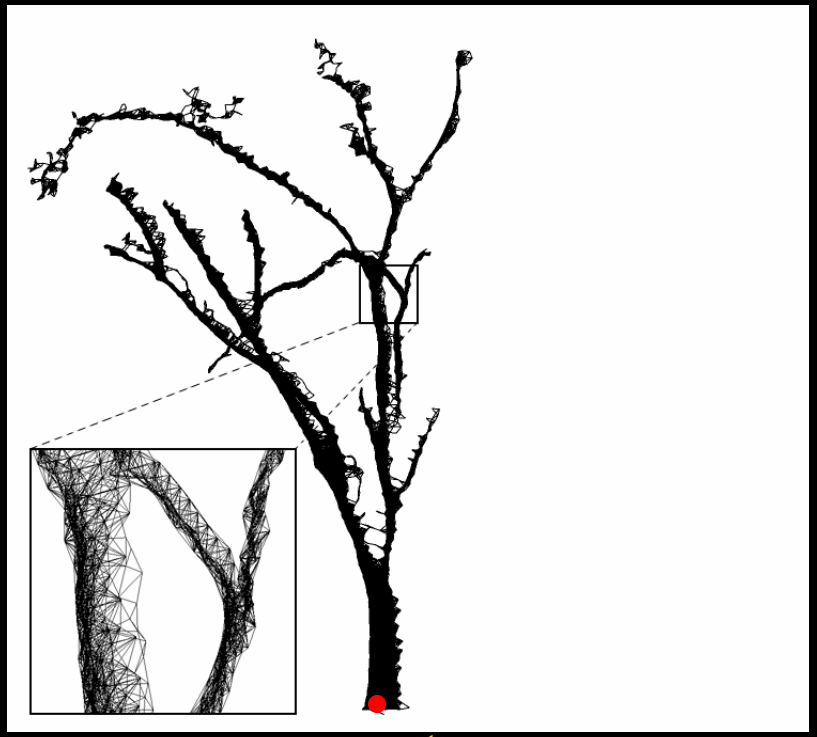
Tree structures
Allometric Theory

Full Geometry

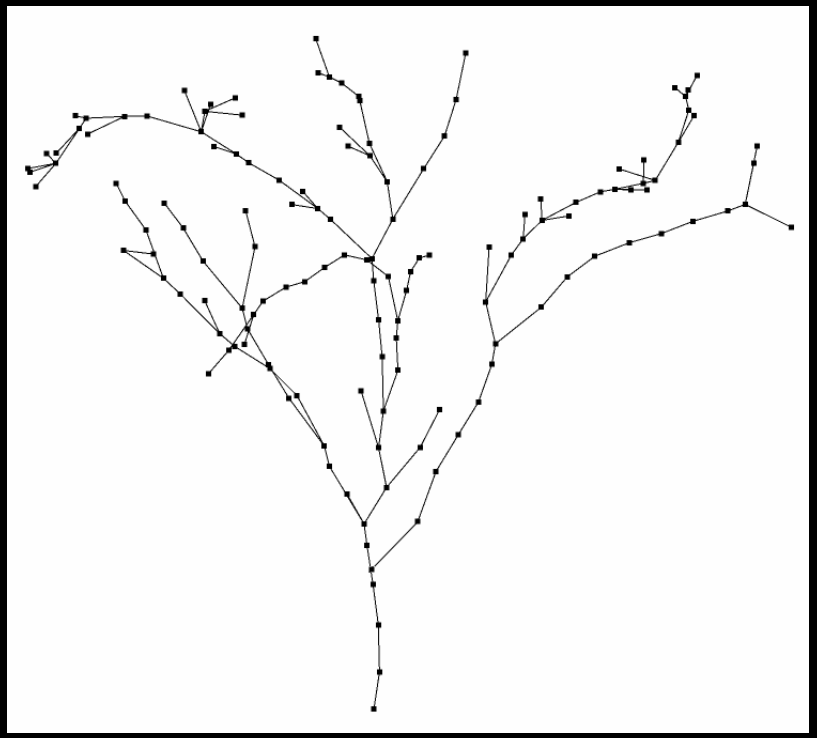
Graph



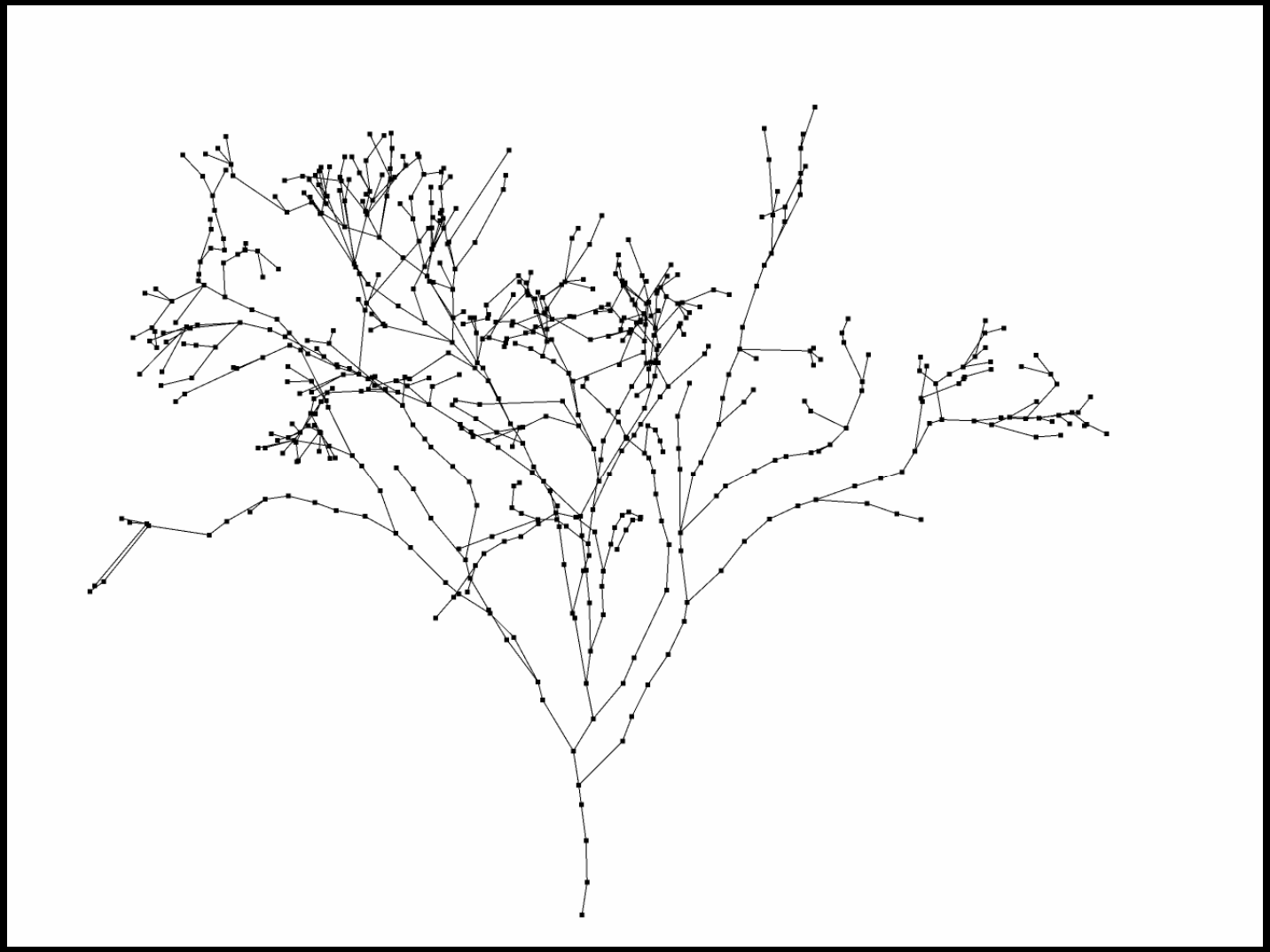
Subgraph to Skeleton



Skeleton Extension

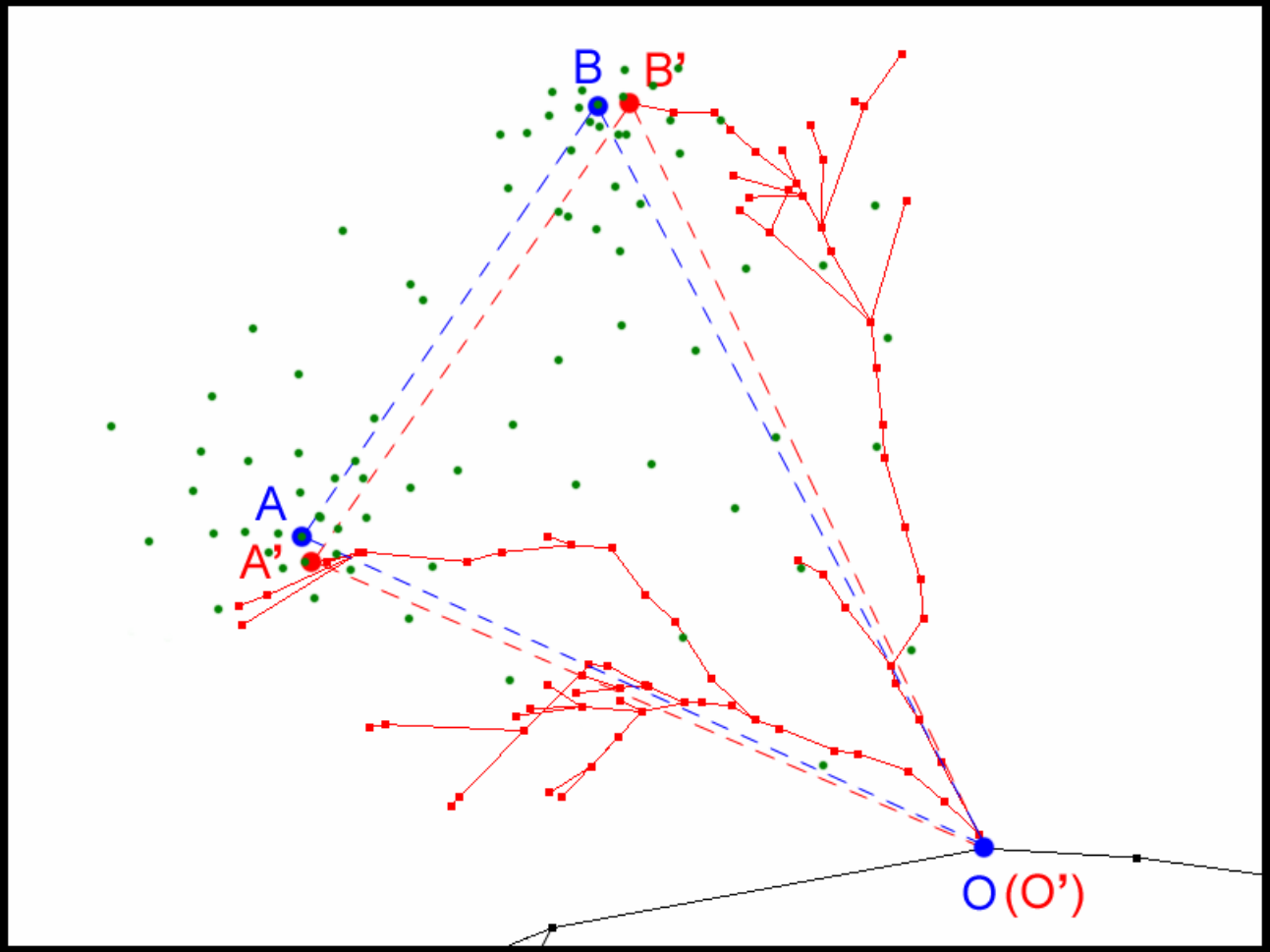


Skeleton Extension



Tree Crown

Skeleton Synthesis



Skeleton to Mesh

Branch Thickness

Allometric Theory:

- Lower branches supports upper branches
  - Pipe Model [Shinozaki et al. 1964]
    - Cross section of branch proportional to number of leaves it supports
  - WBE Model [West et al. 1999]
    - Also account for the amount of mass the branch must structurally support

Skeleton to Mesh

without synthesized branches

Skeleton to Mesh

branch synthesis iteration 1

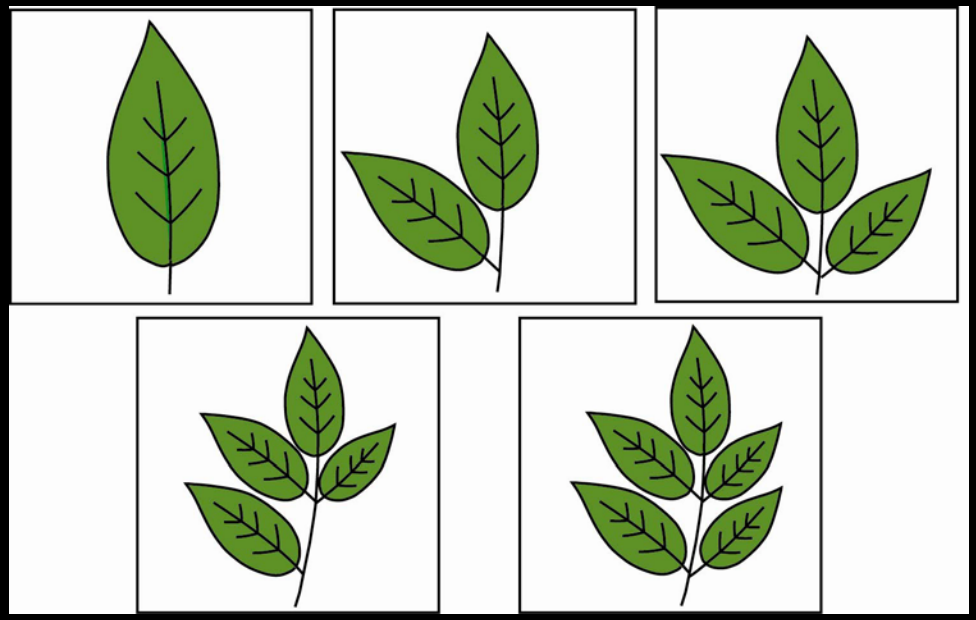
Skeleton to Mesh

branch synthesis iteration 2

Skeleton to Mesh

branch synthesis iteration 3

Leaf Textures



Add Leaves

Close up

Return of the Trees

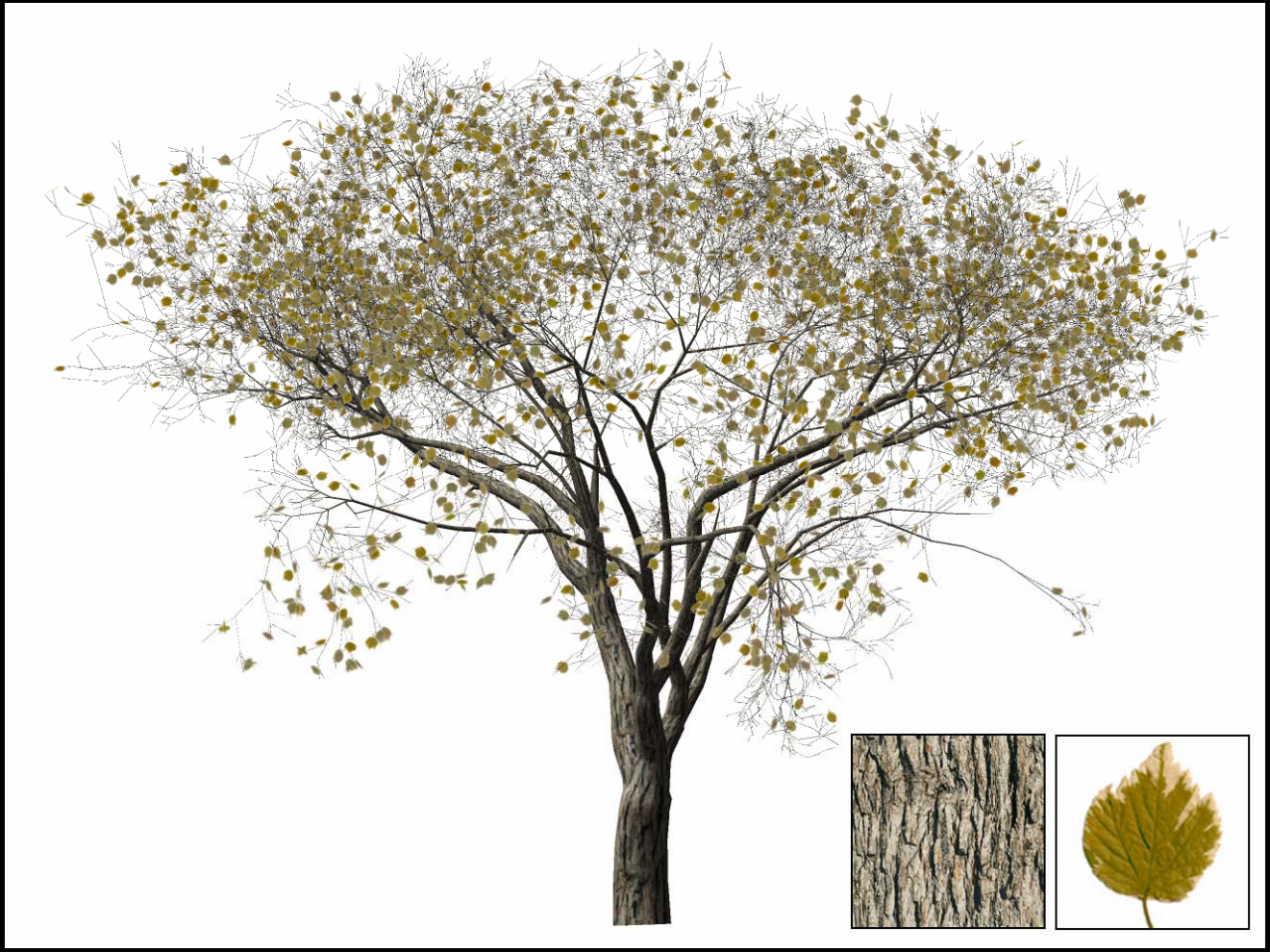
Animations

Tree as points

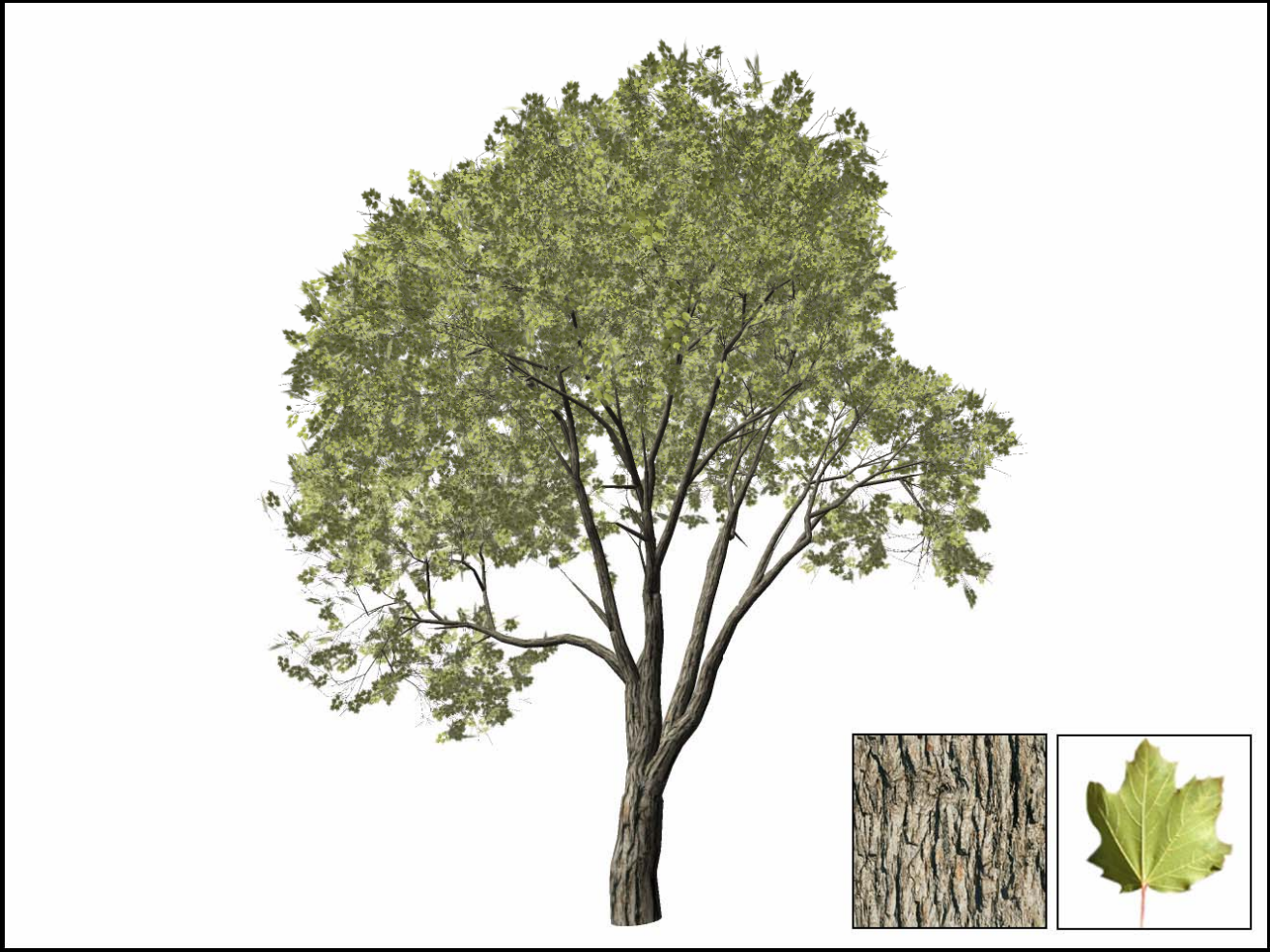
Tree as meshes

Comparison

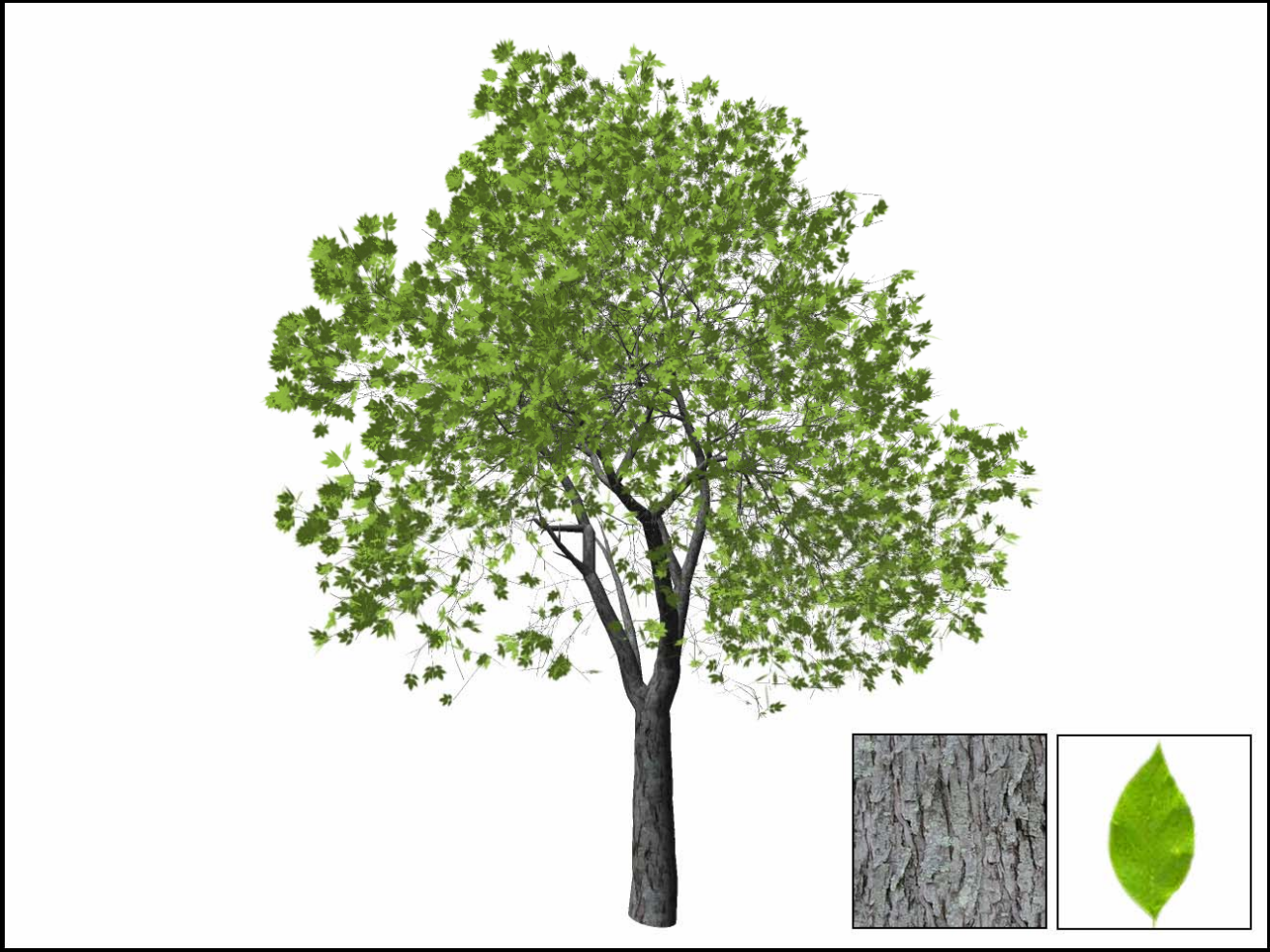
Other Examples



Other Examples



Other Examples



Other Examples

Minnesota trees (polygons) planted at Ephesos excavation site (points)
Rendered by PointWorks

Performance

	Skeleton Production	Branch Synthesis		
		Iteration1	Iteration2	Iteration3
T	4.5s	1.1s	7.4s	20.6s
Ns	615	4,315	9,027	15,214
Nt	13,452	58,260	116,220	191,124

Leaf Generation				Total time
T	20.0s	Nt	55,808	53.6s

T: execution time in seconds; Ns: # of skeleton nodes; Nt: # of triangles

On-going Development

Acknowledgements

- Student Participants:

  Jie Chen, Nathan Gossett, Minh X. Nguyen, Hui Xu, Xiaoru Yuan

- Faculty Collaborators:

  Andrzej Piotrowski (Architecture)

- Funding provided by:

  -NSF CCF-0238486 (CAREER)
  -NSF CCF-0530673 (REU)
  -NSF DMS-0528492 (MSPA-MCS)
  -NSF EIA-0324864 (ITR)
  -NSF CNS-0323471 (Equipment)
  -Ted & Linda Johnson Gift
  -Microsoft Research Gift
  -Riegl Gift
  -UMN McKnight
  -UMN DTC Seed Grants
  -UMN StartUP funds