Introducción a la Fotografia 3D

UBA/FCEN Marzo 27 – Abril 12 2013

Clase 9 : Viernes Abril 12

Gabriel Taubin

Brown University

BROWN

Course Schedule

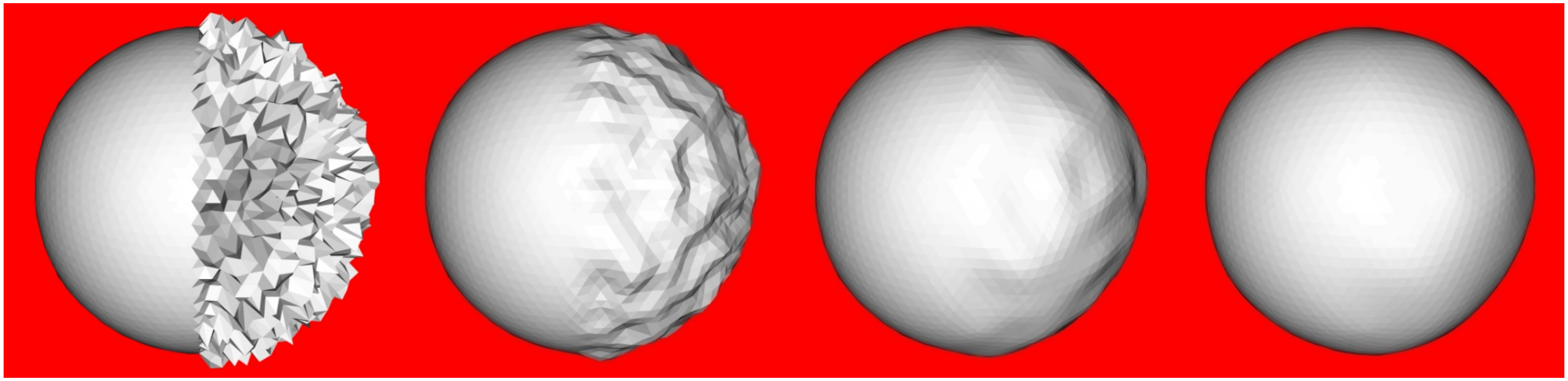
- Structured Lighting
- Projector Calibration / Structured Light Reconstruction
- Combining Point Clouds Recovered from Multiple Views
- Surface Reconstruction from Point Clouds
- ***Elementary Mesh Processing***
- Related Projects
- Conclusion / Q & A

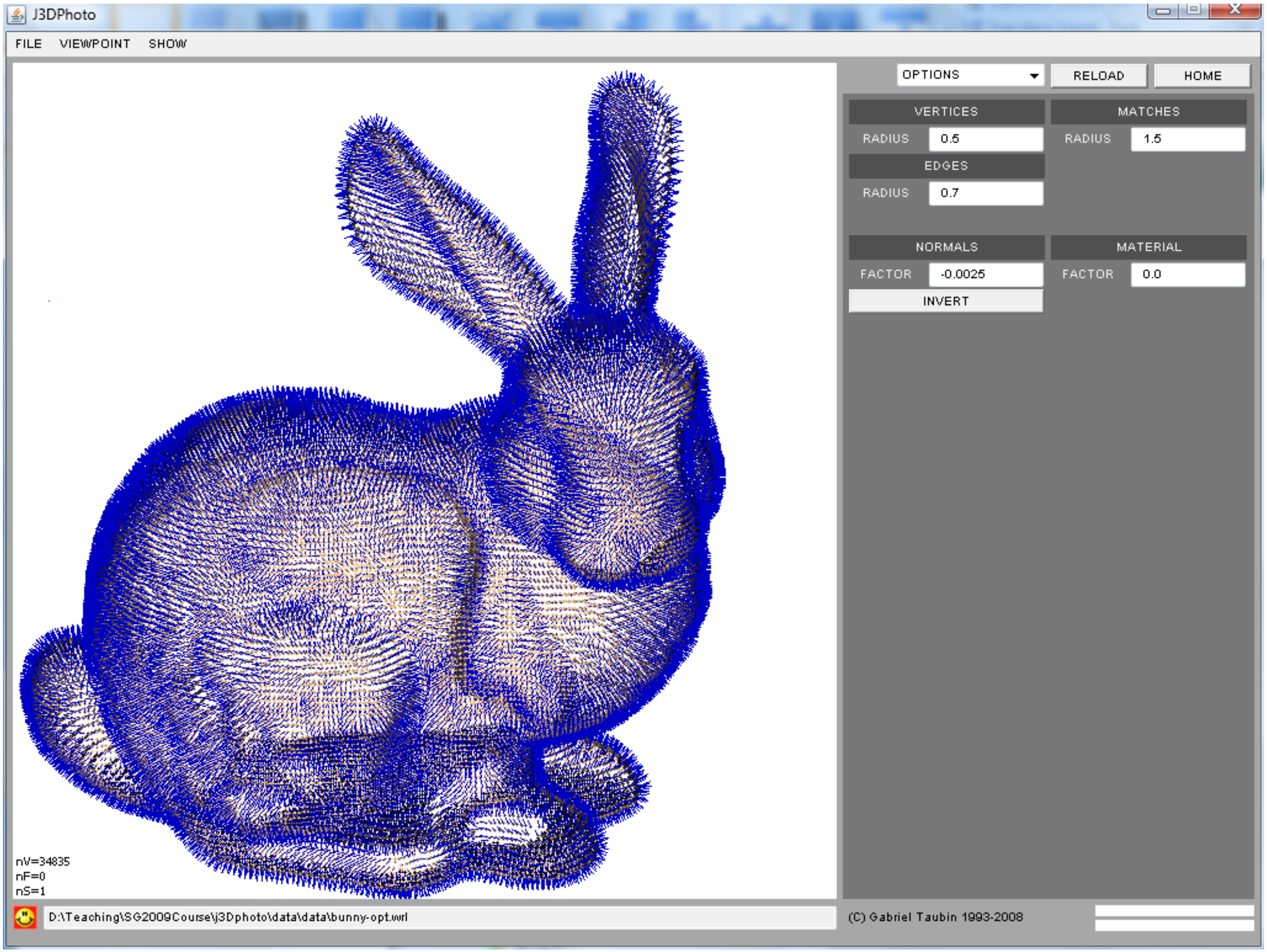
Elementary Mesh Processing

- We will talk about a few simple algorithms which can be applied interactively

- Polygon mesh smoothing / denoising
- Polygon mesh simplification

- j3DPGP (Java 3D Photography and Geometry Processing)

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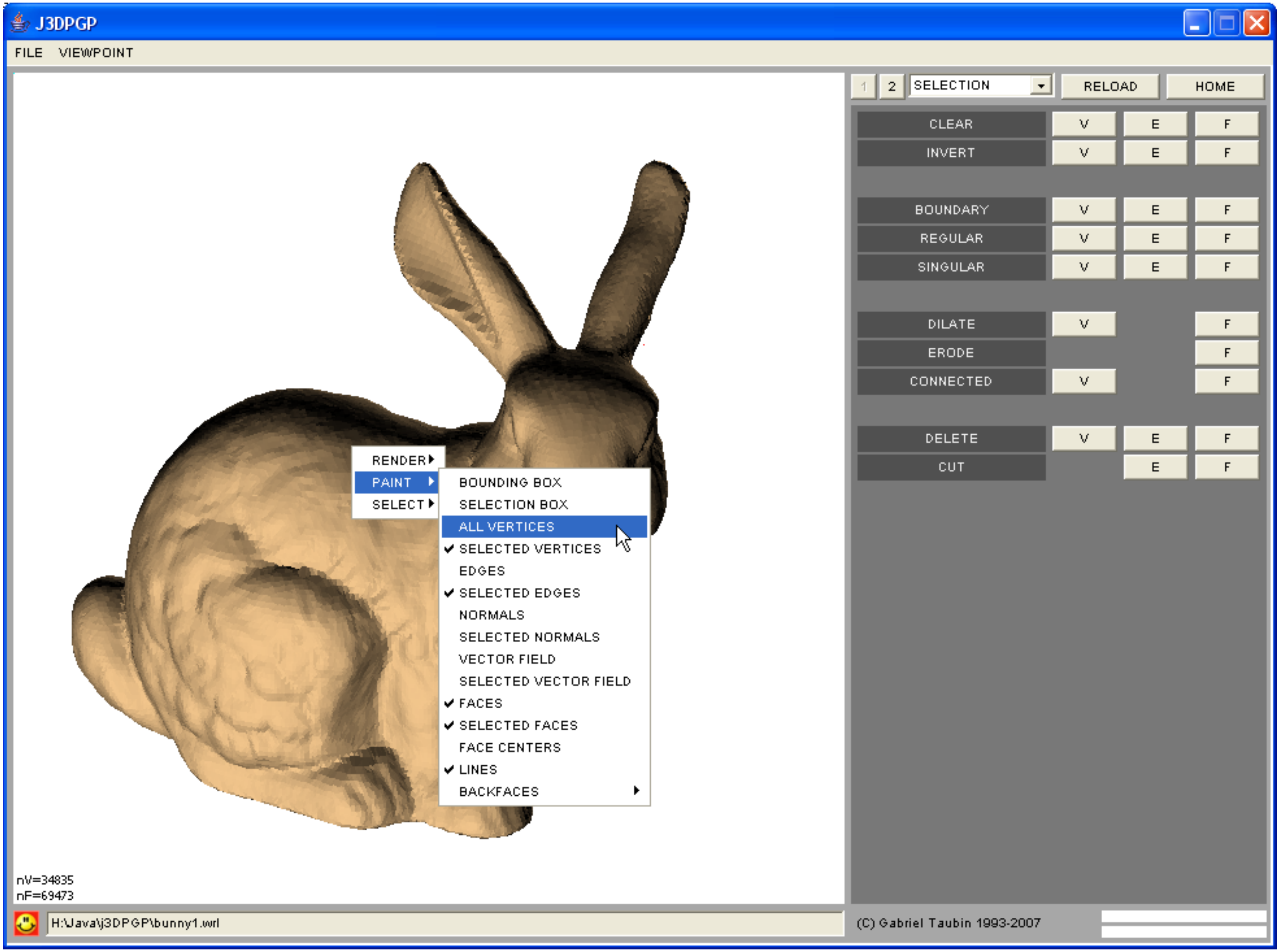
(C) Gabriel Taubin 1993-2008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PAINT
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ALL VERTICES
SELECTED VERTICES
EDGES
SELECTED EDGES
NORMALS
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SELECTED FACES
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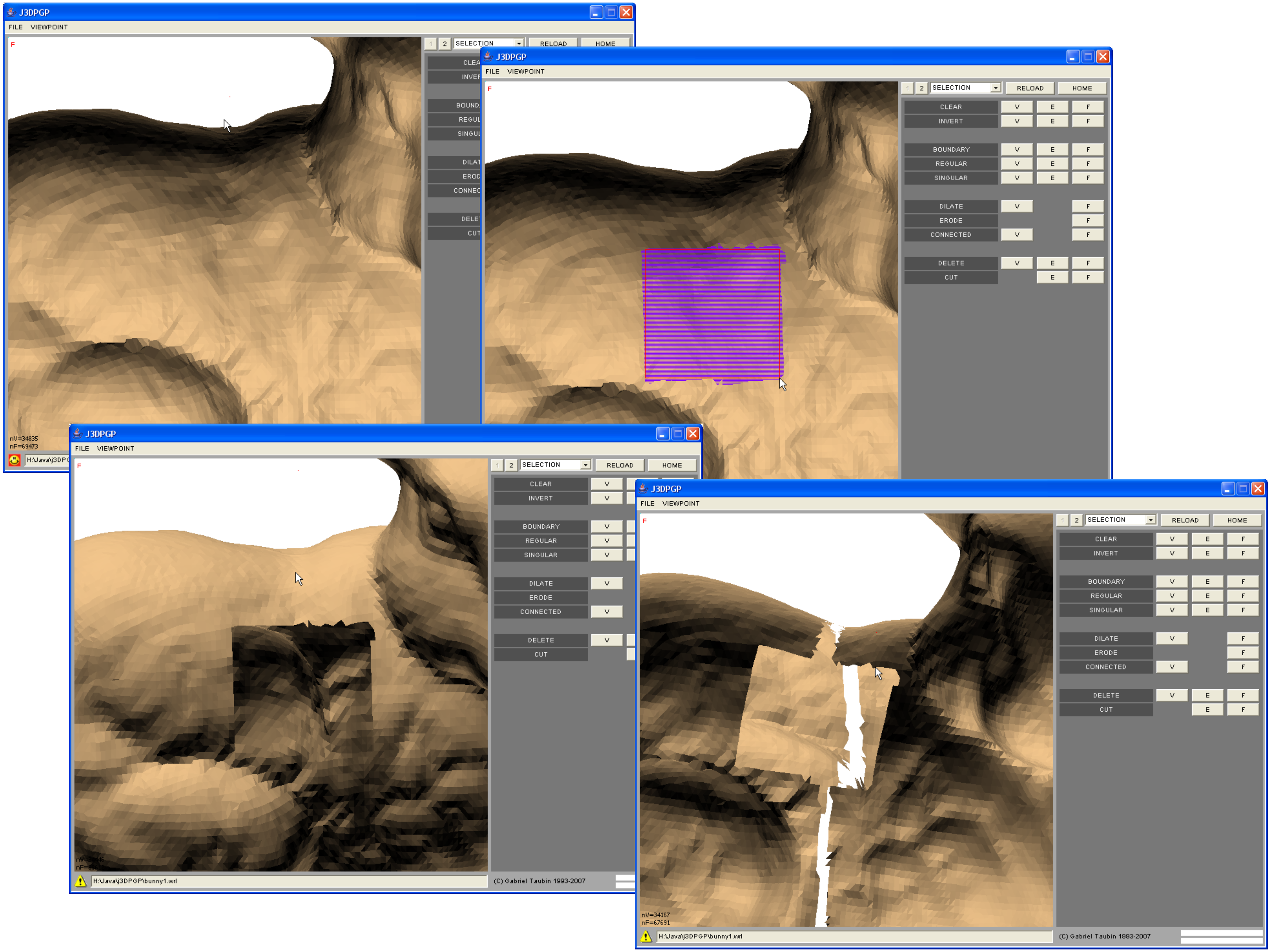
(C) Gabriel Taubin 1993-2007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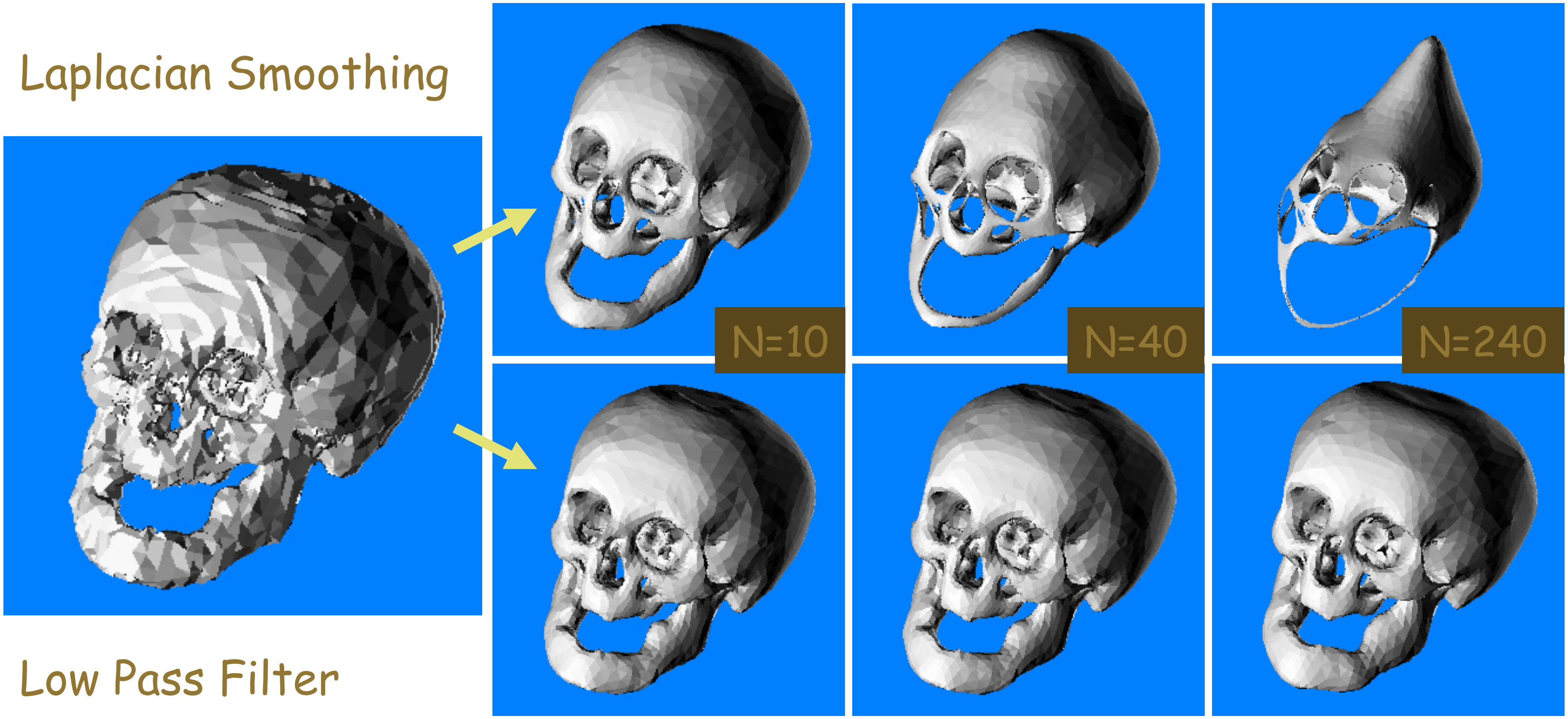
(C) Gabriel Taubin 1993-2007

Polygon Mesh Smoothing / Denoising

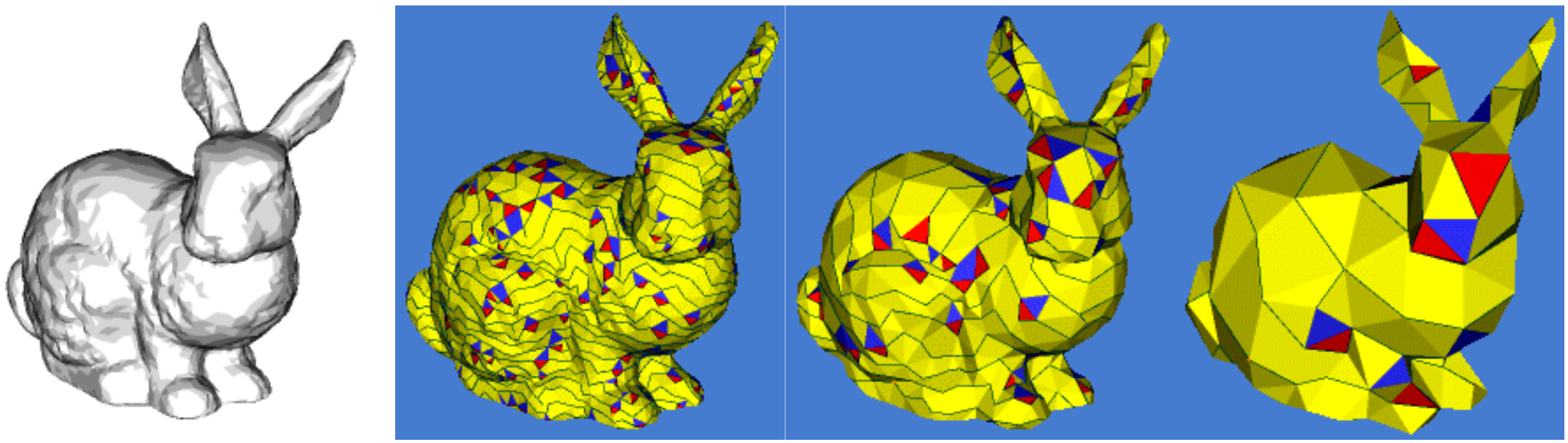


- Laplacian smoothing is the simplest smoothing/denoising algorithm
- Fix to shrinkage problem: toggle parameter sign at each iteration !

G. Taubin. A Signal Processing Approach To Fair Surface Design. Siggraph, 1995

Poligon Mesh Simplification / Decimation

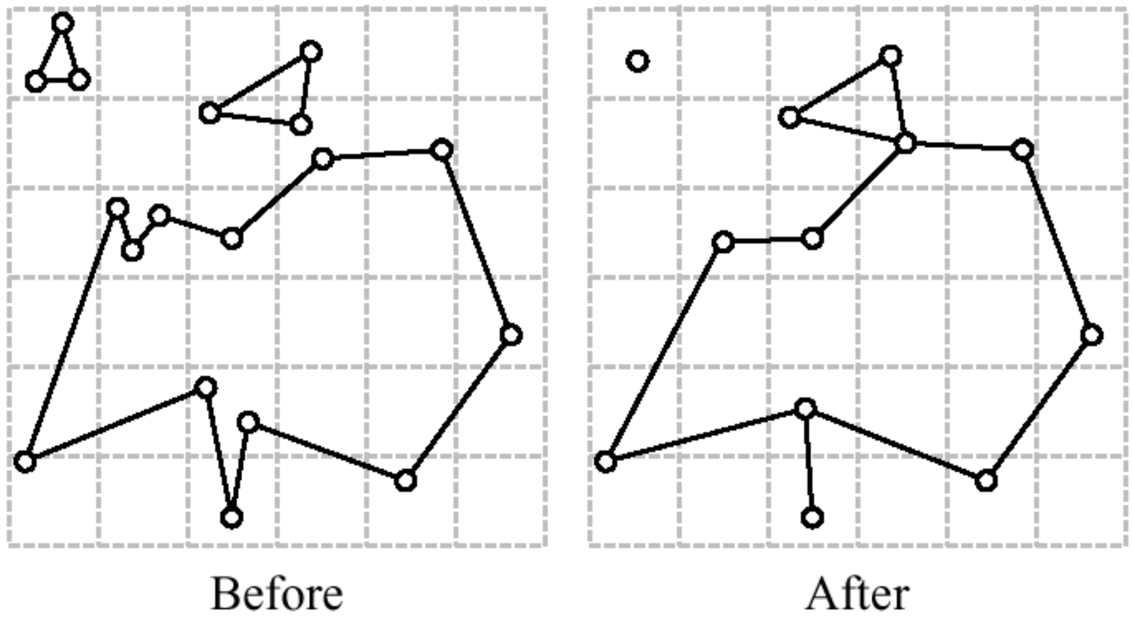
- Algorithms to reduce the number of vertices and faces while preserving geometric approximation to original shape



- Vertex clustering (Rossignac & Borrel, 1993)
- Edge Collapse (Garand Heckbert 1997; many others)

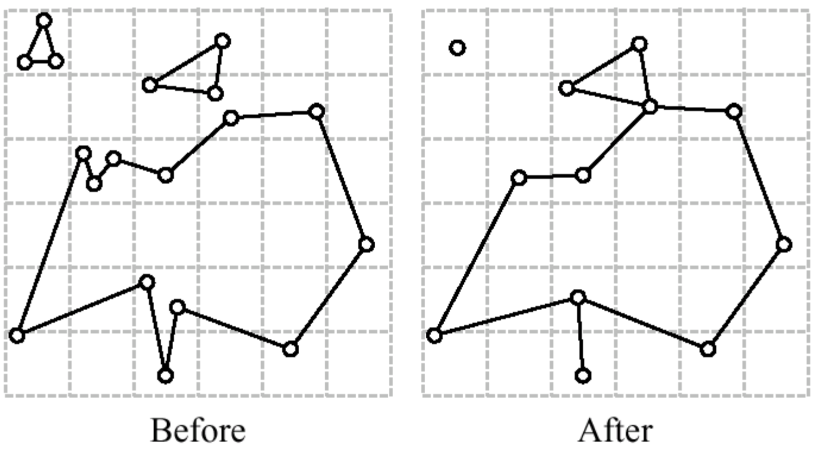
Vertex Clustering

- Quantize coordinates with respect to a bounding box
- Identify vertices with same coordinates
- Remove empty triangles



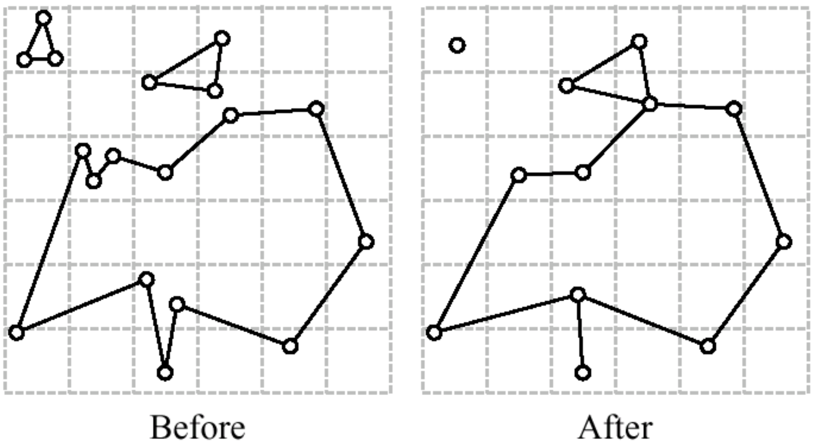
Vertex Clustering Algorithm

- Quantize coordinates with respect to bounding box
- Assign a new vertex index to each occupied cell
- Determine coordinates of new vertices
- Construct new vertex index look-up table
- Replace vertex indices in faces
- Remove empty triangles from list of faces

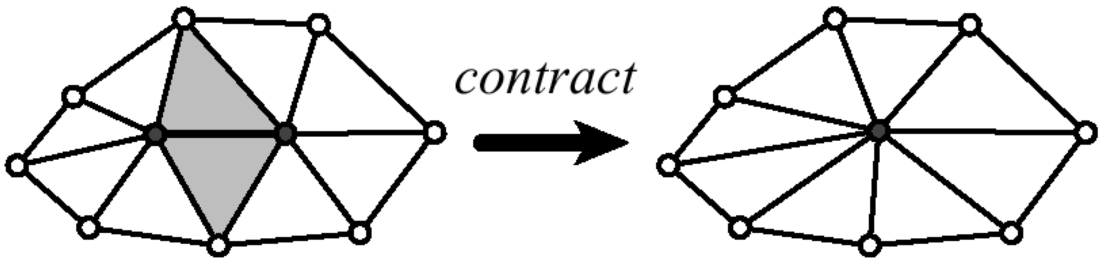


Vertex Clustering

- Advantages
  - Simple to implement
  - Works on large scenes with multiple objects
- No manifold restriction
- Disadvantages
  - Produces non-manifold meshes
  - Quality of simplified model is often not very good

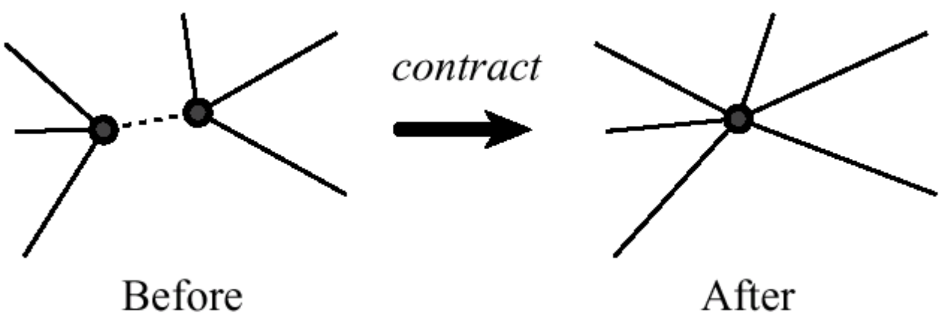


Edge Collapse

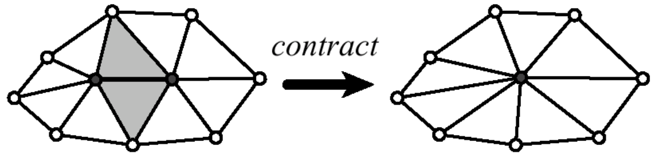


- Identify endpoints
- Determine vertex position
- Remove incident triangles
- Which edges to collapse ?
- In which order ?

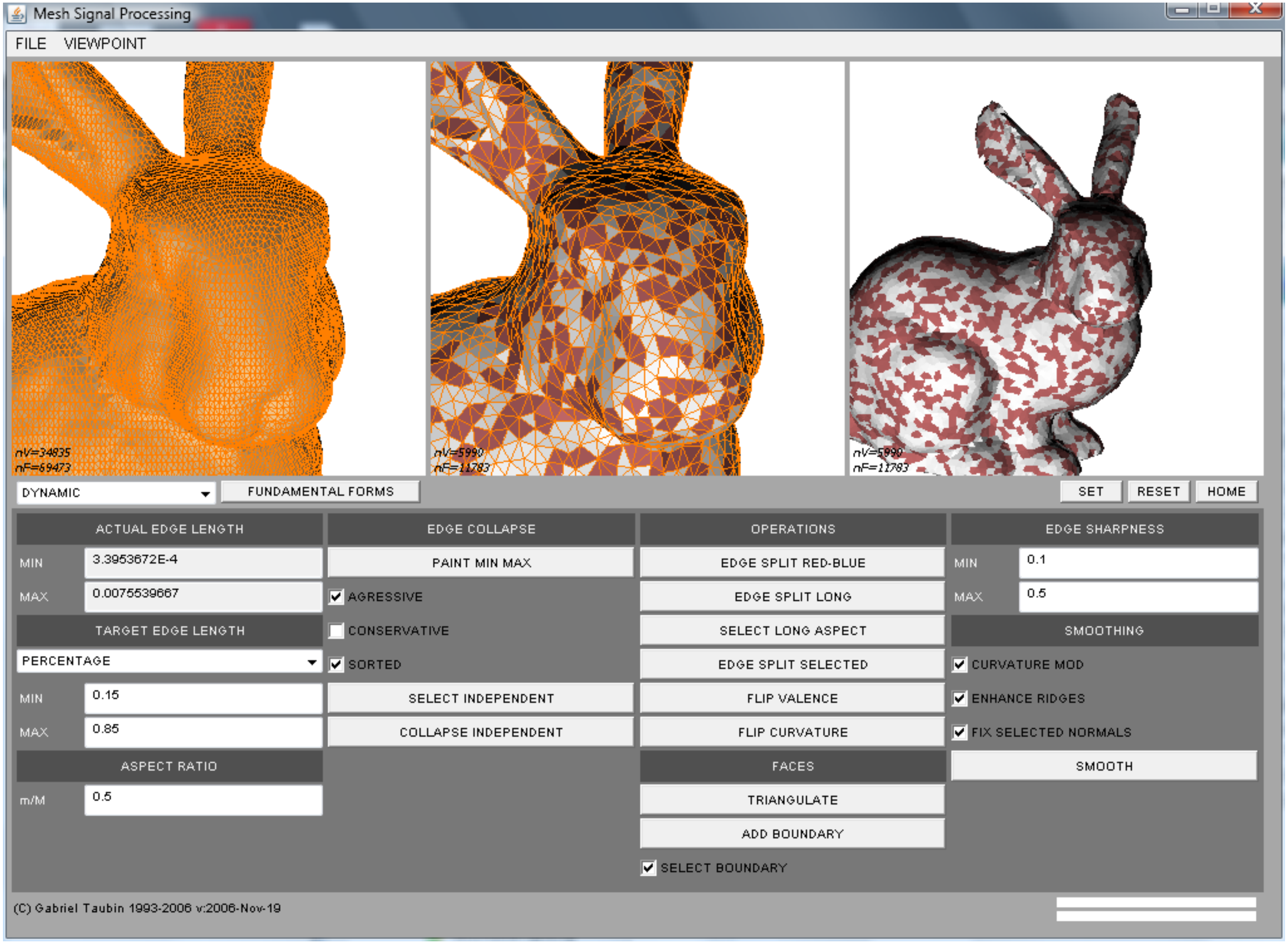
Non-existing edges



Basic Edge Collapse Algorithm



- Put all **collapsible** edges in a priority queue according to **removal error**
- While queue is not empty
  - Delete minimum edge from queue
  - Collapse edge
  - Identify vertices
  - Remove all incident edges from the queue, determine if collapsible, recompute removal error, re-insert in queue
- Need dynamic data structures


Mesh Signal Processing
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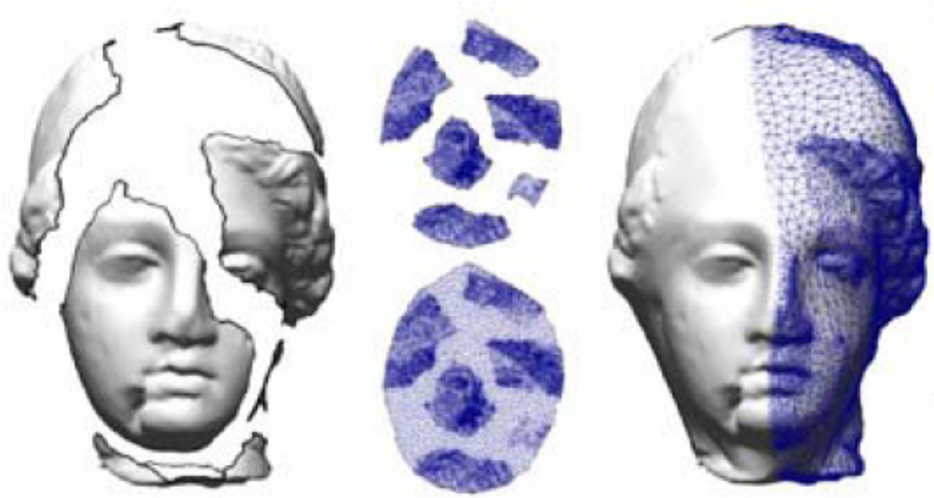
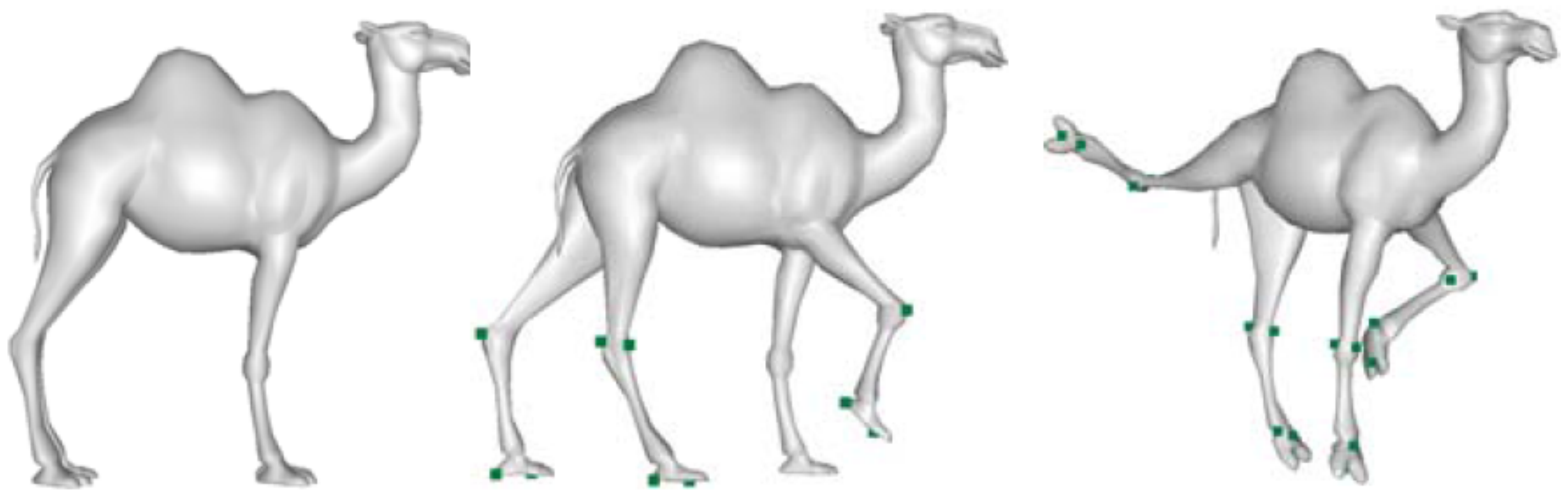
nF=69473
nV=5990
nF=11783
nV=5990
nF=11783
DYNAMIC
FUNDAMENTAL FORMS
SET
RESET
HOME
ACTUAL EDGE LENGTH
MIN
3.3953672E-4
MAX
0.0075539667
TARGET EDGE LENGTH
PERCENTAGE
MIN
0.15
MAX
0.85
ASPECT RATIO
m/M
0.5
EDGE COLLAPSE
PAINT MIN MAX
AGRESSIVE
CONSERVATIVE
SORTED
SELECT INDEPENDENT
COLLAPSE INDEPENDENT
OPERATIONS
EDGE SPLIT RED-BLUE
EDGE SPLIT LONG
SELECT LONG ASPECT
EDGE SPLIT SELECTED
FLIP VALENCE
FLIP CURVATURE
FACES
TRIANGULATE
ADD BOUNDARY
SELECT BOUNDARY
EDGE SHARPNESS
MIN
0.1
MAX
0.5
SMOOTHING
CURVATURE MOD
ENHANCE RIDGES
FIX SELECTED NORMALS
SMOOTH
(C) Gabriel Taubin 1993-2006 v:2006-Nov-19

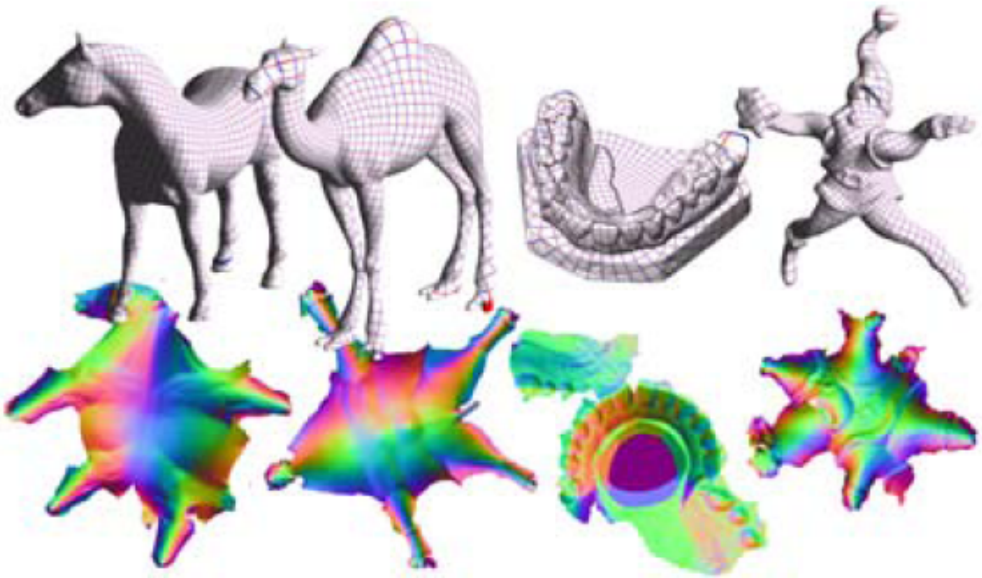
Completion

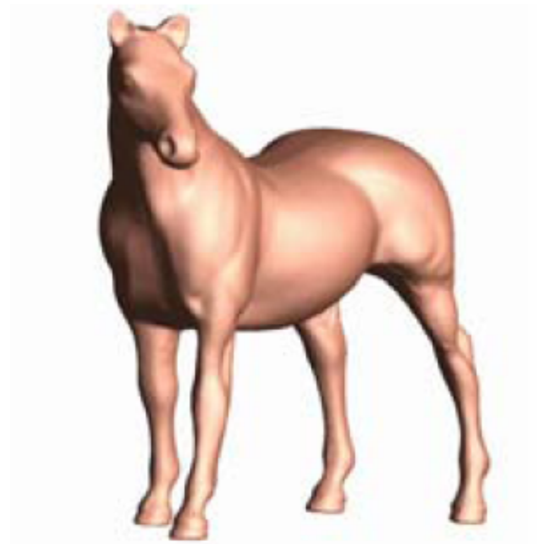


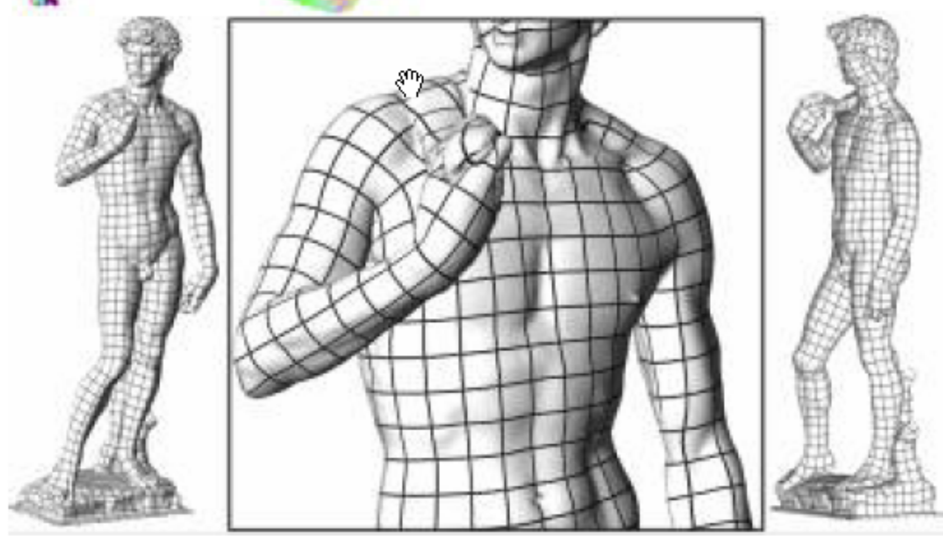
Deformation



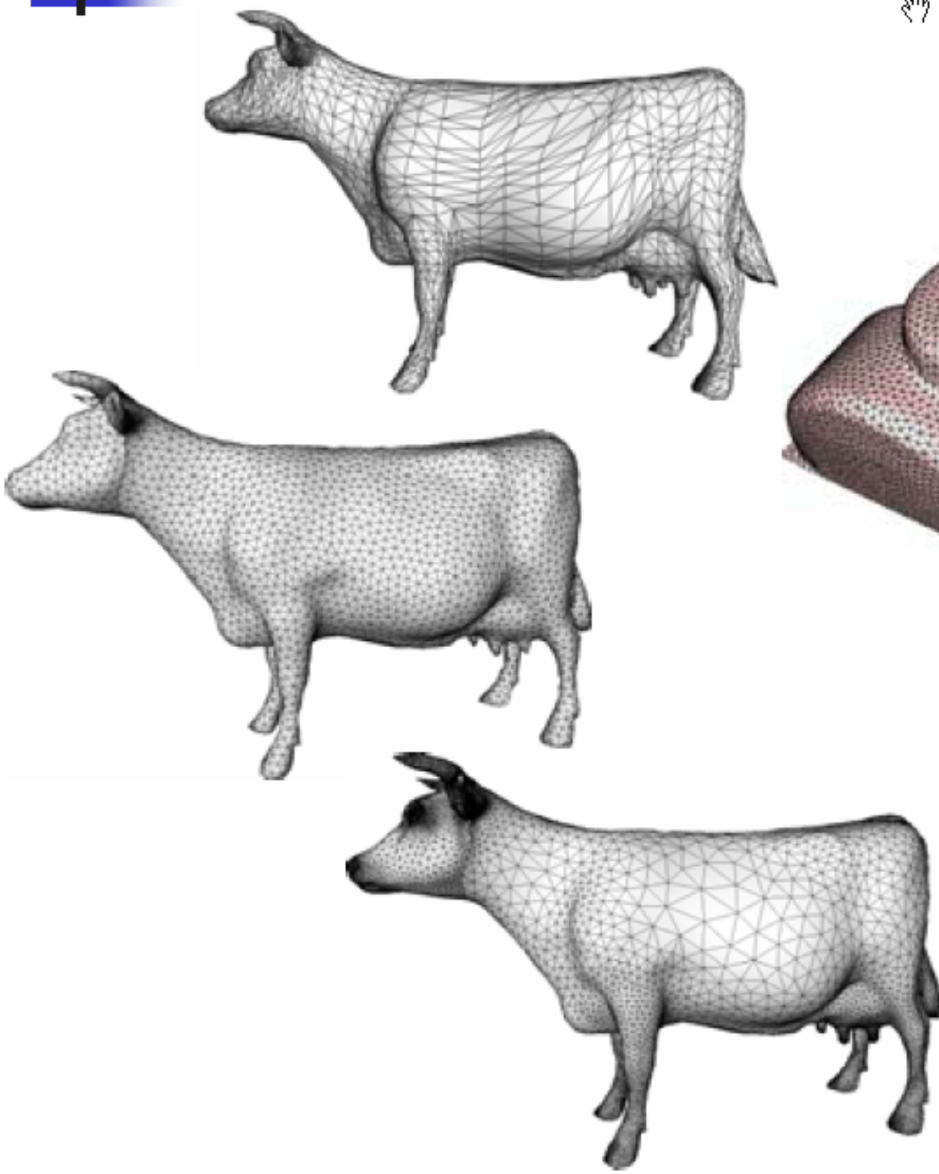
Parameterization

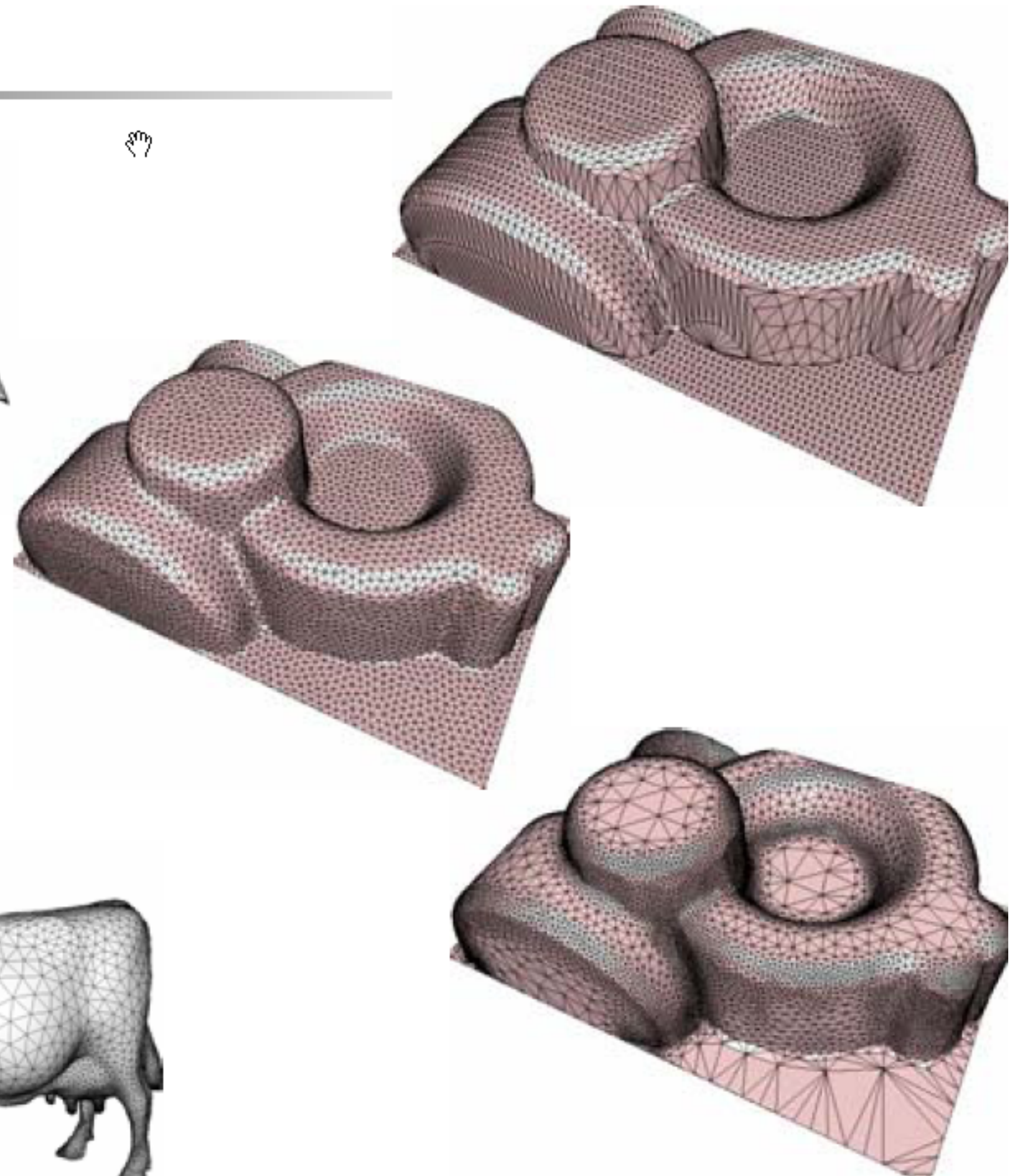




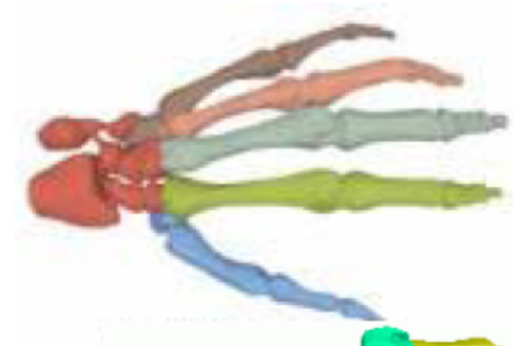


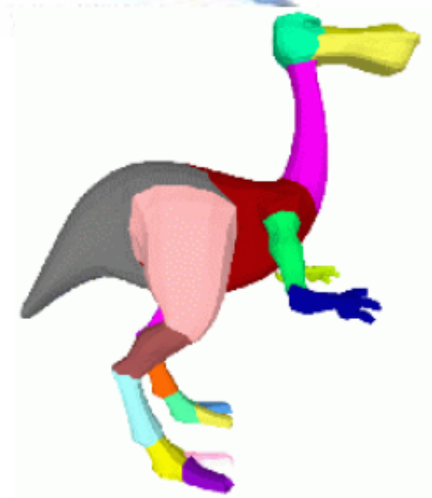
Remeshing





Segmentation





Course Schedule

Session II

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- Projector Calibration / Structured Light Reconstruction
- Combining Point Clouds Recovered from Multiple Views
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REVEAL Digital Archaeology Project

Cooper, Kimia, Taubin, Galor, Sanders, Willis

- Automates the tedious processes of data collection and documentation at the excavation site
- Provides visualization tools to explore the data collected in the database
- Solves specific problems in Archaeology using computer vision techniques
- Integrated Multi-View-Stereo (MVS) pipeline reconstructs 3D shapes from photos captured with hand-held cameras
- MVS pipeline can be installed independently of the rest of the system
- Software distributed as Open Source

http://sourceforge.net/projects/revealanalyze/

REVEAL Archaeological Data Acquisition

Assisted Data Acquisition, Algorithmic Reconstruction, Integrated multi-format analysis

Data Acquisition

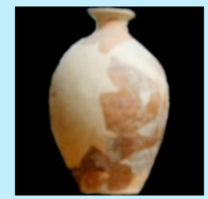
Improve speed and accuracy with computer assisted data entry

Import photos, videos, and laser scans and connect them to database objects

Advanced Algorithms

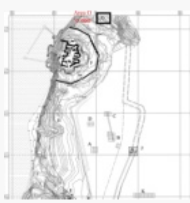
Automatically Convert Photos to 3D Models

Semi-automatically Assemble Fragments Into Artifacts

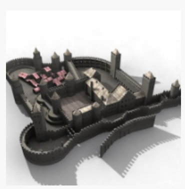


Import External Data

Site Plans



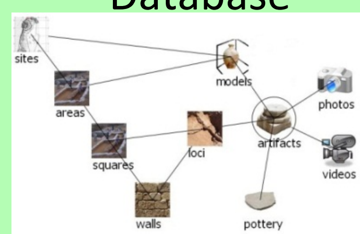
Laser Scanned Models



Rule-based Reconstructions

REVEAL Database

Objects:
Artifacts
Excavations
Areas
Sites

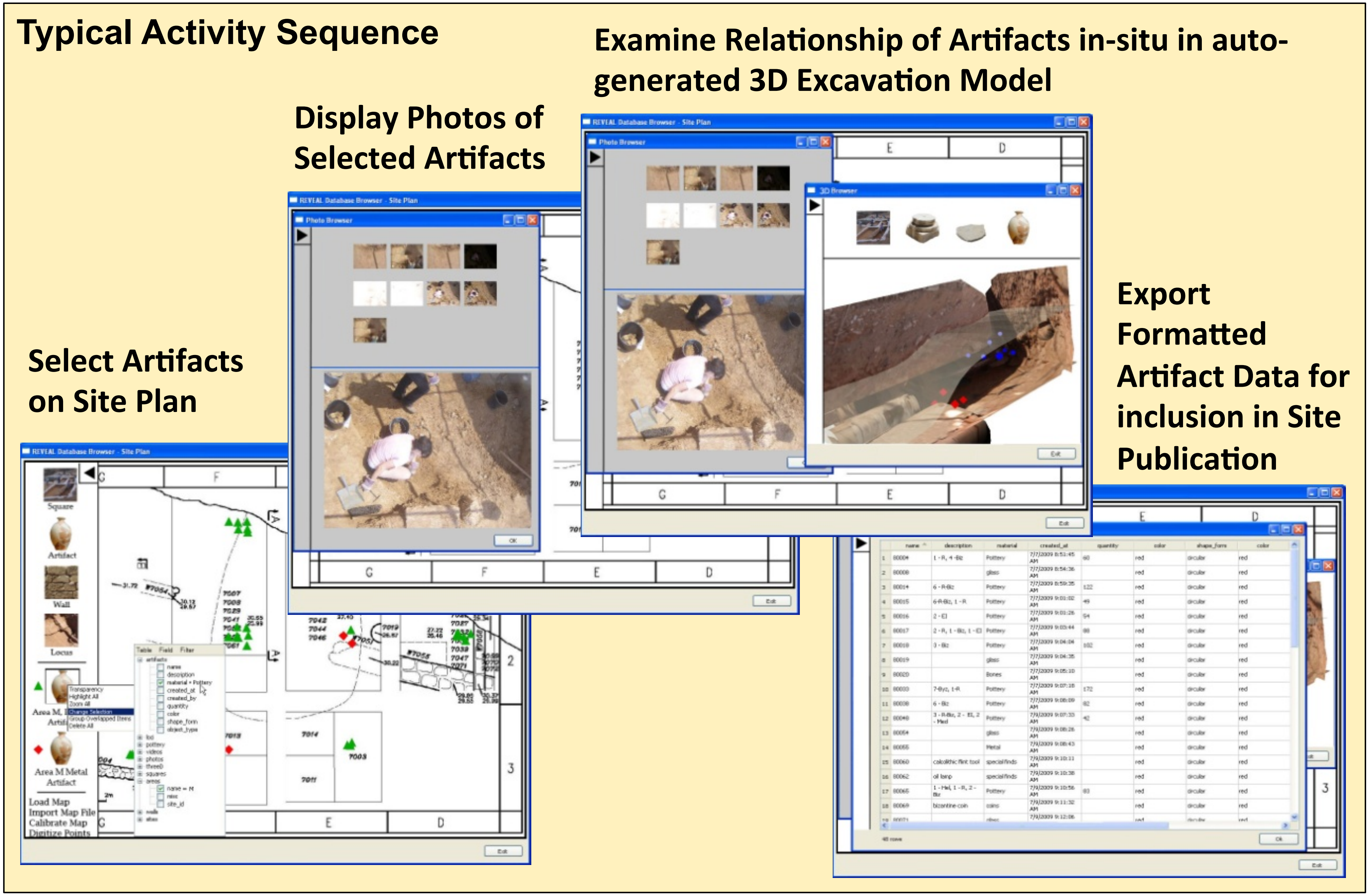


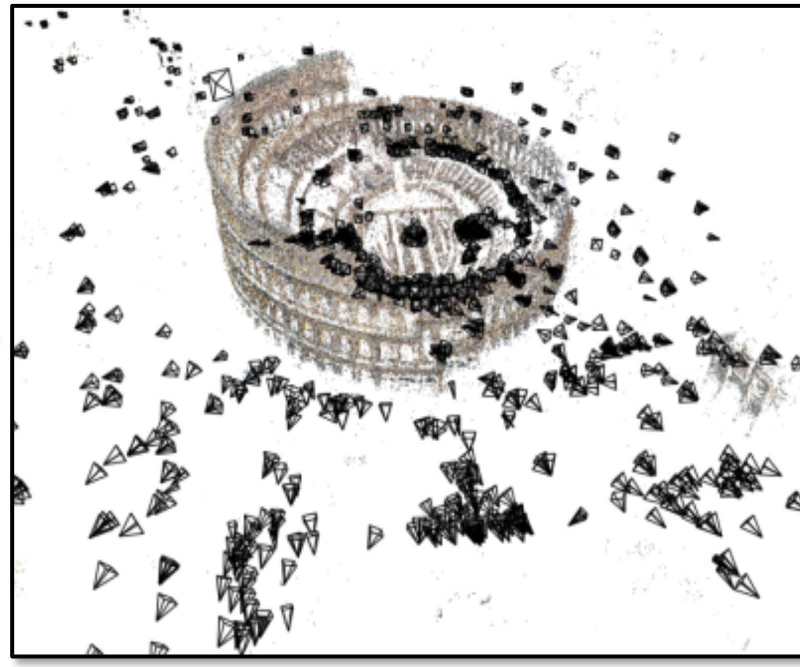
Data:
Text
Photos
Video
3D Models

http://sourceforge.net/projects/revealanalyze

REVEAL Archaeological Analysis

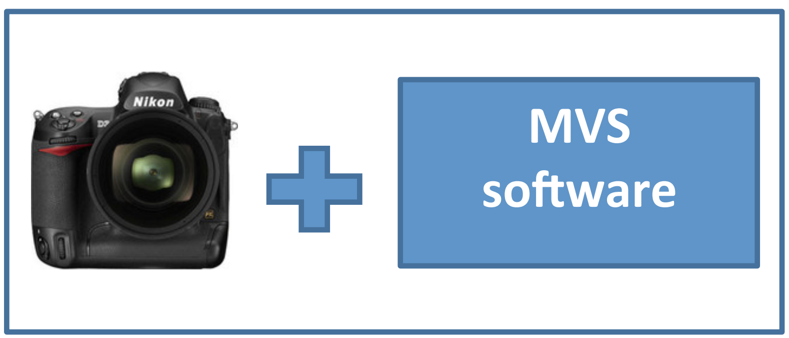
Data integrated and synchronized in tabular, plan drawing, 3D spatial, image, and video formats





[Snavely et. al. 2006]

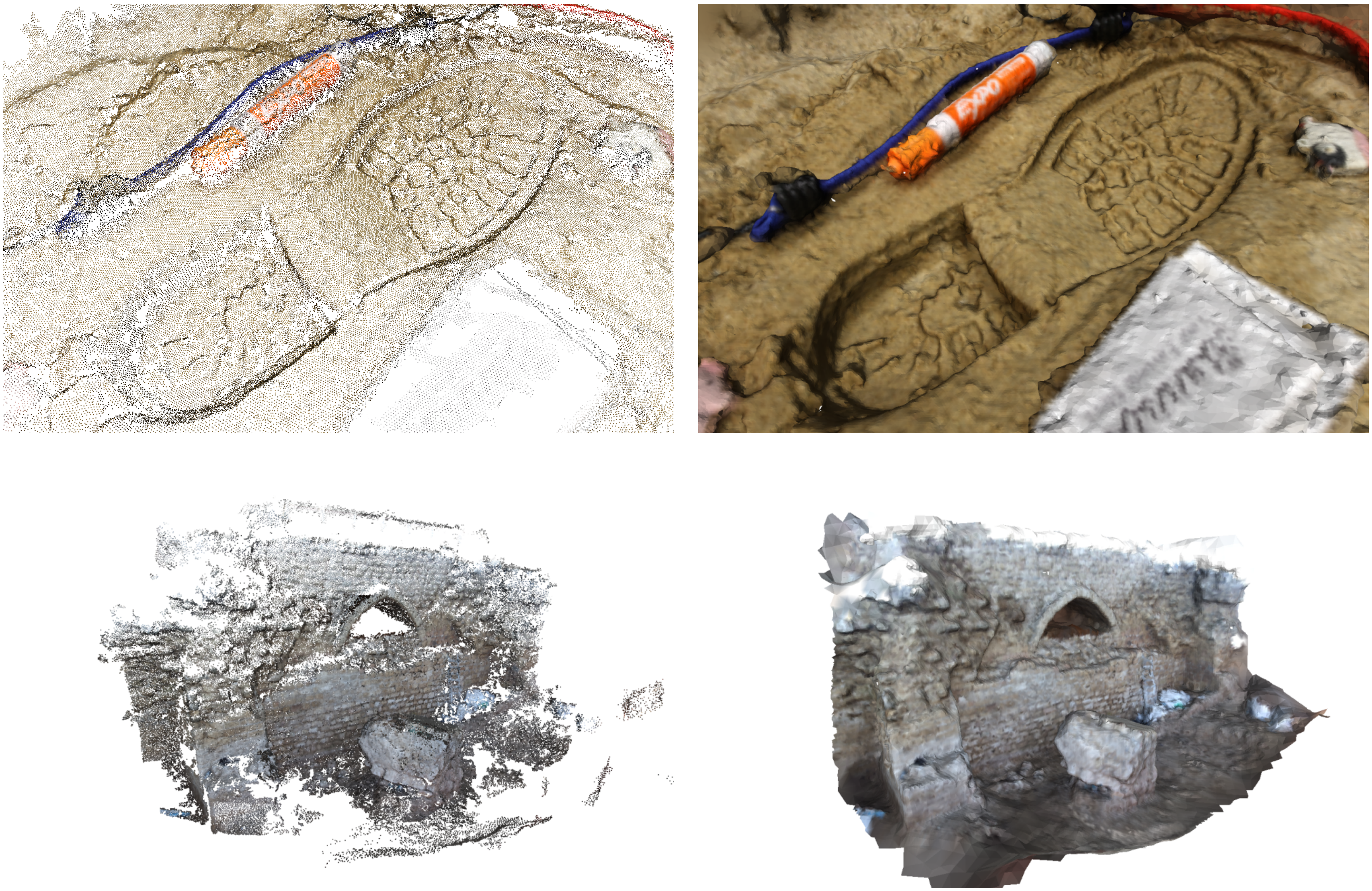
http://phototour.cs.washington.edu/bundler/



[Furukawa and Ponce 2008]

Patch-based **M**ulti-**V**iew **S**tereo (PMVS)
http://grail.cs.washington.edu/software/pmvs/

Reconstruction of colored meshes



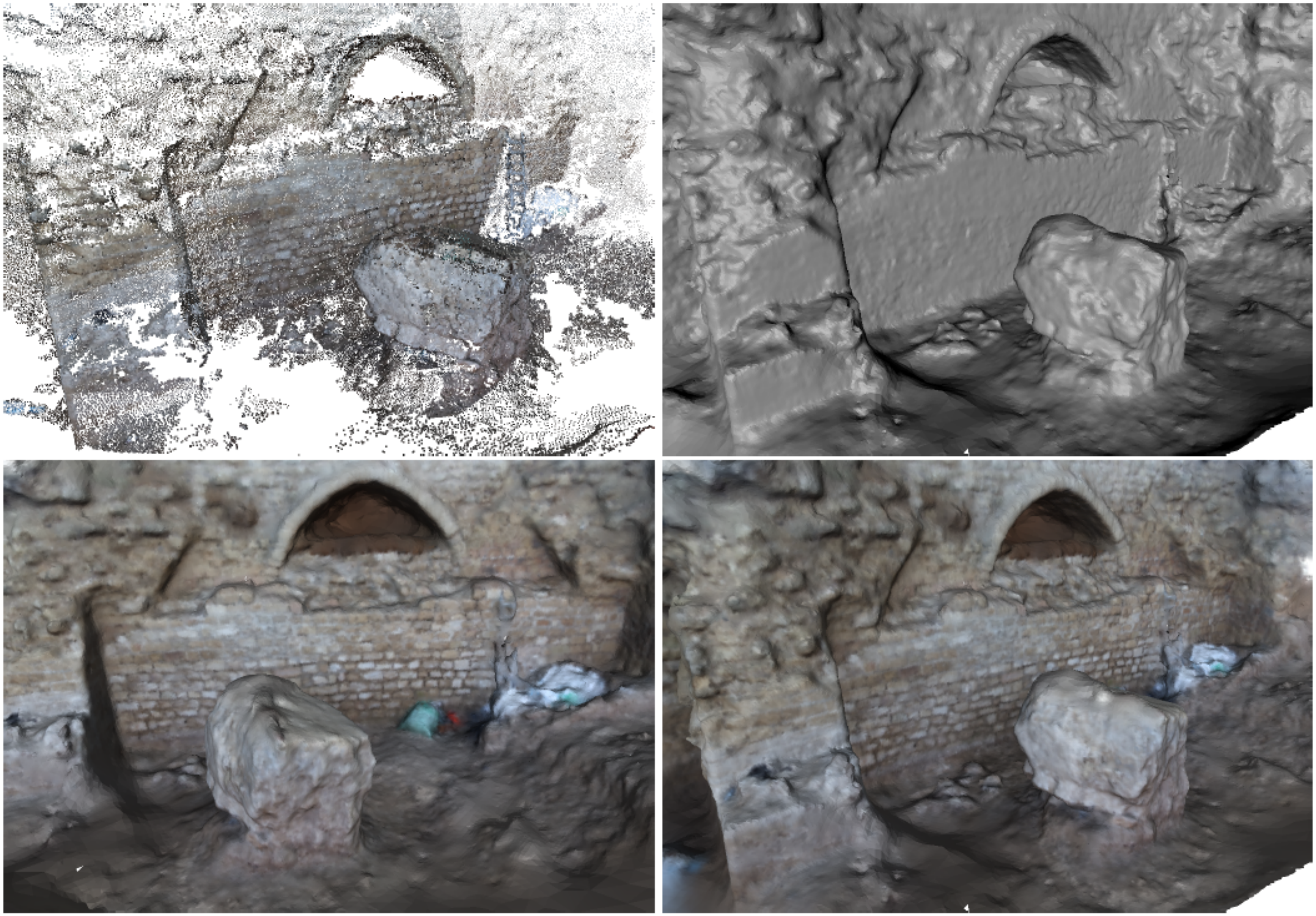
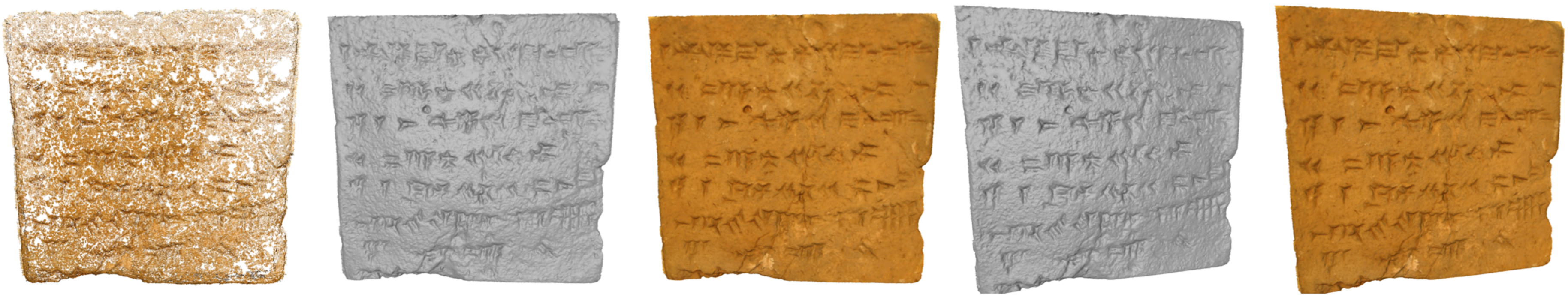


Fig. 1 Reconstruction of the side of a castle model: The input point cloud (top-left), Surface reconstructed by the proposed algorithm(top-right), Two views from the surface and color map reconstructed by the proposed algorithm (bottom).

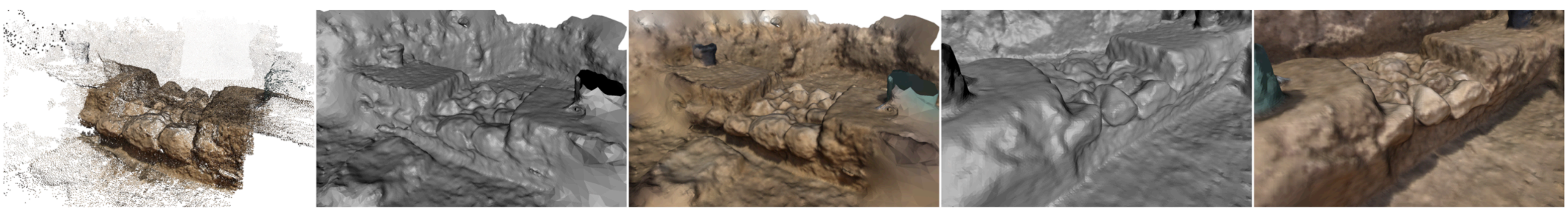
High Resolution Surface and Appearance Modeling for Multi-view Stereo

Fatih Calakli and Gabriel Taubin

Reconstruction of a brick with cuneiform, Mesopotamian, 859-840 BCE, Williams College Museum of Art, Williamstown, MA



Reconstruction of Tel es-Safi wall section

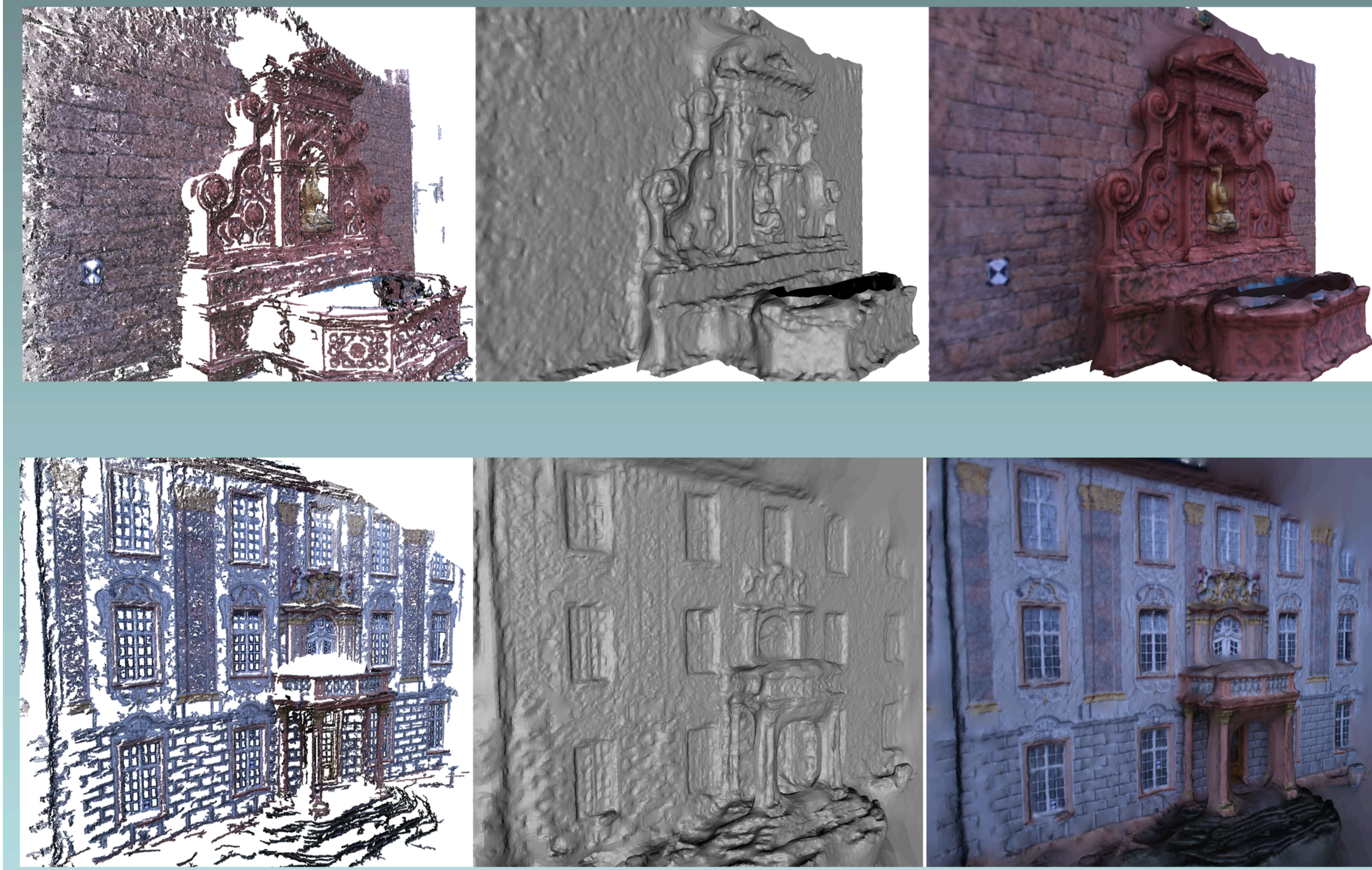


High Resolution Surface and Appearance Modeling for Multi-view Stereo

Fatih Calakli and Gabriel Taubin

Reconstruction of Fountain P-11, from EPFL Benchmark

Reconstruction of Castle-Entry P-10, from EPFL Benchmark



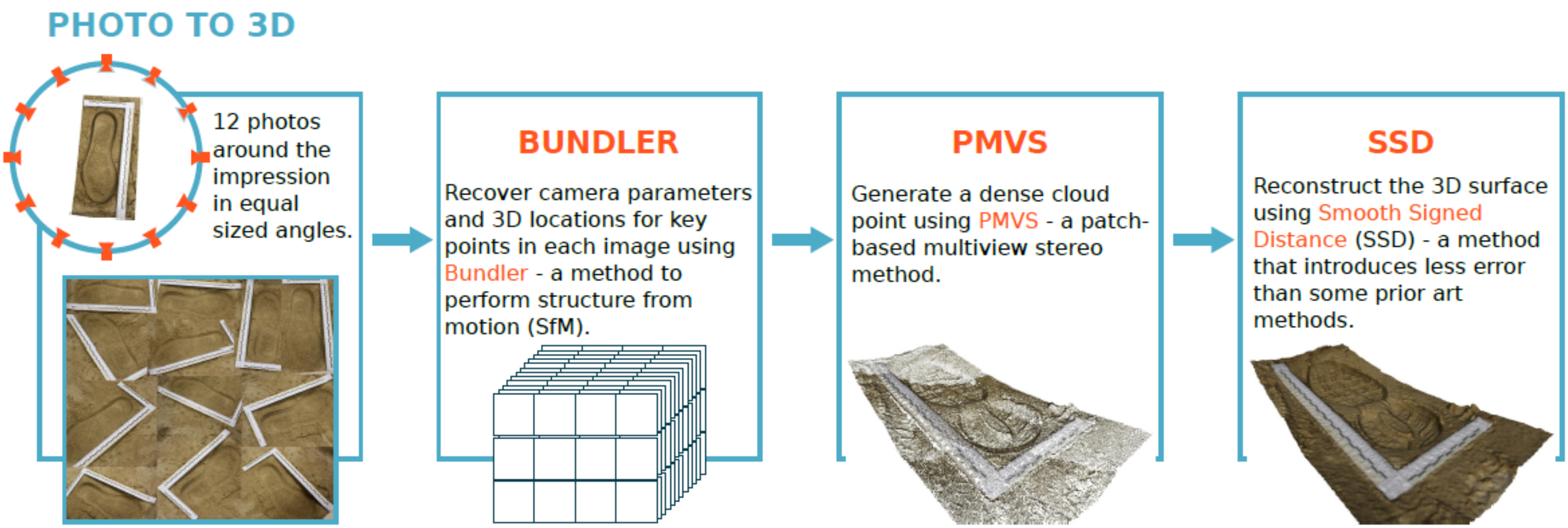
From Multi-View Video Cameras

View Interpolation From Multi-View Video Cameras

With Background Segmentation

Ongoing work

Accurate 3D Footwear Impression Recovery From Photographs,
F. A. Andalo, F. Calakli, G. Taubin, and S. Goldenstein,
International Conference on Imaging for Crime Detection and Prevention (ICDP-2011).



Comparable to 3D Laser Scanner

EXPERIMENTAL RESULTS

3D SCANNER

SHOE SOLES

d_g : Haursdoff distance map between the scanned shoe print and the scanned shoe sole.

d_m : Haursdoff distance map between our 3D model and the scanned shoe sole.

Shoeprint #	$\overline{d_g}$	$\overline{d_m}$	$\overline{d_m} - \overline{d_g}$
1	9.996	10.002	0.006
2	8.157	8.660	0.503
3	8.715	9.480	0.765
4	8.816	9.114	0.298

(mm)

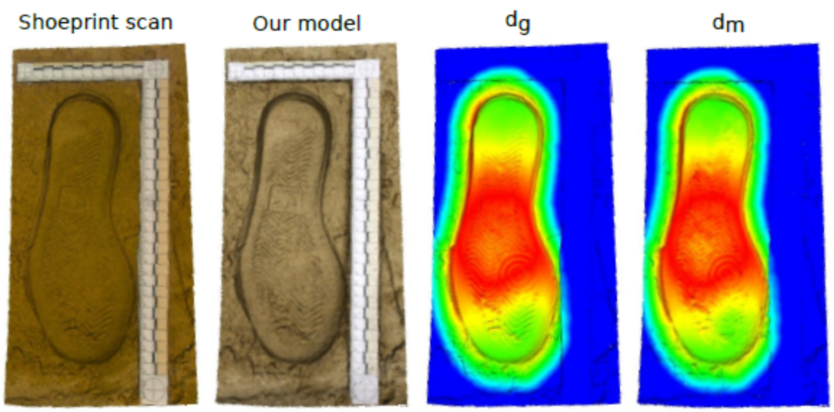
CONCLUSIONS

We presented a pipeline to recover footwear impressions from crime scenes using multiview stereo, which has not been considered for this kind of application until now.

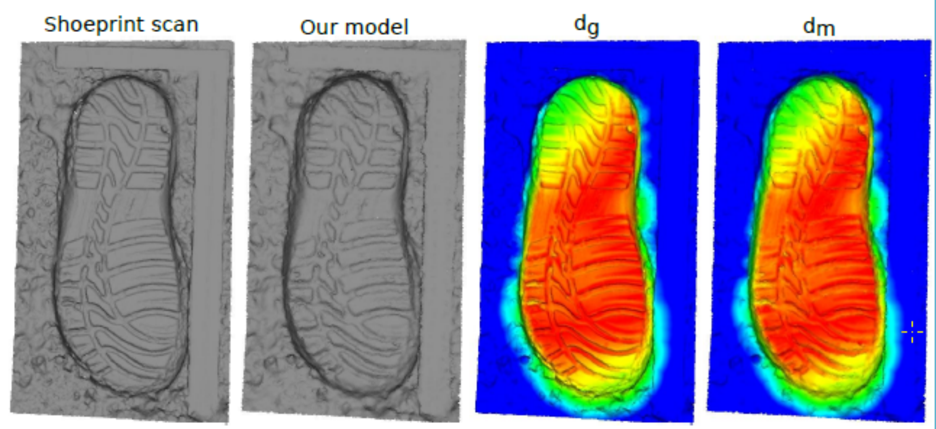
Despite the simplicity, the obtained surfaces are comparable with 3D scanning.

Future work: more experiments - number of images, angle between images, comparison with casting.

EXAMPLES

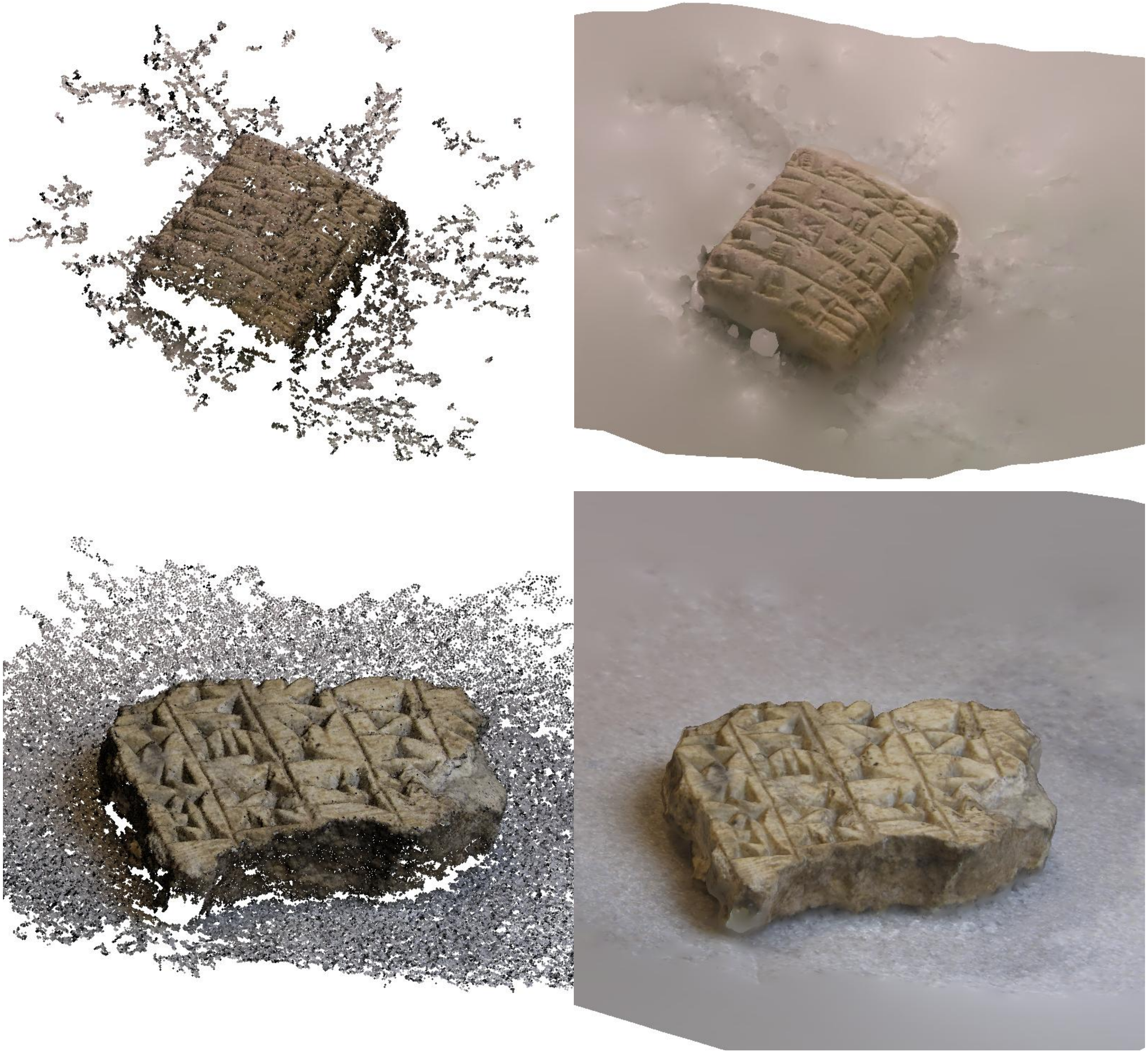


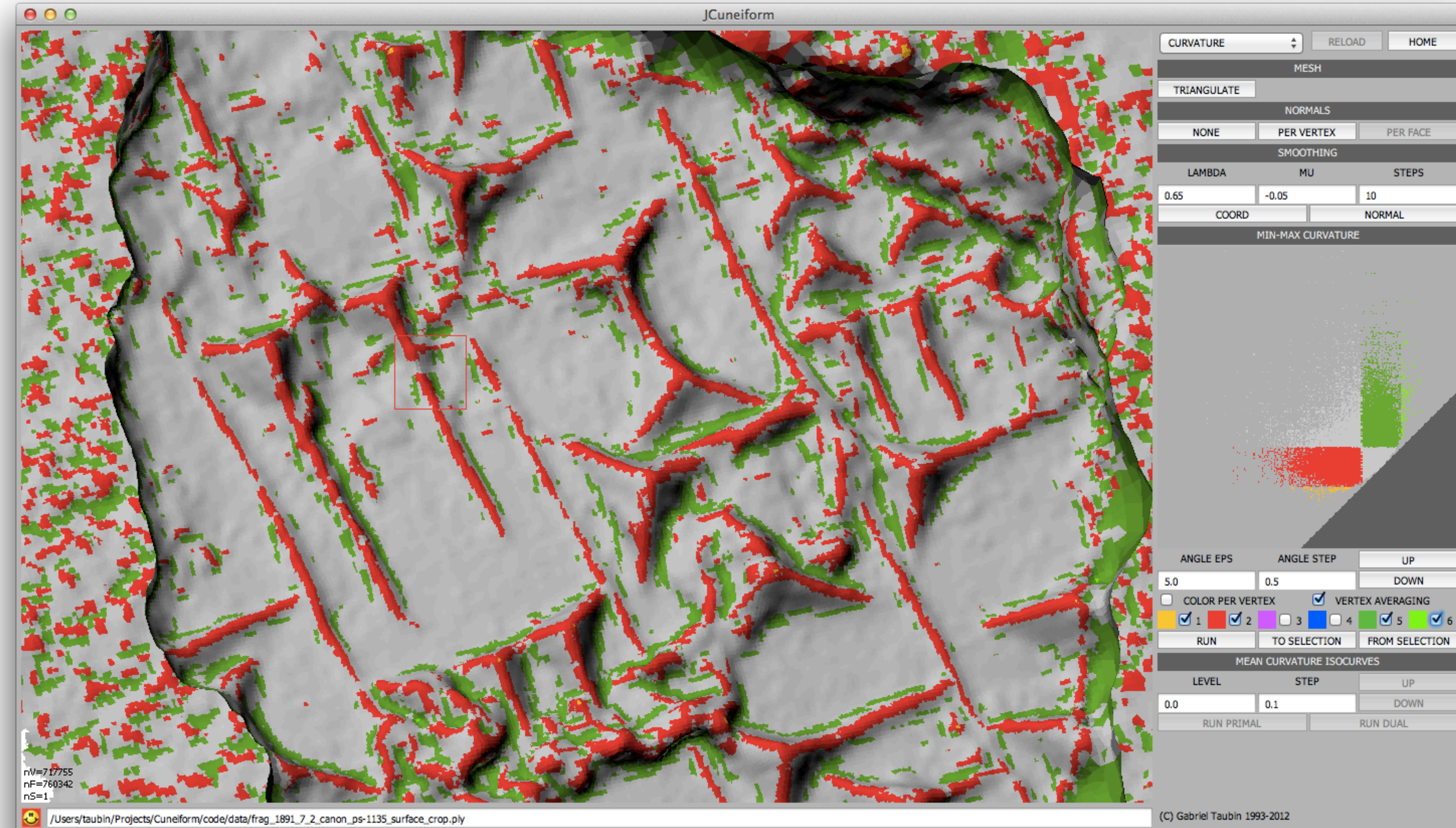
1st Shoeprint



3rd Shoeprint

Fig. 6 Reconstruction of a brick with cuneiform, Mesopotamian, 859-840 BCE, clay, Overall 35 x 35 x 11 cm, Williams College Museum of Art, Williamstown, MA, Gift of Professor Edgar J. Banks and Dr. John Henry Haynes, Class of 1876,(20.1.33.A). Top row: the input point cloud (left), and surface geometry (right) reconstructed by the proposed algorithm. Middle row: Two views from surface and color map reconstructed by the proposed algorithm. Bottom row: 6 examples from the set of 21 images that are used for shape acquisition.

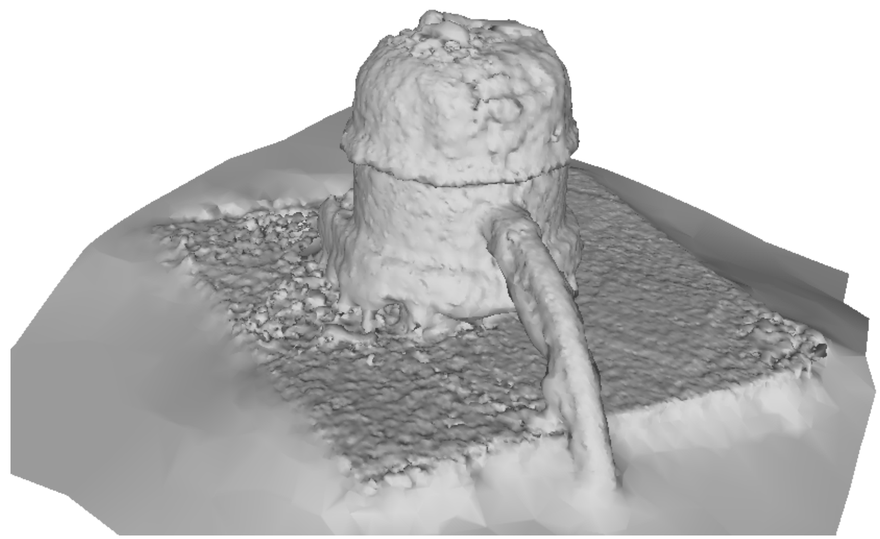


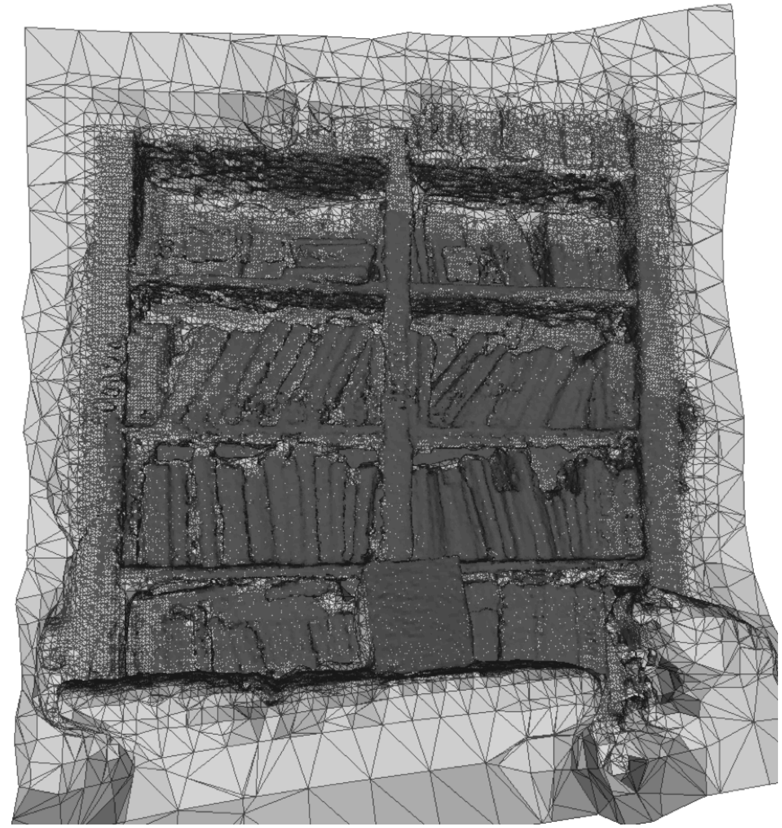
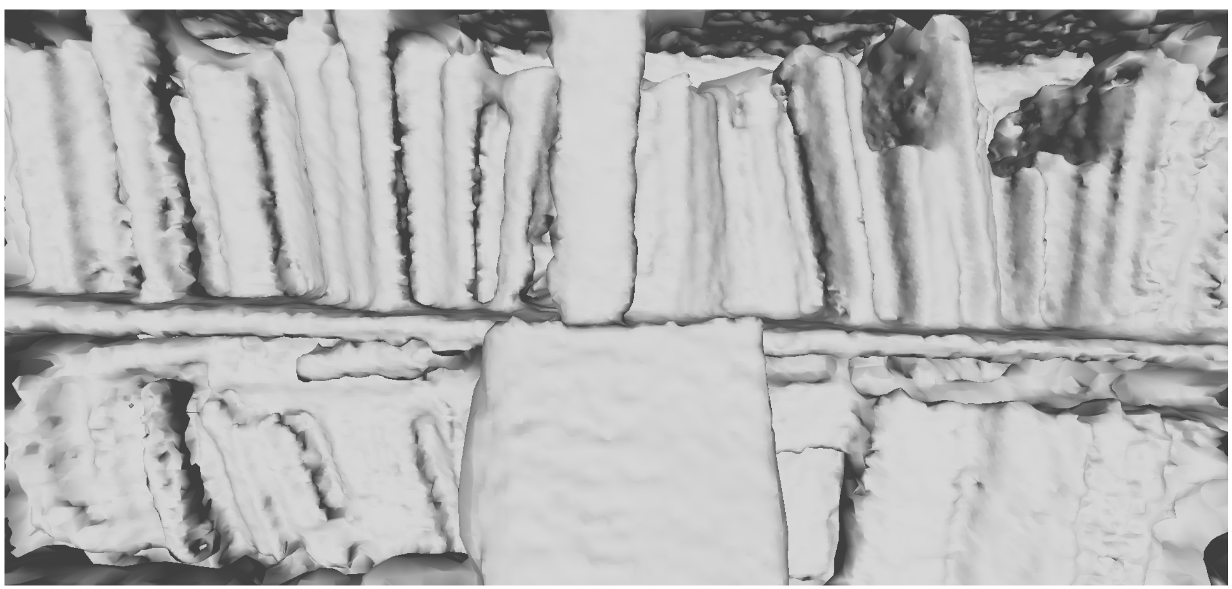

JCuneiform
CURVATURE
RELOAD
HOME
MESH
TRIANGULATE
NORMALS
NONE
PER VERTEX
PER FACE
SMOOTHING
LAMBDA
MU
STEPS
0.65
-0.05
10
COORD
NORMAL
MIN-MAX CURVATURE
ANGLE EPS
ANGLE STEP
UP
5.0
0.5
DOWN
COLOR PER VERTEX
VERTEX AVERAGING
RUN
TO SELECTION
FROM SELECTION
MEAN CURVATURE ISOCURVES
LEVEL
STEP
UP
0.0
0.1
DOWN
RUN PRIMAL
RUN DUAL
nV=717755
nF=760342
nS=1
/Users/taubin/Projects/Cuneiform/code/data/frag_1891_7_2_canon_ps-1135_surface_crop.ply
(C) Gabriel Taubin 1993-2012

Handheld Interactive, Incremental 3D Object Scanning

J. Kim & G. Taubin

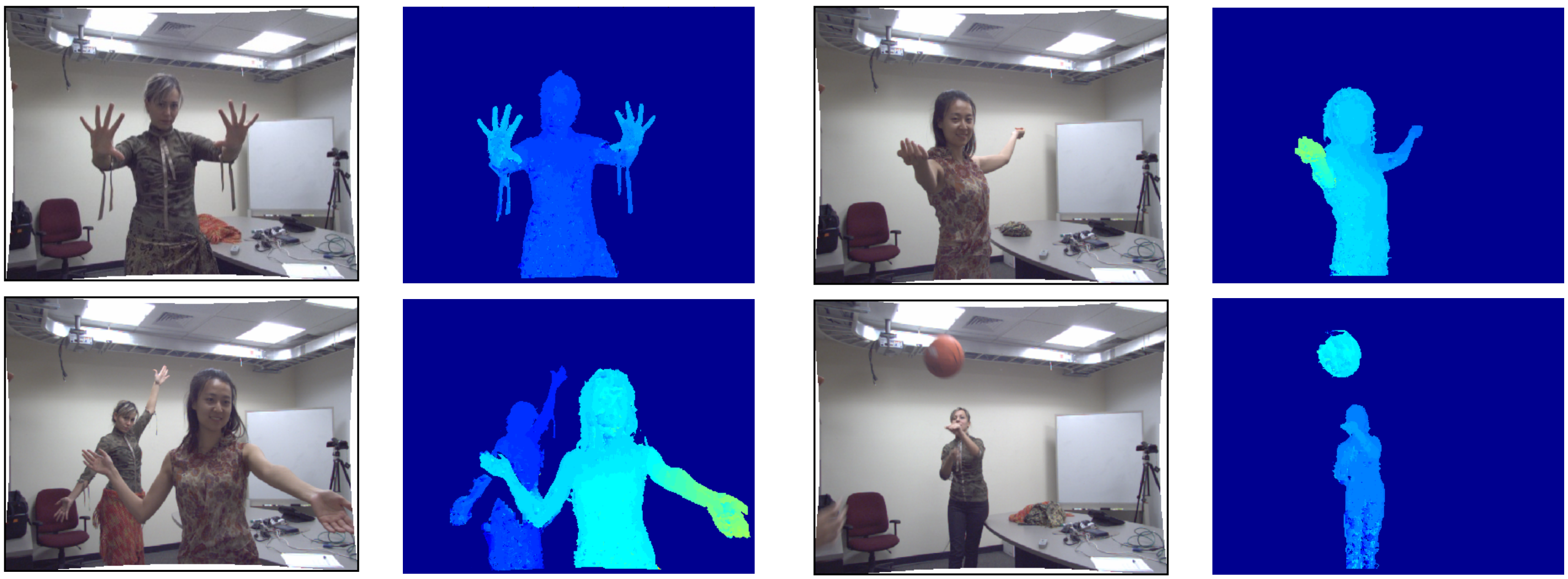
- Based on MS Kinect sensor
- Continuous coarse pose estimation from color camera using PTAM
- 3D snapshots captured from different points of view using depth camera
- Alignment improced with Iterative Closest Points (ICP) algorithm
- SSD is run on aligned 3D snapshots



Real-Time High-Definition Stereo on GPGPU using Progressive Multi-Resolution Adaptive Windows

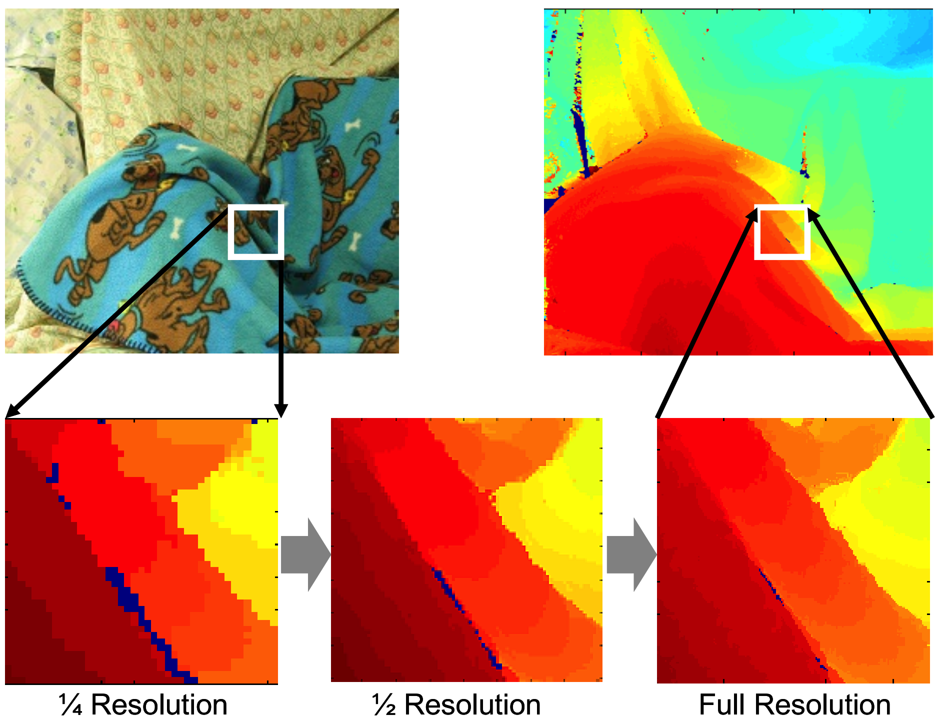
Y. Zhao, and G. Taubin, Image and Vision Computing 2011.



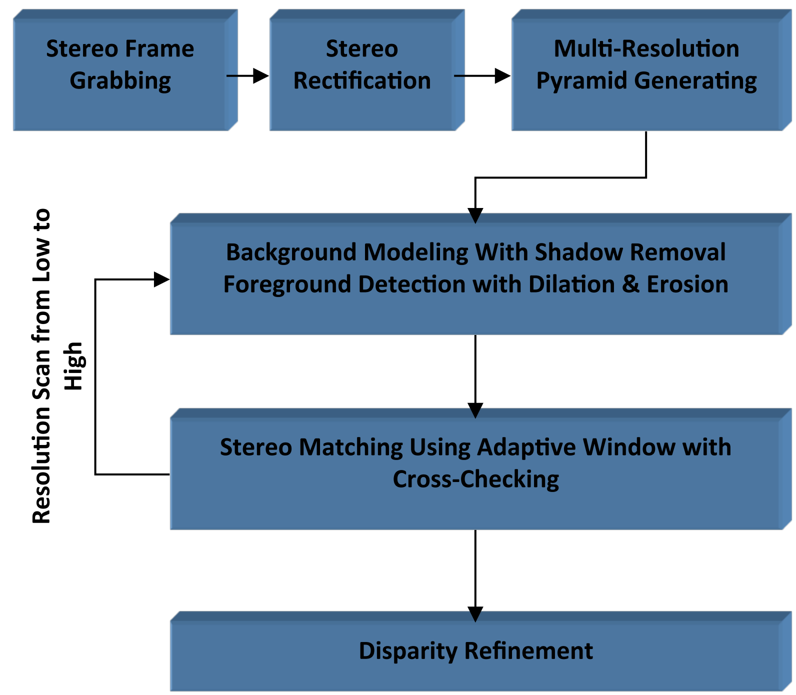
Screen shots of our real-time stereo system working on the field

Real-Time High-Definition Stereo on GPGPU using Progressive Multi-Resolution Adaptive Windows

Y. Zhao, and G. Taubin, Image and Vision Computing 2011.



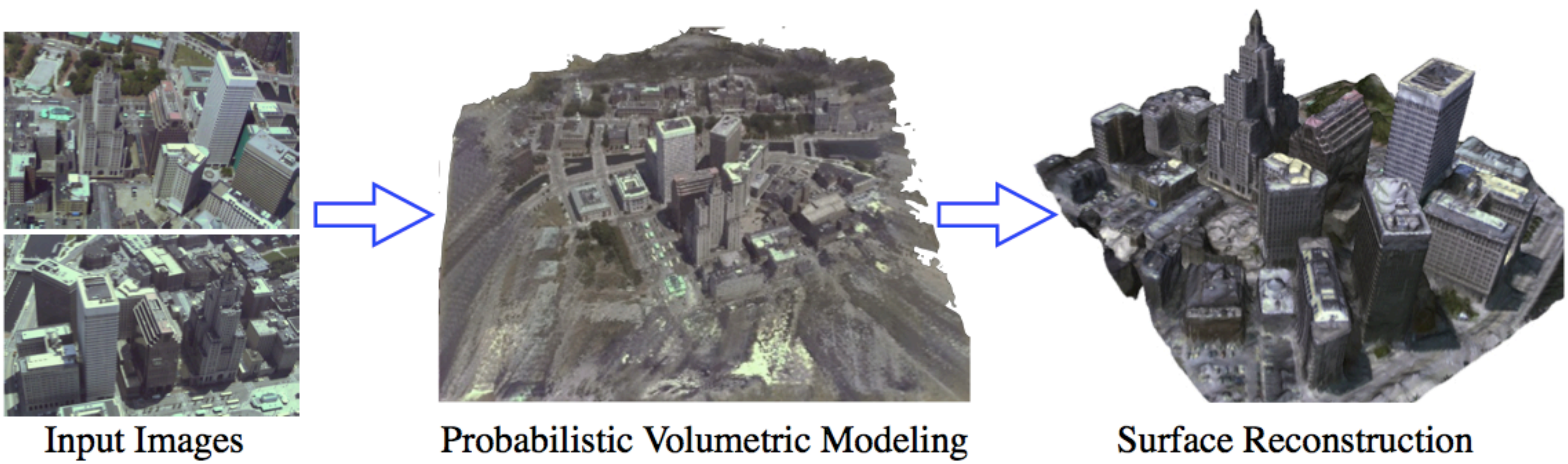
Coarse-to-fine matching on multiple resolutions



Processing Pipeline

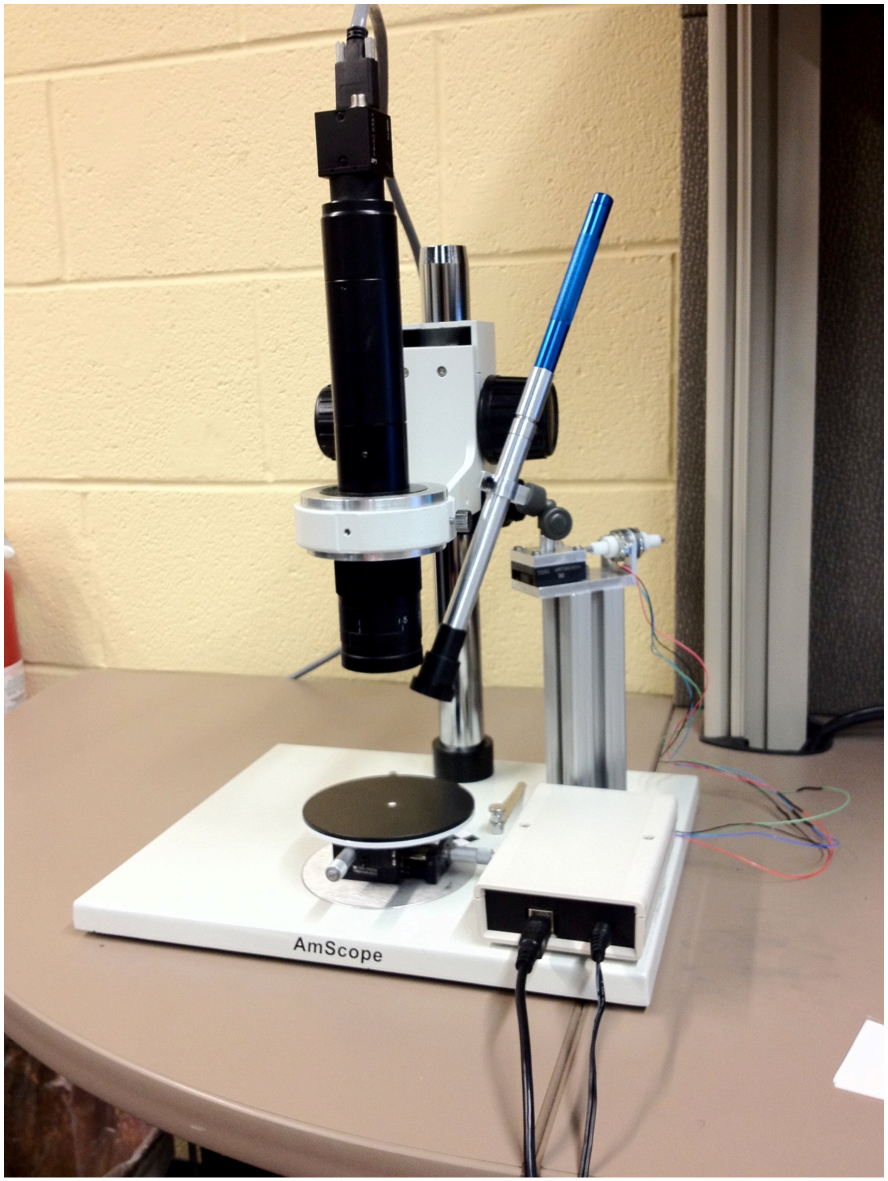
High Resolution Surface Reconstruction from Multi-view Aerial Imagery

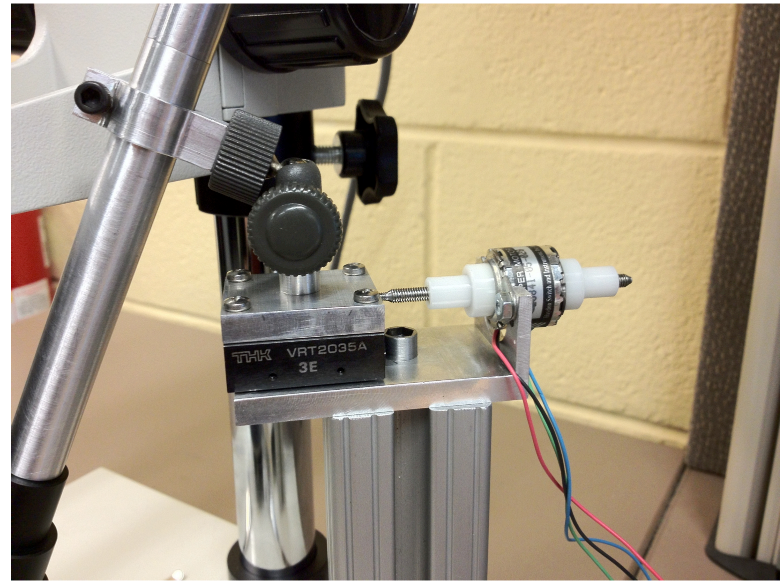
by Calakli, Ulusoy, Restrepo, Mundy & Taubin, 3DIMPVT 2012

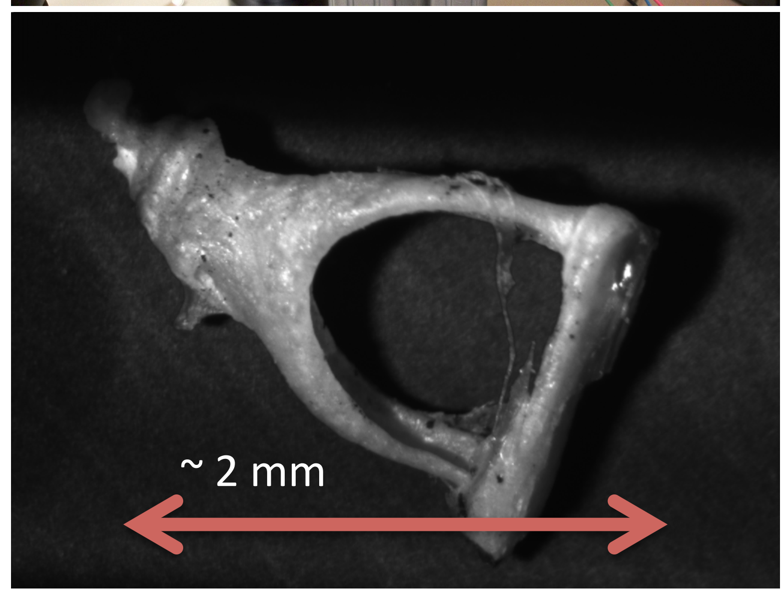


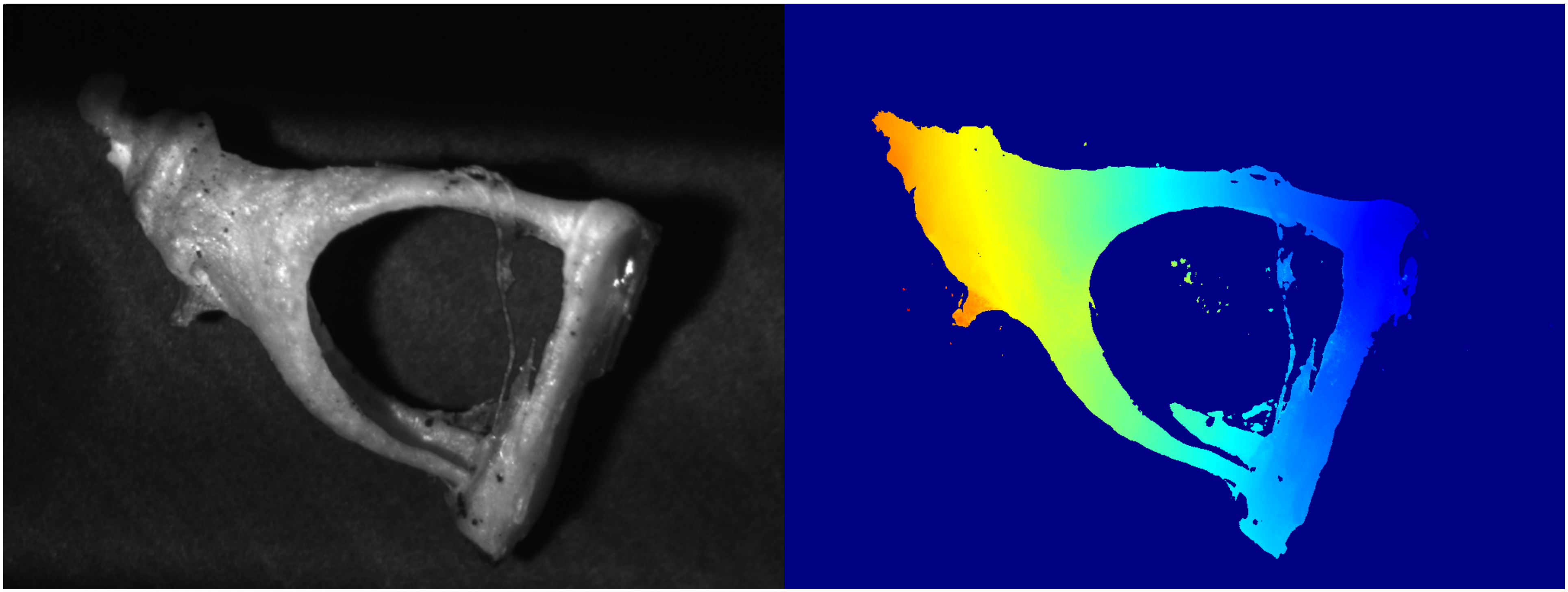
Microscopic 3D Shape Capture

Liberman & Taubin (work in progress)





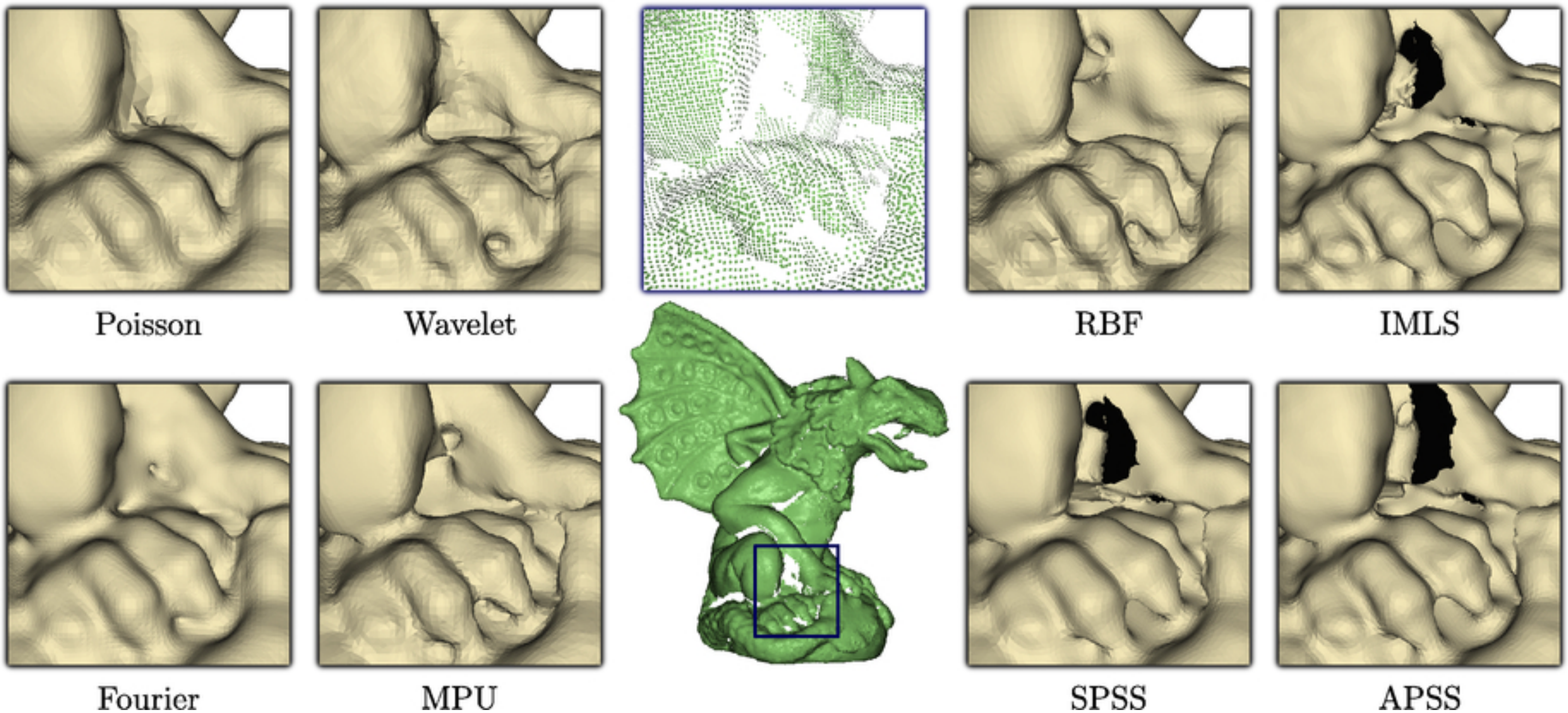




An Evaluation and Comparison of Surface Reconstruction

M. Berger, J. Levine, L. Nonato, C. Silva, and G.Taubin

ACM Transactions on Graphics 2013 (Siggraph 2013)



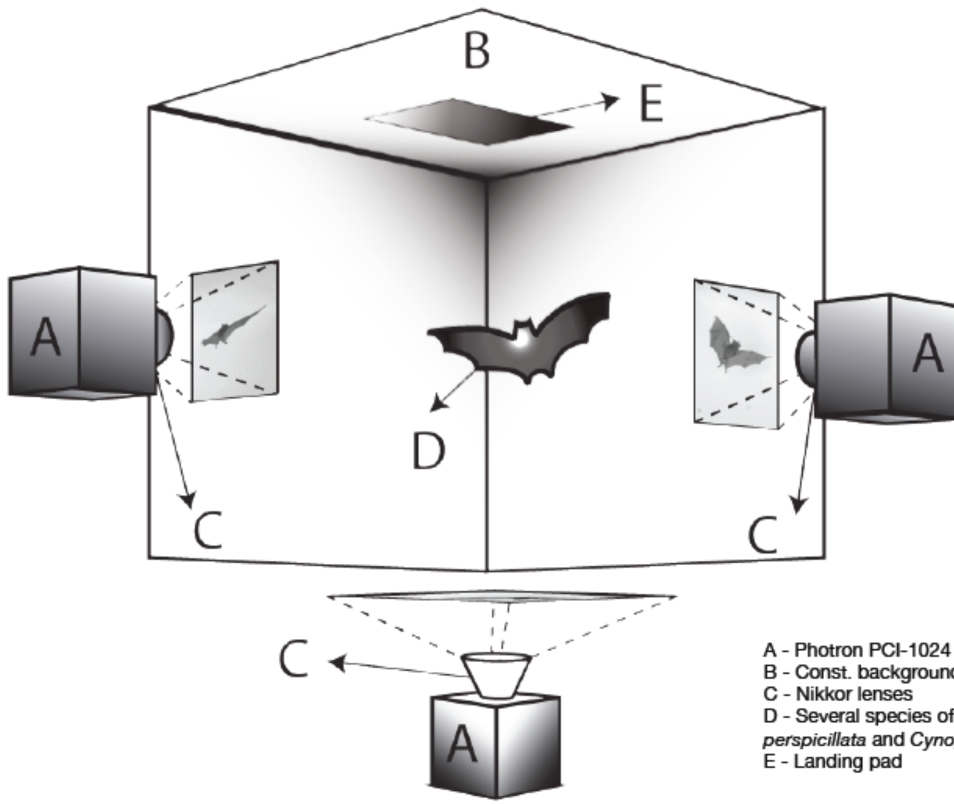
http://www.cs.utah.edu/~bergerm/recon_bench/

3D Reconstruction & Analysis of Bat Flight Maneuvers

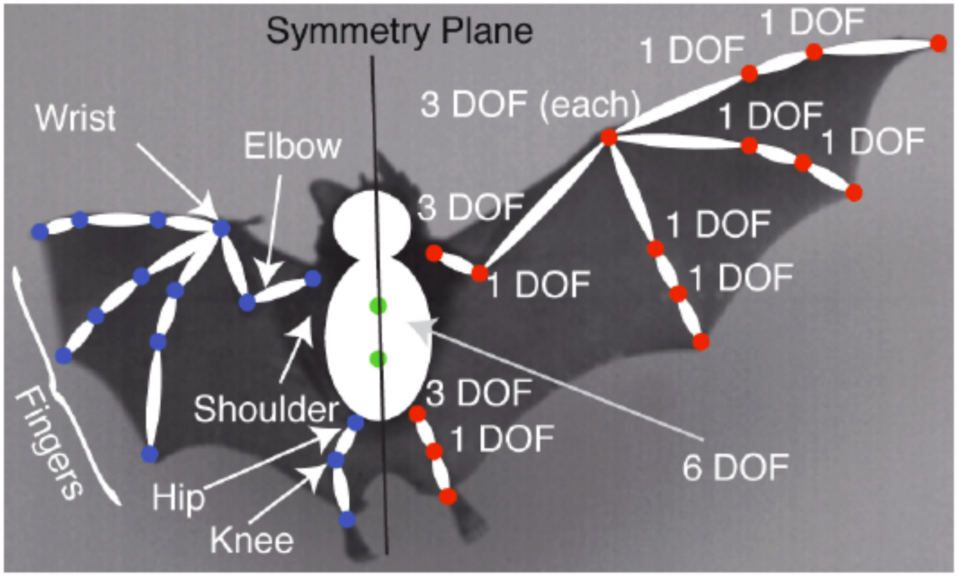
- 3D Reconstruction of Bat Flight Kinematics from Sparse Multiple Views, by A. Bergou, S. Swartz, and G. Taubin, and K. Breuer, 4DMOD, 2011.
- 3D Reconstruction and Analysis of Bat Flight Maneuvers from Sparse Multiple View Video, by A. Bergou, S. Swartz, S. K. Breuer, G. Taubin, BioVis, 2011.
- Falling with Style - The Role of Wing Inertia in Bat Flight Maneuvers, by A. Bergou, D. Riskin, G. Taubin, S. Swartz, and K. Breuer, Annual Meeting, Society for Integrative and Comparative Biology, 2011.
- Falling with Style-Bat Flight Maneuvers, by A. Bergou, D. Riskin, G. Taubin, S. Swartz, and K. Breuer, Bulletin of the American Physical Society, Vol. 55, 2010.

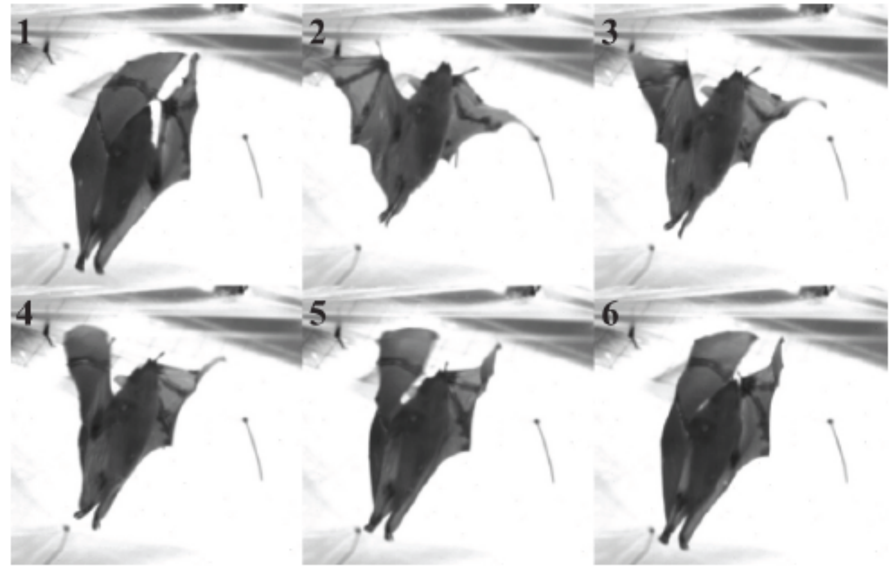
How do we measure bats ?

- Multiple synchronized 1000fps+ cameras
- Controlled environment (backdrop & illumination)
- Bats trained to land on landing pad
- Experiments with several species

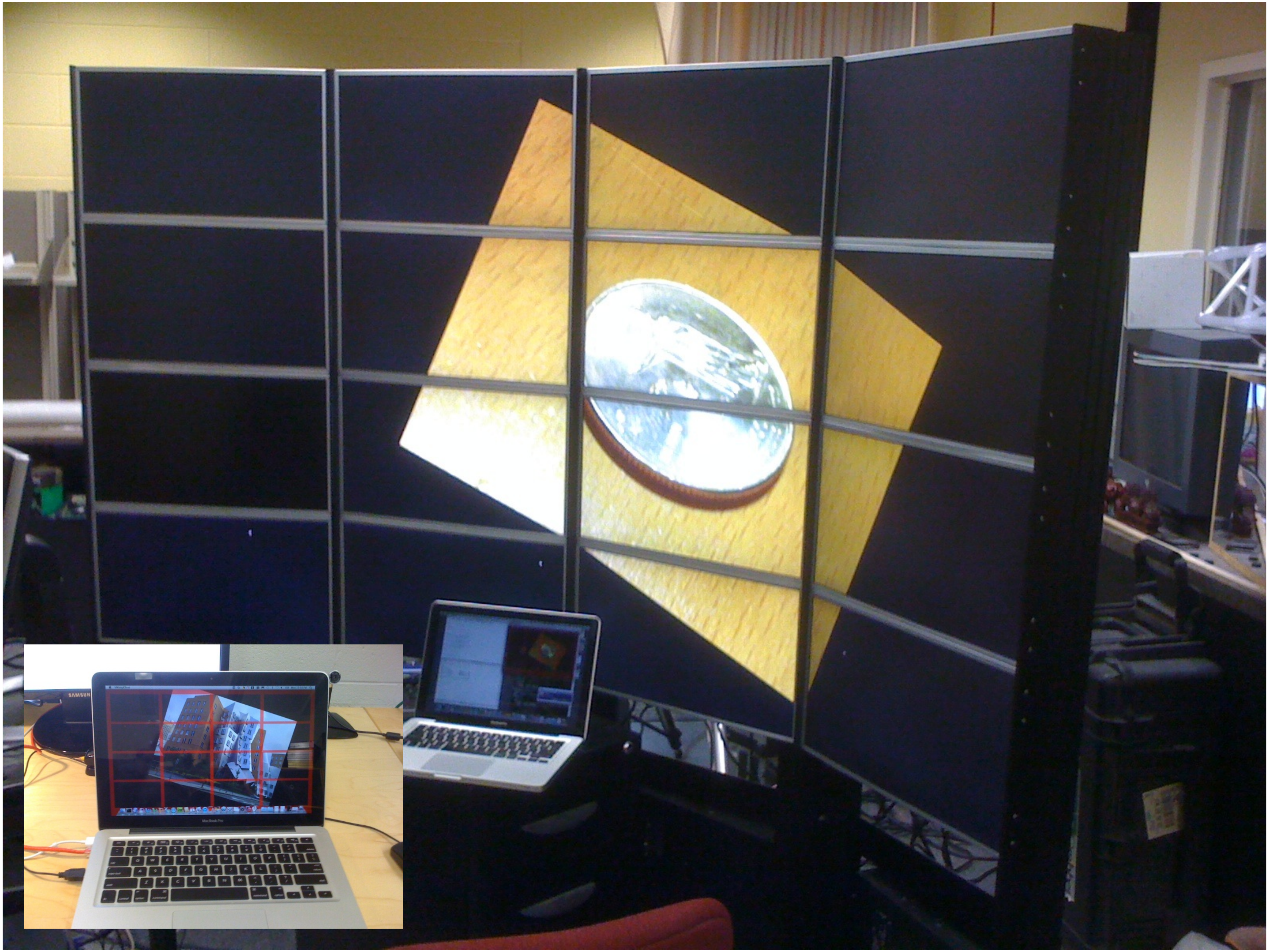


A - Photron PCI-1024 cameras
B - Const. background
C - Nikkor lenses
D - Several species of bats (e.g. *Carollia perspicillata* and *Cynopterus brachyotis*)
E - Landing pad





- Bats have highly articulated wings
- Very complex wing motion
- Current goal: Detailed reconstruction of wing and body kinematics and derivatives from visual data
- Skeleton model with 52 degrees of freedom
- Geometry parameterized by 37 constants
- **Future Goal: Model-less Dynamic Shape Reconstruction**



Course Schedule

Session II

- Structured Lighting
- Projector Calibration / Structured Light Reconstruction
- Combining Point Clouds Recovered from Multiple Views
- Surface Reconstruction from Point Clouds
- Elementary Mesh Processing
- Related Projects
- ***Conclusion / Q & A***