Introducción a la Fotografia 3D
UBA/FCEN Marzo 27 – Abril 12 2013
Clase 9 : Viernes Abril 12

Gabriel Taubin
Brown University

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Course Schedule

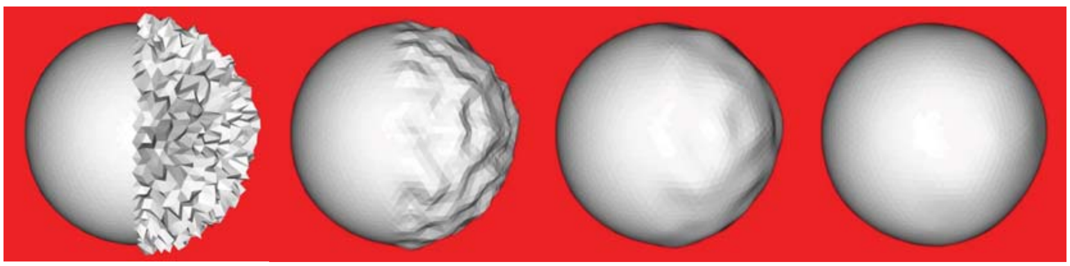
- Structured Lighting
- Projector Calibration / Structured Light Reconstruction
- Combining Point Clouds Recovered from Multiple Views
- Surface Reconstruction from Point Clouds
- ➢ ***Elementary Mesh Processing***
- Related Projects
- Conclusion / Q & A

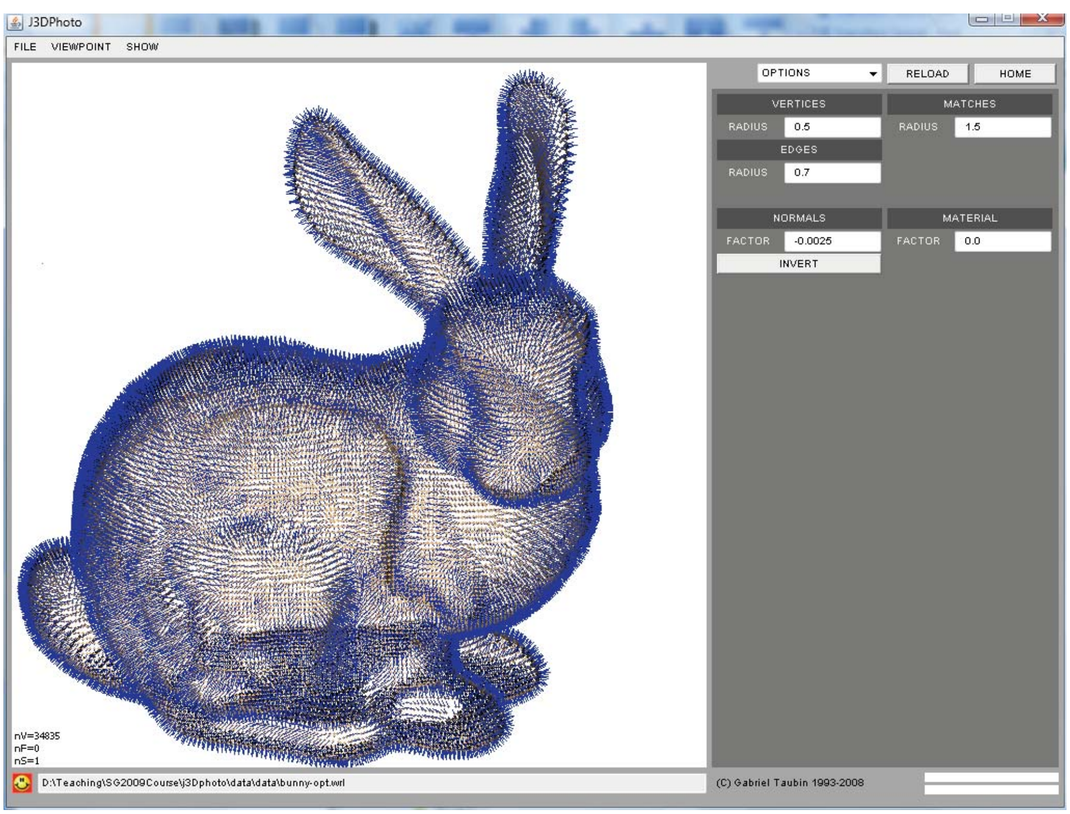
Elementary Mesh Processing

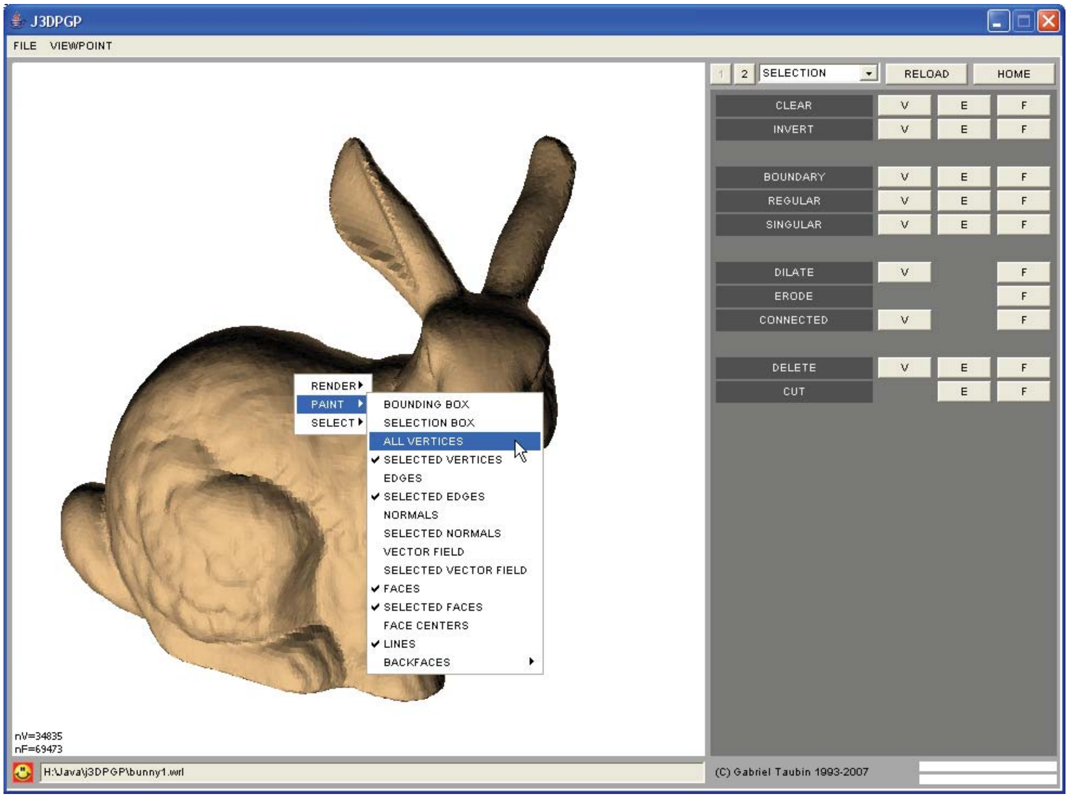
- We will talk about a few simple algorithms which can be applied interactively

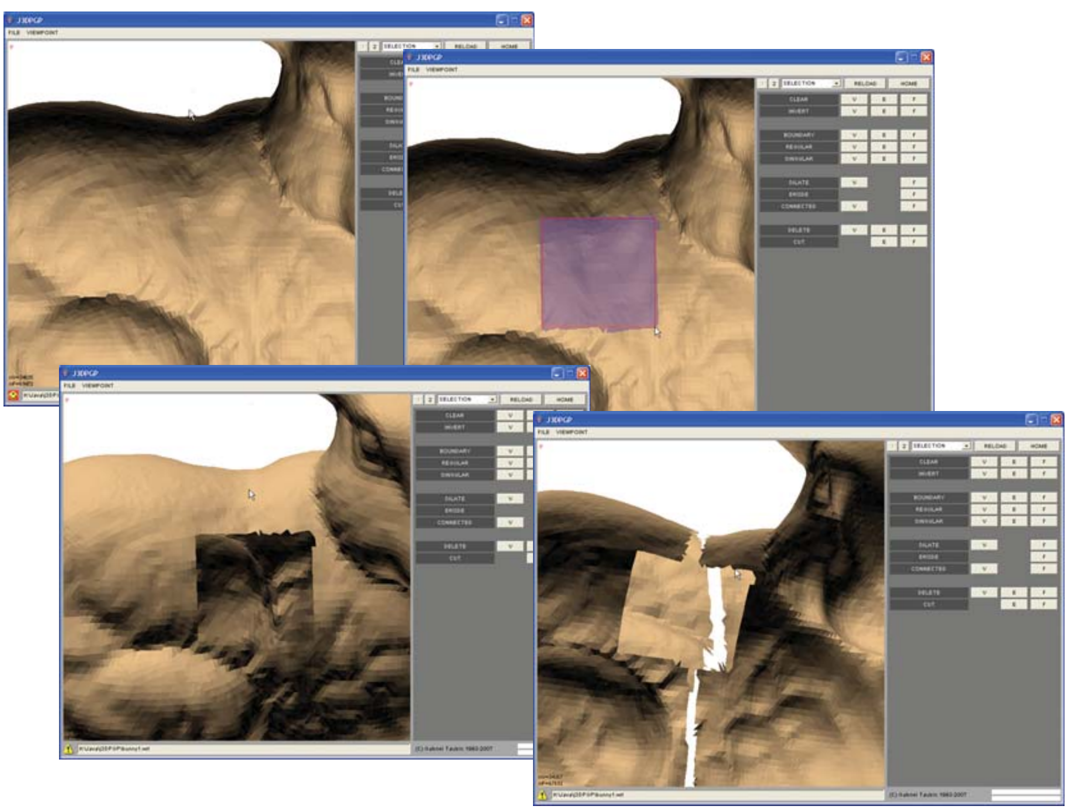
- Polygon mesh smoothing / denoising
- Polygon mesh simplification

- j3DPGP (Java 3D Photography and Geometry Processing)

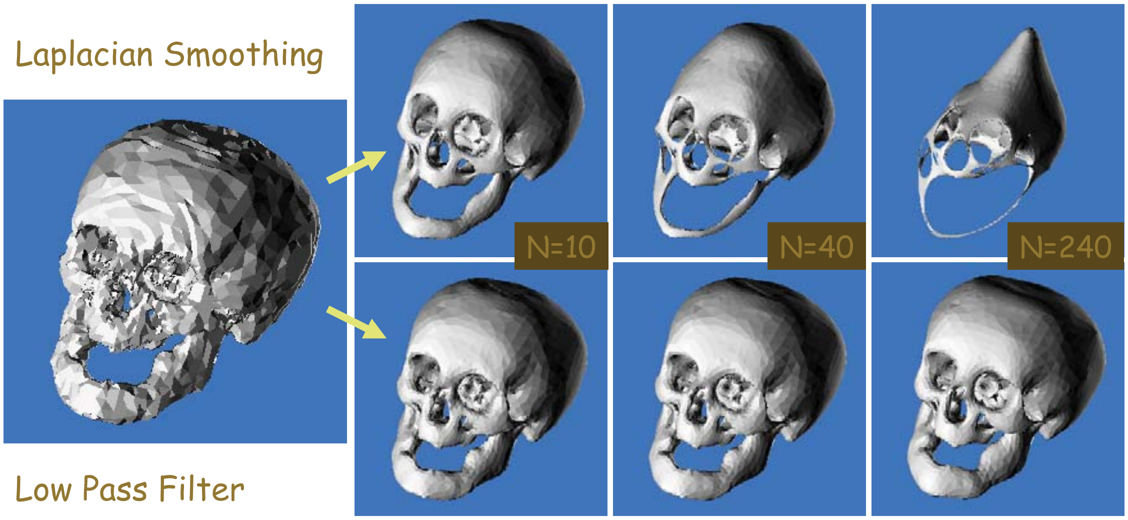





J3DPGP
FILE VIEWPOINT
1 2 SELECTION RELOAD HOME
CLEAR V E F
INVERT V E F
BOUNDARY V E F
REGULAR V E F
SINGULAR V E F
DILATE V F
ERODE F
CONNECTED V F
DELETE V E F
CUT E F
RENDER
PAINT
SELECT
BOUNDING BOX
SELECTION BOX
ALL VERTICES
SELECTED VERTICES
EDGES
SELECTED EDGES
NORMALS
SELECTED NORMALS
VECTOR FIELD
SELECTED VECTOR FIELD
FACES
SELECTED FACES
FACE CENTERS
LINES
BACKFACES
nV=34835
nF=69473
H:\Java\j3DPGP\bunny1.wrl
(C) Gabriel Taubin 1993-2007



Polygon Mesh Smoothing / Denoising

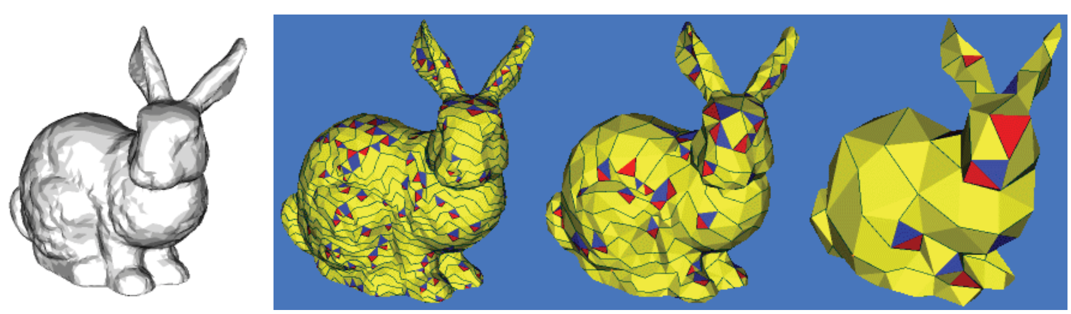


- Laplacian smoothing is the simplest smoothing/denoising algorithm
- Fix to shrinkage problem: toggle parameter sign at each iteration !

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

Poligon Mesh Simplification / Decimation

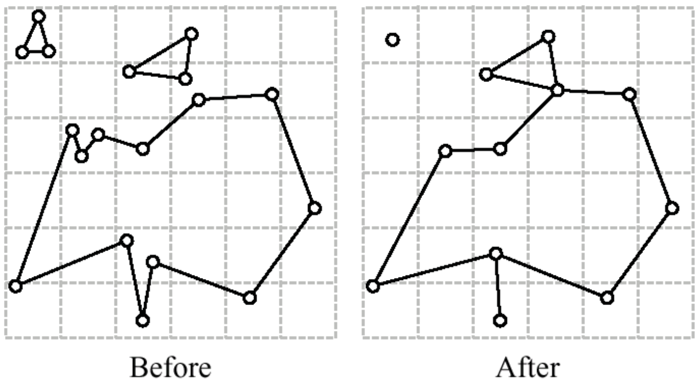
- Algorithms to reduce the number of vertices and faces while preserving geometric approximation to original shape



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

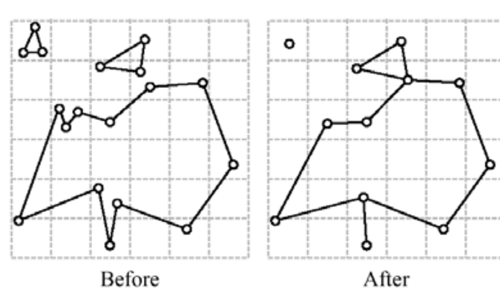
Vertex Clustering

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



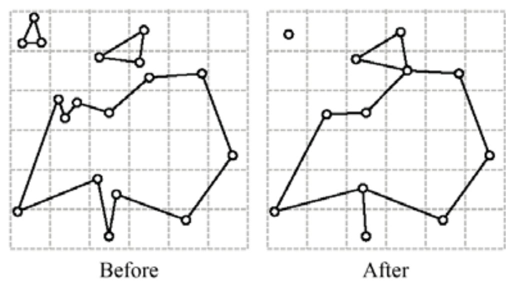
Vertex Clustering Algorithm

- 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

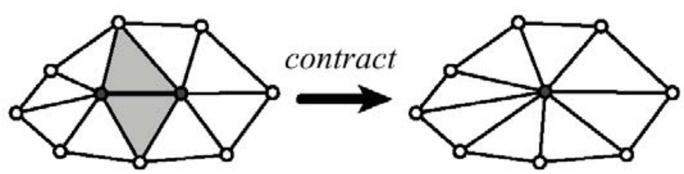


Vertex Clustering

- 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

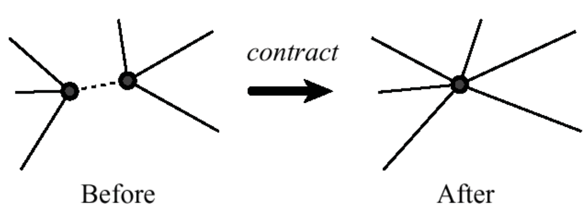


Edge Collapse

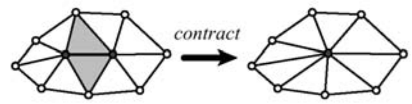


- Identify endpoints
- Determine vertex position
- Remove incident triangles
- Which edges to collapse ?
- In which order ?

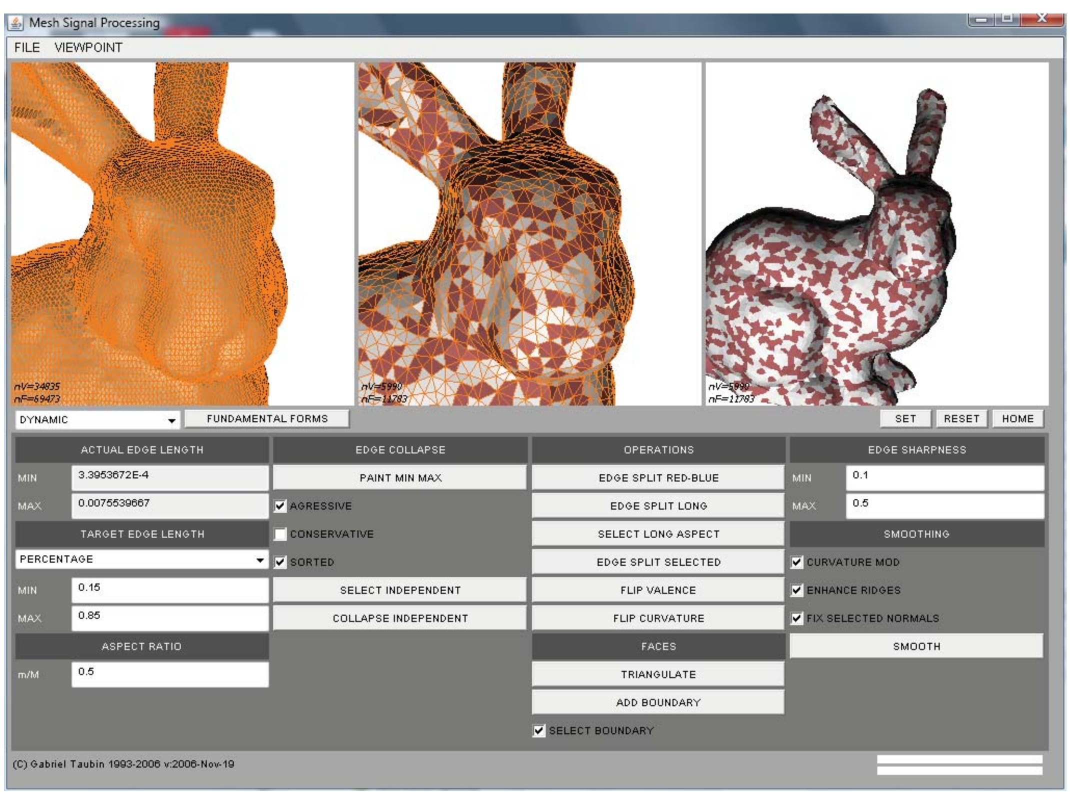
Non-existing edges



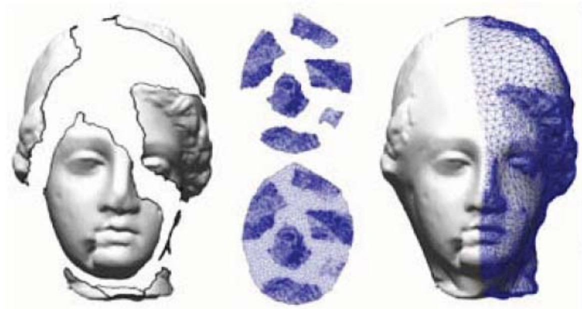
Basic Edge Collapse Algorithm



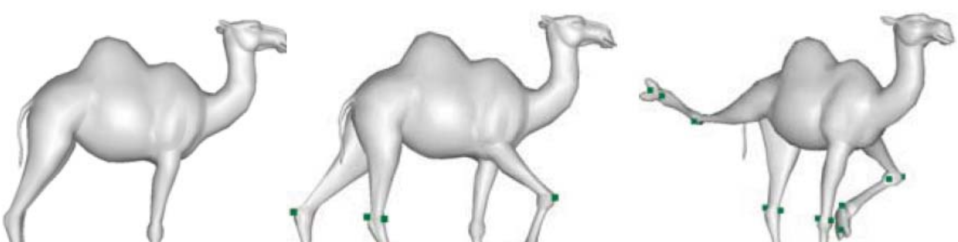
- Put all **collapsible** edges in a priority queue according to **removal error**
- While queue is not empty
  - Delete minimum edge from queue
  - Collapse edge
  - Identify vertices
  - Remove all incident edges from the queue, determine if collapsible, recompute removal error, re-insert in queue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



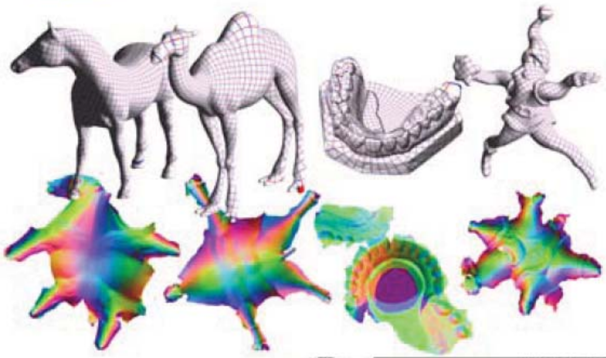
Completion

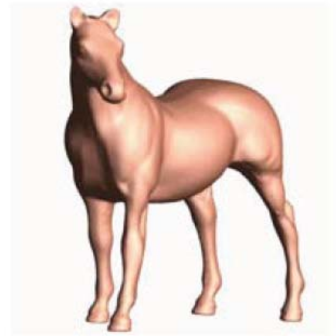


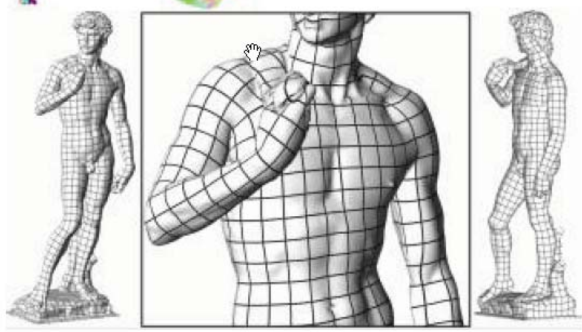
Deformation



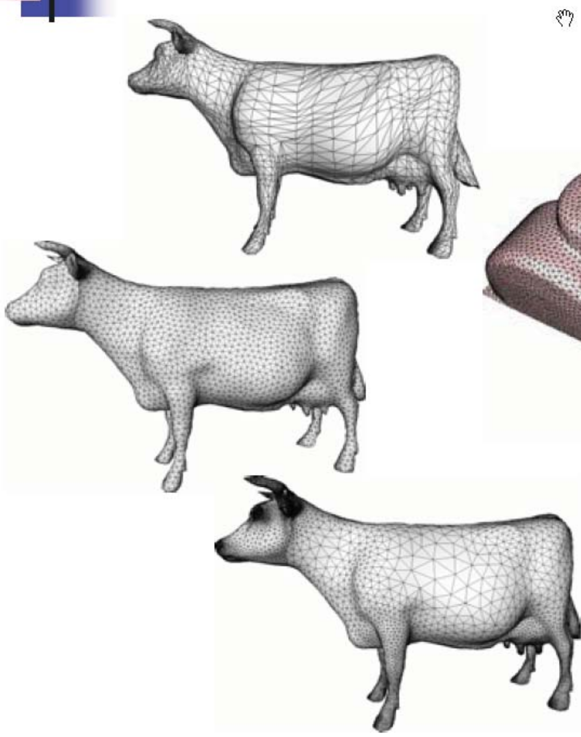
Parameterization

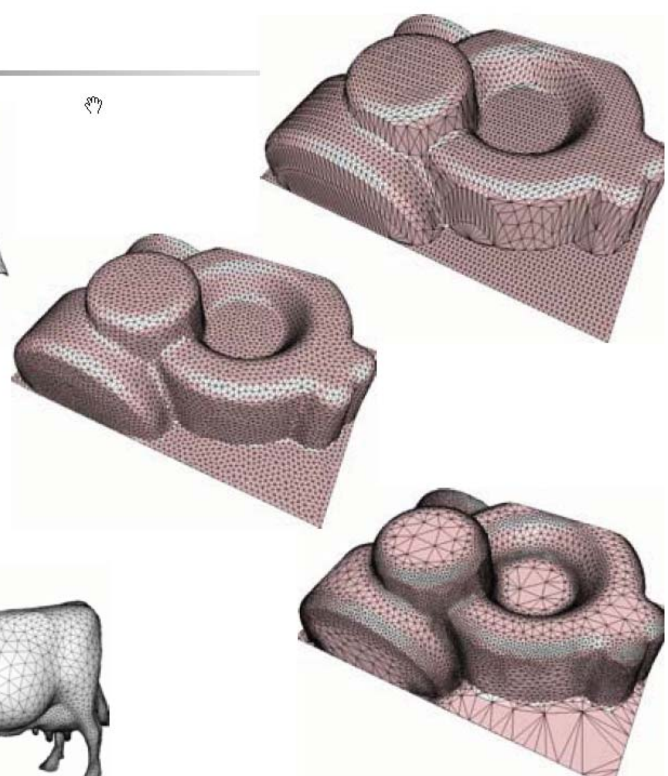




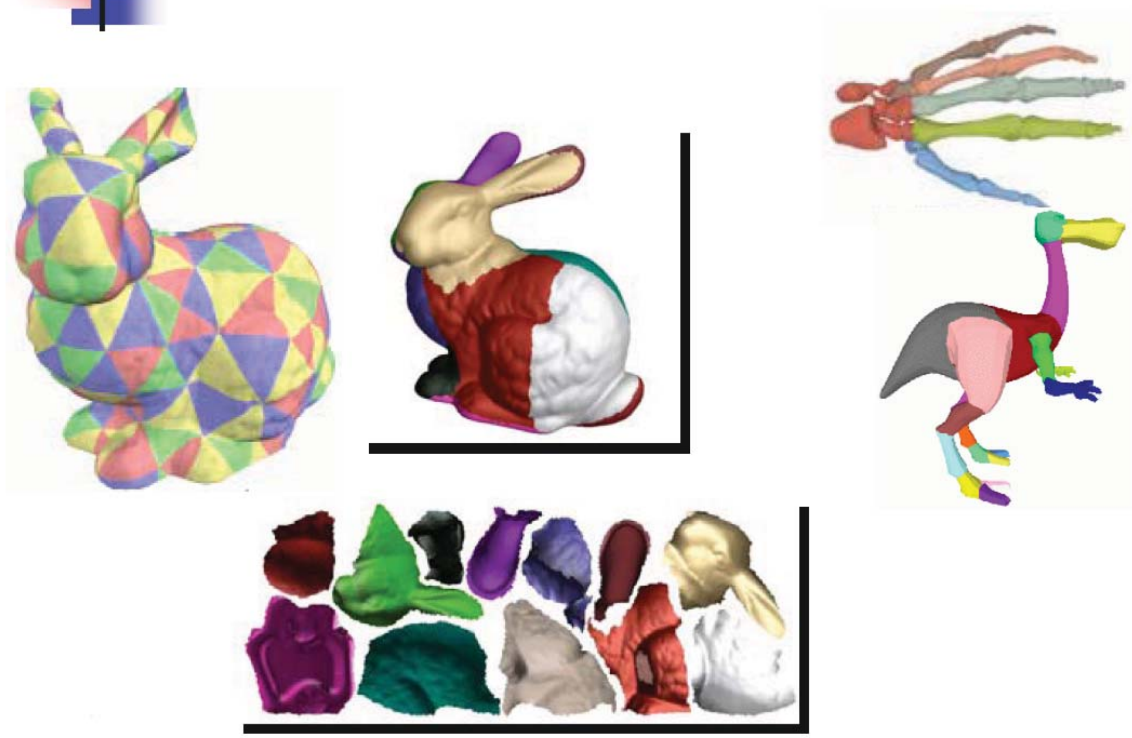


Remeshing





Segmentation



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REVEAL Digital Archaeology Project

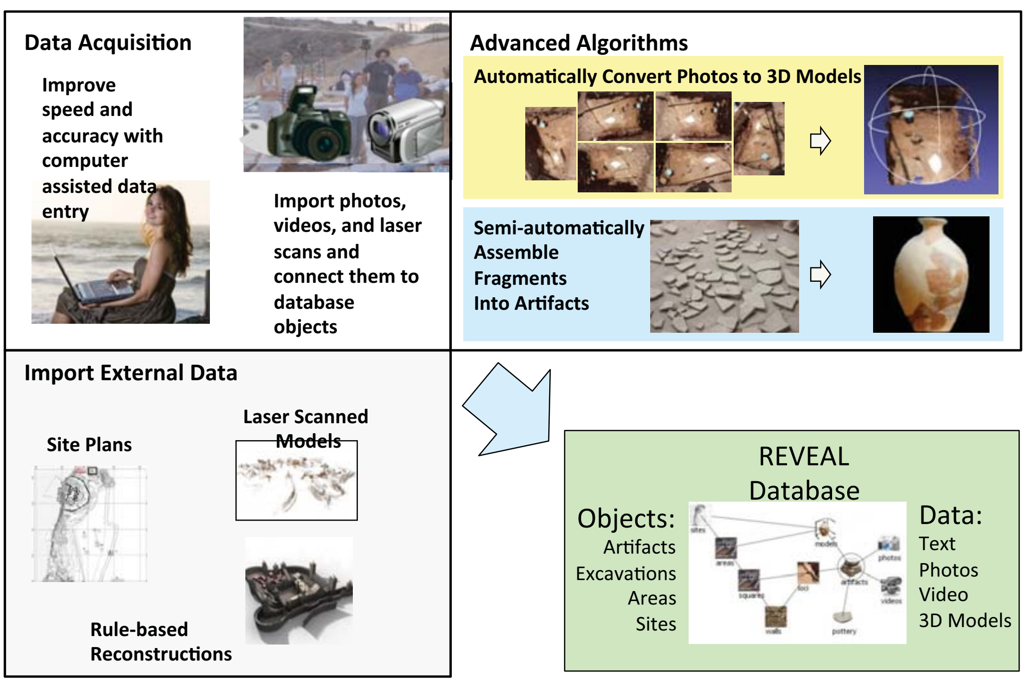
Cooper, Kimia, Taubin, Galor, Sanders, Willis

- 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

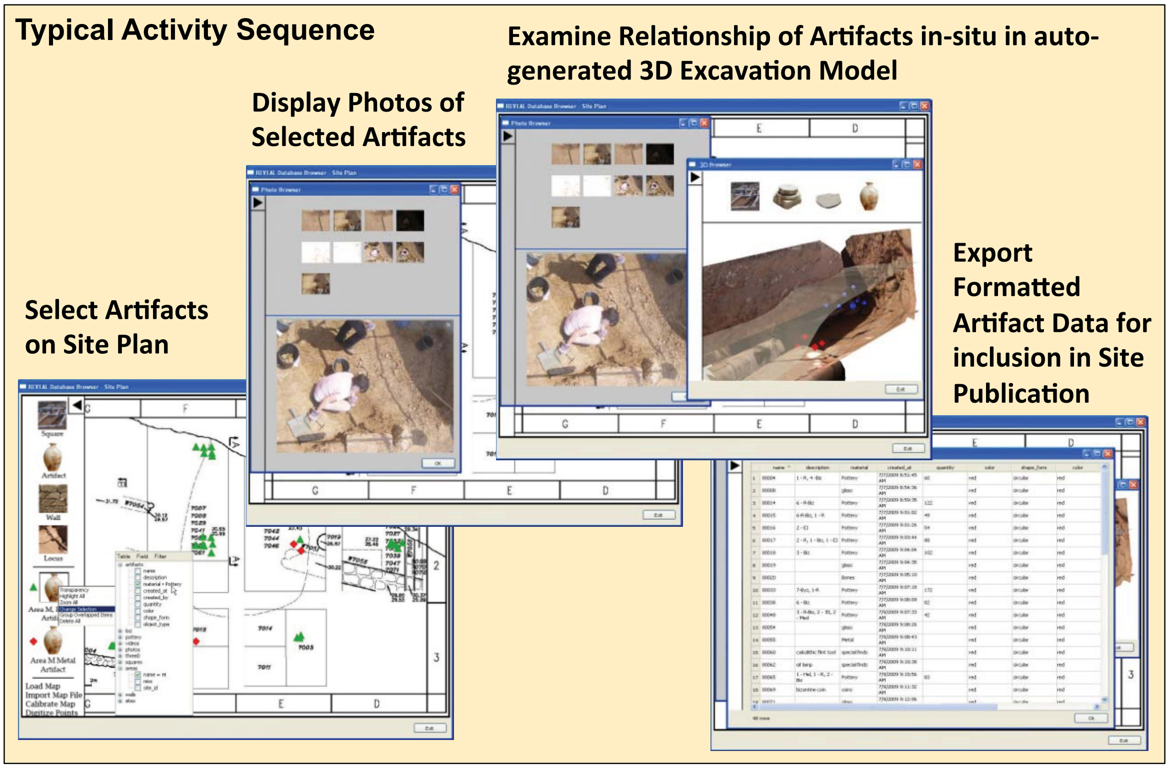
Assisted Data Acquisition, Algorithmic Reconstruction, Integrated multi-format analysis



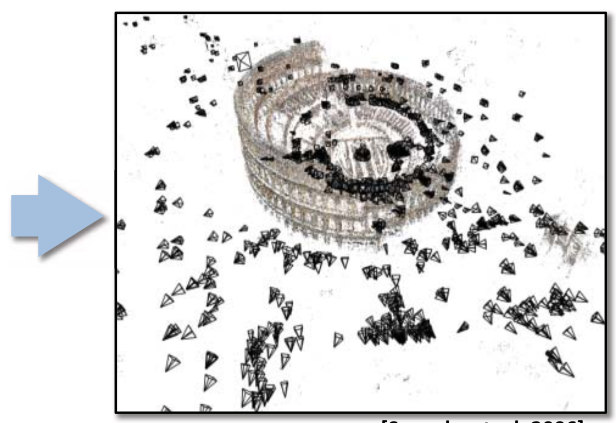
http://sourceforge.net/projects/revealanalyze

REVEAL Archaeological Analysis

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

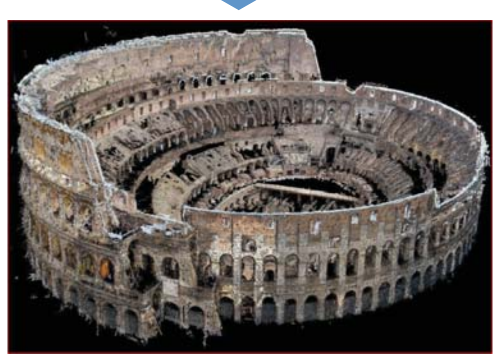


http://phototour.cs.washington.edu/bundler/



[Snavely et. al. 2006]

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



[Furukawa and Ponce 2008]

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).

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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

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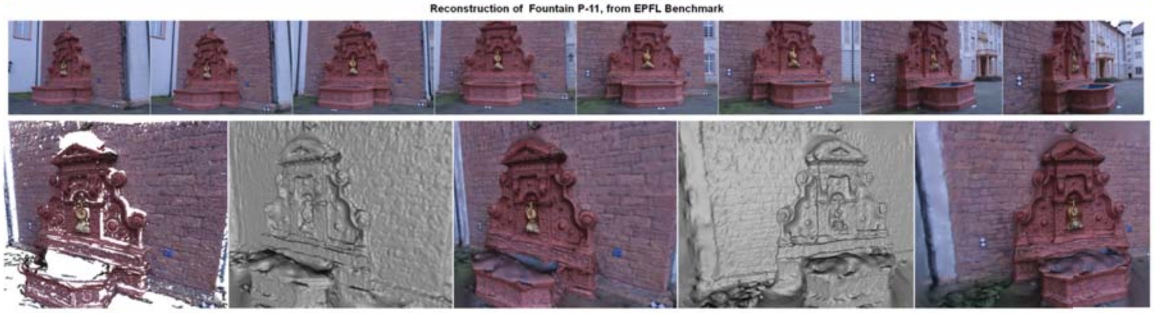
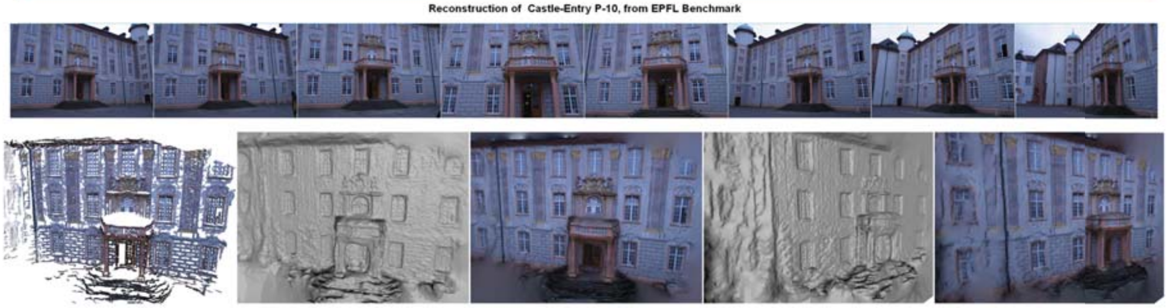
High Resolution Surface and Appearance Modeling for Multi-view Stereo

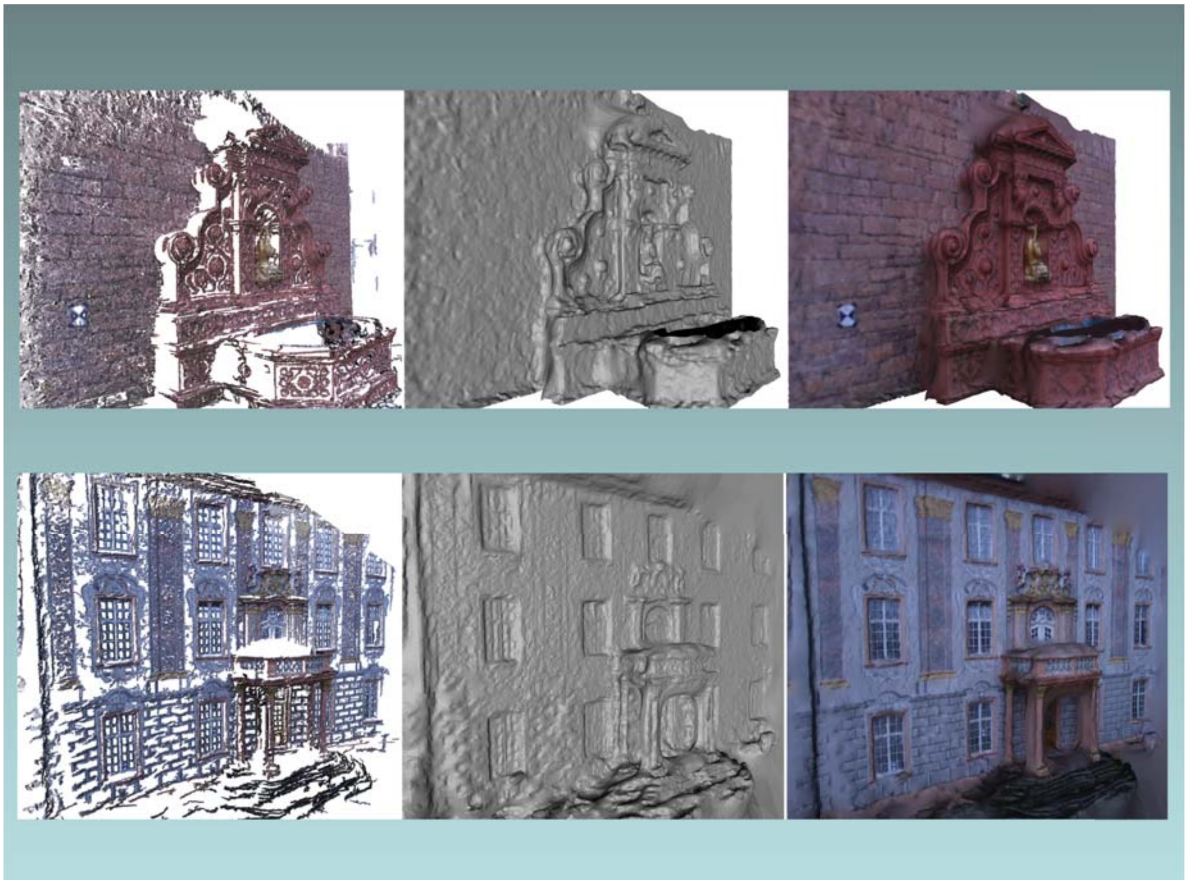
Fatih Calakli and Gabriel Taubin

Reconstruction of Fountain P-11, from EPFL Benchmark



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





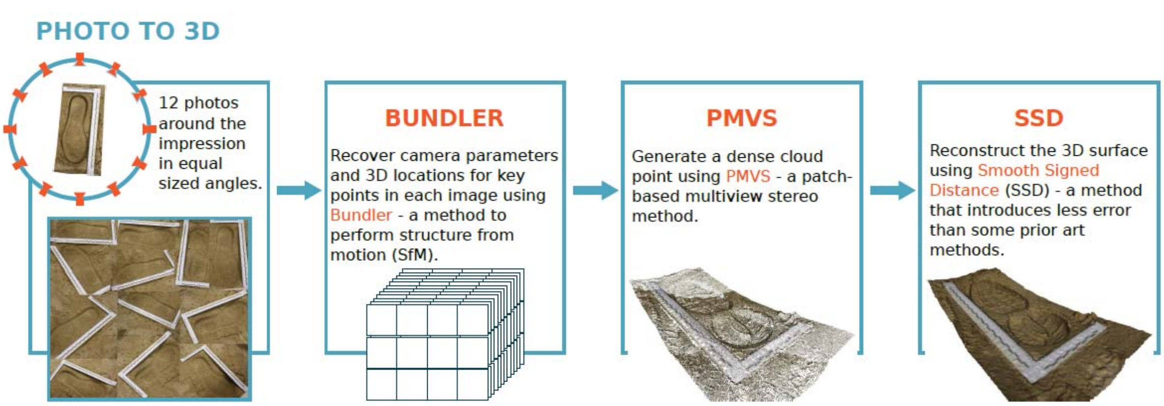
From Multi-View Video Cameras

View Interpolation From Multi-View Video Cameras

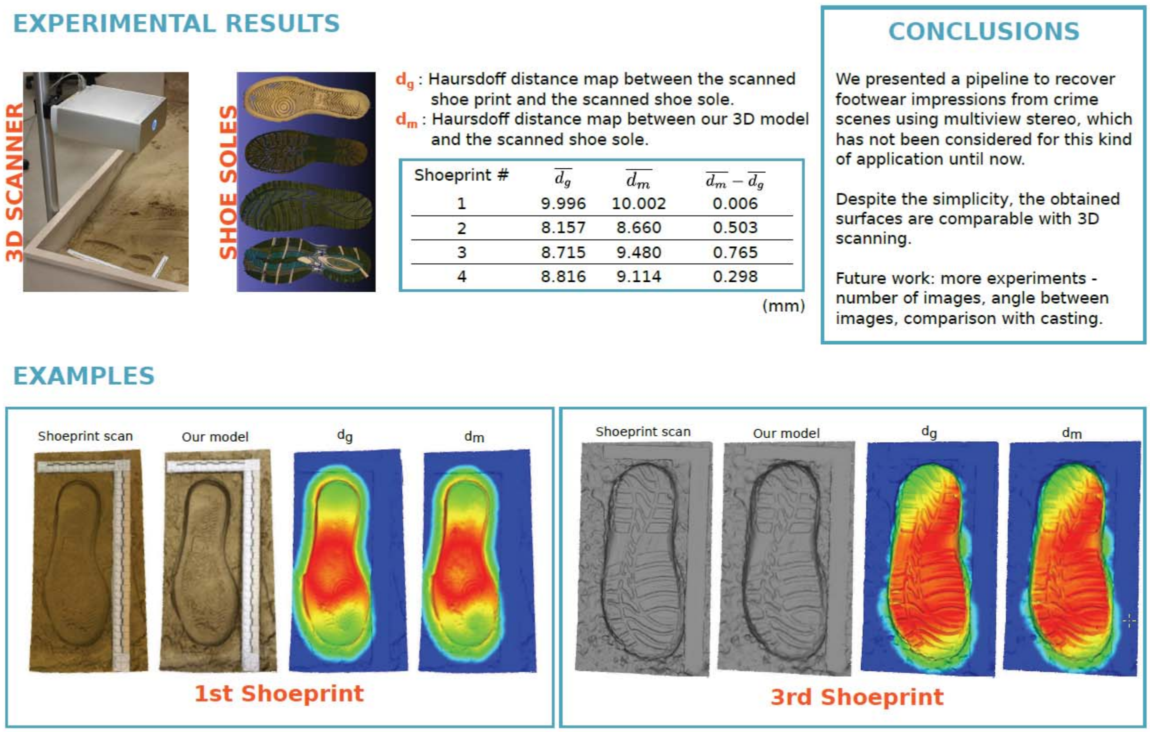
With Background Segmentation

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).

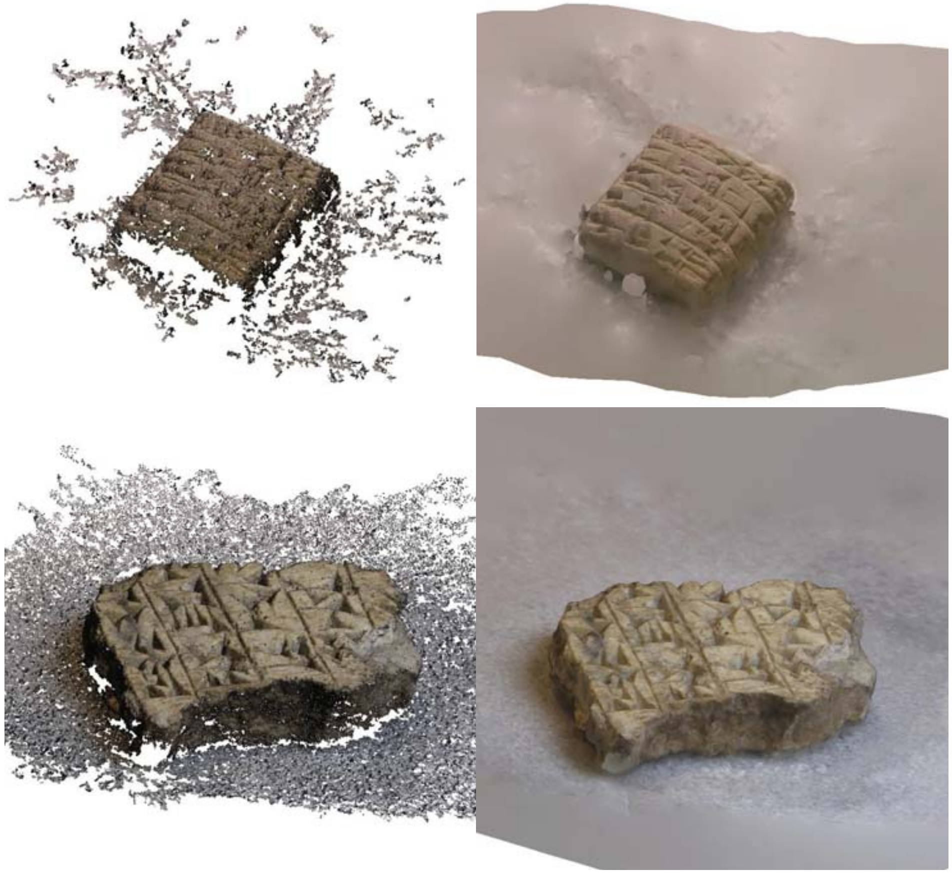


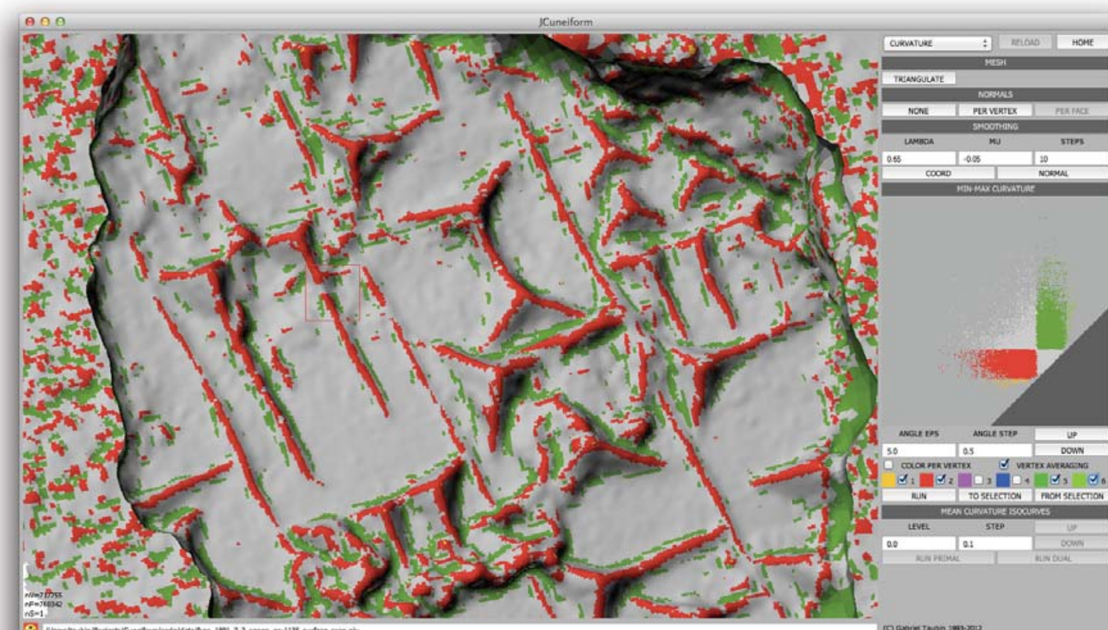
Comparable to 3D Laser Scanner



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

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.

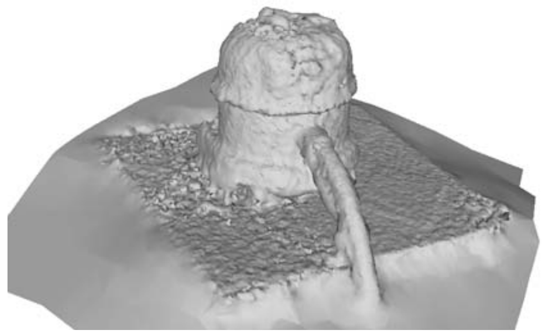


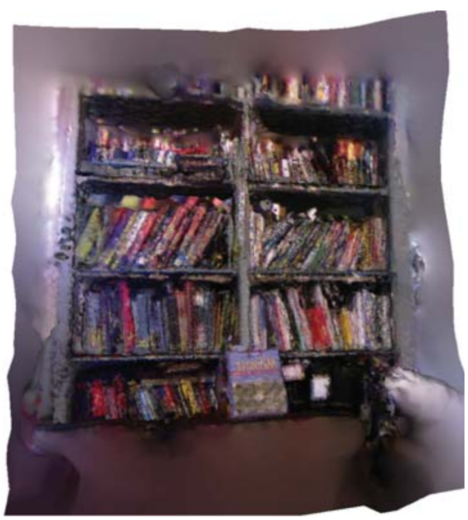

JCuneiform
CURVATURE
RELOAD
HOME
MESH
TRIANGULATE
NORMALS
NONE
PER VERTEX
PER FACE
SMOOTHING
LAMBDA
MU
STEPS
0.65
-0.05
10
COORD
NORMAL
MIN-MAX CURVATURE
ANGLE EPS
ANGLE STEP
UP
5.0
0.5
DOWN
COLOR PER VERTEX
VERTEX AVERAGING
1
2
3
4
5
6
RUN
TO SELECTION
FROM SELECTION
MEAN CURVATURE ISOCURVES
LEVEL
STEP
UP
0.0
0.1
DOWN
RUN PRIMAL
RUN DUAL
/Users/taubin/Projects/Cuneiform/code/data/frag_1891_7_2_canon_ps-1135_surface_crop.ply
(C) Gabriel Taubin 1993-2012

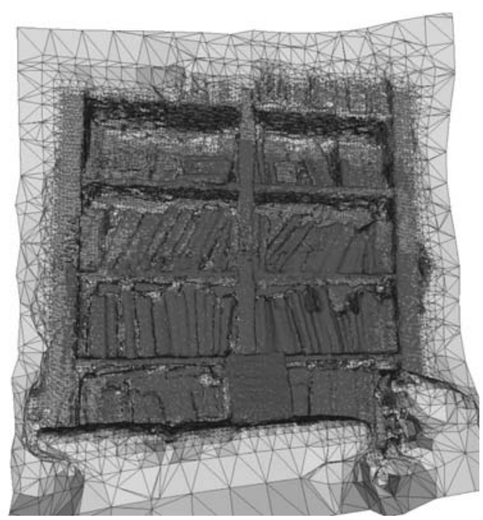
Handheld Interactive, Incremental 3D Object Scanning

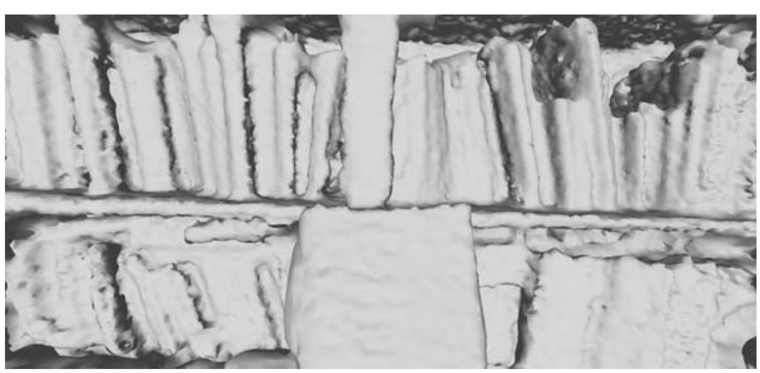
J. Kim & G. Taubin

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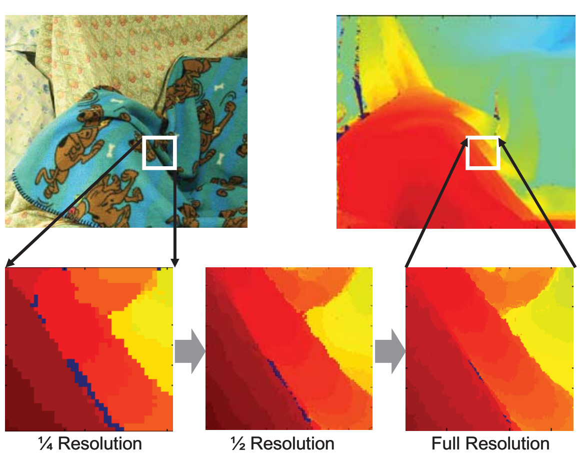
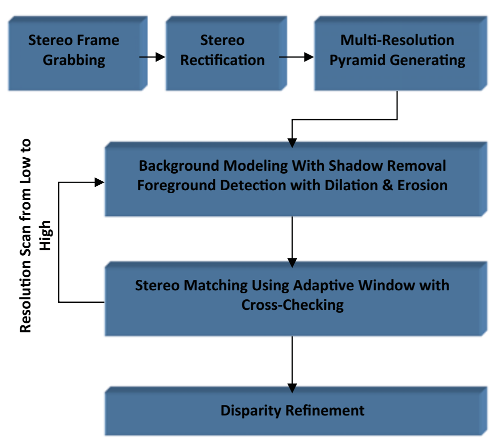
Y. Zhao, and G. Taubin, Image and Vision Computing 2011.



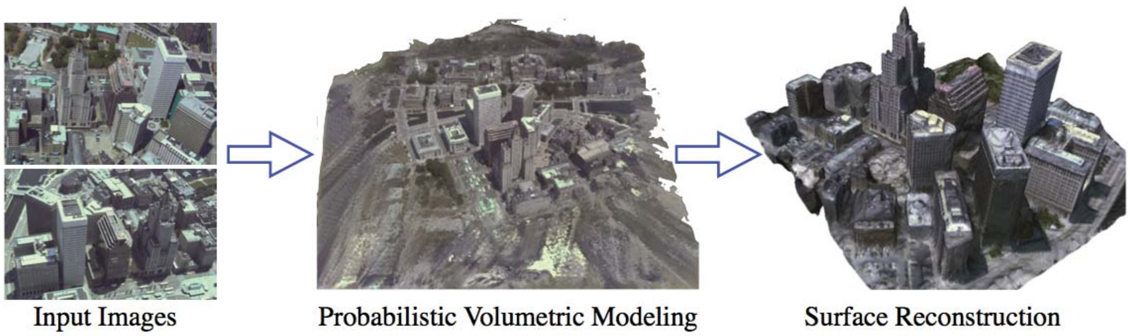
Coarse-to-fine matching on multiple resolutions



Processing Pipeline

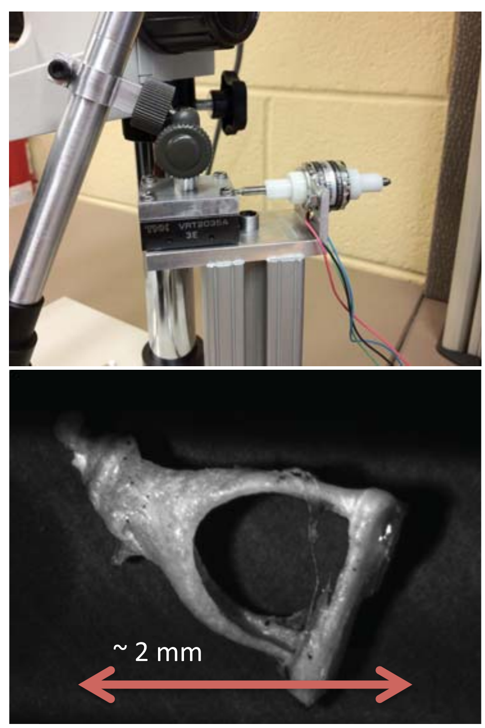
High Resolution Surface Reconstruction from Multi-view Aerial Imagery

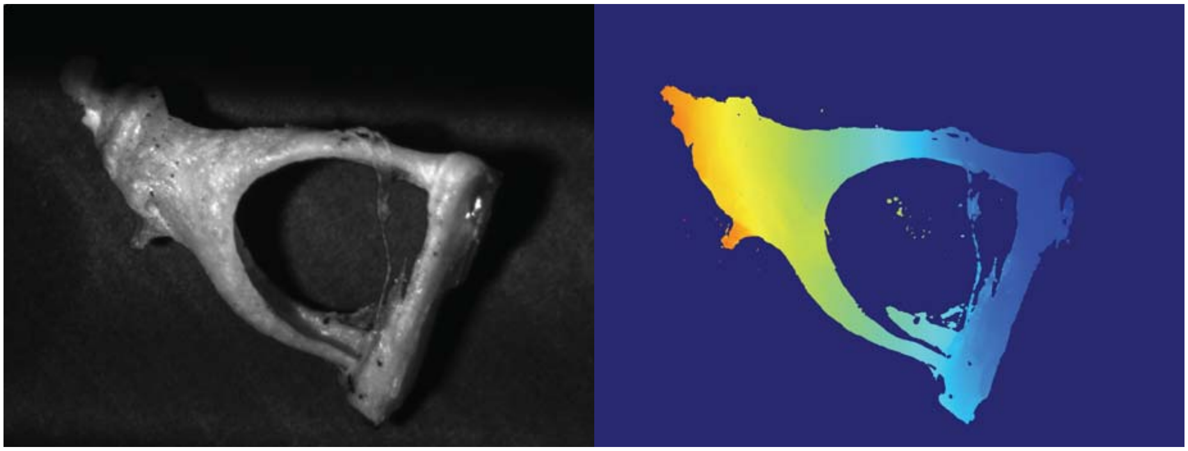
by Calakli, Ulusoy, Restrepo, Mundy & Taubin, 3DIMPVT 2012



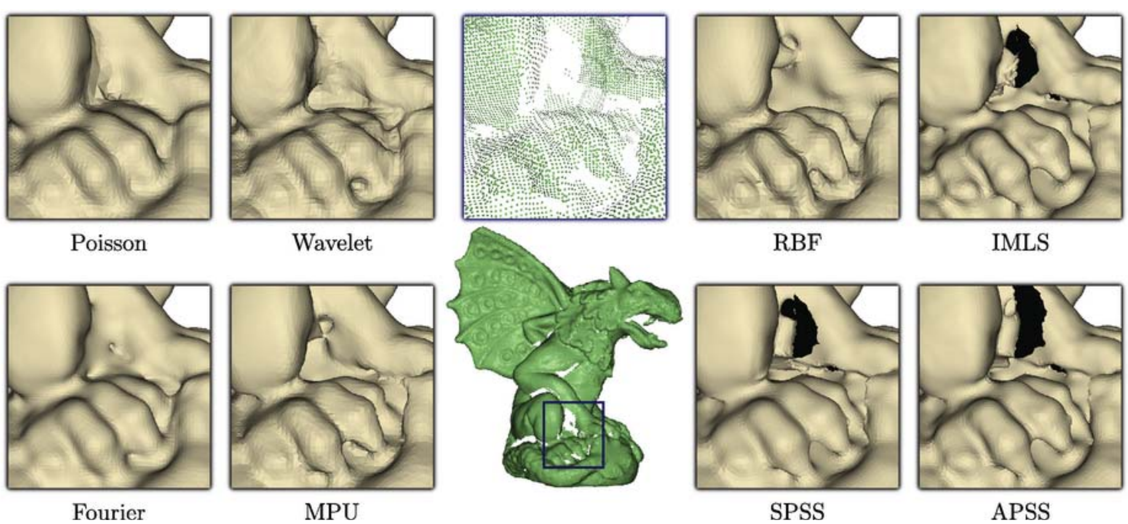
Microscopic 3D Shape Capture

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)



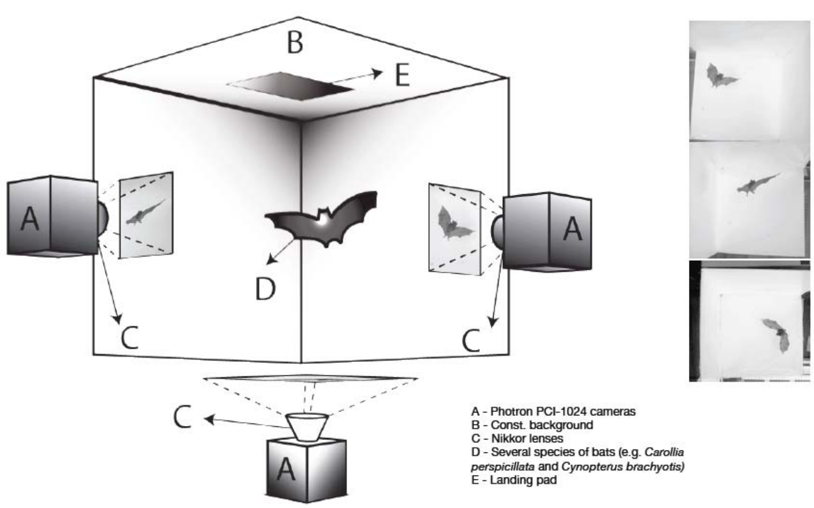
http://www.cs.utah.edu/~bergerm/recon_bench/

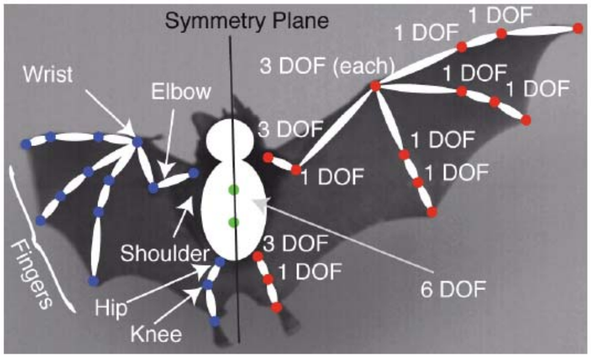
3D Reconstruction & Analysis of Bat Flight Maneuvers

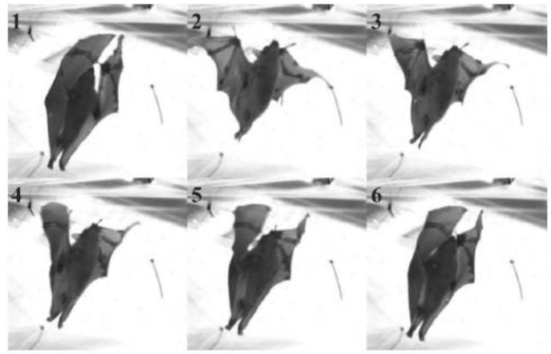
- 3D Reconstruction of Bat Flight Kinematics from Sparse Multiple Views, by A. Bergou, S. Swartz, and G. Taubin, and K. Breuer, 4DMOD, 2011.
- 3D Reconstruction and Analysis of Bat Flight Maneuvers from Sparse Multiple View Video, by A. Bergou, S. Swartz, S. K. Breuer, G. Taubin, BioVis, 2011.
- Falling 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 ?

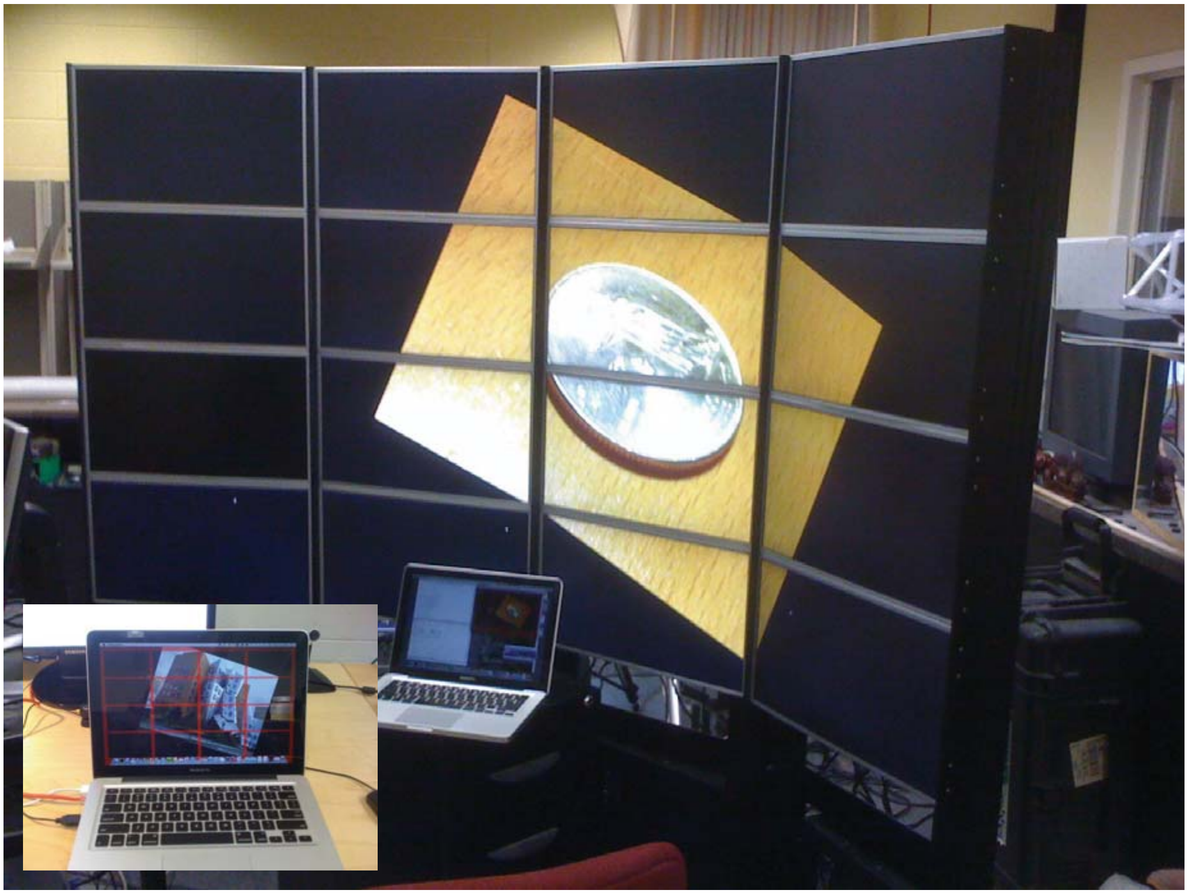
- Multiple synchronized 1000fps+ cameras
- Controlled environment (backdrop & illumination)
- Bats trained to land on landing pad
- Experiments with several species







- 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**



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