



NEW ORLEANS

# Global Non-Rigid Alignment

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# 3-D Scanning Pipeline

- Acquisition

Scanners acquire data from a single viewpoint



# 3-D Scanning Pipeline

- Acquisition
- Alignment



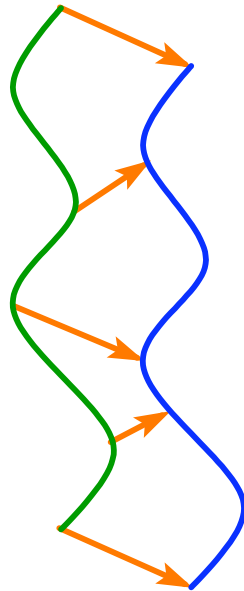
# 3-D Scanning Pipeline

- Acquisition
- Alignment
- Merging



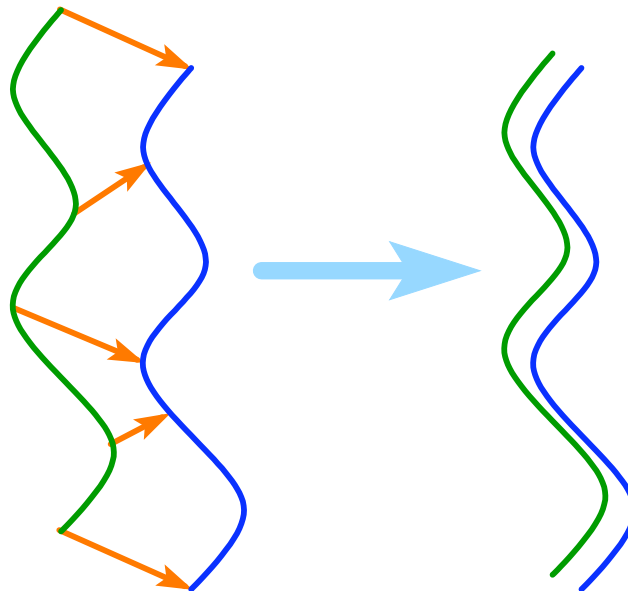
# Iterative Closest Points [Besl92]

- To fit two meshes, need correspondence between points
  - Assume points correspond to **closest** points on other mesh
  - Compute best fit on a subset of all points



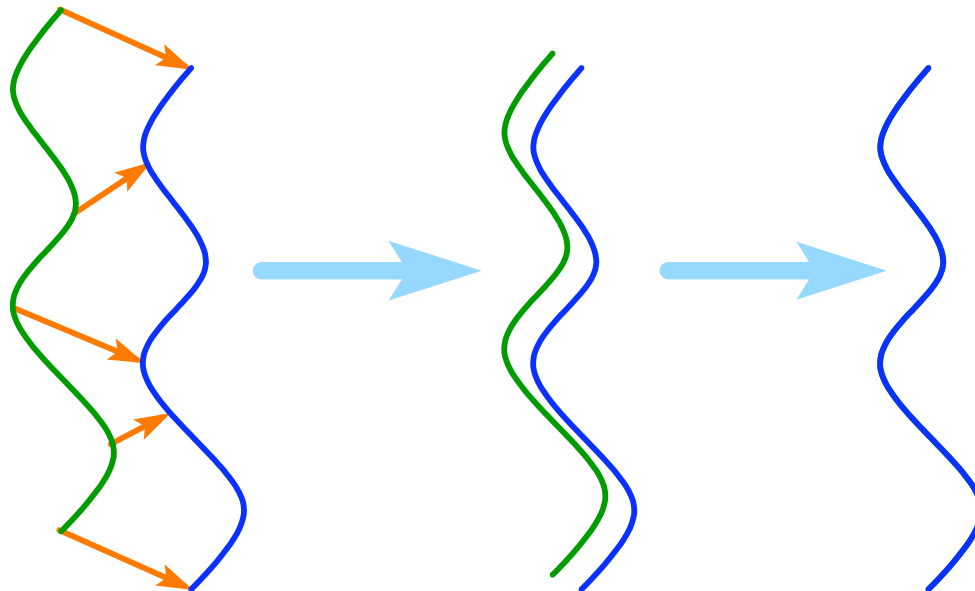
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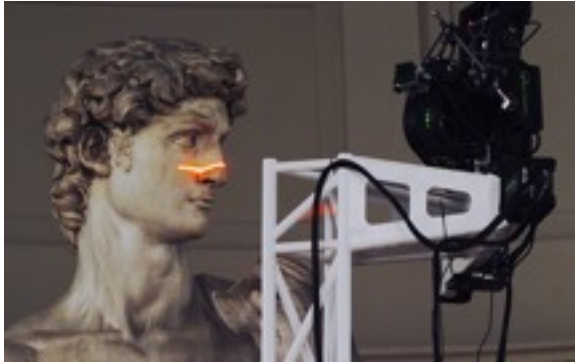


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- To fit two meshes, need correspondence between points
  - Assume points correspond to **closest** points on other mesh
  - Compute best fit on a subset of all points
- If starting point was good, result should be better
  - Iterate until fit converges to minimum error



# Range Scanning: Calibration Error



[Levoy00]

*Courtesy Paul Debevec*

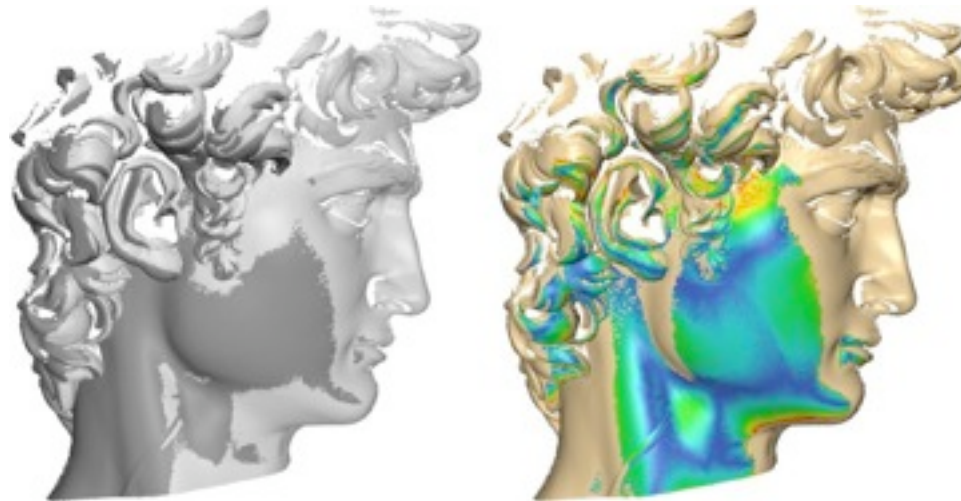


# Range Scanning: Calibration Error

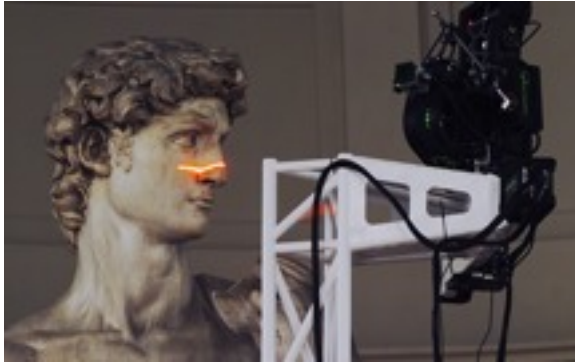


[Levoy00]

*Courtesy Paul Debevec*

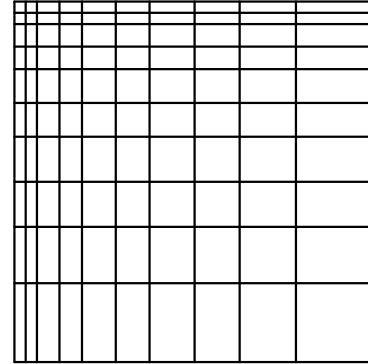


# Range Scanning: Calibration Error

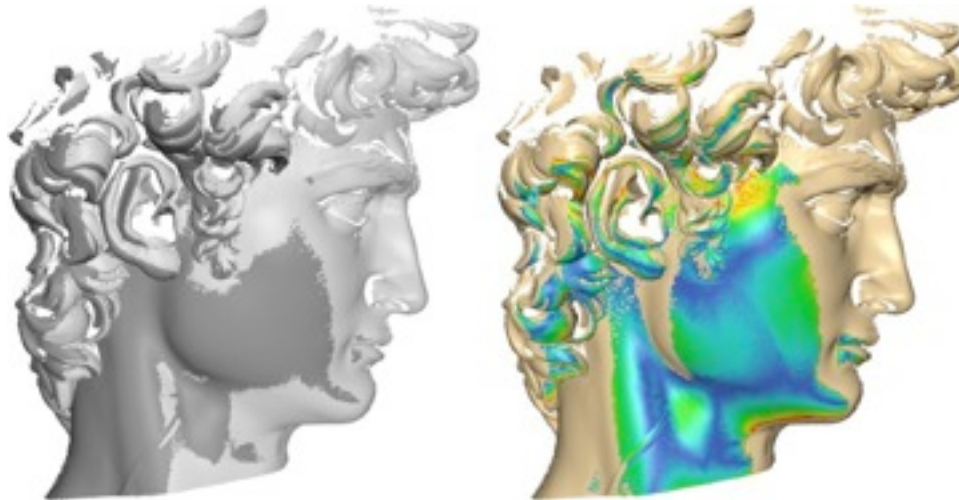


[Levoy00]

Courtesy Paul Debevec



Mechanical Distortion



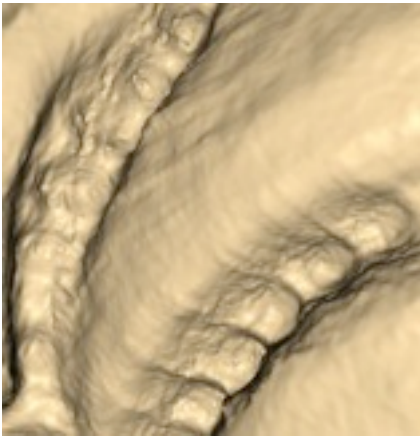
0 mm

2 mm

# Goal: Multi-Scan Non-Rigid Alignment

We desire an algorithm that will:

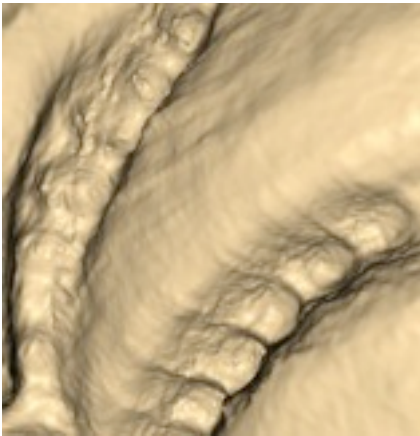
- Prevent artifacts in merging



# Goal: Multi-Scan Non-Rigid Alignment

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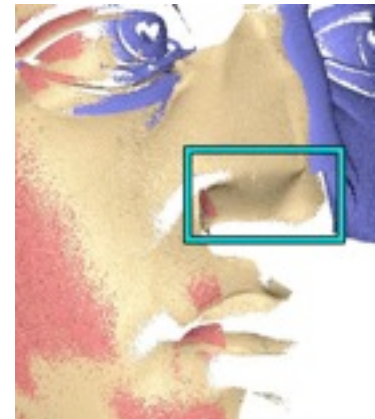
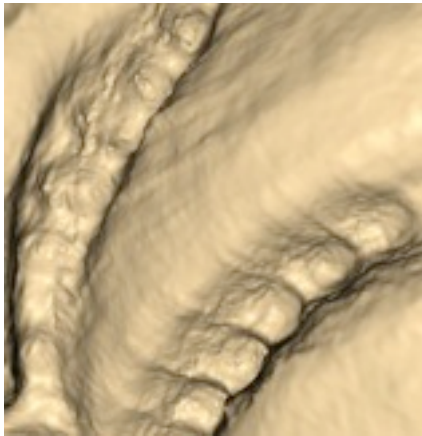
- Prevent artifacts in merging
- Distribute error evenly



# Goal: Multi-Scan Non-Rigid Alignment

We desire an algorithm that will:

- Prevent artifacts in merging
- Distribute error evenly
- Preserve detail without introducing new warp

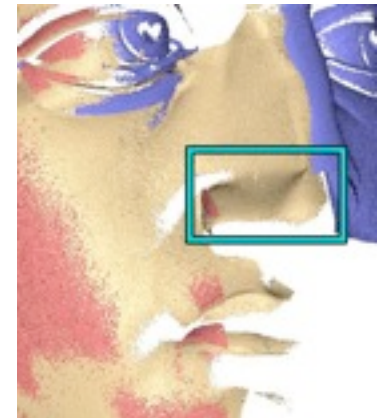
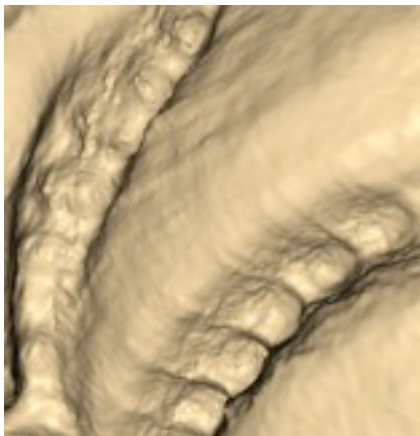


# Goal: Multi-Scan Non-Rigid Alignment

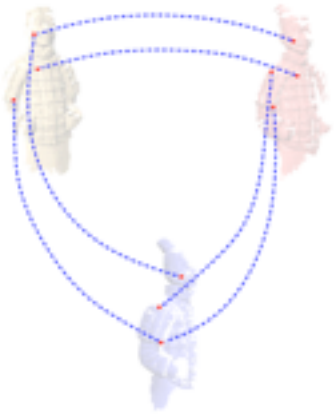
We desire an algorithm that will:

- Prevent artifacts in merging
- Distribute error evenly
- Preserve detail without introducing new warp
- Be practical, efficient, and parallelizable for large datasets

David's head comprises 1400 scans and 230 million vertices

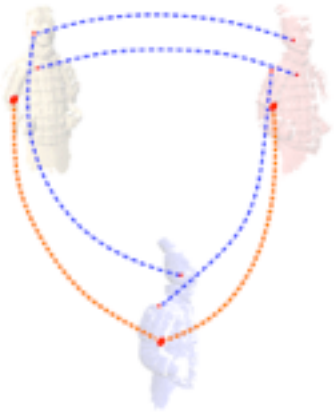


# Global Alignment Pipeline



Pairwise Correspondences

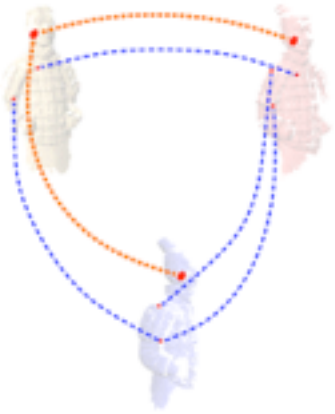
# Global Alignment Pipeline



Pairwise Correspondences

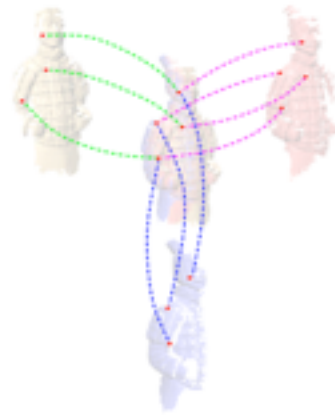
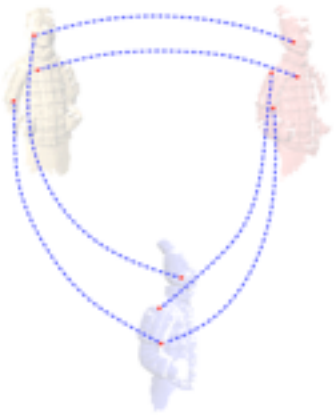


# Global Alignment Pipeline



Pairwise Correspondences

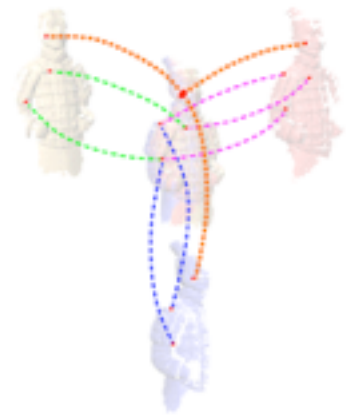
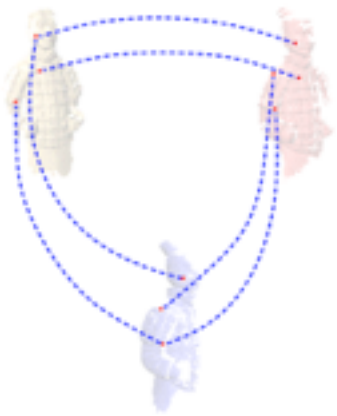
# Global Alignment Pipeline



Pairwise Correspondences

Global Feature Positioning

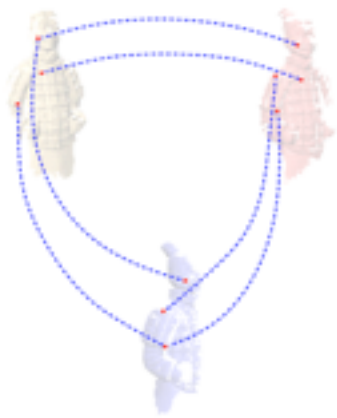
# Global Alignment Pipeline



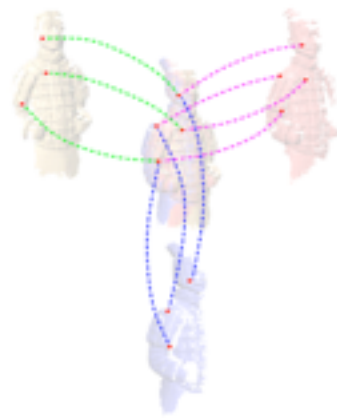
Pairwise Correspondences

Global Feature Positioning

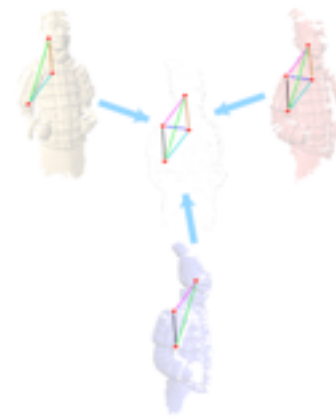
# Global Alignment Pipeline



Pairwise Correspondences

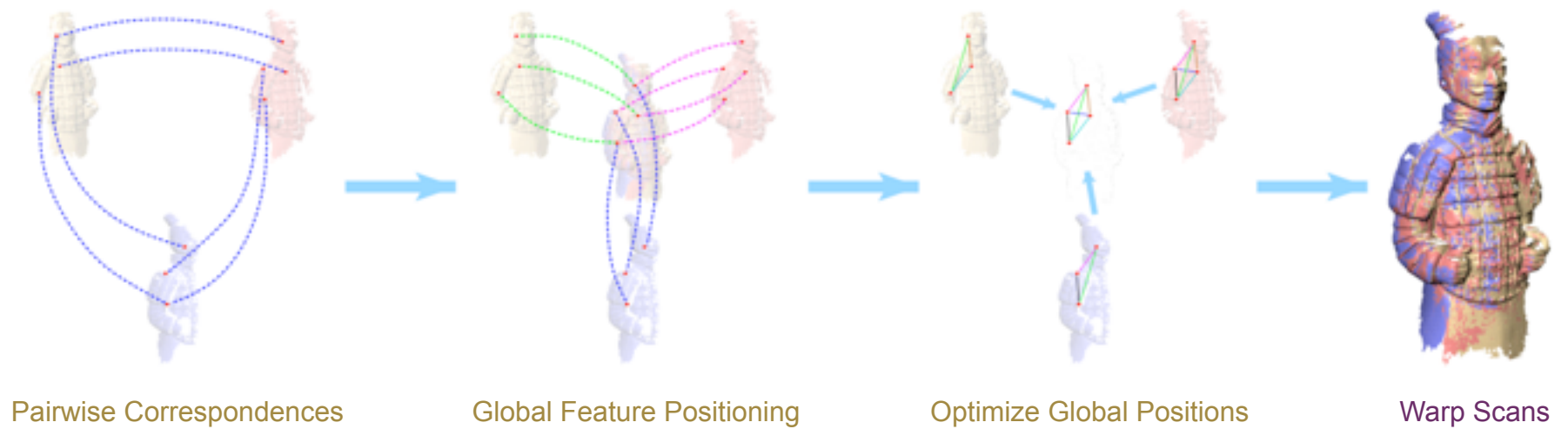


Global Feature Positioning

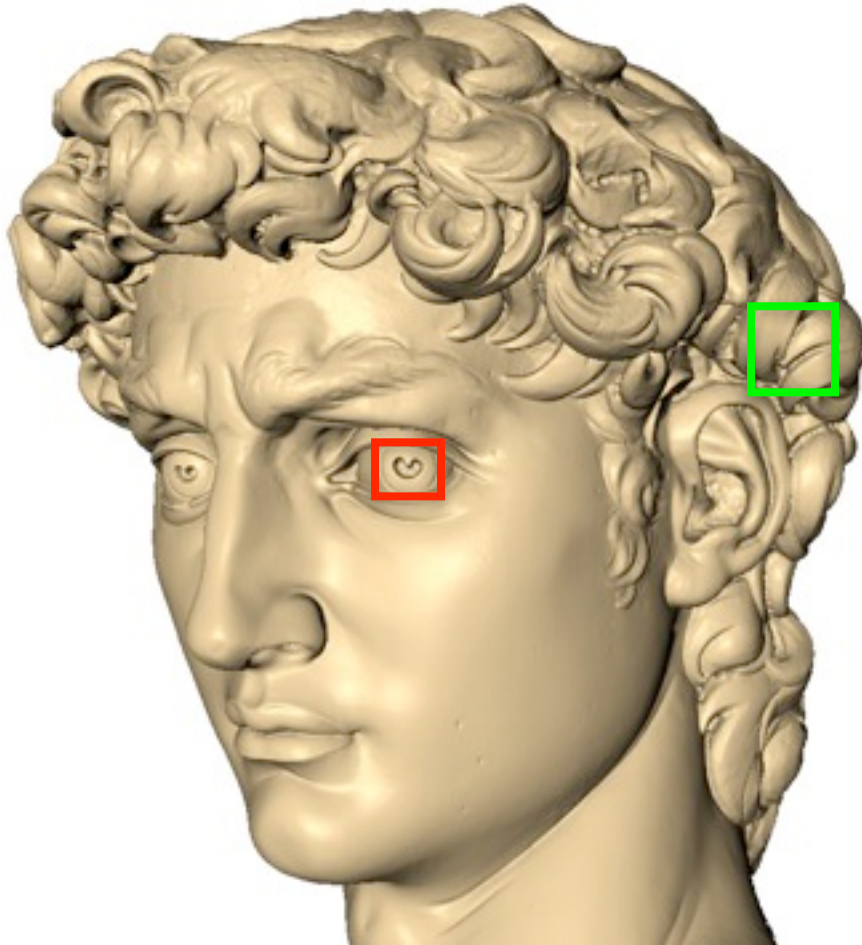


Optimize Global Positions

# Global Alignment Pipeline



# Results: David's Head



- 1400 range scans
- 230 million points

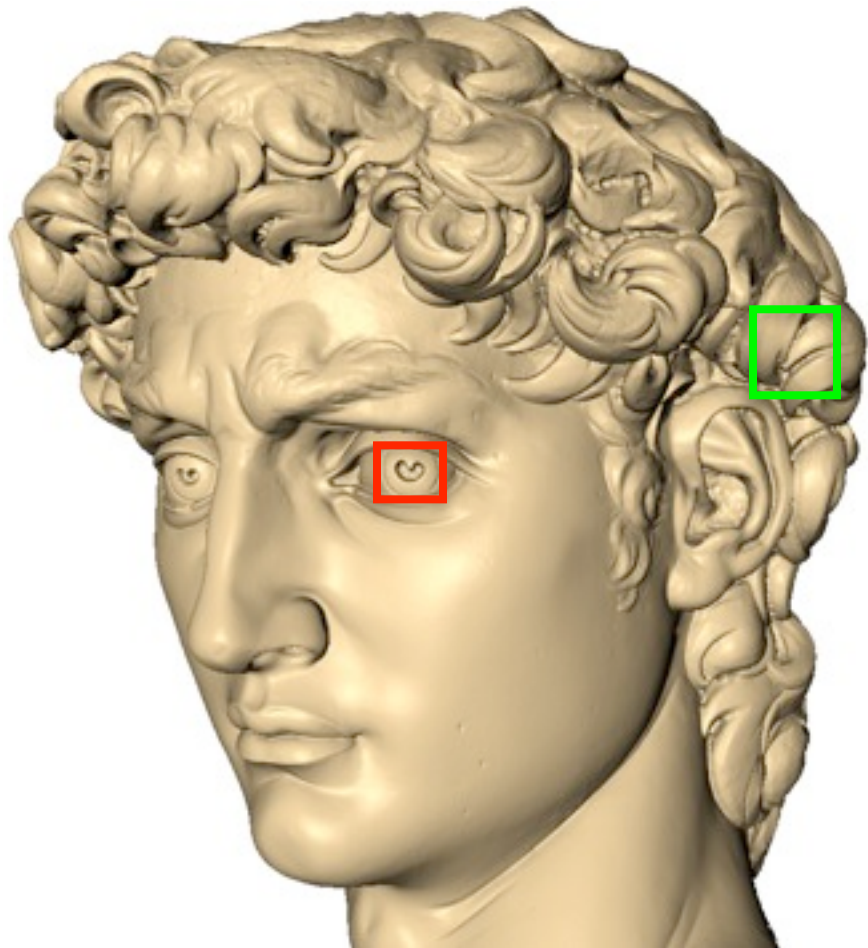
## Correspondences

- 78 hours CPU time
  - 1.5 hours wall time

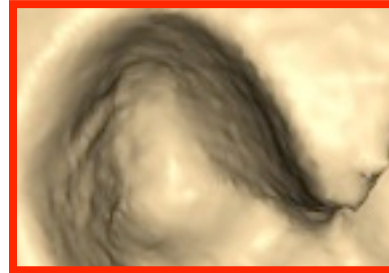
## Positioning and Alignment

- 30 minutes CPU time

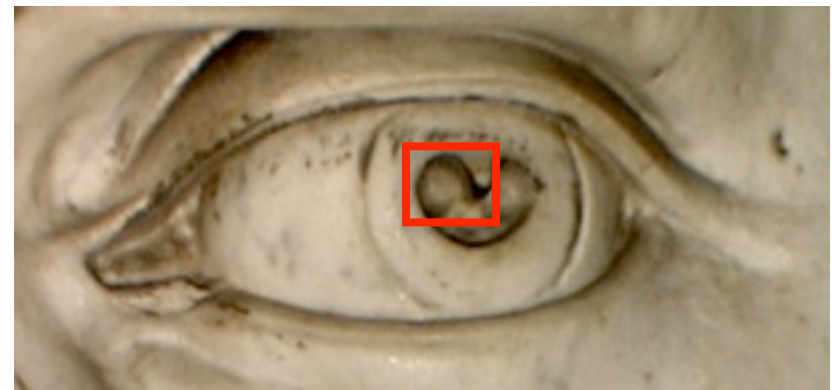
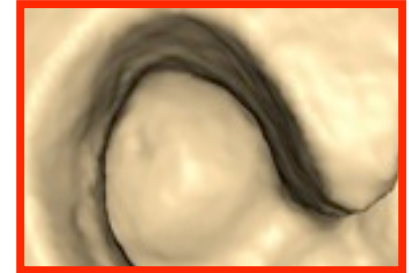
# Results: David's Head



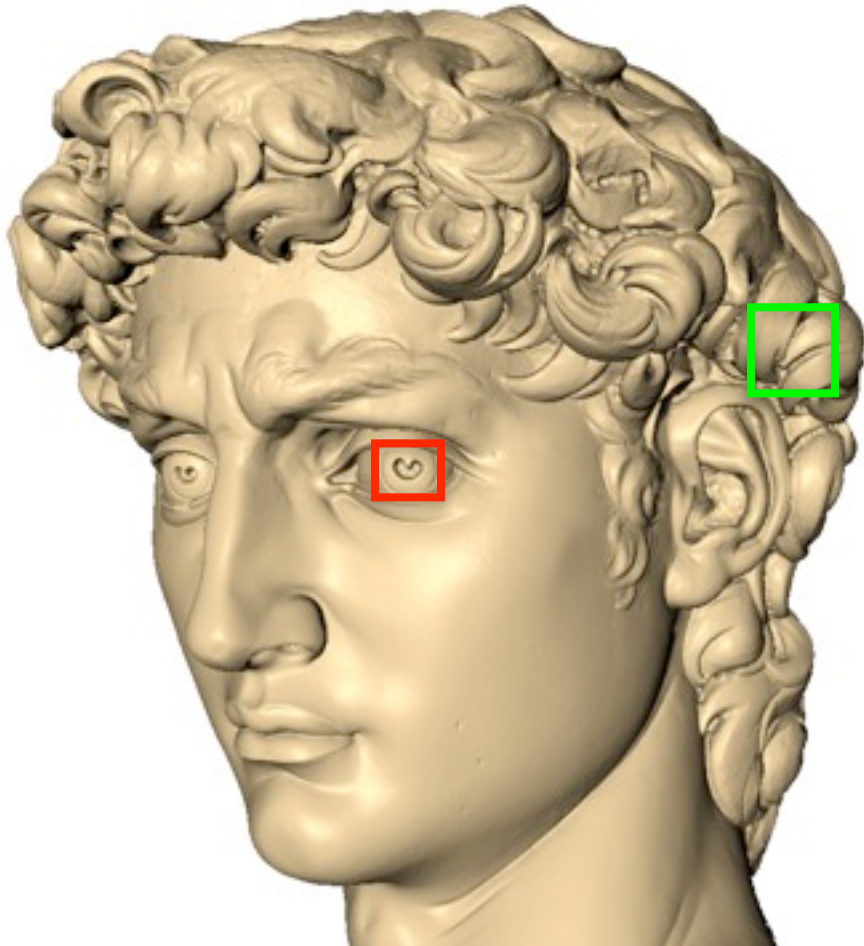
Rigid



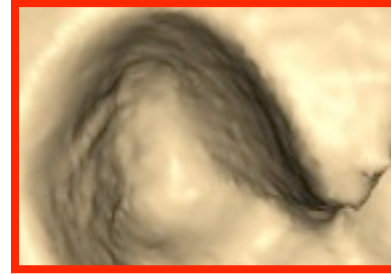
Non-Rigid



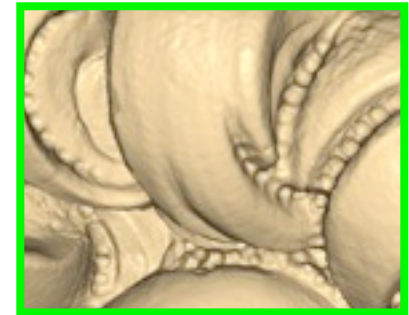
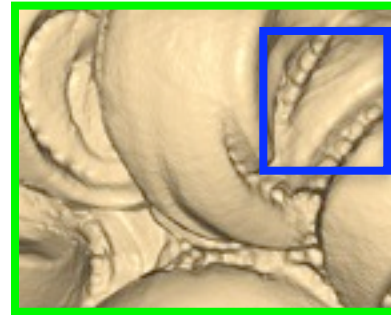
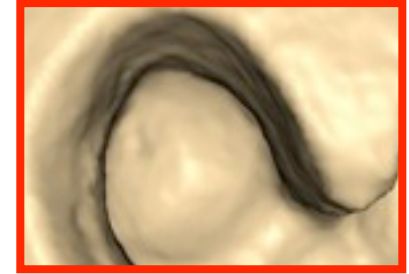
# Results: David's Head



Rigid

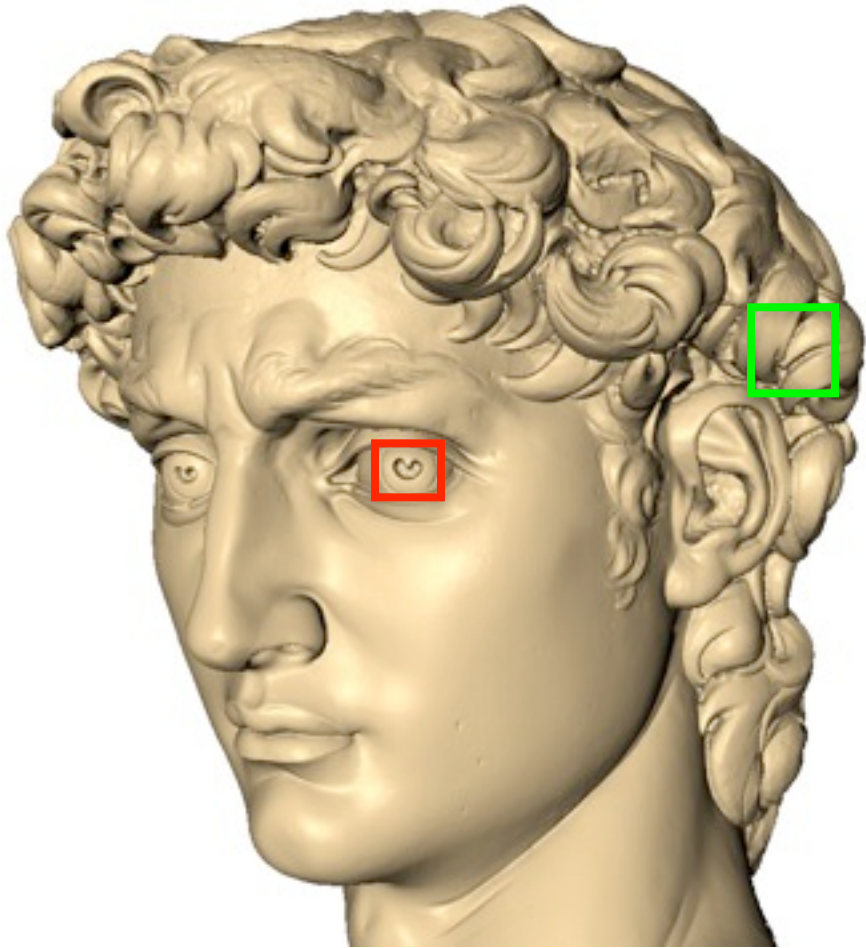


Non-Rigid



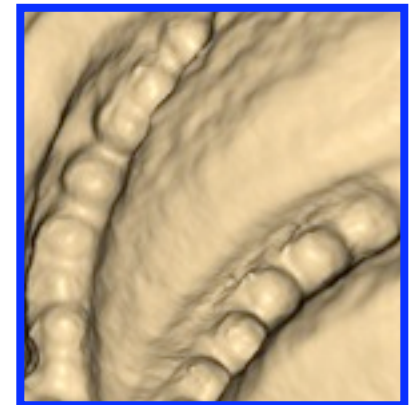
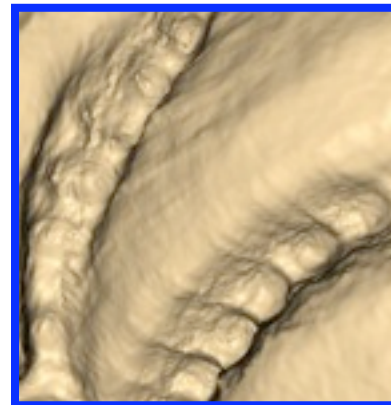
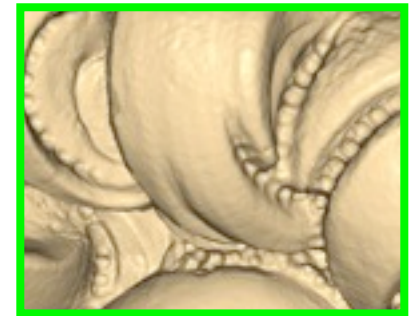
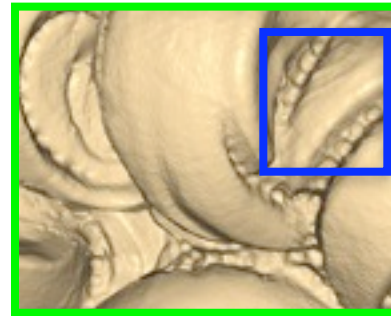
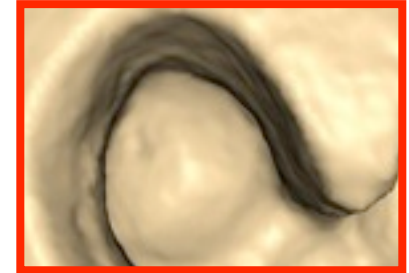
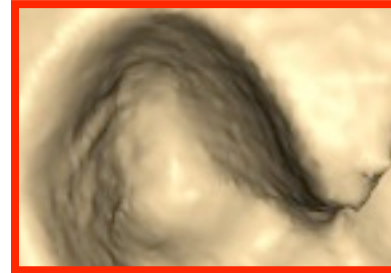


# Results: David's Head



Rigid

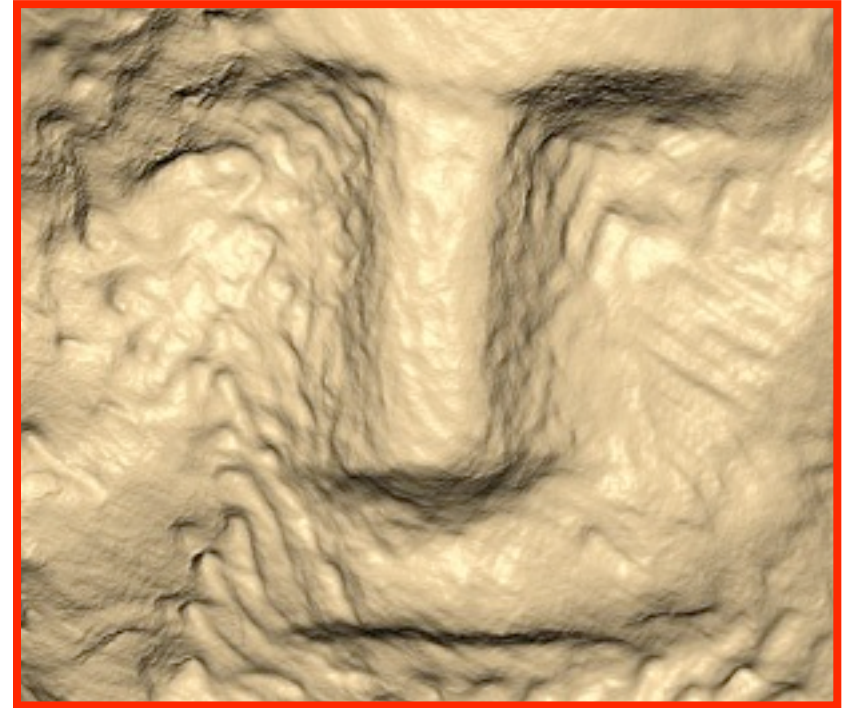
Non-Rigid



# Results: Awakening



Rigid

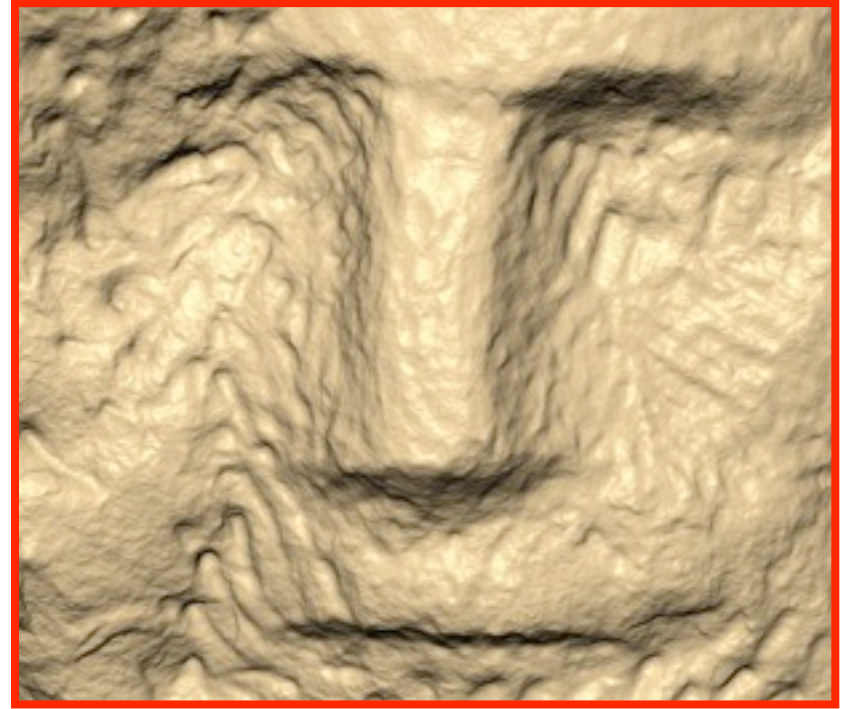


1836 scans, 390 million vertices  
Correspondences: 51.5 CPU hours  
Alignment: 1 CPU hour

# Results: Awakening



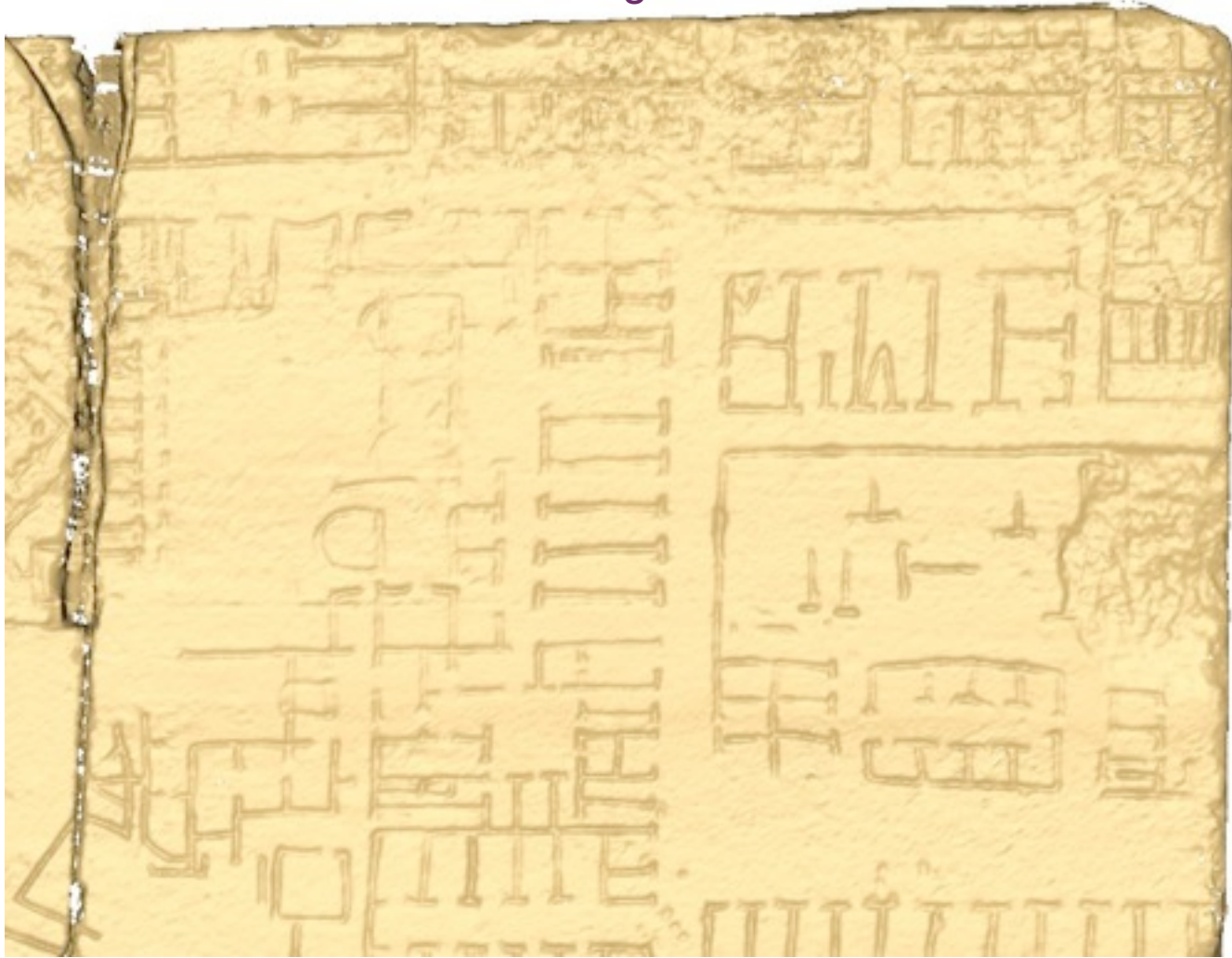
Non-Rigid



1836 scans, 390 million vertices  
Correspondences: 51.5 CPU hours  
Alignment: 1 CPU hour

# Results: Forma Urbis Romae #033

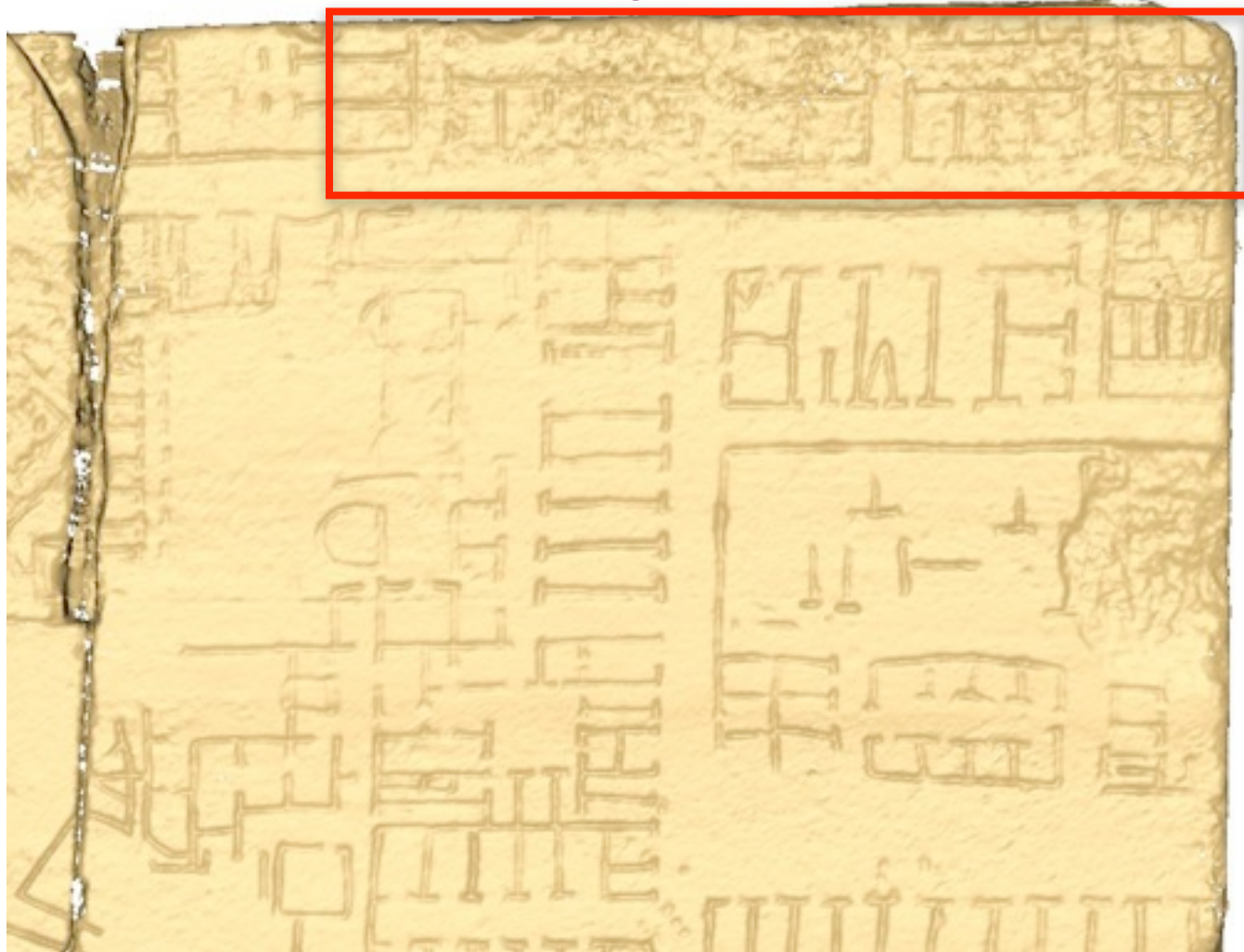
Rigid



140 scans, 71 million vertices; Correspondences: 48 hours; Alignment: 27 minutes

# Results: Forma Urbis Romae #033

Rigid



140 scans, 71 million vertices; Correspondences: 48 hours; Alignment: 27 minutes

# Results: Forma Urbis Romae #033

Non-Rigid



140 scans, 71 million vertices; Correspondences: 48 hours; Alignment: 27 minutes

# Results: Forma Urbis Romae #033

Rigid



140 scans, 71 million vertices; Correspondences: 48 hours; Alignment: 27 minutes

# Results: Forma Urbis Romae #033

Non-Rigid



140 scans, 71 million vertices; Correspondences: 48 hours; Alignment: 27 minutes



# Summary

- Consistently align all pairs of scans to each other
- Scalability: never more than two scans in memory
- Compensates for calibration error and slight deformations
- Supports rigid alignment too: just restrict to rigid transforms
  
- Code: [www.cs.princeton.edu/~bjbrown](http://www.cs.princeton.edu/~bjbrown)