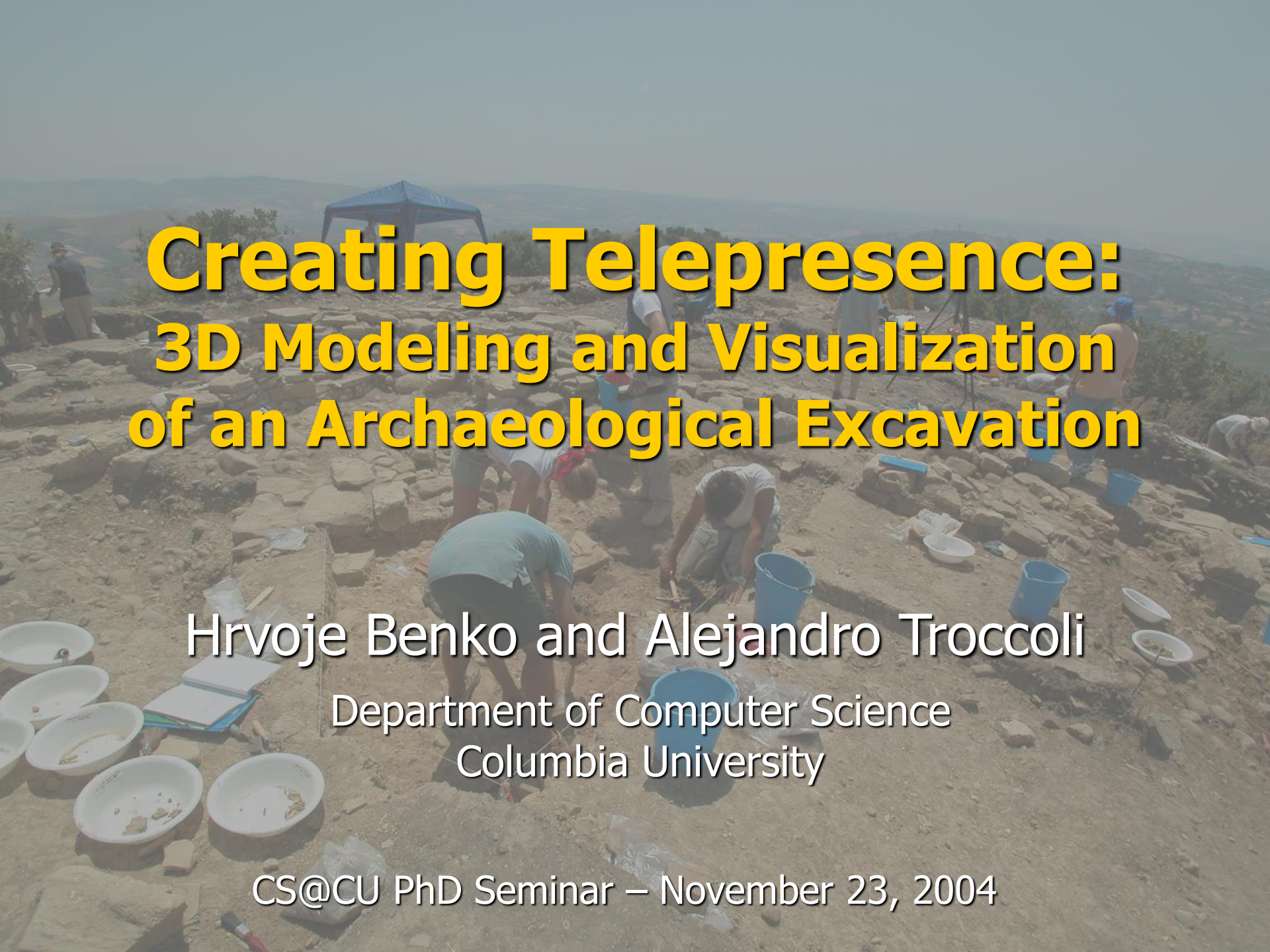


Creating Telepresence:
3D Modeling and Visualization of an Archaeological Excavation

Hrvoje Benko and Alejandro Troccoli

Department of Computer Science
Columbia University

CS@CU PhD Seminar – November 23, 2004

Motivation

- Excavation is destructive and physically "unreconstructable" process
- Need to preserve as much data as possible for analysis
- Data interpretation happens off-site
- Current tools focus on 2D data and do not incorporate 3D information
- Many experts—collaboration is a must!

Project goals

- Create complete 3D model/excavation record
- Enable integrated off-site 3D data visualization

Multidisciplinary Team

- Collaborators:
  - Archaeologists
  - Anthropologists
  - Art historians
  - Computer scientists

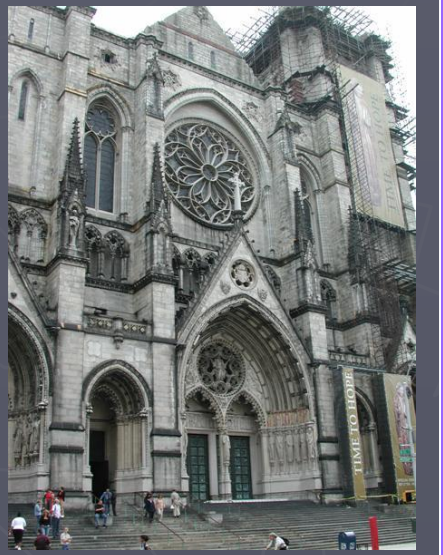
People

Projects

2002

Cathedral of Beauvais
France

2003

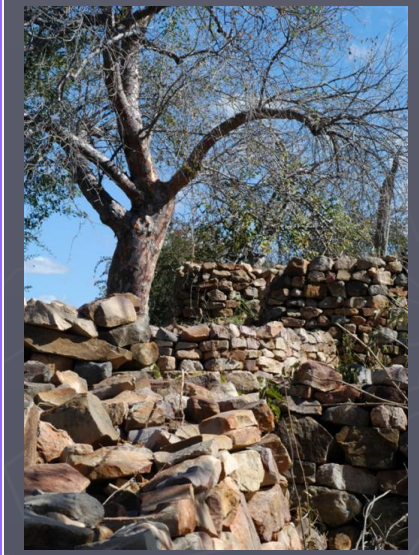


Cathedral of St. John
New York

2003

Monte Polizzo
Sicily

2004

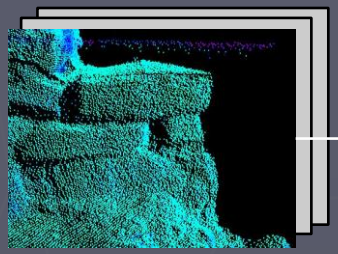


Thulamela
South Africa

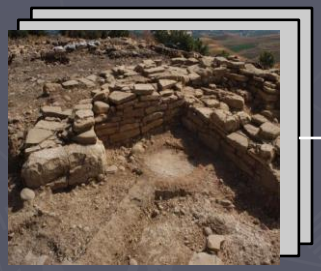
Archaeological Excavation at Monte Polizzo, Sicily, Summer 2003

Ian Morris, Director (Stanford University)

Modeling and Visualization Pipeline



Range scans



Images

Enhanced 3D model with context information

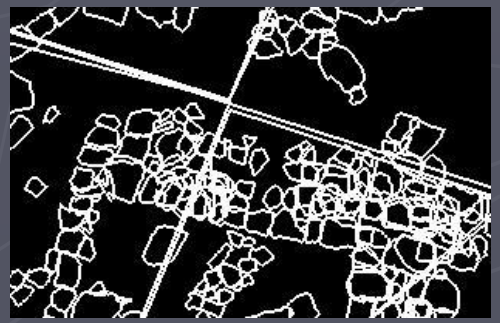
Augmented reality

Multimodal interaction
- Speech
- Gestures

Context information

Video

Panorama



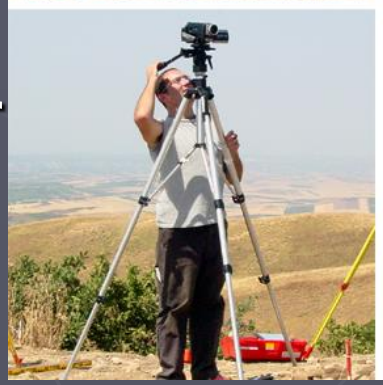
GIS data

3D Modeling

Alejandro Troccoli Ben Smith Peter Allen

Field backpack contains

- Total station
- Laser scanner
- Digital camera
- Video camera
- Laptop computer
- Extra batteries
- Food
- And the most importantly: WATER!!



The Total Station
Leica TPS 705

- Electronic Measurement Device
- Visually aim at point and measure it
- Control points needed if station is moved
- Good for a sparse set of measurements
  - Will have to join the points afterwards
- Range up to 1km with prism pole

The 3D Scanner Leica(Cyrax) HDS 2500

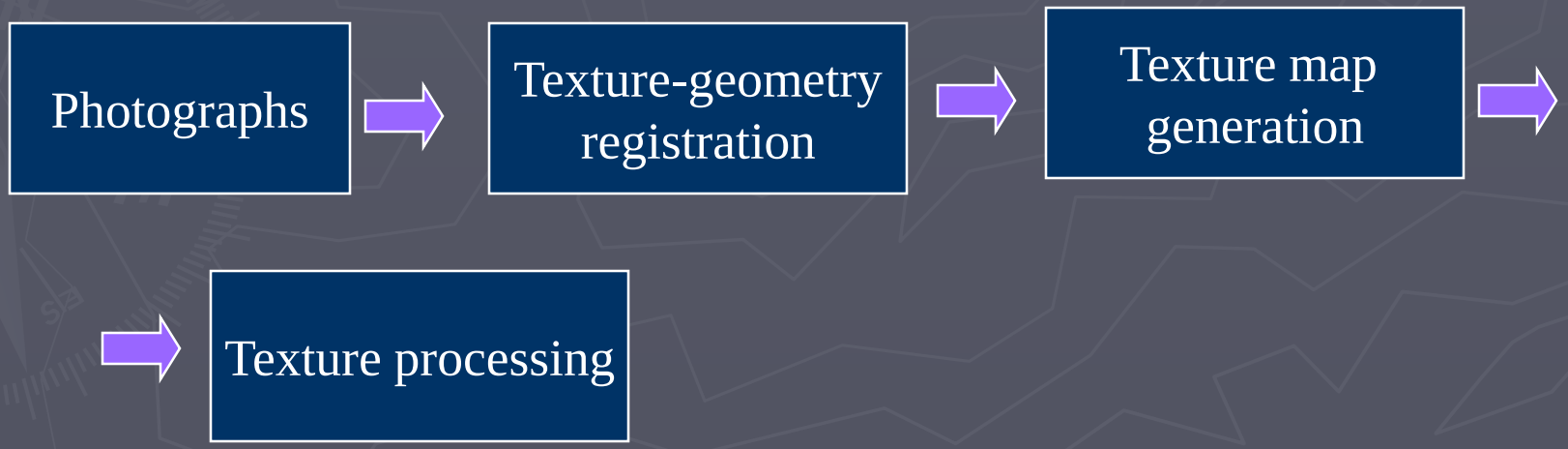
- Produces millions of measurements
- Aim at a region, not at a particular point
- Control points are needed if scanner is to be moved
- Good for high definition models
- Range up to 200m

Laser scanner demo

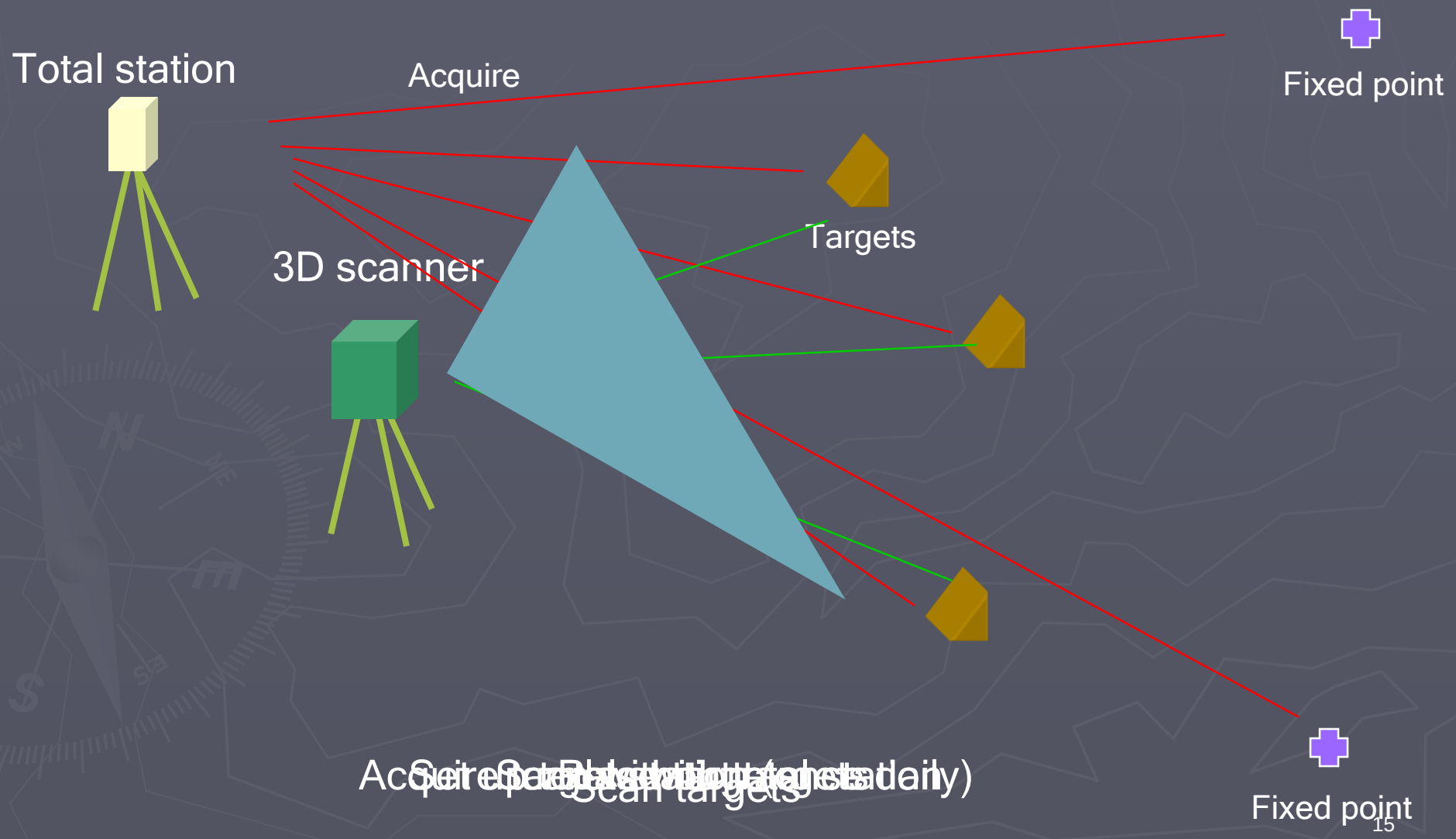
The 3D modeling pipeline

Geometry

Texture

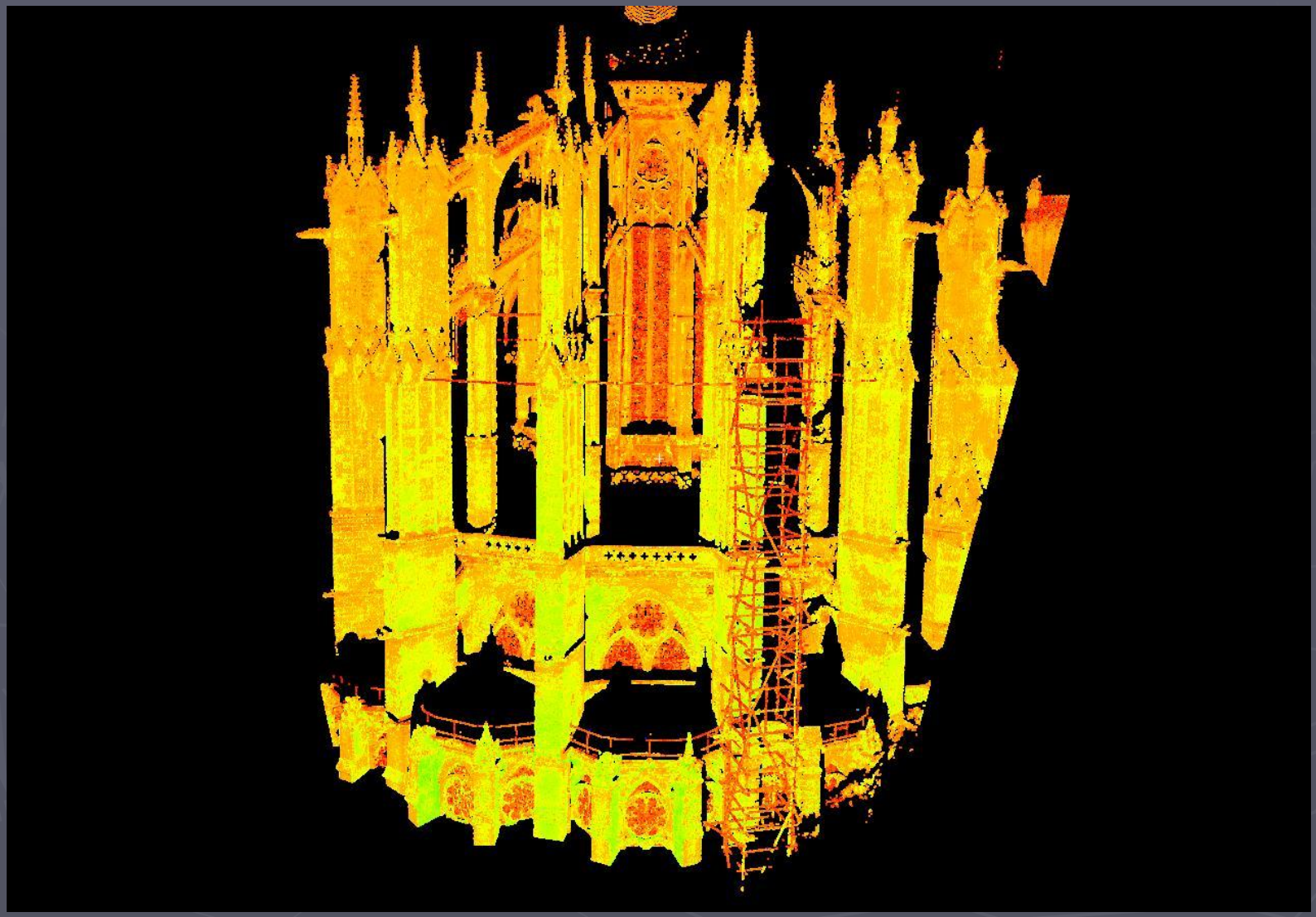


3D modeling: scan registration

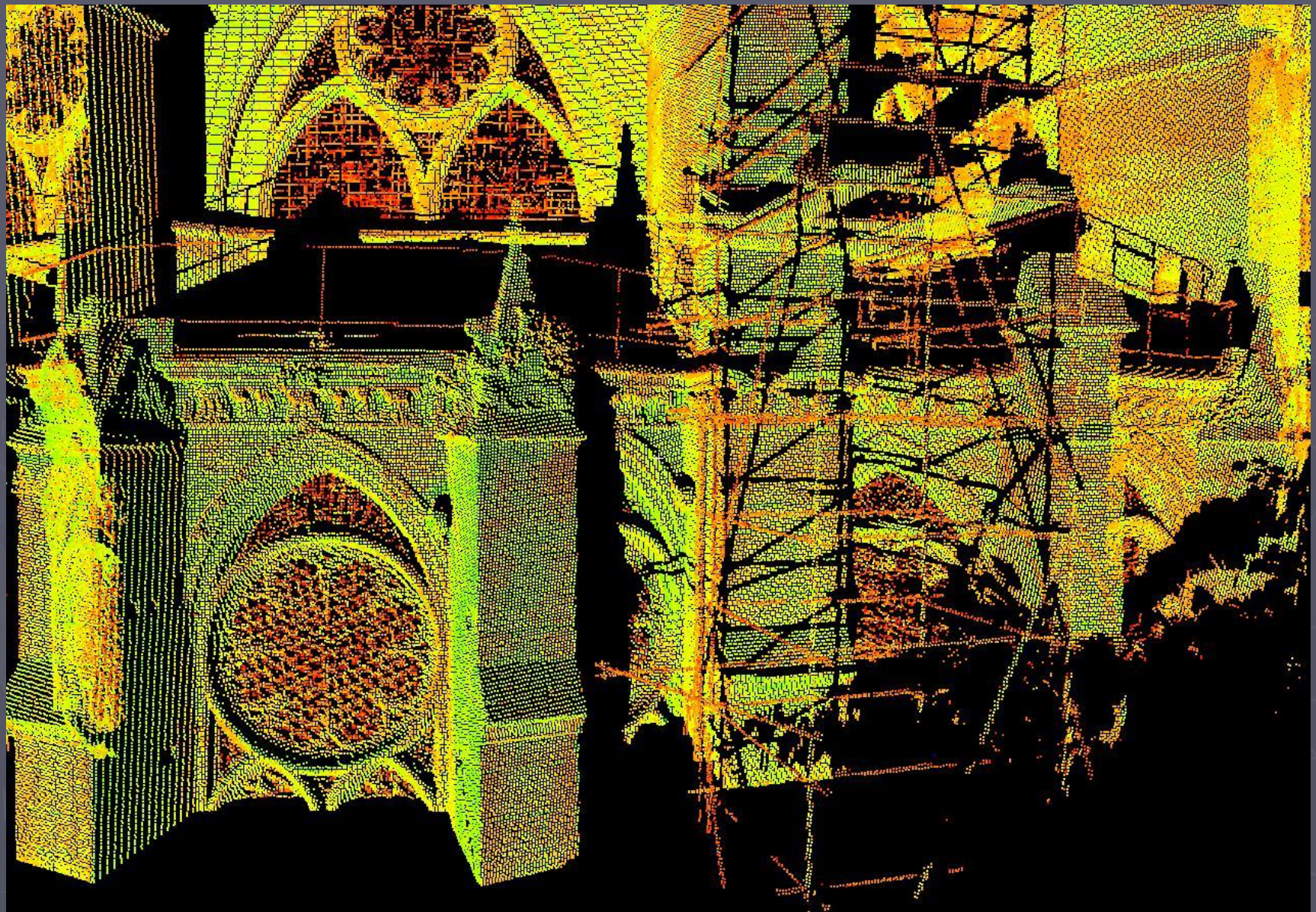


Registration without targets

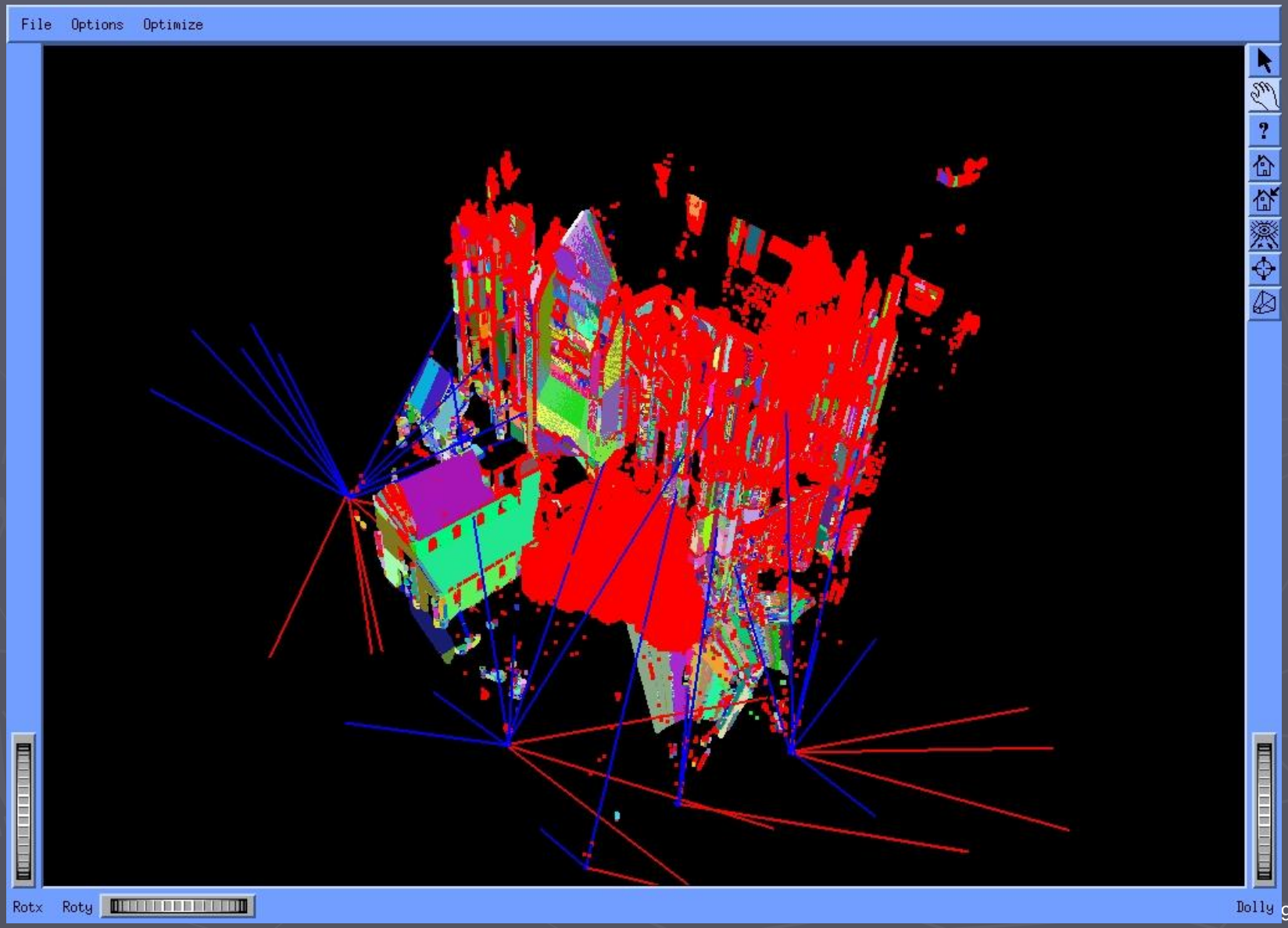
Beauvais cathedral



Scan detail



Range images registration



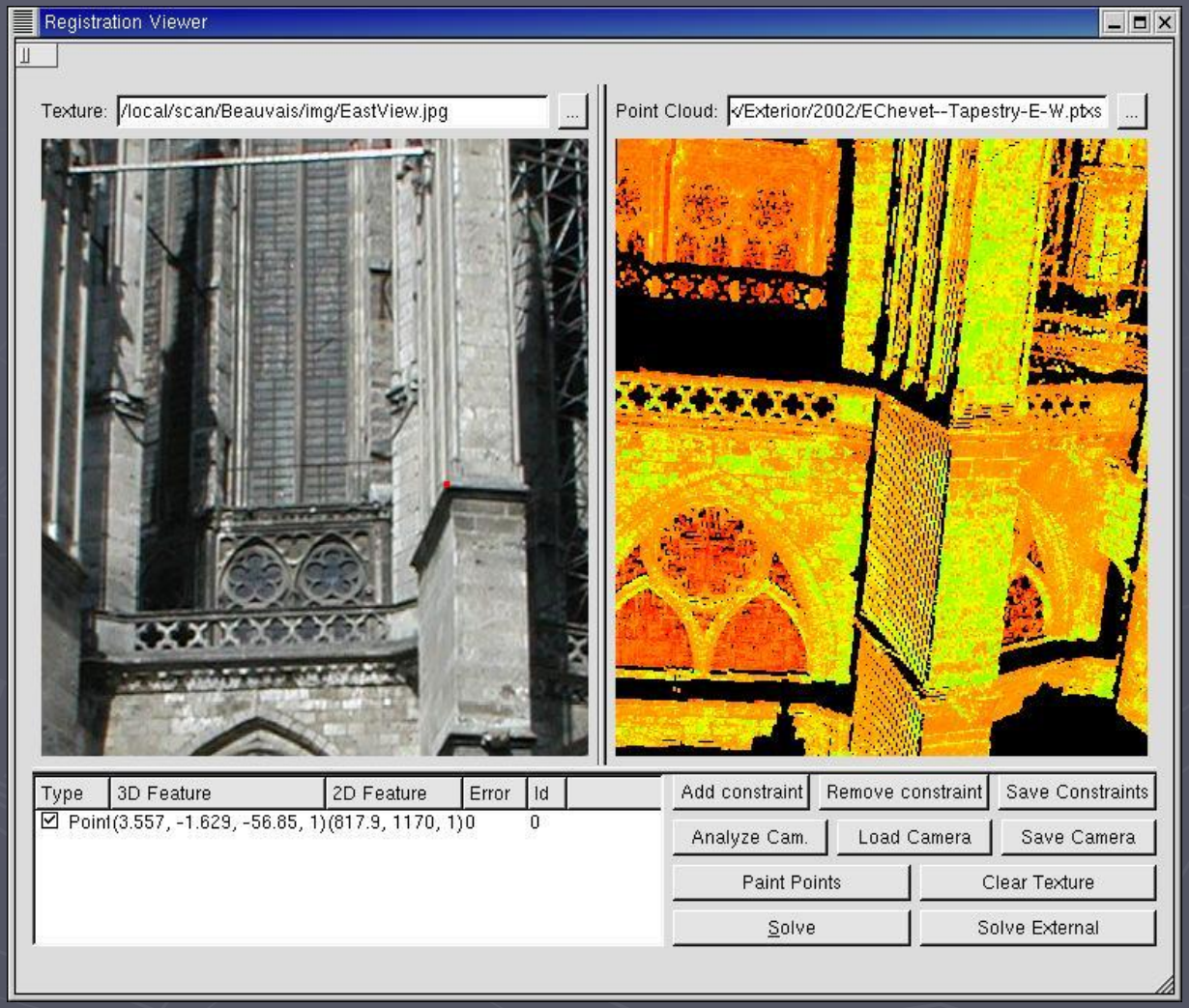
Beauvais Cathedral

Image registration

- Find camera calibration
  - Intrinsic parameters (focal length, center of proj.)
  - Extrinsic parameter (rotation and translation)
- Solved by feature matching
  - Find corresponding 3D and 2D features (points, lines)
  - At least 6 matches required for full complete calibration
  - At least 3 matches required if intrinsic parameters are known

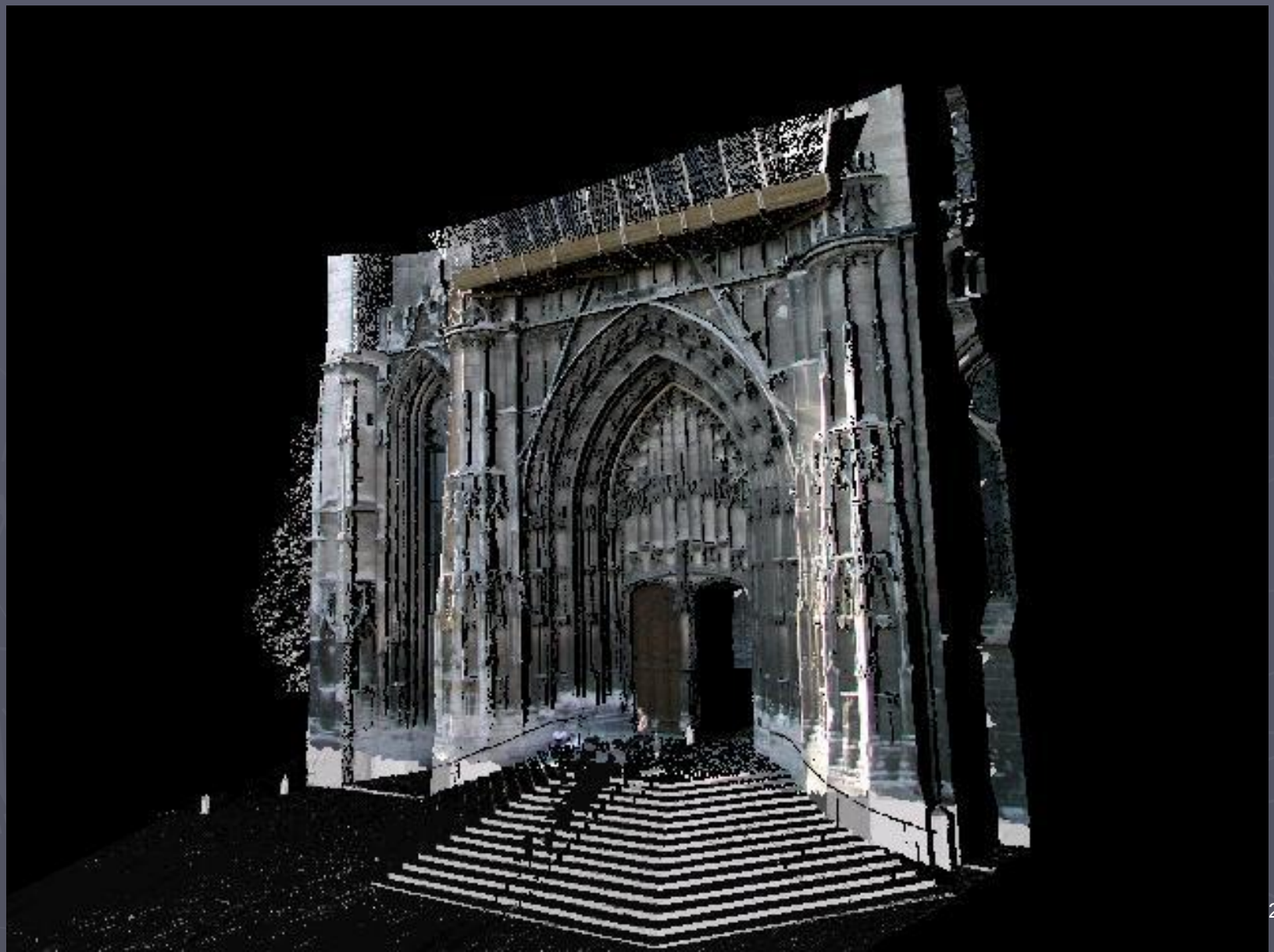
Manual registration

- User manually picks corresponding features

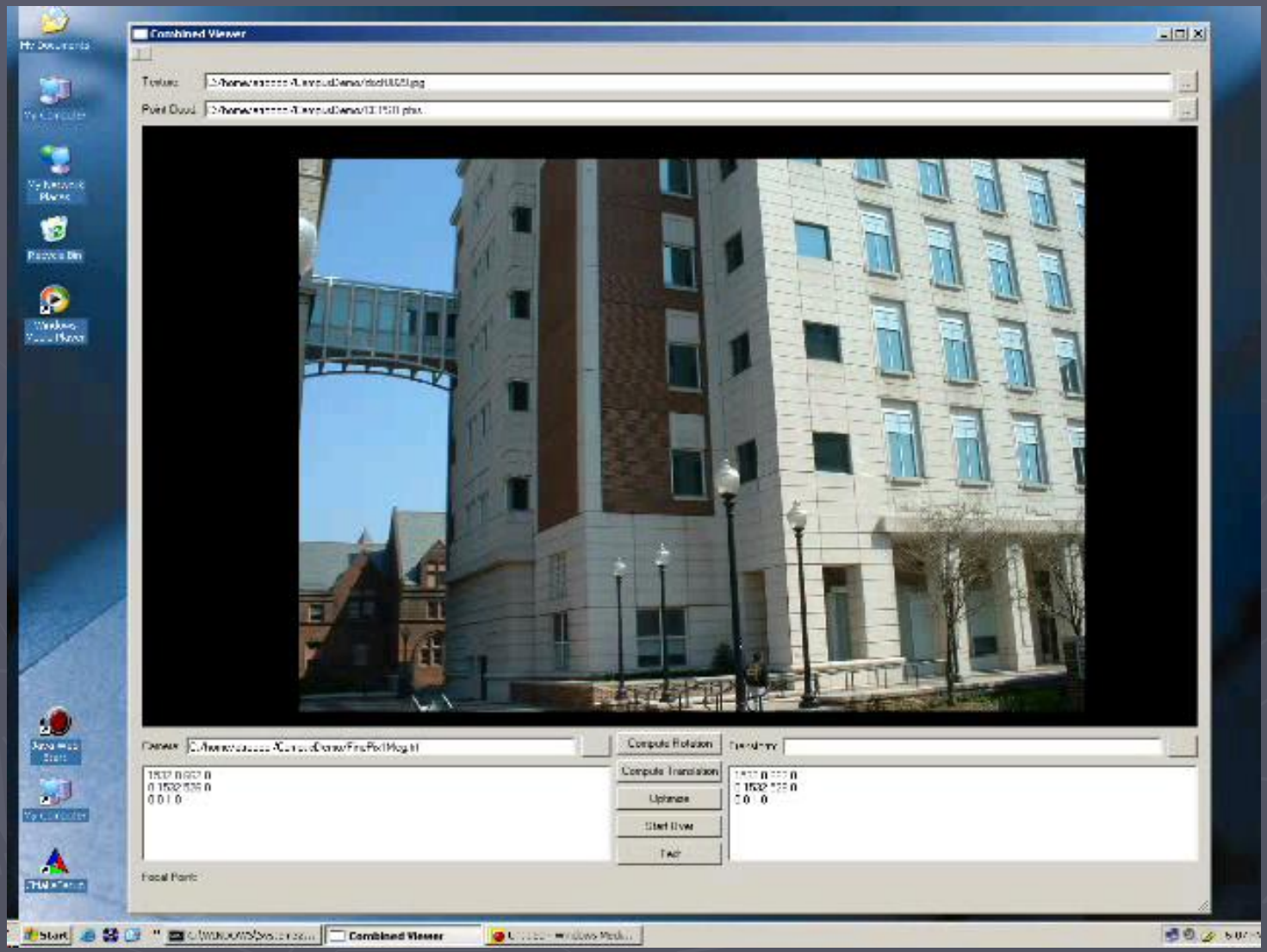


Textured model

Textured model

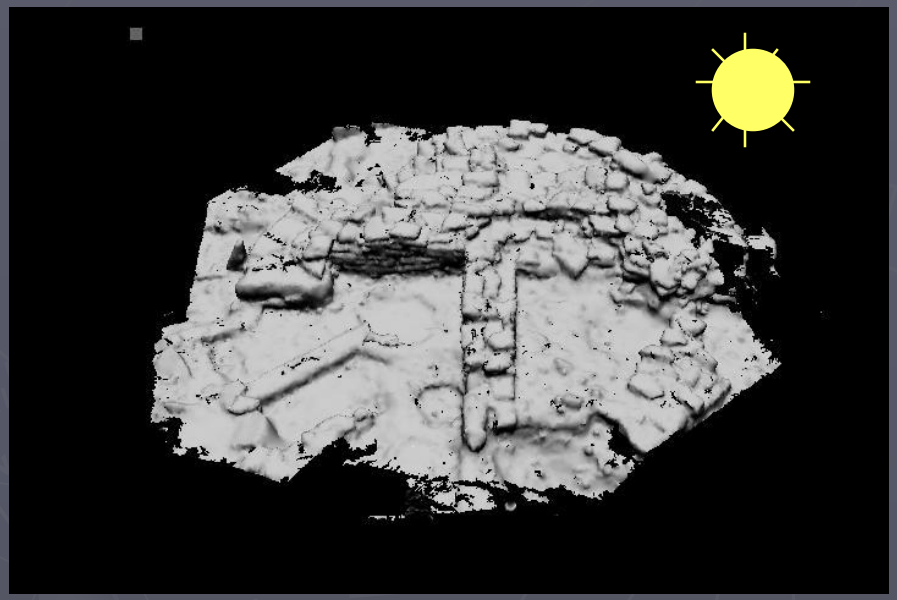


(Semi)Automatic registration



Shadows as features

Geometry + Sun position



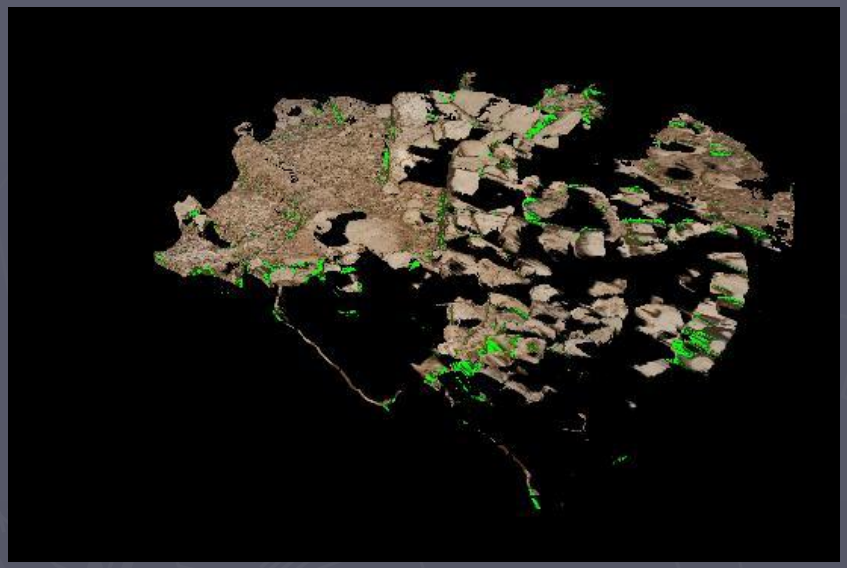
Shadows in 3D world

Image

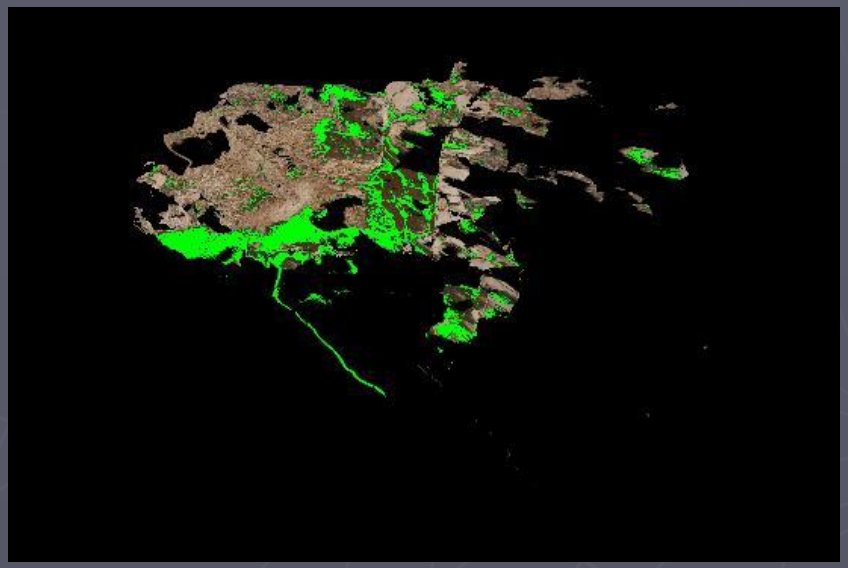
Shadows in 2D image

Match and compute image registration

Shadow match with texture mapping



Shadow pixels = 127
Good match.



Shadow pixels = 1875
Bad match.

Algorithm

Given an initial camera position, find a new one that minimizes the number of shadow pixels.

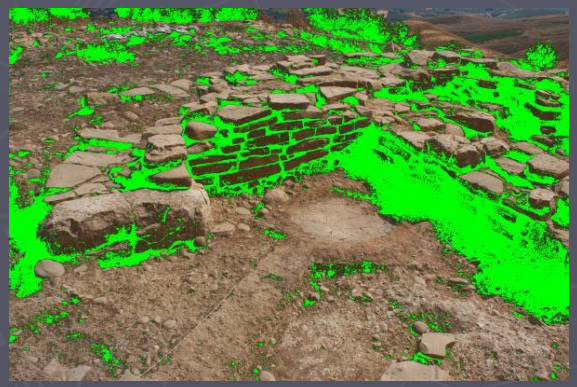
Minimization

Simulated annealing

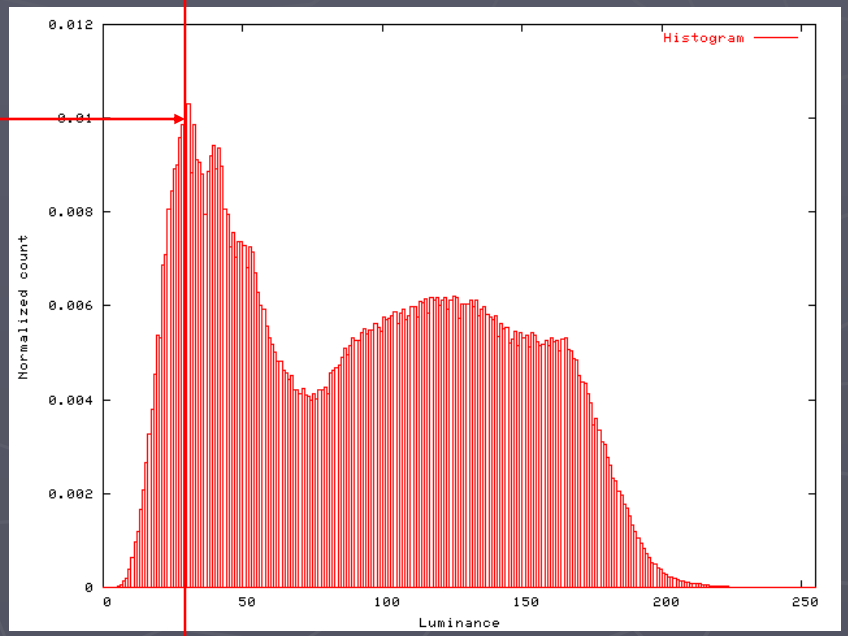
Preprocessing: masking shadow

- Threshold by luminance value.
- Suggested threshold is obtained from the image histogram.

Use a threshold value after the first max



Threshold = 38



30

Results

- Applied method to 10 of the 13 images of our model

Before

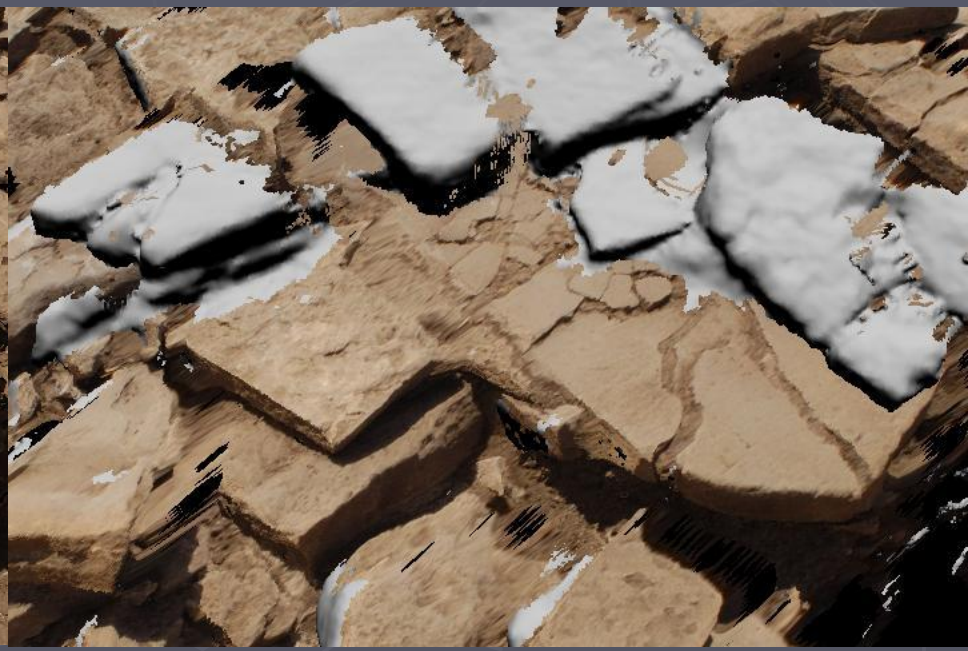
After

Mt. Polizzo, Sicily

Site change tracking

- Goal: update 3D model as excavation progresses
  - Incremental fashion: no need to re-scan all site again
  - Scan affected area only

Before



After

Future work: relighting

- Different images captured a different color for same surface
- Reasons:
  - Different camera settings
  - Different light conditions

Visualization

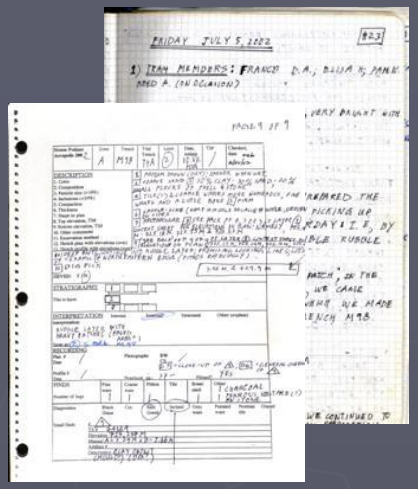
Hrvoje Benko Edward Ishak Steven Feiner

We have a 3D site model, now what?

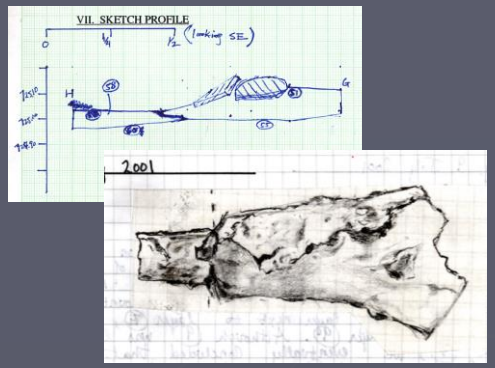
Real

Virtual

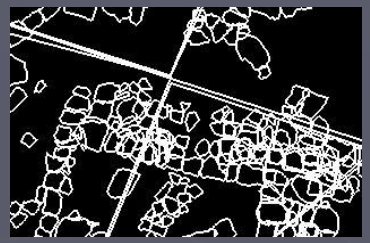
Field Notes



Drawings

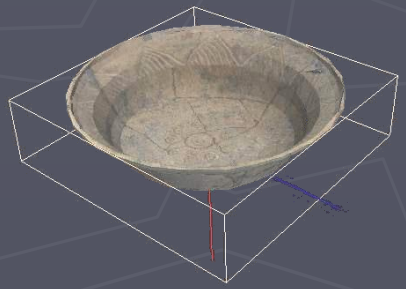


GIS Data



High Resolution Images

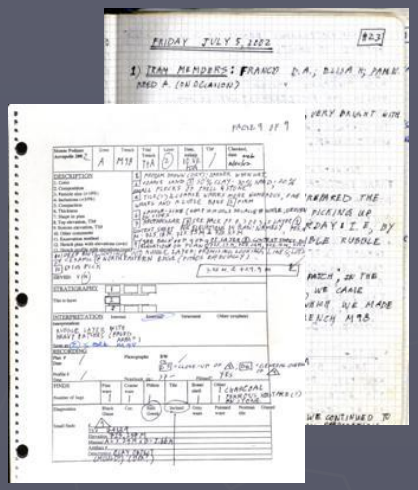
Videos



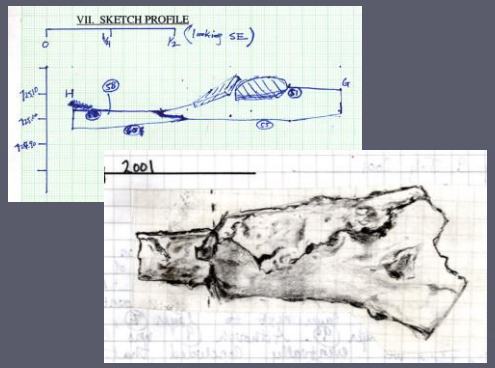
3D Object Models

Panoramic Images

Field Notes



Drawings



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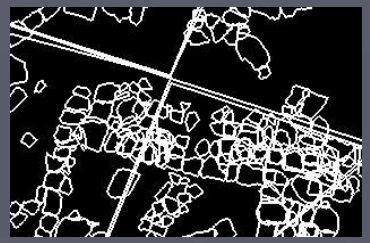
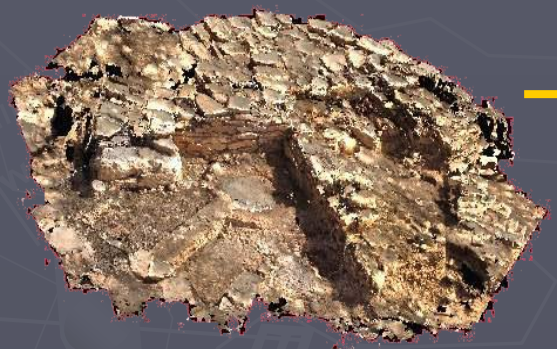


High Resolution Images

Database

3D Site Model



3D Object Models

Panoramic Images

Videos

Two Problems

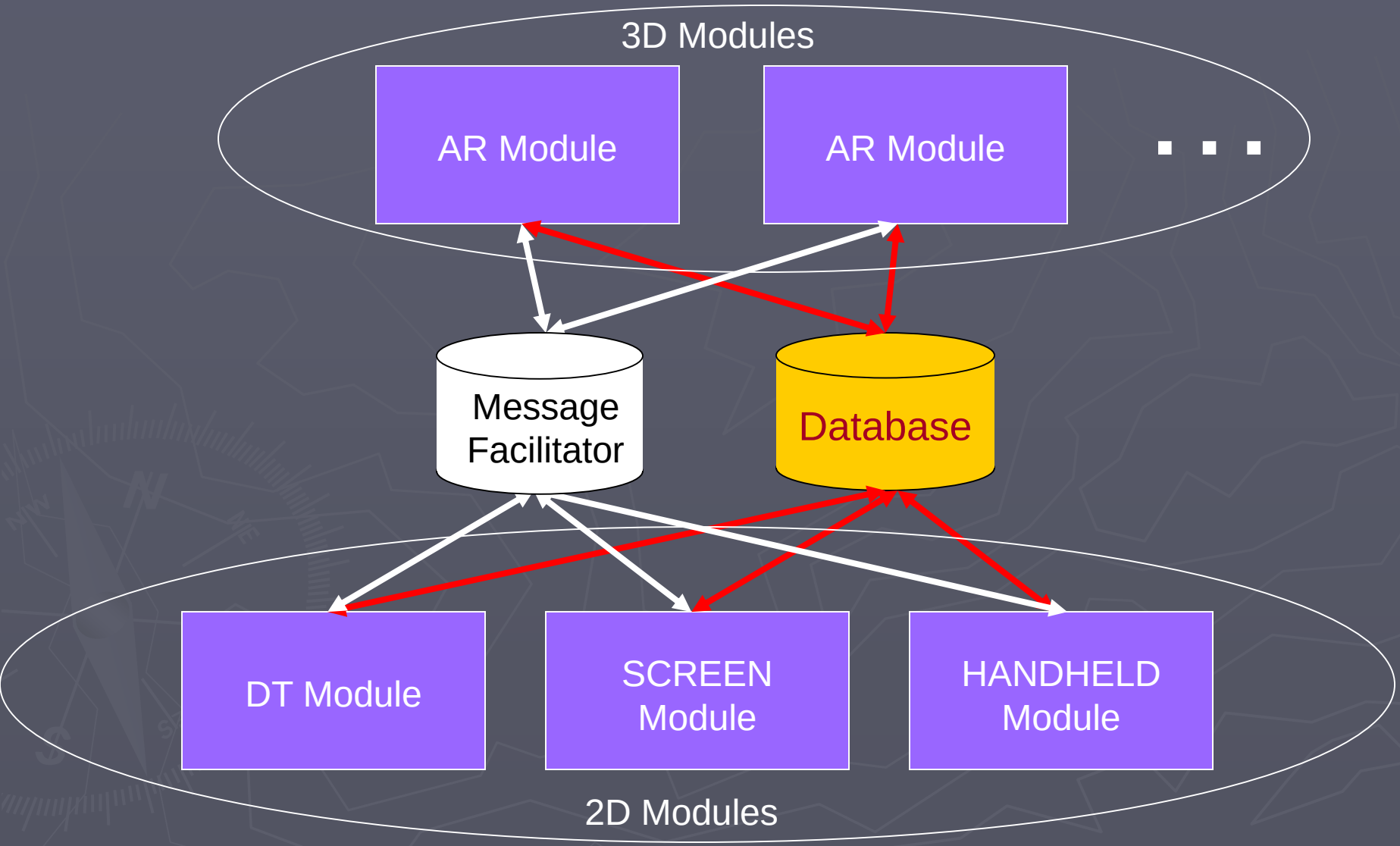
- How to combine all this data in one seamless environment?
- How to make it easy to interact with?

VITA:
Visual Interaction Tool *for* Archaeology

- Multiple users
- Multiple displays
  - Projected tabletop
  - Handheld
  - High-resolution monitor
  - See-through head-worn
- Multiple interaction devices
  - MERL DiamondTouch table
  - EssentialReality P5 gloves
  - Speech input
  - 6DOF tracker

- Facilitate both human-system and human-human interaction

Modular Architecture



AR Module Components

Sony Head-Worn Display
(LDI-D100B)

Head Tracker
Hand Tracker
(Intersense IS900)

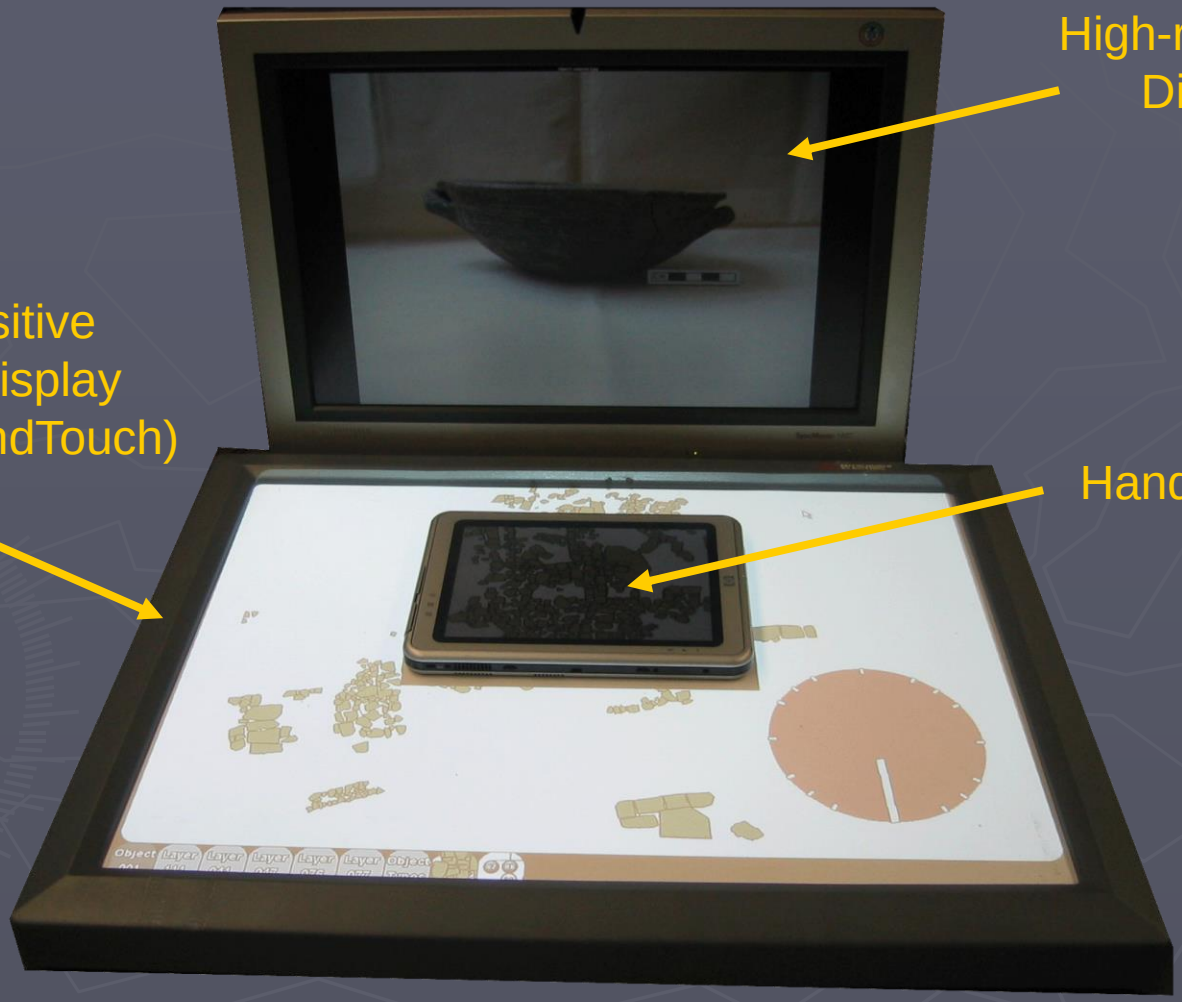
Microphone

P5 Glove
(Essential Reality)

DiamondTouch Table
Connector
(MERL)

Life-size Immersive Exploration

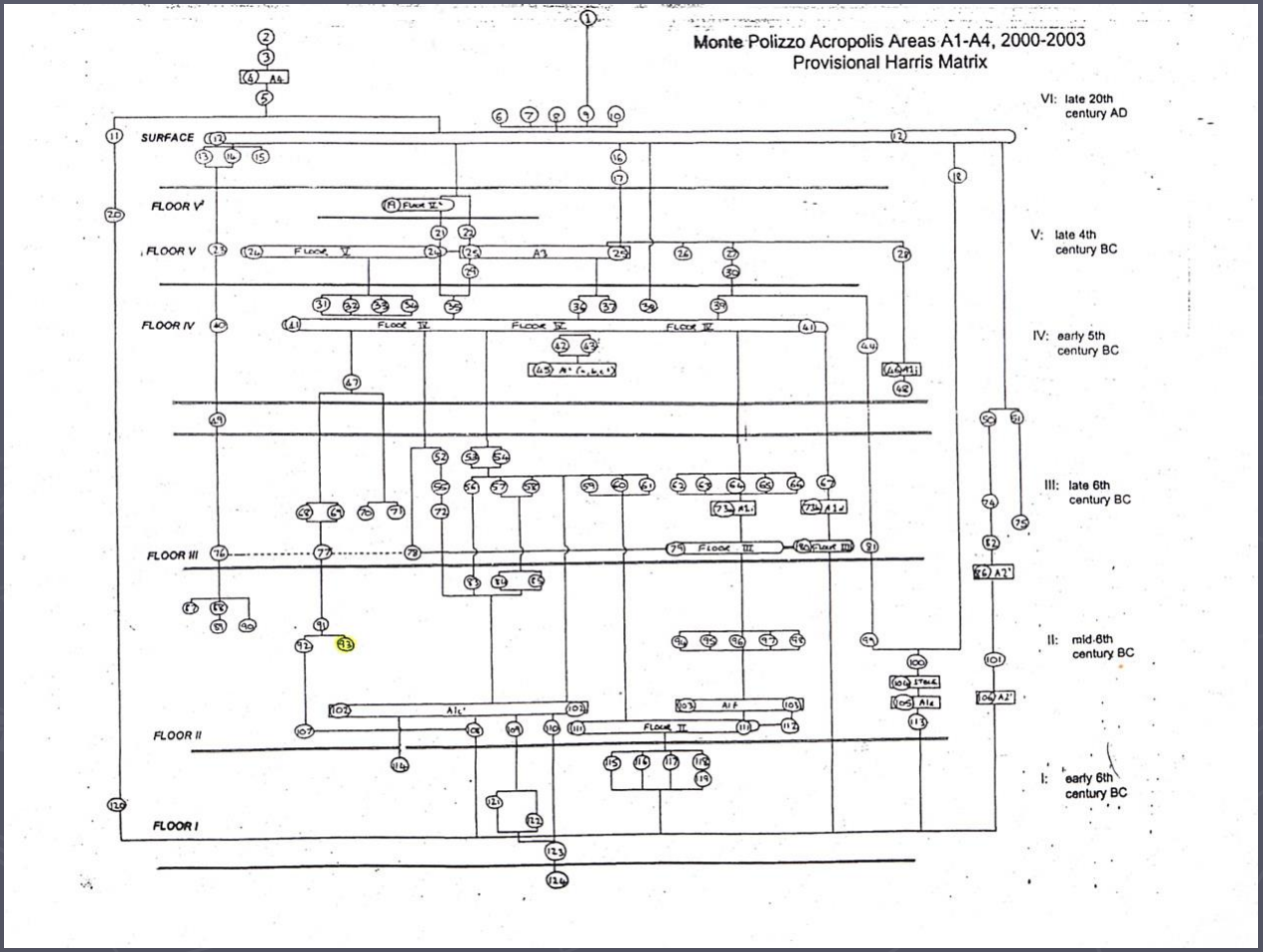
Desktop Components



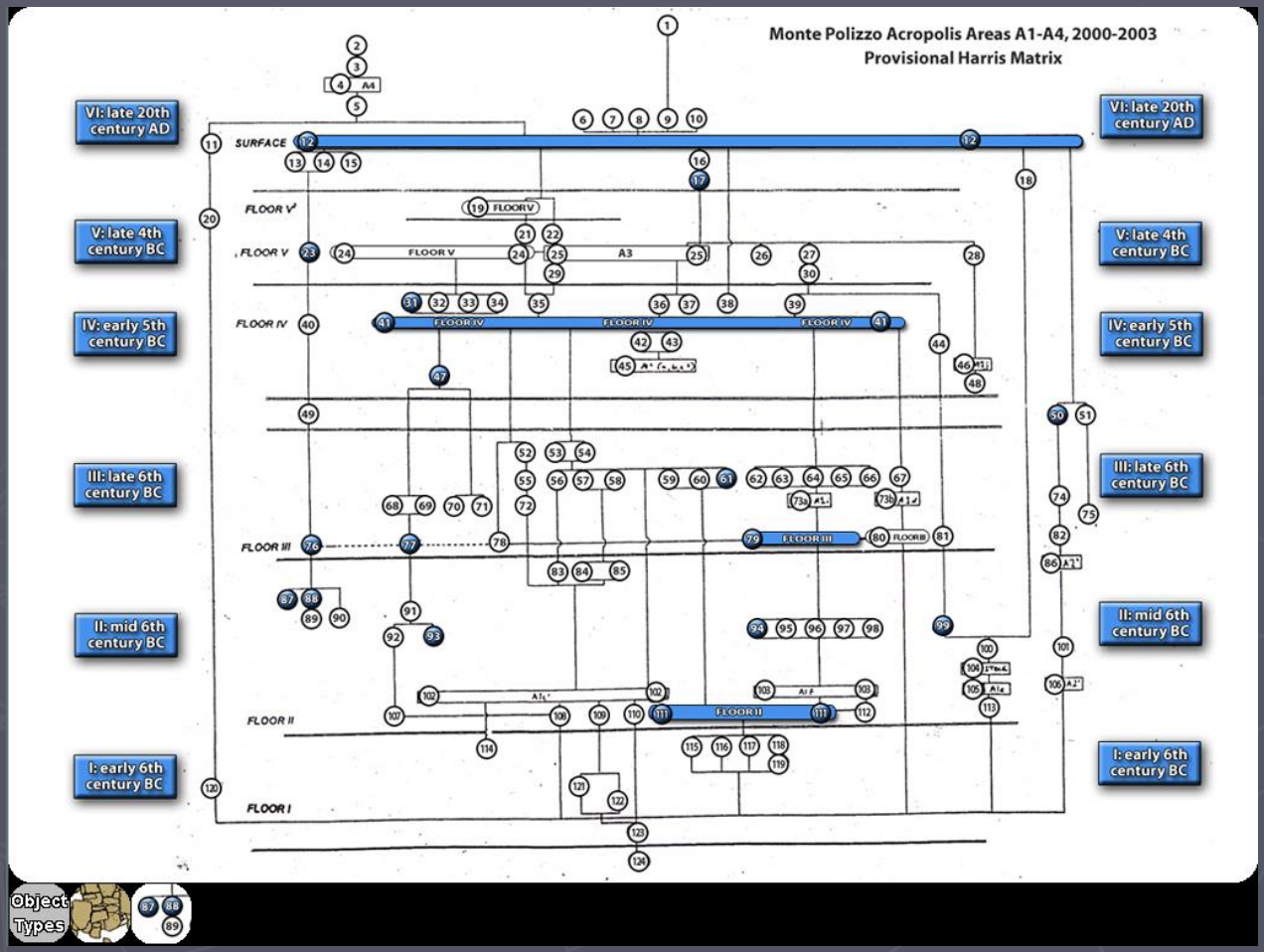
World-In-Miniature

Tabletop Interaction

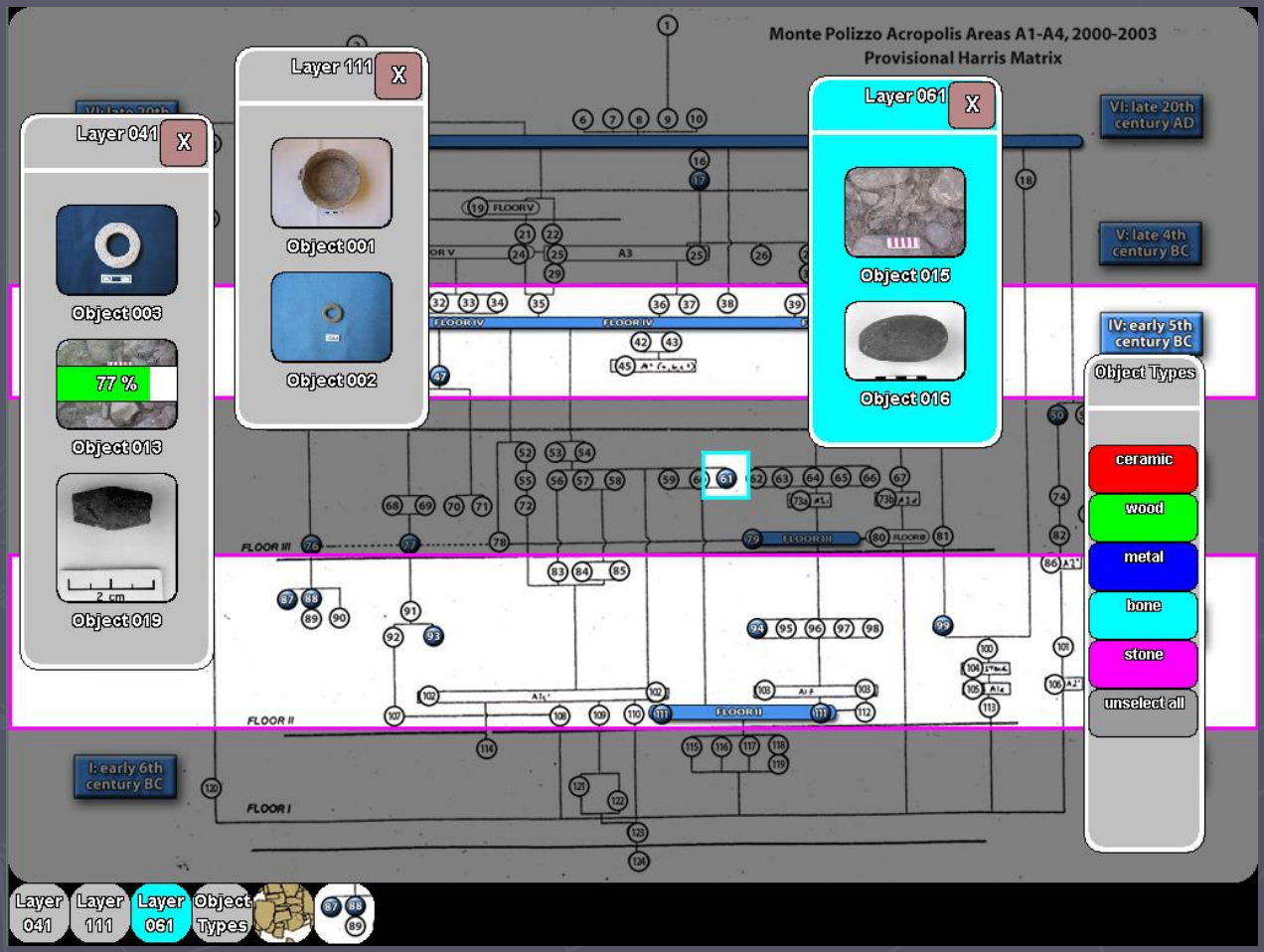
Harris Matrix



Enhanced Harris Matrix



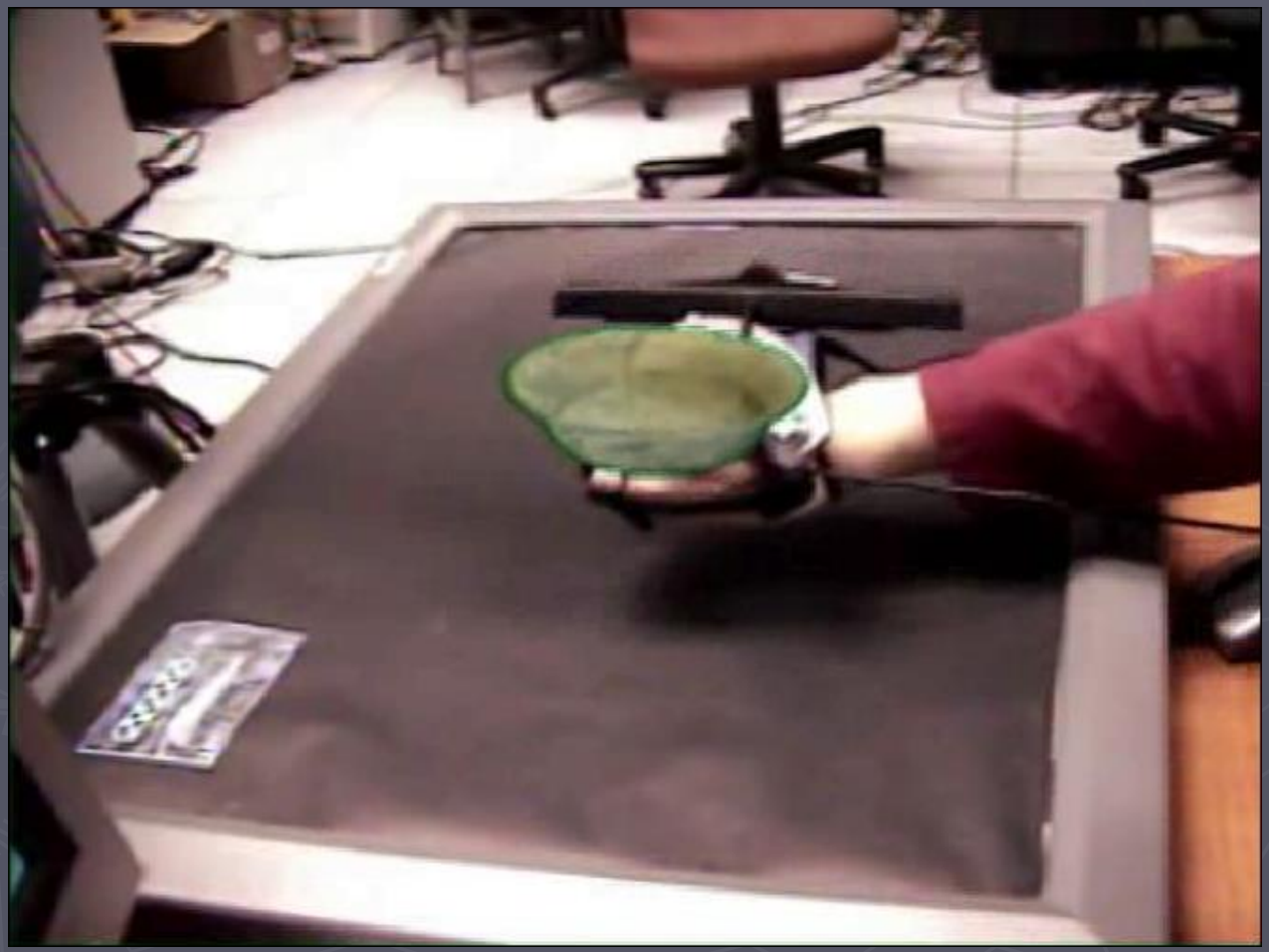
Enhanced Harris Matrix



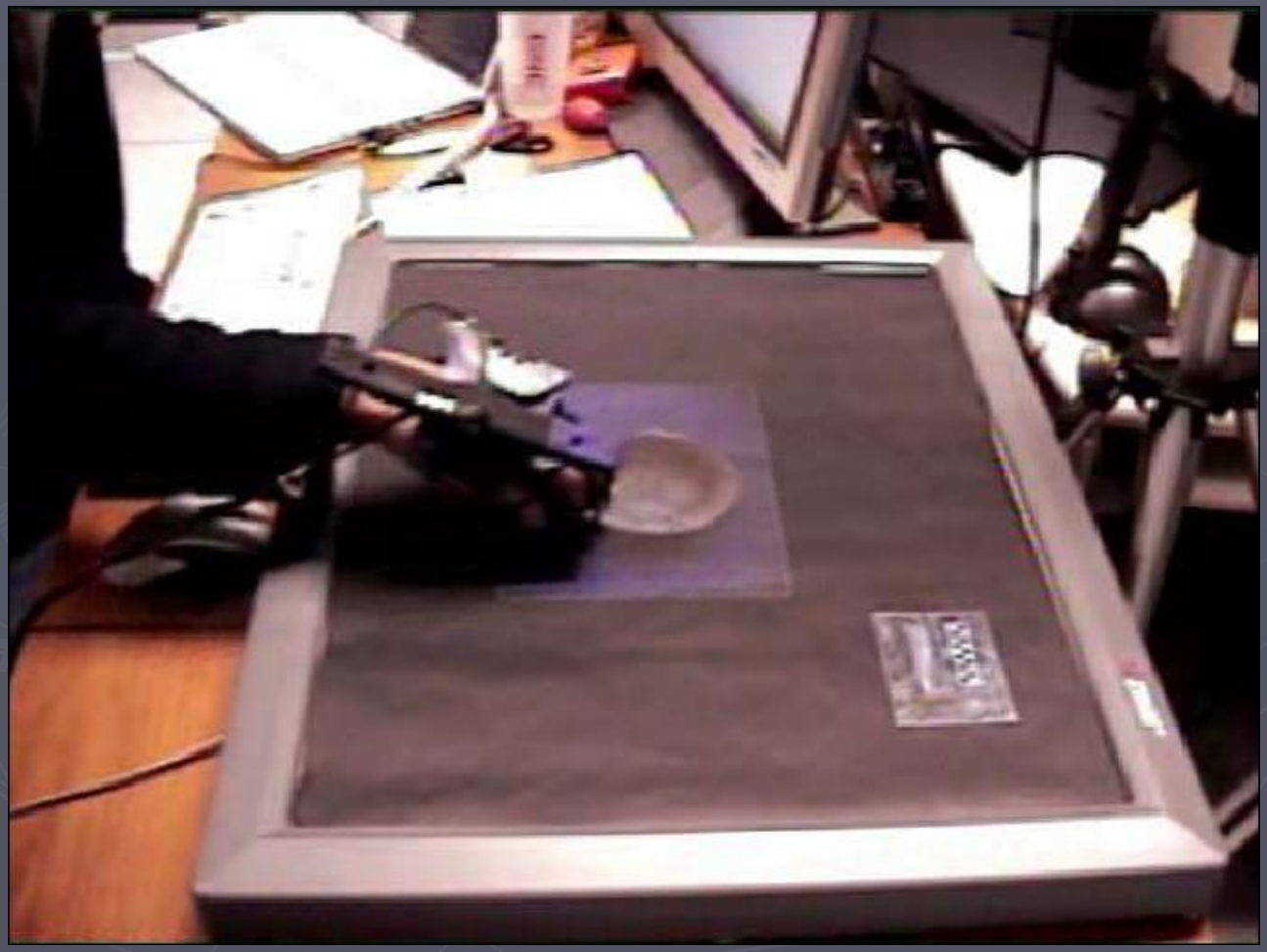
Cross-Dimensional Hybrid Gestures

- Synchronized 2D and 3D gestures
- Facilitate seamless transition across dimensions

Cross-Dimensional Hybrid Gestures



Cross-Dimensional Hybrid Gestures



Handheld Focus-in-Context Display

- Movable high-resolution inset
  - Tracked by DiamondTouch
  - Projection suppressed in its bounds
  - Physical magic lens

3D Multimodal Interaction

- Provide natural interaction mechanism for our 3D environment
- Modalities
  - Speech: IBM ViaVoice 10
  - Gestures: EssentialReality P5 glove
  - Selection statistics: SenseShapes
- Focus on selection
  - Based on collaboration with Phil Cohen et al. (*ICMI 2003*) and SenseShapes (*ISMAR 2003*)

VirtualTray

User Evaluation

- 2 informal experiments with archaeologists:
  - Site exploration scenario (8 participants)
  - Learning tool scenario (3 participants)

Learning Tool Scenario Evaluation

- Participants:
  - One site expert
  - Two archaeology students
- Two 30-min teacher-student sessions (no developer assistance)
- Potential tool in site-orientation archaeology course

User Feedback

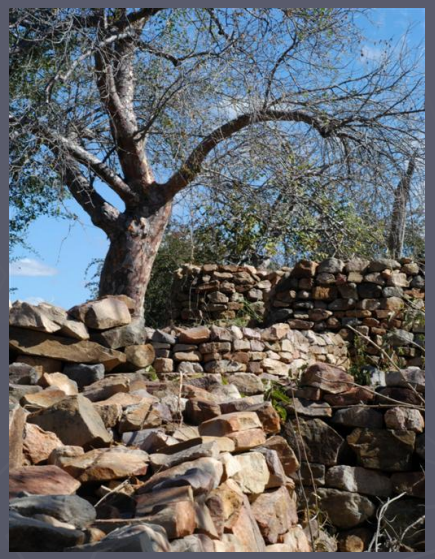
- Overall very positive reaction
- Archaeologists benefited from:
  - Temporal–Spatial connection
  - Aggregated collection of all data
  - Accurate 3D model
  - Simple touch-based interactions
- Potential for increased collaboration

Room for Improvement

- Reduce wires
- Reduce weight
- Eye occlusion hinders communication
- Missing data:
  - More objects, features, notes and pictures
  - More scans during excavation (time-lapse spatial record)
- Missing features:
  - Virtual scale measure (implemented since)
  - Variable site model scaling
  - Improved selection in world-in-miniature

Current and Future Work

- Larger Site:
  - Summer 2004 - Thulamela, South Africa
- Archaeology classroom evaluation
- Personalized user experience based on expertise
- More scans during excavation (time-lapse spatial record)
- Remote collaboration



Acknowledgments

- Special thanks to:
  - Ian Morris, Trinity Jackman, and the Stanford Archaeology Center
  - Lynn Meskell and James Conlon (archaeological advice)
  - Sajid Sadi and Avinanindra Utukuri (P5 glove)
  - Shezan Baig (surface meshing)
  - Mitsubishi Electric Research Labs (DiamondTouch table)
  - Alias Systems
  - Microsoft Research
- Funded in part by NSF ITR Grants IIS-0121239 and IIS-00-82961, and Office of Naval Research Contracts N00014-99-1- 0394, N00014-99-1-0683, N00014-99-1-0249, and N00014-04-1-0005.

Questions?

VirtualTray Widget

- User can store selected objects in a wearable "virtual tray"
- Tray is normally invisible, but can be visualized on demand
- Interactions performed via buttons on glove

Design Considerations

- Incorporate all "standard" archaeological data
- Pick the best display given the media properties
- Encourage collaboration
- Make interaction easy

Site Exploration Scenario

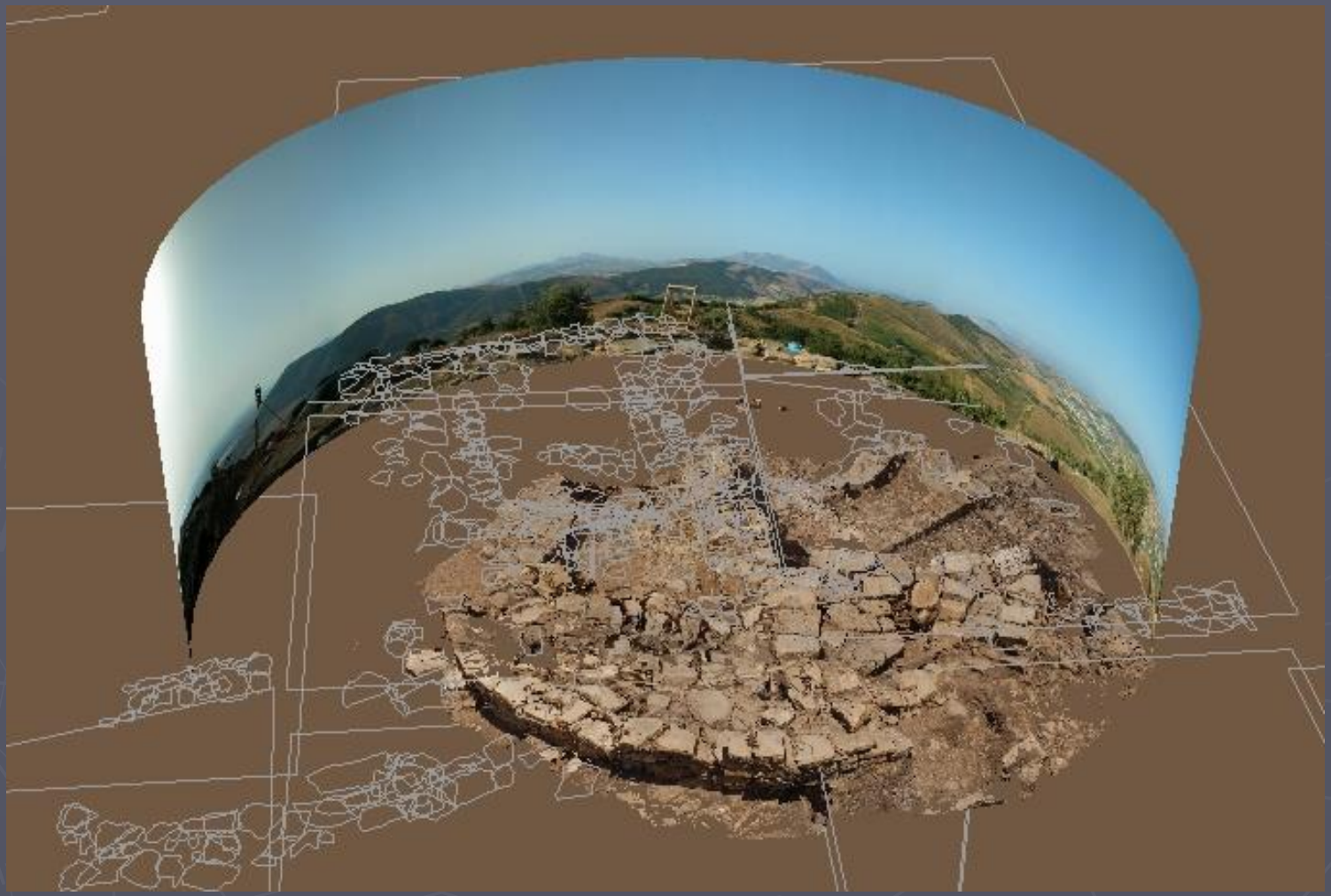
- Six participants (all archaeologists)
- Paired exploration:
  - 1 user + 1 VITA developer
- No. 1 benefit cited:
  - Connecting the temporal relationships of excavated objects (in the Harris matrix) with their 3D spatial relationships

Conclusions

VITA: Visual Interaction Tool *for* **Archaeology**

- Experimental, collaborative, multimedia–rich mixed reality system
- Provides offsite visualization of an archaeological excavation
- Received very positive initial user reactions

Complete model



Equipment