New Reflection Transformation Imaging Methods for Rock Art and Multiple-Viewpoint Display

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Cultural Heritage Imaging
A California Nonprofit Corporation

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VAST/CIPA 2006, Nicosia Cyprus
November 4, 2006

Topics

- What is RTI?
- How RTI works
- Fundamental Understandings
- Existing RTI Capture Systems
- New Method, Highlight RTI
- Multi-view RTI
- Future Work

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Reflection Transformation Imaging (RTI)

- Term coined by our coauthor Tom Malzbender and Dan Gelb of HP Labs, inventers of Polynomial Texture Mapping (PTMs)
- Stores surface reflection information for each image pixel
- 2D images with true 3D information
- Information is image based, not requiring geometry in Cartesian space
- No data loss from shadows and specular highlights
- Mathematical explanation available at: hpl.hp.com/research/ptm

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RTI Basics

- Fixed camera position
- Multiple images illuminated from different known light positions
- Images synthesized into a single RTI image
- RTI captures “real world” reflectance characteristics of subject
- Reflectance information generates perception of shape
- Enhancement discloses additional information

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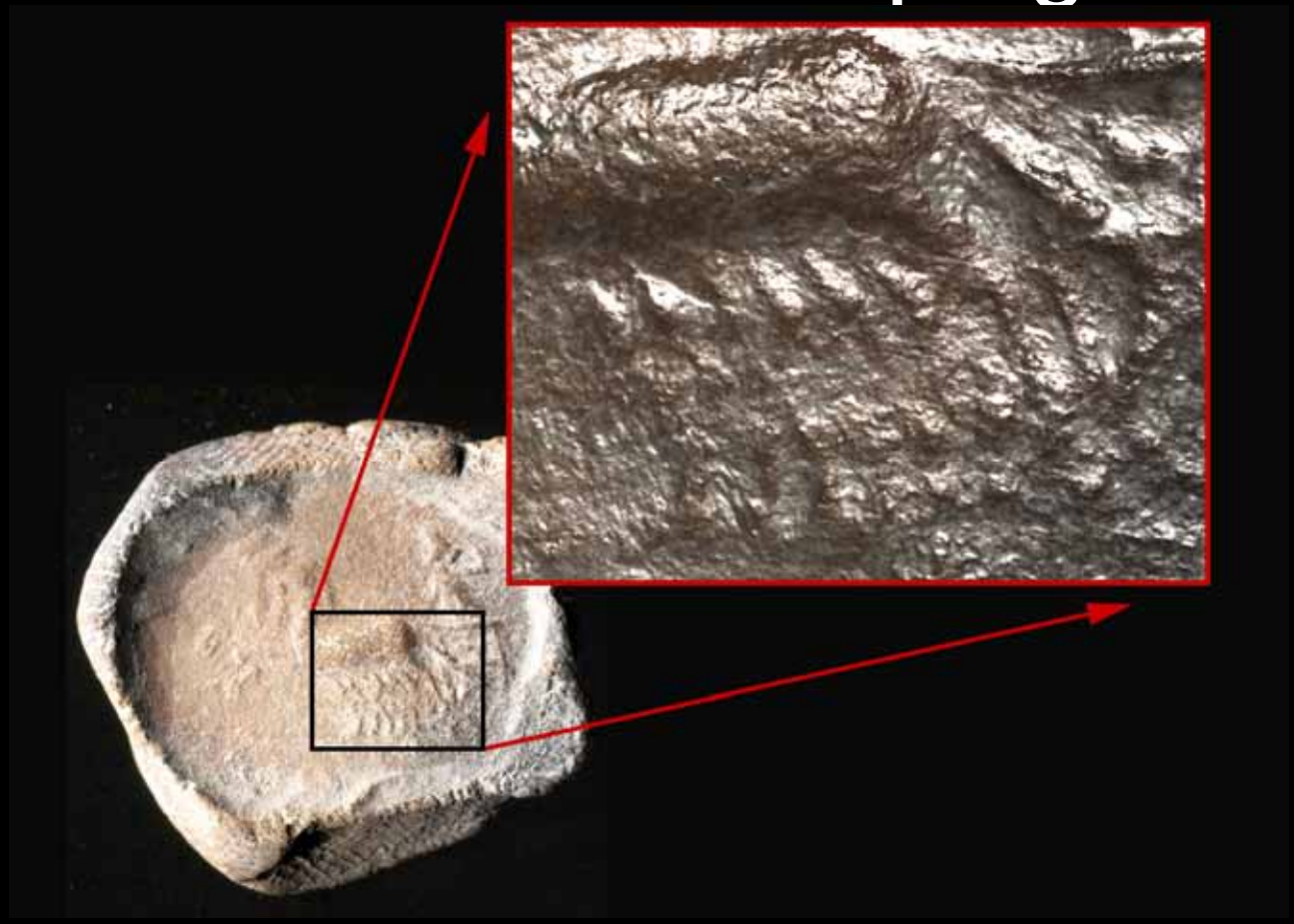
Ceramic Stamping



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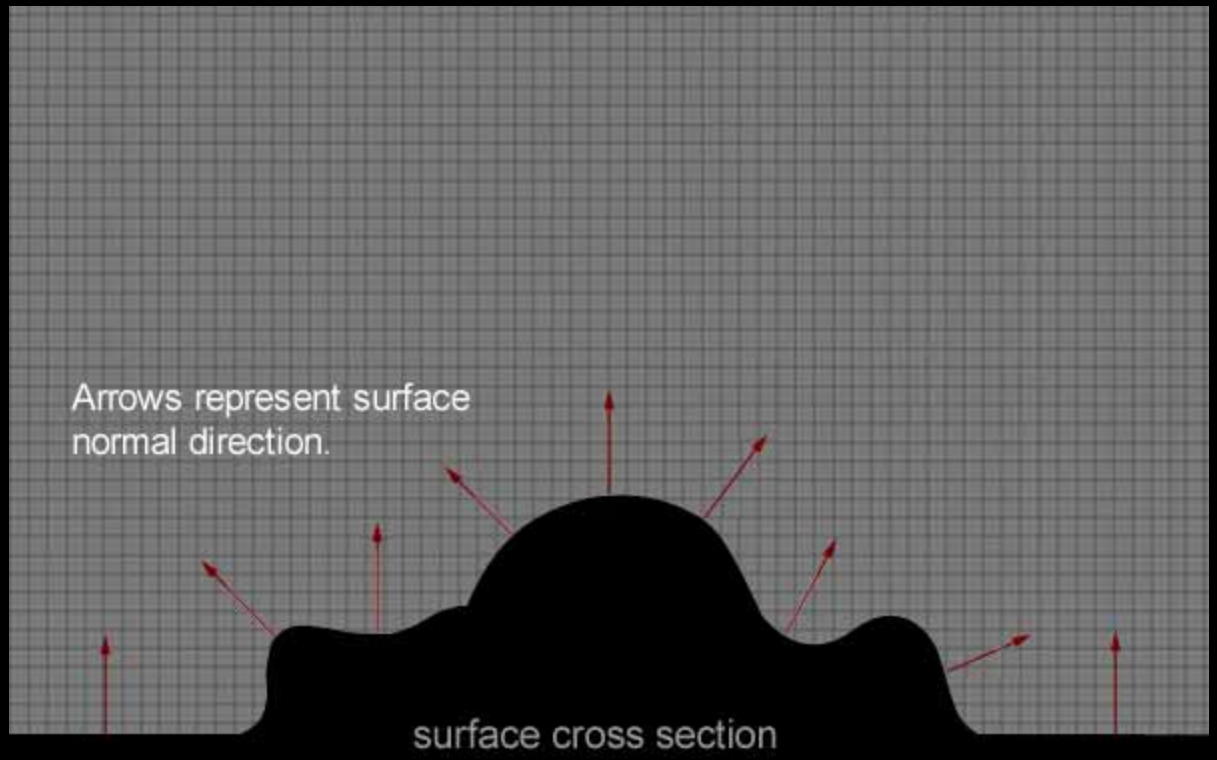
Archaeologial Research Collection
University of Southern California

How RTIs work



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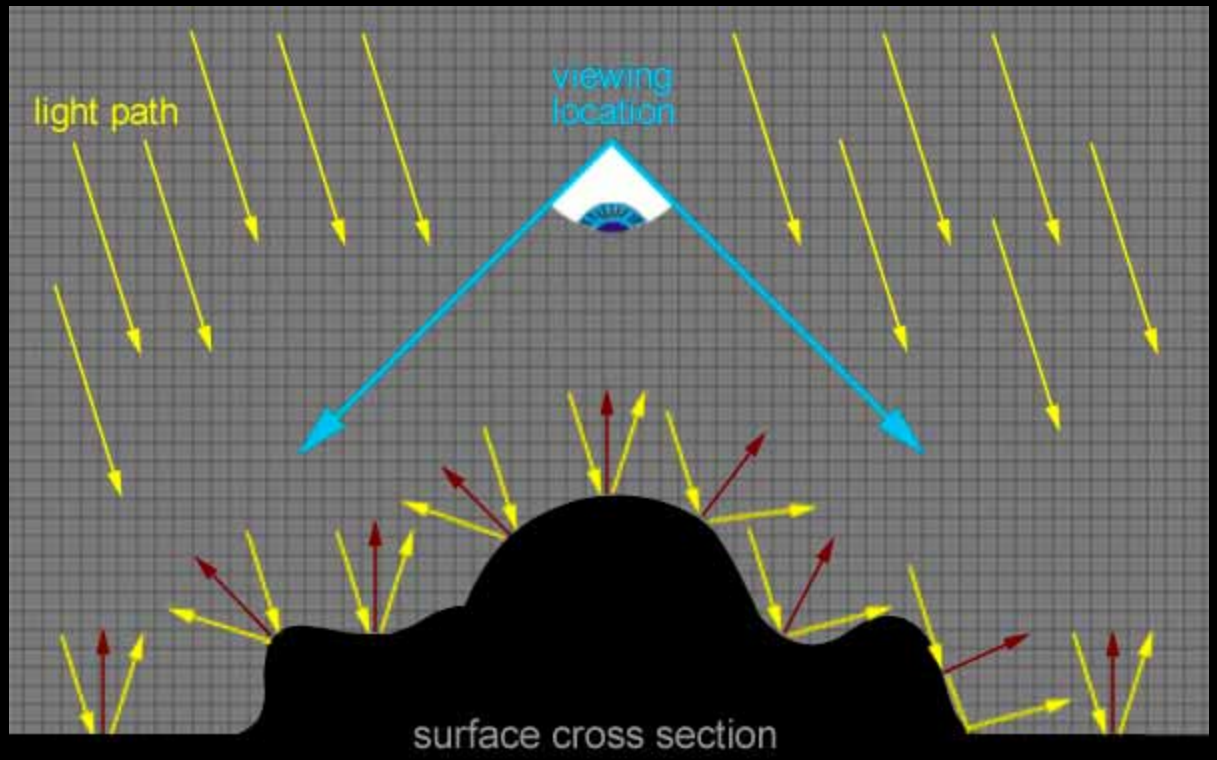
How RTIs work



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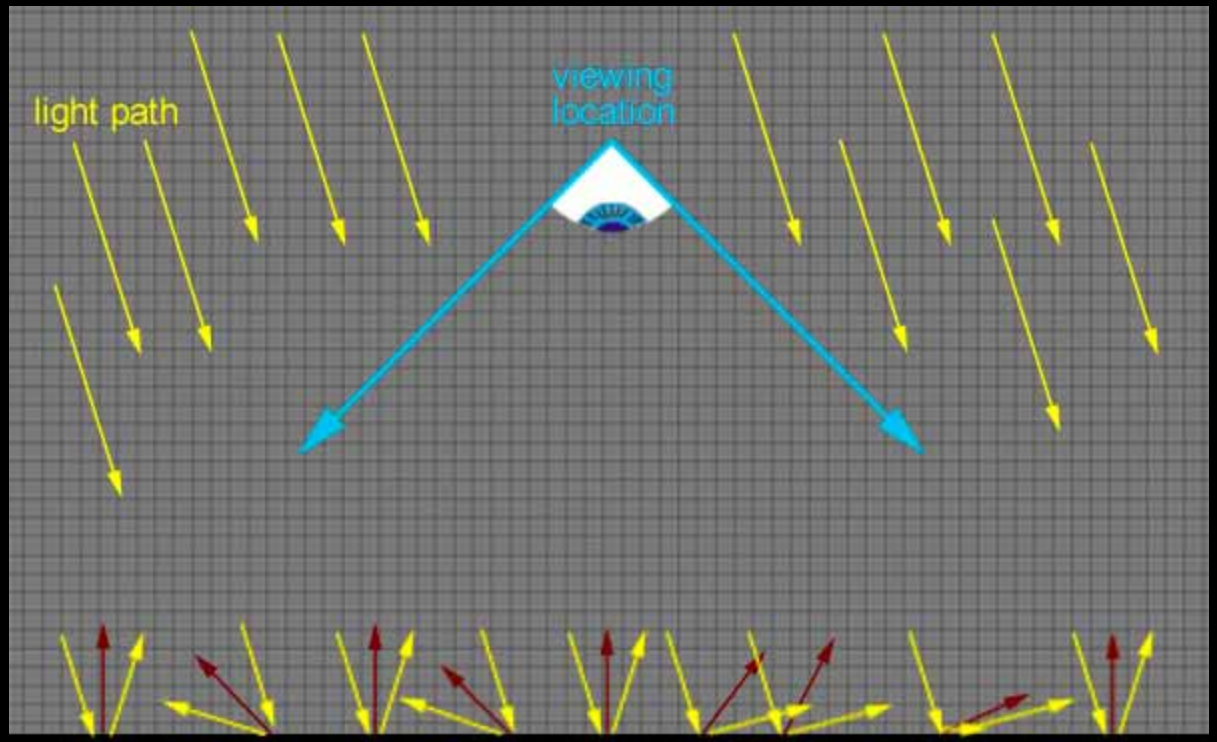
How RTIs work



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Fundamental Understandings

- Digital technology for CH must be:
  - Adapted to the cultural heritage (CH) community
  - Adopted by the CH community
  - The result of early and on-going collaboration and evaluation with CH professionals
  - Freely available to the CH community

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Fundamental Understandings

- Based on digital photography because those skills are already widespread
- Compatible with existing skill sets and working cultures
- Possible to automatically process the photos
- No need for help from digital imaging experts during empirical data capture

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Fundamental Understandings

- New Standards of Best Practice through:
  - New tools and methods
  - Worldwide communication
  - Pilot projects and demonstrations
  - Automatic “Empirical Provenance”

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Empirical Provenance

- Access to process history and raw data
- When included with digital representations of cultural heritage materials:
  - Permits the qualitative evaluation of digital information
  - Increases the acceptance of online information by scholars, educators, and the public
  - promotes collaborative, distributed scholarship
- Now being mapped to the CIDOC/CRM

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Known Light Position RTI Capture Techniques

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HP’s RTI Capture Systems

Photo: courtesy HP Labs

Photo: courtesy HP Labs

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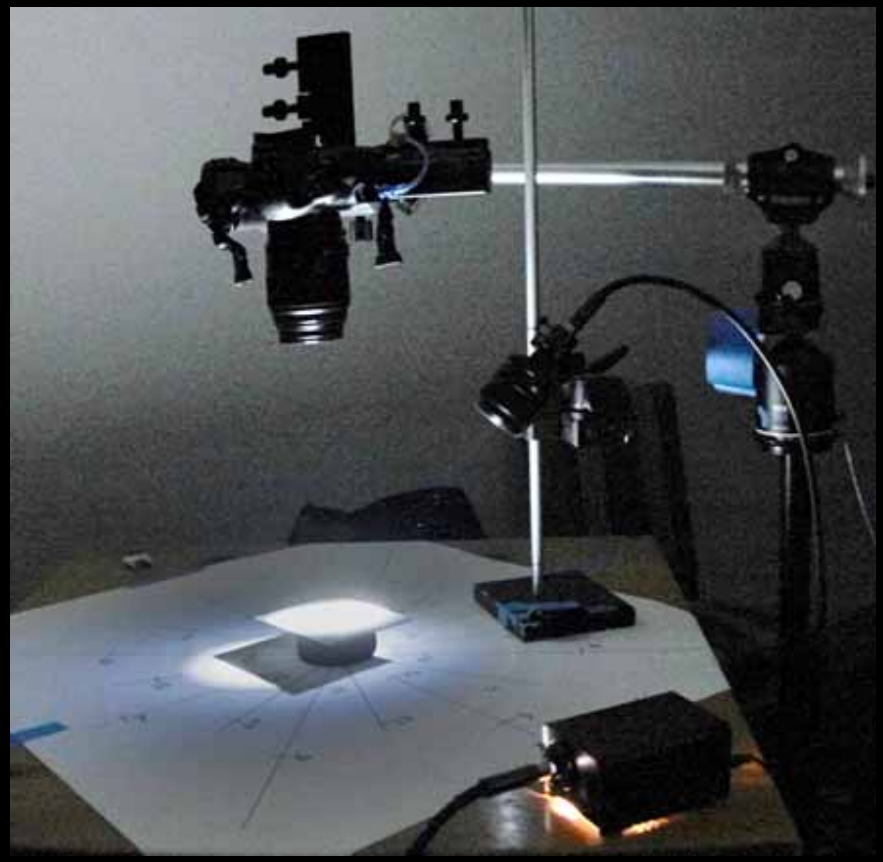
CHI's Manual, Low Cost, Template System



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CHI's Automatic RTI Capture Dome

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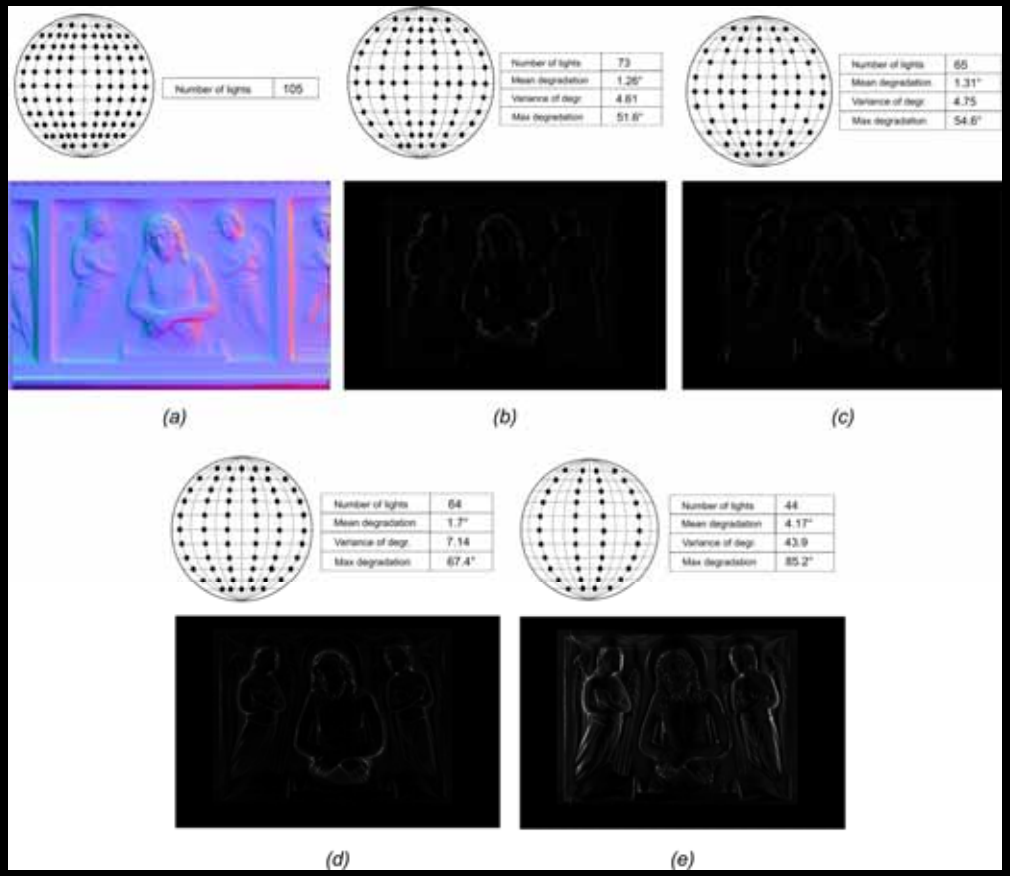
ISTI/CNR PISA Quality Assessment



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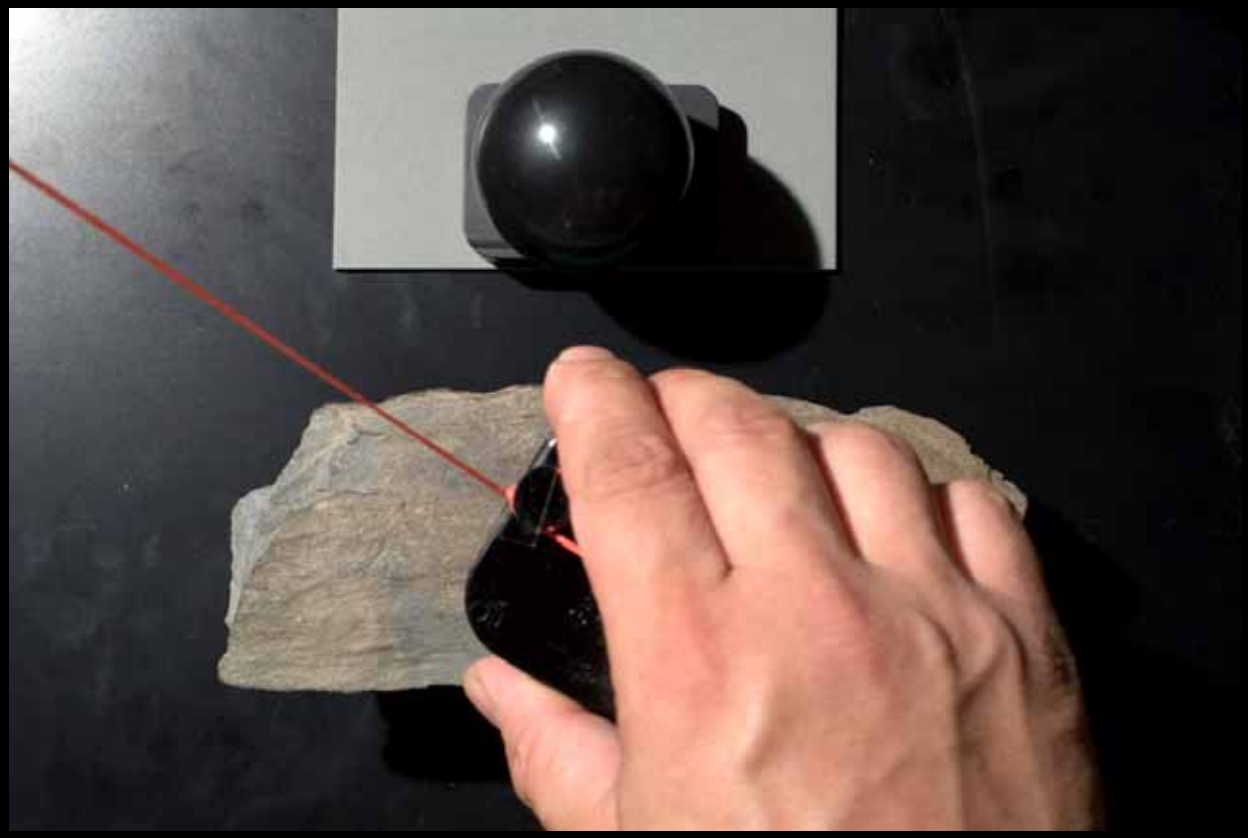
New Method: Highlight RTI



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No prior knowledge of light position needed

Highlight RTI in the Field

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Rocha 2 da Ribeira de Piscos
Parque Arqueologico Vale do Coa
5 June 2006

Highlight RTI in the Laboratory

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Instituto Portugues de Arqueologica
Centro Nacional de Arte Rupestre
7 June 2006

Equipment Required

- SLR digital camera
- Light reducing neutral density filters
- Tripods
- Black ball on length and angle adjustable boom
- Measuring tape
- Retractable surveyors plumb-bob string (bob removed)
- Light source
  - 1 to 1/32 power adjustable 320 watt second (minimum) flash - with battery pack and radio flash triggers

  OR
  - intensity adjustable continuous light - generator or indoors
- Laptop Computer
  - remote camera control software
  - image viewing software (Photoshop, Irfanview, etc.)
  - black cloth

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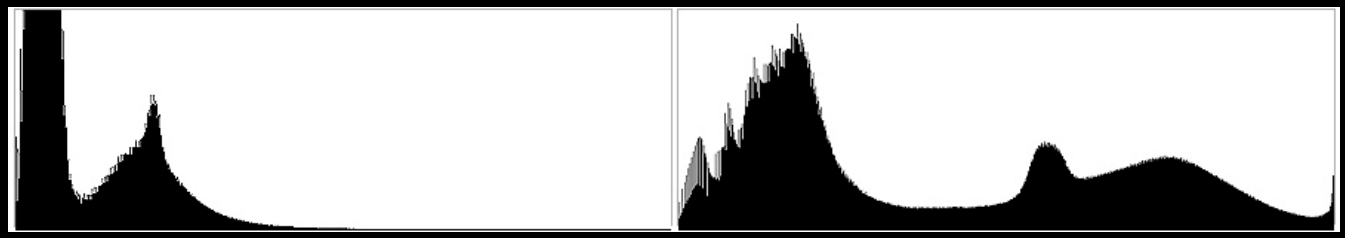
Field Considerations

- Ambient light
  - Use neutral density filters to block daylight
- Light radius management
  - Illumination intensity central to accurate normal calculation
  - Low dynamic range in digital cameras
  - All the available histogram range used by incident light angle range



Grazing Incident Angle

'High Noon' incident angle

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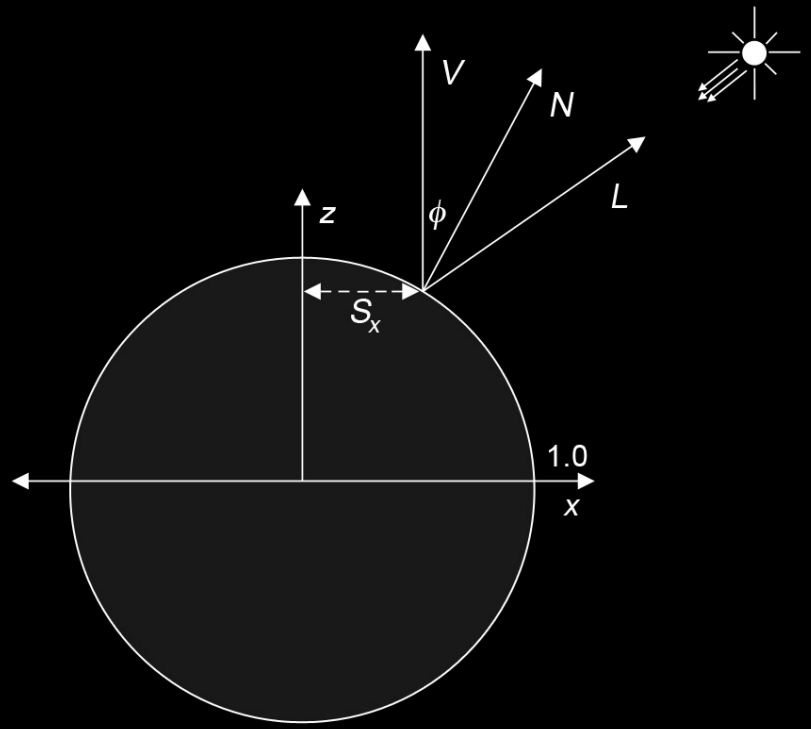
Estimating Lighting Direction From Highlight Location

- V is the view vector pointing to the camera
- N is the surface normal
- L is the unknown, normalized light vector we solve for



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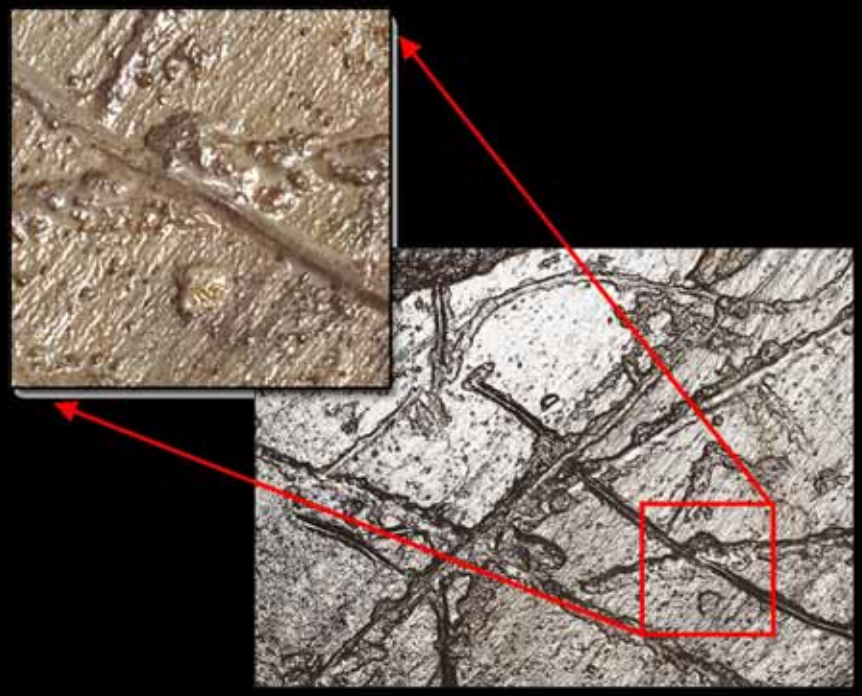
Prior use of spheres to collect lighting direction:
Masseulus ‘02, Einarsson ‘04

Results: Goat Petroglyph



68cm by 46cm area
Normal every 166 microns or
36 samples per sq. mm

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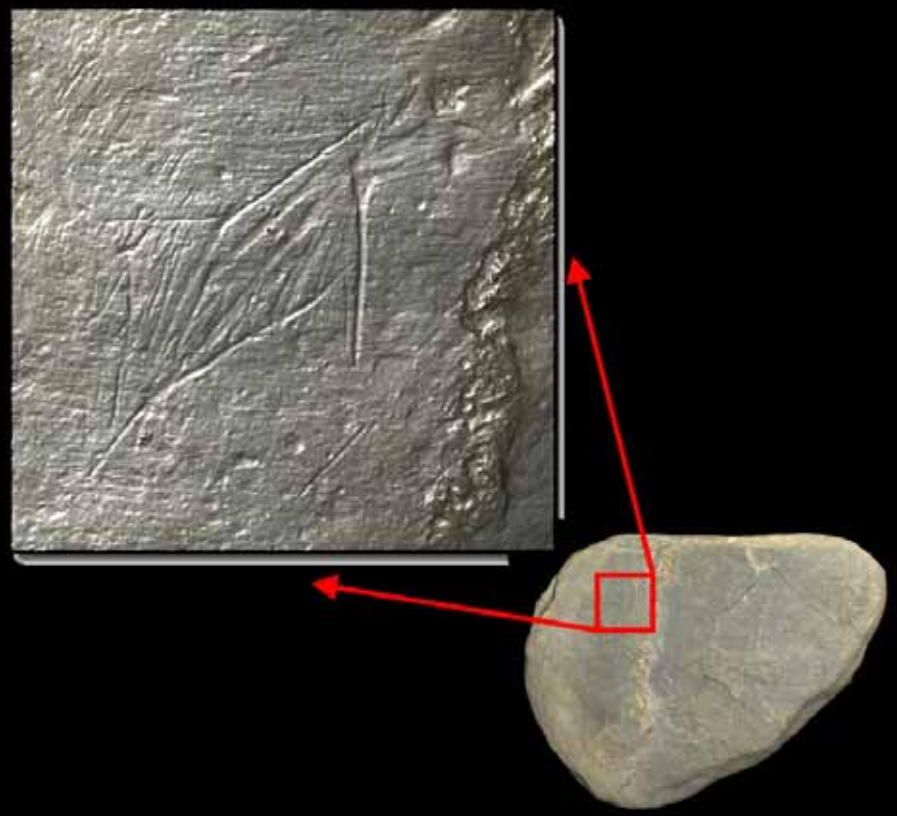
Results: Portable Rock Art



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‘Portable Art’ - Magdalenian period (14,000 – 12,000 BP)
Stone is 18 cm wide
Normal captured every 65.7 microns or 231 per sq. mm
Inset petroglyph is only 3.1cm in length

Multi-View RTI

- Multiple RTIs are captured from different viewpoints around the subject
- These viewpoints are integrated in an interactive viewer
- Image based 3D representation of objects from multiple viewing angles without 3D geometric models

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First Multi-view RTI:

Bronze Age Torque – 1600-2000 BCE

Collection Archéologie du Musée
de l'Hospice du Grand St. Bernard

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Highlight RTI Future work

- Automatically detect highlights on the ball
- Make capture process more efficient
- Explore stereo camera setup
- Use 2 black spheres for precise light Positions
- Explore non-photorealistic rendering

Legend Rock, Wyoming Petroglyph Site
August, 2006

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Multi-View RTI Future Work:

- Recent CHI funding from the U.S. Institute of Museum and Library Services (IMLS) National Leadership Grant will:
  - Create easy to use and cost effective Multi-View RTI capture techniques
    - Require only object placement and digital photography skill sets
    - Provide an automatic RTI processing pipeline
    - Compatible with existing professional cultures
  - Automatic generation of empirical provenance

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3D Range Geometry Future work:

- New research suggests possible automatic extraction of full 3D geometry from multi-view RTI image sequences
- Geometry extraction enables:
  - Viewing from any direction
  - Measurement
  - Re-lighting from any direction or source
  - Reduction in the number of required RTI capture angles
  - Physical reconstruction, animation, and analysis of the subject

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Acknowledgements

Thanks to:

- Parque Arqueologico do Vale do Coa (PAVC)
- Centro Nacional de Arte Rupestre (CNART)
- Universidade do Minho
- The Congregation of the Grand St. Bernard
- Szymon Rusinkiewicz – Princeton
- James Davis – UC Santa Cruz
- U. S. Bureau of Land Management – Denver Technology Center, Archaeologist Mike Bies
- CHI supporters and the CHI Board of Directors

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