TEXTURE IMAGING FROM CAPTURE TO ACCESS

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TEXTURE IN CULTURAL HERITAGE

- Deliberate
- Non-deliberate

TEXTURE IN CULTURAL HERITAGE

- Deliberate
  - Cuneiform
  - Inscriptions
  - Coins
  - Dry-point
  - Painting
  - Bas-relief
  - Figurines
- Non-deliberate

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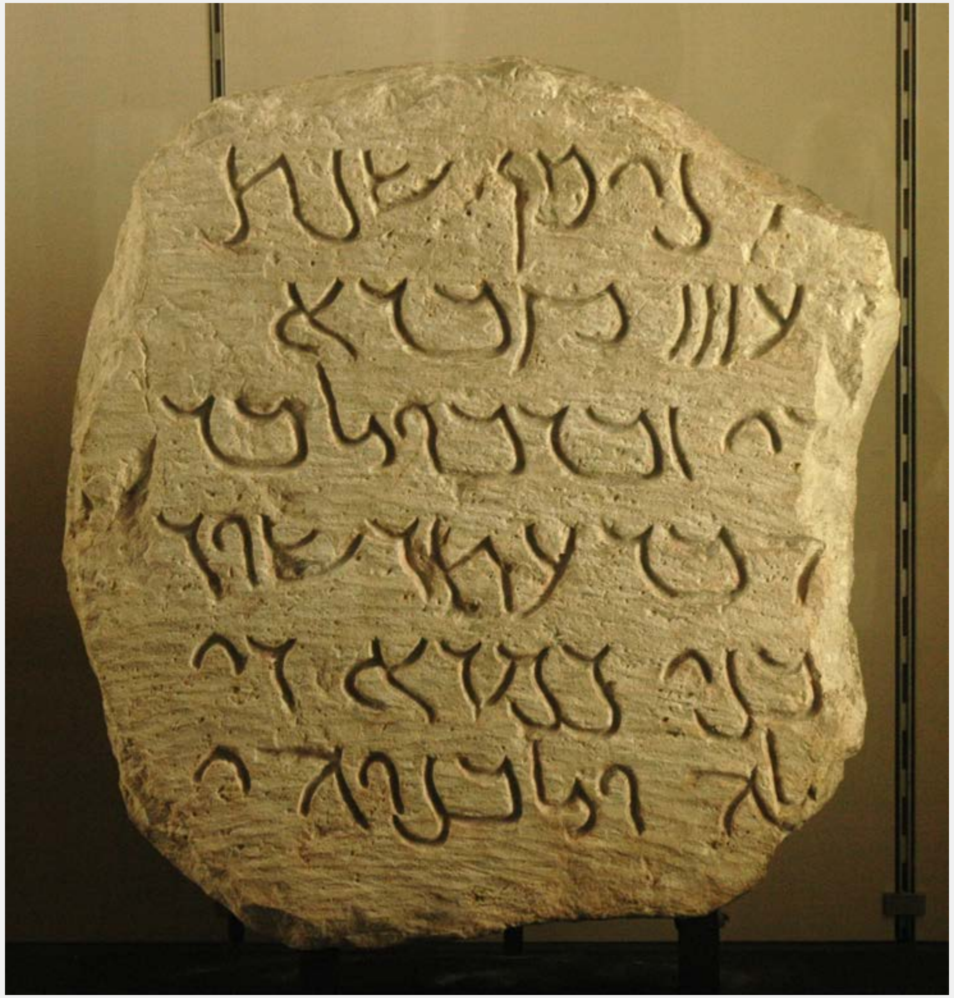

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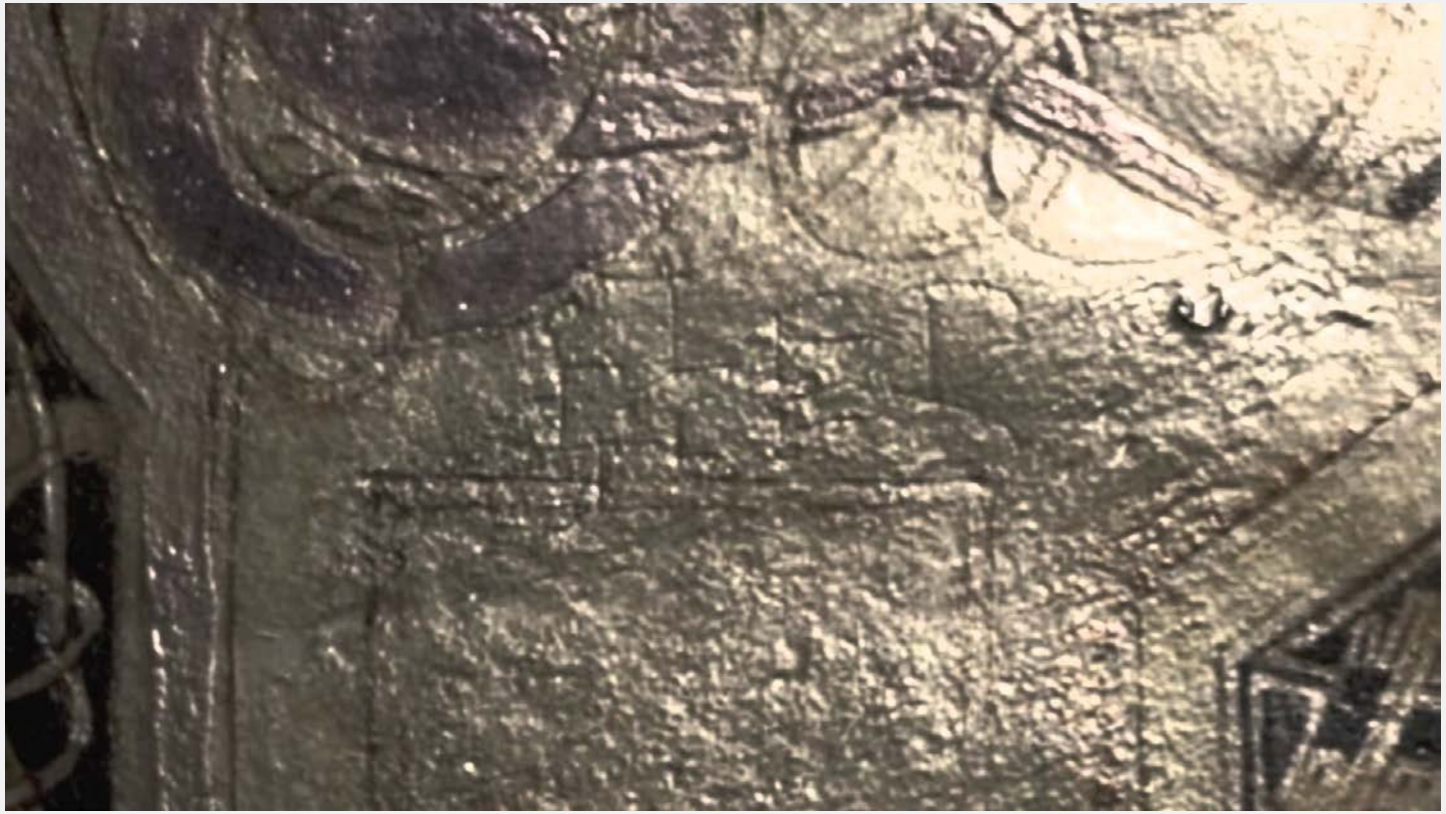

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- Deliberate
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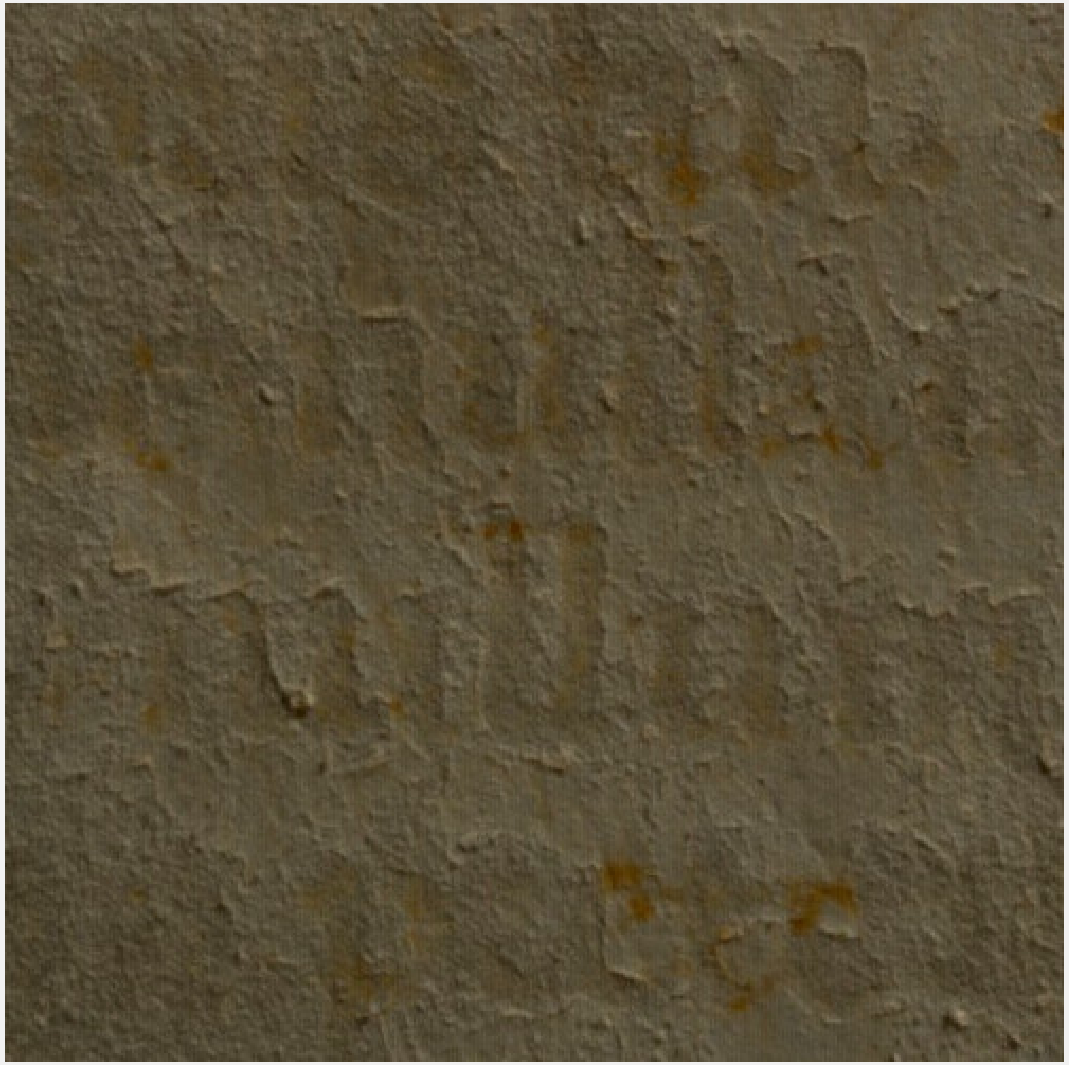
  - Corrosion of ink into parchment
  - Thickness and flaking of ink
  - Holes and accretions
  - Warp and cockle
  - Evidence of use
  - All the little things that make manuscript specialists say there is no substitute for first-hand inspection



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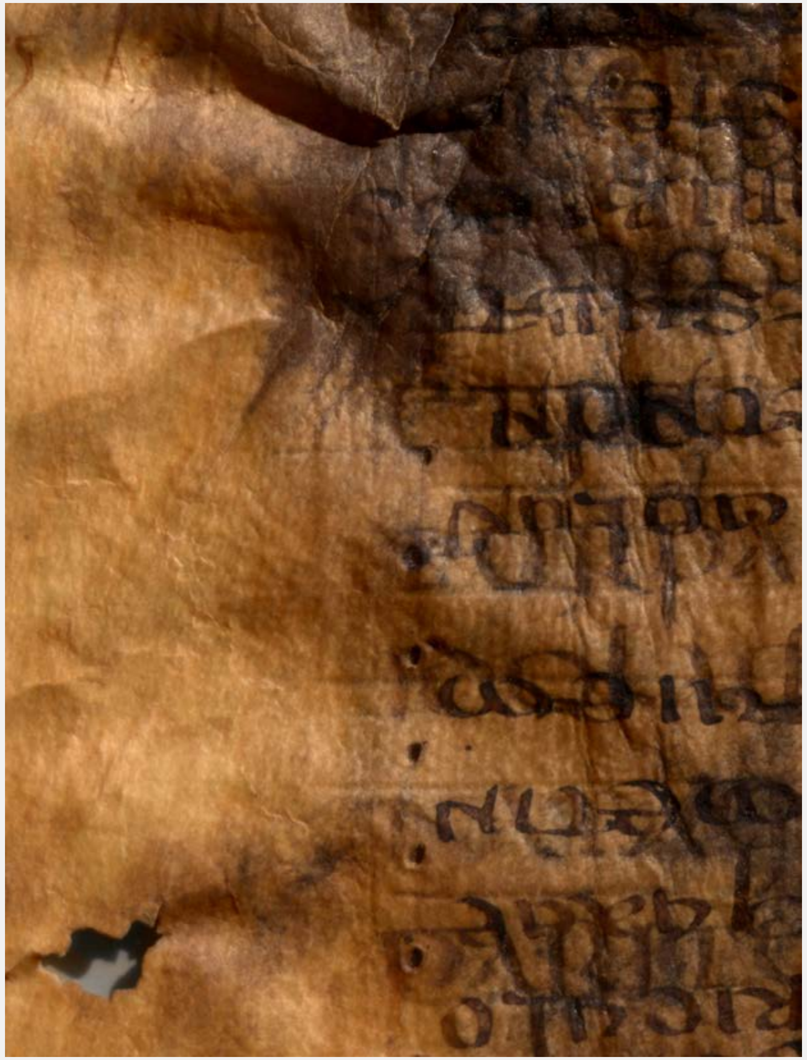
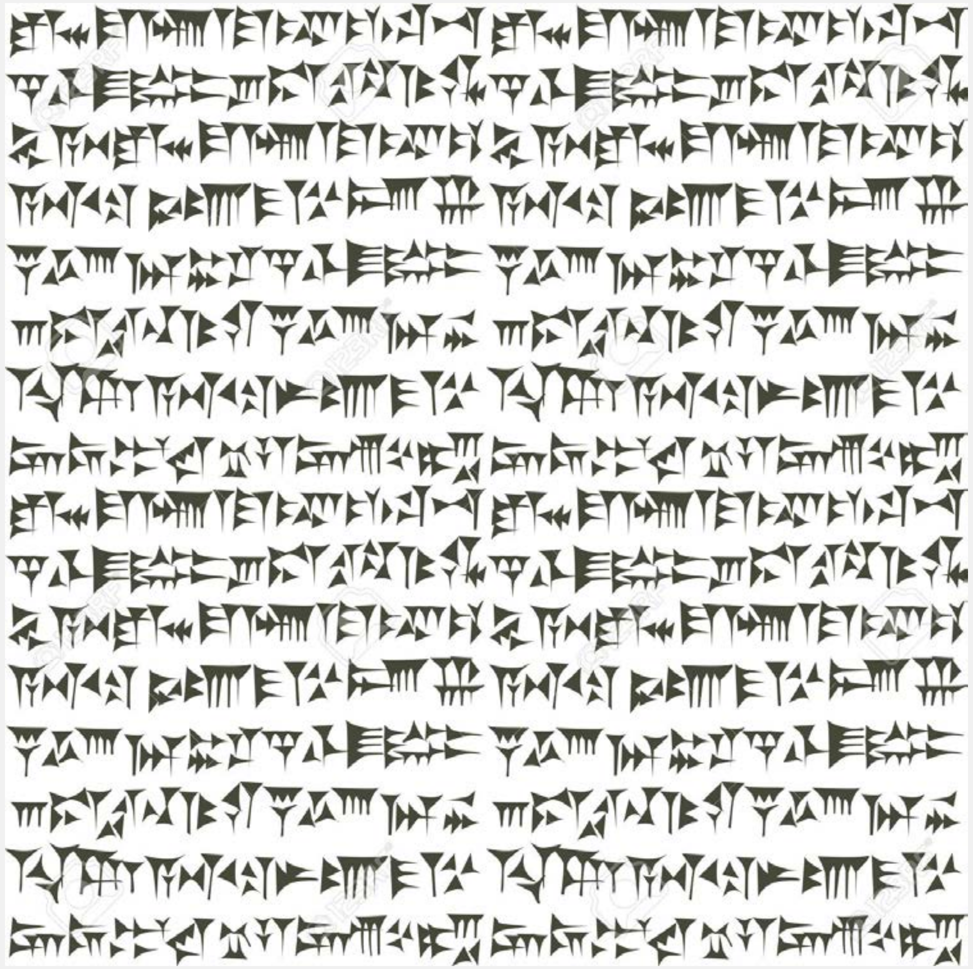


DIGITIZING TEXTURE OF CULTURAL HERITAGE OBJECTS

- Line drawings
- Raking light
- Laser scanning and photogrammetry
  - Distinguish structural boundary from texture
- Reflectance Transformation Imaging (RTI)



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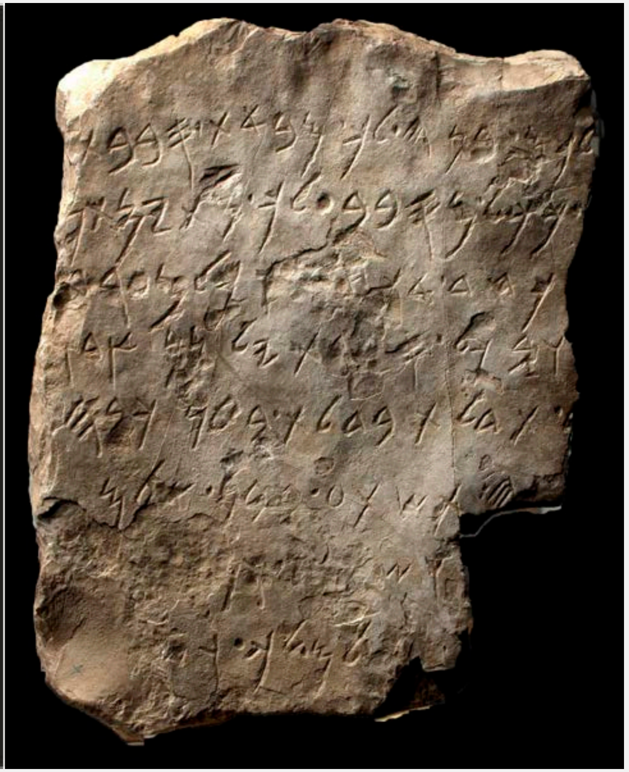

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RTI CAPTURE

- Object and camera remain in same position
- 35-60 raking light captures evenly distributed around a virtual hemisphere
- The radius should be consistent (for exposure settings) and as large as possible (for collimation)
- Lights can be mounted on a physical dome, a handheld flash, or a swinging arc

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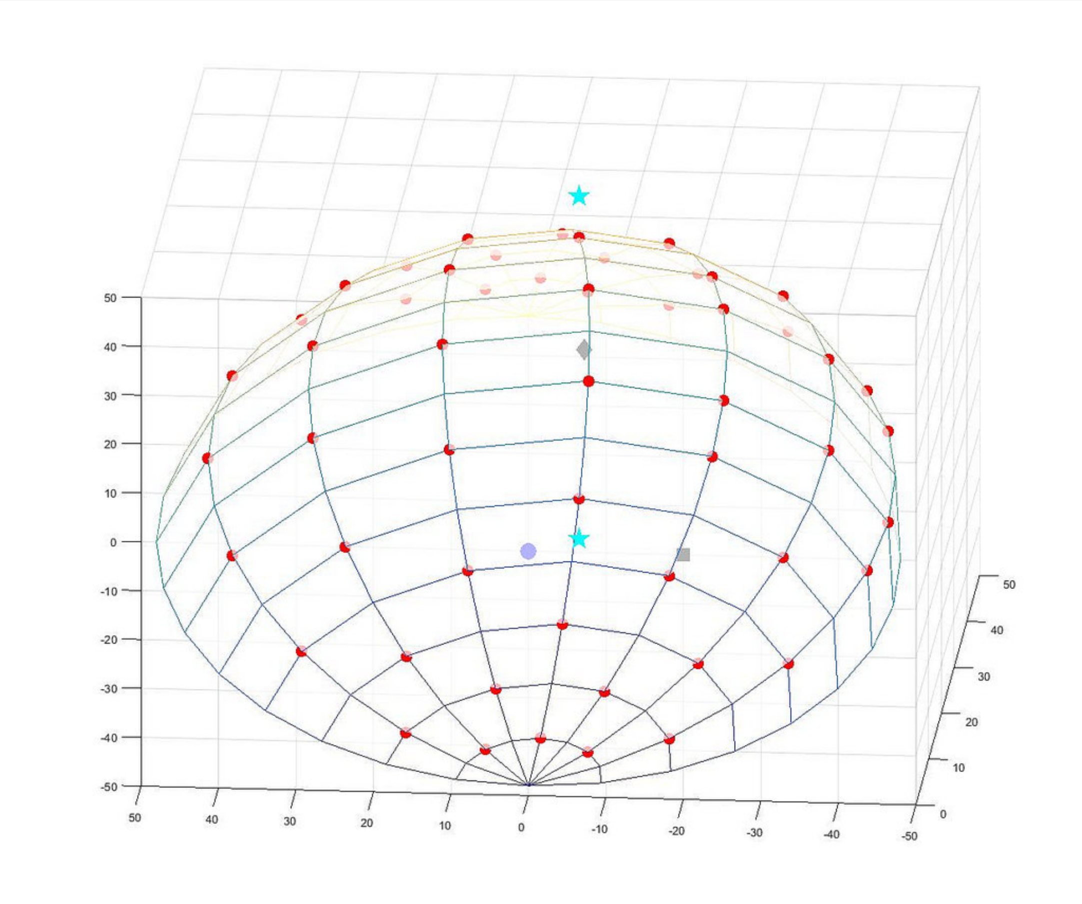

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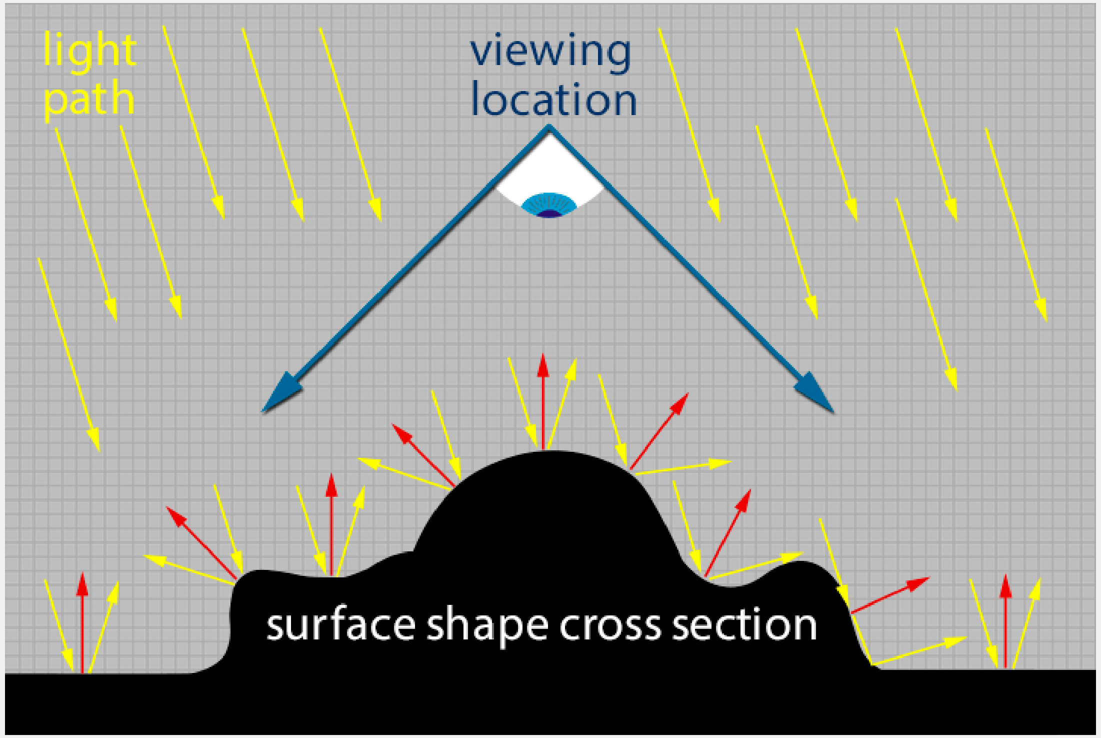

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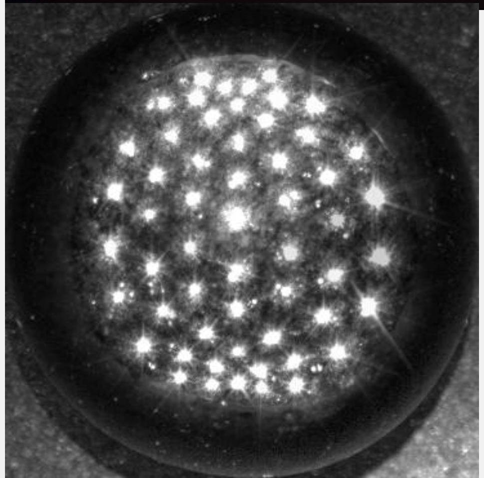
RTI PROCESSING

- The position of the light in each capture must be measured or calculated
  - Since the radius is constant the light position can be calculated from the position of the highlight on a reflective sphere placed in the object frame
- For each pixel, a formula is calculated to best fit the captured data
- The PTM and RTI files store the coefficients necessary to calculate the luminosity for a given light position



RTI PROCESSING

- The position of the light in each capture must be measured or calculated
- For each pixel, a formula is calculated to best fit the captured data
  - The luminance of the pixel as a function of the position of the light
  - Earlier method uses second-order bi-quadratic polynomials (PTM)
  - Later method uses third-order hemispherical harmonics (HSH)
- The PTM and RTI files store the coefficients necessary to calculate the luminosity for a given light position

$$C = a_0 L_u^2 + a_1 L_v^2 + a_2 L_u L_v + a_3 L_u + a_4 L_v + a_5$$

RTI PROCESSING

- The position of the light in each capture must be measured or calculated
- For each pixel, a formula is calculated to best fit the captured data

```
hsh_matrix[9*in->num_used+i] = 2*sqrt(35/M_PI)  * cos(3*phi)*pow((cos(theta) - pow(cos(theta),2)),(3/2));
hsh_matrix[10*in->num_used+i] = (sqrt(210/M_PI)  * cos(2*phi)*(-1 + 2*cos(theta))*(-cos(theta) + pow(cos(theta),2)));
hsh_matrix[11*in->num_used+i] = 2*sqrt(21/M_PI)  * cos(phi)*sqrt(cos(theta) - pow(cos(theta),2))*(1 - 5*cos(theta) + 5*pow(cos(theta),2));
hsh_matrix[12*in->num_used+i] = sqrt(7/(2*M_PI)) * (-1 + 12*cos(theta) - 30*pow(cos(theta),2) + 20*pow(cos(theta),3));
hsh_matrix[13*in->num_used+i] = 2*sqrt(21/M_PI)  * sqrt(cos(theta) - pow(cos(theta),2))*(1 - 5*cos(theta) + 5*pow(cos(theta),2))*sin(phi);
hsh_matrix[14*in->num_used+i] = (sqrt(210/M_PI)  * (-1 + 2*cos(theta))*(-cos(theta) + pow(cos(theta),2))*sin(2*phi));
hsh_matrix[15*in->num_used+i] = 2*sqrt(35/M_PI)  * pow((cos(theta) - pow(cos(theta),2)),(3/2))*sin(3*phi);
```

  - Later method uses third-order hemispherical harmonics (HSH)
- The PTM and RTI files store the coefficients necessary to calculate the luminosity for a given light position

RTI PROCESSING

- The position of the light in each capture must be measured or calculated
- For each pixel, a formula is calculated to best fit the captured data
- The PTM and RTI files store the coefficients necessary to calculate the luminosity for a given light position
  - Either for each of three color channels
  - Or once accompanied by Cb and Cr channels
  - Luminance at non-captured light positions can be extrapolated
  - Surface normal is easily derivable

$$C = a_0 L_u^2 + a_1 L_v^2 + a_2 L_u L_v + a_3 L_u + a_4 L_v + a_5$$

$$\mathbf{a_0^Y, a_1^Y, a_2^Y, a_3^Y, a_4^Y, a_5^Y, C_r, C_b}$$

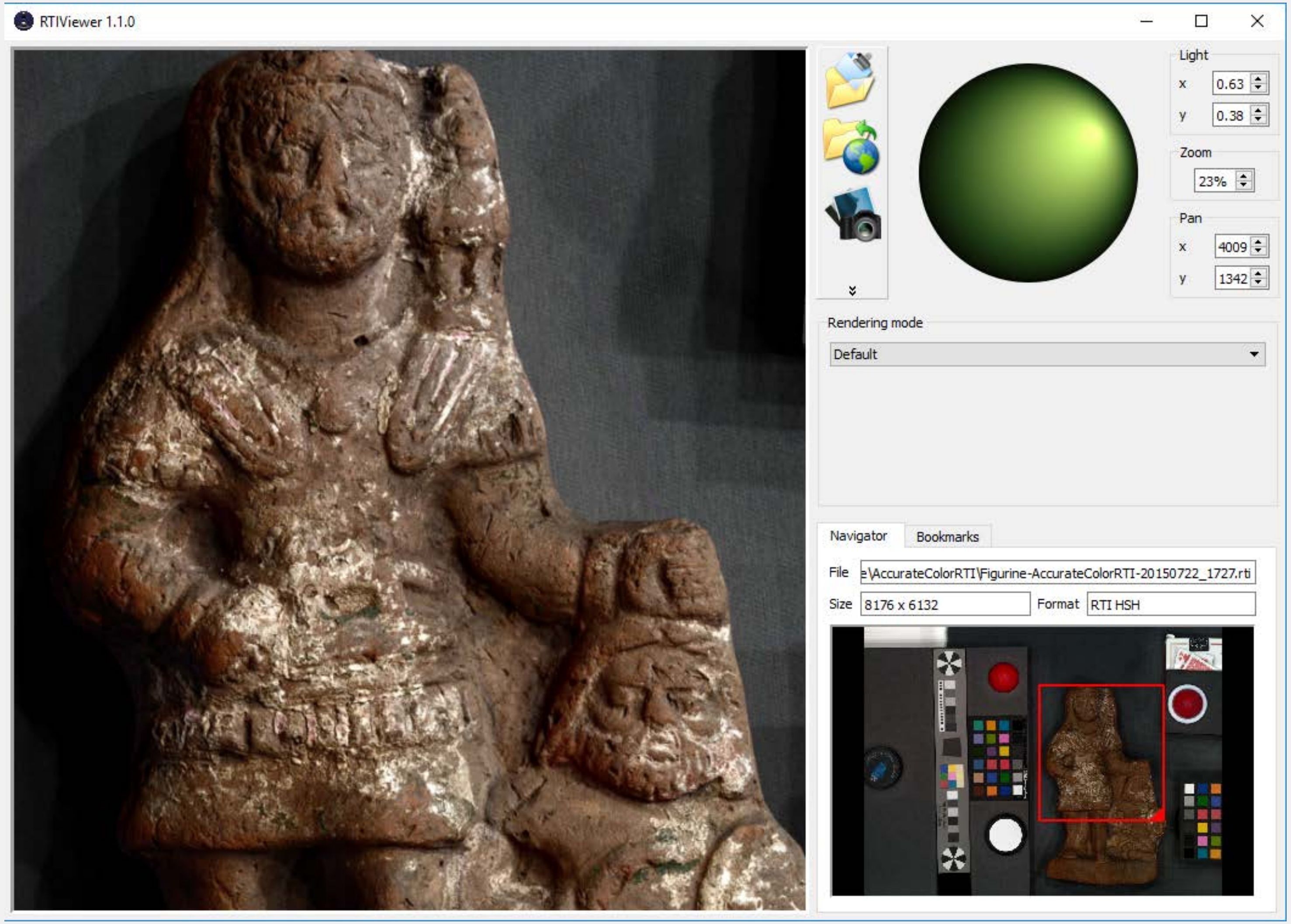
RTI PROCESSING

- The position of the light in each capture must be measured or calculated
- For each pixel, a formula is calculated to best fit the captured data
- The PTM and RTI files store the coefficients necessary to calculate the luminosity for a given light position
- Desiderata: 64-bit architecture, uncompressed input, more options for output, light position triangulation, evaluate discrete modal decomposition

```
* jpeglib.h
*
* Copyright (C) 1991-1998, Thomas G. Lane.
* Modified 2002-2009 by Guido Vollbeding.
* This file is part of the Independent JPEG Group's software.
* For conditions of distribution and use, see the accompanying README file.
*
* This file defines the application interface for the JPEG library.
* Most applications using the library need only include this file,
* and perhaps jerror.h if they want to know the exact error codes.
*/
```

RTI VIEWING

- Today
  - RTI Viewers
  - WebRTI using WebGL
- On the horizon
  - 3D engines
  - Virtual and augmented reality



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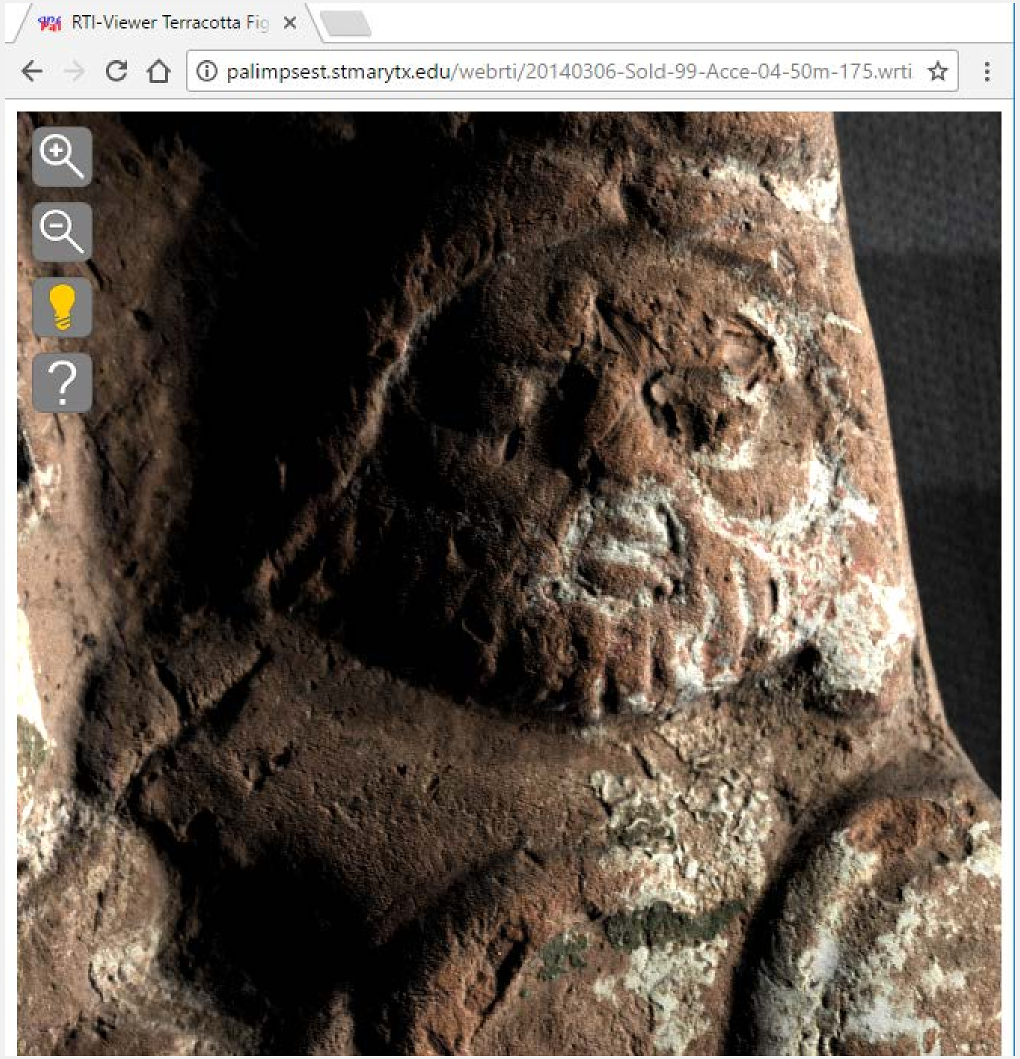

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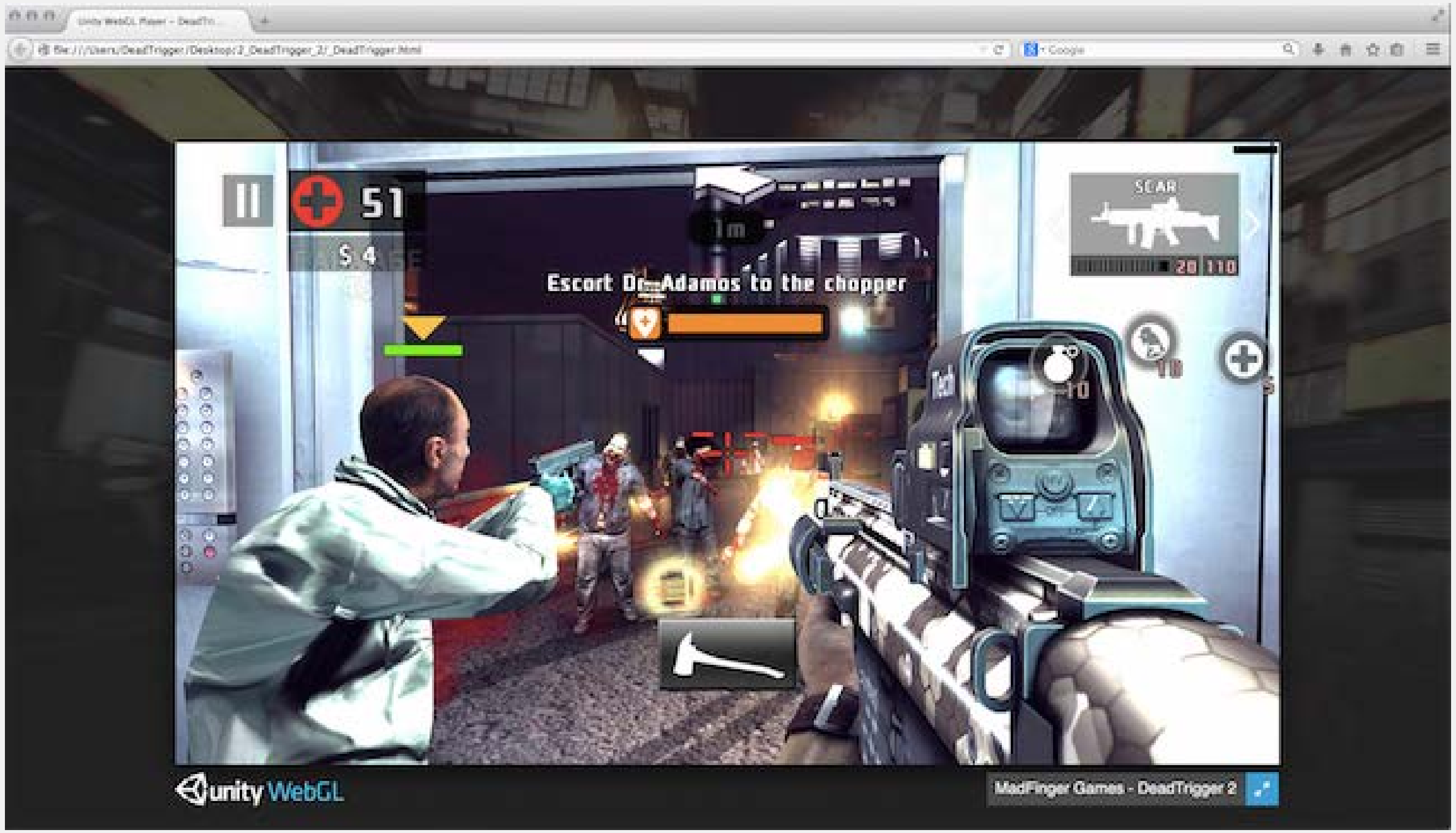

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SPECTRAL RTI

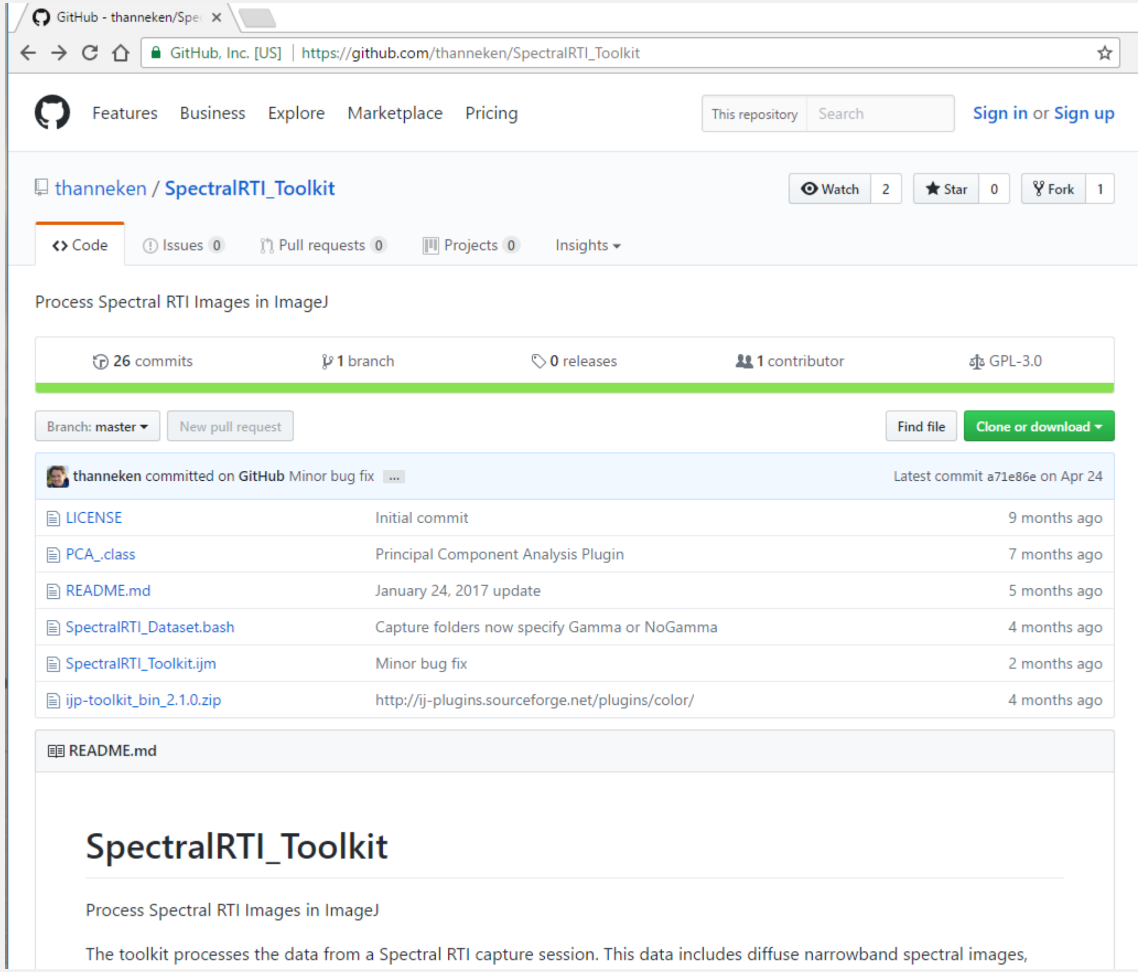
- Spectral imaging
  - Concerned with color (wavelengths in or near the visible light range of the electromagnetic spectrum)
  - Typically strives for diffuse illumination to minimize texture highlights and shadows
- RTI
  - Concerned with texture as an expression of luminance variation as a function of light position (glimmer, highlights, shadows)
  - Typically pays no more attention to color than the three color channels of a DSLR

SPECTRAL RTI

- Spectral imaging
  - Concerned with color
- RTI
  - Concerned with luminance
- The distinction and complementarity of luminance and color in color spaces such as YCbCr and L*A*B*

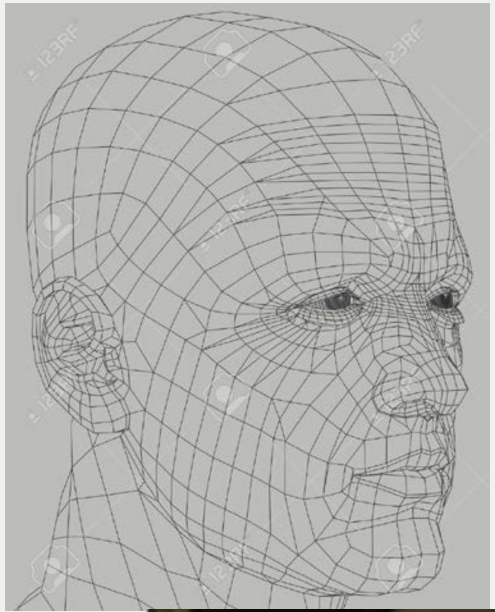
SPECTRAL RTI

- Spectral imaging
  - Concerned with color
- RTI
  - Concerned with luminance
- The distinction and complementarity of luminance and color in color spaces such as YCbCr and L*A*B*
- The currently available Spectral RTI Toolkit combines luminance and chrominance before HSH fitting
- Future potential to direct color and luminance function data directly to layers in WebGL



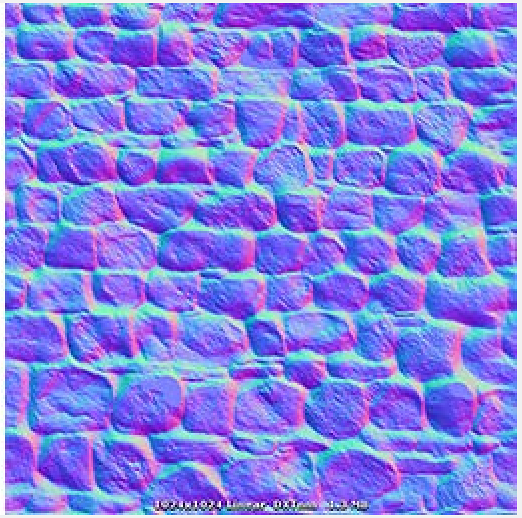
TEXTURE AND 3D

- Texture mapping is part of 3D
- Structural boundaries
  - Captured with laser scanning and photogrammetry
  - Processed as point clouds and polygon wire frames
- Surface texture
  - The appearance of a pixel on the surface of any one of those polygons as a function of ambient light
  - Primitive 3D used bare wire frame, solid colors, gradient shaders, or simple bitmaps for surfaces
  - Today's 3D uses bump mapping, surface normal mapping, specular mapping, occlusion mapping
  - Finer detail than polygons
  - Faster / less processing intensive than more polygons



TEXTURE AND 3D

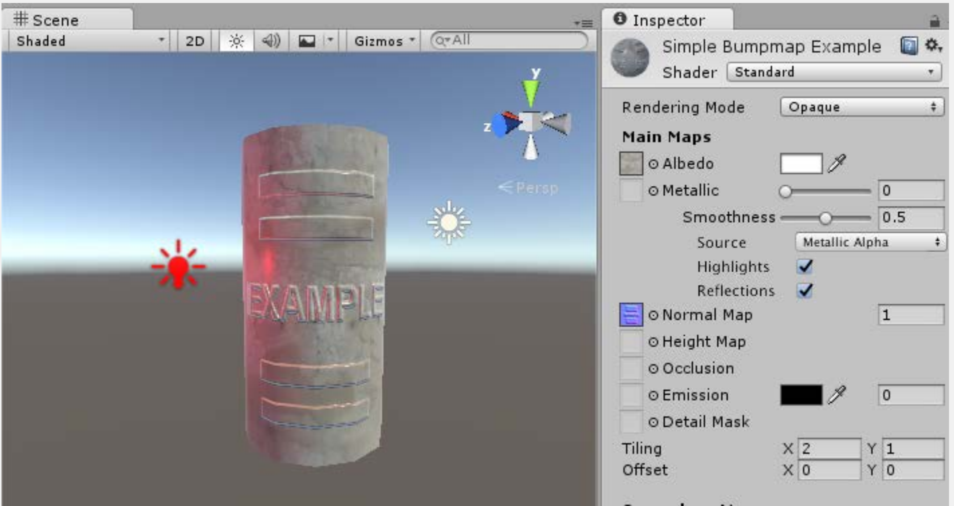
- Texture mapping is part of 3D
- Structural boundaries
- Surface texture
- The integration of RTI captured texture maps into 3D models has not happened yet
  - Polynomial Texture Mapping and RTI began at HP Labs with 3D in mind
  - In the 3D world, most texture maps are not captured
  - In the RTI world, texture maps are not assigned to polygons in larger 3D models

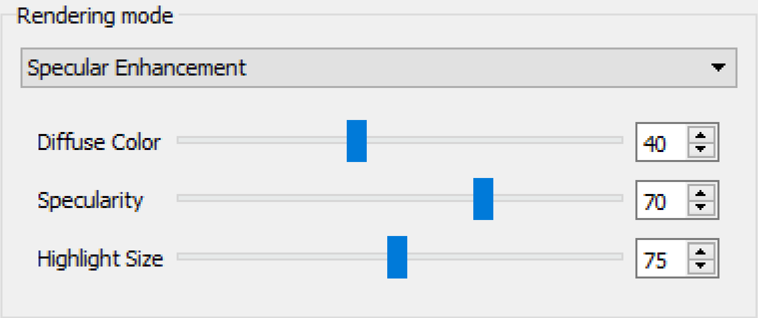


TEXTURE AND 3D

- The language of 3D (Unity engine)
  - Albedo
  - Specular
    or metallic highlights and reflections
  - Surface normal
  - Occlusion / transparency
  - Emission

- The language of Spectral RTI
  - Diffuse color
  - Specular
  - Surface normal
  - Transmissive illumination captures
  - Fluorescence (roughly)





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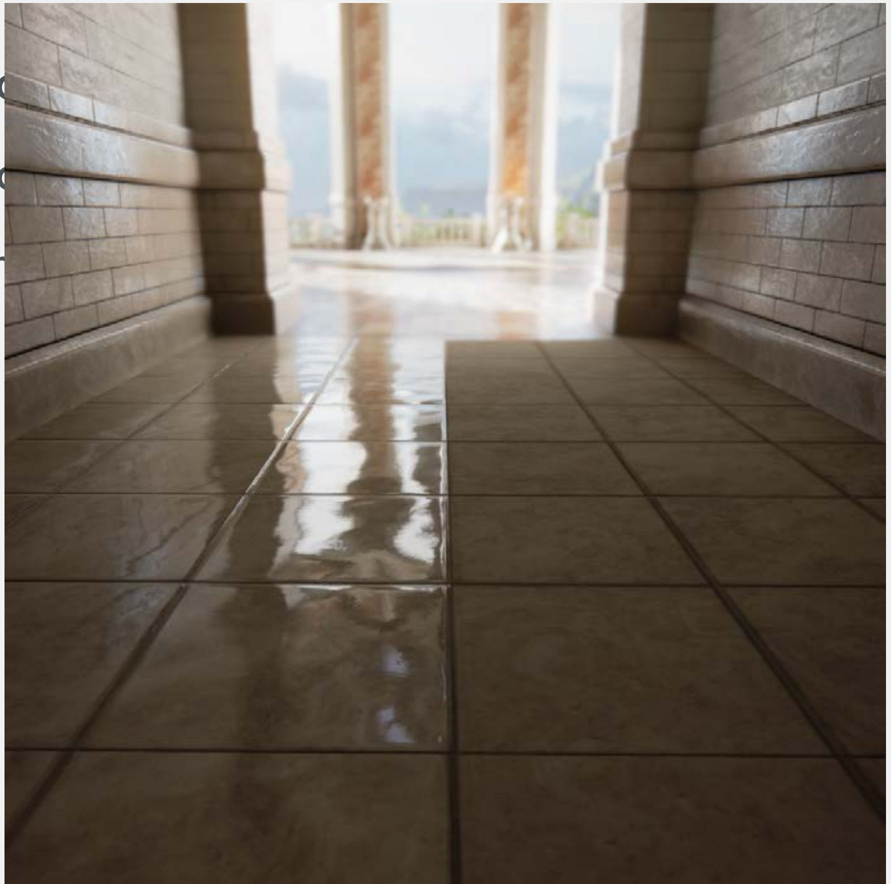

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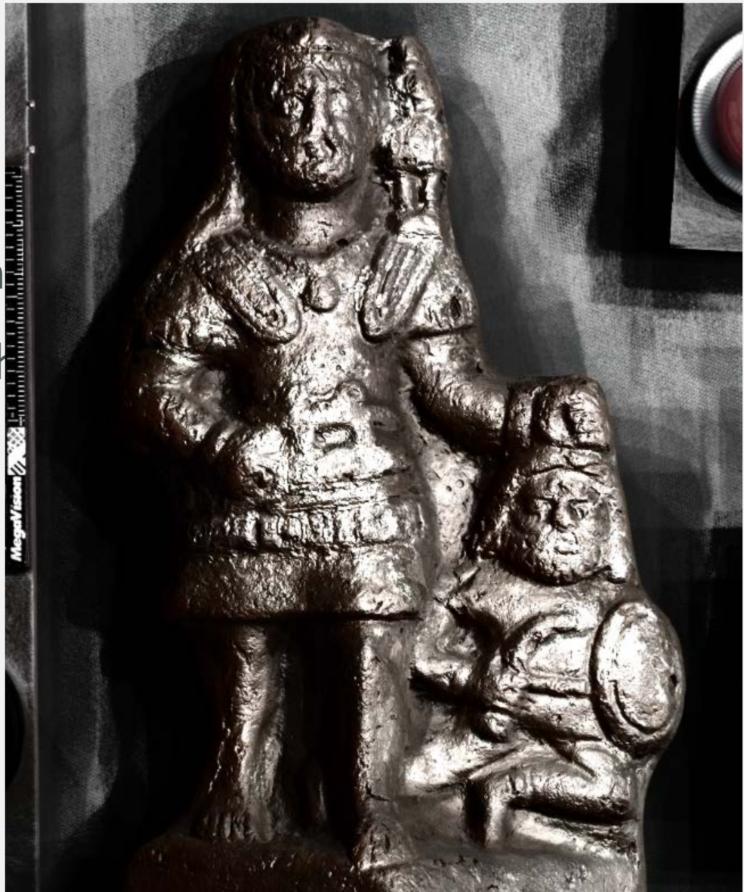

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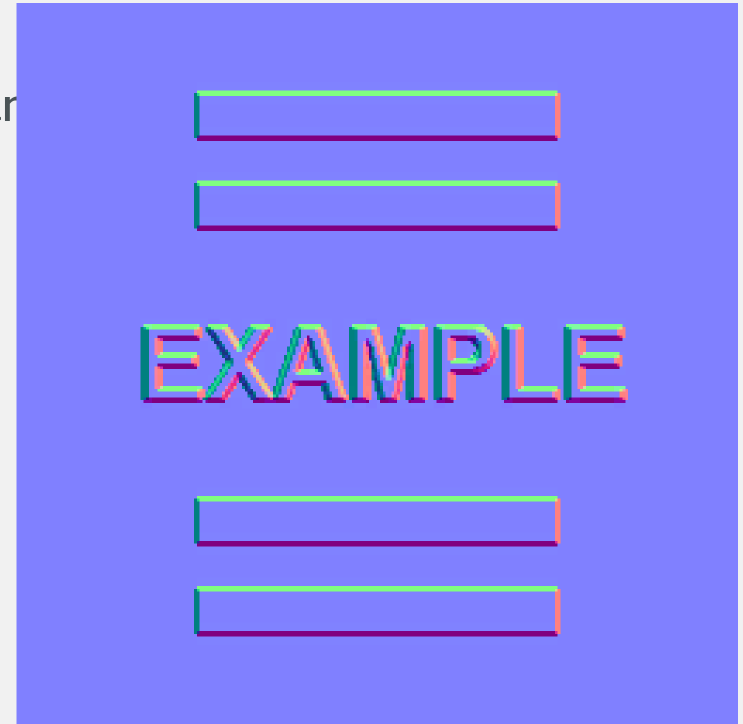

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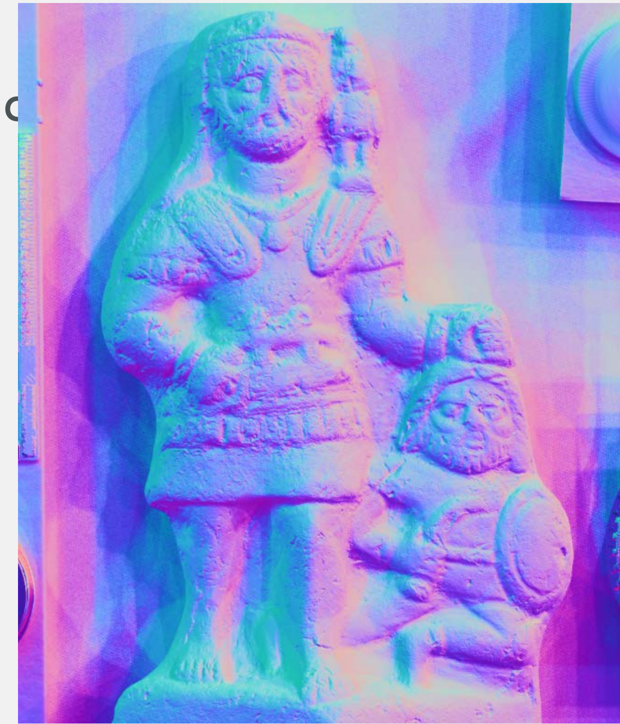

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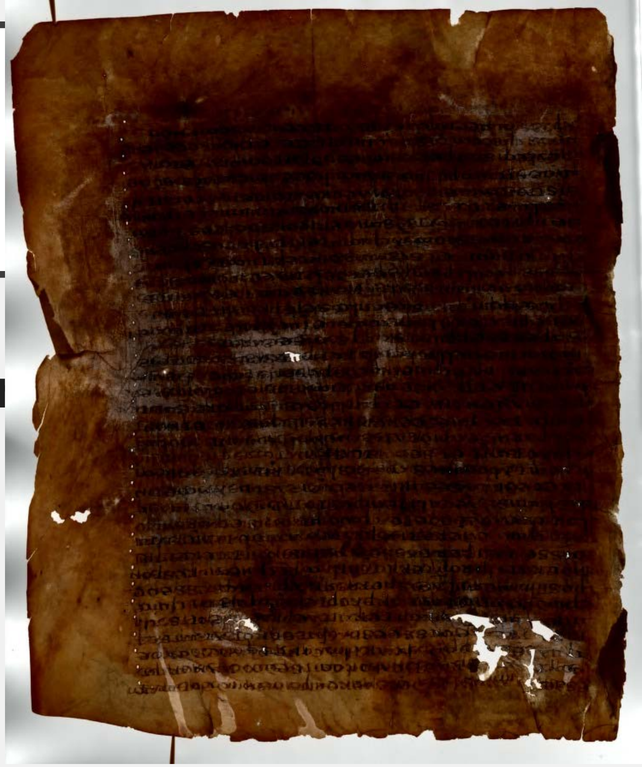

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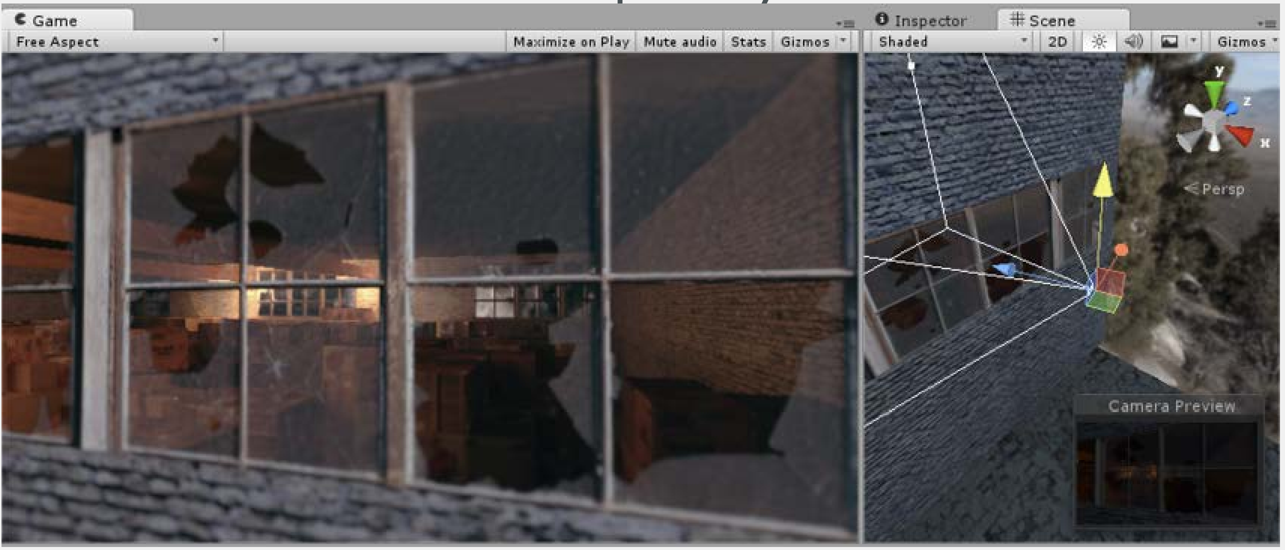

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CULTURAL HERITAGE BENEFITS

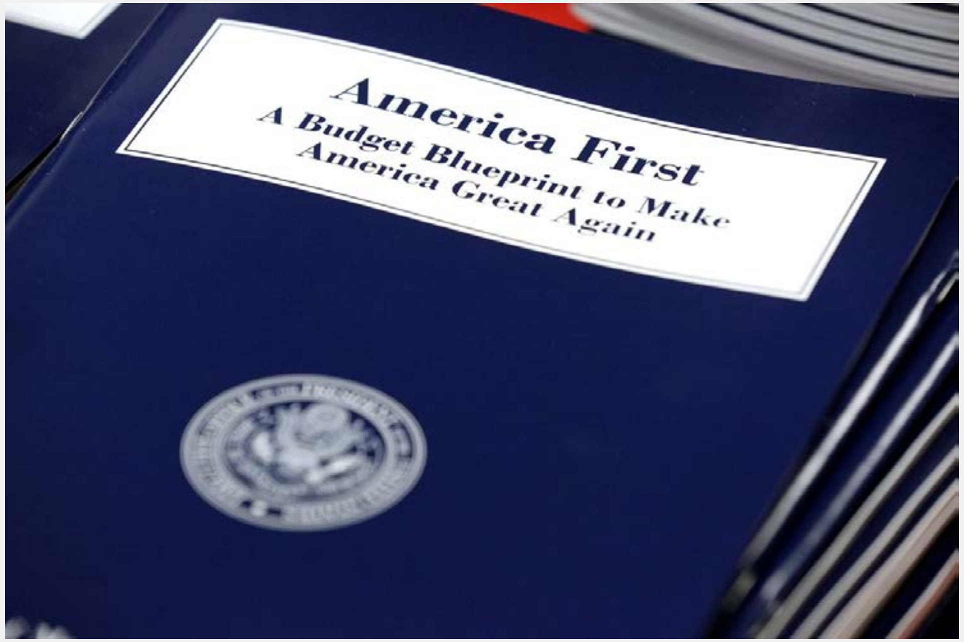
- In a virtual reality environment the entire user interface could have intuitive equivalents
  - Scholars could "hold the folio up to the light" rather than select the transmissive light source layer
  - Scholars could "flip the page" to distinguish show through rather than load the corresponding recto or verso
  - Teachers could point to features with a virtual hand following the movements of a physical hand rather than a mouse pointer
- Students could have a more natural experience of primary sources
- Teachers could situate a surface in context
  - An inscription on a monument
  - A folio in a codex
  - An icon in a chapel
- Exhibitors could interpret artifacts online or with a kiosk in a museum
  - More interactive than a coin with a mirror behind it
  - More interactive than a codex open to one folio

ECONOMIC CONSIDERATIONS

- Can cultural heritage projects afford this?
- Who (with money) cares?

ECONOMIC CONSIDERATIONS

- Can cultural heritage projects afford this?
  - RTI technology today is mostly in an (underfunded) cultural heritage silo
  - It will cost less to build a bridge to generalized technologies than to update and improve specialized tools
  - WebGL and Unity engine are free, ubiquitous, maintained, and growing
- Who (with money) cares?

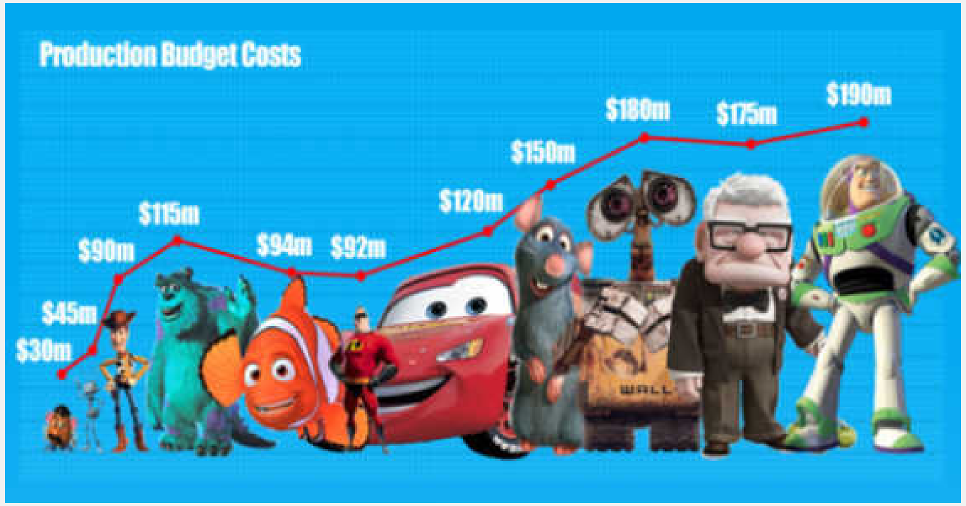


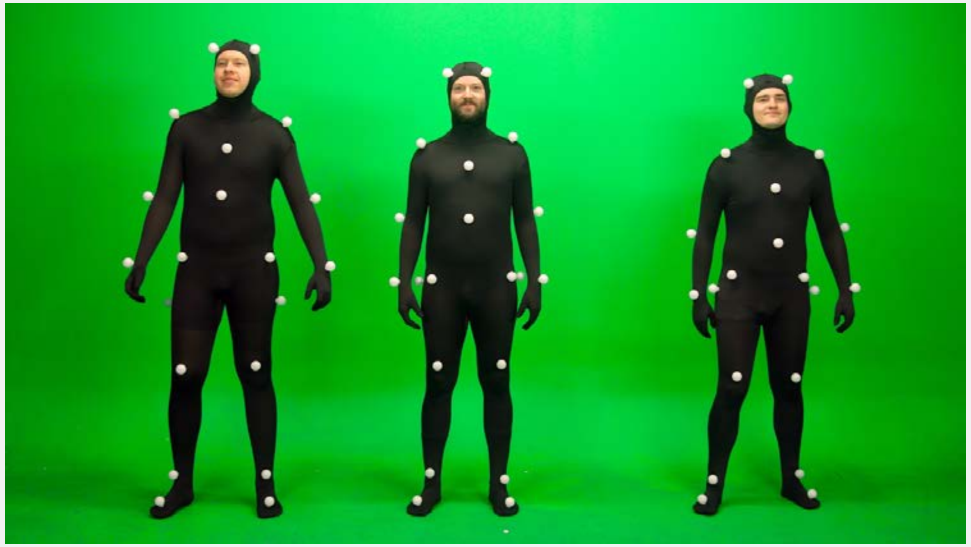
ECONOMIC CONSIDERATIONS

- Can cultural heritage projects afford this?
- Who (with money) cares?
  - Gaming
    - Generally as a driver of underlying hardware and software engines
    - Virtual reality trying to be more real
    - Cf. the Voynich manuscript in Assassin's Creed
  - Movies and television
  - Healthcare

ECONOMIC CONSIDERATIONS

- Can cultural heritage projects afford this?
- Who (with money) cares?
  - Gaming
  - Movies and television
    - Budget and number of people credited in a Pixar movie
    - Compare motion capture to captured surface texture
  - Healthcare





ECONOMIC CONSIDERATIONS

- Can cultural heritage projects afford this?
- Who (with money) cares?
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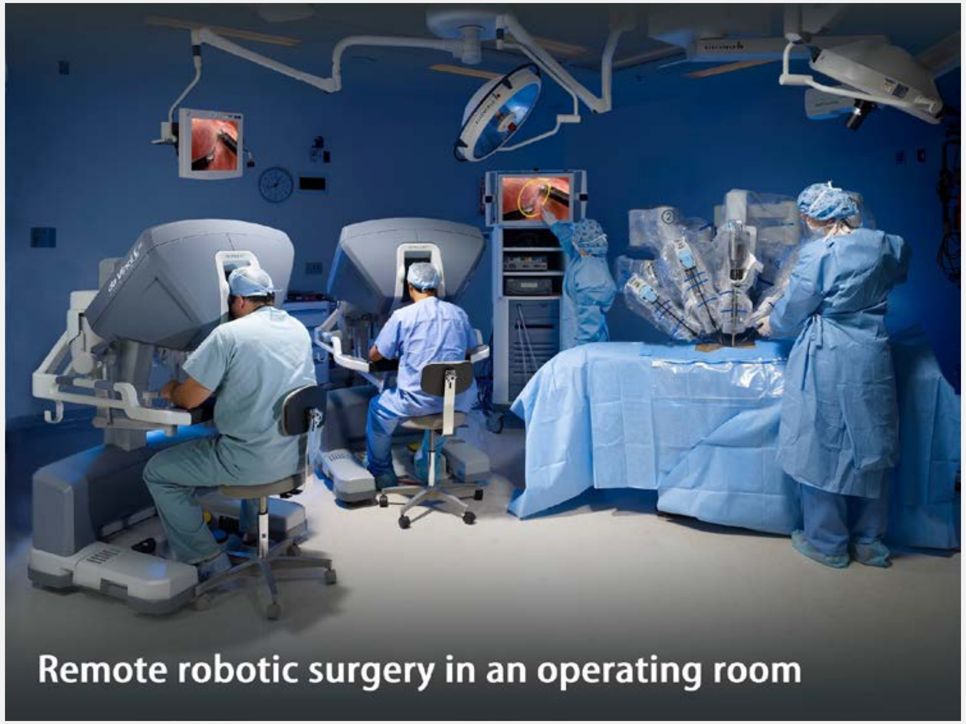
  - Movies and television
  - Healthcare
    - Texture of skin conditions, wounds, infections could be compared across time
    - And across geography when medical professionals are not available locally



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