Visualisation of “Real” Objects & Environments

Visualisation – Lecture 15

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Example : object capture & visualisation

- Capture **real world objects** into a **computer based representation**
  - **process and visualise** them as **3D data**

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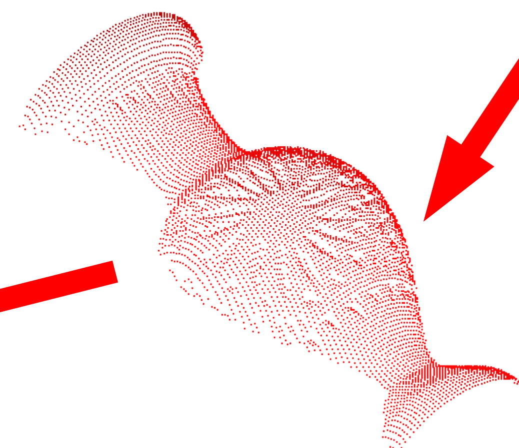
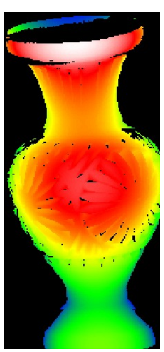
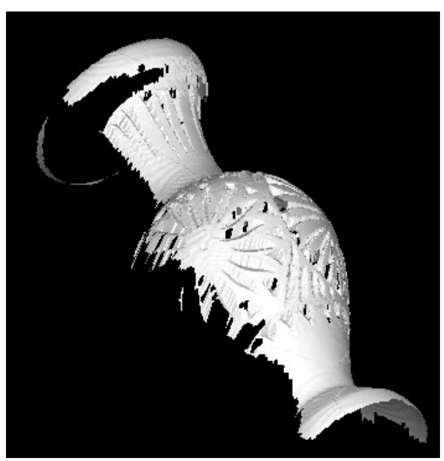
202.0000000000 -221.0050048828 -170.1450042725
202.5000000000 -220.5050048828 -169.8619995117
202.5000000000 -221.0050048828 -169.7920074463
209.0000000000 -296.5029907227 -165.5749969482
.....
```

Raw 3D points from a range scanner



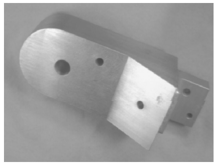
Projected 3D point cloud

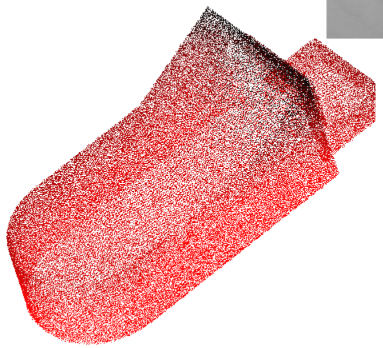




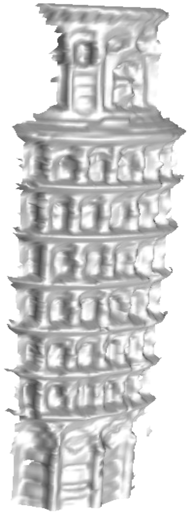
Triangulated 3D surface + associated depth colouring

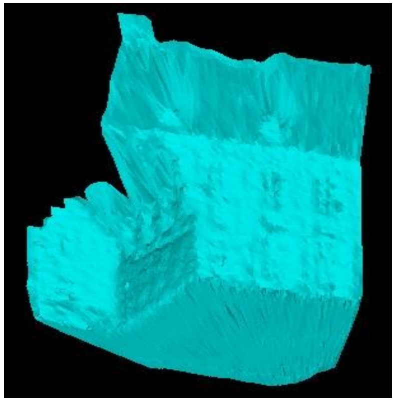
Motivation

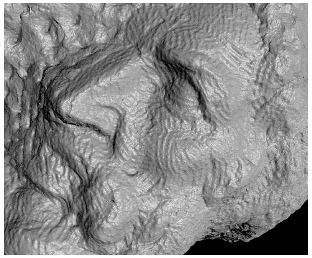


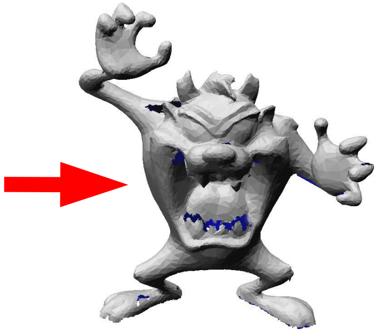


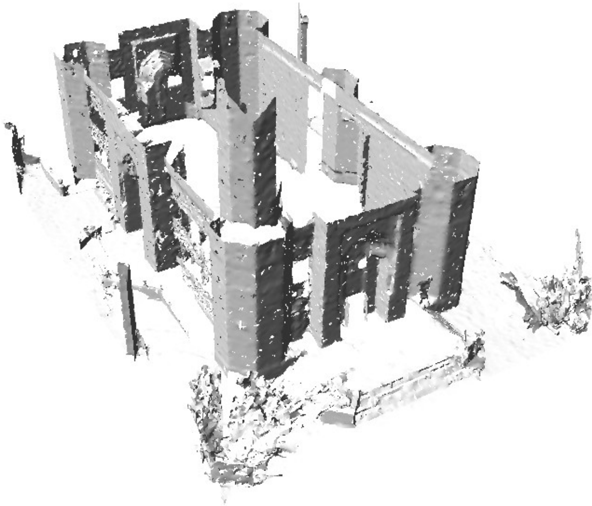
- Analysis
  - structural
  - visual inspection



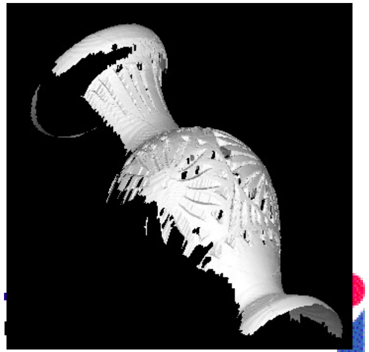








- Virtual Reality
  - games / movies
  - digital archiving of 3D objects

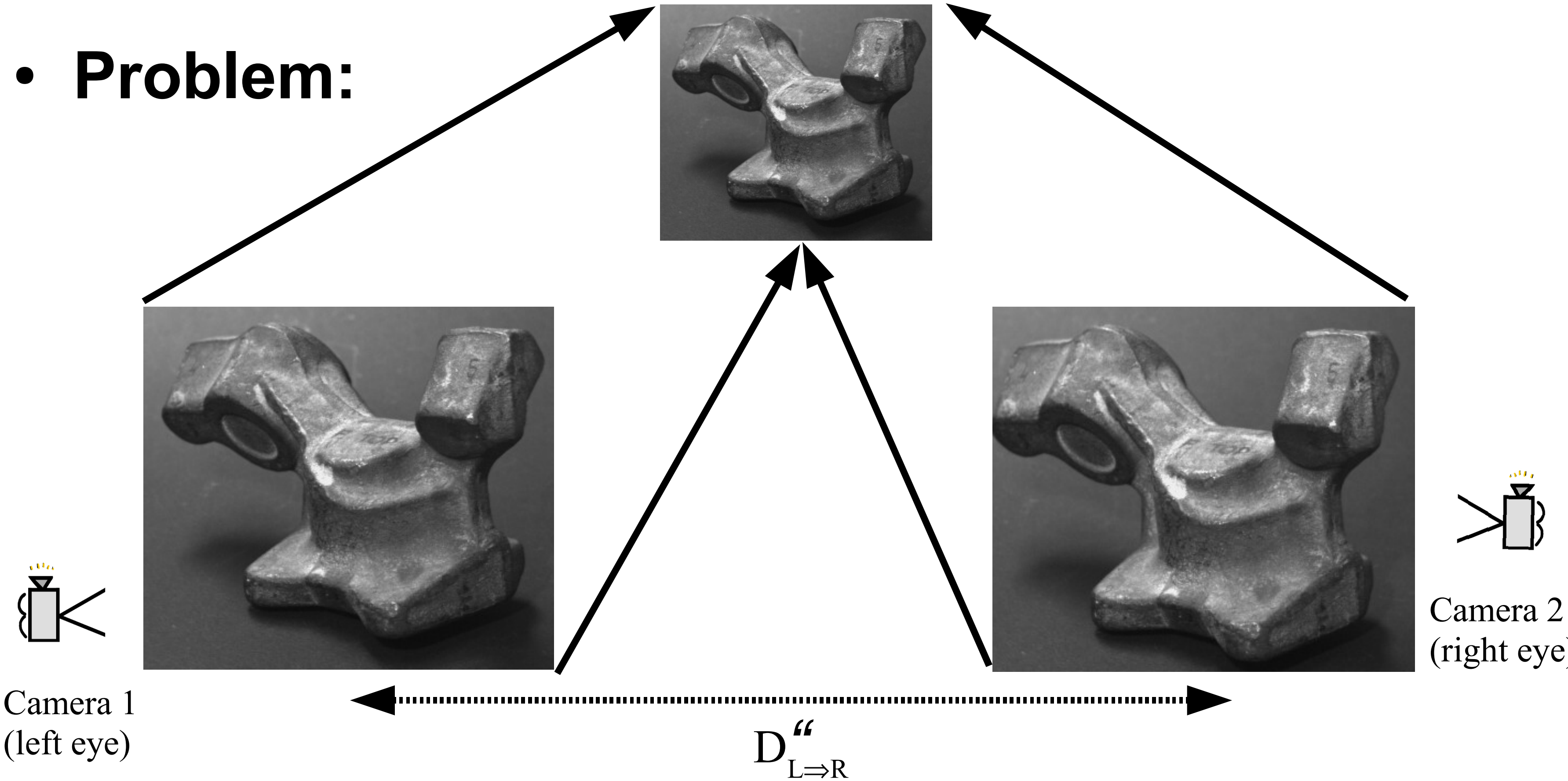


Capture Pipeline : 3D surfaces

- **Calibrate** position of **3D sensor** *(camera / scanner)*
  - finding out the location and orientation of the sensor/cameras
- **Recover distance measurements** from sensors (camera/scanner) to surfaces
  - Computing the depth of objects/environment surfaces from the sensors
- **Processing** of 3D data: registration, triangulation, rendering

3D Capture : Stereo Vision

- **Problem:**



Given two 2D images of an object, how can we reconstruct 3D awareness of it?"

Stereo Vision : 3 key stages

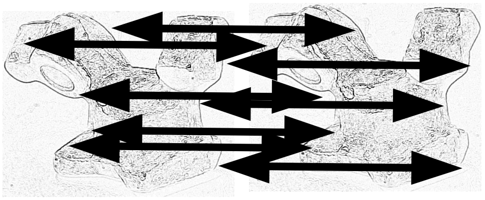
1) **Feature Identification**

identify image features in each image

2) **Correspondence**

Matching: find a set of feature correspondences

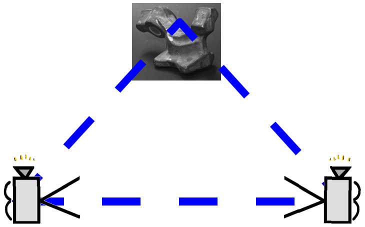
(left image ⇔ right image)



3) **Triangulation**

triangulate from known camera positions

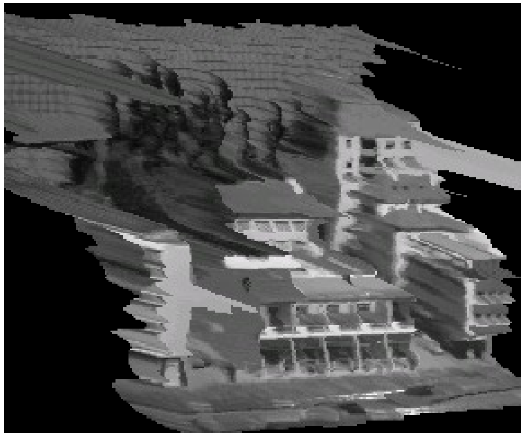
recover 3D depth information



Result : Stereo Vision

Input : Image x 2

Result :
depth map representation



Result : novel view
(point cloud representation)

[Matthies, Szeliski, Kanade'88]

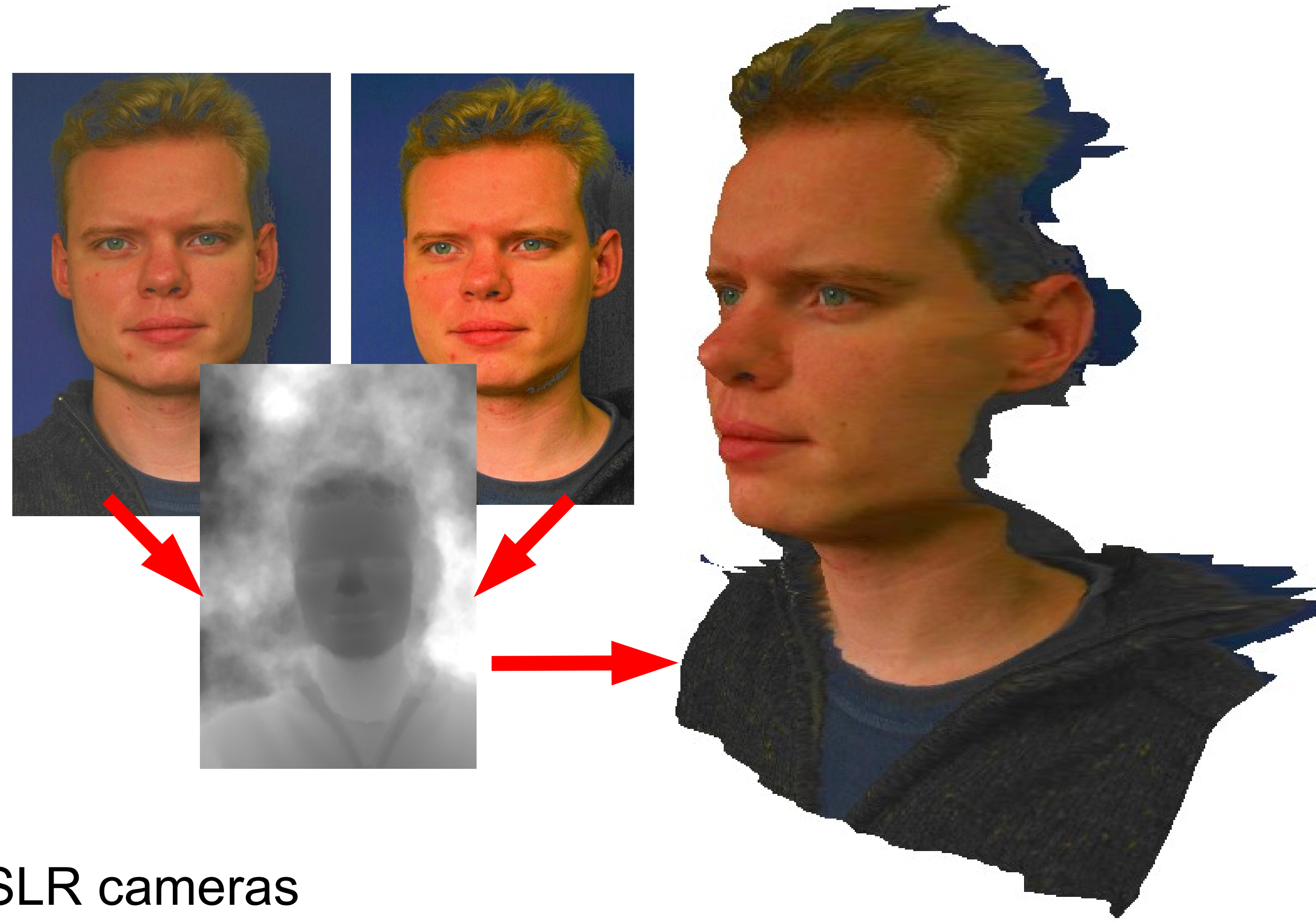
- **Result** : depth map (2D structured grid)
  - knowledge of 3D depth and colour (from input) in each cell
- **Problems** : poor matches = poor 3D information

  e.g. right hand side of example

Stereo Vision

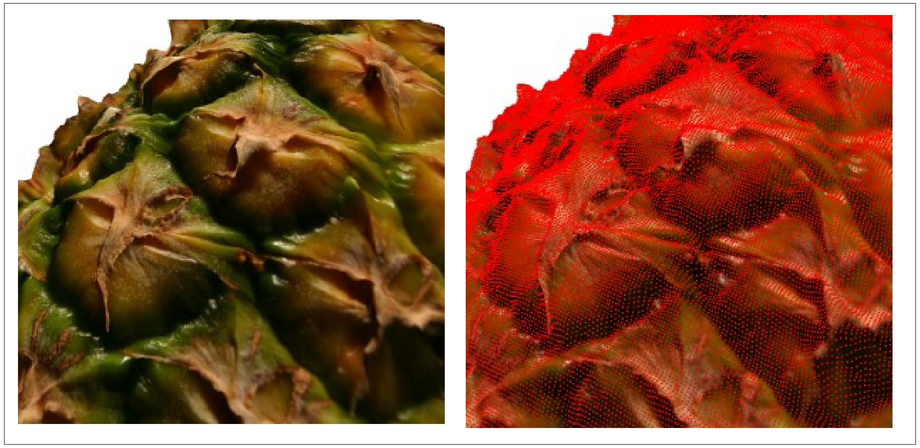
- Passive technique
- Advantages
  - uses only **image cameras** : no expensive sensors
- Limitations
  - **accurate prior calibration** of cameras required
  - fails on textureless surfaces
    - lighting affects images (e.g. specular highlights)
    - Produces errors
  - results : often sparse incomplete surfaces

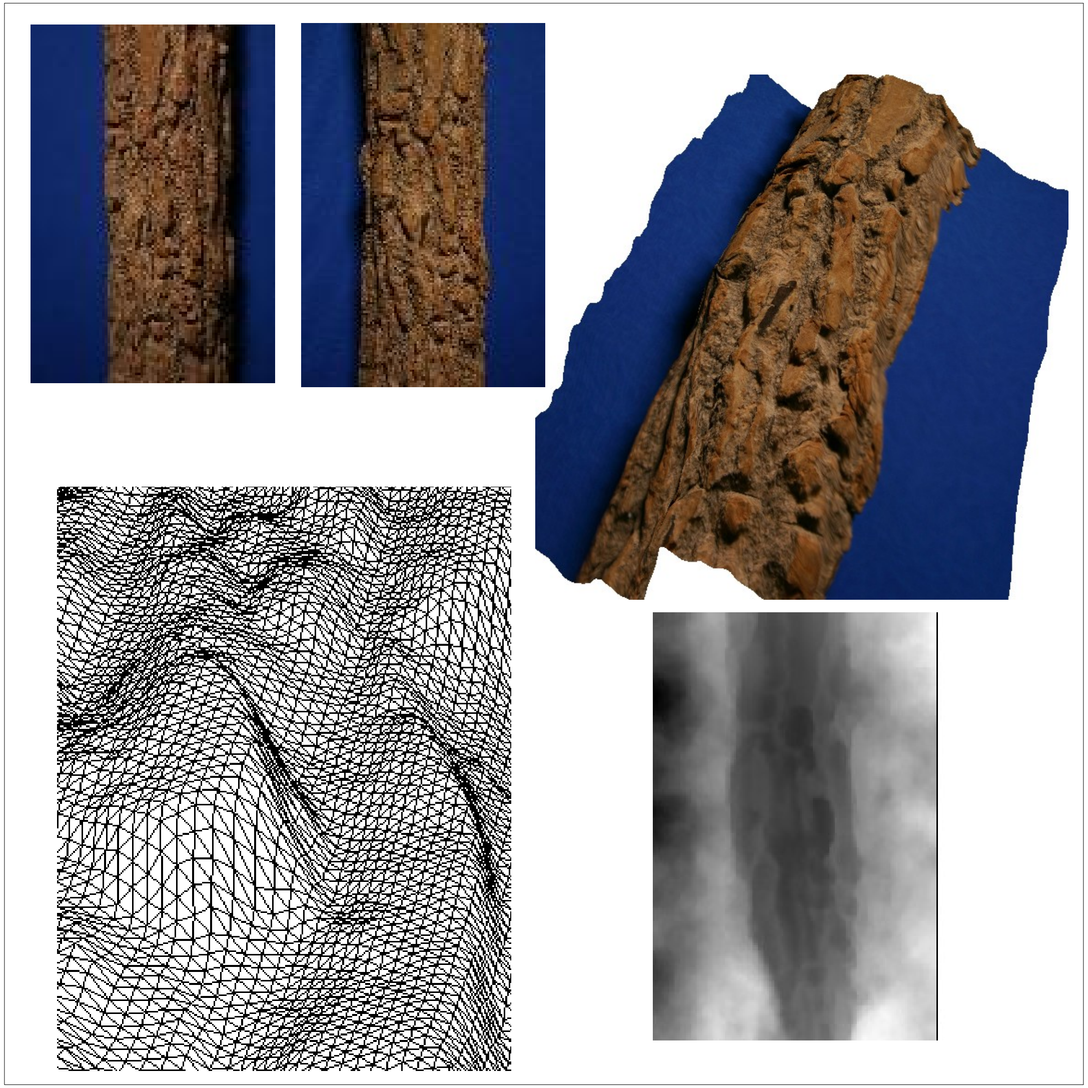
Commercial System : 3D face capture



- 2 x 6 mega-pixel digital SLR cameras
- Commercial 3D stereo software (http://www.di3d.com/)
  - *Results : 6 mega-pixel depth map / VRML 3D surface mesh model*

Example : 3D objects / closeups

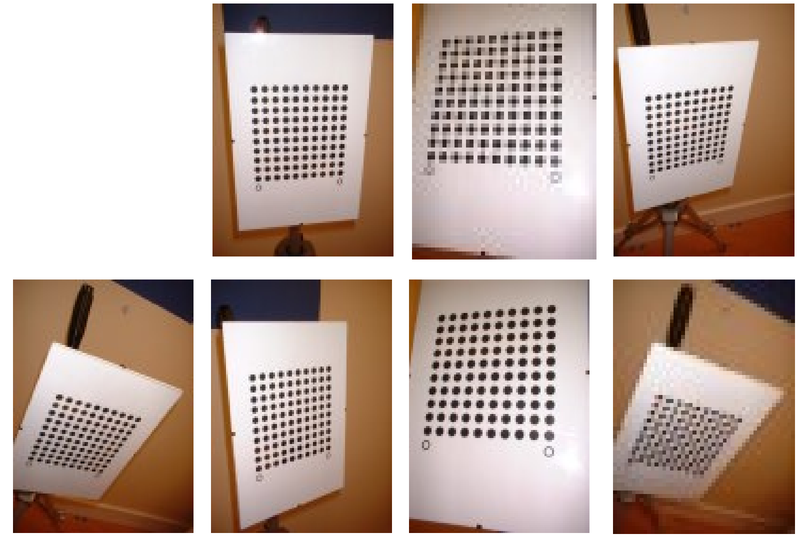




http://www.di3d.com/

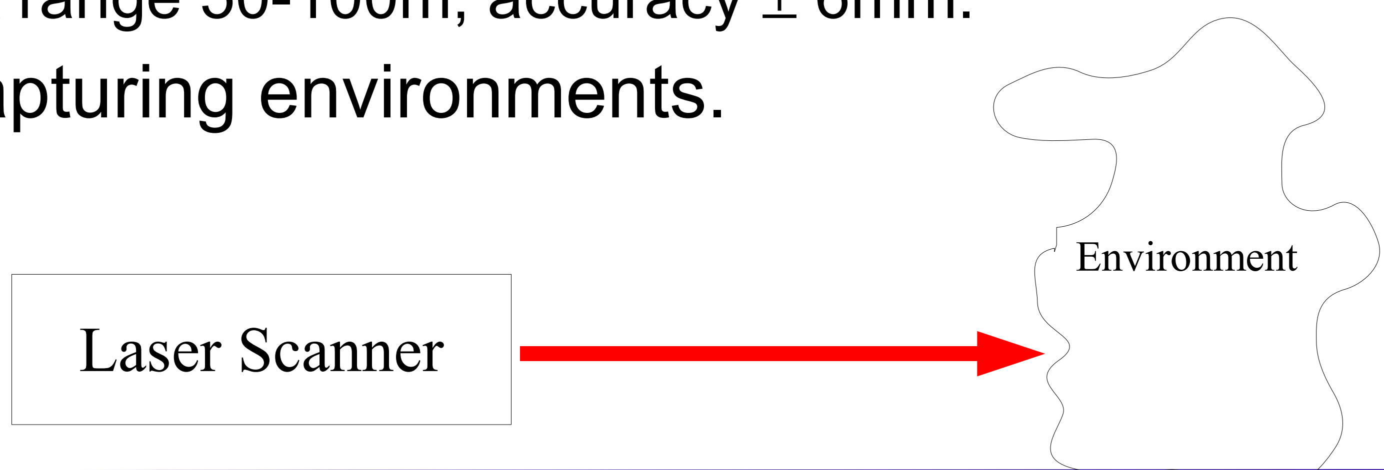
Stereo : Calibration Required

- Need to know **accurate camera positions**
  - Find out the location/orientation of the camera by checking how a fixed pattern appears in the image



3D capture : laser range scanning

- **Active depth sensing** using laser beam signal
  - **direct, accurate 3D** scene information
  - Measures time taken for a pulse of laser light to return to the scanner.
  - $d = ct/2$ c: speed of light, d : distance, t: time
  - Accurate over longer ranges.
    - Acuity Research, max range 13m, accuracy ± 2mm
    - Cyra, max range 50-100m, accuracy ± 6mm.
  - Good for capturing environments.

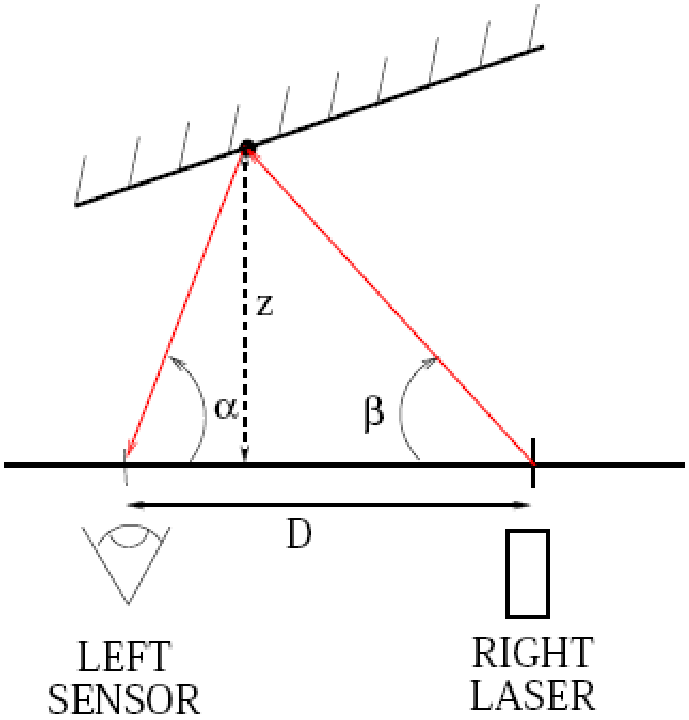


3D capture : laser range scanning

- **Limitations**
  - hidden surfaces
  - dark/shiny objects do not scan well
  - expensive hardware
  - The error grows as the distance is shorter

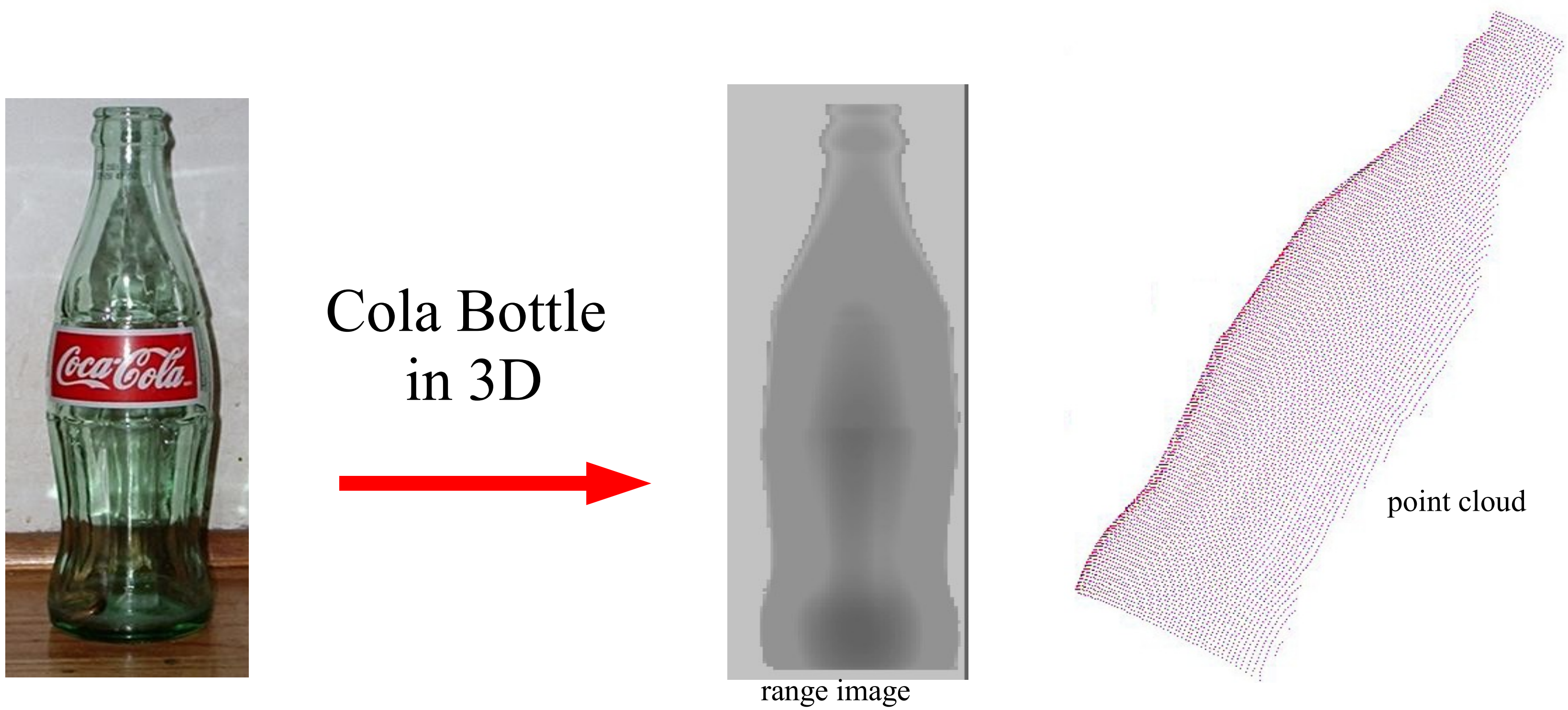
Laser Scanning Technologies - 2

- **Triangulation** based range sensor
  - distance measured via optical triangulation over a known baseline D
  - depth, z, measured as $z = f(\alpha, \beta, D)$
    - Very accurate
    - The capturing range is only meters
  - Light beam : usually laser
    - hence ***"laser range scanning"***
    - bright, single frequency
    - use optical filter to eliminate other light

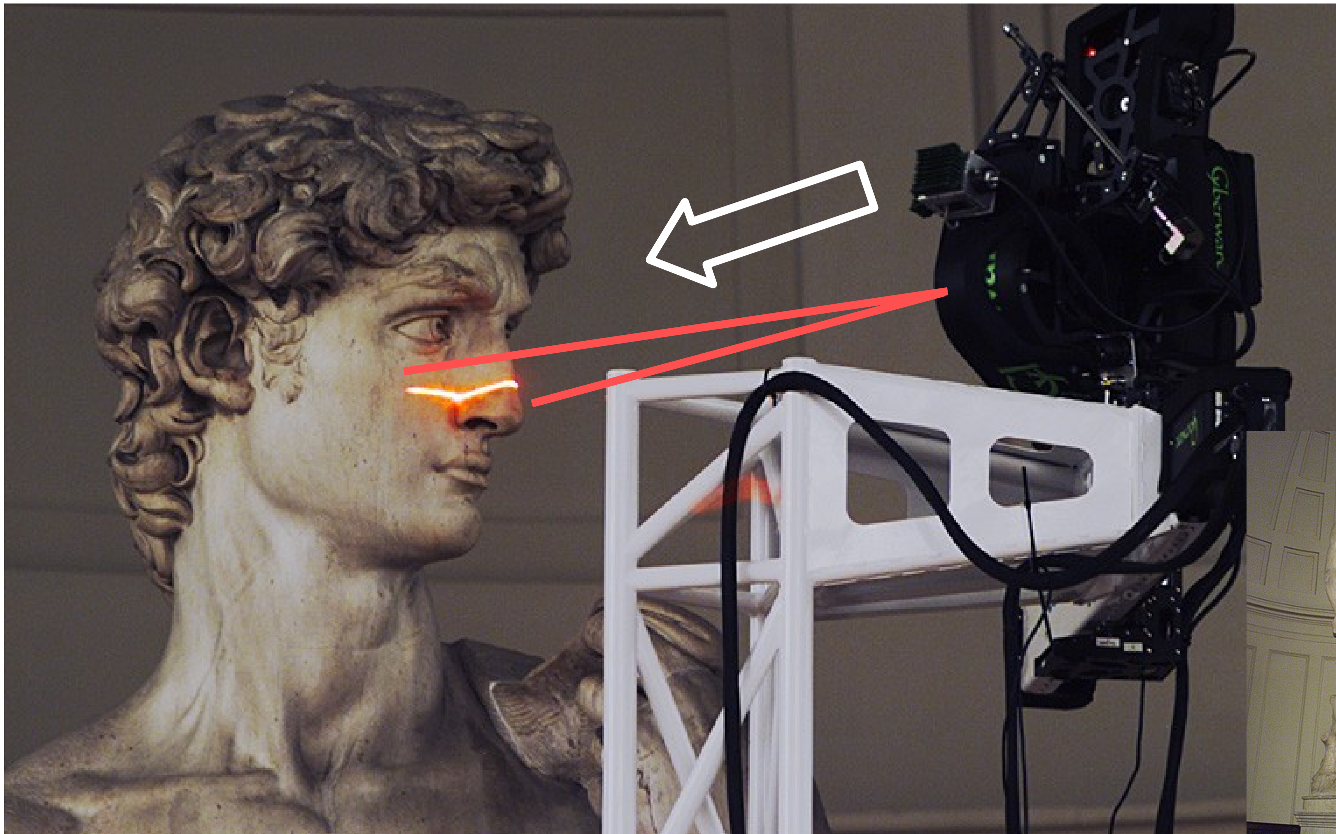


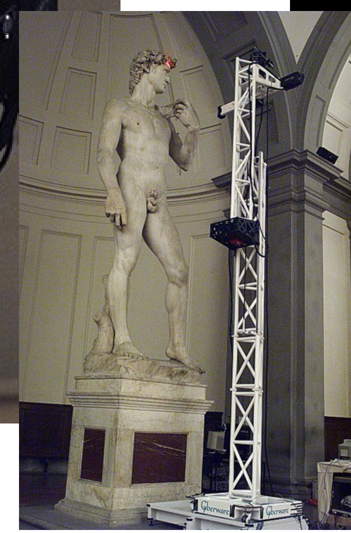
3D Data Representation

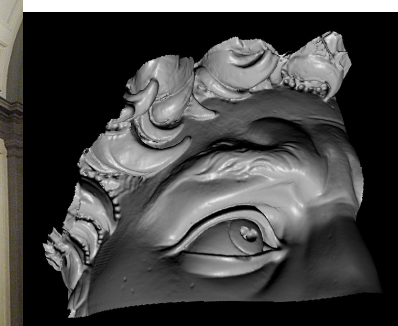
- 3D **Data Representation**
  - **2D grid** of depth values (**range image** representation)
  - **OR: 3D unstructured points** (**point cloud** representation)

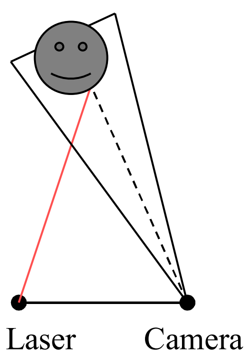


Example : Digital Michaelangelo





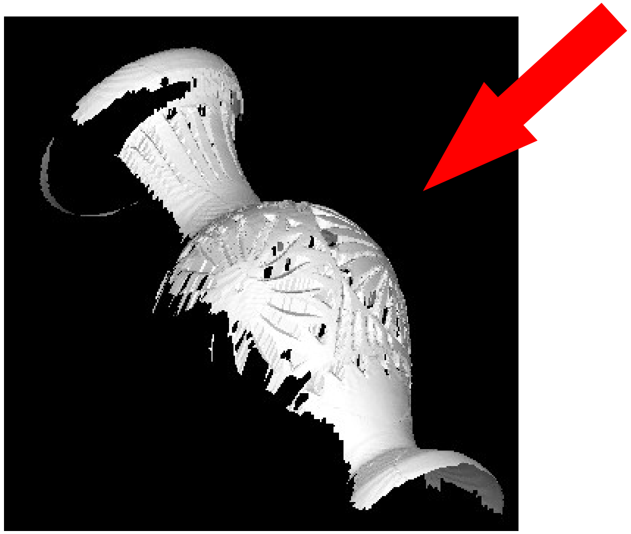


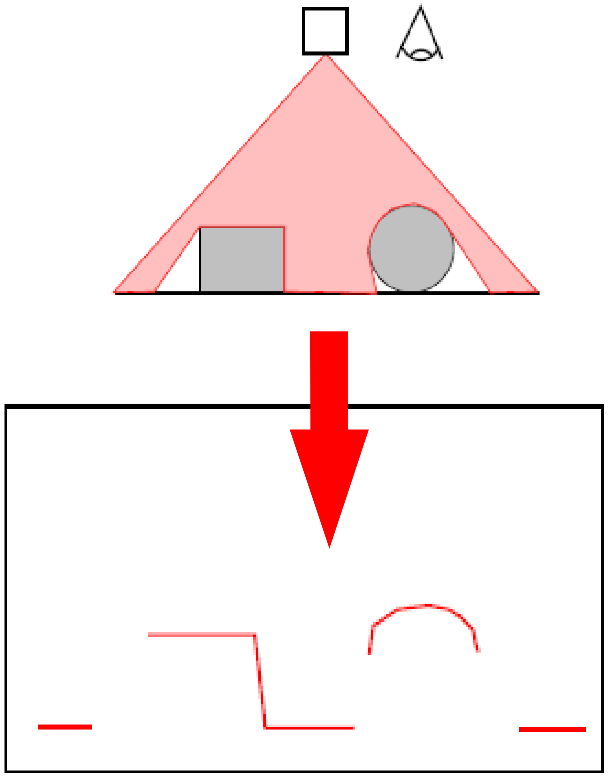


Stanford's *Digital Michaelangelo* Project – capture using 3D laser triangulation
http://graphics.stanford.edu/projects/mich/

2½D Limitation

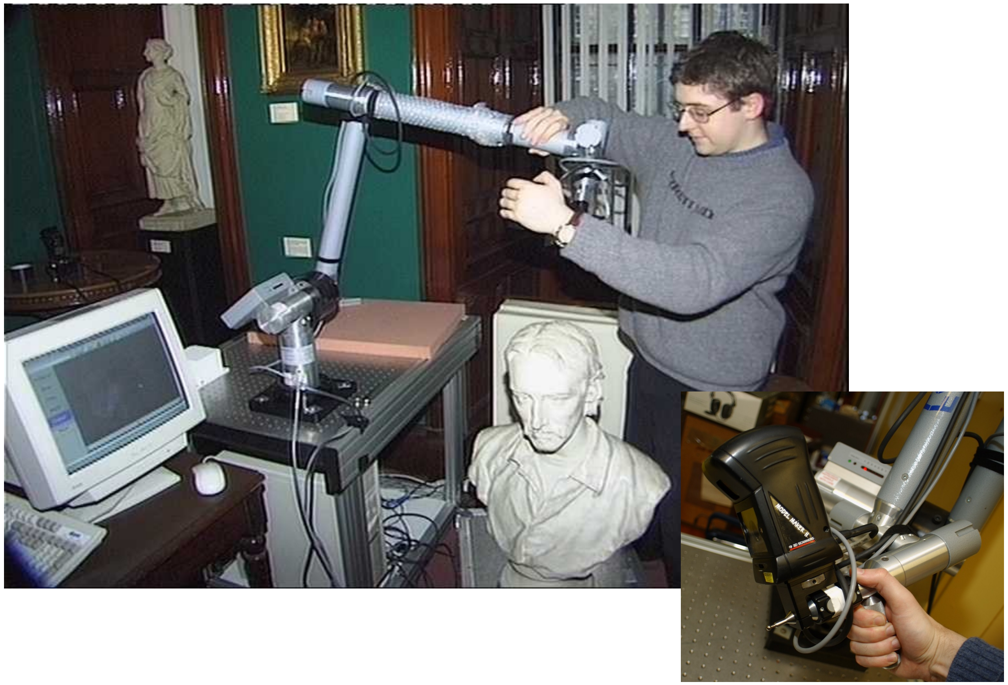
- We have depth – i.e. 3D knowledge
  - BUT only in one direction!
  - e.g.

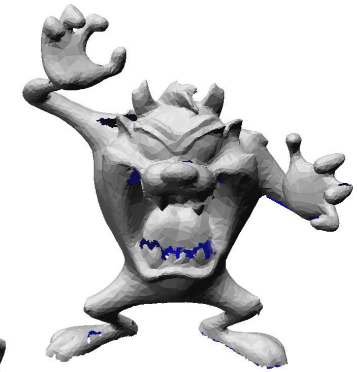




  - This is called 2 1/2D!
  - Possible Solutions
    - capture from different directions and merge

2½D : Difficult Models to Scan



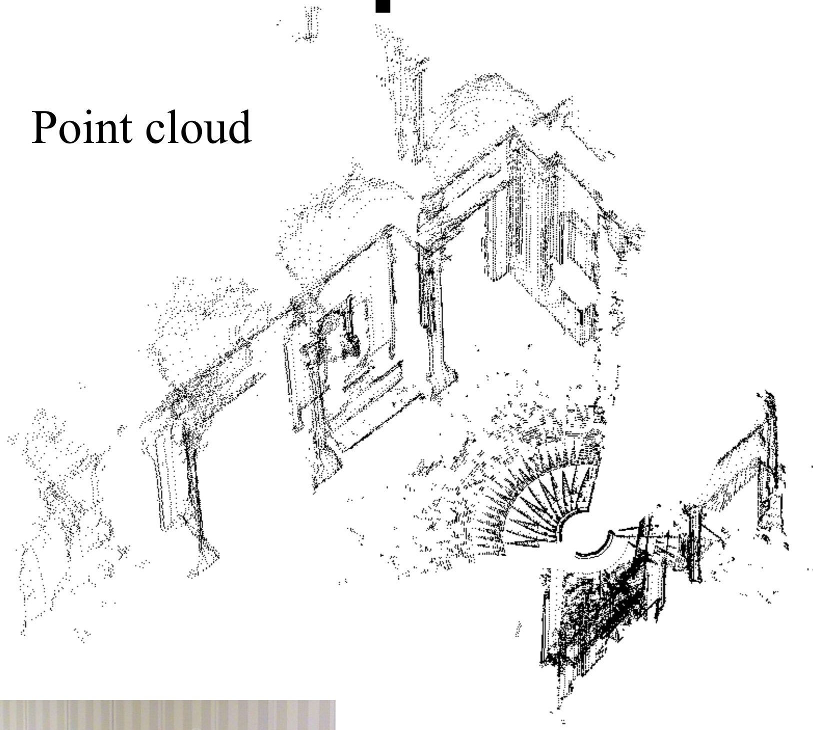


Blue areas indicate no data.

- Even with hand driven manoeuvrable scanner - difficult to get complete scan
- Especially the concave area

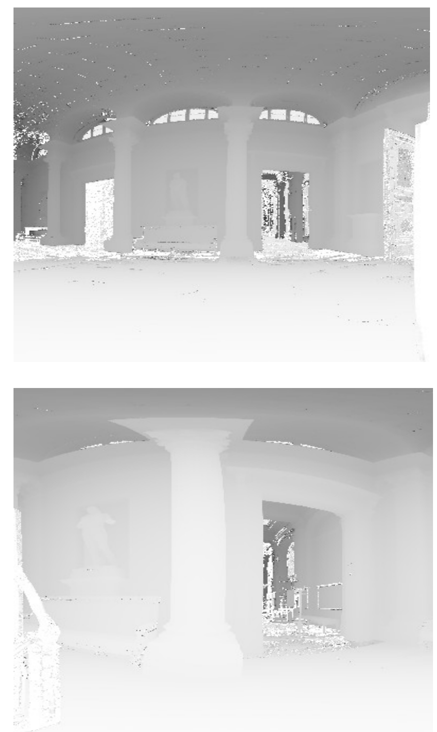
Example : Environment Scanning

Point cloud

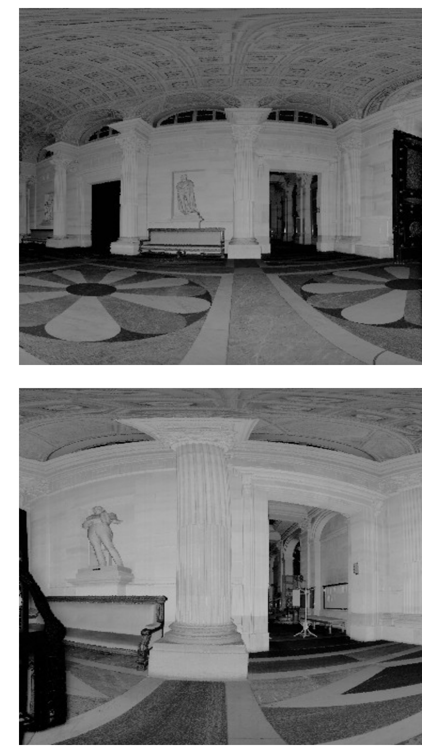


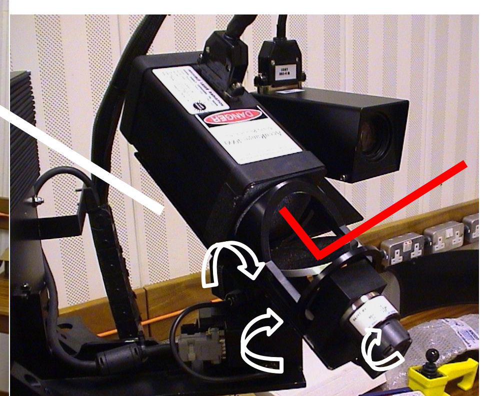
- Resulting point cloud limited to 2½D

Range.



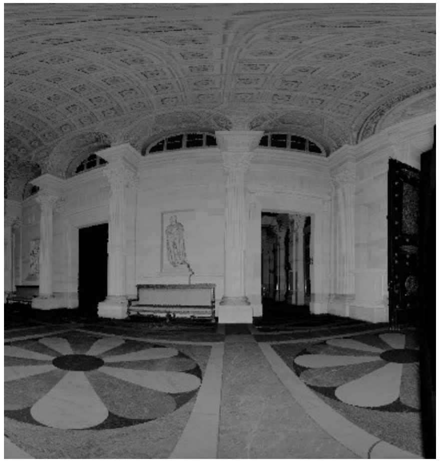
Reflected laser power



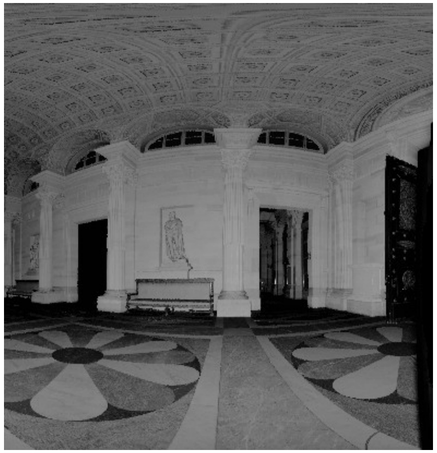


Mobile scanner unit

Example : single viewpoint scan

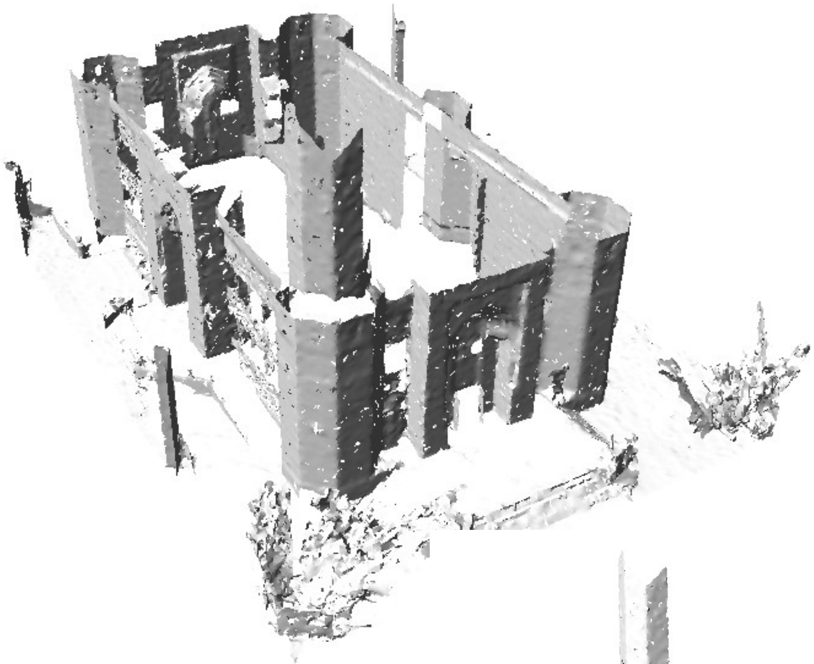


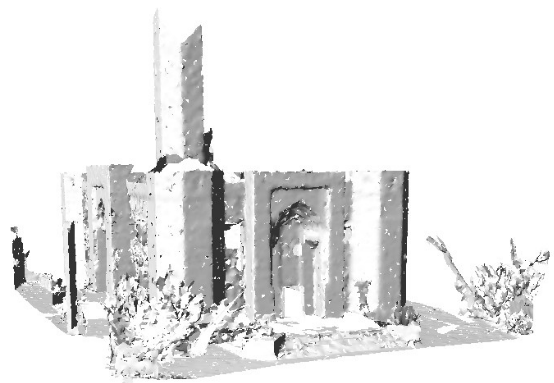
Example : multi-viewpoint scan

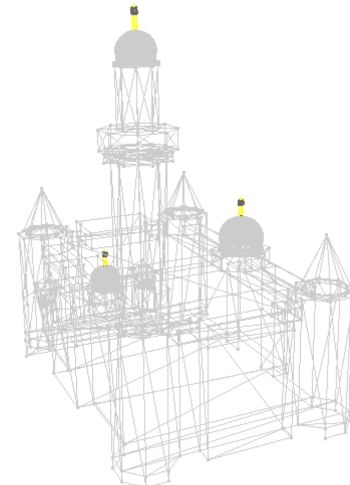


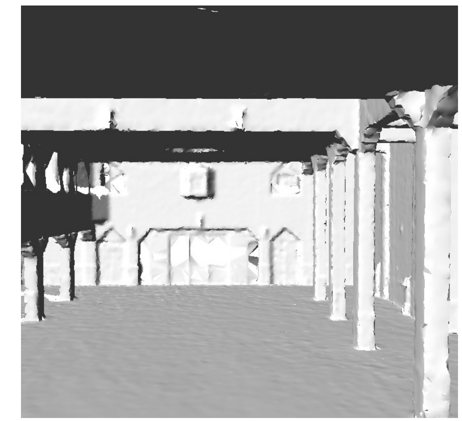
- *Some* holes filled
  - more information
  - requires **registration** of one point cloud to the other

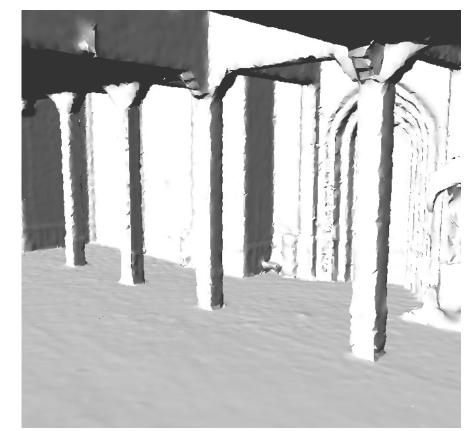
Example : Edinburgh Central Mosque









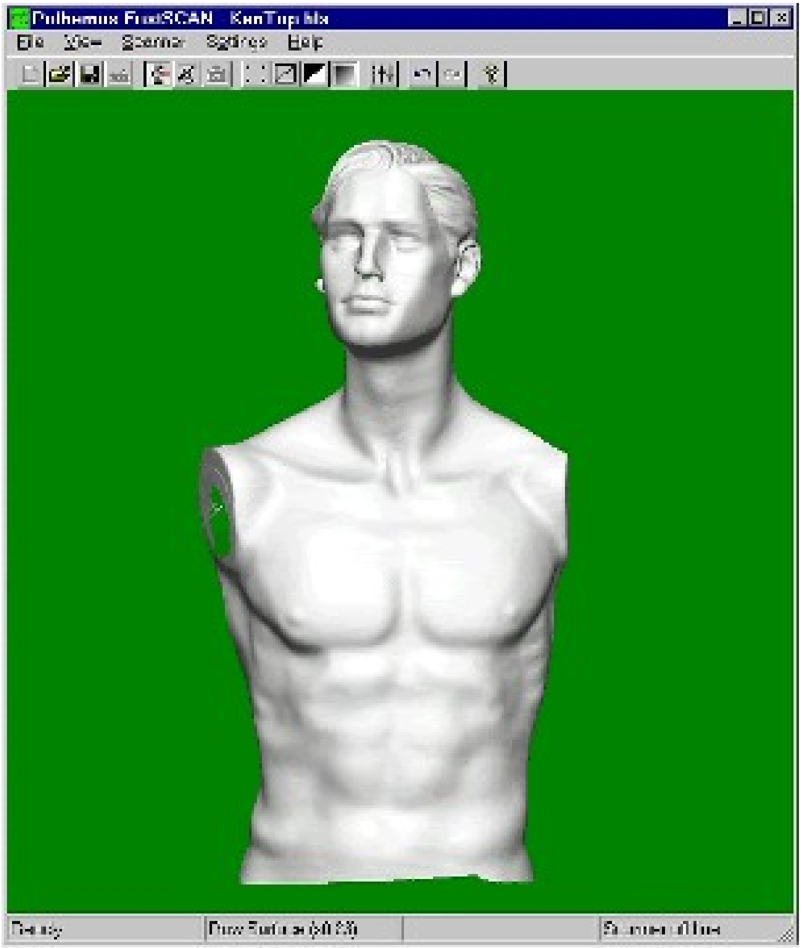


http://3d.edmosque.com

[Fisher / McCormick / Bannai '02-04]

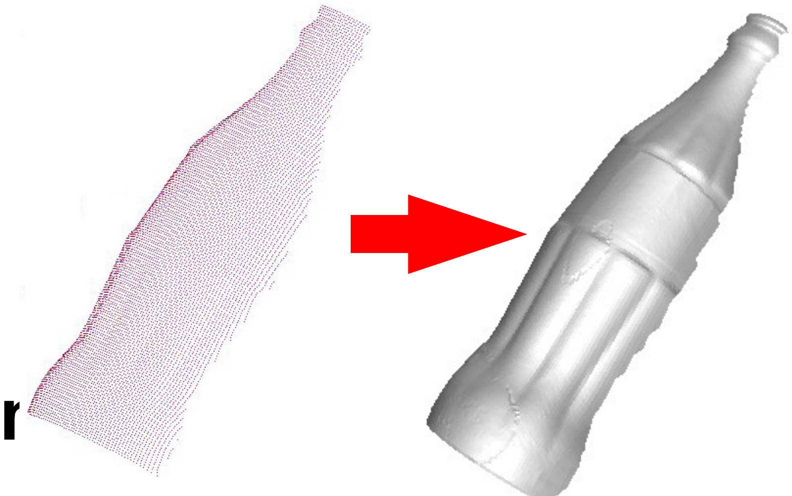
- **Scanning** : multiple positions with environment laser scanners
- **Data** : millions of points, noisy - processed to VRML mesh

FastScan : handheld laser scanner

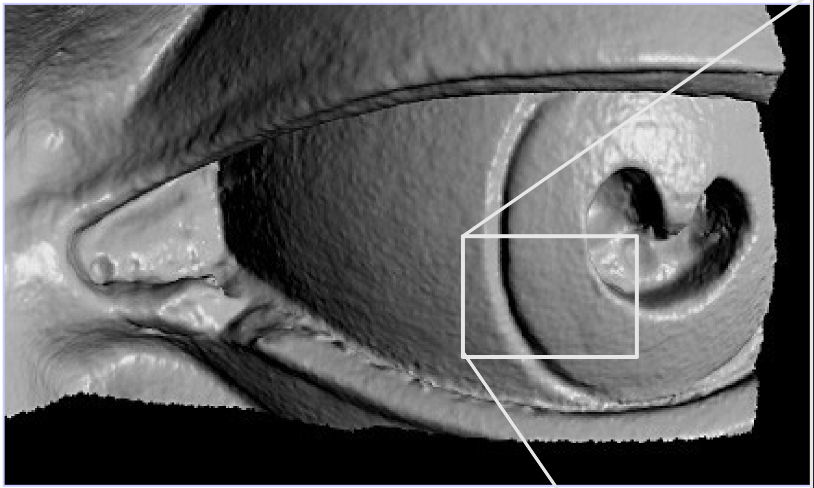


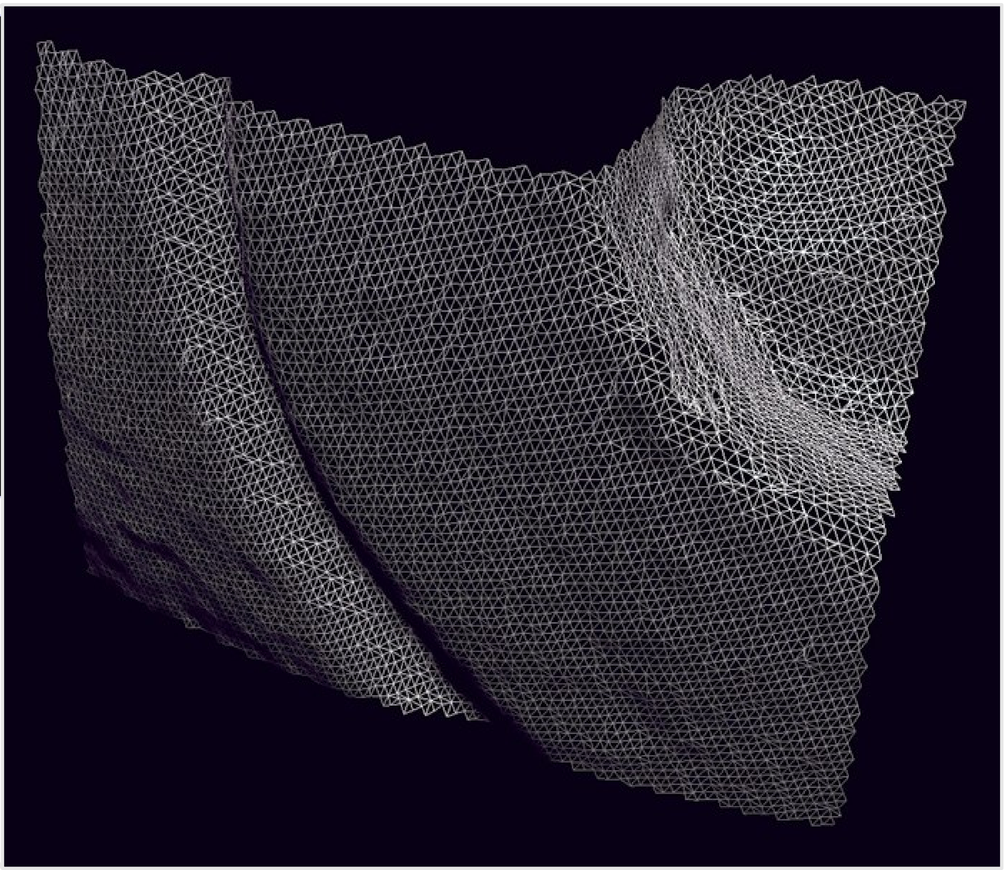
3D Data Processing : Rendering

- Point clouds **transformed to surfaces for rendering**
  - surface **triangulation**
    - *numerous methods:*
      - commonly use Delaunay
      - or iso-surface based on distance
  - change in **data representation**
    - 3D **unstructured points to surface mesh representation**
    - addition of **topology**
      - **irregular geometry** and **regular topology**



Surface Detail : very fine





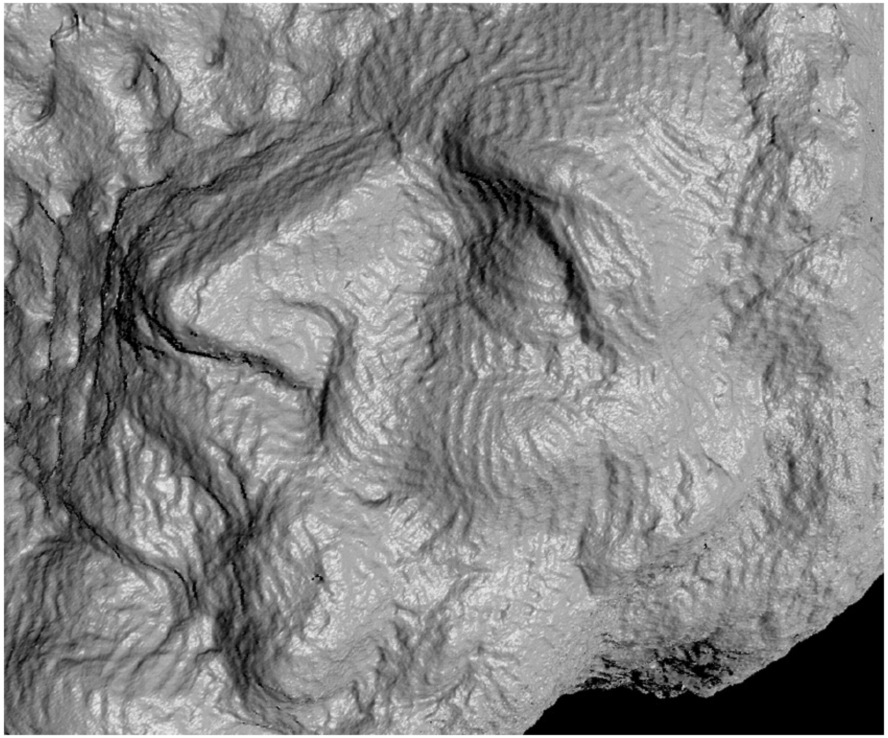
0.25mm scan resolution.

- How can we **visualise** this **fine detail**?

Rendering : Lighting Surface Detail

- Surface detail illuminated using diffuse (left) and specular (right) lighting

3D Model of Michaelangelo's Unfinished Statue of St. Matthew (Stanford).



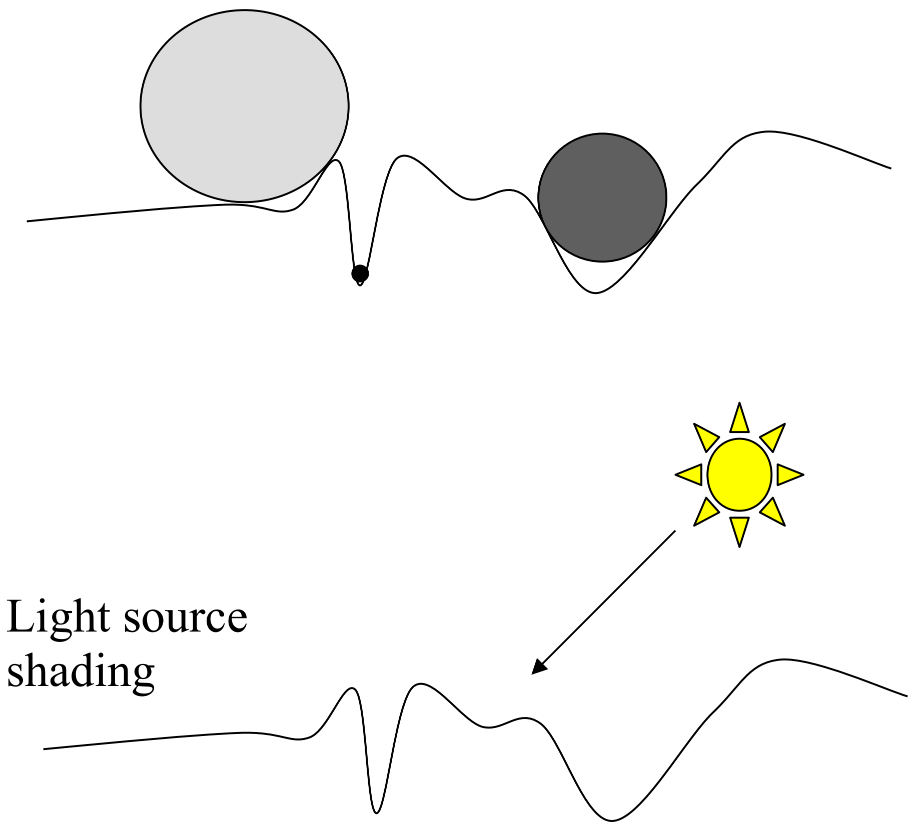
Chisel marks can be seen
– but can this be improved

Rendering : Lighting Surface Detail

- **Requirement:** visualise **fine surface detail**
  - **here** : interested in **how work was carved**, possibly what kind of chisel was used
    - need to visualise **fine detail of chisel marks on surface**

- **Conventional Lighting Choices**
  - **Diffuse :** lighting has smooth curve with surface normal
    - only see **brightness change at steep angles to light source**
  - **Specular :** steeper lighting gradient but only locally
    - Can only highlight some regions of the whole surface

Alternative : Accessibility Shading



Shade the surface **according to the size of the largest sphere that can touch the surface** (i.e. how accessible it is).

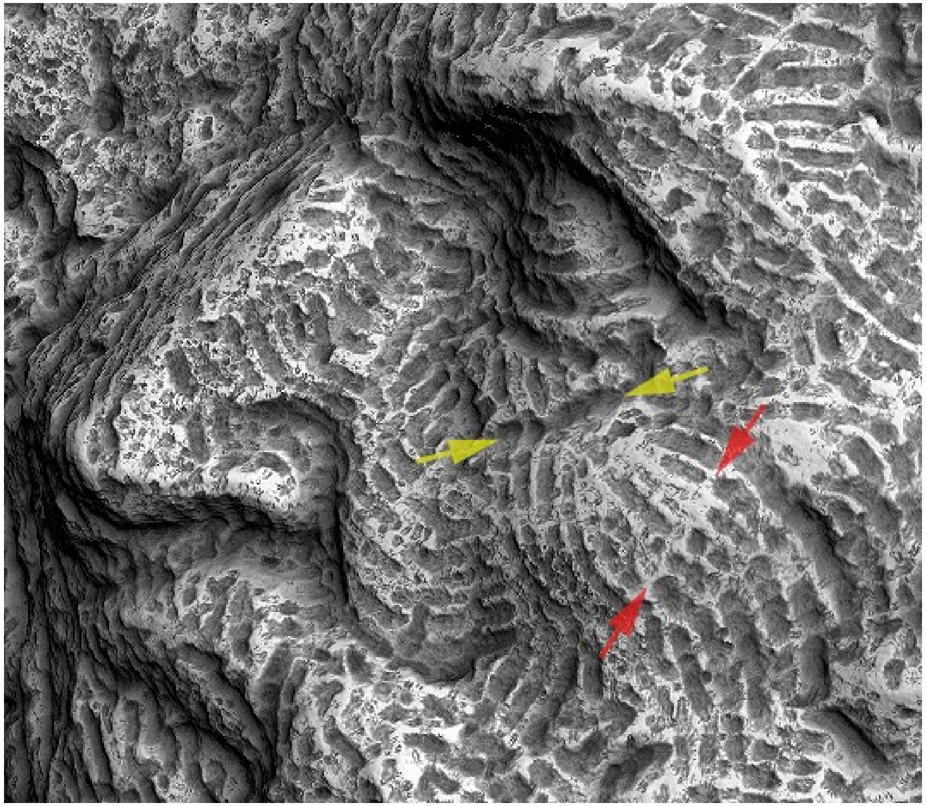
- **Darkens inaccessible parts** of model.

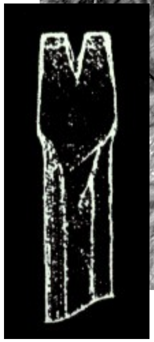
- Gives an objective view of the surface independent of choice of illumination angle (objective shading).

- Lights surface **in proportion to local granularity of detail**
  - ideal for visualisation of the surface details

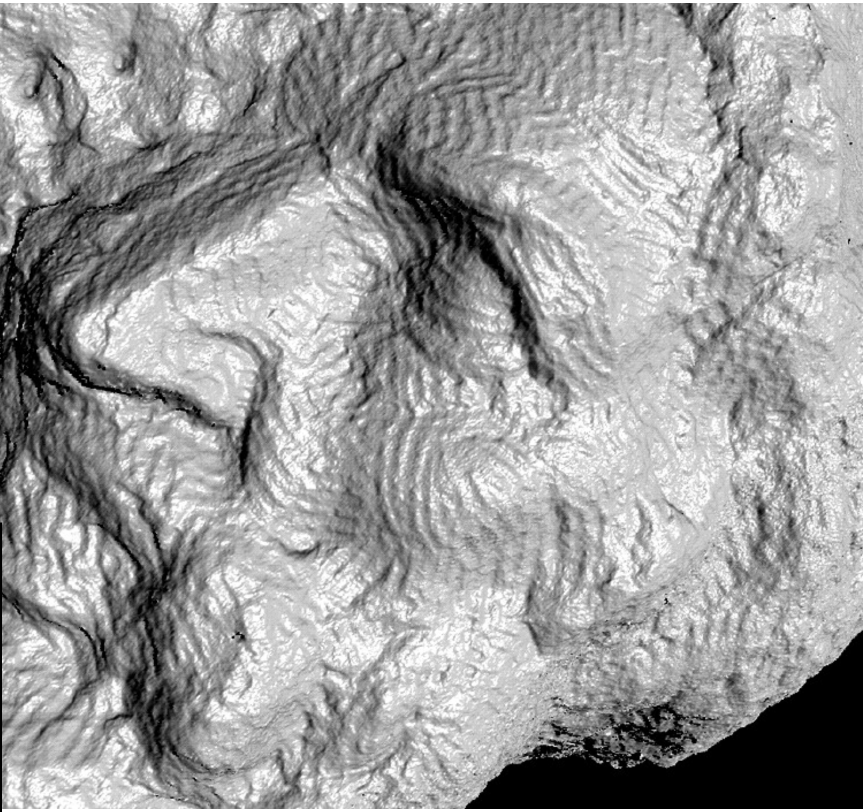
Example : chisel analysis

Accessibility shading – clear detail





Specular shading – less clear detail



- From effective visualisation further historical conclusions on chisel type can be made – *by bringing information out of data*

Accessibility Shading

- accessibility shading can be used to render dust covered or tarnished surfaces

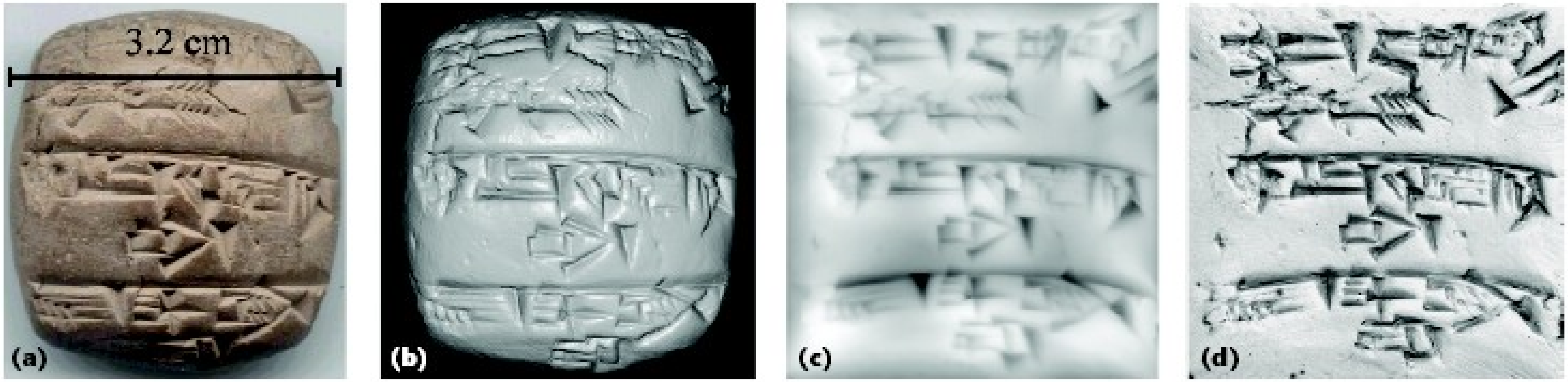
Visualising the Cuneiform Tablets

- *Cuneiform clay tablets were inscribed in Mesopotamia millenia ago*
- *Visualizing cuneiform writing is important when*
  - *finding out what is written on the tablets.*
  - *reproducing the tablets in papers and books*
- *photographs are not easy to see*

http://www.graphics.stanford.edu/projects/cuneiform

Surface Lighting Comparison

- Surface detail visualisation methods
  - example : Stanford cuneiform tablet example



photo

Scanned surface

Unwrapped and shown as a displacement map

Accessibility shading.

Summary

- **Stereo** Vision
  - **dense stereo matching**
    - high-resolution data from commercial systems
  - full **body scanners**
- **Laser scanners**
  - laser scanner technologies
  - **data representation** and limitations (**2½D**)
  - effectively **lighting 3D surface detail**