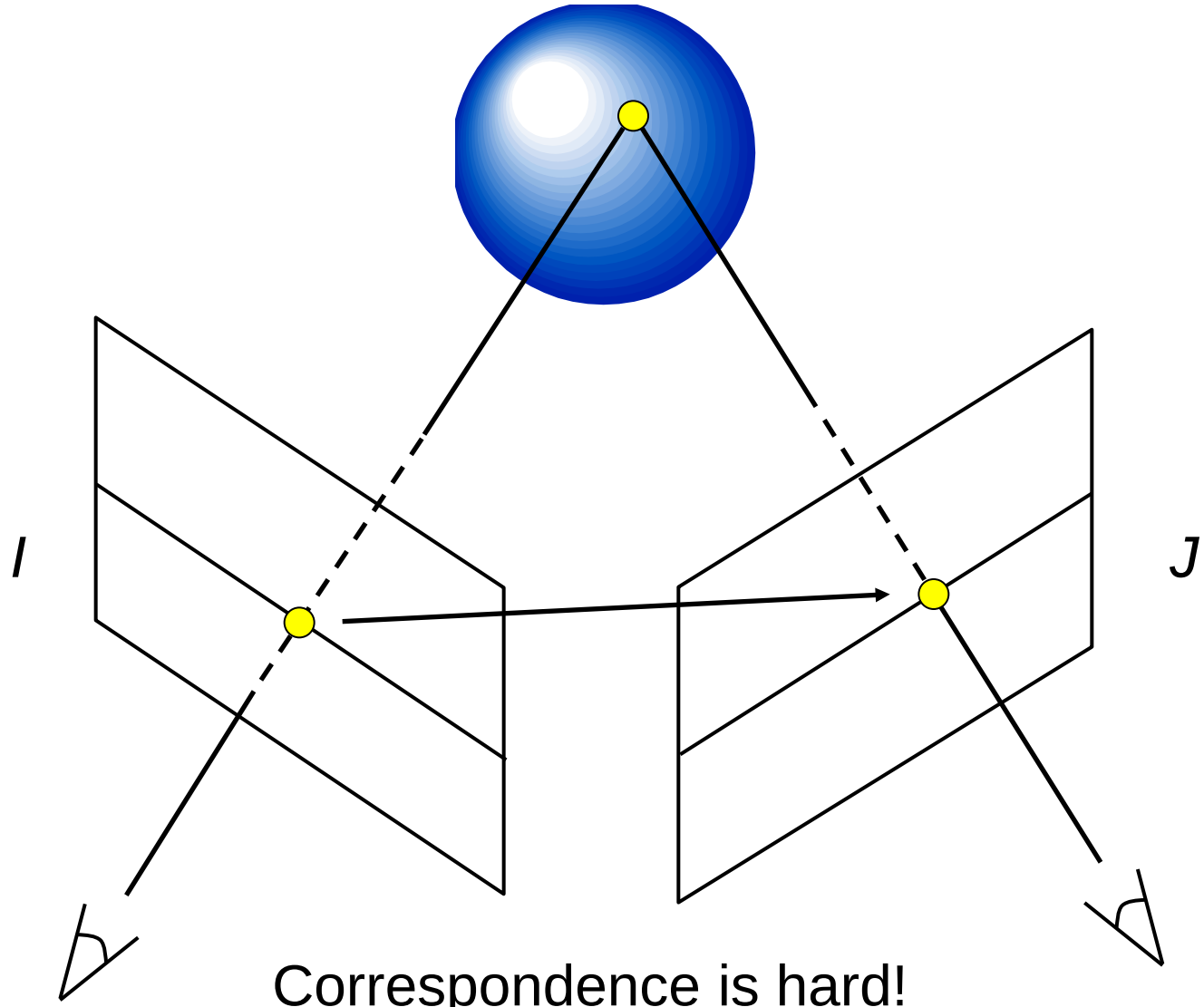
L2 – Data Acquisition

- Mechanical measurement (CMM)
- Structured light
- Range images
- Shape from shading
- Other methods

Coordinate Measurement Machine

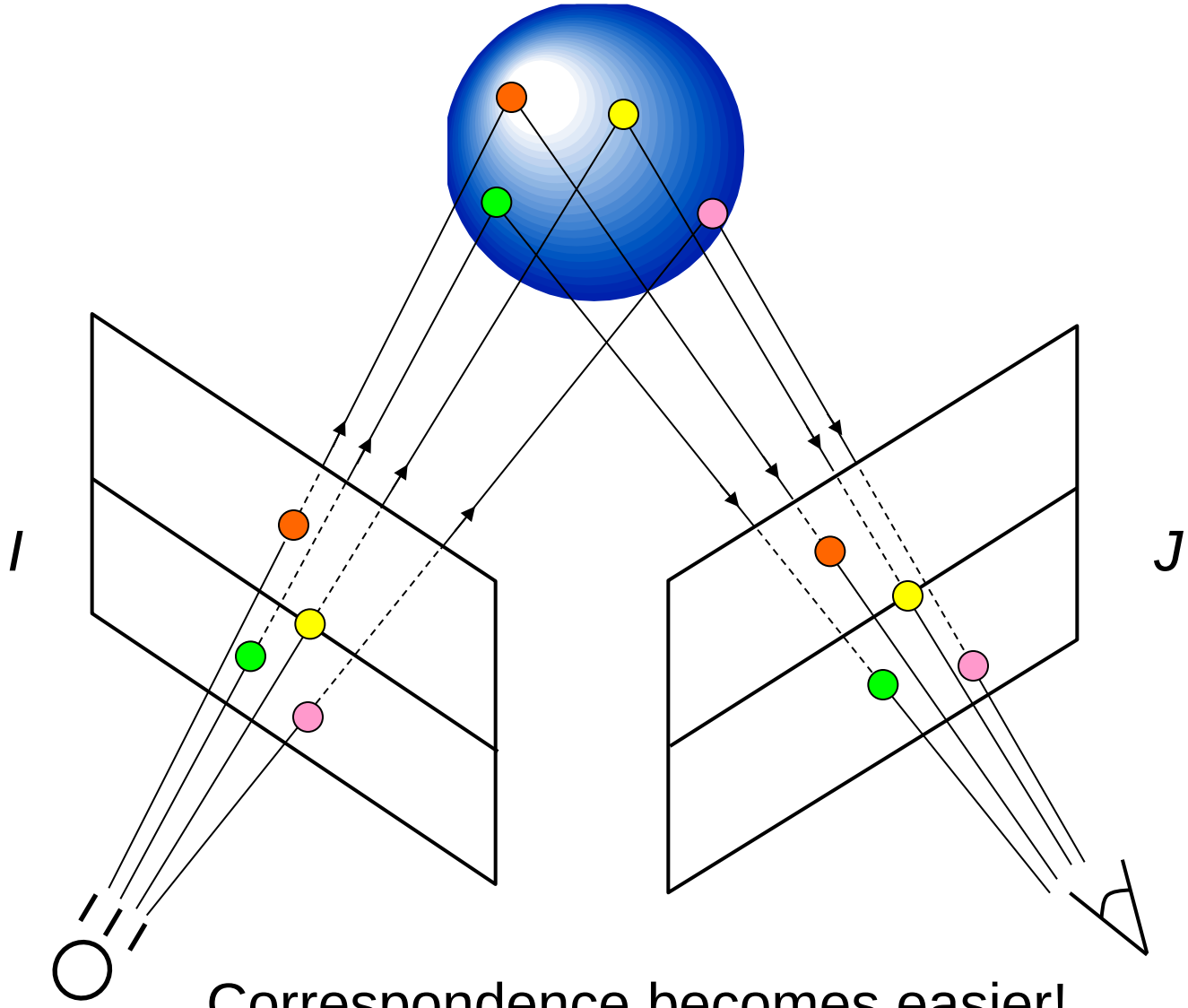
- Touch based
- Slow
- Sparse Data
- Complex planning
- Accurate

Vision-based Method: Stereo Triangle



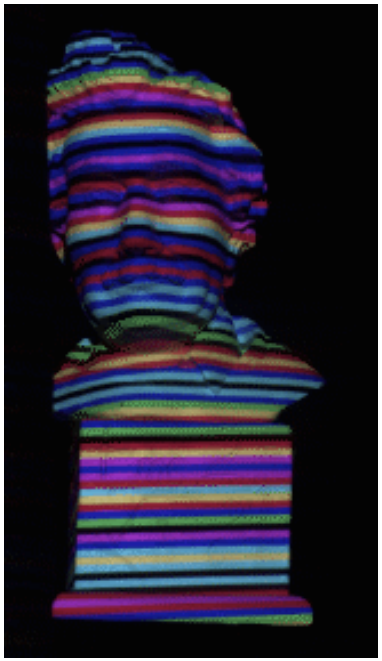
Correspondence is hard!

Structured Light Triangulation



Correspondence becomes easier!

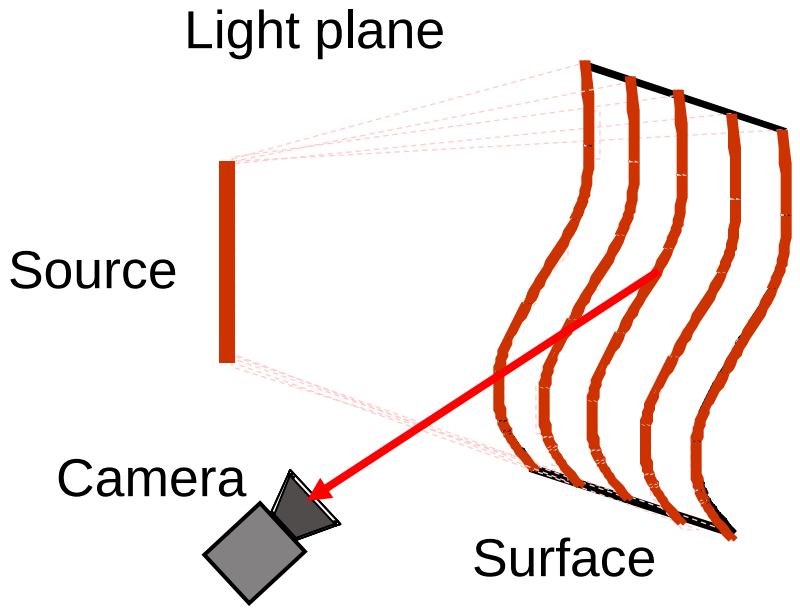
What is Structured Light?



- Any spatio-temporal pattern of light projected on a surface (or volume).
- Cleverly illuminate the scene to extract scene properties (eg., 3D).
- Avoids problems of 3D estimation in scenes with complex texture/BRDFs.
- Very popular in vision and successful in industrial applications (parts assembly, inspection, packaging, etc).

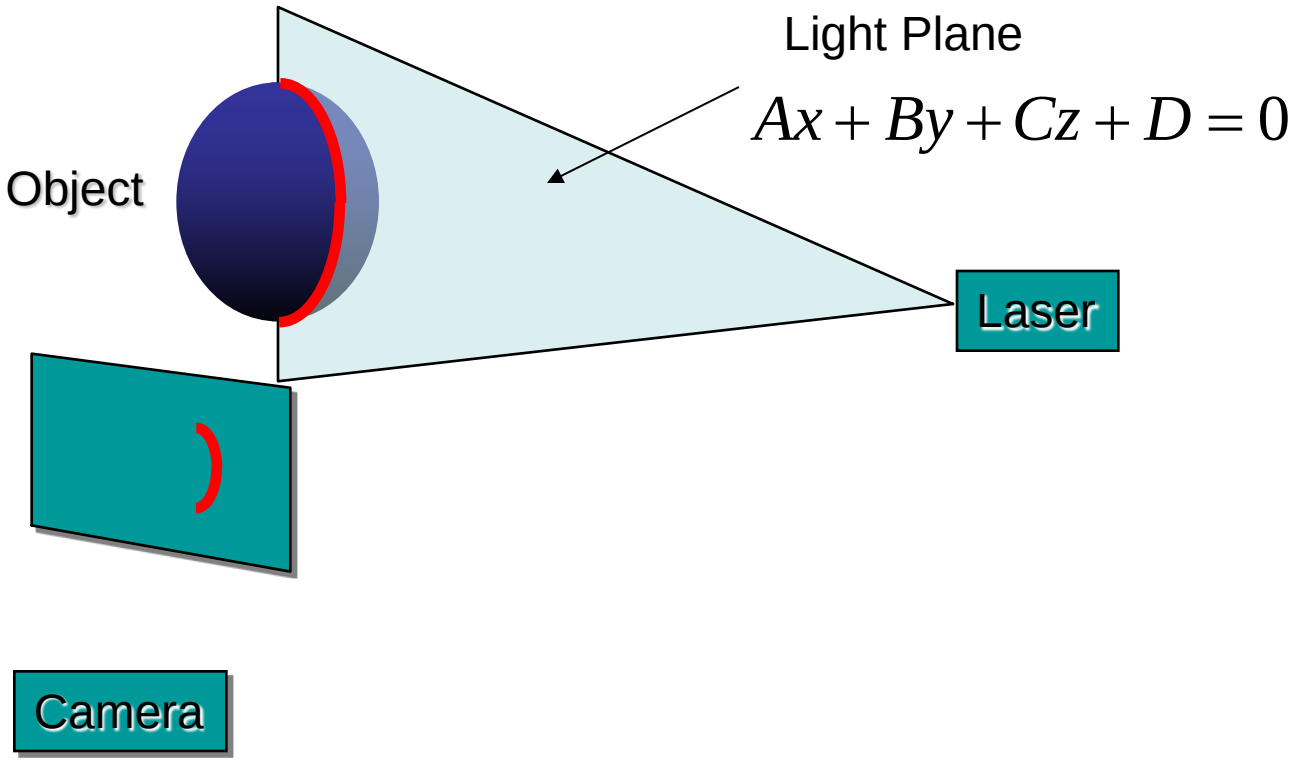
Light Strip Scanning – Single Strip

- Optical triangulation
  - Project a single stripe of laser light
  - Scan it across the surface of the object
  - This is a very precise version of structured light scanning
  - Good for high resolution 3D, but needs many images and takes time



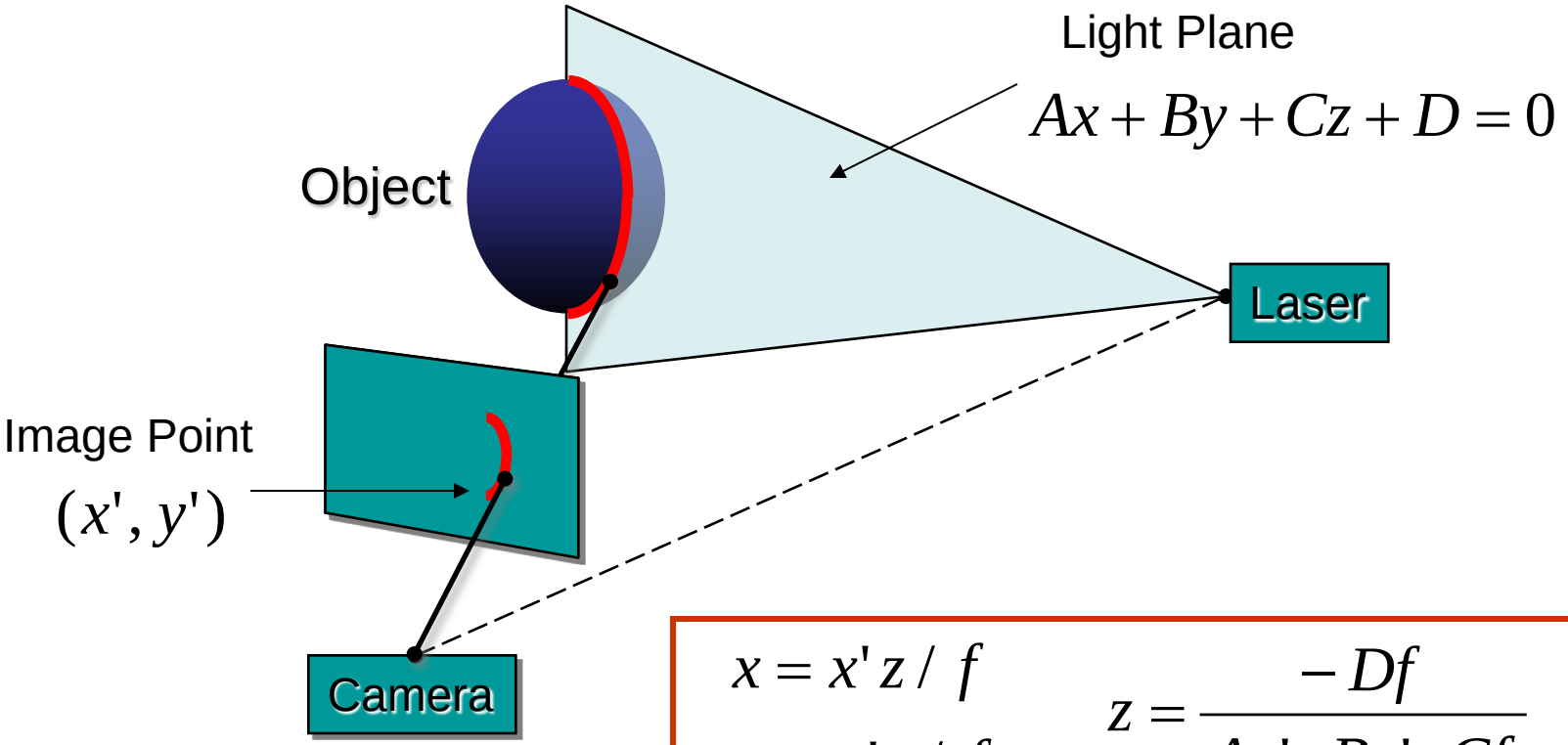
Triangulation

- Project laser strip onto the object



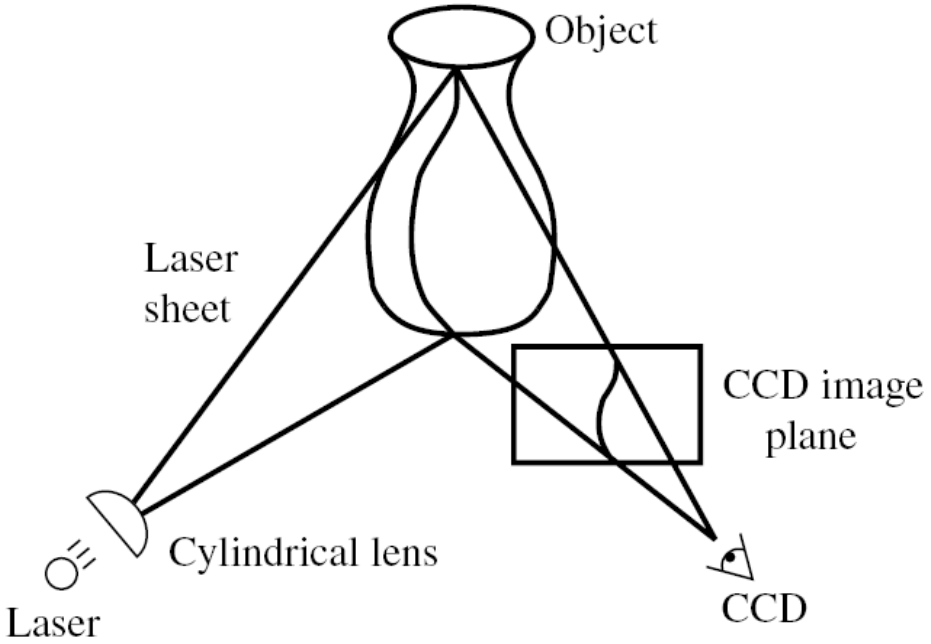
Triangulation

- Depth from ray-plane triangulation:
  - Intersect camera ray with light plane



$$x = x'z / f \qquad y = y'z / f \qquad z = \frac{-Df}{Ax' + By' + Cf}$$

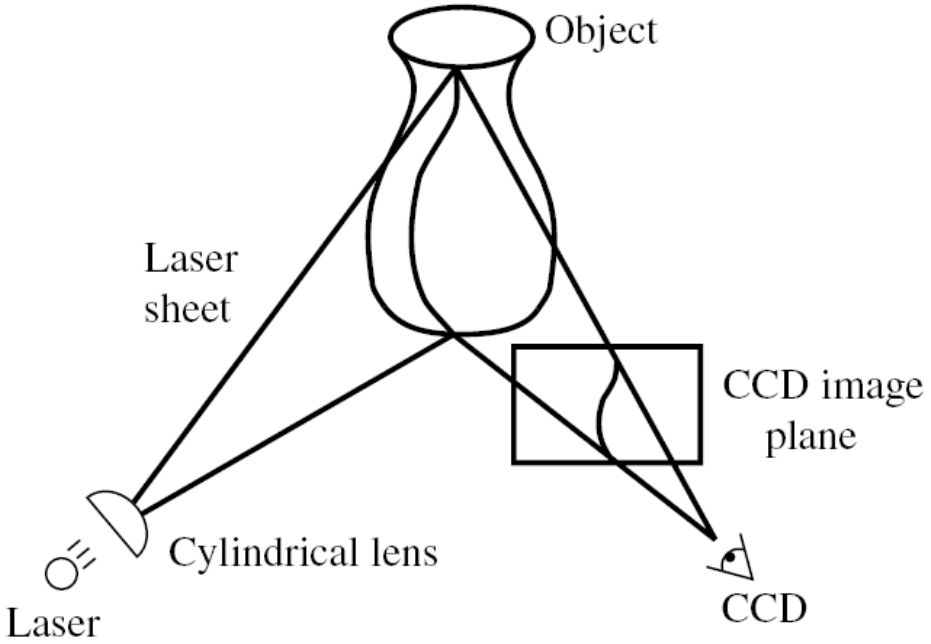
Example: Laser Scanner

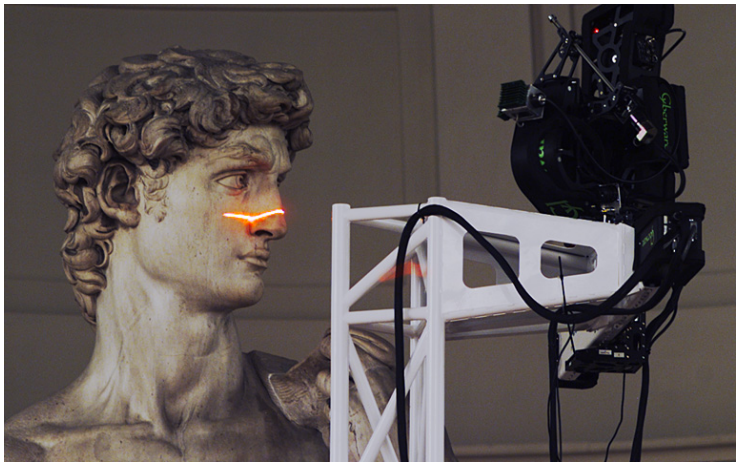


Cyberware® face and head scanner

+ very accurate < 0.01 mm
- more than 10sec per scan

Example: Laser Scanner





Digital Michelangelo Project
http://graphics.stanford.edu/projects/mich/

+ very accurate < 0.01 mm
- more than 10sec per scan

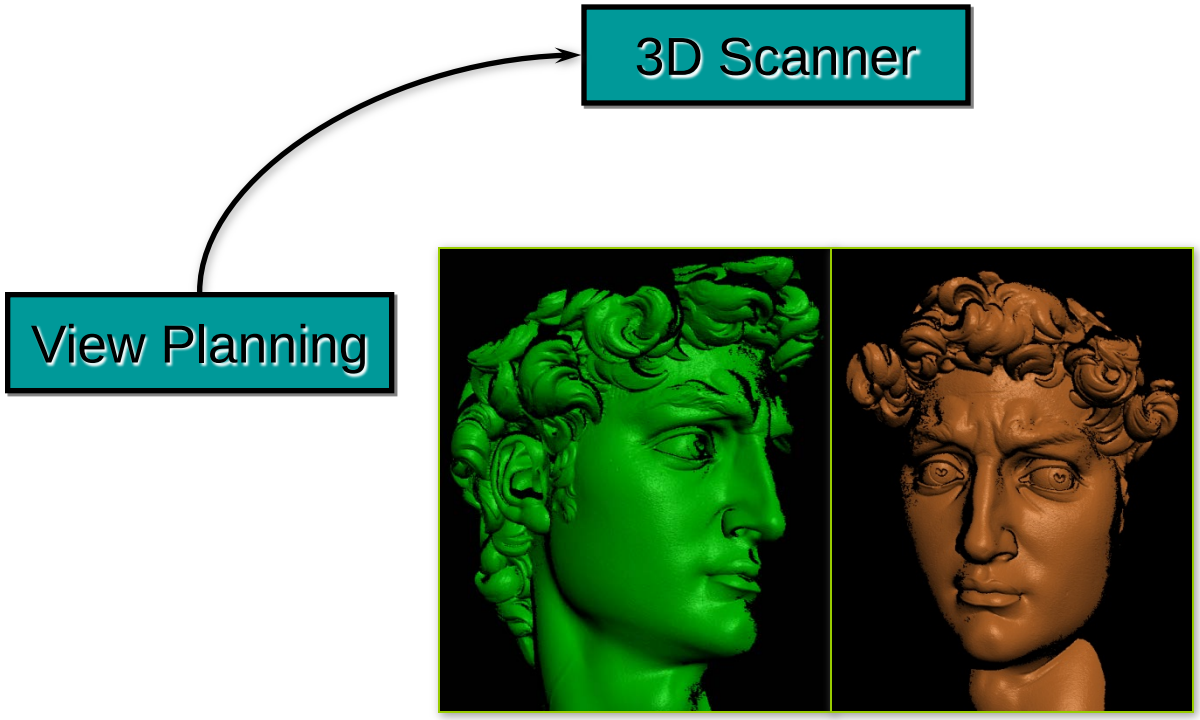
3D Model Acquisition Pipeline

- A range image

3D Scanner

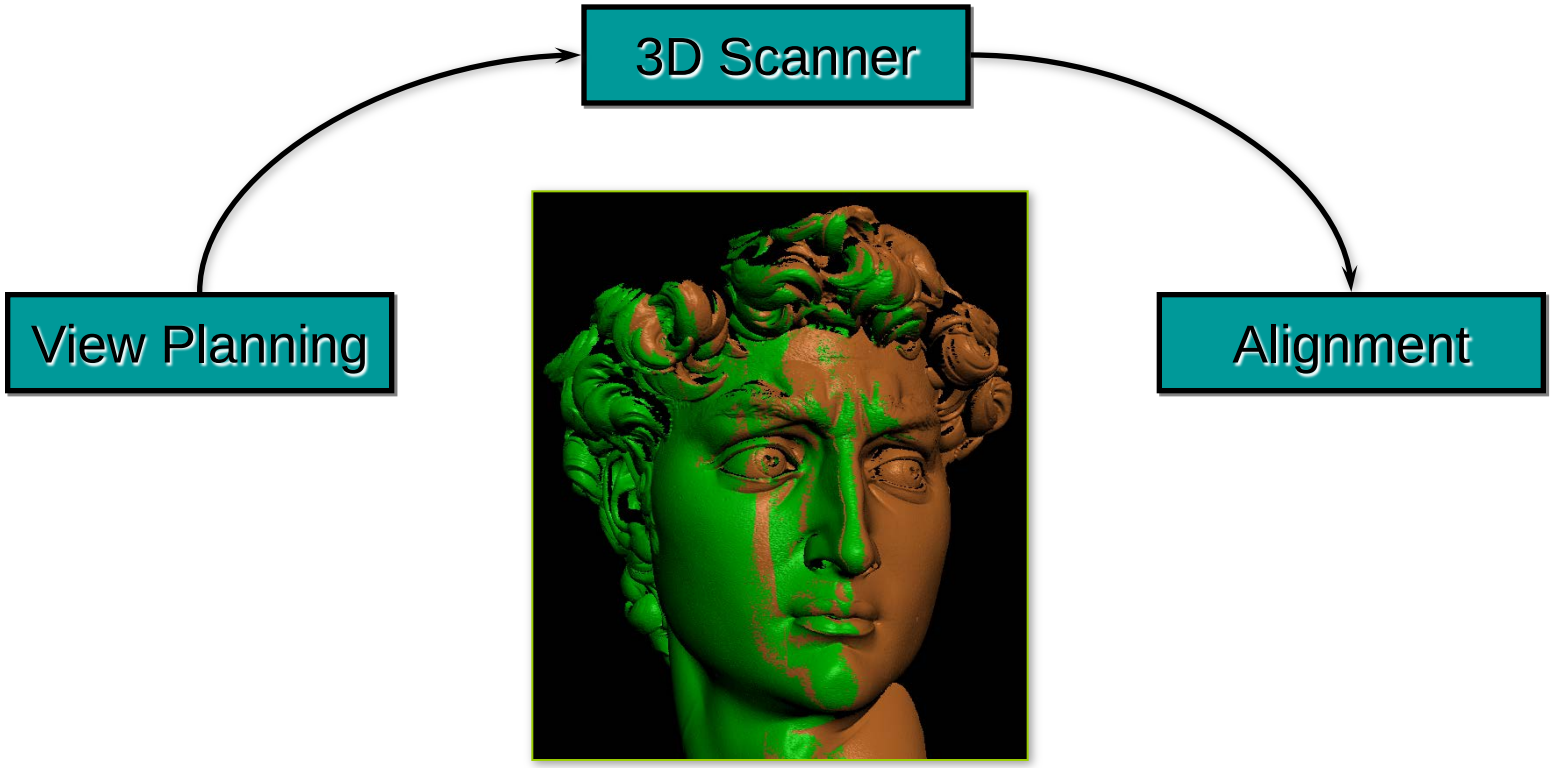
3D shape as seen from a single point of view

3D Model Acquisition Pipeline



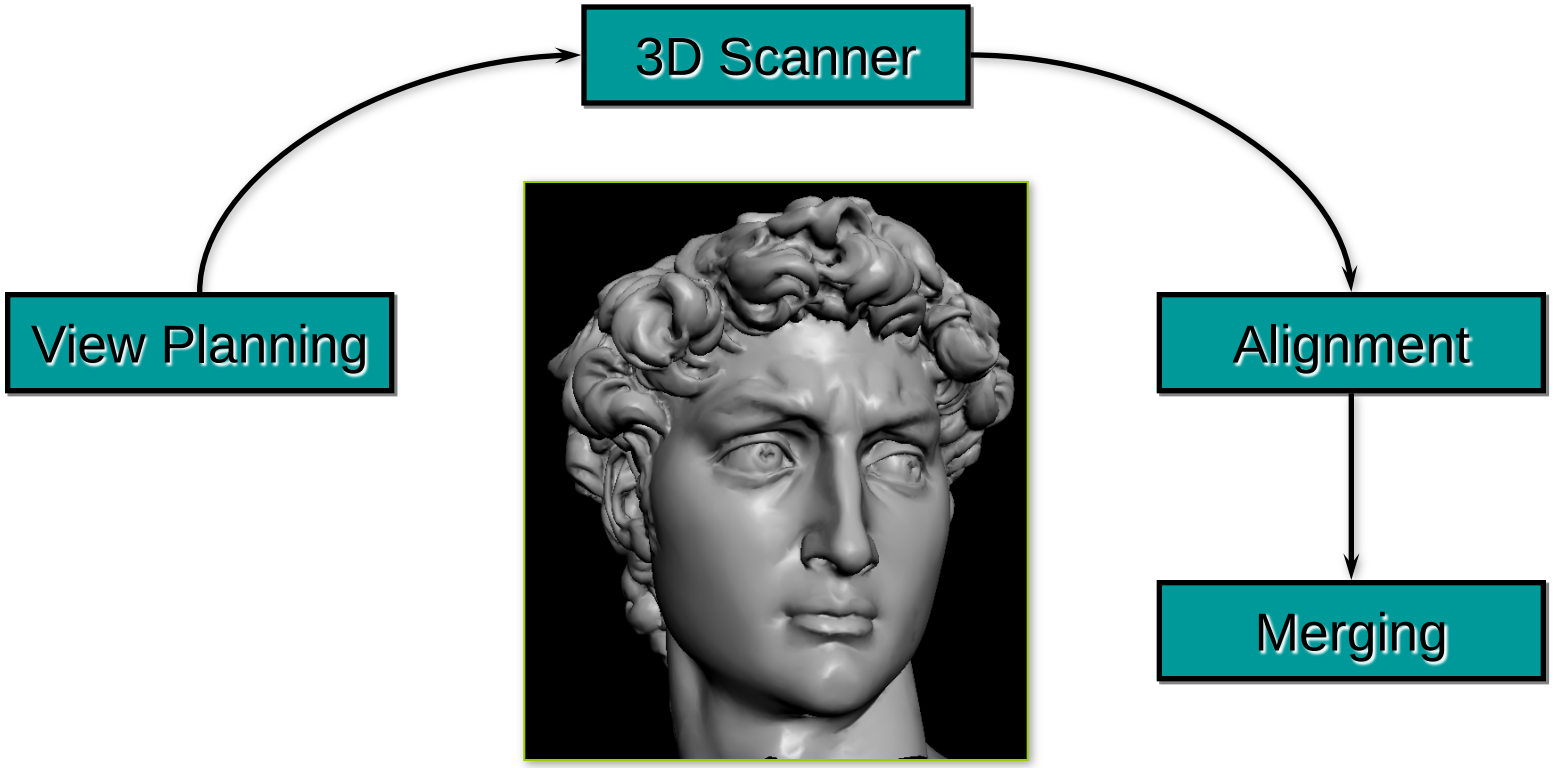
- Move scanner around object (or move object w.r.t. scanner)

3D Model Acquisition Pipeline



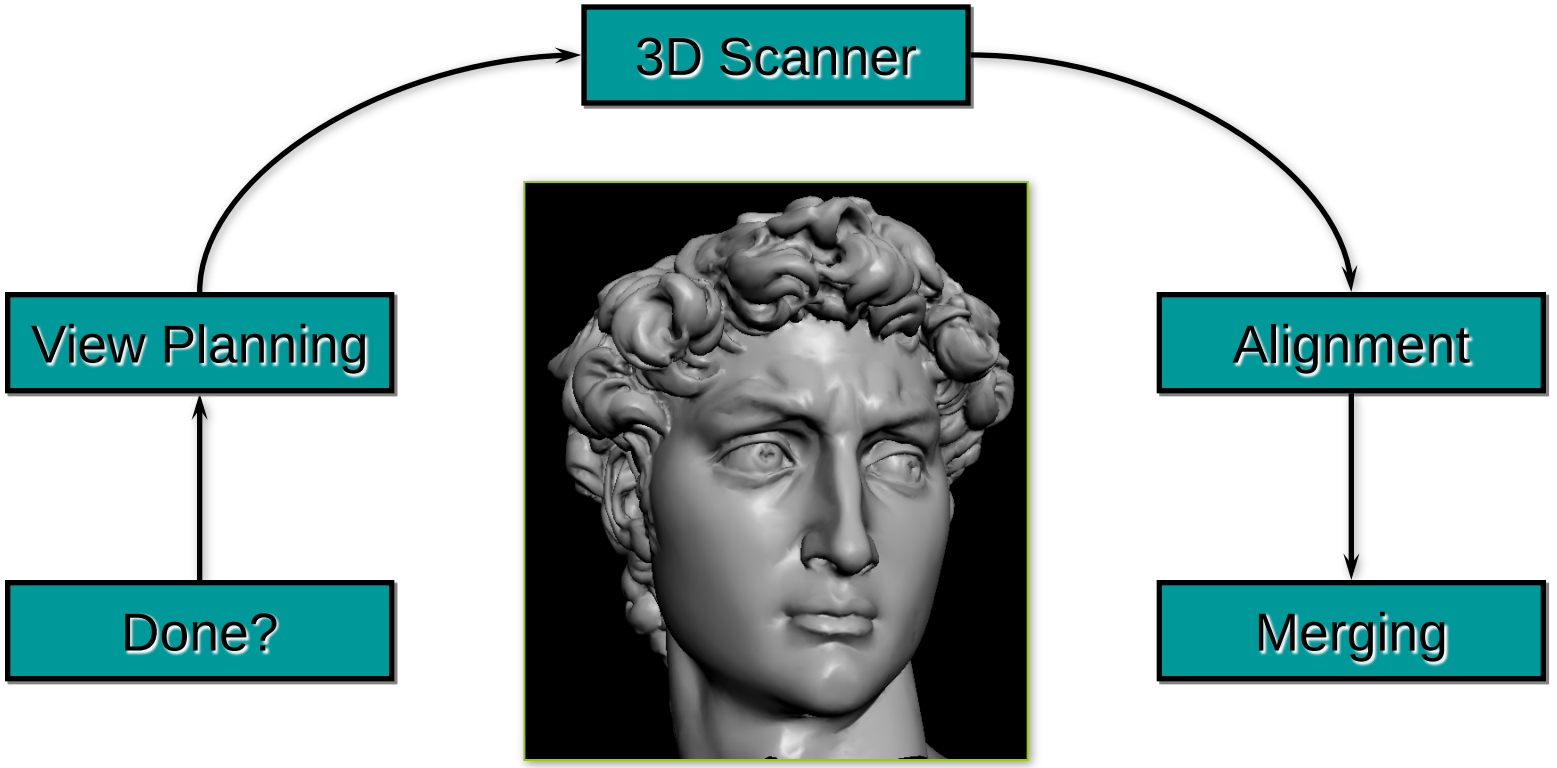
- Multi-scans need to be aligned

3D Model Acquisition Pipeline



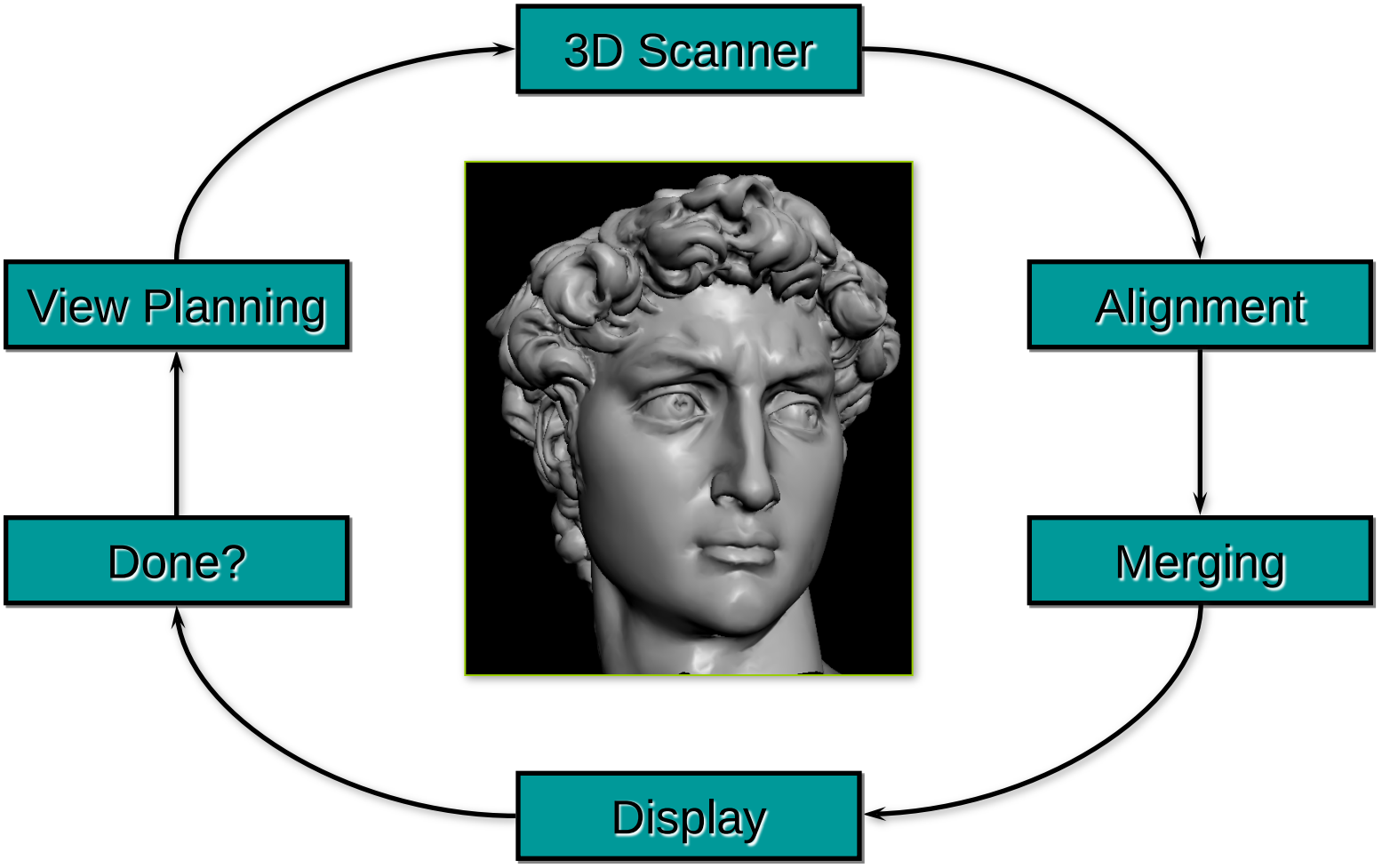
- How to merge?

3D Model Acquisition Pipeline



- Now, the user needs to plan further scans and determine whether the **entire** object has been covered.

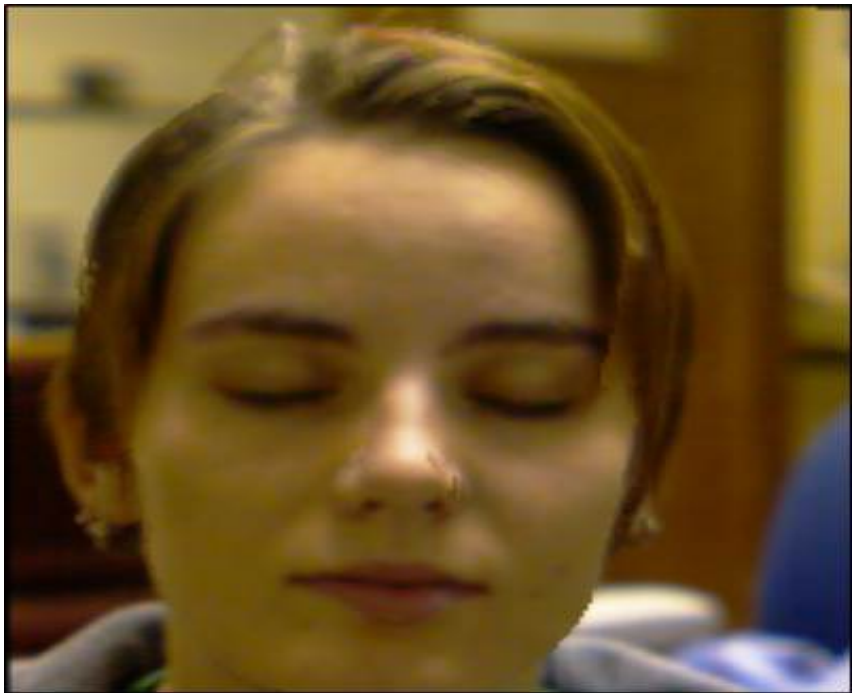
3D Model Acquisition Pipeline



http://graphics.stanford.edu/projects/mich/

Portable 3D Laser Scanner

- Many choices available on market now



Faster Acquisition

- Project multiple stripes simultaneously
- Correspondence problem: which stripe is which?

- Common types of patterns:
  - Binary coded light striping
  - Gray/color coded light striping

Binary Coding

- Faster:

(2^n-1) stripes in *n* images

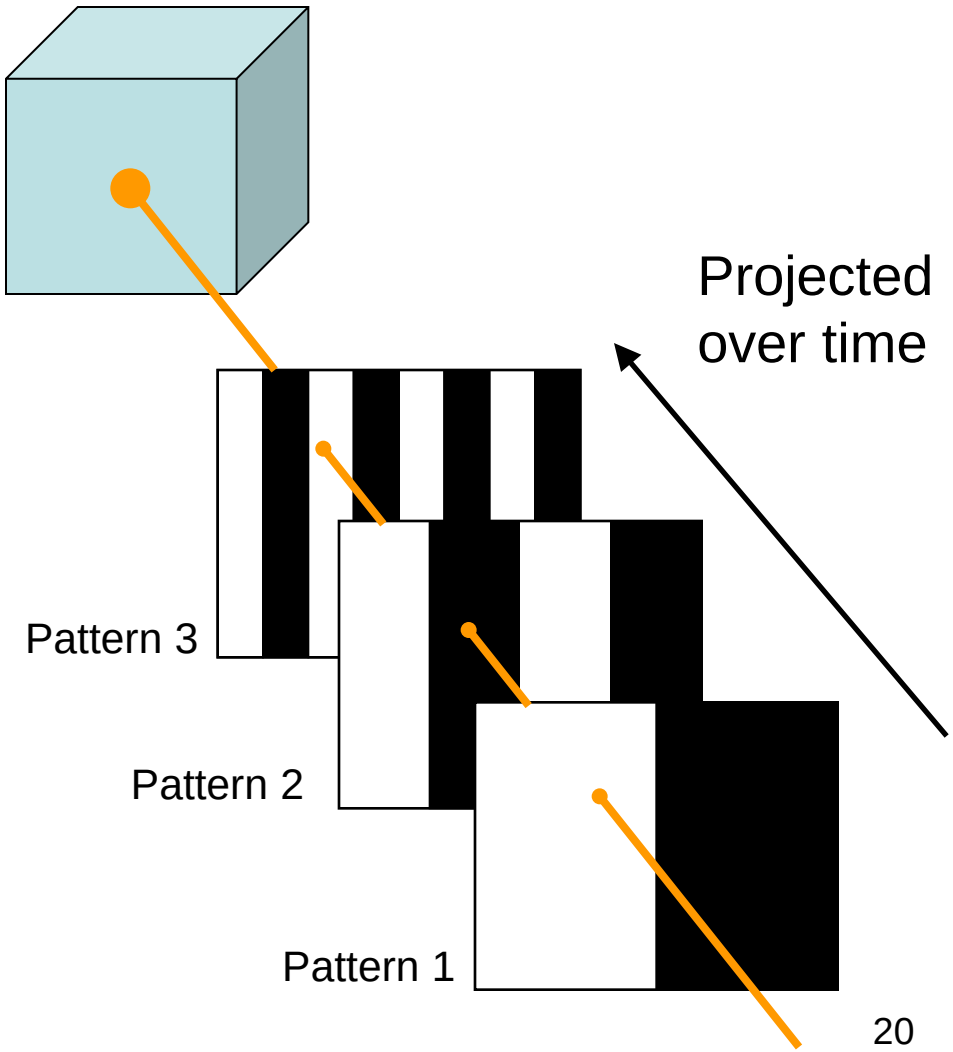
Example:

3 binary-encoded patterns

which allows the measuring

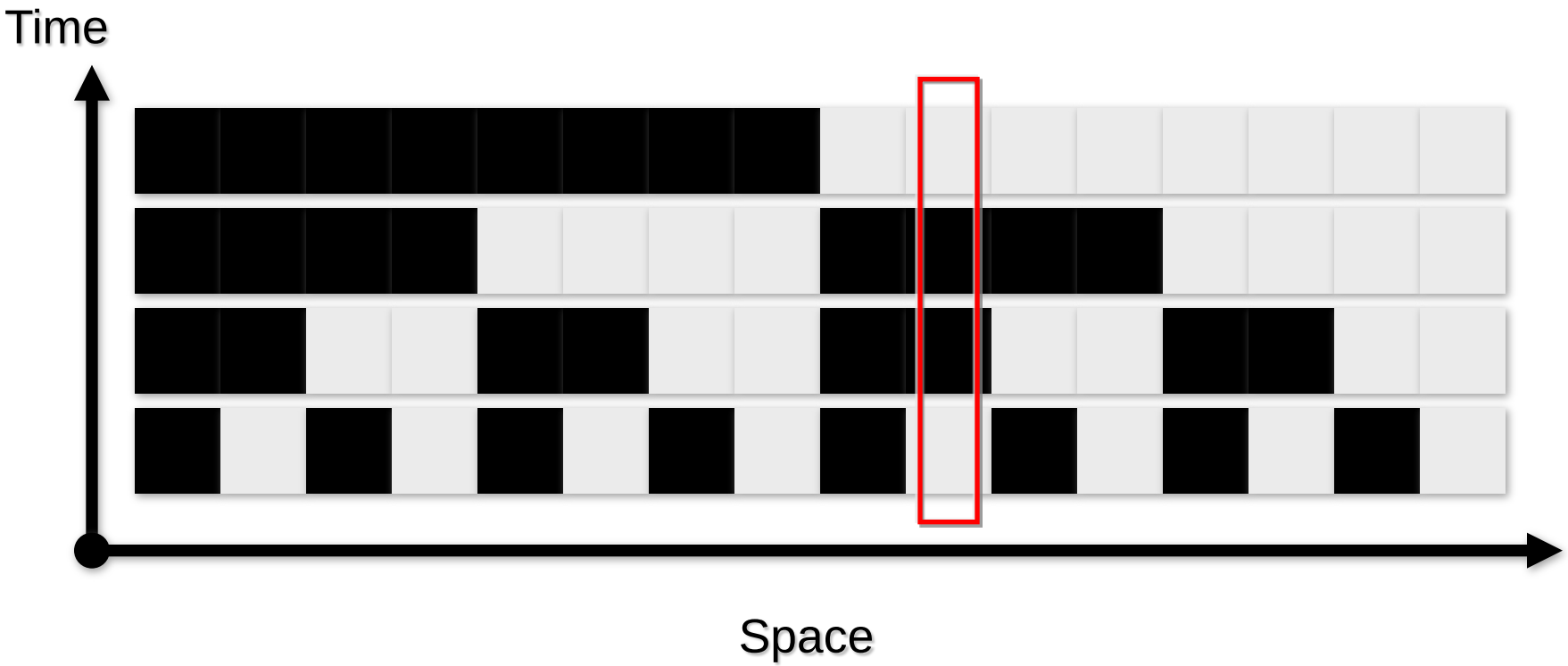
surface to be divided in

8 sub-regions

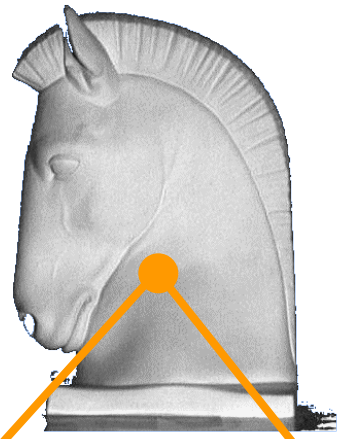


Binary Coding

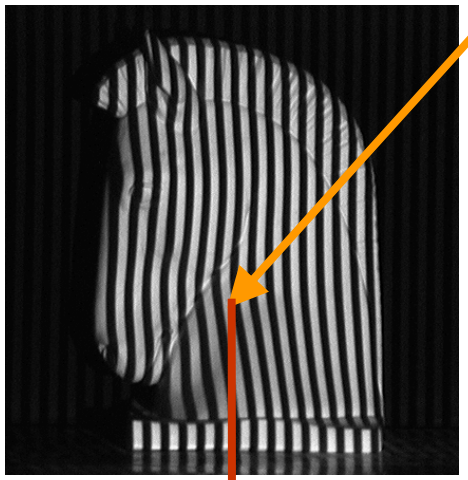
Assign each stripe a unique illumination code over time [Posdamer 82]



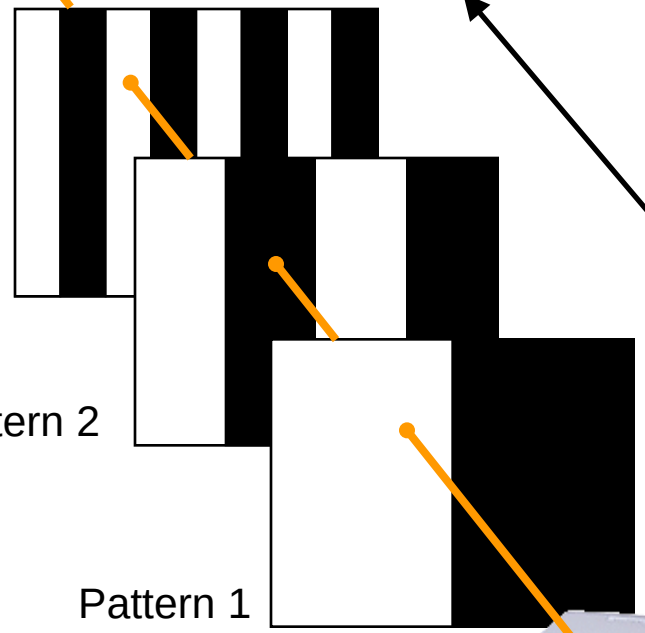
Binary Coding



Example: 7 binary patterns proposed by Posdamer & Altschuler



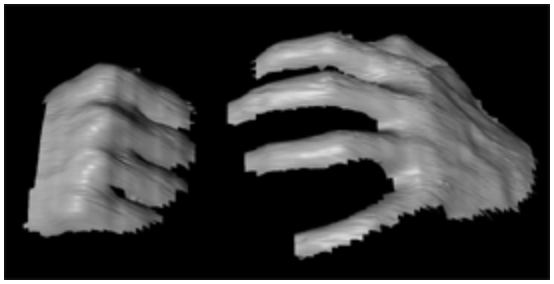
...



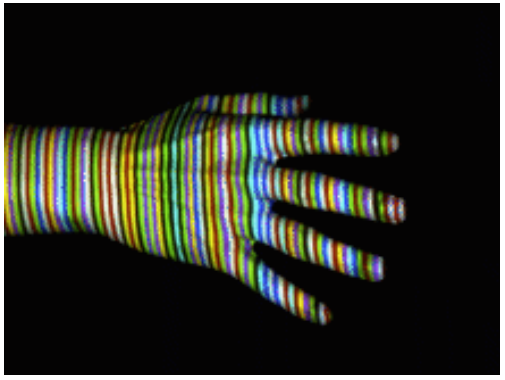
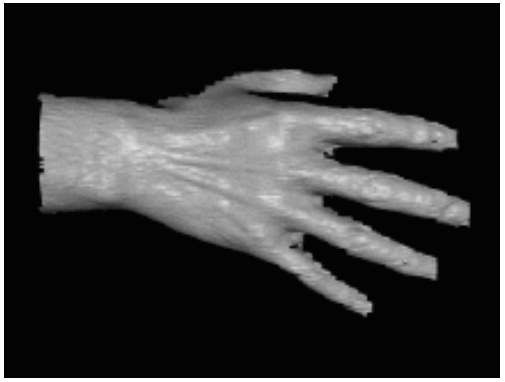
Codeword of this píxel: 1010010 → identifies the corresponding pattern stripe

More Complex Patterns





Works despite complex appearances

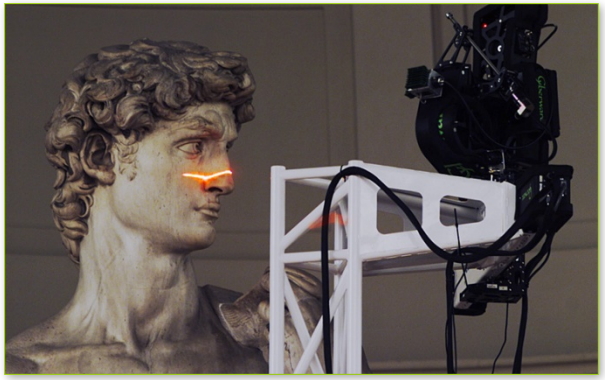
Works in real-time and on dynamic scenes

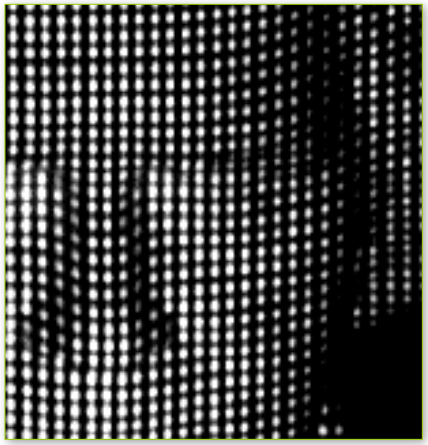
- Need very few images (one or two).
- But needs a more complex correspondence algorithm

Real-Time 3D Model Accquisition

http://graphics.stanford.edu/papers/rt_model/

Continuum of Triangulation Methods





Multi-stripe
Multi-frame

Single-stripe

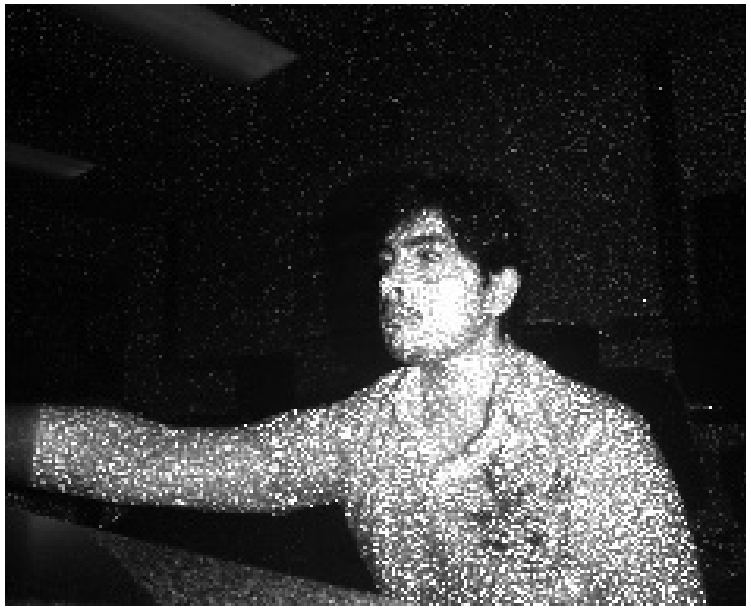
Single-frame

Slow, robust

Fast, fragile

Microsoft Kinect

Microsoft Kinect



Speckled IR Pattern

Depth map

Shape-from-Shading

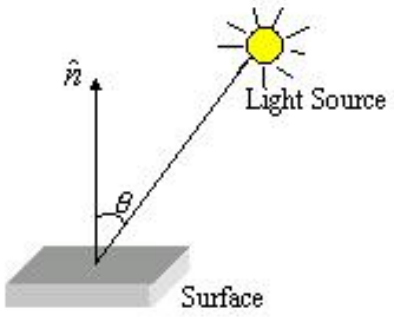
- Assumptions of Imaging model
  - Lambertian surface
  - The viewer and light source is sufficiently far from the object
  - Brightness is independent of the viewing direction

- Reflection function: $R(\hat{n}) = k \cdot \hat{n} \cdot \hat{l}$

$$R(\hat{n}) = k \cdot \cos\theta$$

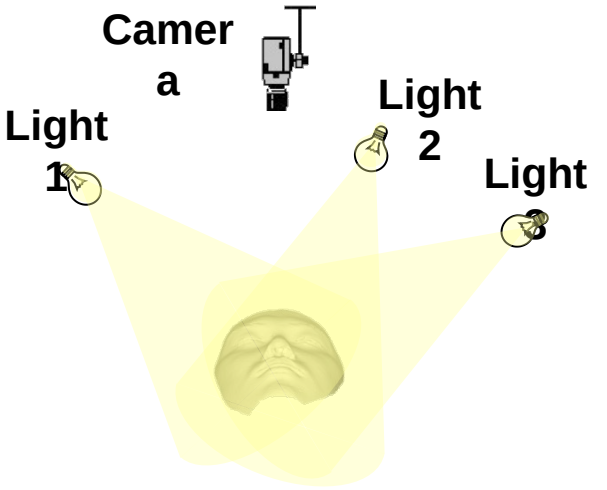
- Image irradiance equation:

$$I(x, y) = R(\hat{n})$$



Photometric Stereo

Obtain Normal-Field

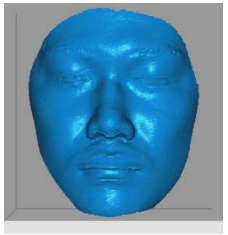


Photometric Stereo

Normal
Field

Surface from Gradient (SfG)

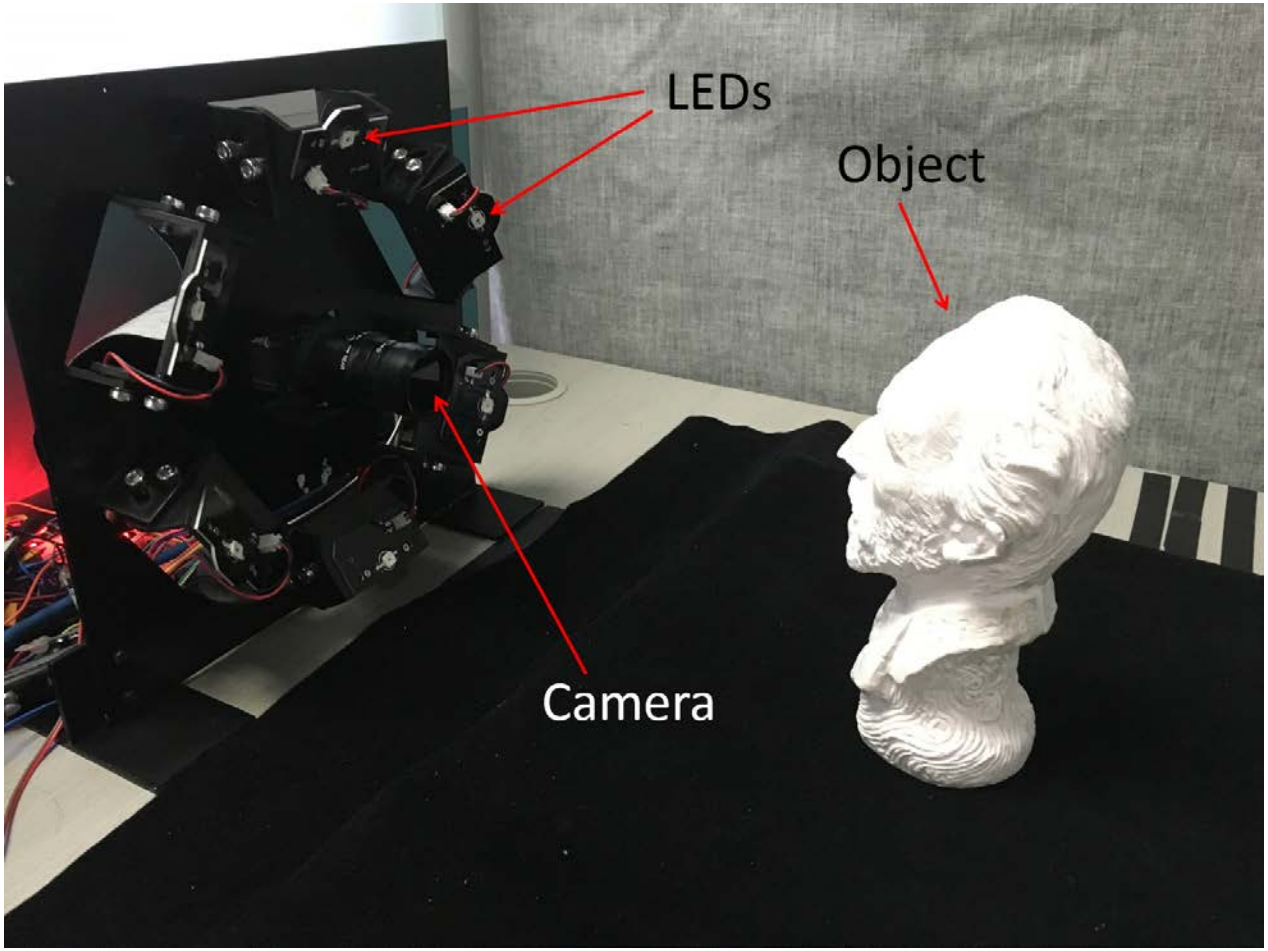
Reconstruction



"Surface-from-Gradients: An approach based on discrete geometry processing", IEEE CVPR 2014.

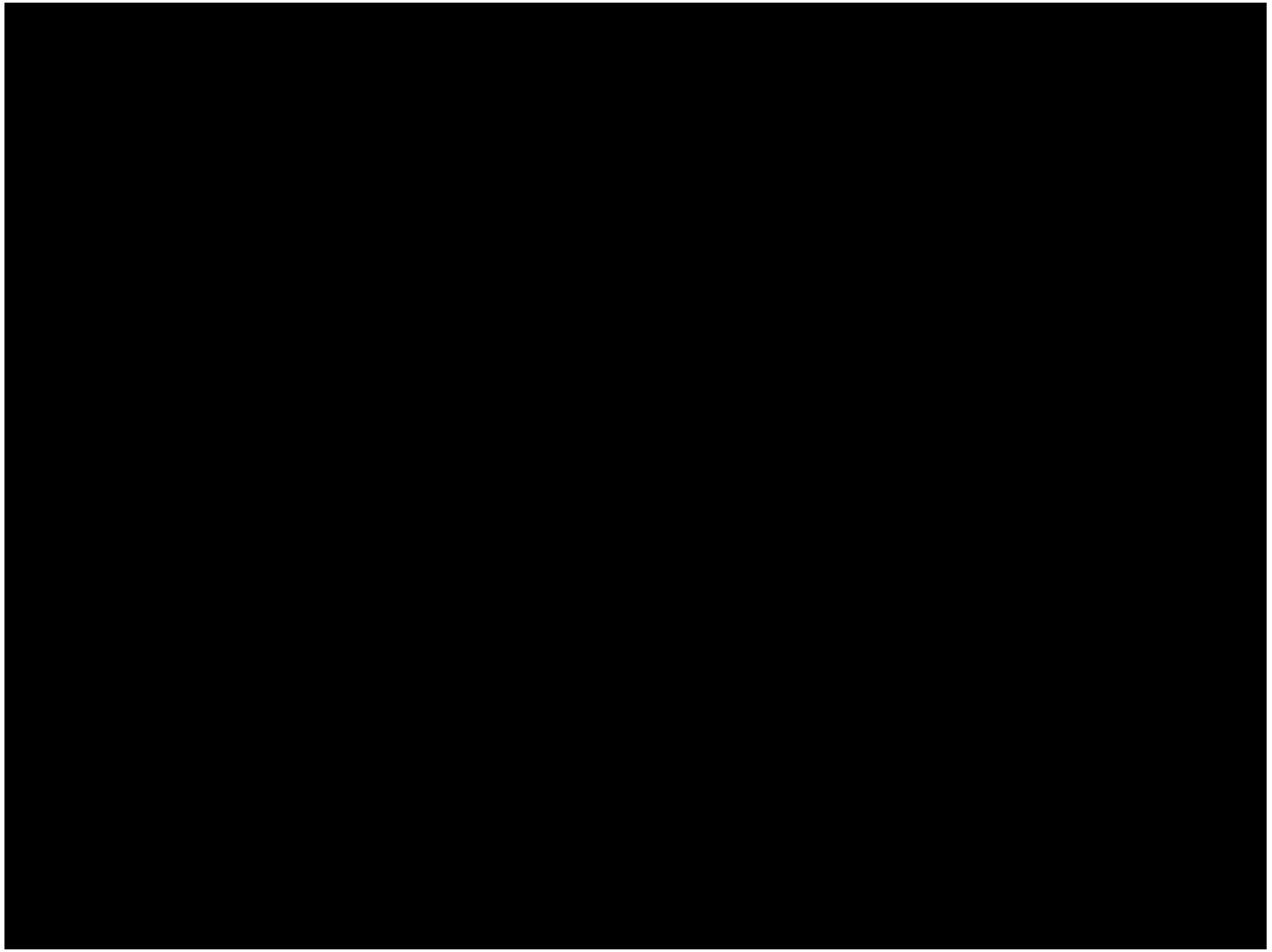
http://homepage.tudelft.nl/h05k3/Projects/CVPRReconProj.htm

Photometric Stereo with Near Point Lighting

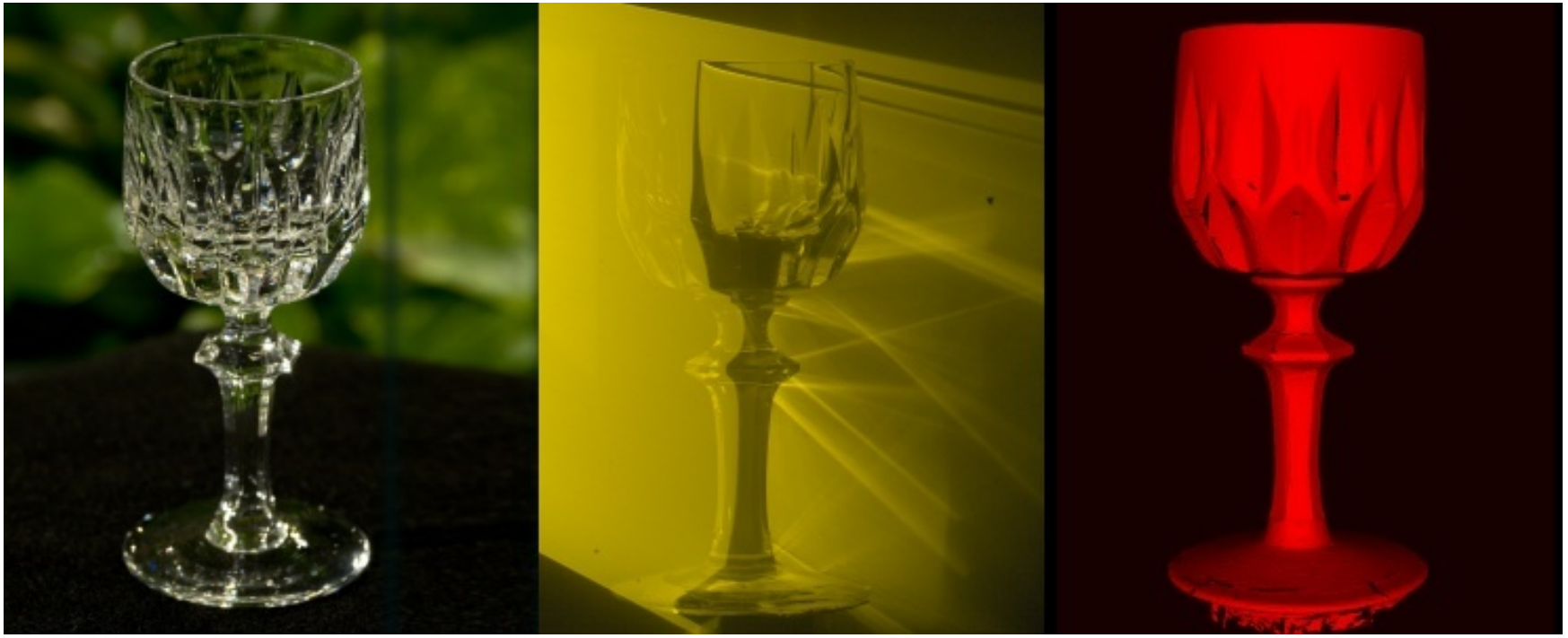


https://youtu.be/Aspm4Rsr53A

Photometric Stereo with Near Point Lighting



Fluorescent Immersion Range Scanning



http://www.mpi-inf.mpg.de/resources/FIRS/

Fluorescent Immersion Range Scanning

Dip Transform for 3D Shape Reconstruction

http://irc.cs.sdu.edu.cn/3dshape/

Dip Transform for 3D Shape Reconstruction

Dip Transform for 3D Shape Reconstruction

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