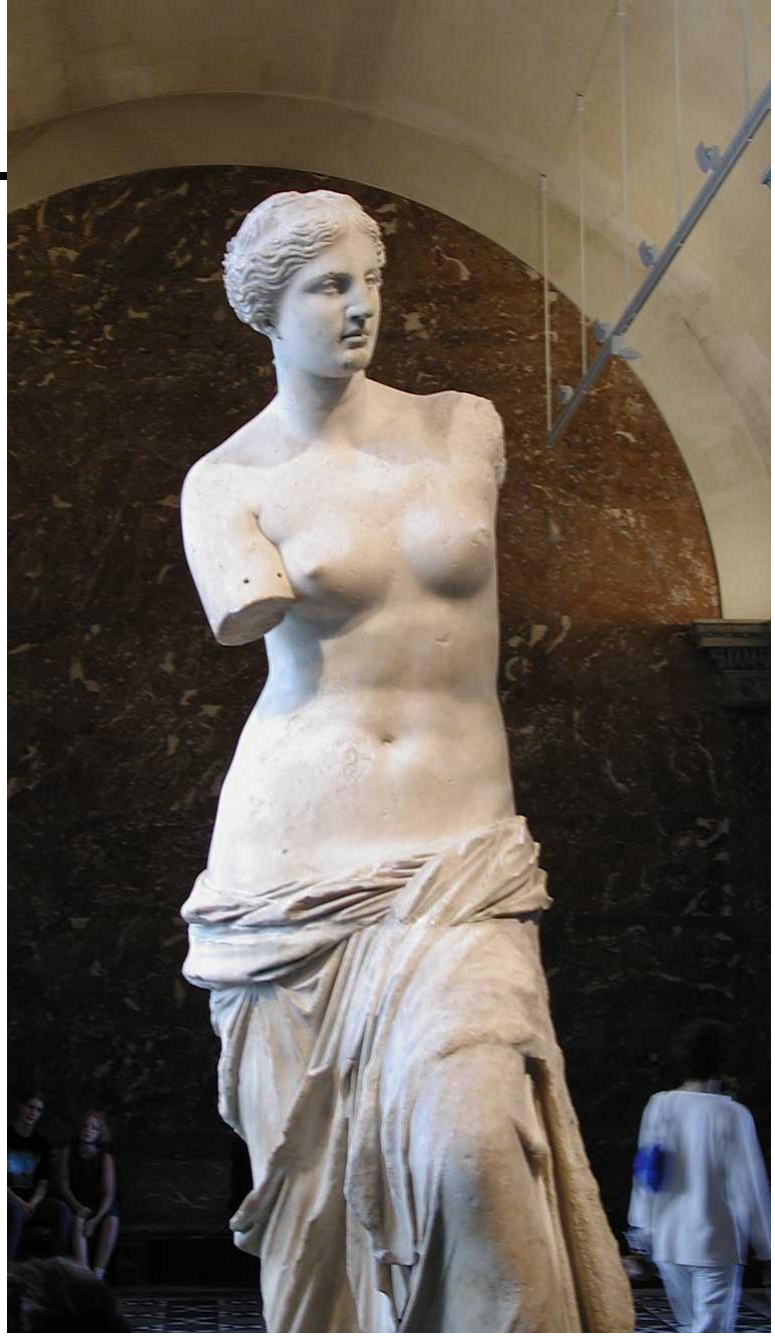
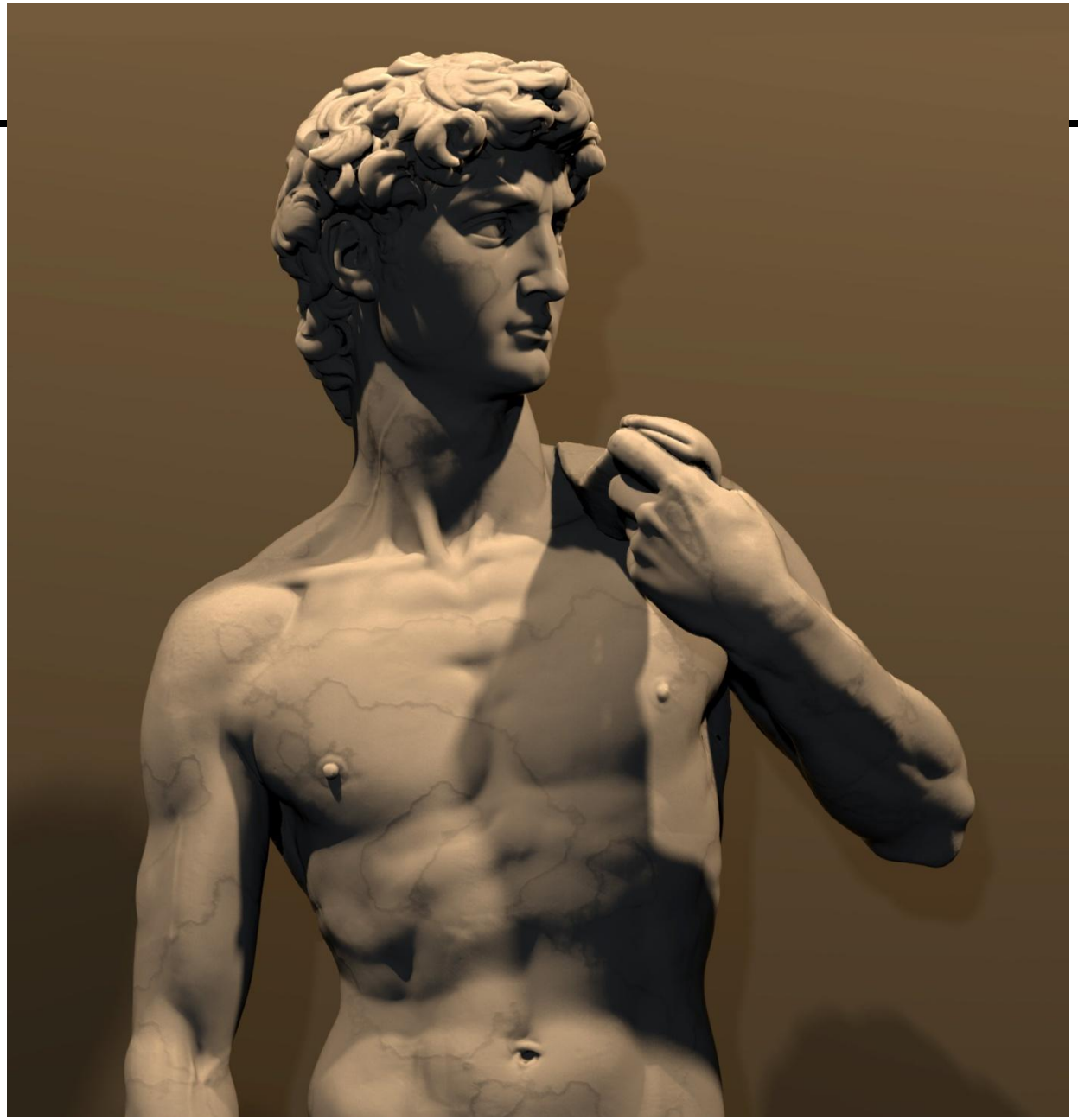
Vision Sensing

Multi-View Stereo for Community Photo Collections
Michael Goesele, et al, ICCV 2007

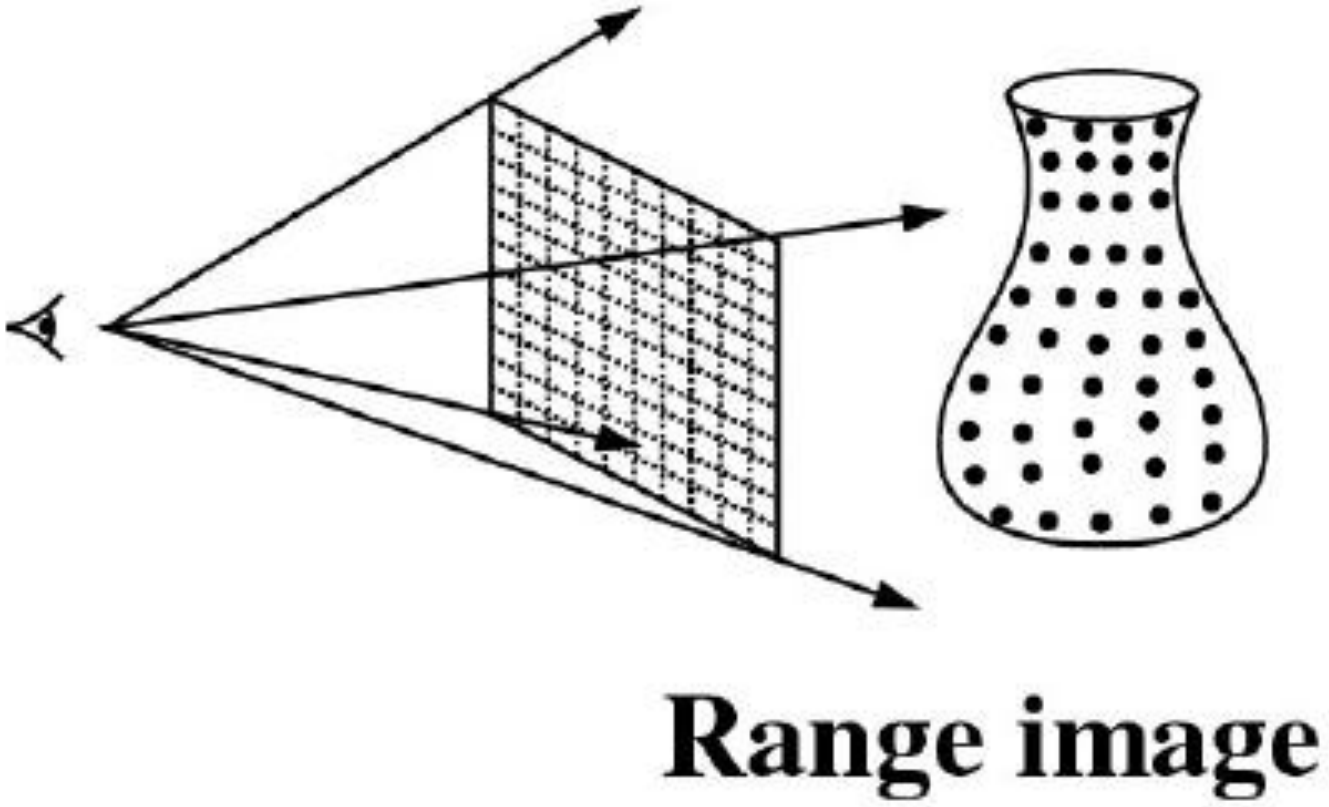


Venus de Milo



The Digital Michelangelo Project, Stanford

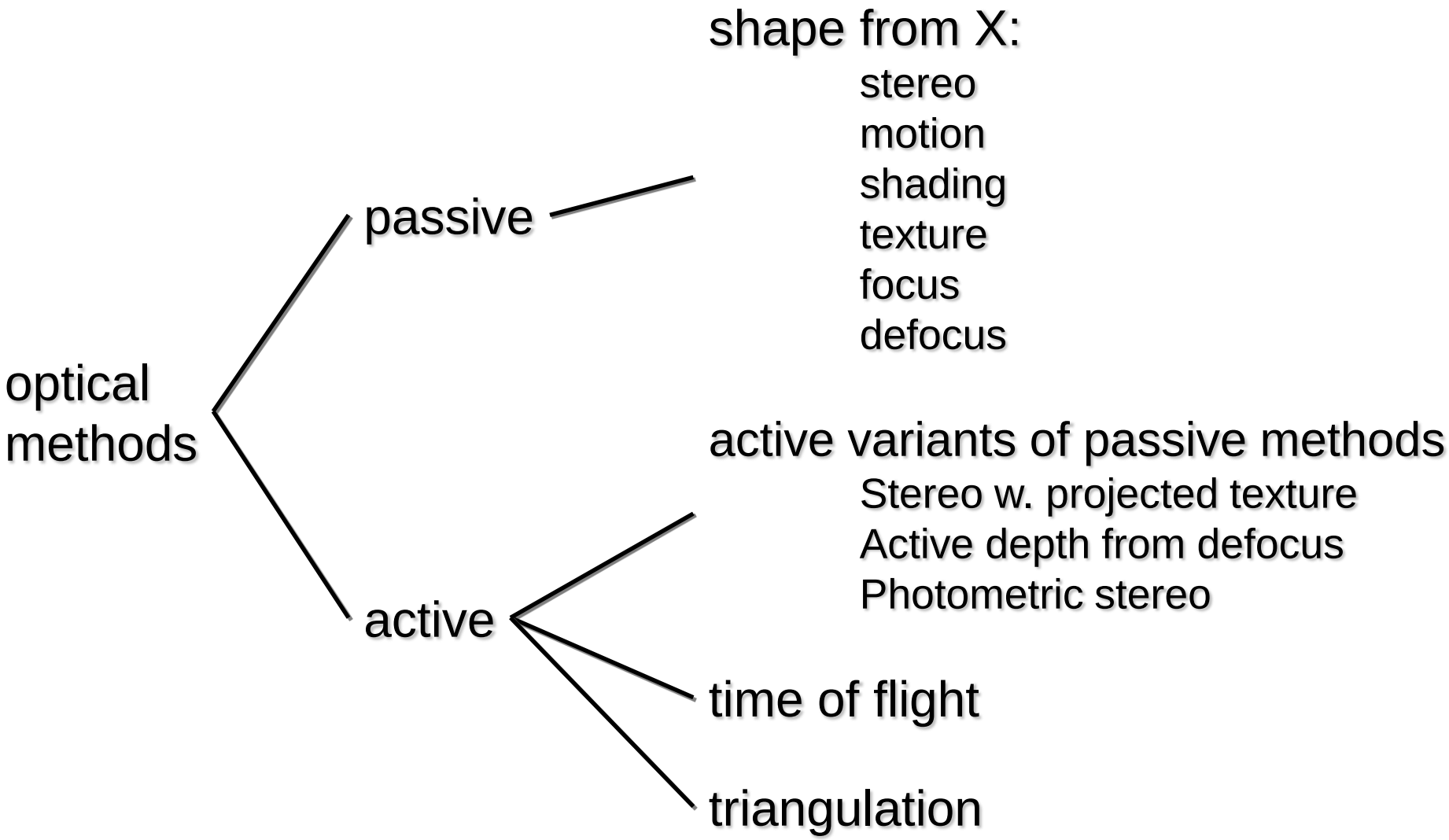
How to sense 3D very accurately?



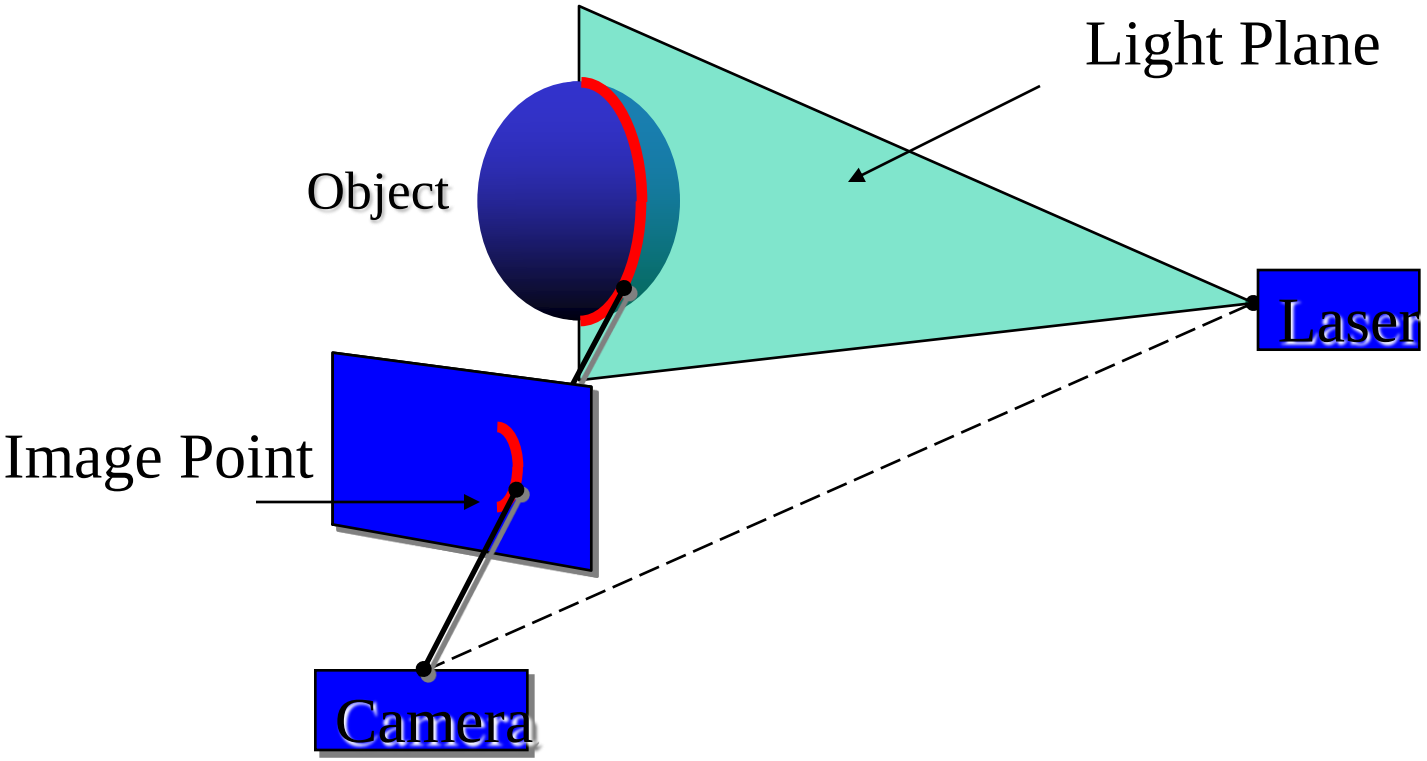
How to sense 3D very accurately?

range acquisition

- contact
  - mechanical (CMM, jointed arm)
- transmissive
  - industrial CT
  - MRI
- reflective
  - non-optical
    - radar
    - ultrasound
    - sonar
  - optical

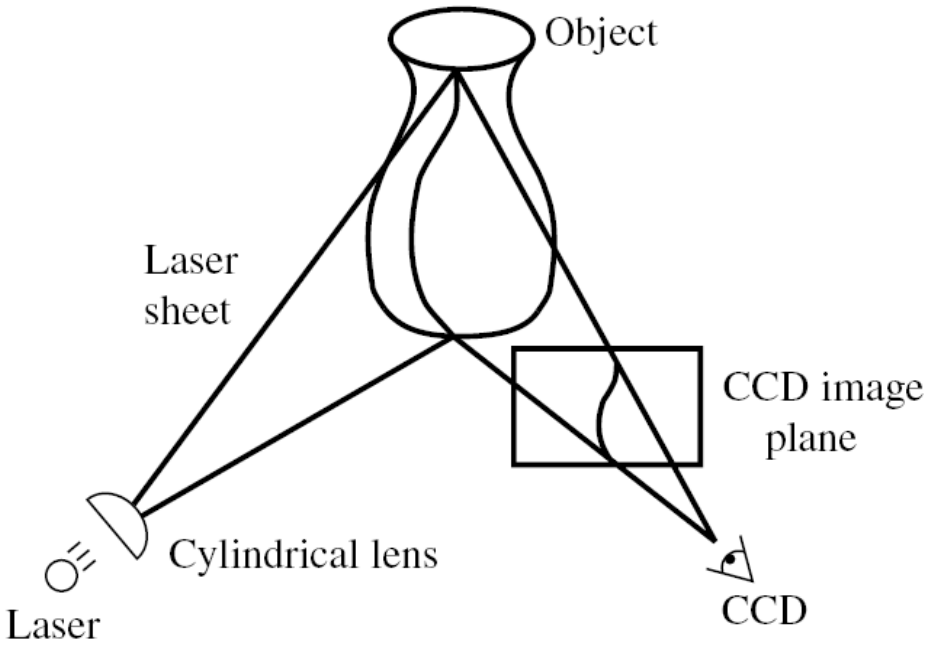

optical methods
passive
active
shape from X:
stereo
motion
shading
texture
focus
defocus
active variants of passive methods
Stereo w. projected texture
Active depth from defocus
Photometric stereo
time of flight
triangulation

Triangulation



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

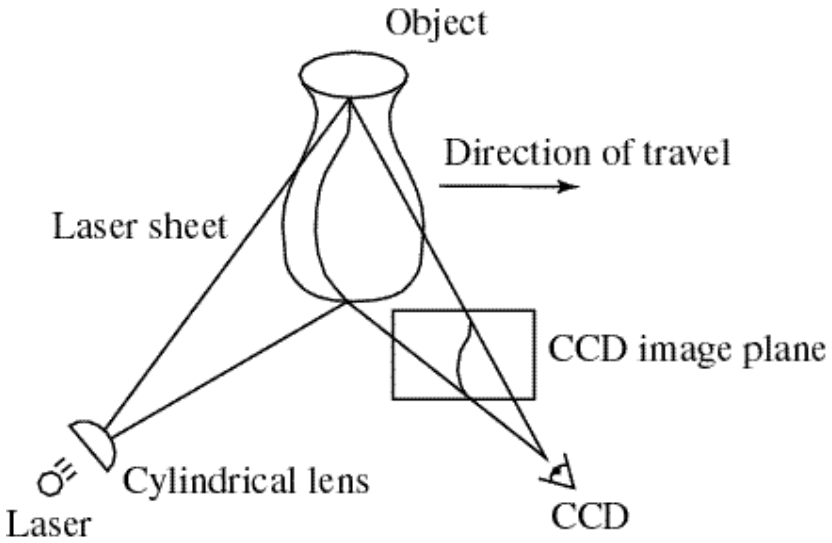
Example: Laser scanner

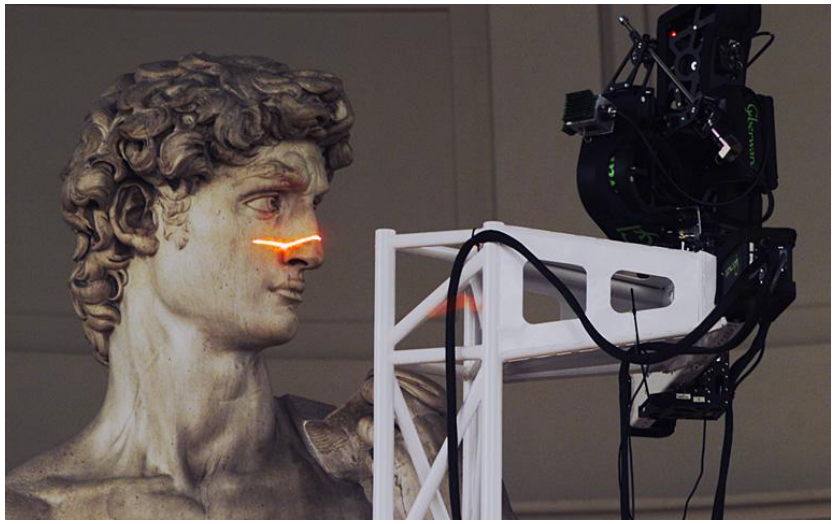


Cyberware® face and head scanner

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

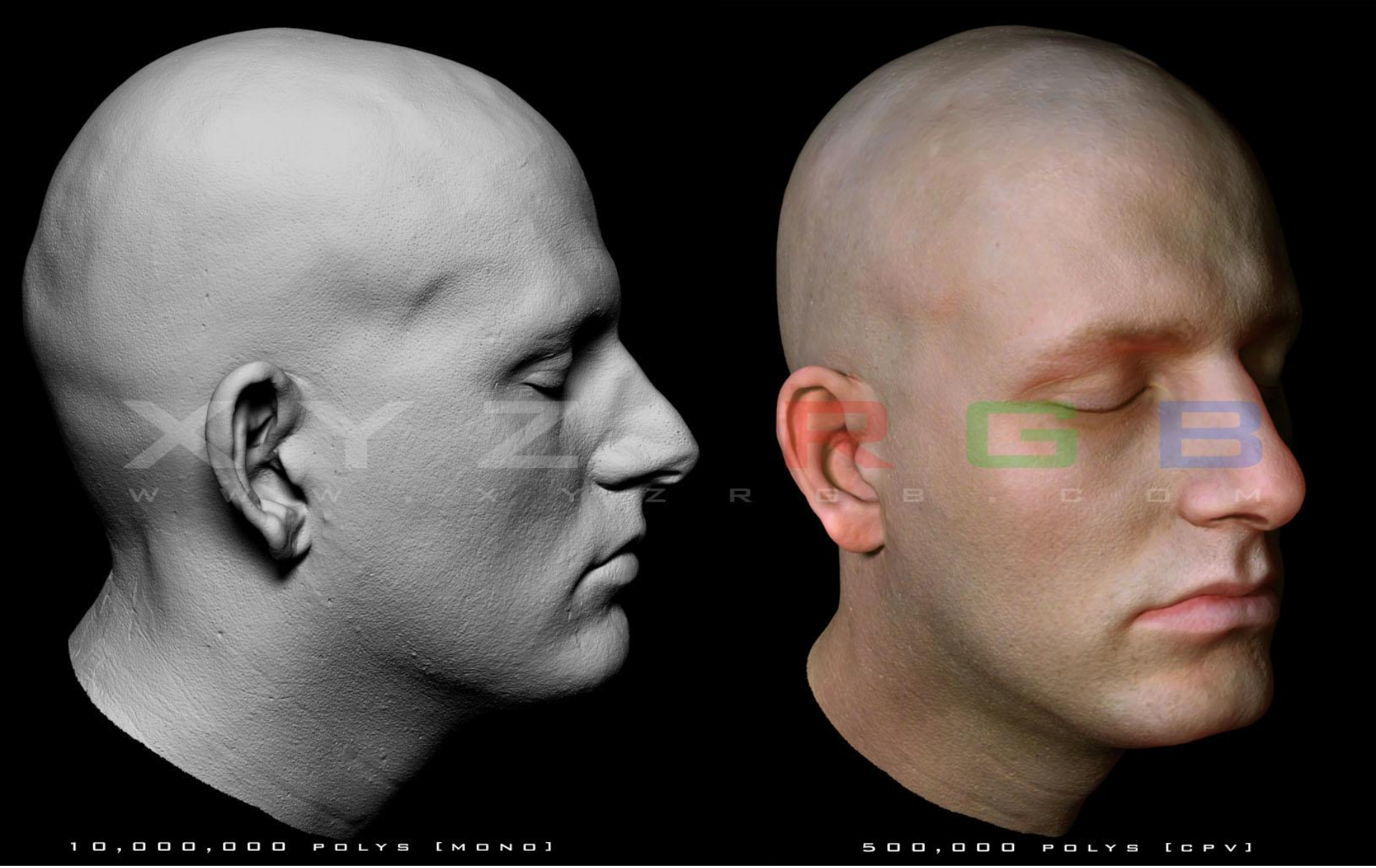
Example: Laser scanner





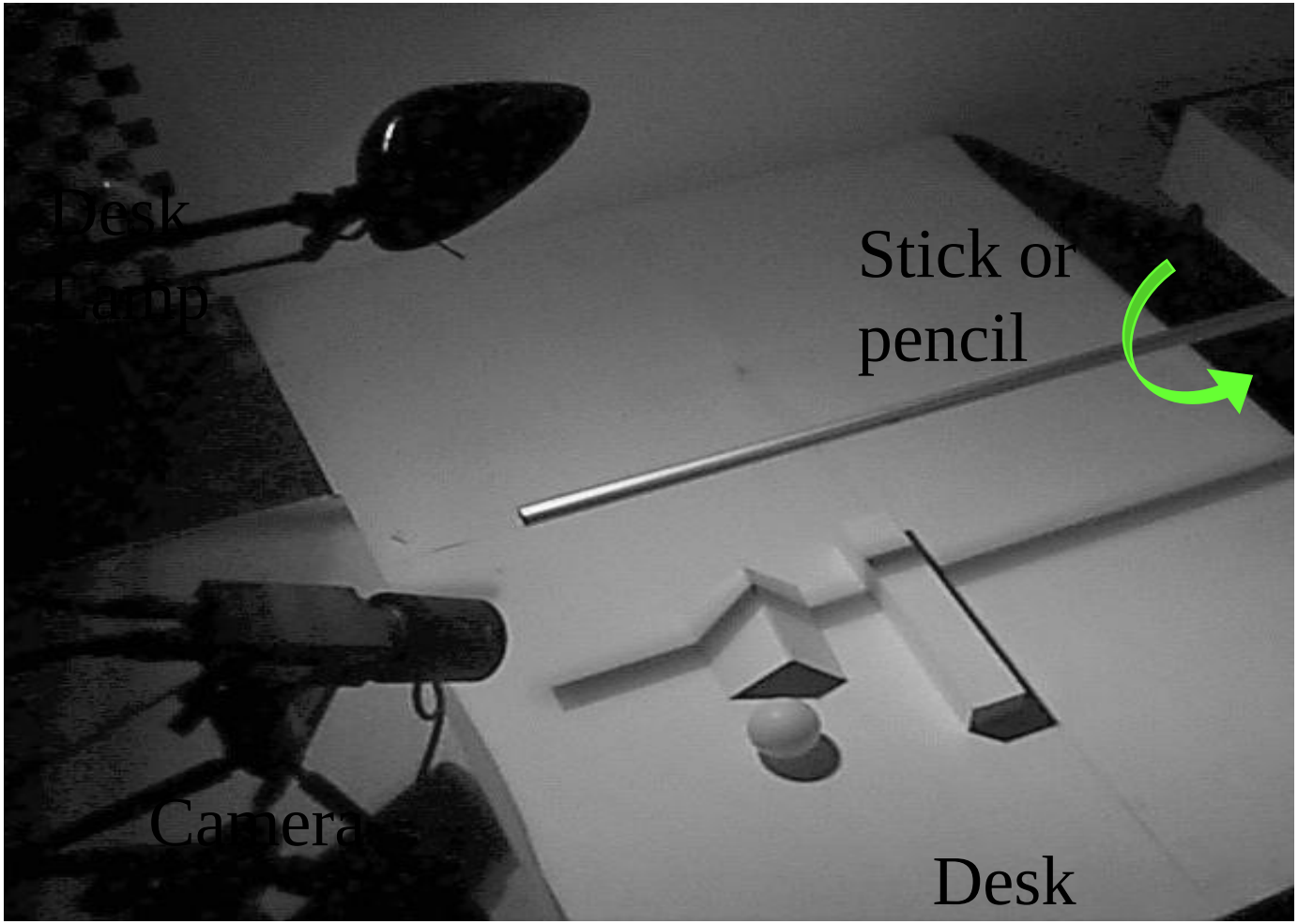
Digital Michelangelo Project

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



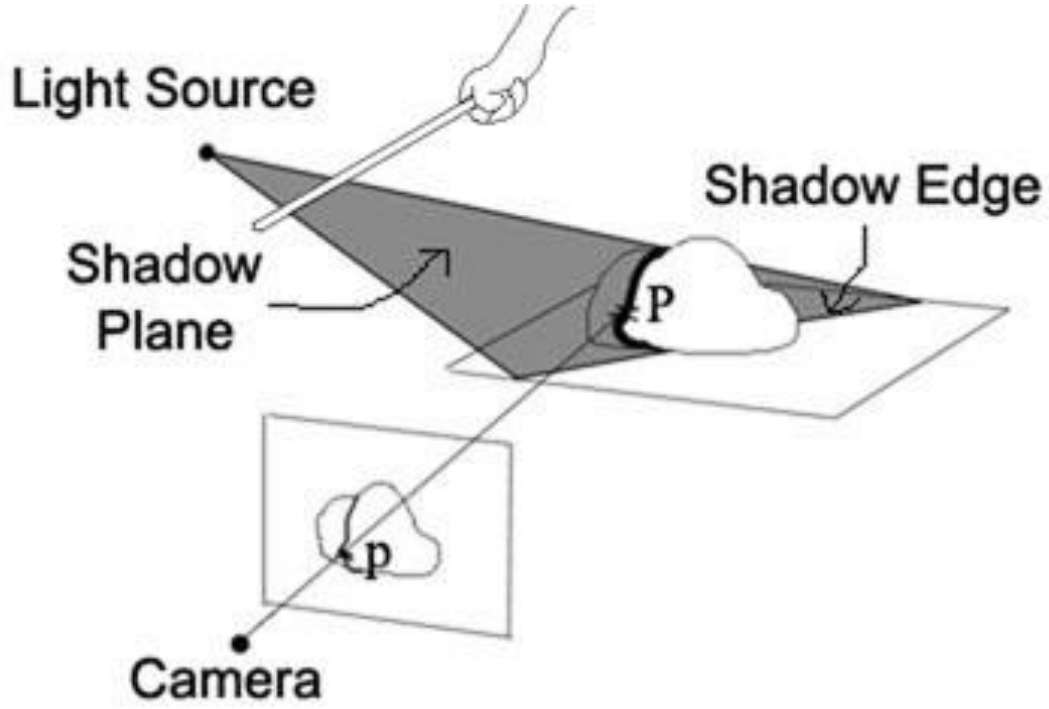
XYZRGB

Shadow scanning



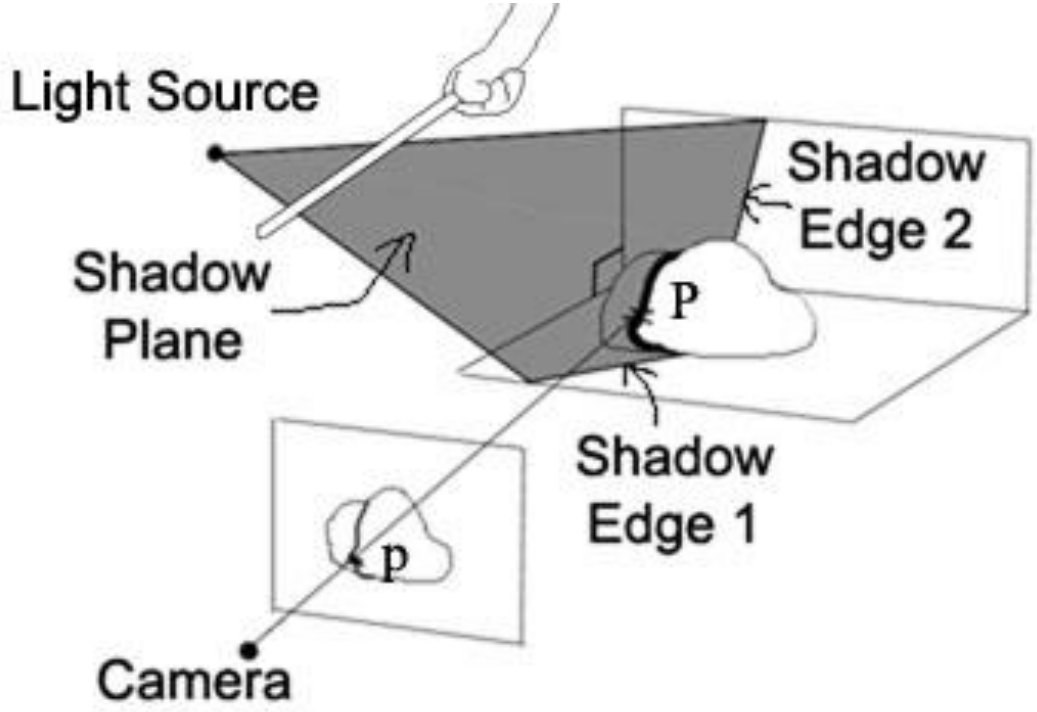
http://www.vision.caltech.edu/bouguetj/ICCV98/

Basic idea



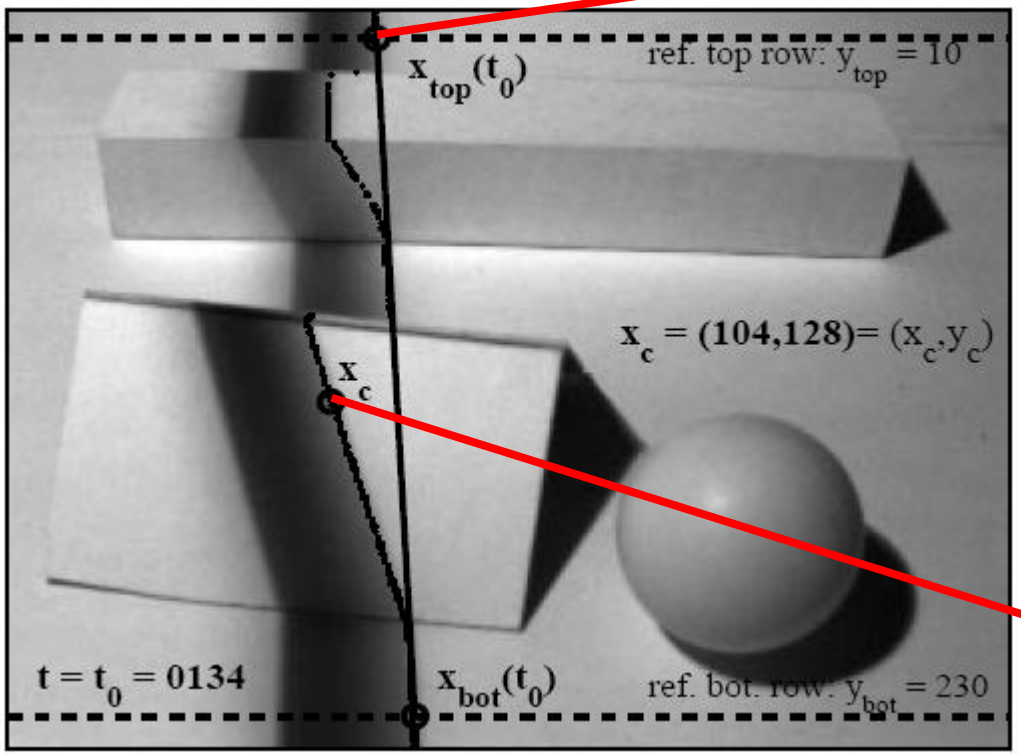
- Calibration issues:
  - where's the camera wrt. ground plane?
  - where's the shadow plane?
    - depends on light source position, shadow edge

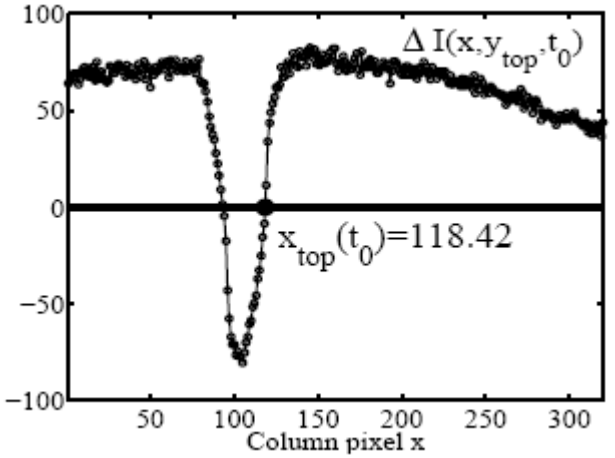
Two Plane Version

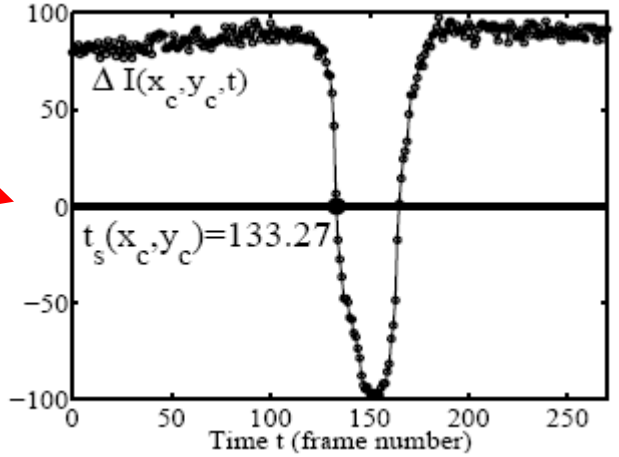


- Advantages
  - don’t need to pre-calibrate the light source
  - shadow plane determined from two shadow edges

Estimating shadow lines

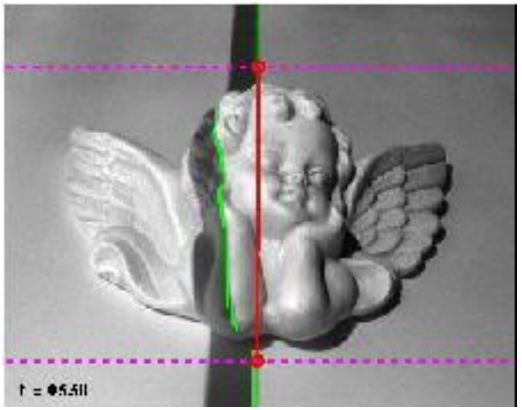


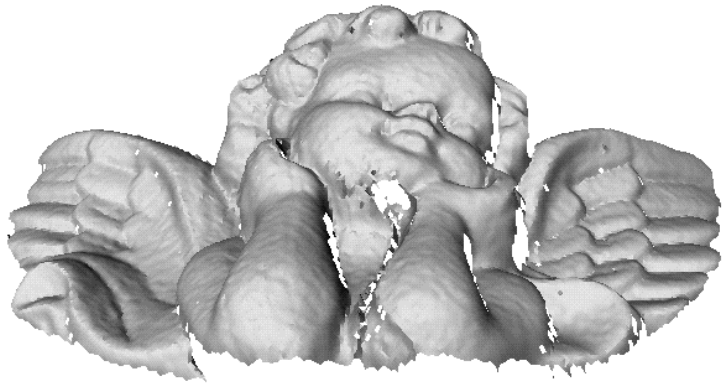




Shadow scanning in action

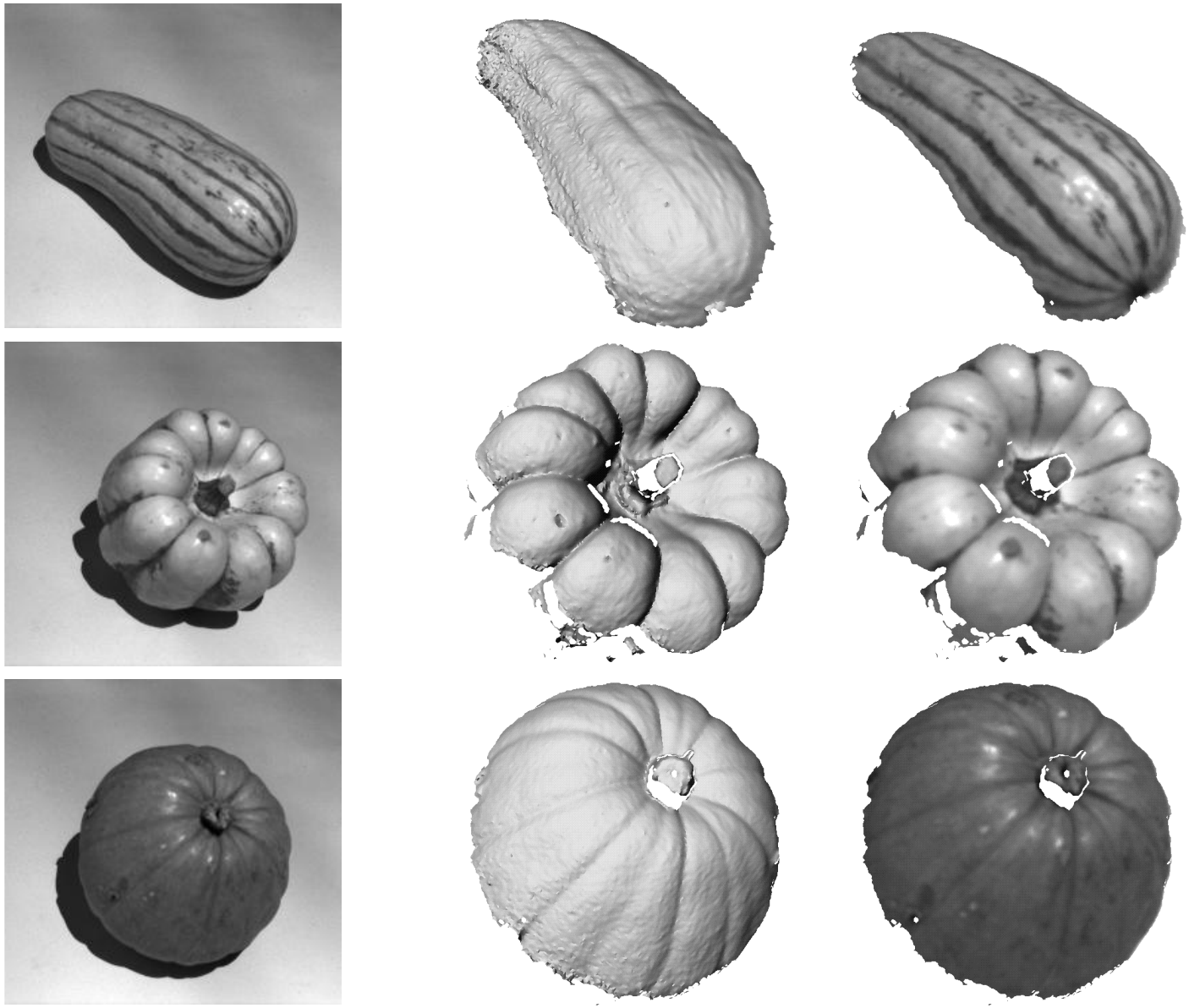
Results



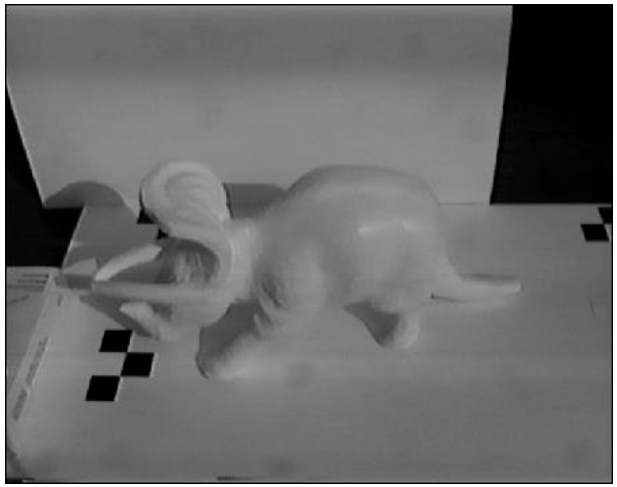


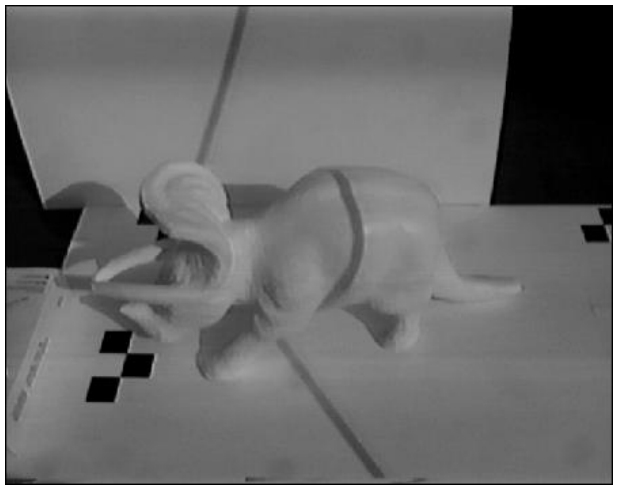
accuracy: 0.1mm over 10cm → ~ 0.1% error

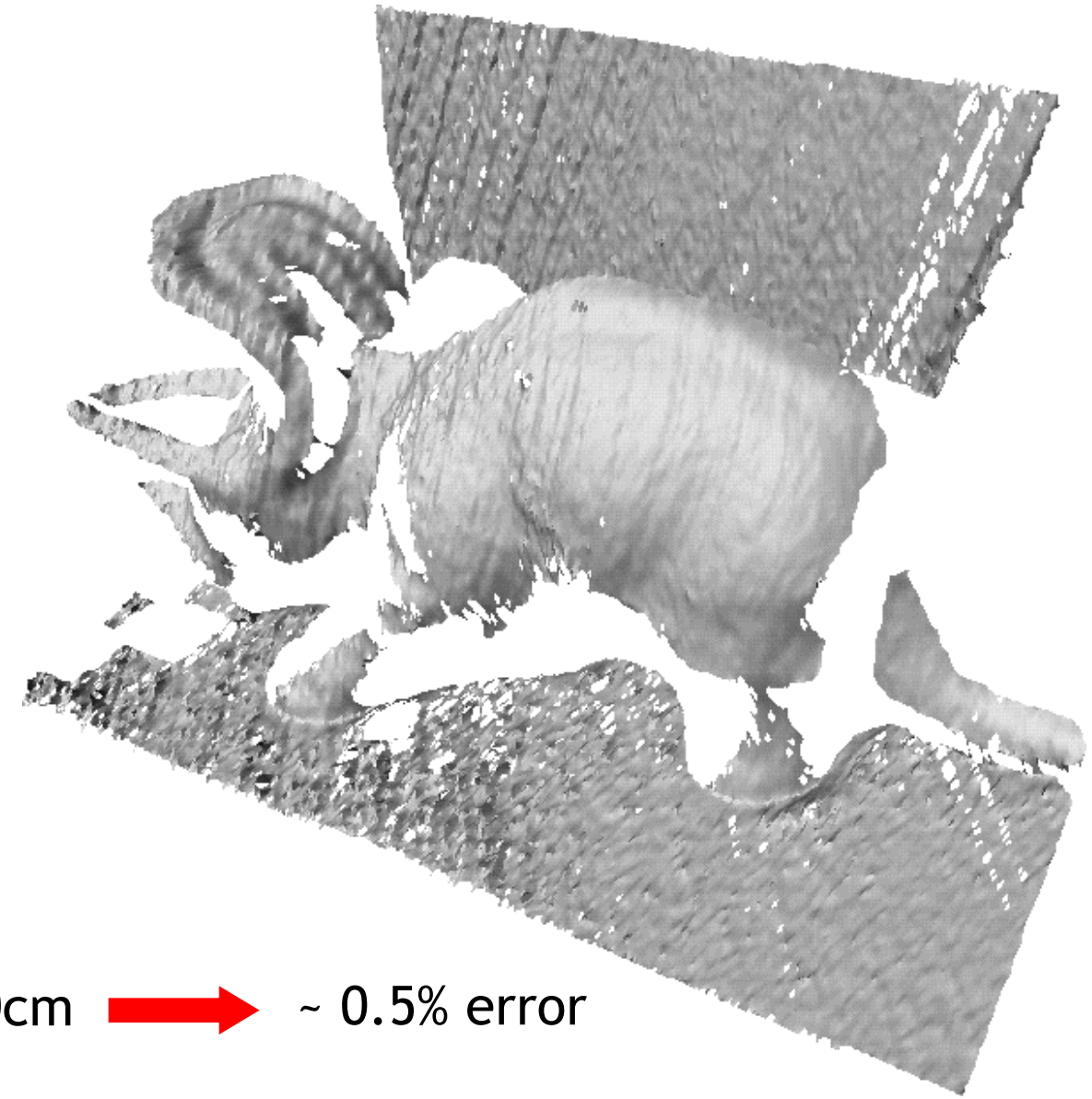
Textured objects



Scanning with the sun

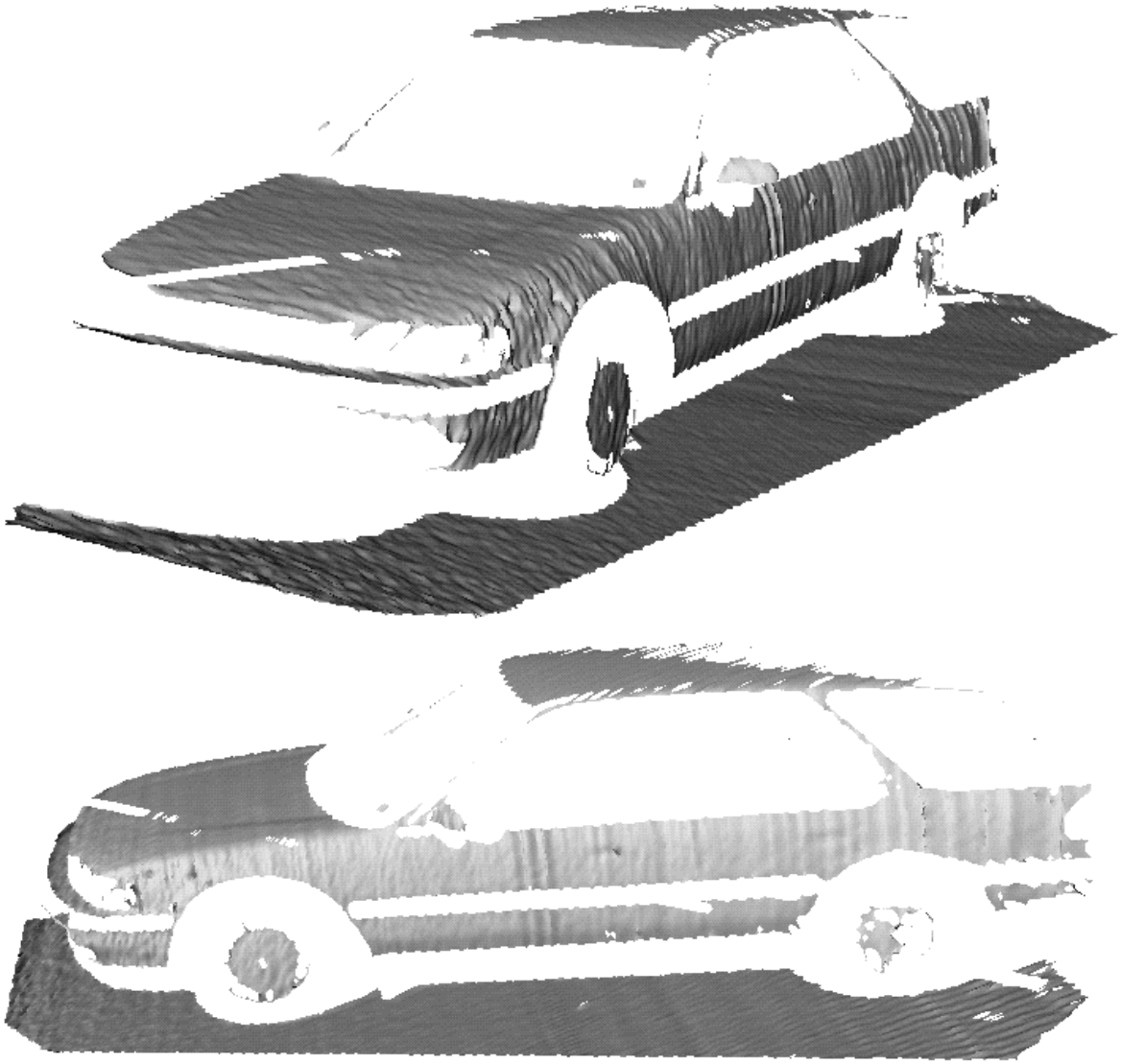






accuracy: 1mm over 50cm → ~ 0.5% error

Scanning with the sun



accuracy: 1cm over 2m

~ 0.5% error

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

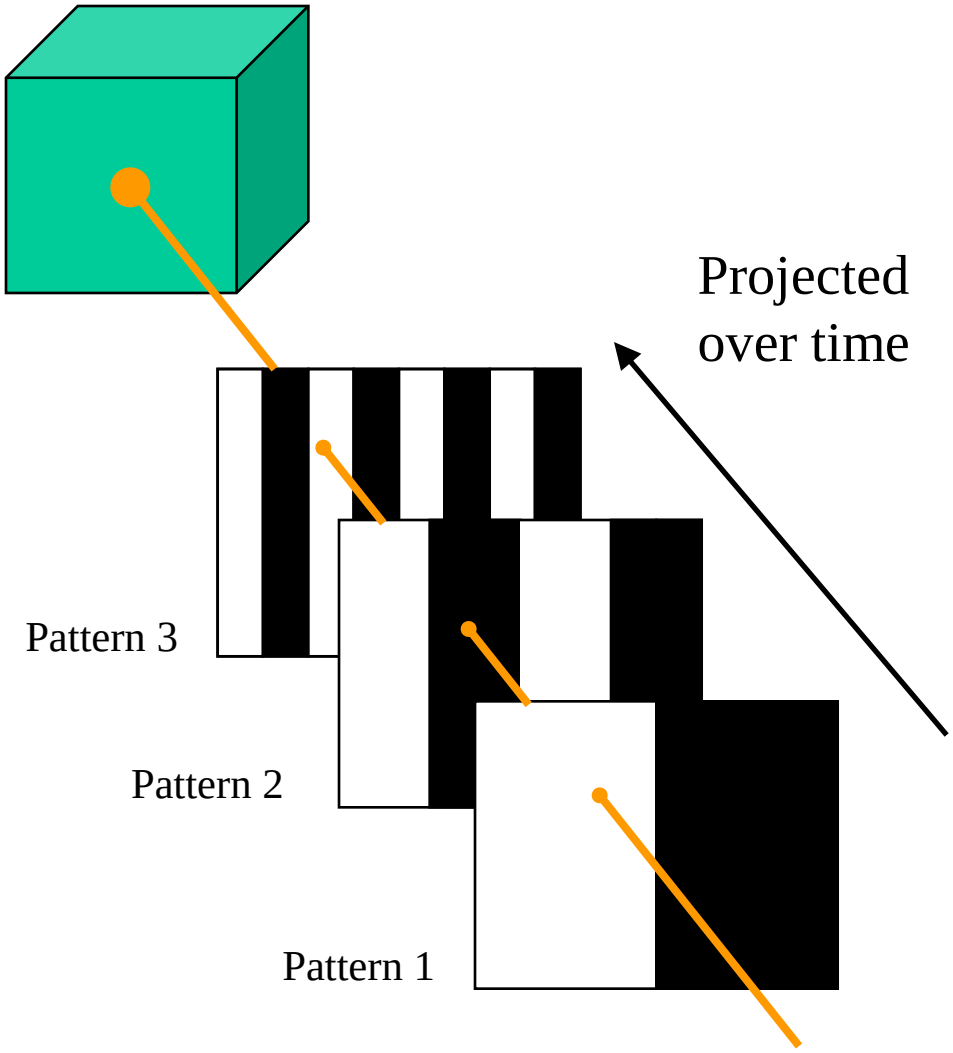
Binary Coding

Faster:

$2^n - 1$ stripes in n images.

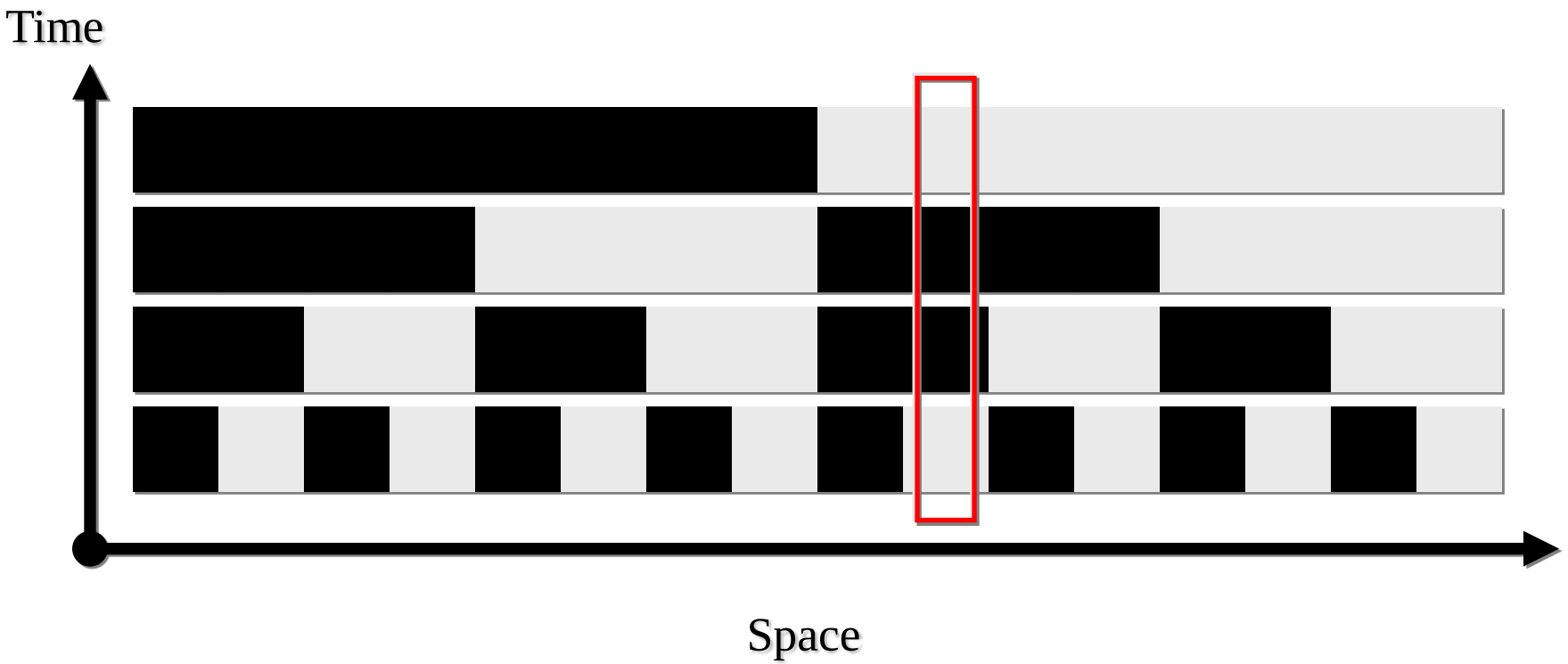
Example:

3 binary-encoded patterns which allows the measuring surface to be divided in 8 sub-regions

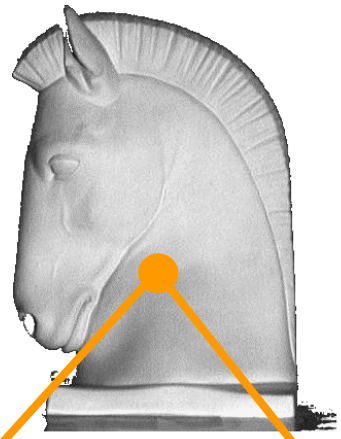


Binary Coding

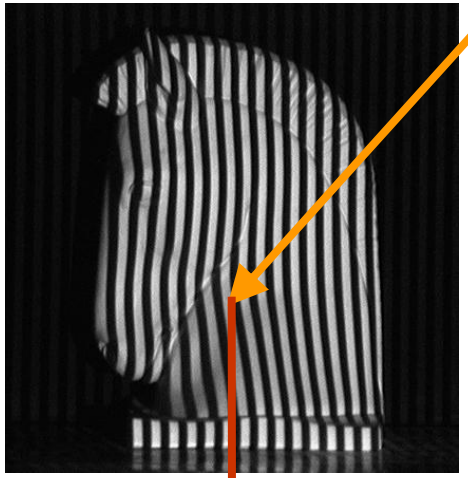
- Assign each stripe a unique illumination code over time [Posdamer 82]



Binary Coding



Example: 7 binary patterns proposed by Posdamer & Altschuler



• • •

Pattern 3

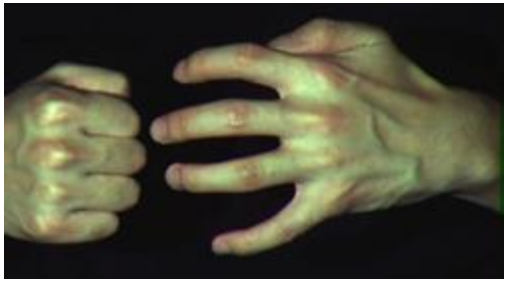
Pattern 2

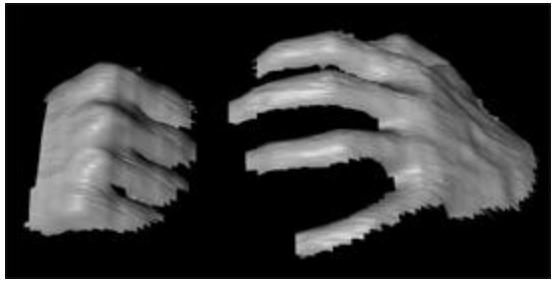
Pattern 1

Projected over time

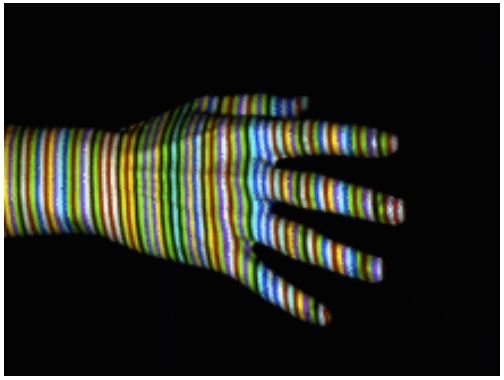
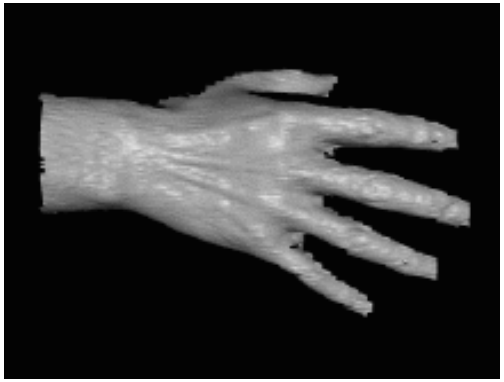
Codeword of this píxel: 1010010 → identifies the corresponding pattern stripe

More complex patterns





Works despite complex appearances

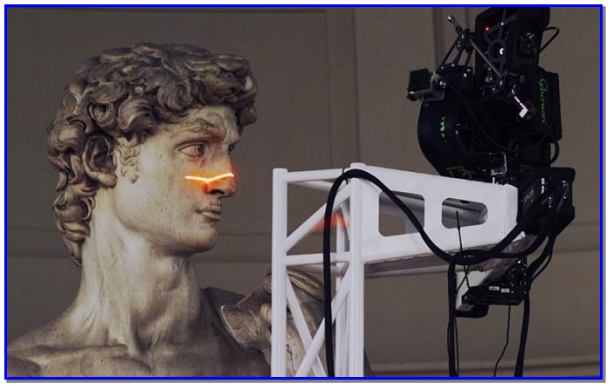



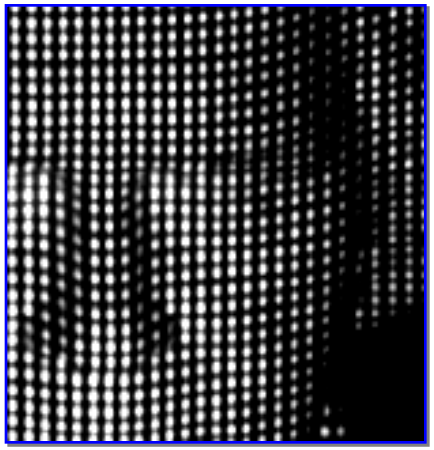
Works in real-time and on dynamic scenes

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

Zhang et a

Continuum of Triangulation Methods





Multi-stripe
Multi-frame

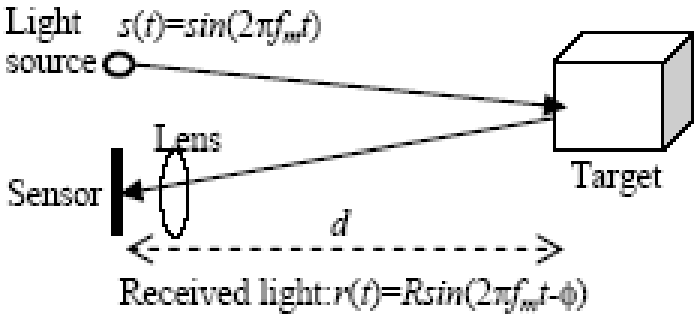
Single-stripe

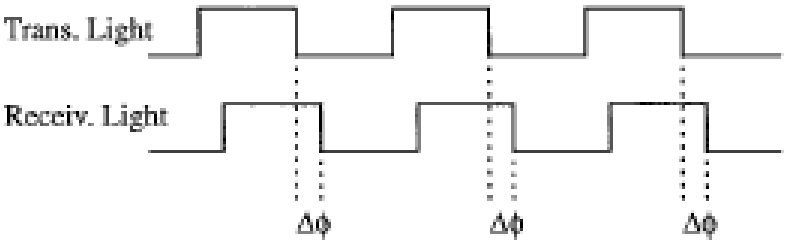
Single-frame

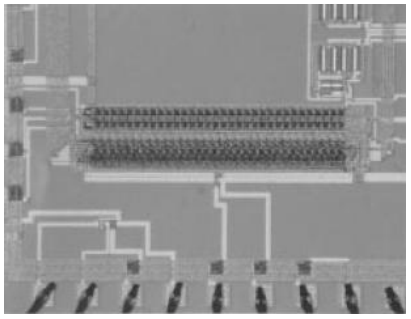
Slow, robust

Fast, fragile

Time-of-flight







+ No baseline, no parallax shadows
+ Mechanical alignment is not as critical
– Low depth accuracy
– Single viewpoint capture

Miyagawa, R., Kanade, T., "CCD-Based Range Finding Sensor", IEEE Transactions on Electron Devices, 1997

Working Volume: 1500mm - Accuracy: 7%

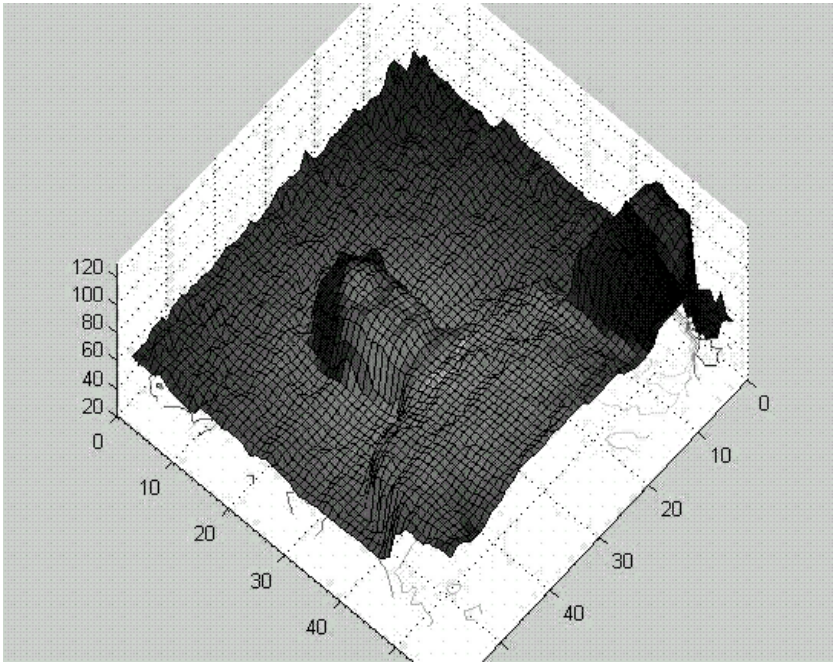
Spatial Resolution: 1x32- Speed: ??

Comercial products

Canesta

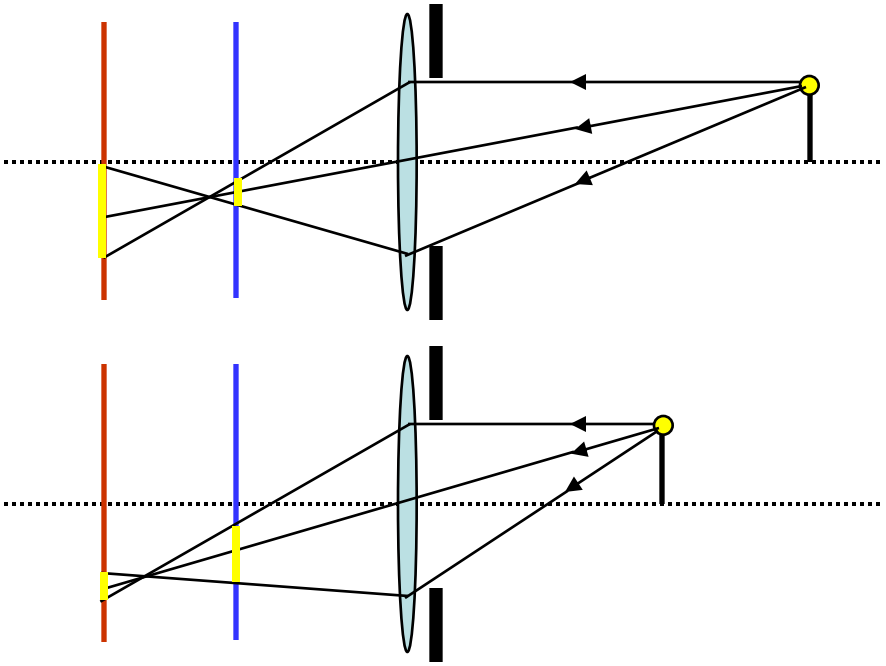
64x64@30hz
Accuracy 1-2cm

Not accurate enough for face modeling, but good enough for layer extraction.

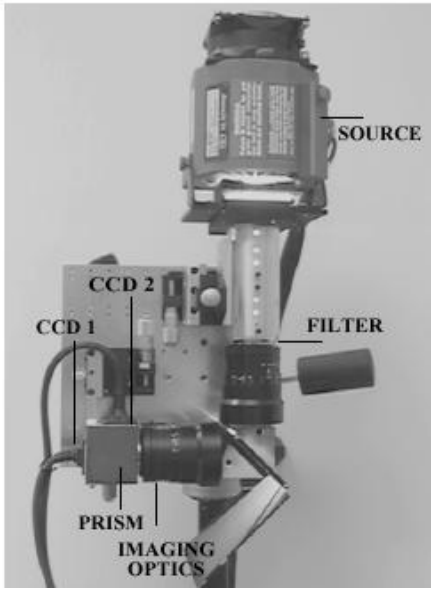


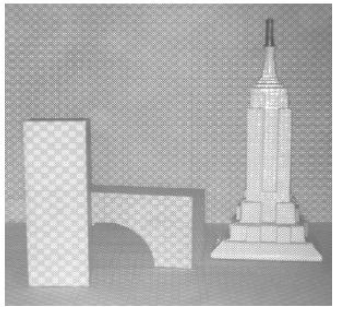
Depth from Defocus

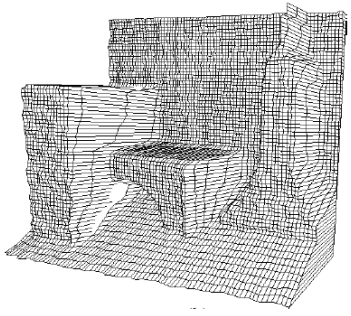
Depth from Defocus



Depth from Defocus







+ Hi resolution and accuracy, real-time
– Customized hardware
– Single view capture?

Nayar, S.K., Watanabe, M., Noguchi, M., “Real-Time Focus Range Sensor”, ICCV 1995

Working Volume: 300mm - Accuracy: 0.2%

Spatial Resolution: 512x480 - Speed: 30Hz

Capturing and Modeling Appearance

Computer Vision

Underwater Imaging

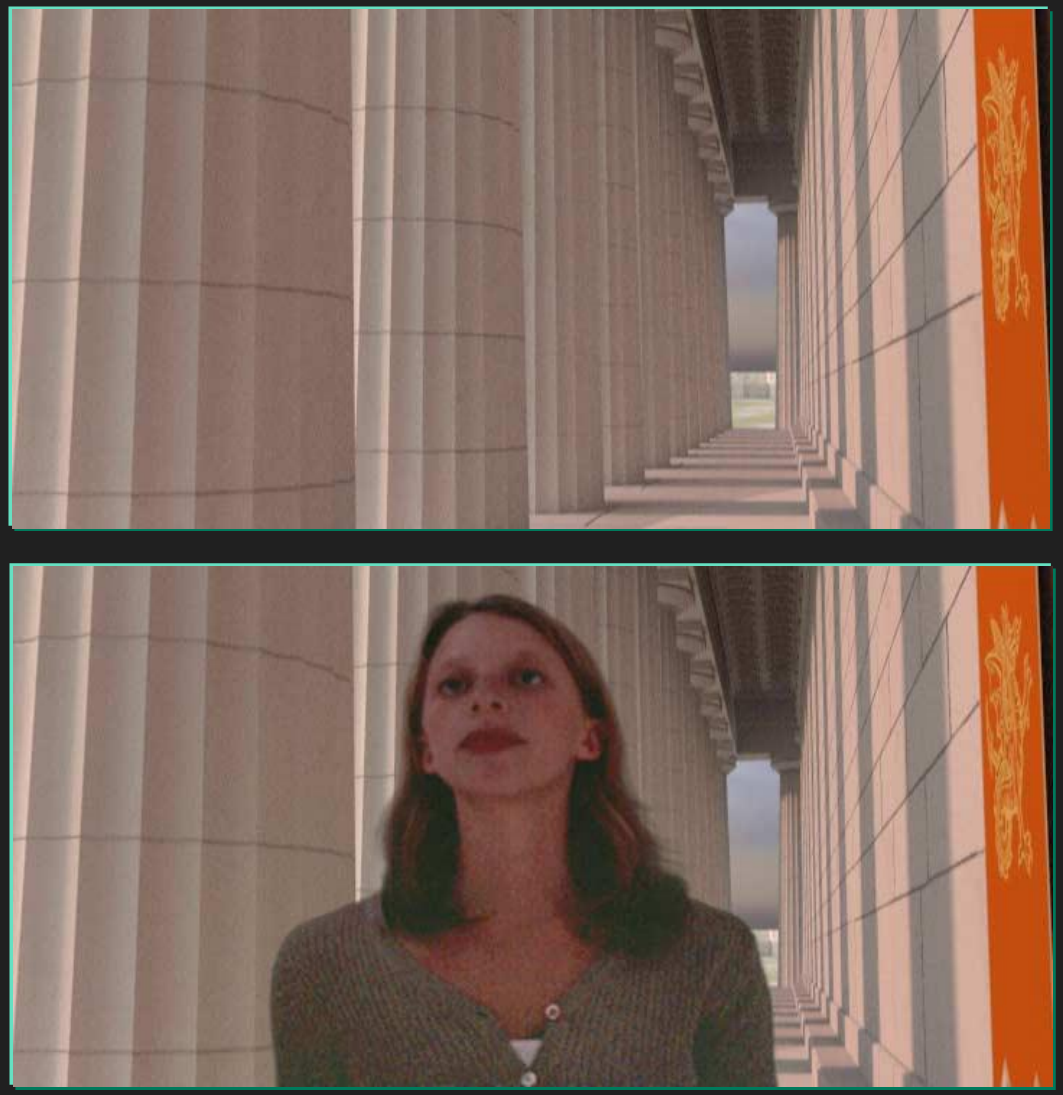
Appearance

Computer Graphics

Medical Imaging

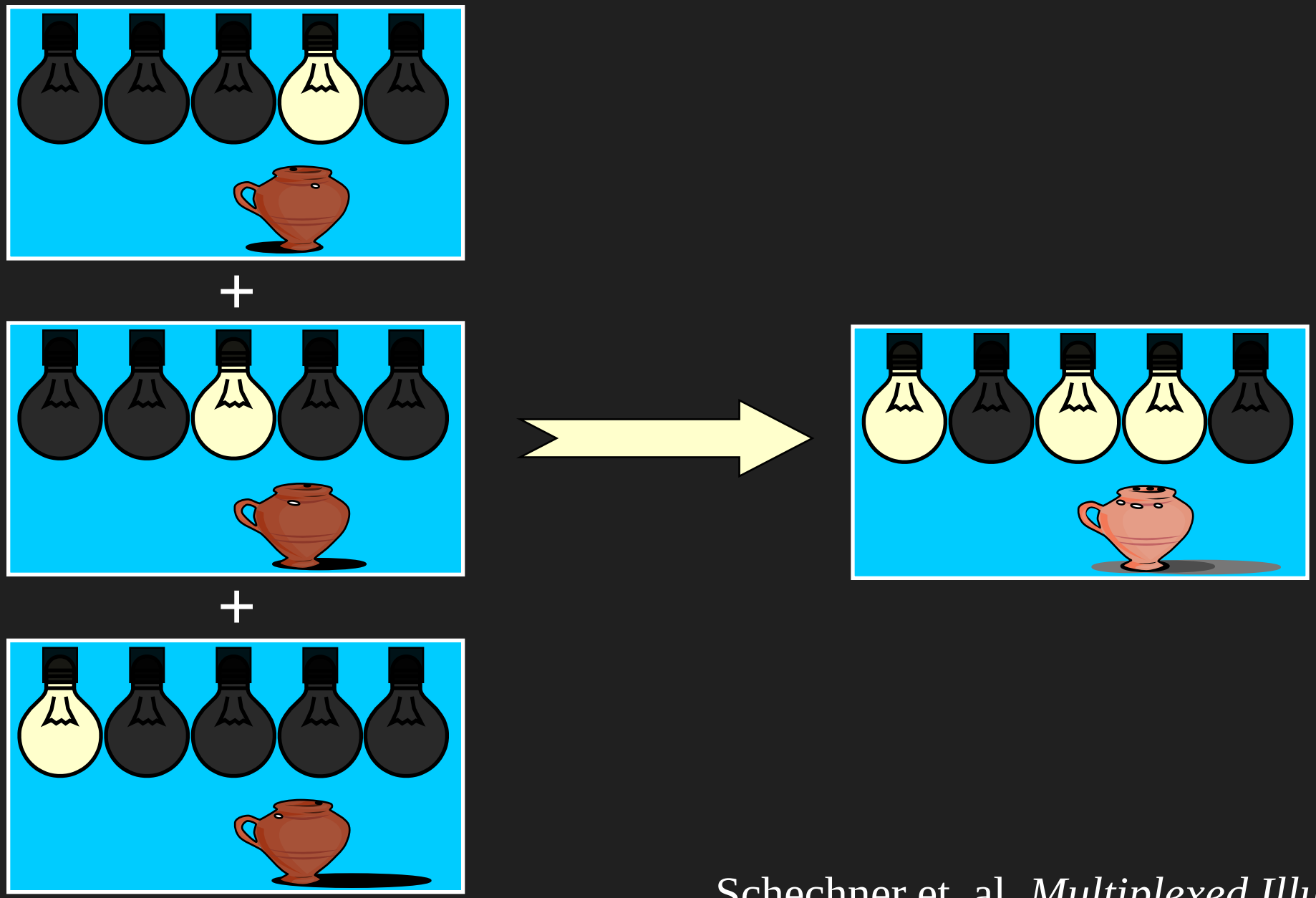
Satellite Imaging

Capture Face Appearance



Debevec, Siggraph 2002

Image-Based Rendering / Recognition



Schechner et. al. *Multiplexed Illum*

Paul Debevec's Light Stage 3

Light Stage Data

Original Resolution: 64×32

Lighting through image recombination: Haeberli ‘92, Nimeroff ‘94, Wong ‘97

Shape Recovery

BRDF

Material Recognition

Human Vision

Rendering

Object / Face Recognition

Georghiades, Belhumeur & Kriegman
Yale Face Database B