Computer Vision

Spring 2006 15-385,-685

Instructor: S. Narasimhan

Wean 5403
T-R 3:00pm – 4:20pm

Lecture #17

Structured Light + Range Imaging

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(Thanks to Slides from Levoy, Rusinkiewicz, Bouguet, Perona)

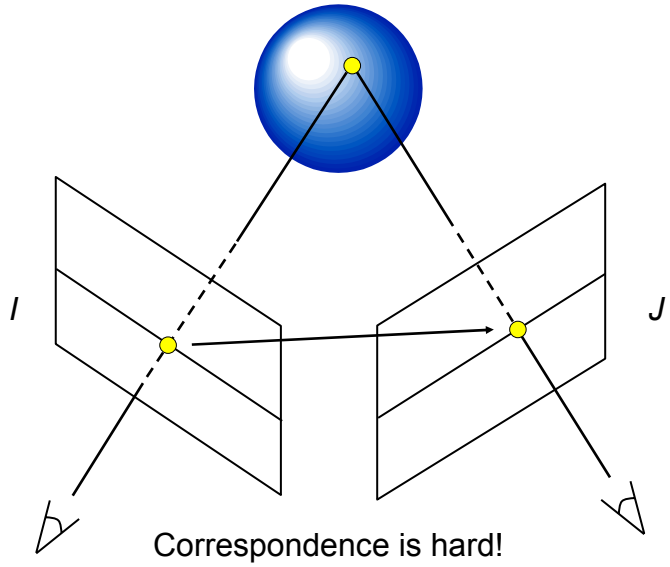
3D Scanning

Structured Light Reconstruction

- Avoid problems due to correspondence
- Avoid problems due to surface appearance
- Much more accurate
- Very popular in industrial settings

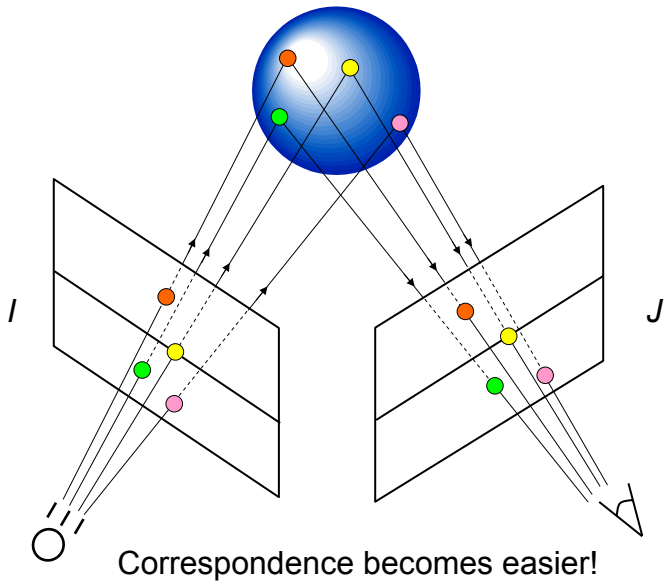
- Reading:
  - Marc Levoy's webpages (Stanford)
  - Katsu Ikeuchi's webpages (U Tokyo)
  - Peter Allen's webpages (Columbia)

Stereo Triangulation



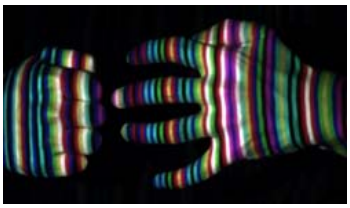
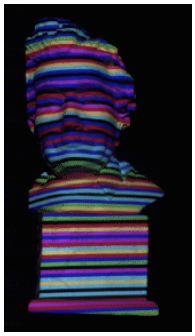
Correspondence is hard!

Structured Light Triangulation



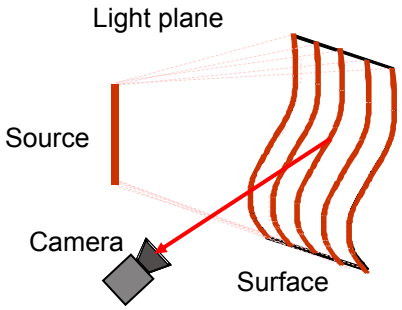
Correspondence becomes easier!

Structured Light

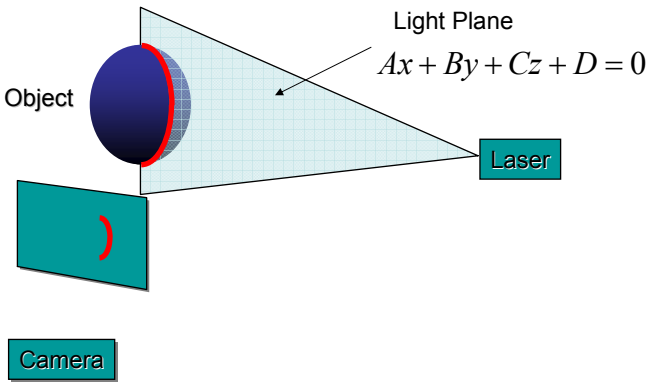
- Any spatio-temporal pattern of light projected on a surface (or volume).
- Cleverly illuminate the scene to extract scene properties (eg., 3D).
- Avoids problems of 3D estimation in scenes with complex texture/BRDFs.
- Very popular in vision and successful in industrial applications (parts assembly,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

Light Stripe Scanning – Single Stripe



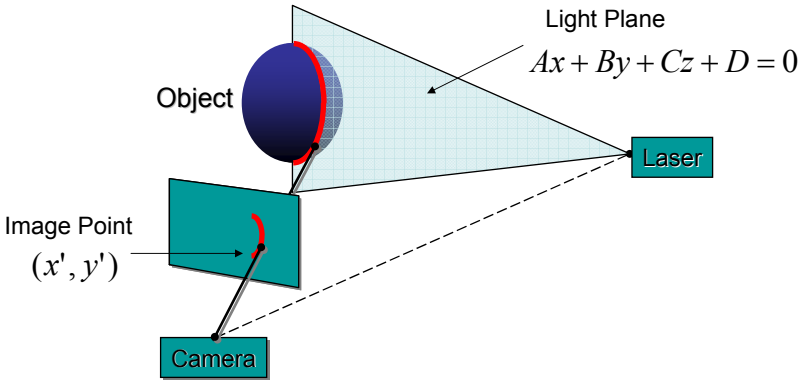
- Optical triangulation
  - Project a single stripe of laser light
  - Scan it across the surface of the object
  - This is a very precise version of structured light scanning
  - Good for high resolution 3D, but needs many images and takes time

Triangulation



- Project laser stripe onto object

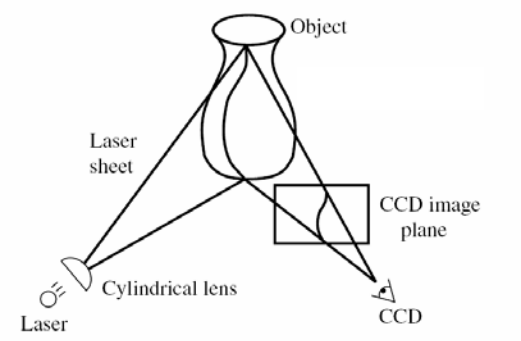
Triangulation



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

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

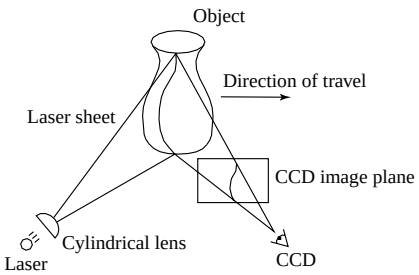
Example: Laser scanner

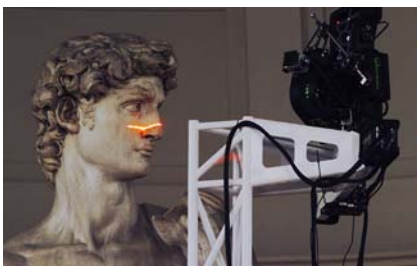


Cyberware® face and head scanner

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

Example: Laser scanner





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

Portable 3D laser scanner (this one by Minolta)

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

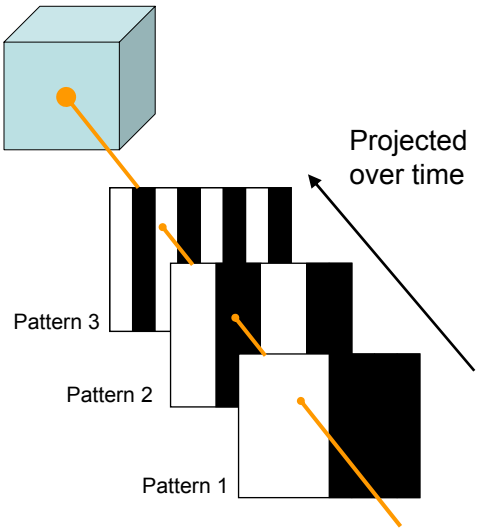
Binary Coding

Faster:

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

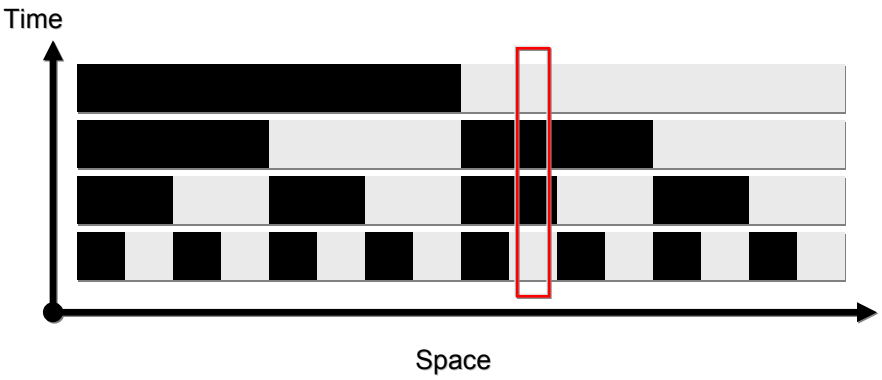
Example:

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

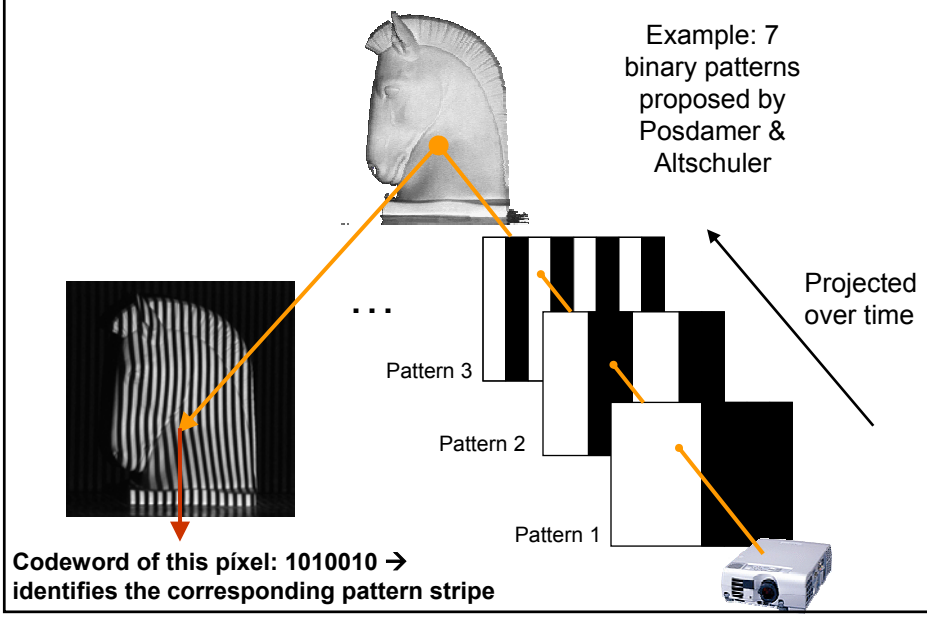


Binary Coding

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

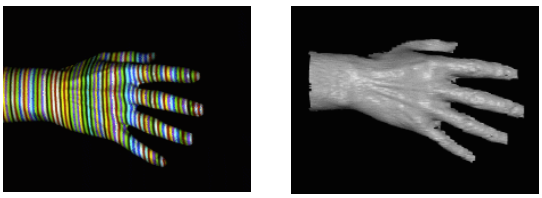


Binary Coding



More complex patterns

Works despite complex appearances

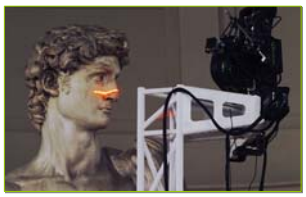


Works in real-time and on dynamic scenes

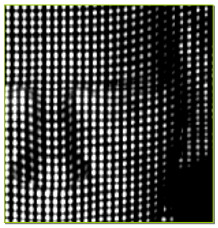
- Need very few images (one or two).
- But needs a more complex correspondence algorithm

Zhang et al

Continuum of Triangulation Methods



Multi-stripe
Multi-frame



Single-stripe

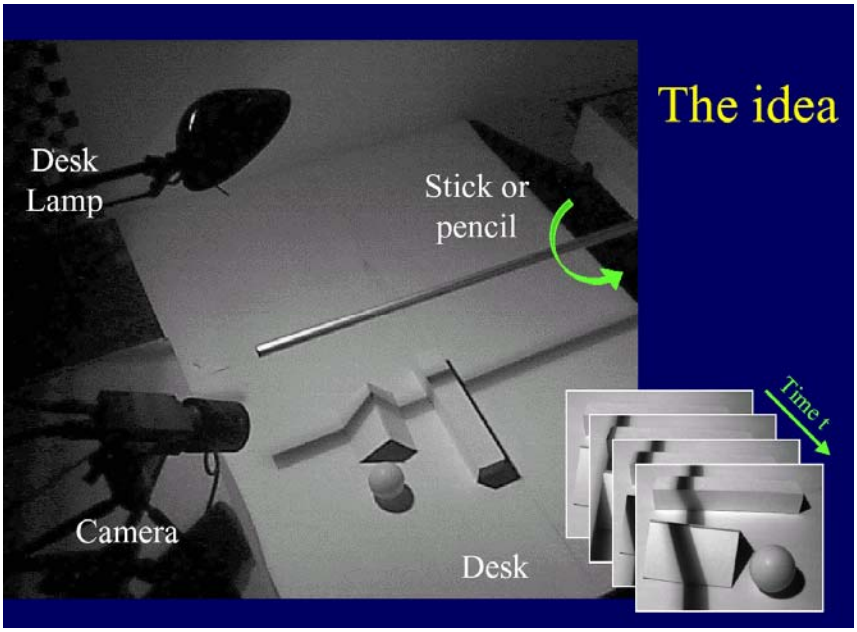
Single-frame

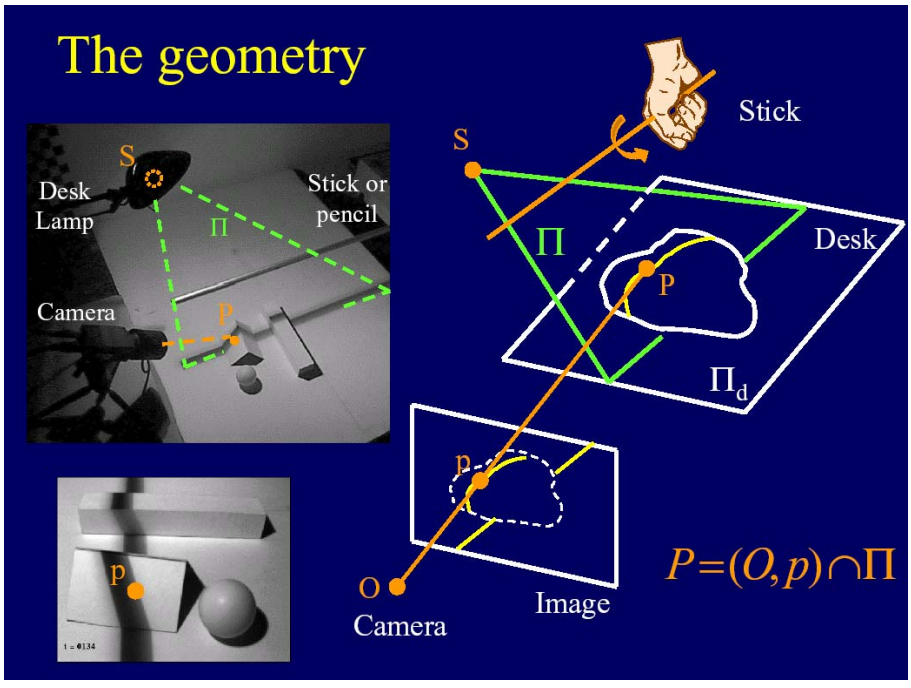
Slow, robust

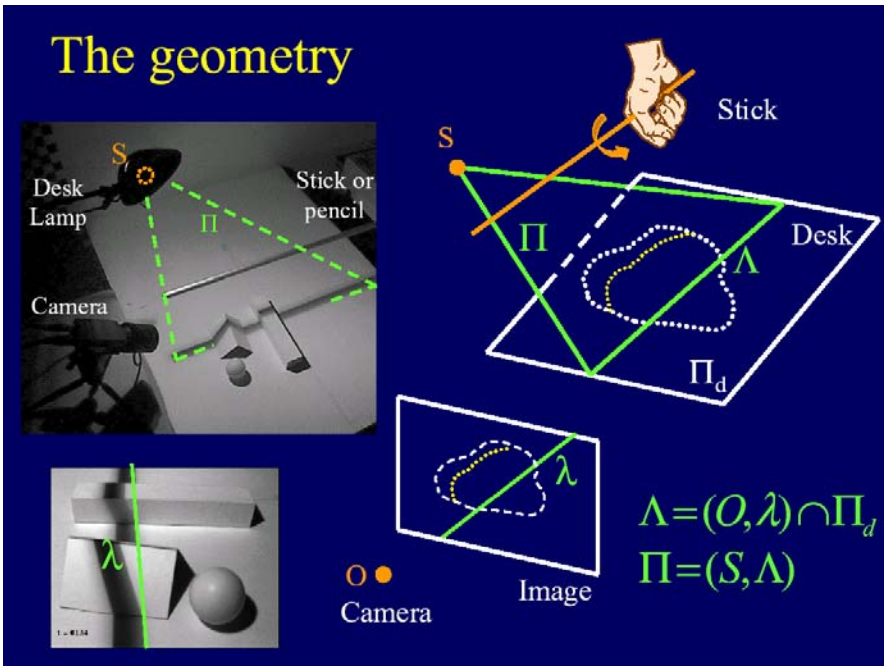
Fast, fragile

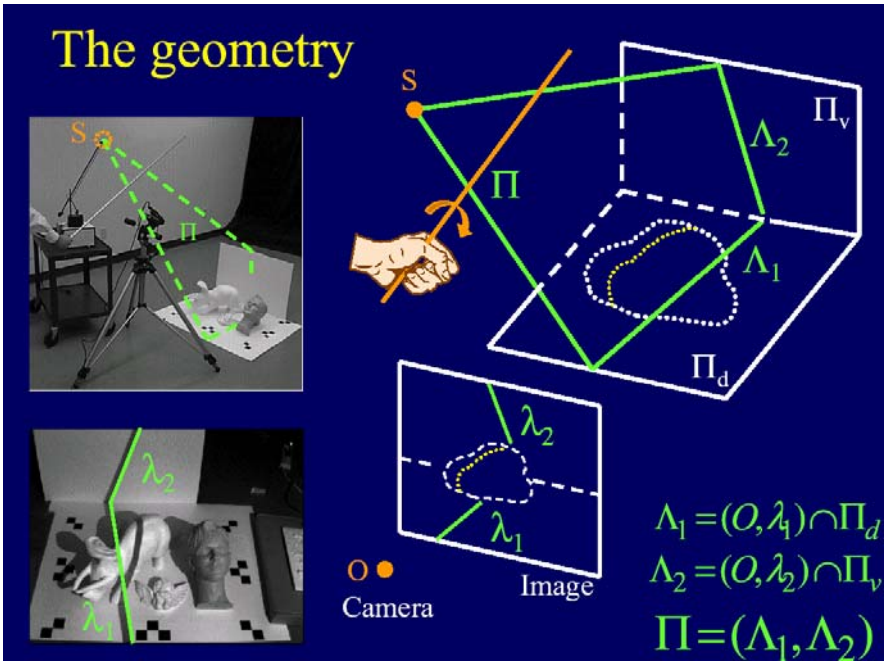
3D Acquisition from Shadows

Bouguet-Perona, ICCV 98


The idea
Desk
Lamp
Stick or
pencil
Time t
Camera
Desk


The geometry
S
Desk
Lamp
Stick or
pencil
Π
Camera
p
p
Stick
S
Π
Desk
P
Π_d
p
O
Camera
Image
$P=(O,p)\cap\Pi$


The geometry
S
Desk
Lamp
Stick or
pencil
Π
Camera
λ
Stick
S
Π
Desk
Λ
Π_d
λ
O
Camera
Image
Λ=(O,λ)∩Π_d
Π=(S,Λ)


The geometry
S
Π
λ_2
λ_1
S
Π
Π_v
Λ_2
Λ_1
Π_d
λ_2
λ_1
O
Camera
Image
Λ_1=(O,λ_1)∩Π_d
Λ_2=(O,λ_2)∩Π_v
Π=(Λ_1,Λ_2)

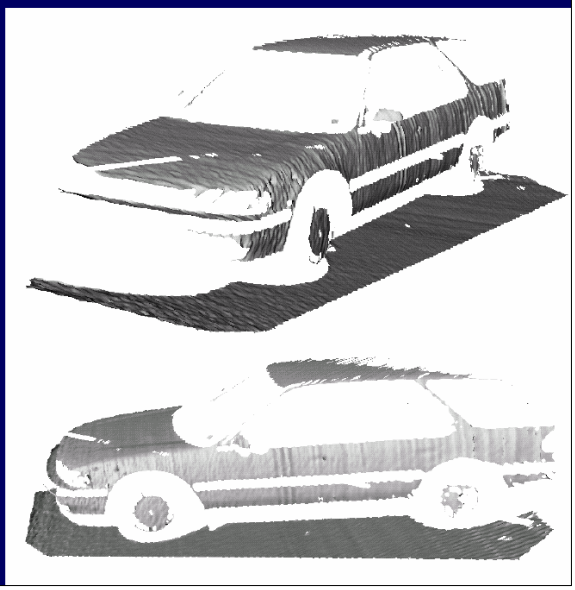
Angel experiment

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

Scanning with the sun

Accuracy: 1cm over 2m

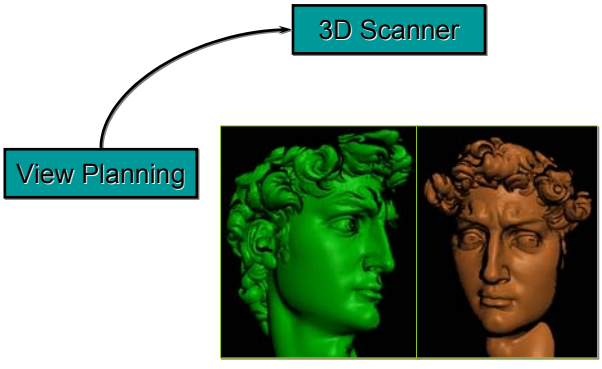
→ ~ 0.5% error



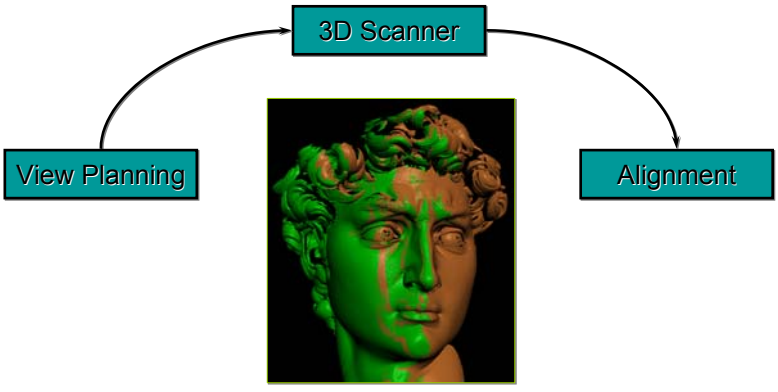
3D Model Acquisition Pipeline

3D Scanner

3D Model Acquisition Pipeline



3D Model Acquisition Pipeline



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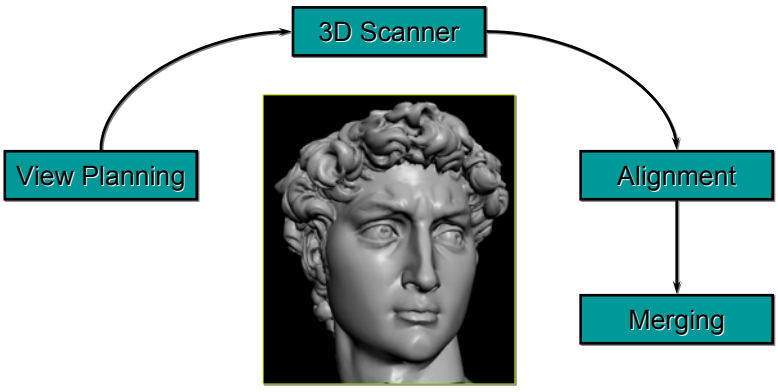

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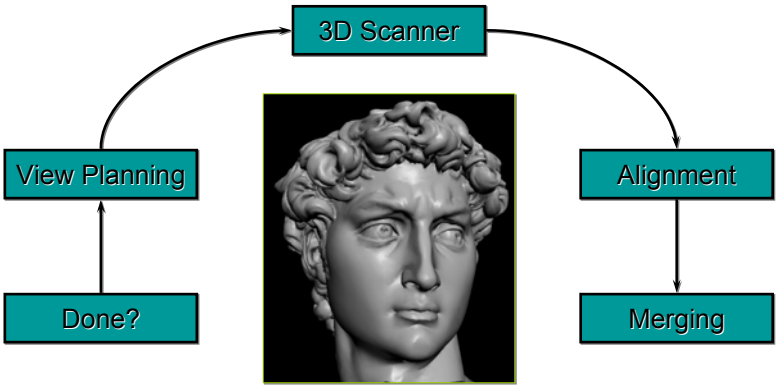
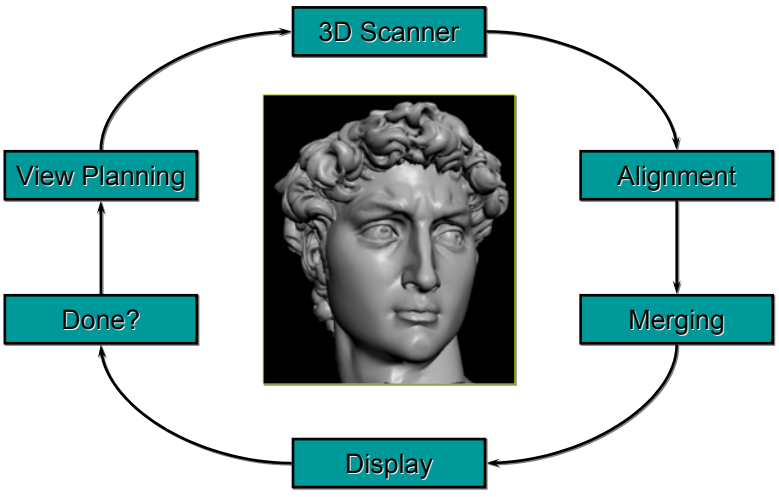
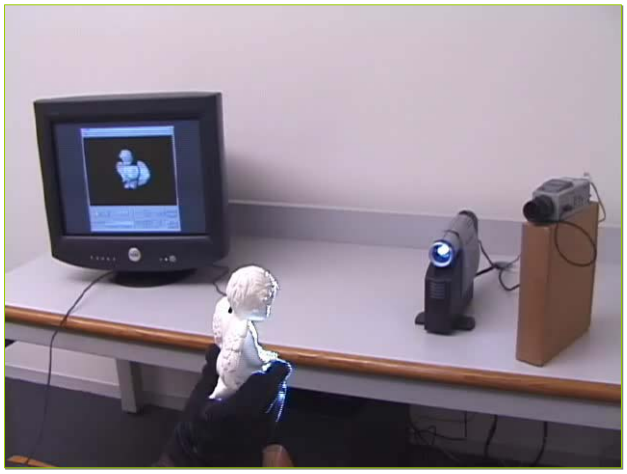


3D Model Acquisition Pipeline



Real-Time 3D Model Acquisition



Next Class

- Polyhedral Objects and Line Drawing
- Reading → Notes