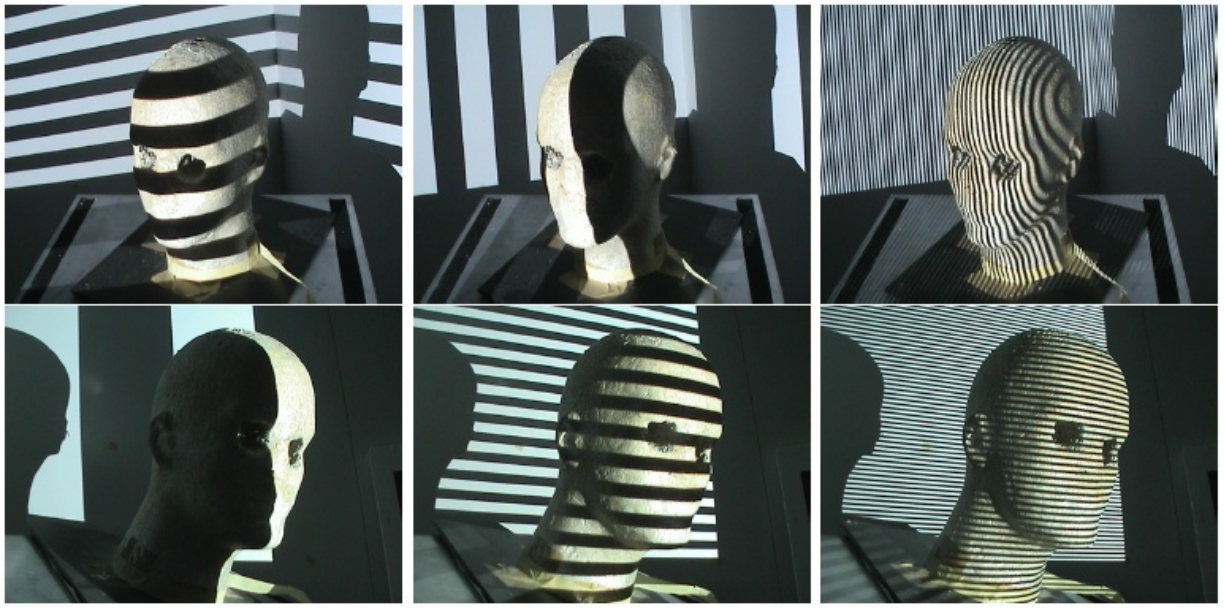


Structured Lighting

Guido Gerig, Univ. of Utah

CS 6320, 3D Computer Vision

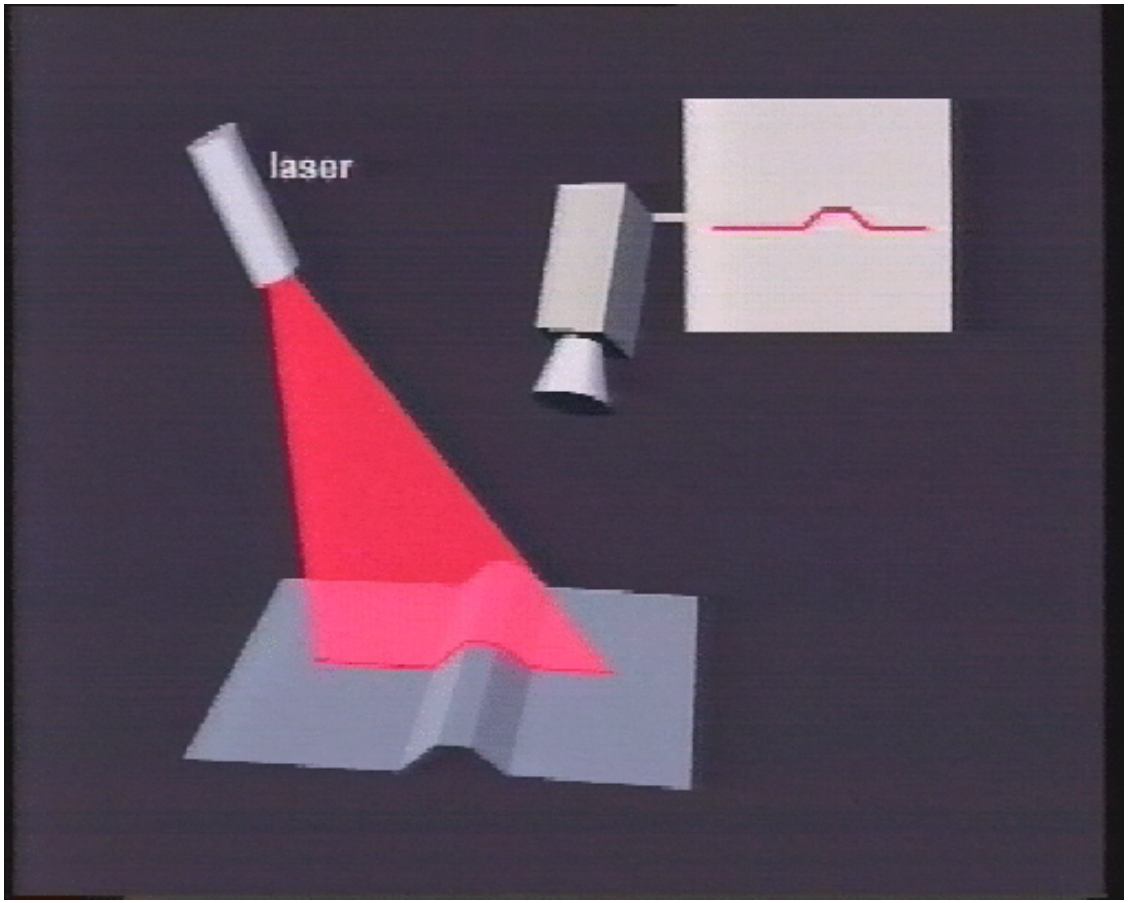
Spring 2012

(thanks: some slides S. Narasimhan CMU, Marc Pollefeys UNC)

http://www.cs.cmu.edu/afs/cs/academic/class/15385-s06/lectures/ppts/lec-17.ppt

From Guido Gerig,
Univ. of Utah
CS 6320, 3D
Computer Vision
Spring 2012

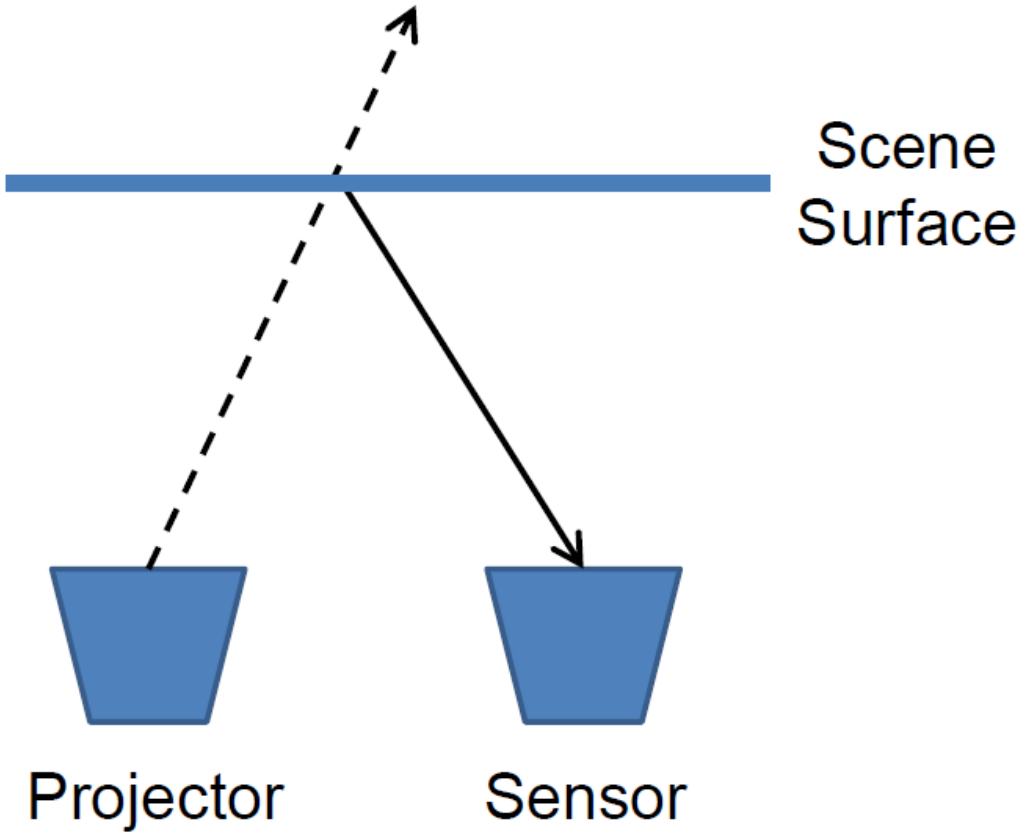
Active Stereo



Active manipulation of scene: Project light pattern on object. Observe geometry of pattern via camera → 3D geometry

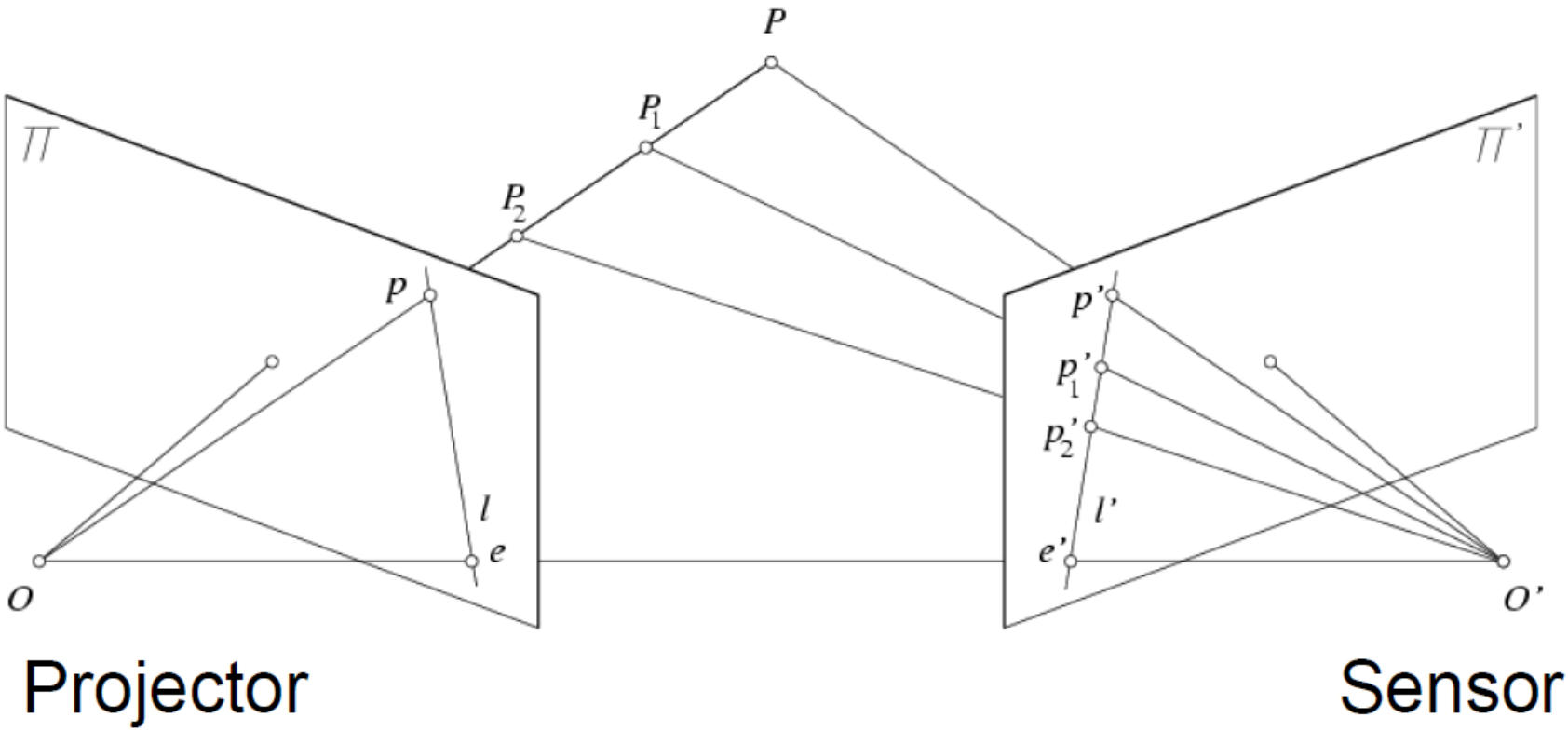
Depth from Projector-Sensor

Only one image: How is it possible to get depth?



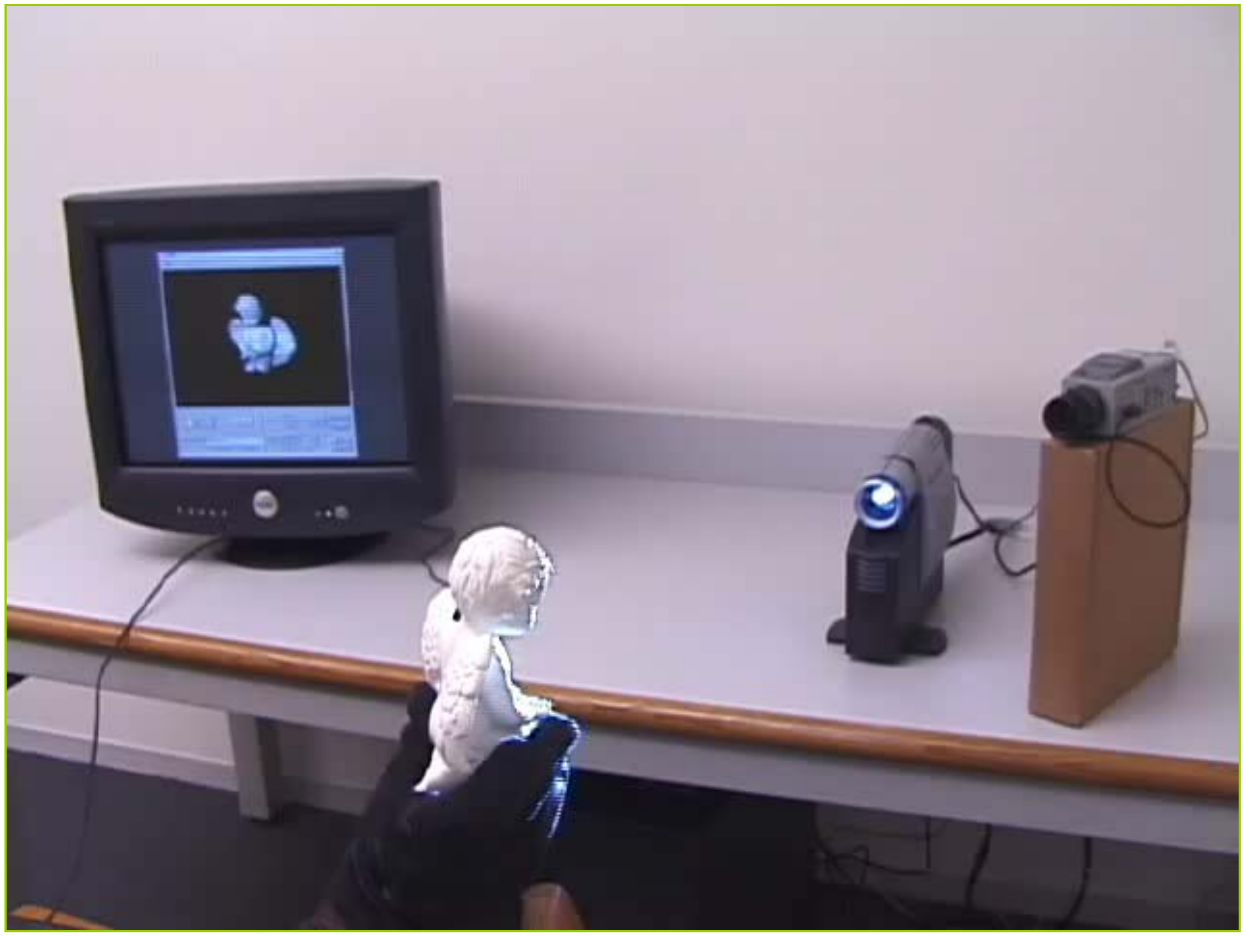
Courtesy of Derek Hoiem, University of Illinois

Same stereo algorithms apply



Courtesy of Derek Hoiem, University of Illinois

Real-Time 3D Model Acquisition



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

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

The SIGGRAPH Paper:
Full paper as PDF.
One-page abstract and Figure 1 as PDF.
Two-page abstract and Figure 1 as PDF.
A 5-minute video describing the system:
AVI file, 640 x 480 pixels (19MB)
RealVideo stream, 640 x 480 pixels, 1536 kbs
RealVideo stream, 320 x 240, 56 - 904 kbs
SIGGRAPH 2002 talk:
Talk as PPT
Embedded video clip:
sig02_begin_m.avi
Embedded video clip:
sig02_recap.avi
Embedded video clip: turtle2.avi

General Setup

- one camera
- one light source
  - types
    - slide projector
    - laser
  - projection
    - spot
    - stripe
    - pattern

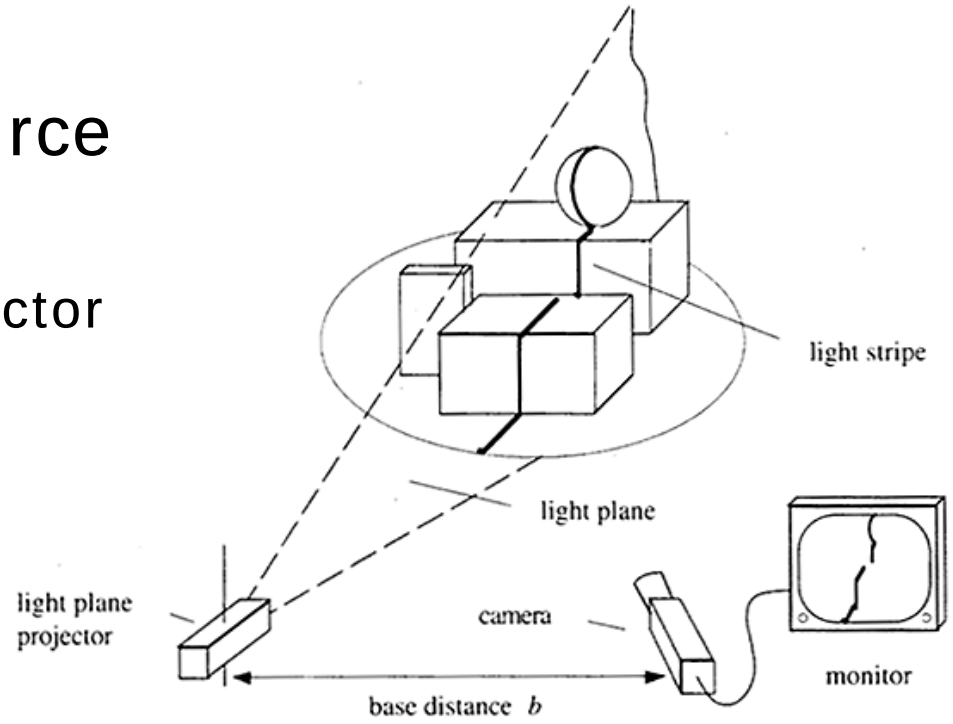
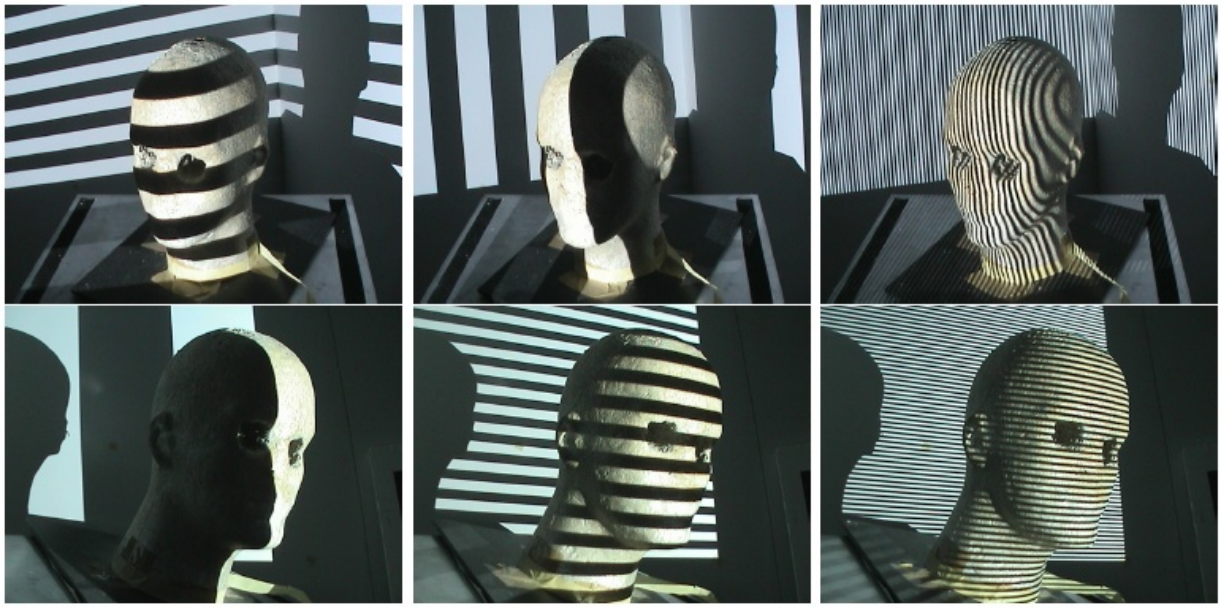


Figure 9.6: Image acquisition set-up for the light stripe projection technique.



Structured Lighting

Guido Gerig

CS 6320, 3D Computer Vision

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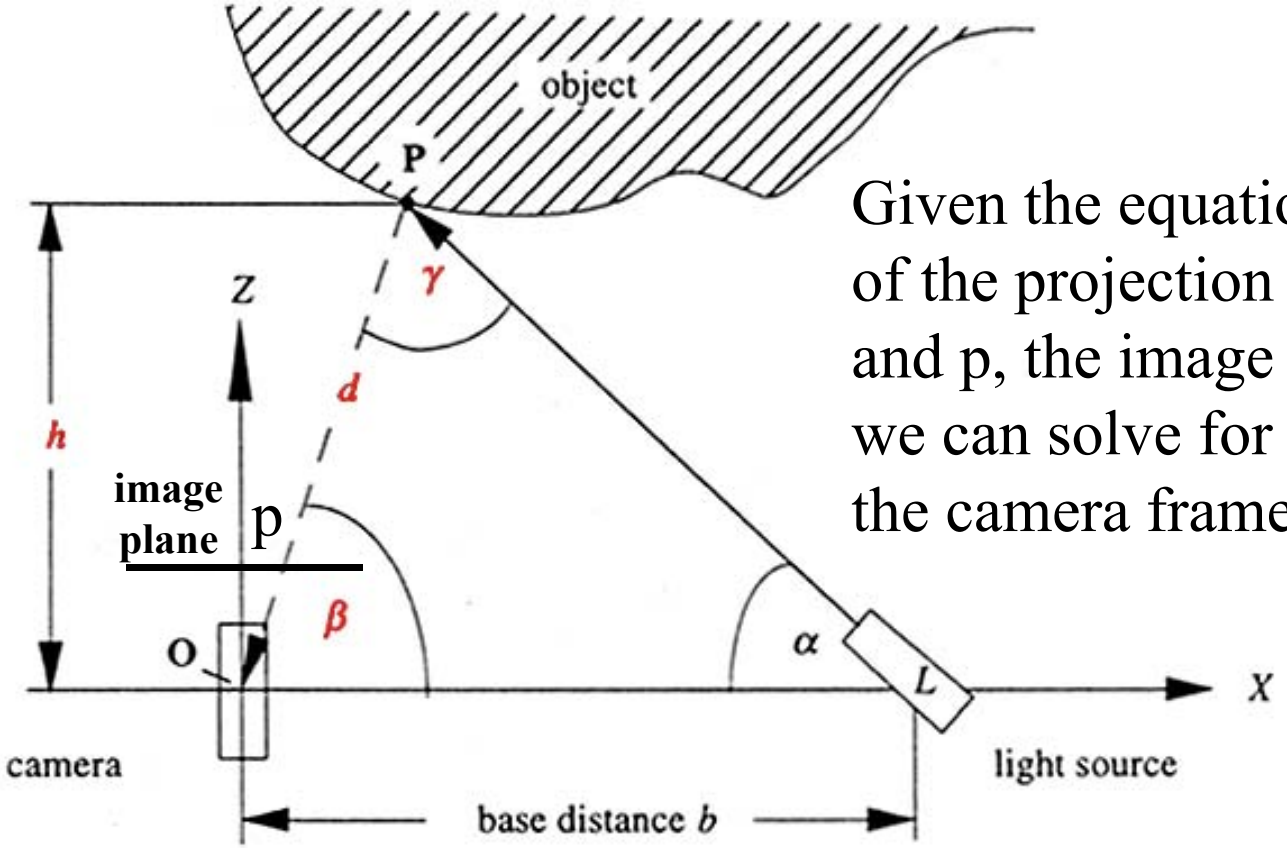
http://www.cs.cmu.edu/afs/cs/academic/class/15385-s06/lectures/ppts/lec-17.ppt

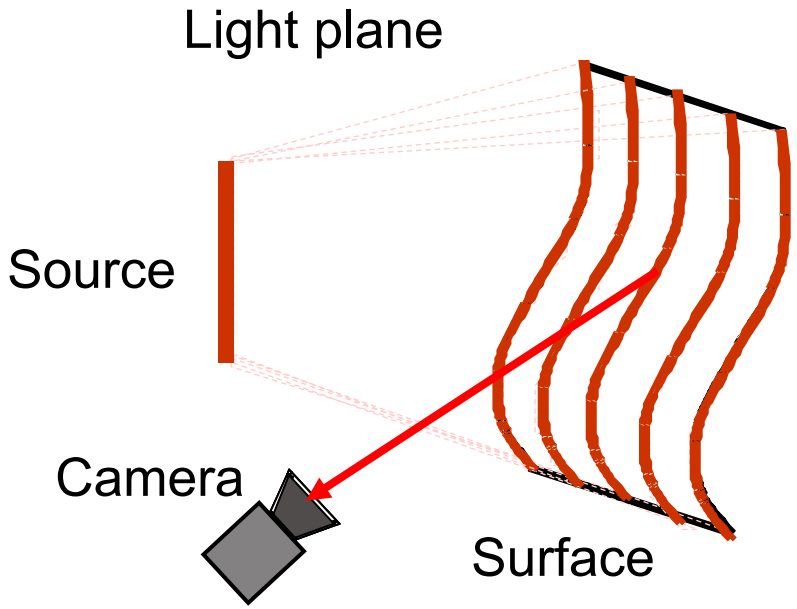
Light Spot Projection

Assume point-wise illumination by laser beam



Given the equation of the projection line LP and p, the image of P , we can solve for P w.r.t. the camera frame.

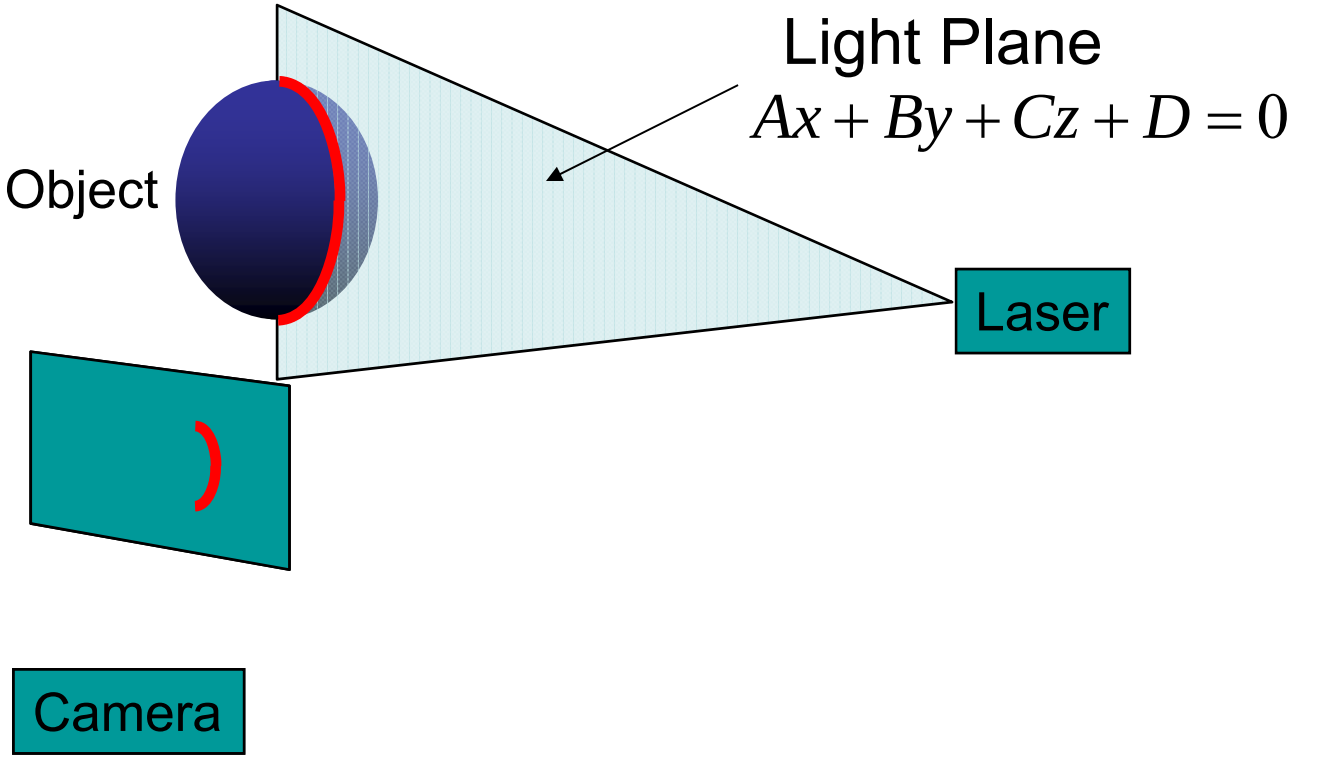
Light Stripe Scanning – Single Stripe



- 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

Courtesy S. Narasimhan, CMU

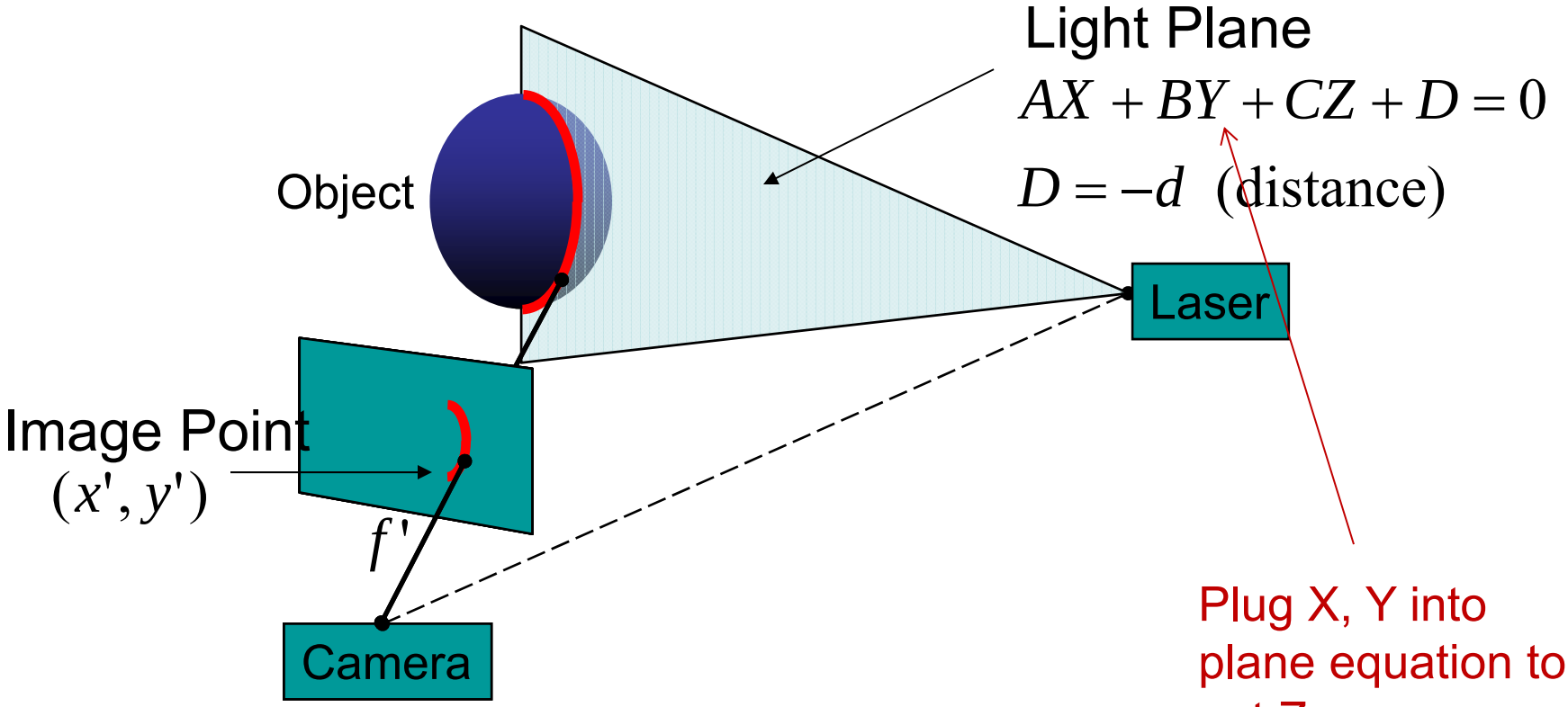
Triangulation



- Project laser stripe onto object

Courtesy S. Narasimhan, CMU

Triangulation

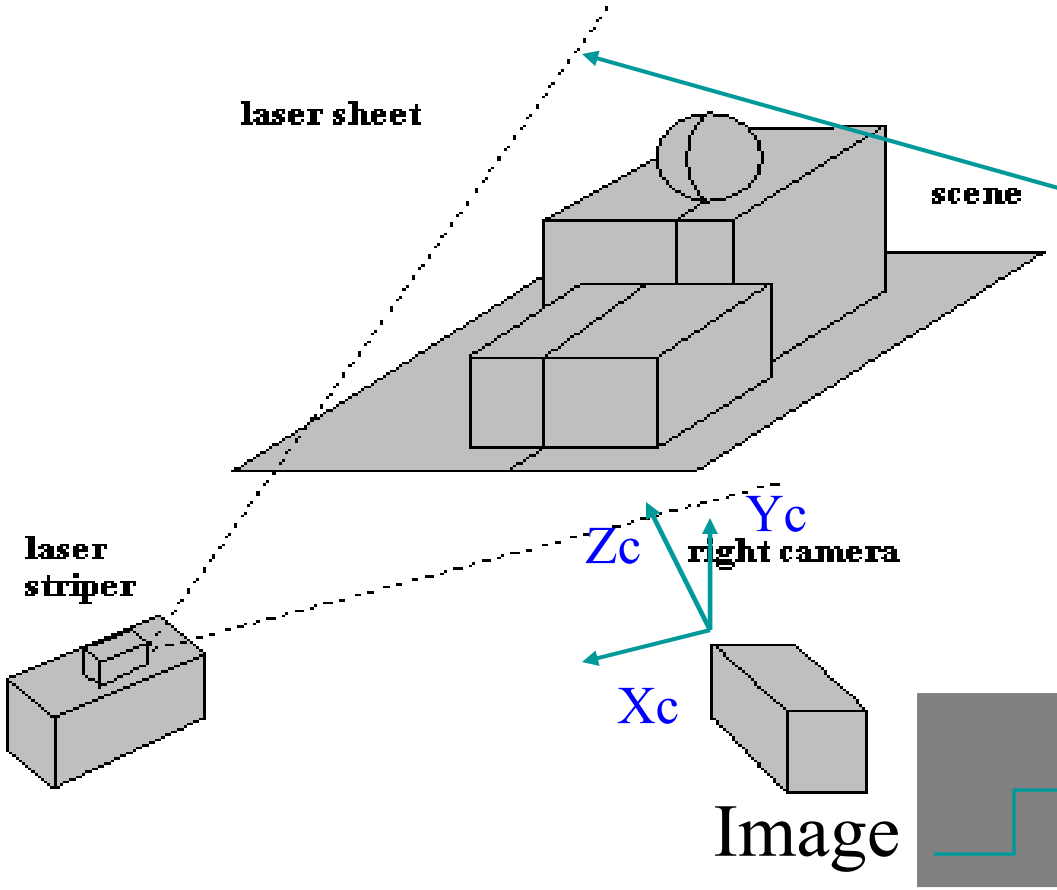


- Depth from ray-plane triangulation:
  - Intersect camera ray with light plane

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

Courtesy S. Narasimhan, CMU

Triangulation



Light Stripe System.

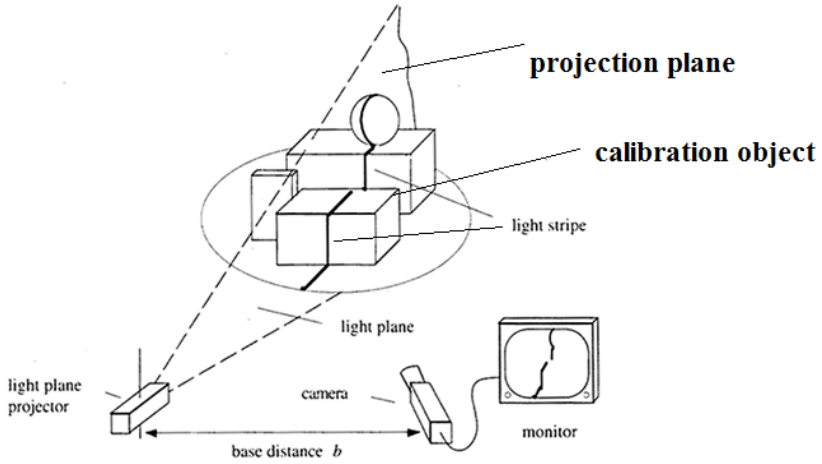
Light Plane:
$AX+BY+CZ+D=0$
(in camera frame)
Image Point:
$x=f\,X/Z$, $y=f\,Y/Z$
(perspective)

Triangulation: $Z=-D\,f/(A\,x + B\,y + C\,f)$

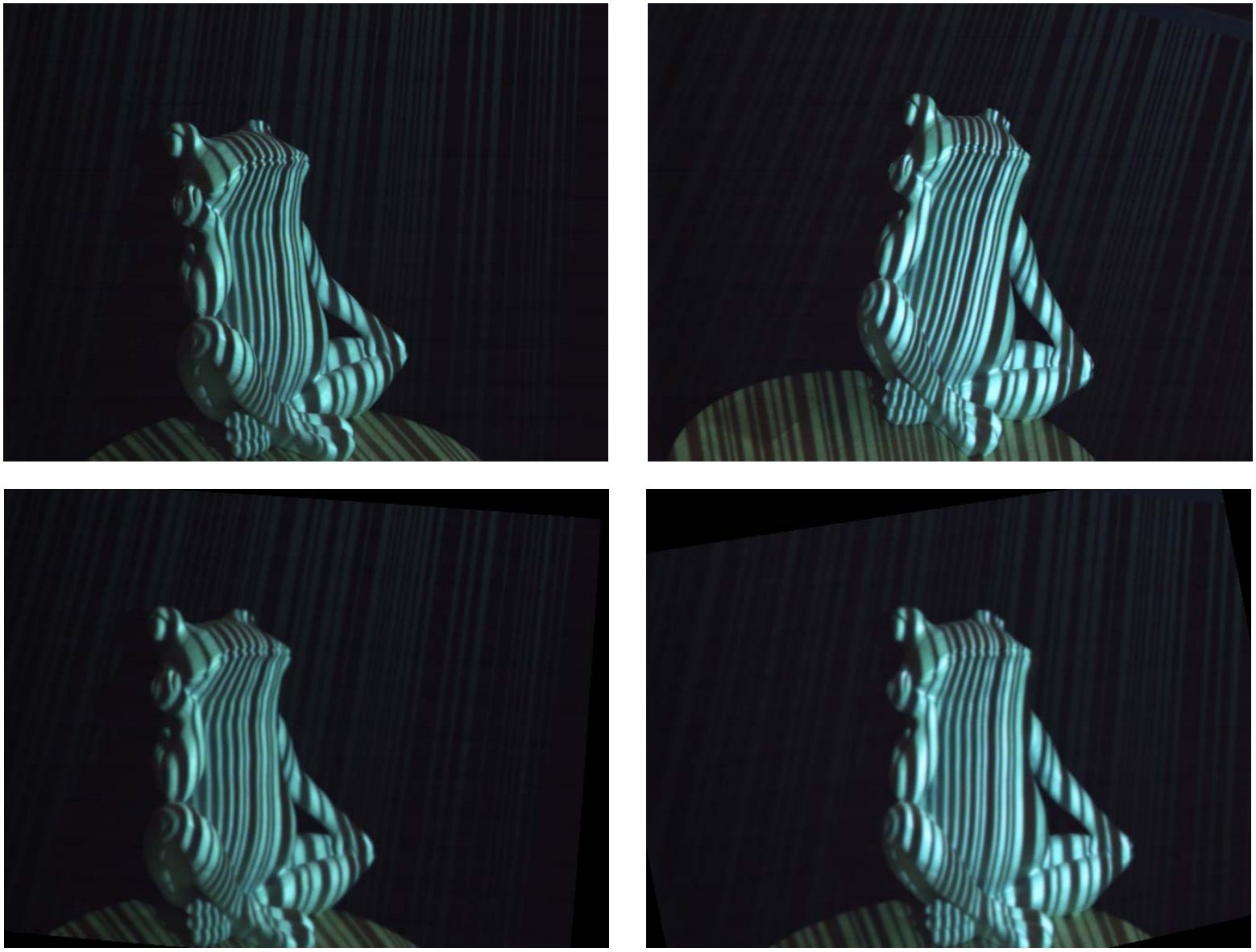
Move light stripe or object.

Active Stereo Calibration

1. Put a calibration object (such as a cube) in the scene as shown in the figure
2. Obtain the pose of the calibration object, i.e., the equations of each plane w.r.t the camera frame through an object pose estimation
3. Project a plane light on the calibration objects, producing two light stripes resulted from the intersection of two planes of the object with the project light plane as shown in the figure
4. Given the equations of the object planes as derived from Step 2 and the images of the two stripes, the equations of the two stripes w.r.t camera frame can be recovered
5. Use the equations of the two stripes to derive the equation of the projection plane

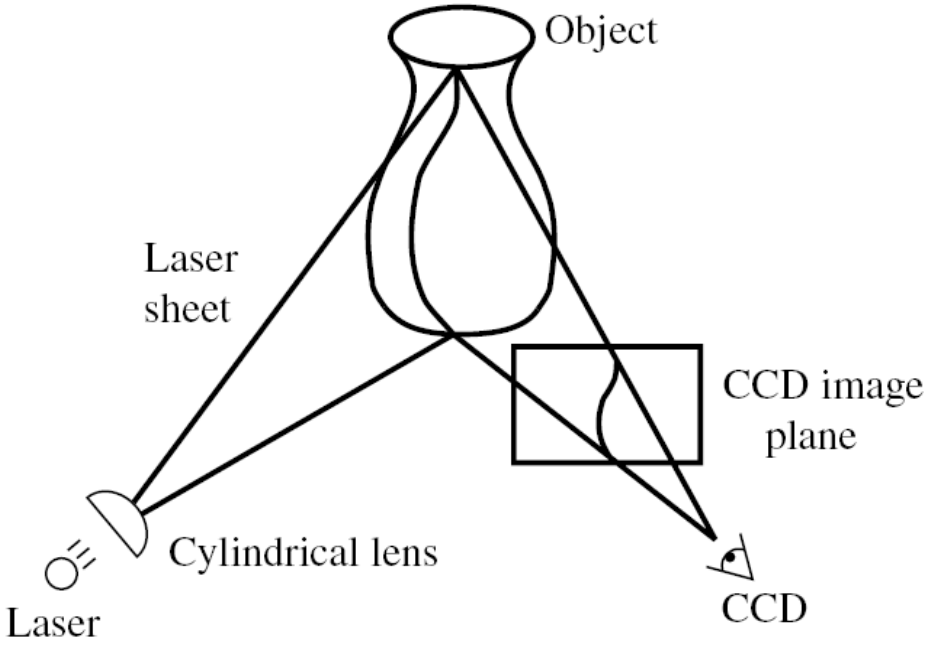


Active Stereo (Structured Light)



From Sebastian Thrun/Jana Kosecka

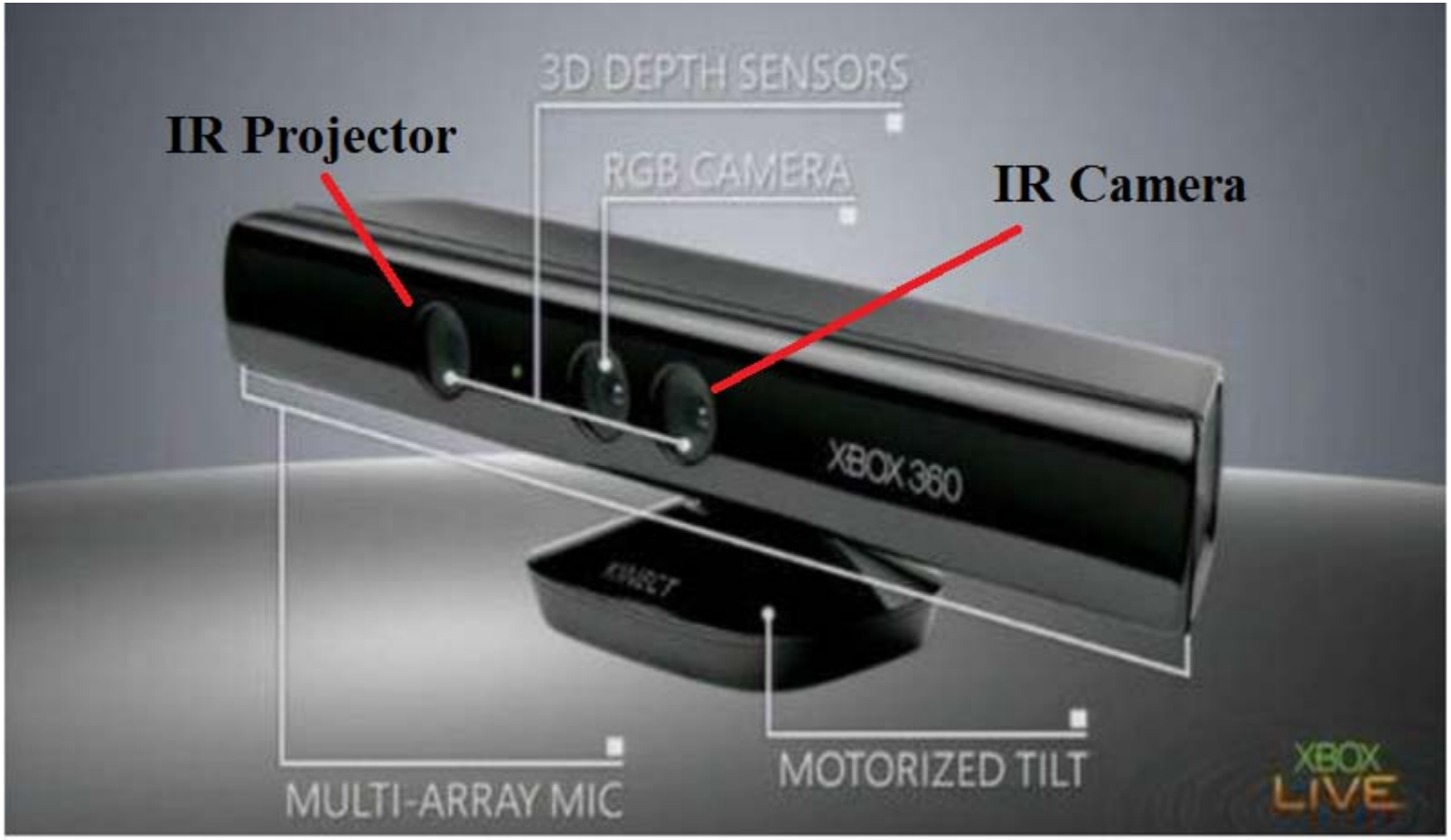
Example: Laser scanner



Cyberware® face and head scanner

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

Microsoft Kinect



Kinect Device

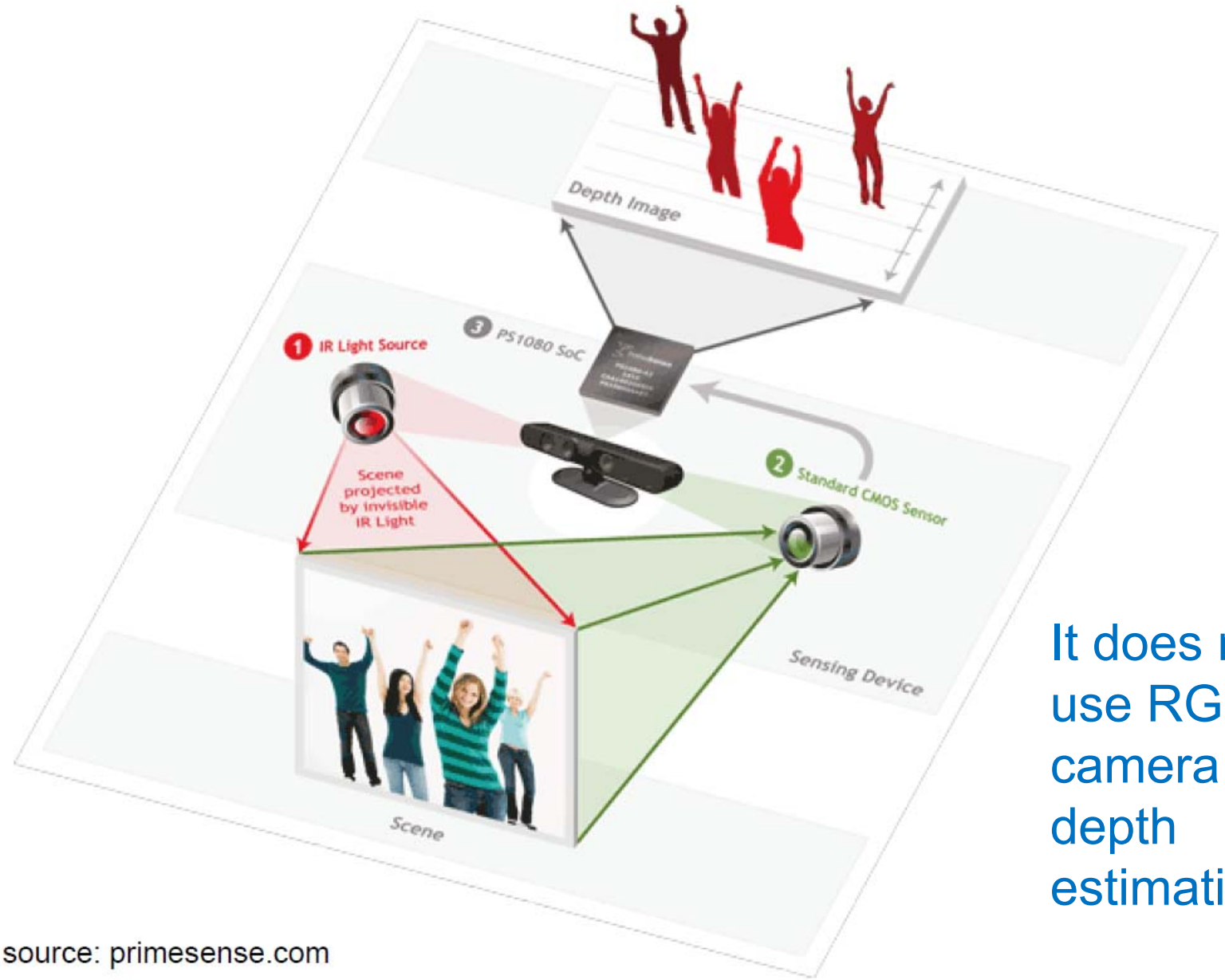


illustration source: primesense.com

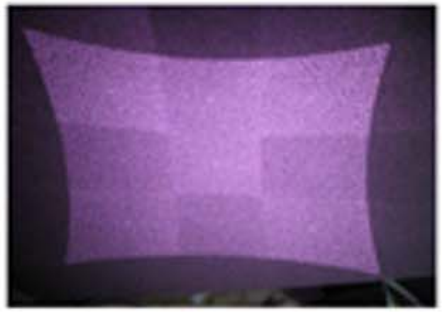
It does not use RGB camera for depth estimation!.

How Kinect Works: Overview

Courtesy of Derek Hoiem, University of Illinois

IR Projector

IR Sensor

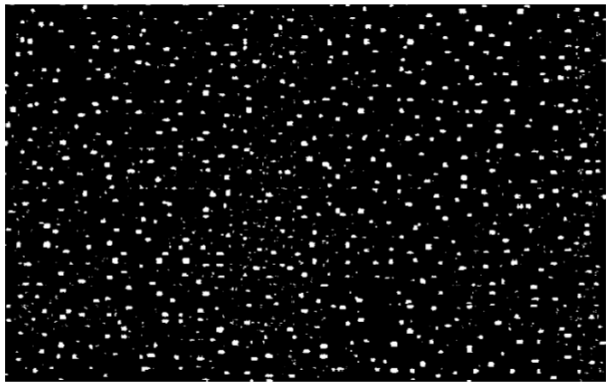


Projected speckle (dot) light pattern

Stereo Algorithm

Depth Image

The Kinect uses infrared laser light, with a speckle pattern

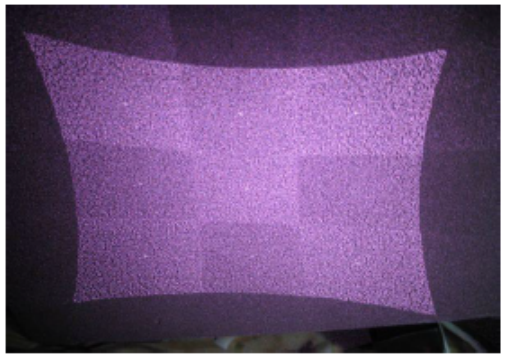


Shpunt et al, PrimeSense patent application US 2008/0106746

How Kinect Works: Overview

Courtesy of Derek Hoiem, University of Illinois

IR Projector



IR Sensor

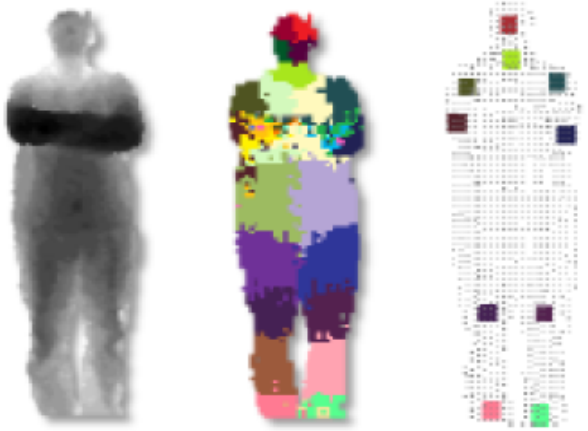
Projected Light Pattern

Projected speckle (dot) light pattern

Stereo Algorithm

Depth Image

Segmentation, Part Prediction

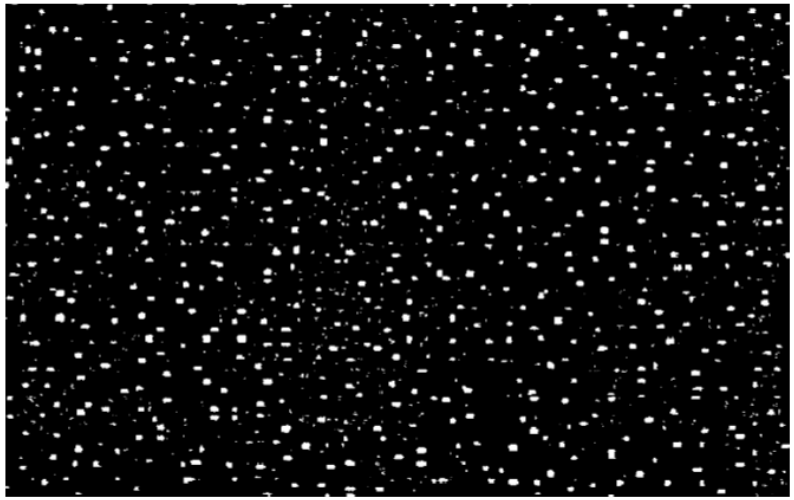


Body Pose

Microsoft Kinect

The Kinect combines structured light with two classic computer vision techniques: depth from focus, and depth from stereo. It does not use RGB camera!.

The Kinect uses infrared laser light, with a speckle pattern



Shpunt et al, PrimeSense patent application US 2008/0106746

Details are not publicly available

http://users.dickinson.edu/~jmac/selected-talks/kinect.pdf

Region-growing Random Dot Matching

1. Detect dots ("speckles") and label them unknown
2. Randomly select a region anchor, a dot with unknown depth
   a. Windowed search via normalized cross correlation along scanline
      – Check that best match score is greater than threshold; if not, mark as "invalid" and go to 2
   b. Region growing
      1. Neighboring pixels are added to a queue
      2. For each pixel in queue, initialize by anchor's shift; then search small local neighborhood; if matched, add neighbors to queue
      3. Stop when no pixels are left in the queue
3. Stop when all dots have known depth or are marked "invalid"

http://www.wipo.int/patentscope/search/en/WO2007043036

Projected IR vs. Natural Light Stereo

- What are the advantages of IR?
  - Works in low light conditions
  - Does not rely on having textured objects
  - Not confused by repeated scene textures
  - Can tailor algorithm to produced pattern

- What are advantages of natural light?
  - Works outside, anywhere with sufficient light
  - Uses less energy
  - Resolution limited only by sensors, not projector

- Difficulties with both
  - Very dark surfaces may not reflect enough light
  - Specular reflection in mirrors or metal causes trouble

Courtesy of Derek Hoiem, University of Illinois

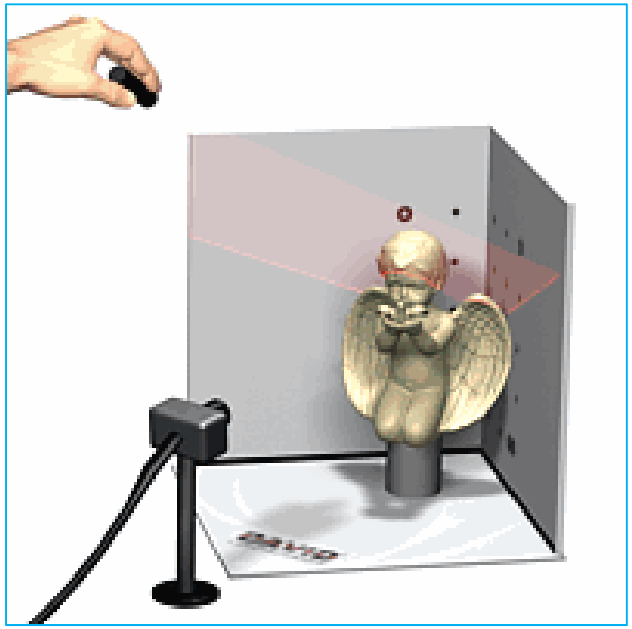
Microsoft Kinect

Inferring body position is a two-stage process: first compute a depth map, then infer body position

http://users.dickinson.edu/~jmac/selected-talks/kinect.pdf

Low-Cost 3D Scanner for Everyone

http://www.david-laserscanner.com/



What do I need to build a 3D scanner?

- A camera (e.g. web cam)
- A hand-held line laser (starting at €19.90)
- Two plain boards in the background
- A Windows PC
- Our free software DAVID-LASERSCANNER

Or use the brand-new DAVID Starter-Kit!

If you don't want to start searching and tinkering, the DAVID Starter-Kit contains all necessary hardware and software to set up your own 3d scanner!

Roter Linienlaser, 5mW, Batteriebetrieben, 90°

19,90 EUR incl. 19 % UST exkl.Versandkosten

CLOSE X

Strait-Line
Laser Level

★★★★☆ 4/5 8 Reviews

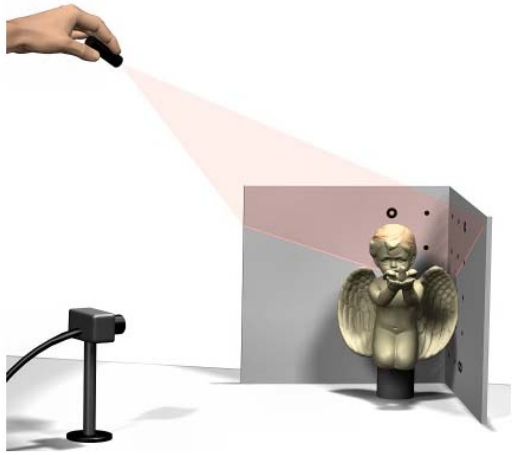
$15.97

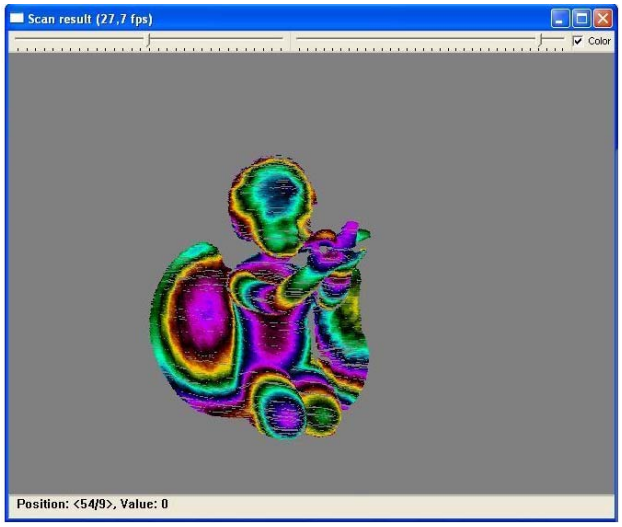
Ships FREE with $45.00 Order

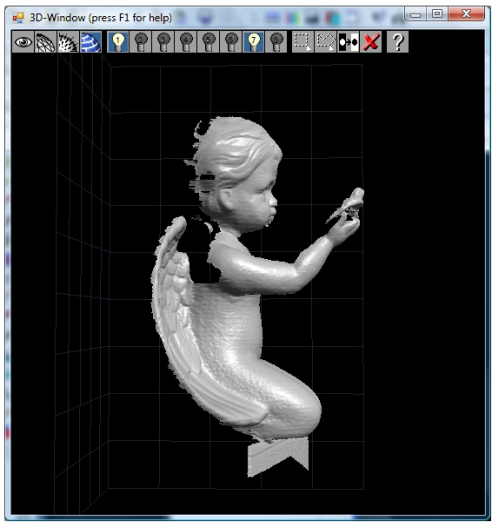
Description:
The Strait-Line Laser Level features dual-bubble vials for accurate, easy-to-read horizontal and vertical readings. The laser level projects up to a 15 ft. laser line to help provide accurate readings at a distance. The 360-degree rotation and pivot creates 30 ft. of work space. The level is accurate within

Low-Cost 3D Scanner for Everyone

http://www.david-laserscanner.com/wiki/user_manual/3d_laser_scanning

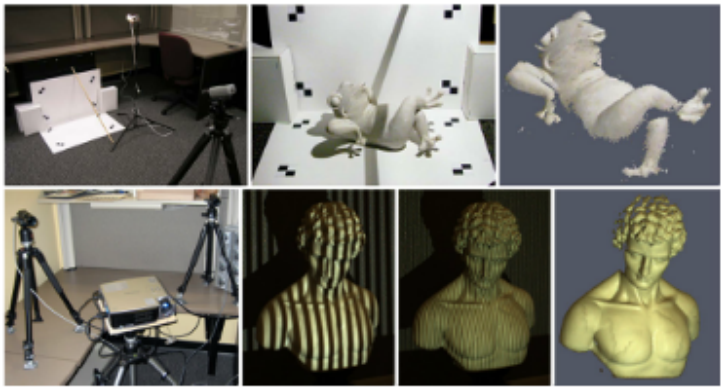






Excellent Additional Materials

Build Your Own 3D Scanner:
3D Photography for Beginners



SIGGRAPH 2009 Course Notes
Wednesday, August 5, 2009

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- Course notes: http://mesh.brown.edu/byo3d/notes/byo3D.pdf
- Slides: http://mesh.brown.edu/byo3d/slides.html
- Source code: http://mesh.brown.edu/byo3d/source.html