3D Computer Vision Introduction

Guido Gerig

CS 6320, Spring 2015

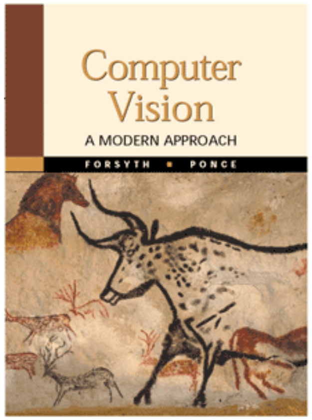
gerig@sci.utah.edu

Acknowledgements: some slides from Marc Pollefeys and Prof. Trevor Darrell, trevor@eecs.berkeley.edu

Administrivia

- Classes: M & W, 1.25-2:45
Room WEB L126
- Instructor: Guido Gerig
gerig@sci.utah.edu
- TA: Padmashree Teeka
- Prerequisites: CS 6640 ImProc (or equiv.)
- Textbook:

  "Computer Vision: A Modern Approach" by Forsyth & Ponce



- Organization:

  Admin/Grading/Uploads:

  UofU canvas

  Slides, documents and assignments:

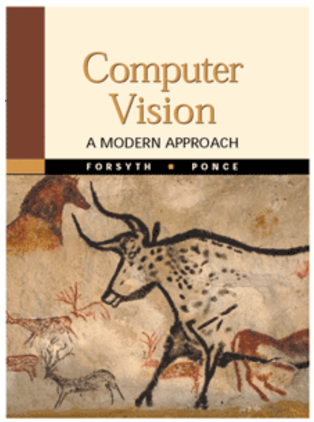
  Course Website

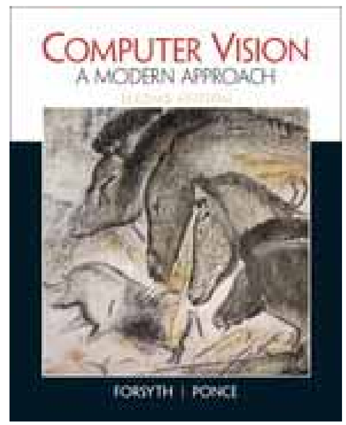
Administrivia

- Textbook:

  "Computer Vision: A Modern Approach" by Forsyth & Ponce

  Version 1 **Version 2e 2012**





- The Version 1 is sufficient for this course, but you can also buy the new updated version.
- Electronic version: http://www.coursesmart.com/IR/5316068/9780132571074?__hdv=6.8

Web-Site

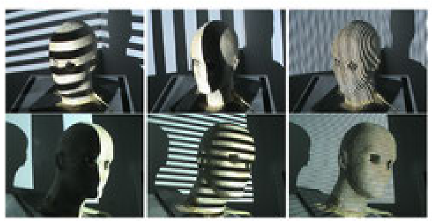
- Linked to canvas CS 6320-001 home page
- Linked to my home page (teaching):
  http://www.sci.utah.edu/~gerig/CS6320-S2015/CS6320_3D_Computer_Vision.html

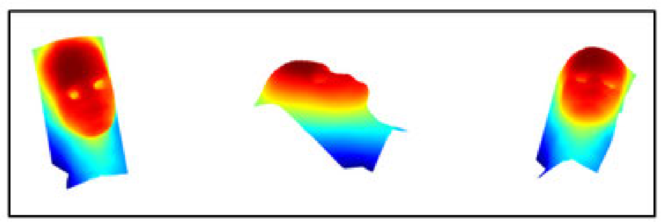
SCHOOL OF COMPUTING
THE UNIVERSITY OF UTAH

CS6320 3D Computer Vision, Spring 2015

Computing properties of our 3-D world from passive and active sensors

Syllabus, Guido Gerig (home)





Goal and Objectives:

- To introduce the fundamental problems of 3D computer vision.
- To introduce the main concepts and techniques used to solve those.
- To enable participants to implement solutions for reasonably complex problems.
- To enable participants to understand basic methodology that is discussed in the computer vision literature.

TA / SW Tools / Office Hours

- TA: Padmashree Teeka
- HW/SW: Matlab+ ev. Imaging Toolbox
  CADE lab WEB 130
  http://www.cade.utah.edu/
- Office Hours TA (MEB 3115) Hours: tbd
- Office Hours instructor: Mo/Wed 3-5pm after class (tbd)

MATLAB

- This course will support MATLAB for practical parts of assignments. C++ or other languages can be used but there will be no support and we need proof that code is fully developed by the student.
- Access via COE CADE computer lab, Matlab licences available. Remote access possible, but very slow.
- Matlab is also installed on the computers in the Knowledge Commons at the Mariott Library on Campus:
  - http://www.lib.utah.edu/services/knowledge-commons/index.php
  - According to this webpage, it is also available to use remotely: http://www.lib.utah.edu/services/labs/software.php
- If students want to purchase their own copy, Matlab for students is $50, or $99 (including 10 toolboxes.), link
- We will ***NOT USE Toolboxes*** but implement our own code.

Prerequisites

- General Prerequisites:
  - Data structures
  - A good working knowledge of MATLAB programming (or willingness and time to pick it up quickly!)
  - Linear algebra
  - Vector calculus
- Assignments include theoretical paper questions and programming tasks (Matlab or C++).
- **Image Processing CS 6640** (or equivalent).
- Students who do not have background in signal processing / image processing: Eventually possible to follow class, but requires <u>significant special effort</u> to learn basic image processing.
- THIS IS NOT AN IMAGE PROCESSING COURSE BUT FOCUSES ON 3D VISION ASPECTS.

Grading - Weights

- Assignments (4-5 theory/prog.): 60%
- Final project (incl. design, proposal, demo, presentation, report): 30%
- Class participation (active participation in summaries and discussions): 10%
- Quizzes with discussions to check understanding (scoring part of partic.)
- Final project replaces final exam
- Successful final project required for passing grade

Assignments & Projects

- Assignments: Theoretical and Practical Part: Example
- Strict deadlines: 10% deduction per day late, no more accepted after 3 days.
- Assignments solutions include:
  - Solutions to theoretical parts (can be handwritten and scanned)
  - Detailed report on practical solution (pdf document)
  - Code used to solve practical part
- Important:
  - Be creative with own images and experiments with your code. Try different scenarios and discuss pro’s and con’s.
  - Report needs to include description of what you did, description of results, and critical assessment of results, limitations, etc.
  - Code with image data submitted a separate tar/zip file.

Other Resources

- Cvonline: http://homepages.inf.ed.ac.uk/rbf/CVonline/
- A first point of contact for explanations of different image related concepts and techniques. CVonline currently has about 2000 topics, 1600 of which have content.
- See list of other relevant books in syllabus.

Some Basics

- Instructor and TA do not use email as primary communication tool.
- It will be your responsibility to regularly read the Announcements on canvas.
- We don’t need a laptop for the class, please keep them closed !!!!!
- Please interact, ask questions, clarifications, input to instructor and TA.
- Cell phones …., you surely know.

Syllabus

- See separate syllabus (linked to web-site and included on canvas).
- Document

Goal and objectives

- To introduce the fundamental problems of computer vision.
- To introduce the main concepts and techniques used to solve those.
- To enable participants to implement solutions for reasonably complex problems.
- To enable the student to make sense of the literature of computer vision.

CV: What is the problem?

Image Formation: From World to Image

- Camera model (optics & geometry): From points in 3D scene to points on 2D image.
- Photometry: From lights and surfaces in scene to intensity (brightness) and color in image.

Vision: From Image to (Knowledge of the) World

- Reconstruct scene (**world model**) from images.
- Extract sufficient **information** for detection/control **task**.

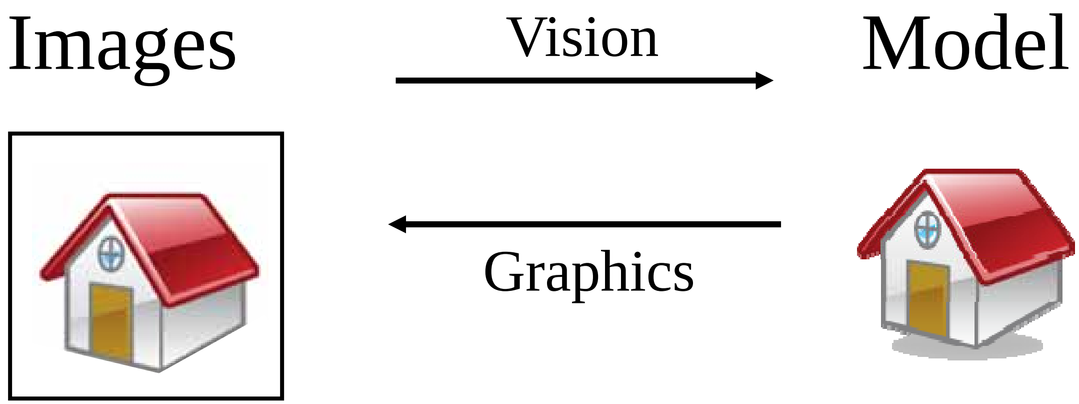
CV: A Hard Problem

- Under-constrained inverse problem – 3D world from 2D image.
- Images are **noisy** – shadows, reflections, focus, (ego-)motion blur – and noise is hard to model.
- Appearances – shape, size, color – of objects change with pose and lighting conditions.
- Image understanding requires cognitive ability ("AI-complete").
- Robotics & Control: massive data rate, real-time requirements.

What is Computer Vision?

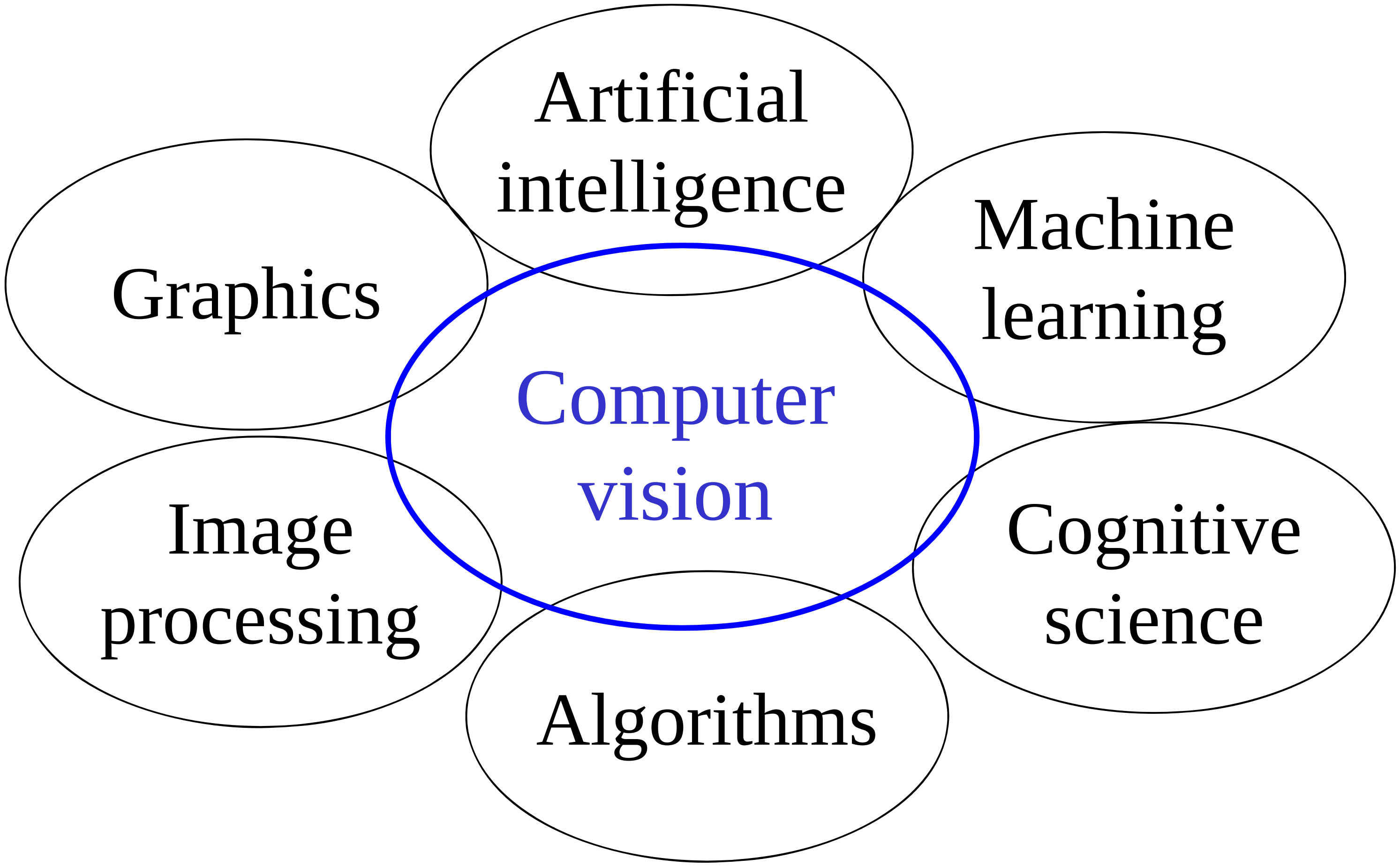
- Automatic understanding of images and video
  - Computing properties of the 3D world from visual data *(measurement)*
  - Algorithms and representations to allow a machine to recognize objects, people, scenes, and activities. *(perception and interpretation)*

Vision and graphics



Inverse problems: analysis and synthesis.

Related disciplines



Object recognition (in mobile phones)

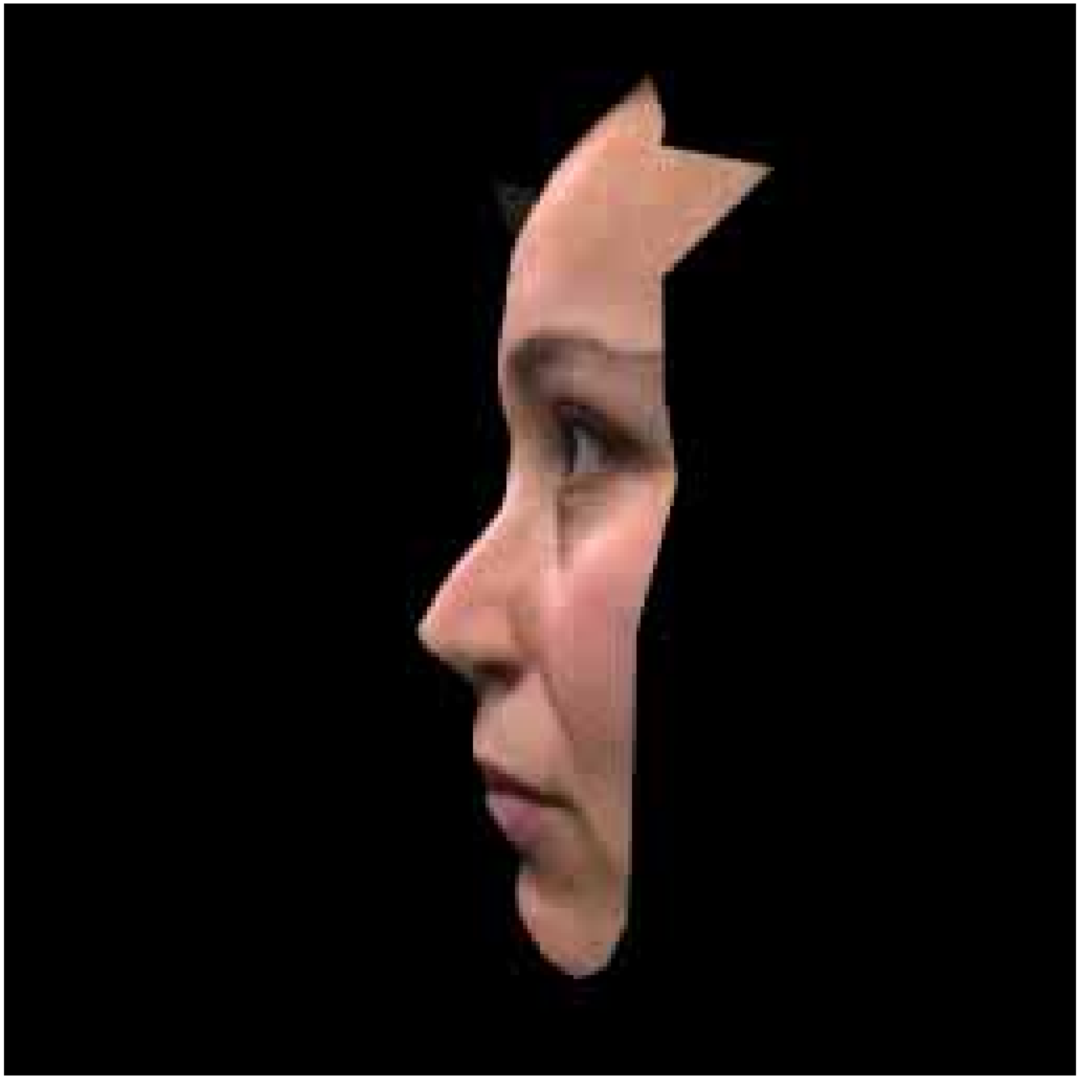
- This is becoming real:
  - Lincoln Microsoft Research
  - Point & Find, Nokia
  - SnapTell.com (now amazon)

Smart cars

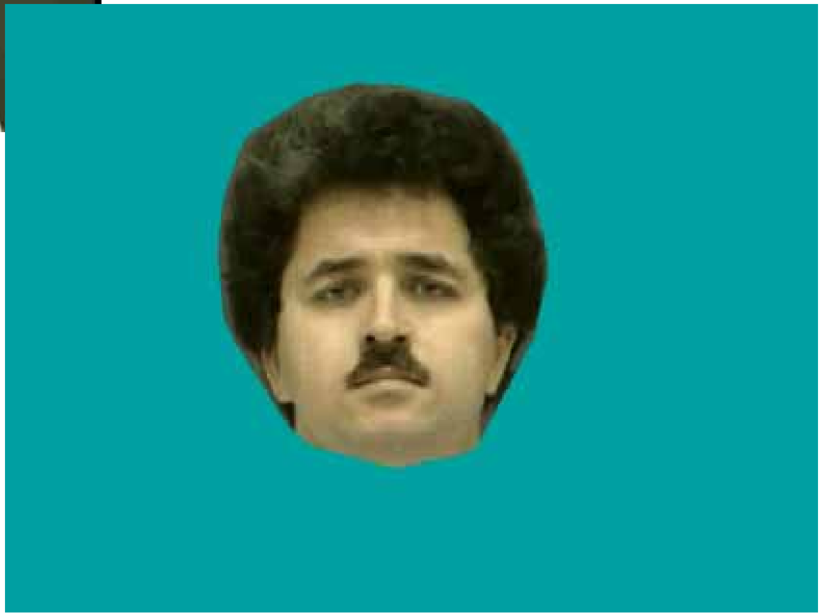
- Mobileye
  - Vision systems currently in high-end BMW, GM, Volvo models
  - By 2010: 70% of car manufacturers.
  - Video demo
  - YouTube, TestMovie

Slide content courtesy of Amnon Shashua

Modeling 3D Structure from Pictures or 3D Sensors



Modeling ctd.



Main topics

- Shape (and motion) recovery

  "What is the 3D shape of what I see?"
- Segmentation

  "What belongs together?"
- Tracking

  "Where does something go?"
- Recognition

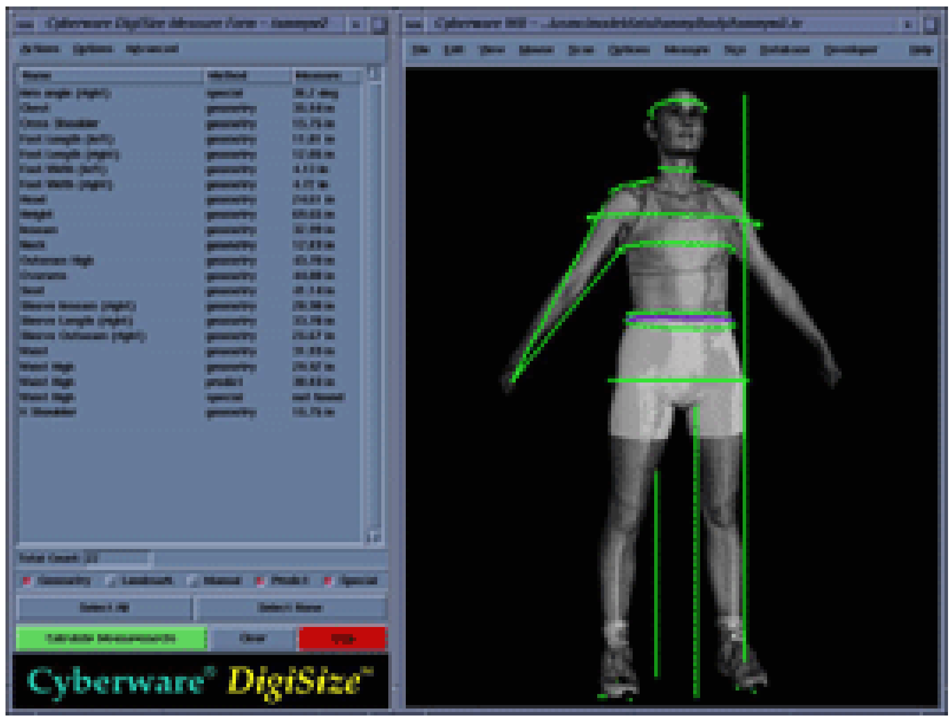
  "What is it that I see?"

Why study Computer Vision?

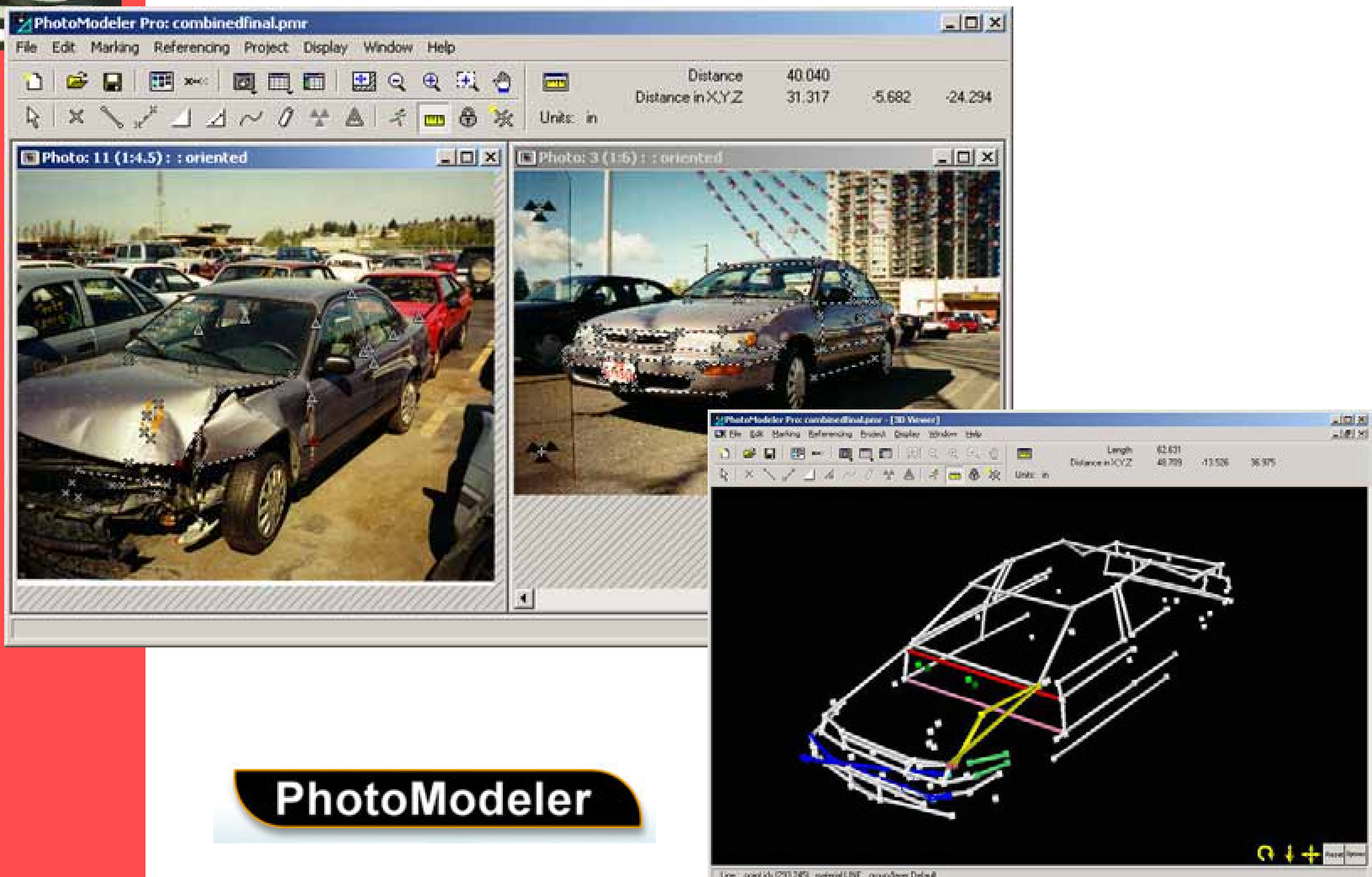
- Images and movies are everywhere
- Fast-growing collection of useful applications
  - building representations of the 3D world from pictures
  - automated surveillance (who's doing what)
  - movie post-processing
  - CAM (computer-aided manufacturing
  - Robot navigation
  - face finding
- Various deep and attractive scientific mysteries
  - how does object recognition work?
- Greater understanding of human vision

Clothing

- Scan a person, custom-fit clothing



Forensics



PhotoModeler

3D urban modeling

drive by modeling in Baltimore

Earth viewers (3D modeling)

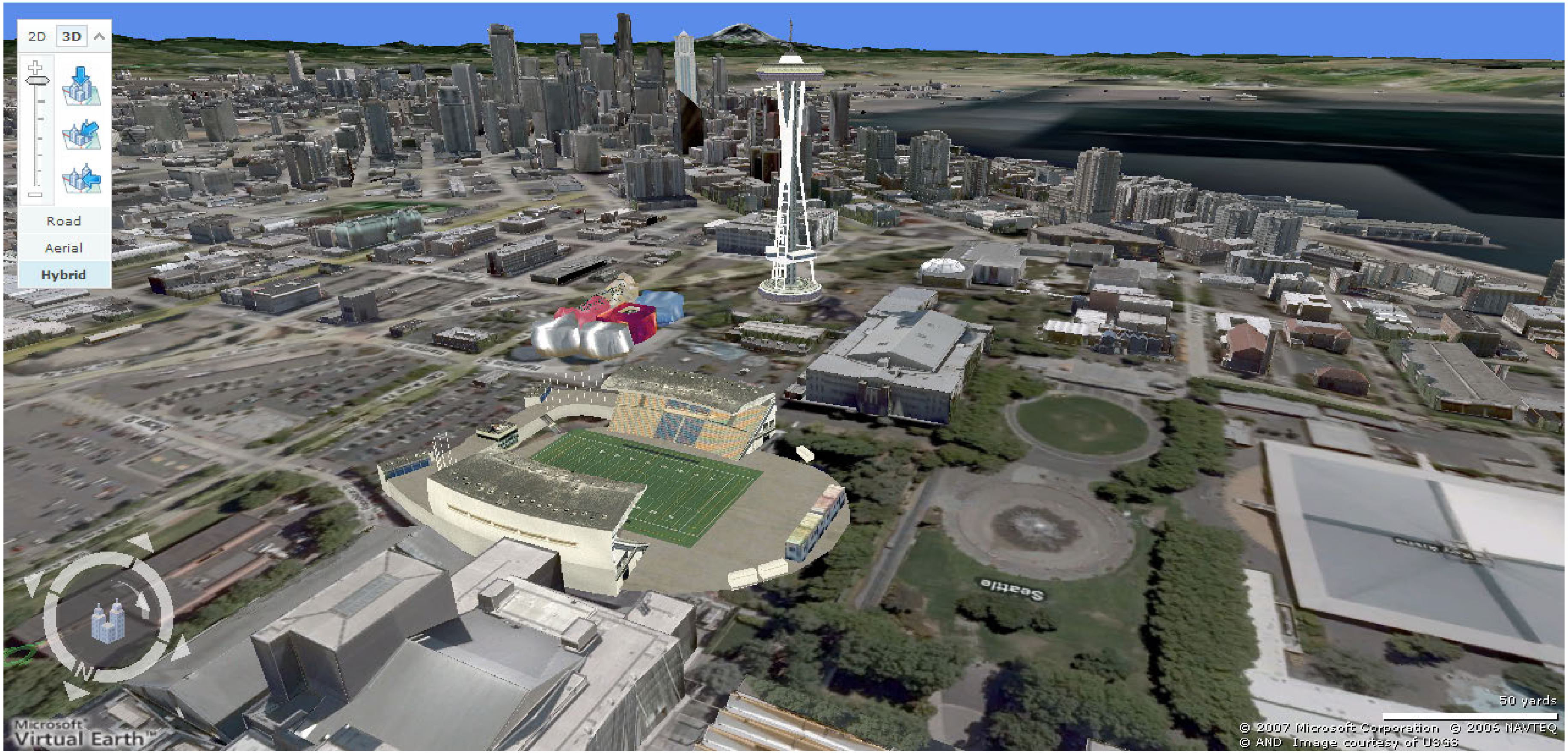
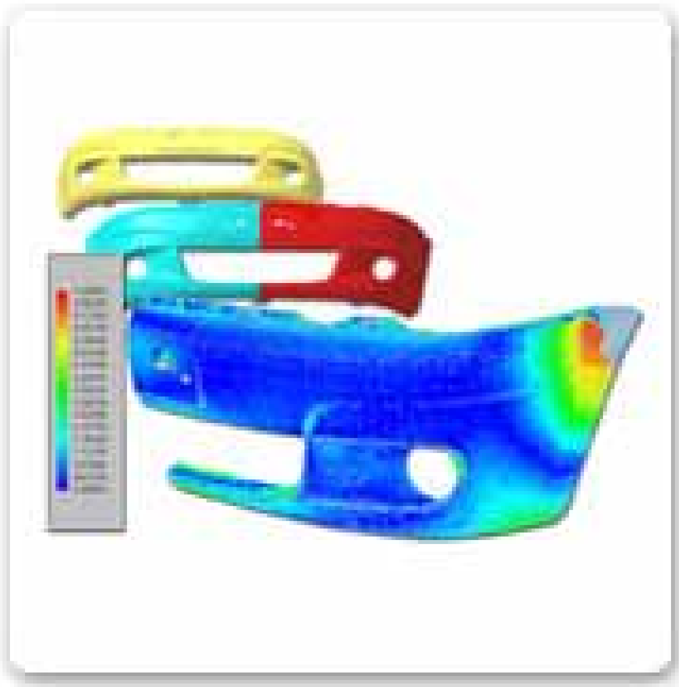


Image from Microsoft's Virtual Earth
(see also: Google Earth)

Industrial inspection

- Verify specifications
- Compare measured model with CAD



Scanning industrial sites

as-build 3D model of off-shore oil platform

Leica Geosystems

Vision in space

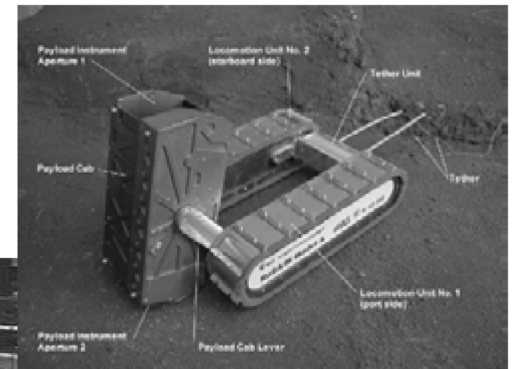
NASA'S Mars Exploration Rover Spirit captured this westward view from atop a low plateau where Spirit spent the closing months of 2007.

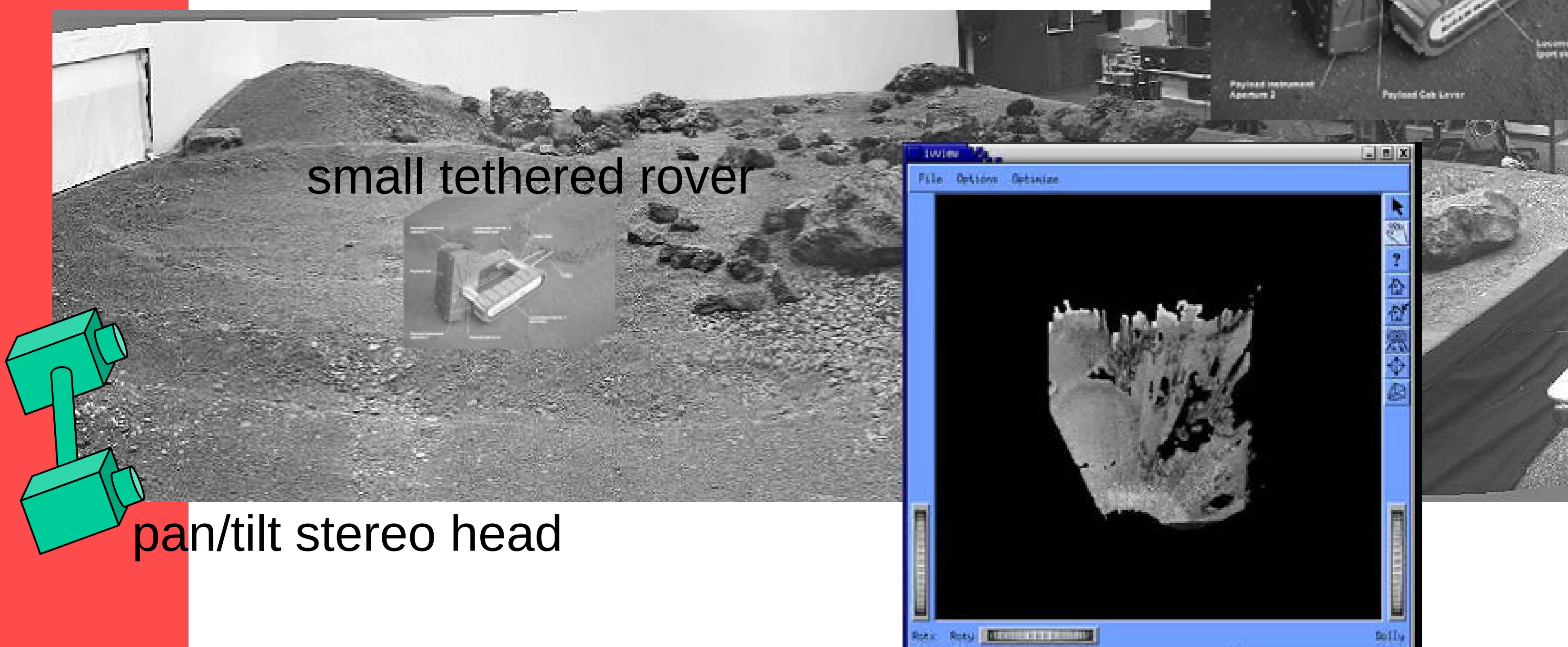
Vision systems (JPL) used for several tasks

- Panorama stitching
- 3D terrain modeling
- Obstacle detection, position tracking
- For more, read "Computer Vision on Mars" by Matthies et al.

Robot navigation

ESA project
our task: Calibration + Terrain modelling + Visualization





small tethered rover

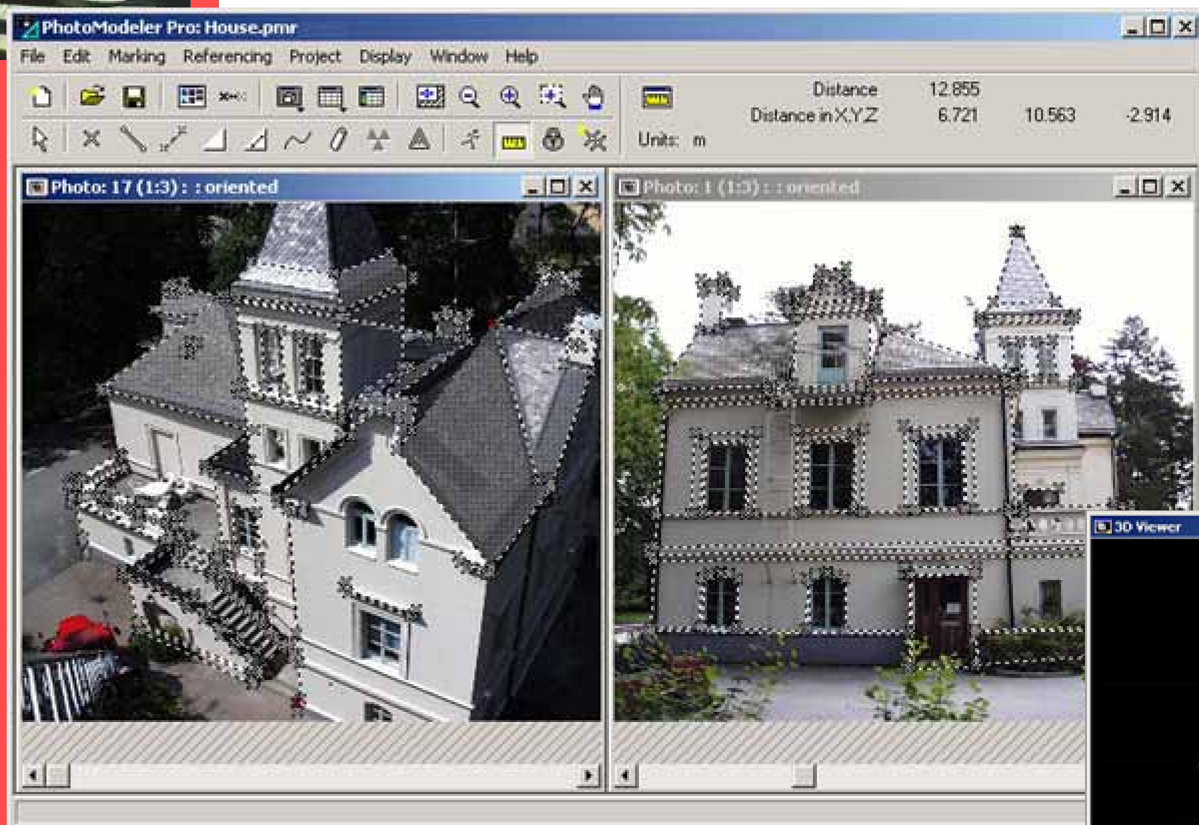
pan/tilt stereo head

Robotics

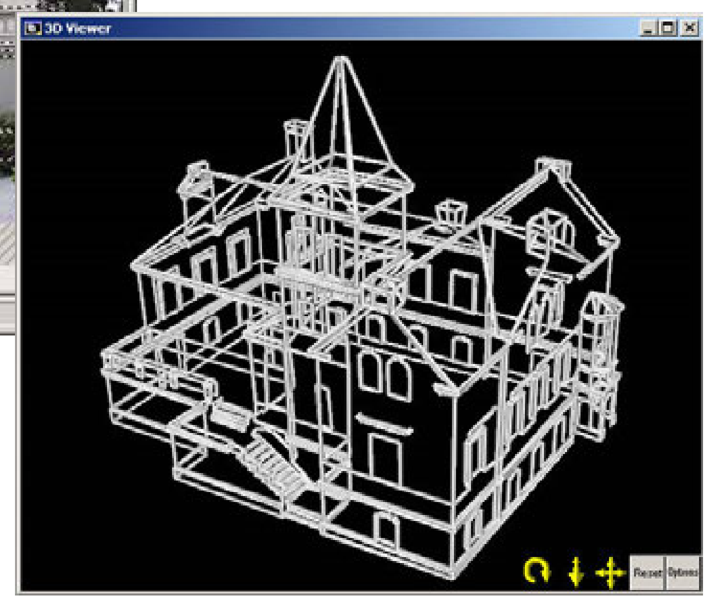
NASA's Mars Spirit Rover
http://en.wikipedia.org/wiki/Spirit_rover

http://www.robocup.org/

Architecture



Survey
Stability analysis
Plan renovations



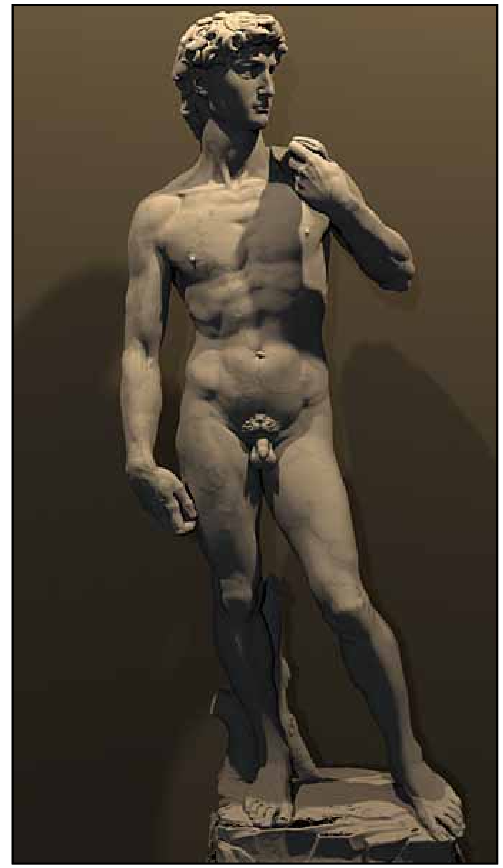
PhotoModeler

Architecture

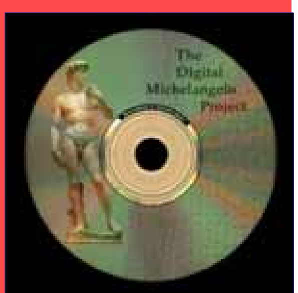
Survey
Stability analysis
Plan renovations

Cultural heritage

Stanford’s Digital Michelangelo

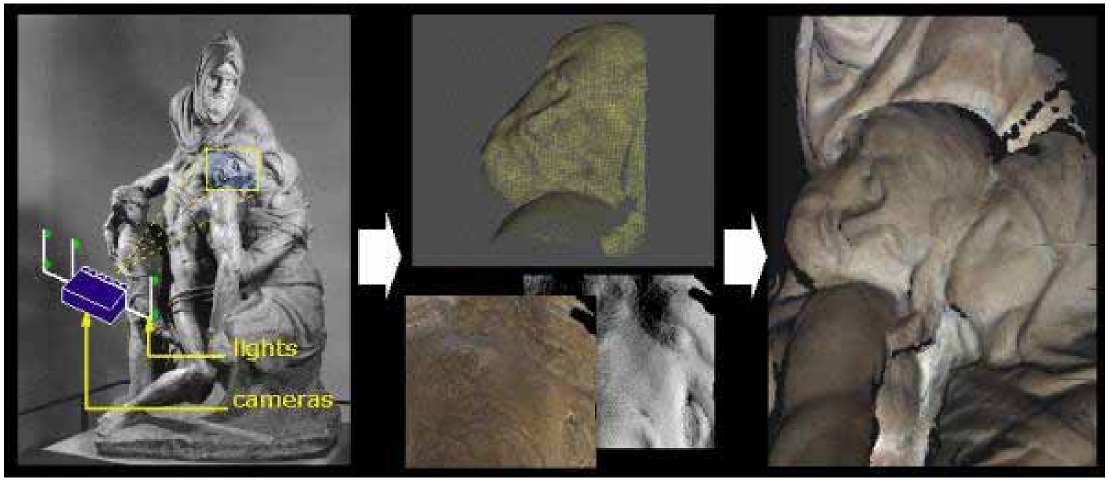


Digital archive
Art historic studies



IBM's pieta project

Photometric stereo + structured light



more info:

http://researchweb.watson.ibm.com/pieta/pieta_details.htm

Archaeology

accuracy ~1/500 from DV video
(i.e. 140kb jpegs 576x720)

Visual Cues: Stereo and Motion

Disparity map from Stereo

image I(x,y)

Disparity map D(x,y)

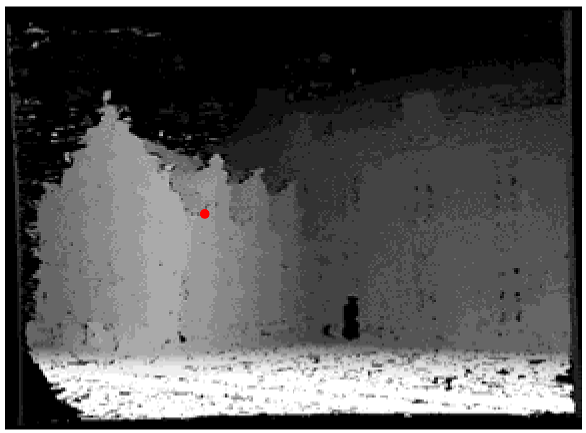
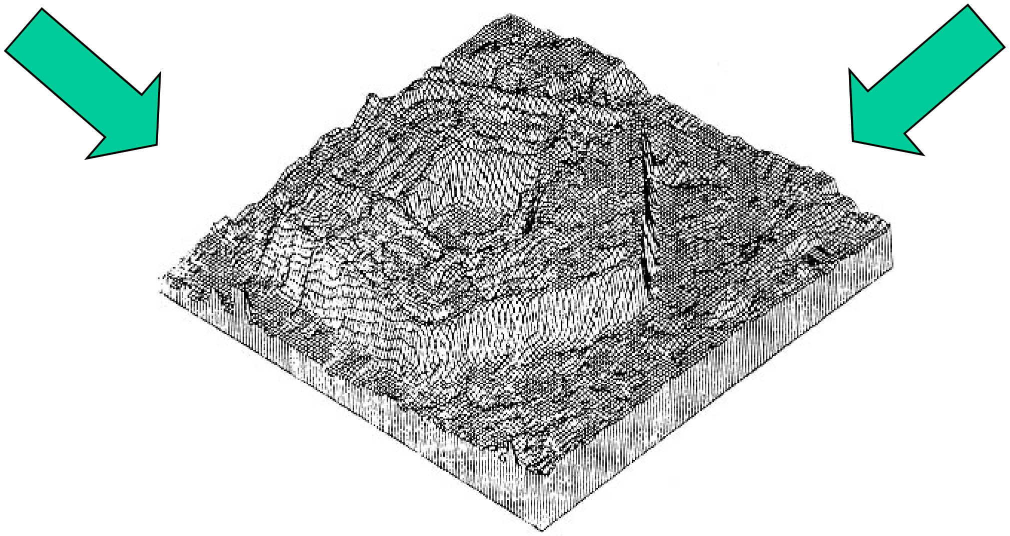


image I´(x´,y´)

$$(x',y')=(x+D(x,y),y)$$

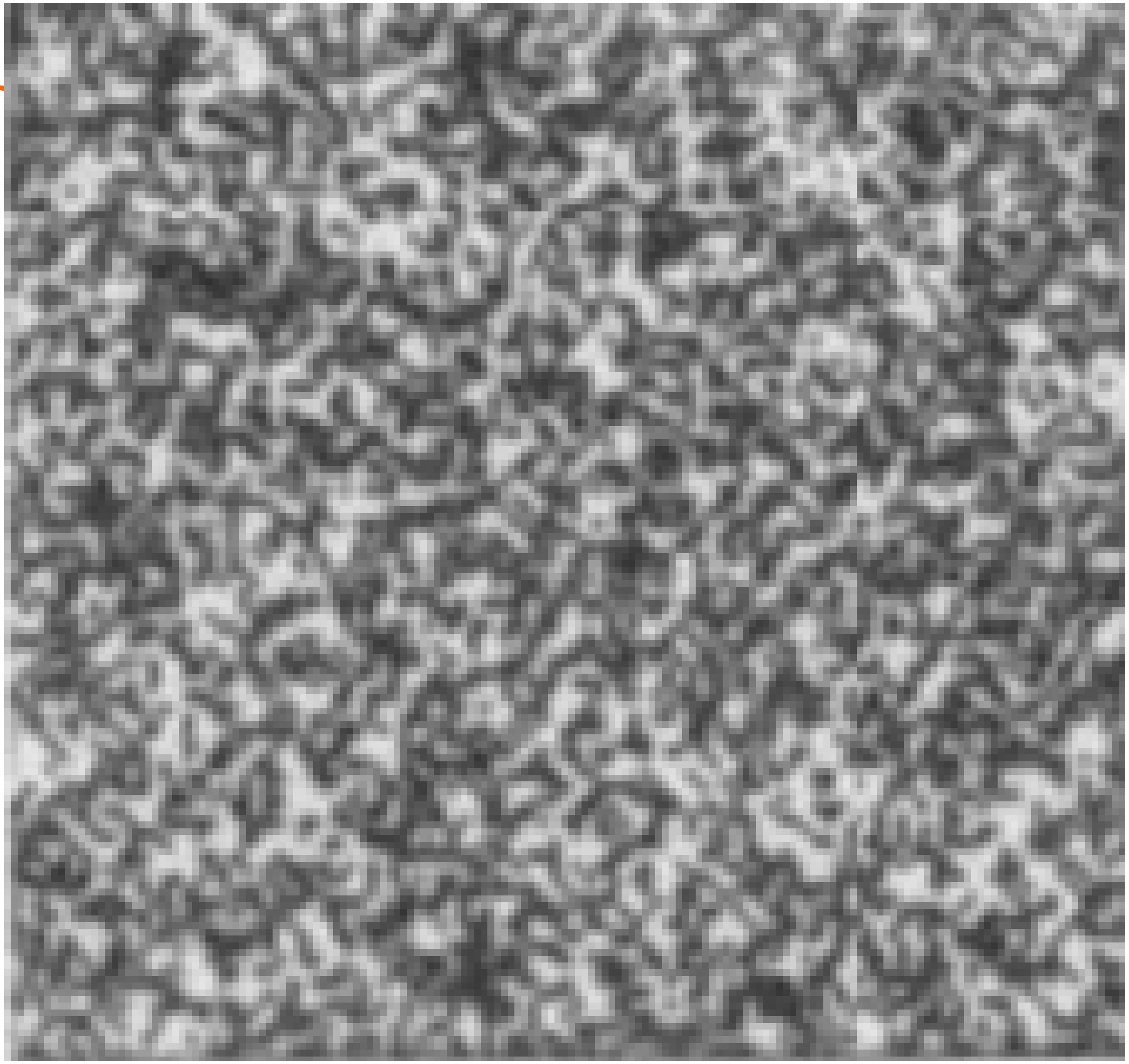
Dynamic Programming (Ohta and Kanade, 1985)



Reprinted from "Stereo by Intra- and Intet-Scanline Search," by Y. Ohta and T. Kanade, IEEE Trans. on Pattern Analysis and Machine Intelligence, 7(2):139-154 (1985). © 1985 IEEE.

Optical flow

Wh

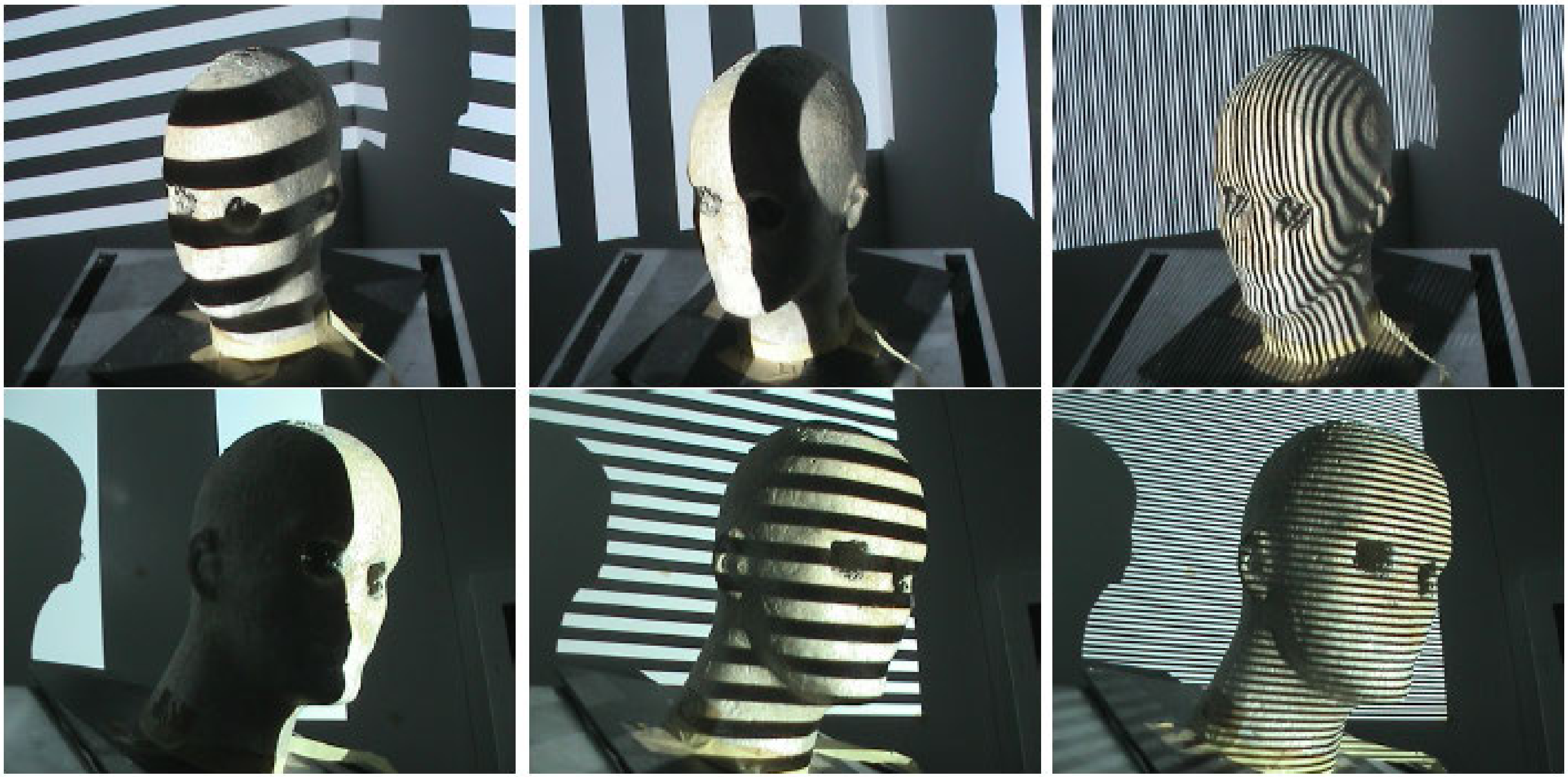


Optical flow

Results

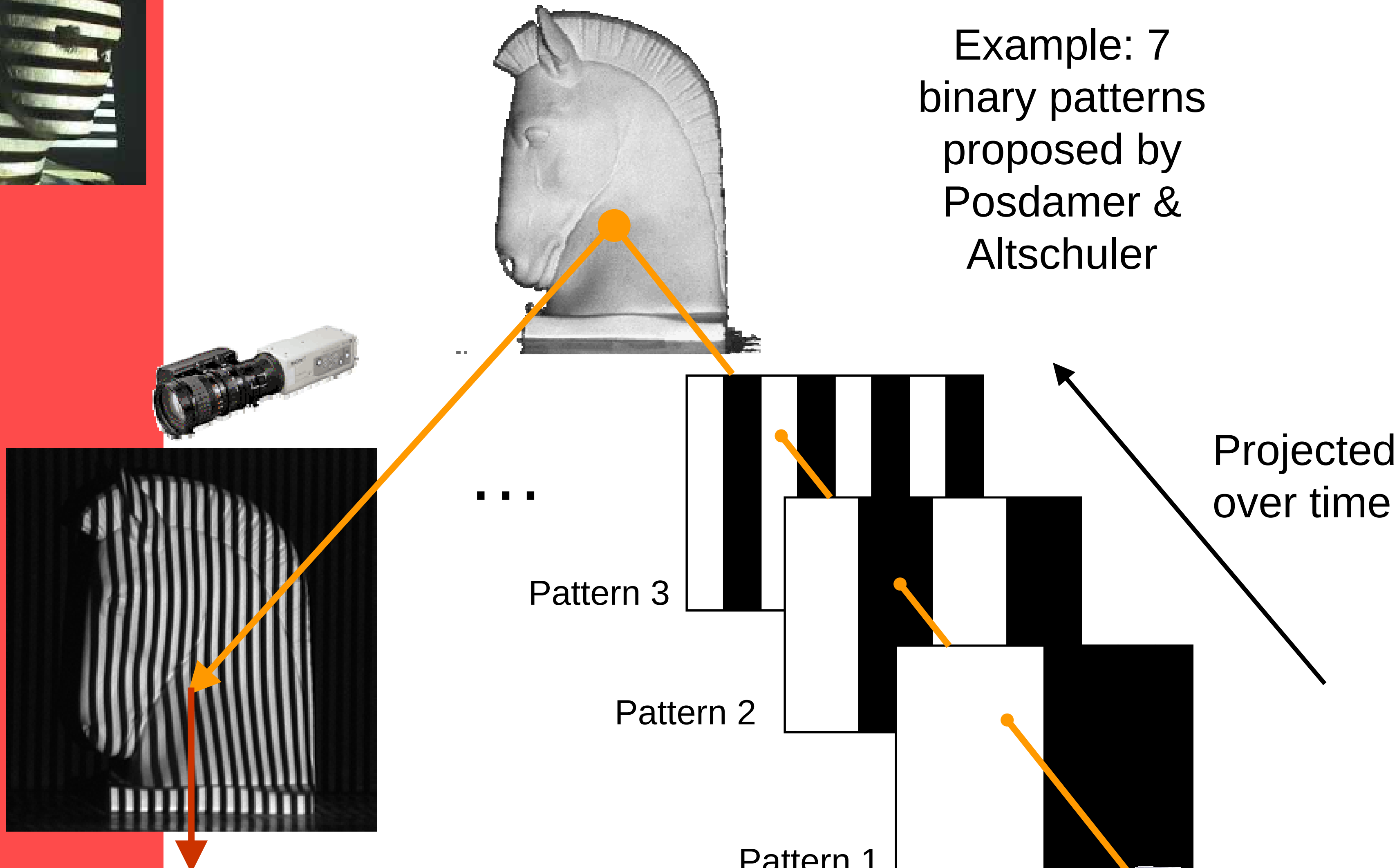
Active Vision:
Structured Light

Active Vision: Structured Light



Binary Coding

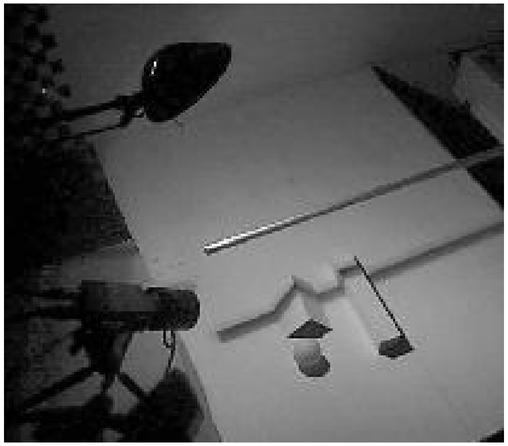
Example: 7 binary patterns proposed by Posdamer & Altschuler



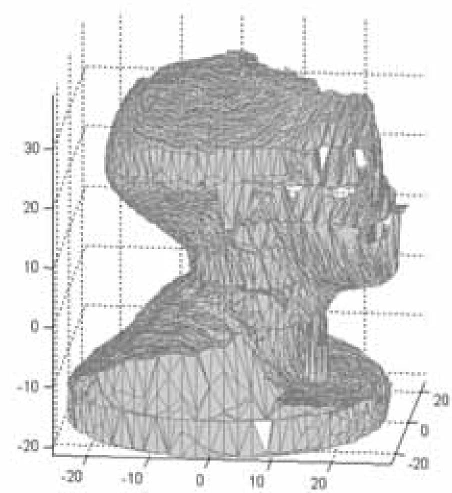
Codeword of this píxel: 1010010 → identifies the corresponding pattern stripe

Example: Bouguet and Perona, ICCV'98

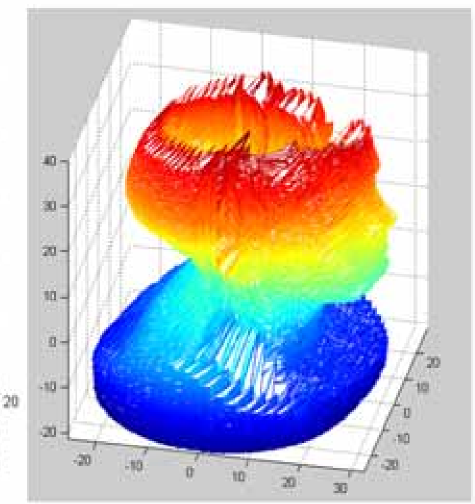
"Cheap and smart" Solution



Structured Light Using a Rotating Table
James Clark, 3D CV F2009

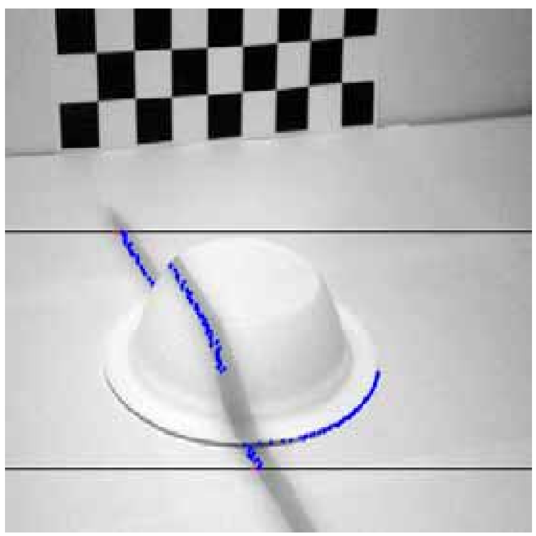


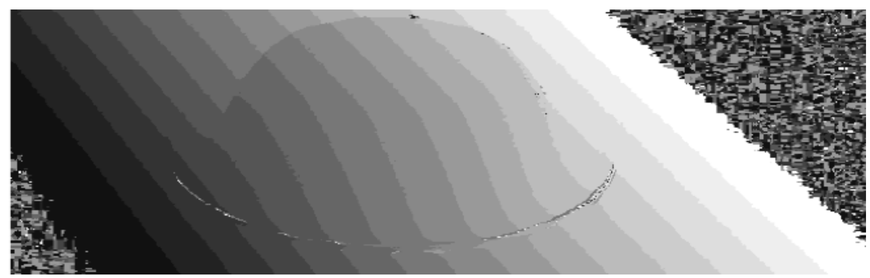
Height Strip Mesh



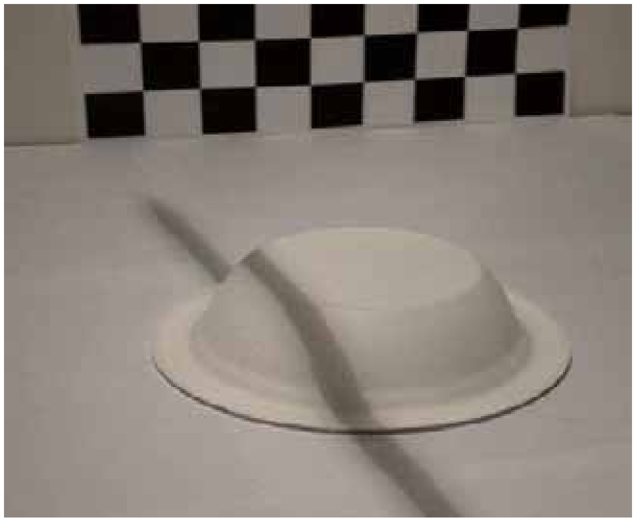
Localized Mesh

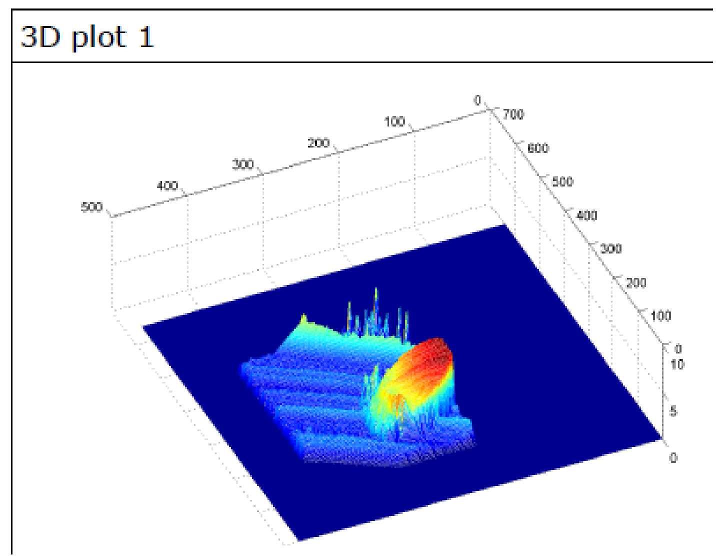
Structured Light
Anuja Sharma, Abishek Kumar

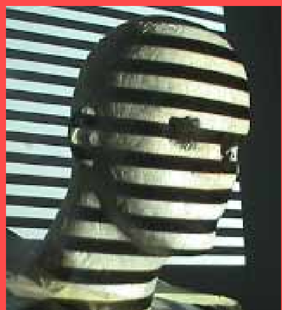




Structured Light
Anuja Sharma, Abishek Kumar

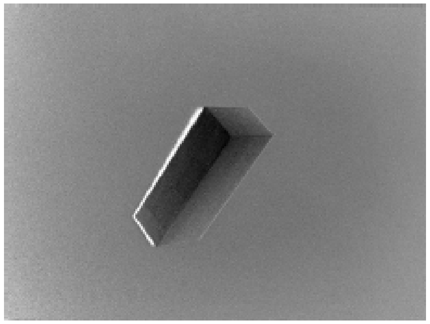


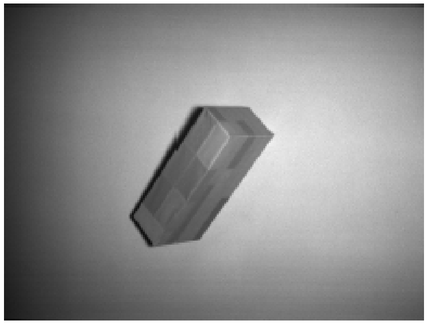




Range Sensor Data Processing to get 3D Shapes

Input Data: Depth Maps

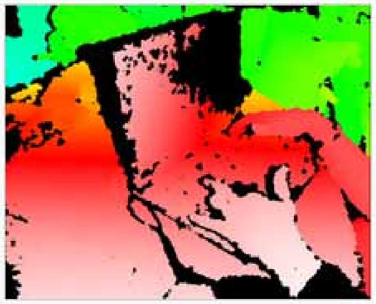




Range Image (left) and gray level image (right)

A slide from Microsoft's E3 Conference showing a diagram of the technologies in Kinect

This infrared image shows the laser grid Kinect uses to calculate depth



The depth map is visualized here using color gradients from white (near) to blue

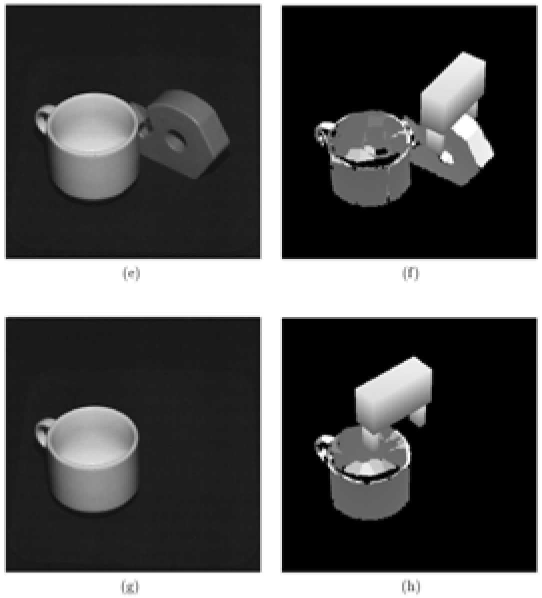
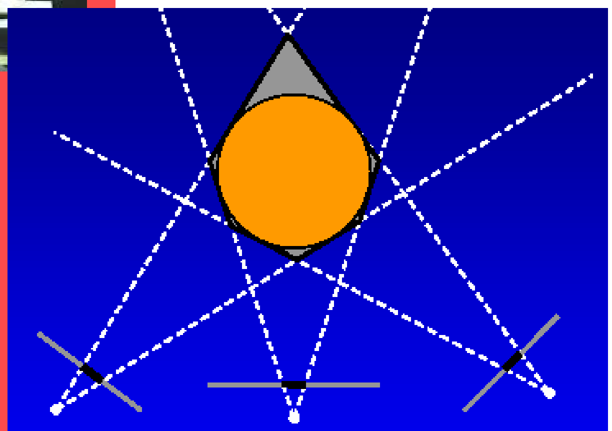
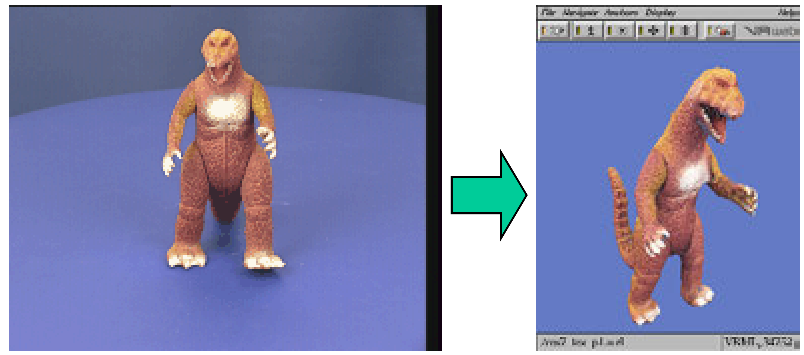


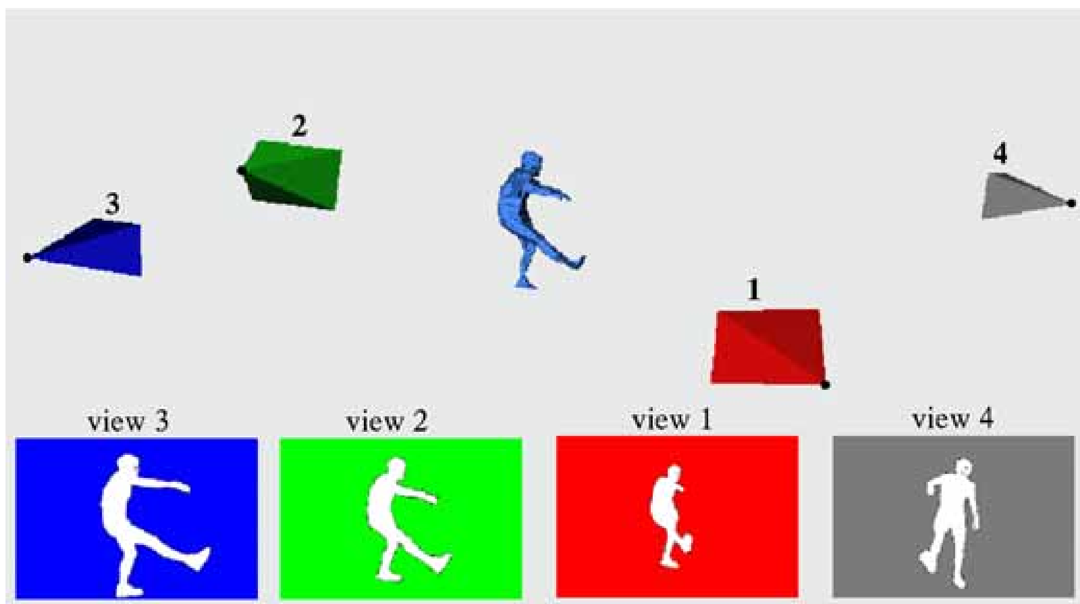
Figure 9: Continuation of the example scene consisting of four objects. (e) and (f) grasping the Scotch tape roller, and (g) and (h) grasping the coffee cup.

3D Shape Cues:
Shape from Silhouettes

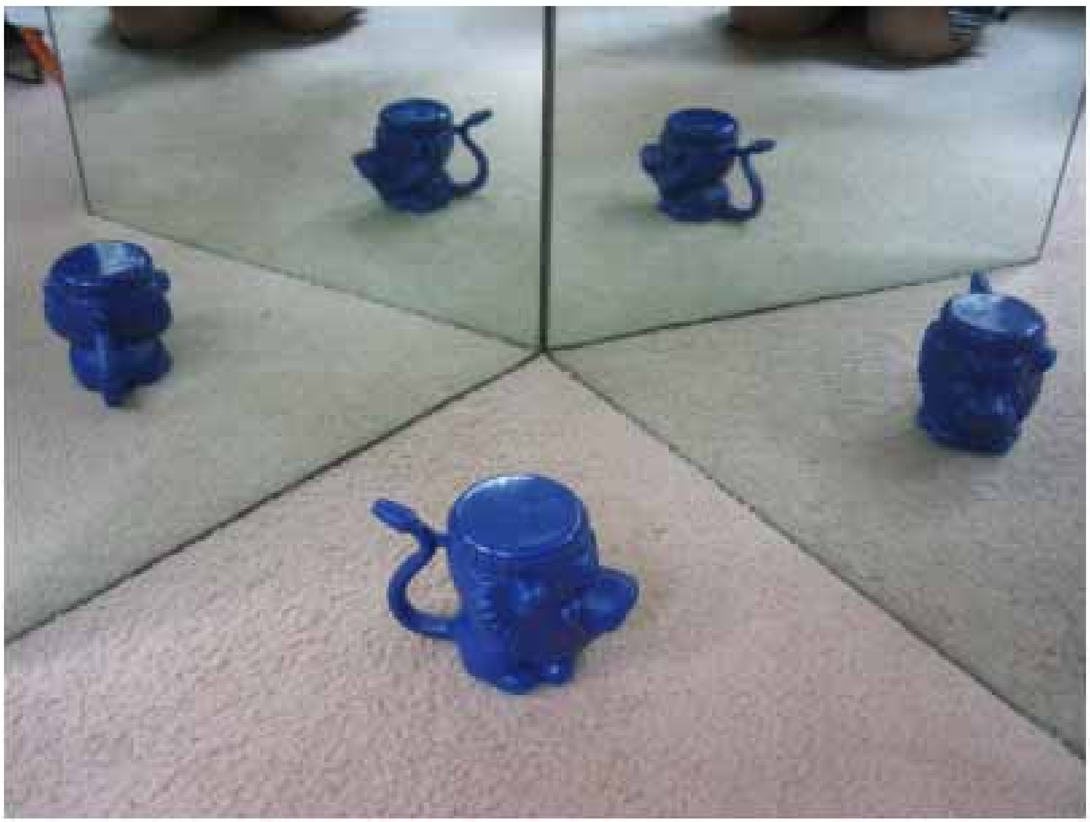
3D Shape from Silhouettes







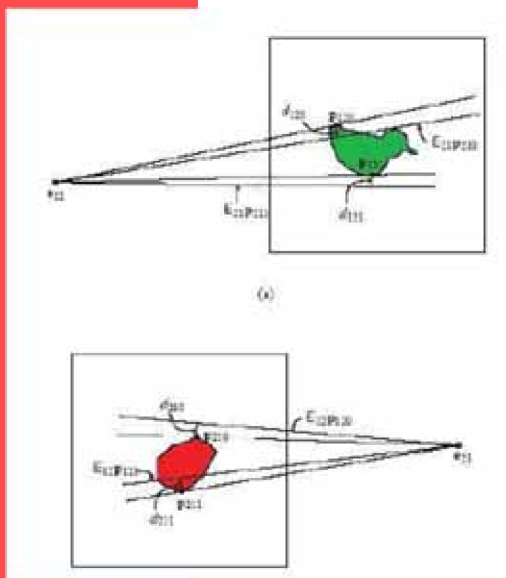
3D shape from silhouettes: Two Mirrors and uncalibrated camera



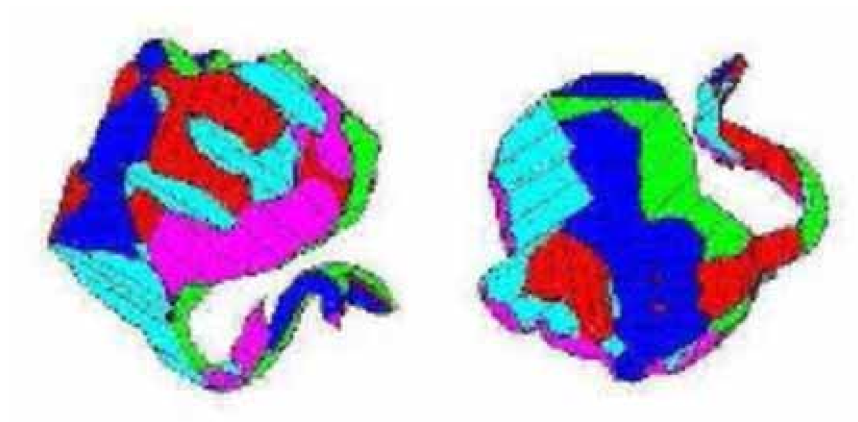
Forbes et al., ICCV2005

Christine Xu, Computer Vision Student Project

3D shape from silhouettes



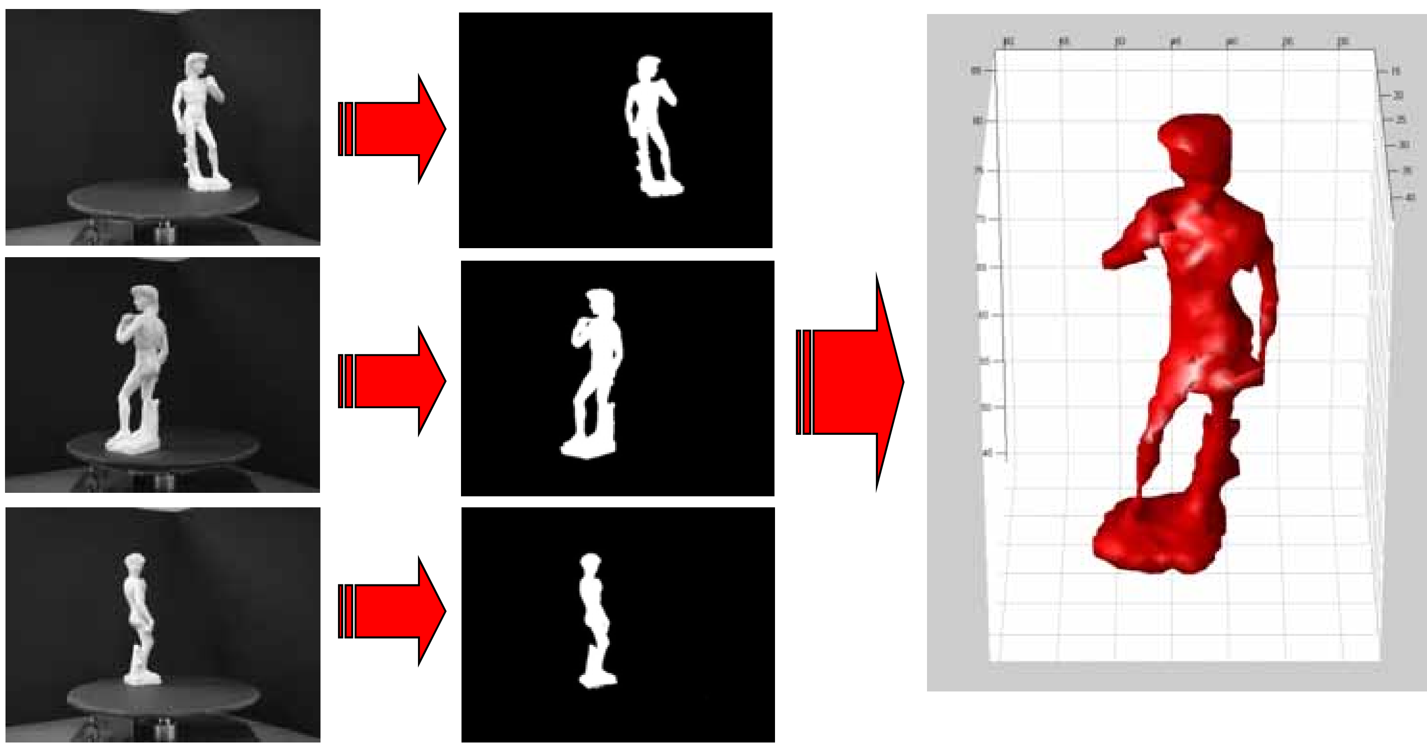
Build 3D model



Visualize 3D model from arbitrary viewing angles

Example

- Compute visual hull with silhouette images from multiple calibrated cameras
- Compute Silhouette Image
- Volumetric visual hull computation
- Display the result



Shape from Shading

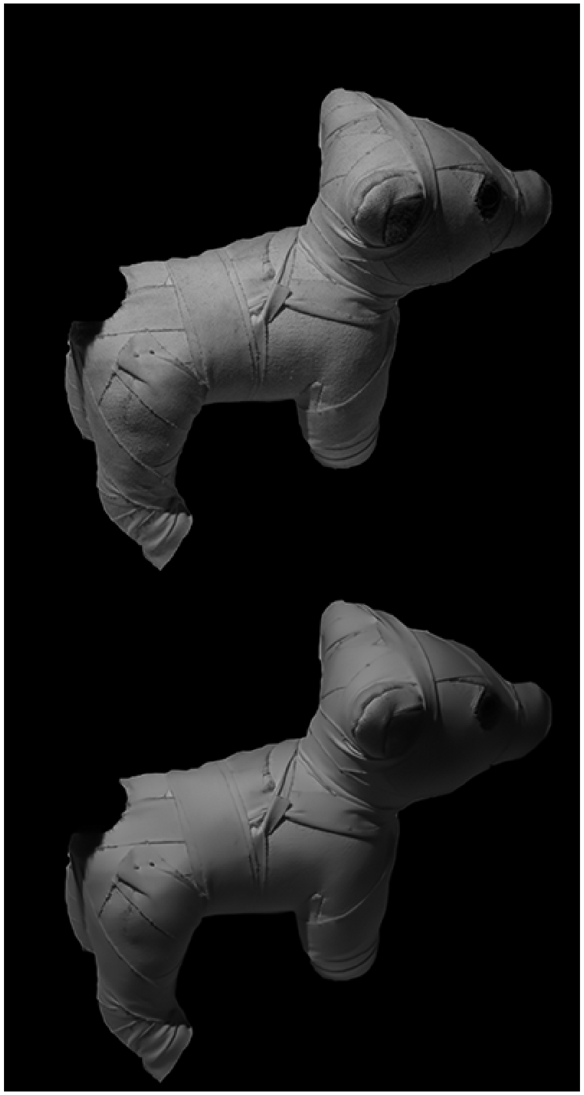
Photometric Stereo
Christopher Bireley

Bandage Dog

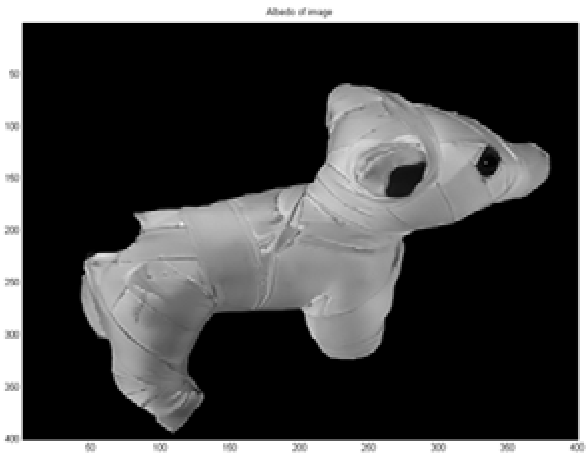
Imaging Setup

Preprocessing

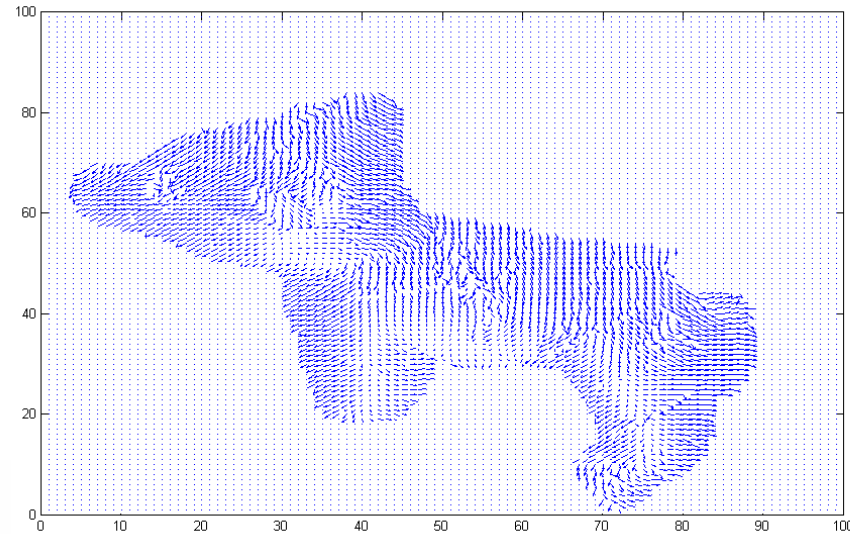
- Remove background to isolate dog
- Filter with NL Means



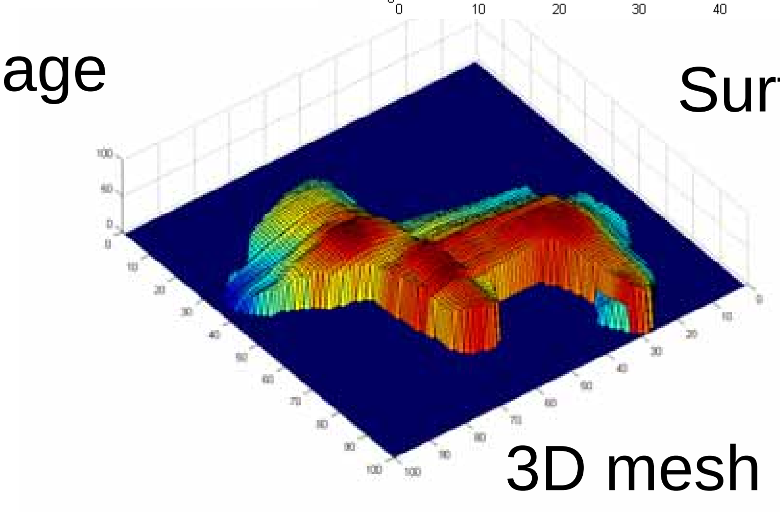
Photometric Stereo
Christopher Bireley



Albedo image



Surface Normals

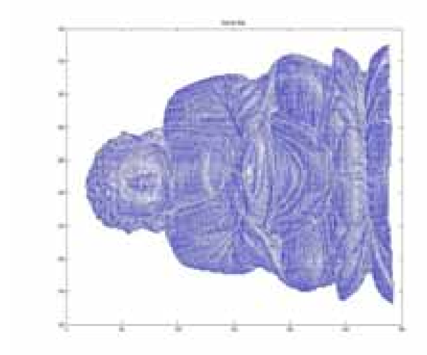


3D mesh

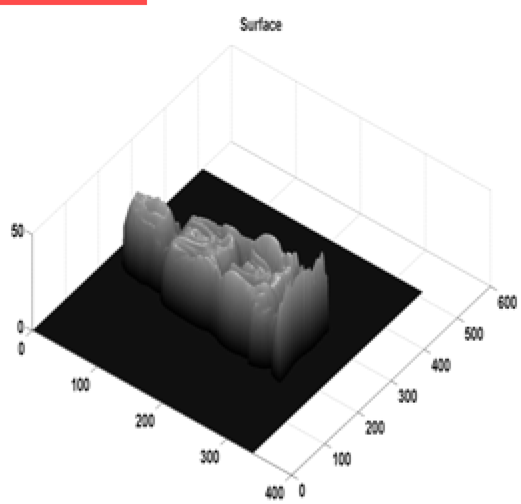
Results – Lord Buddha Images – Pre-Processed Images
Guozhen Fan and Aman Shah

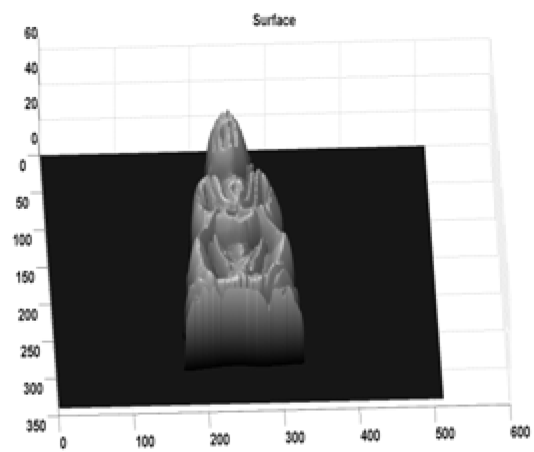
Original Image

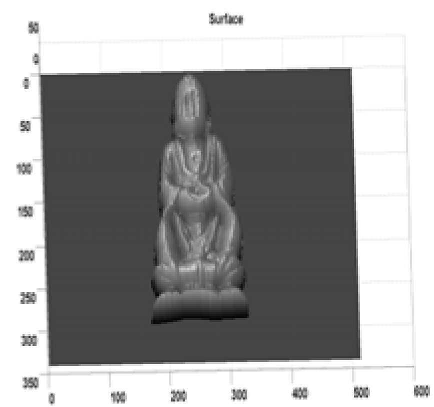
Albedo Map



Surface Normals



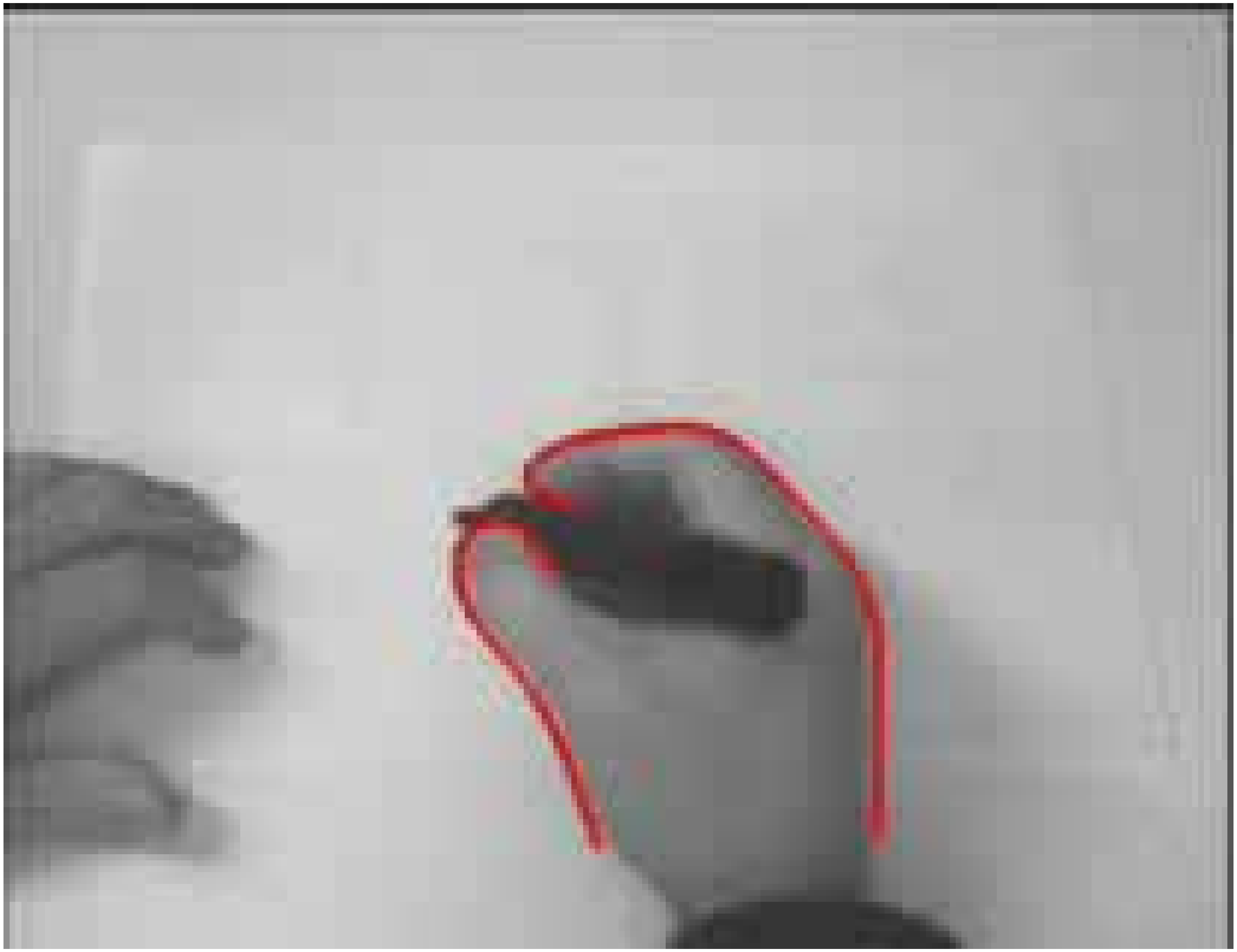




Obtained Surfaces from different angles

Object Tracking

Object Tracking: Using Deformable Models in Vision



Object Tracking: Using Deformable Models in Vision: II

Unifying Boundary and Region-based information for Geodesic Active Tracking

Object Tracking III

Computer Vision Systems

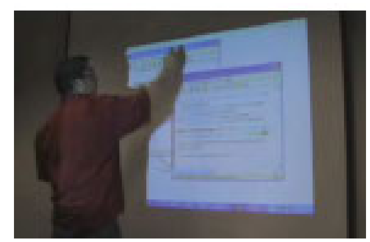
Webcam Based Virtual Whiteboard

Jon Bronson James Fishbaugh

- Blackboards came first

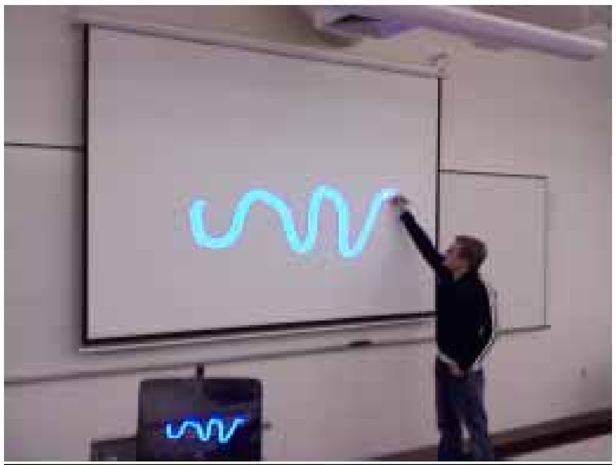
- Whiteboards eventually followed

- Virtual Whiteboards are coming
- Basic Idea:
  - Write on any surface
  - Use no ink/chalk
  - Store all information to disk



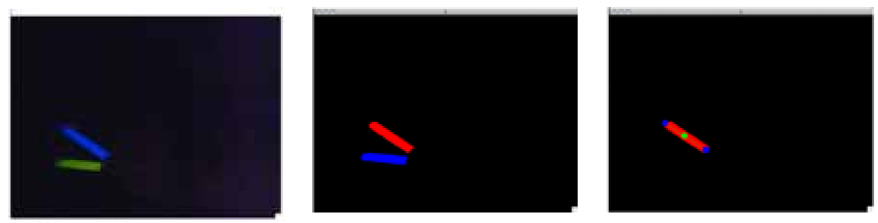
Webcam Based Virtual Whiteboard

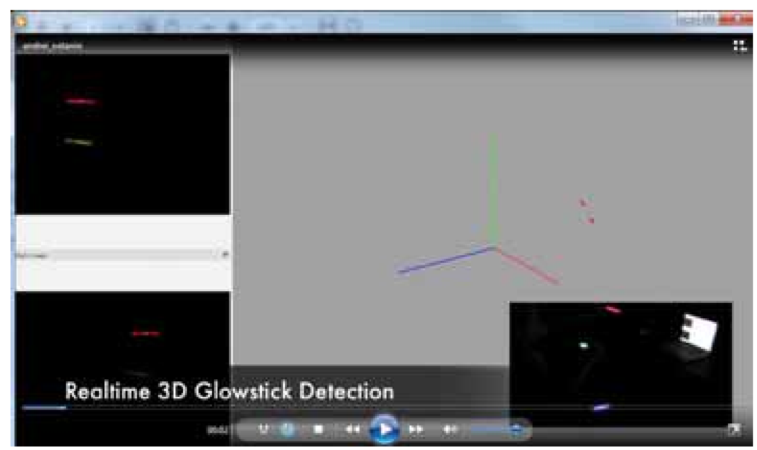
Jon Bronson James Fishbaugh



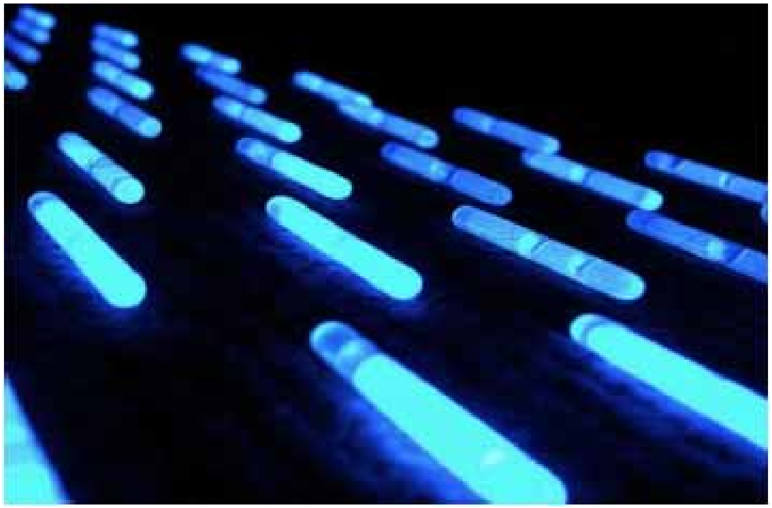
Real-Time 3D Glowstick Detection
Computer Vision Project 2009
Andrei Ostanin

Detecting the 3D position of glowsticks in real-time using two cameras.

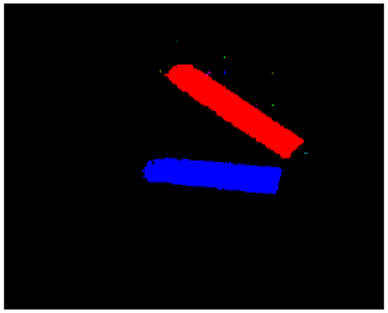




Realtime Glowstick Detection
Andrei Ostanin



- Capture the 3D position of glowsticks in real-time using two webcams
- Environment dark enough that glowsticks are easily segmented out
- Prefer speed over correctness

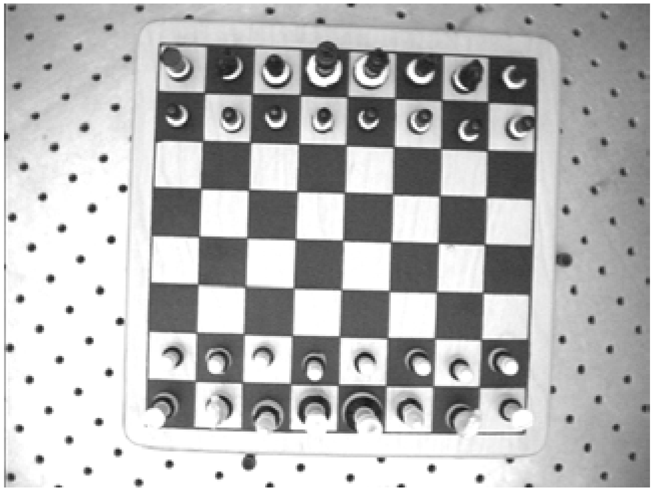


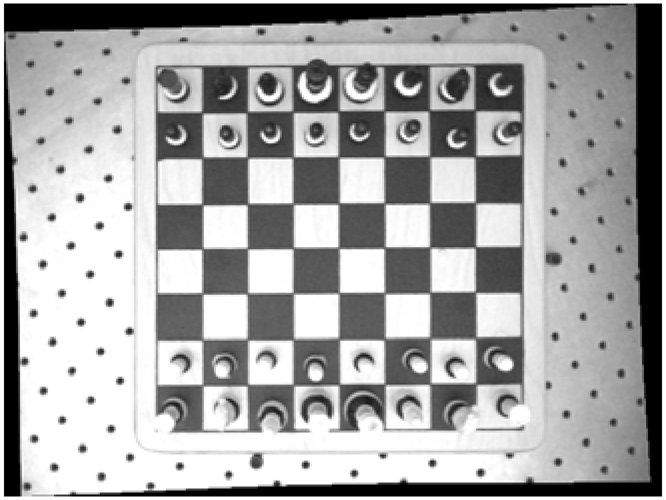
movie

Student Project: Playing Chess, Recognition and Simulation

- Track individual chess pieces
- Maintain state of board
- Graphically represent state changes and state
- D. Allen, D. McLaurin UNC
- Major ideas:
  - 3D from stereo
  - detect and describe changes
  - Use world knowledge (chess)

Calibration, Rendering & Replay





Movie

Goal and objectives

From Snapshots, a 3-D View

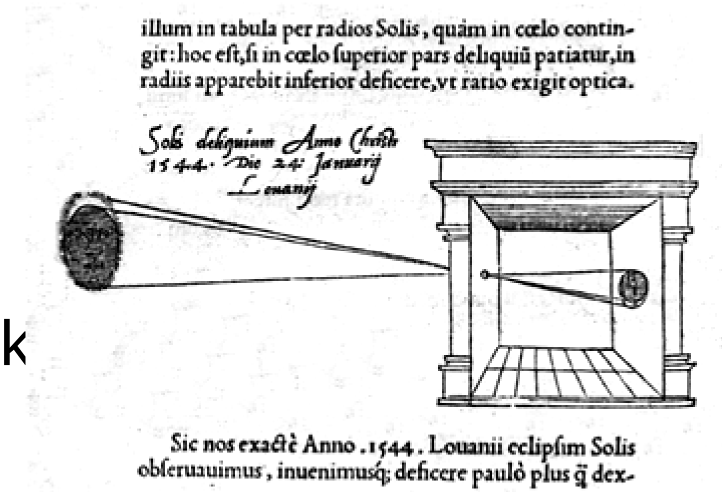
NYT, August 21, 2008, Personal Tech

http://www.nytimes.com/2008/08/21/technology/personaltech/21pogue.html

Stuart Goldenberg

Next class: Image Formation
Chapter 1: Cameras

- Please find pdf copies of Chapters 1&2, Forsyth&Ponce, on the website.
- Purchase the course book on your own.



Assignment:

- Read Chapter 1: Cameras, Lenses and Sensors: See Course [home page]