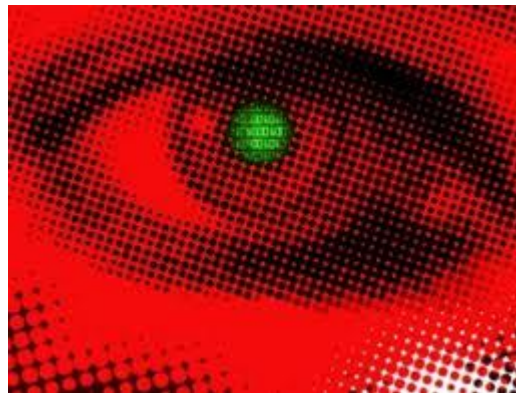


# Fundamentals of Computer Graphics, Image Processing, and Vision



# Fundamentals of Computer Graphics, Image Processing, and Vision

- מרצים: דניאל כהן-אור והדר אלאור
  - [dcor@post.tau.ac.il](mailto:dcor@post.tau.ac.il)
  - אתר שלי: <http://www.cs.tau.ac.il/~dcor>
  - אתר הקורס: <http://www.cs.tau.ac.il/~dcor/Graphics/graphics2013.html>
  - שעת קבלה: בתאום (שרייבר 216)
- בודק תרגילים?

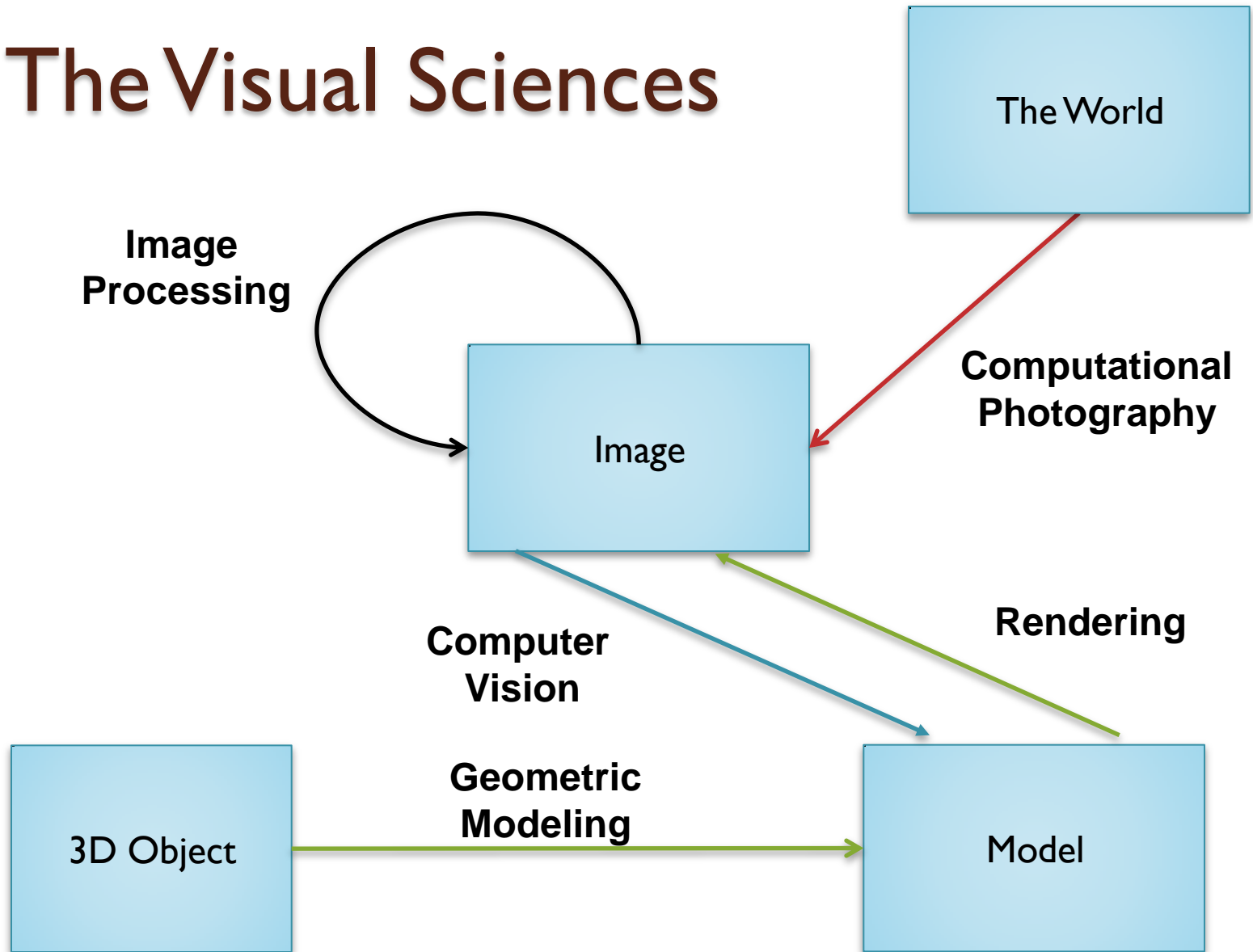
# התכנית להיום

## 1. הקדמה

- גרפיקה ממוחשבת ועיבוד תמונה
- ראייה ממוחשבת
- סילבוס (מה נלמד בקורס)
- דרישות (תרגילים, מבחן)

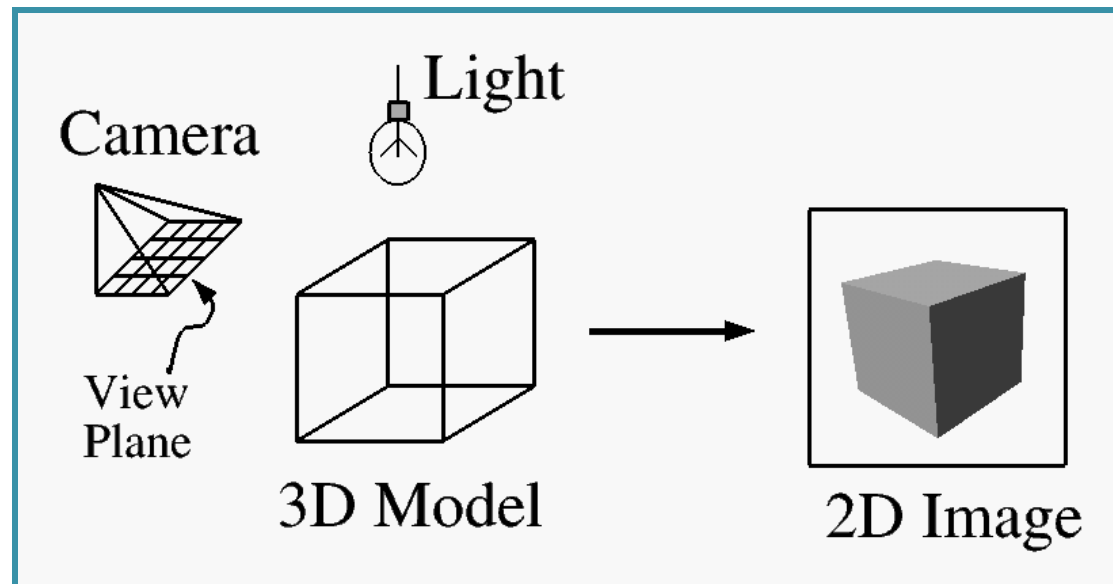
## 2. Half Toning

# The Visual Sciences



# גרפיקה ממוחשבת?

- Imaging = *representing 2D images*
- Modeling = *representing 3D objects*
- Rendering = *constructing 2D images from 3D models*
- Animation = *simulating changes over time*



# ראיה ממוחשבת?

- Methods for acquiring, processing, analyzing, and understanding images
- Challenge: Structure and depth are inherently ambiguous from single views.



# עיבוד תמונה?

- Manipulation of images to produce new images...



# Computer Graphics





# שימושים לגרפיקה ממוחשבת

- 
- **Entertainment**
  - Computer-aided design
  - Scientific visualization
  - Training
  - Education
  - E-commerce
  - Computer art



King Kong  
(Universal Pictures)



Flower  
(Sony)



The Incredibles  
(Pixar)



Crysis  
(Crytek)

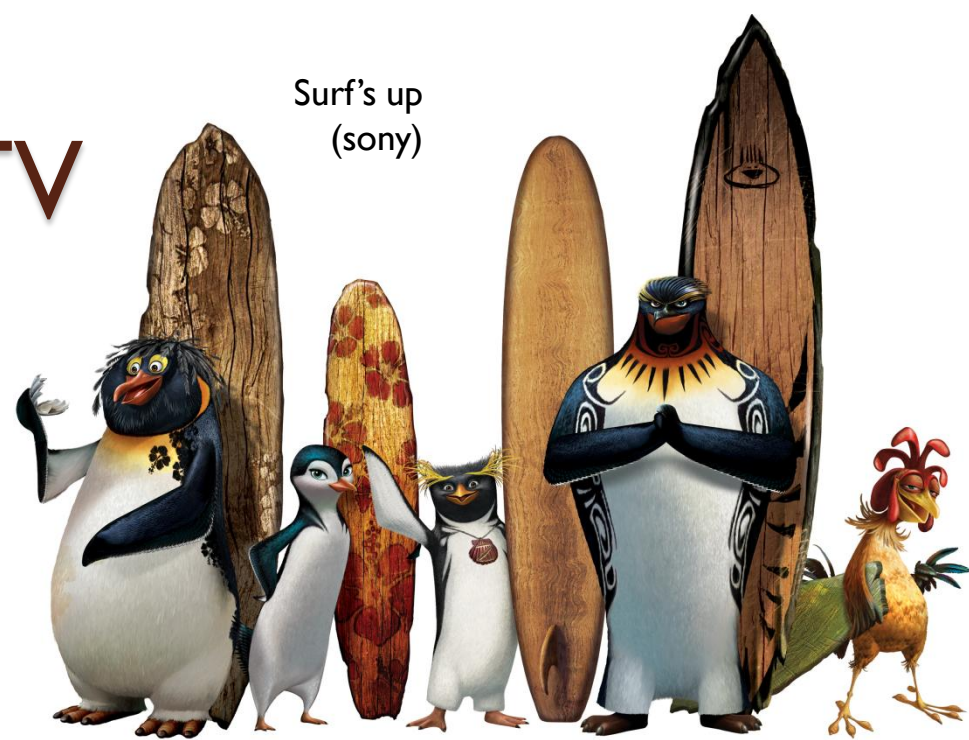
# Movies and TV



Rugby commercial



(ad)  
(making of)



Octapodi

Movie  
Making of

# Luxo Jr

- Pixar Animation Studios, 1986
- Director: John Lasseter



# Games

1993 - Doom



1996 - Doom II



1998 - Unreal



1997 - Quake II



2004 - UT 2004



2009 - CryEngine 3



# Simulation

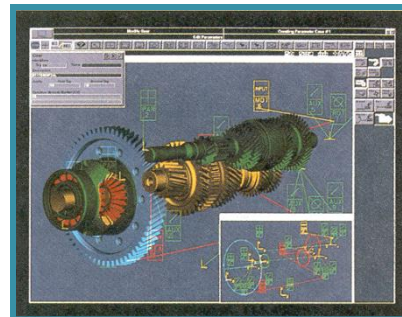


# Applications

- Entertainment
- • **Computer-aided design**
- Scientific visualization
- Training
- Education
- E-commerce
- Computer art



Los Angeles Airport  
(Bill Jepson, UCLA)

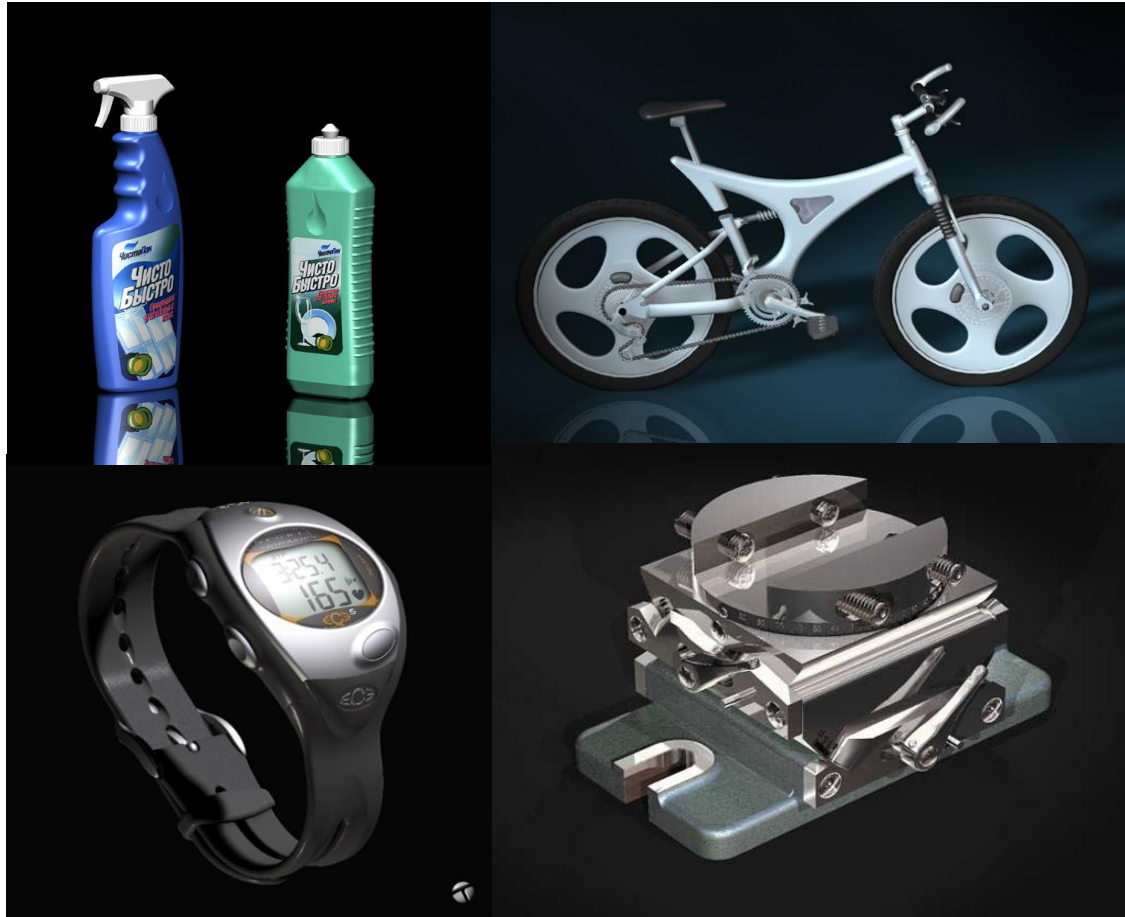


Gear Shaft Design  
(Intergraph Corporation)



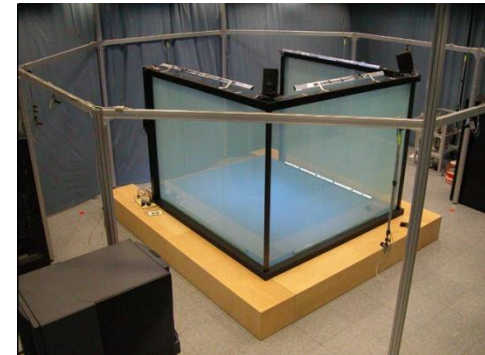
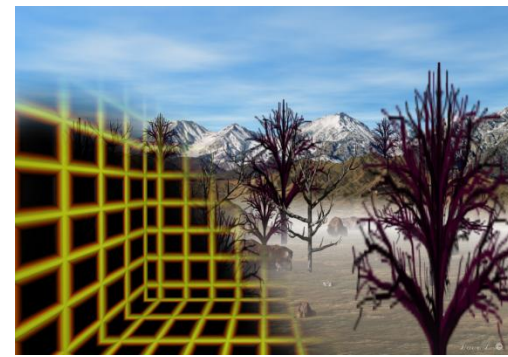
Boeing 777 Airplane  
(Boeing Corporation)

# CAD-CAM & design



# Virtual reality

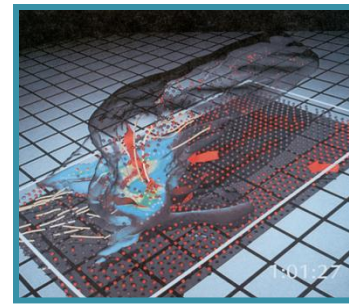
- Virtual Reality
  - C.A.V.E
- Augmented Reality
- Augmented Virtuality
- Human-Machine Interfaces
  - [Jeeves](#)
  - [Photogeist](#)
- Virtual Worlds



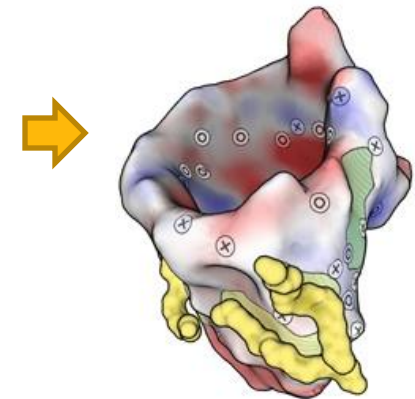


# Applications

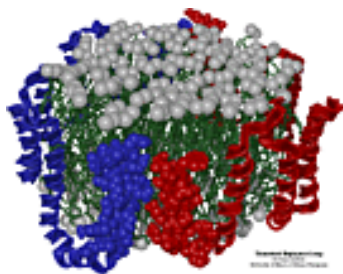
- Entertainment
- Computer-aided design
- • **Scientific visualization**
- Training
- Education
- E-commerce
- Computer art



Airflow Inside a Thunderstorm  
(Bob Wilhelmson,  
University of Illinois at Urbana-Champaign)

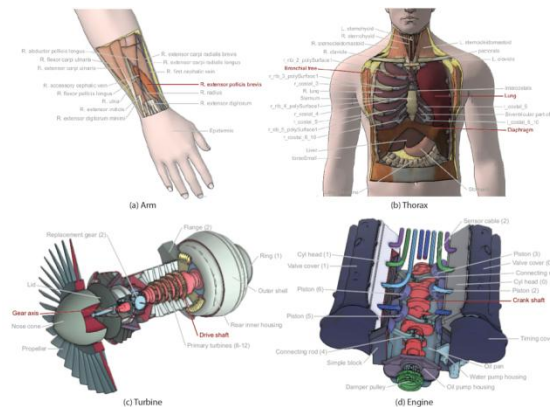


Molecular Surface  
Abstraction  
(Cipriano et al)



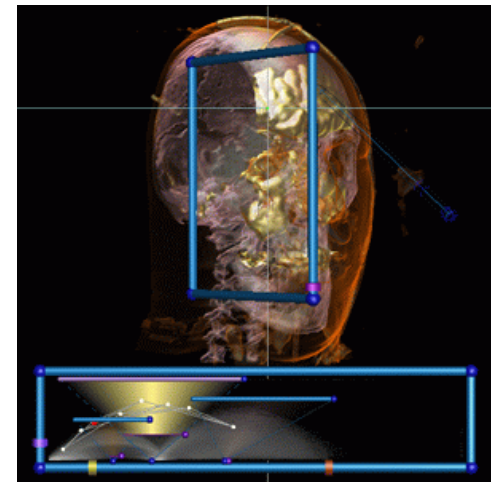
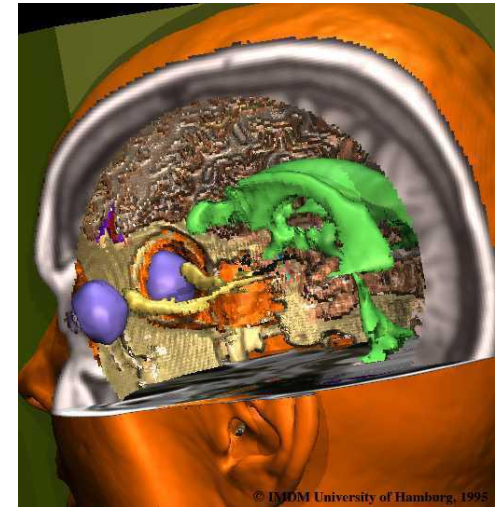
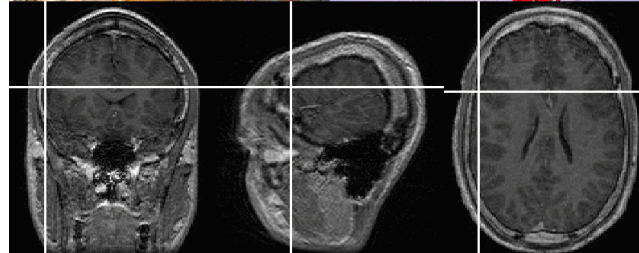
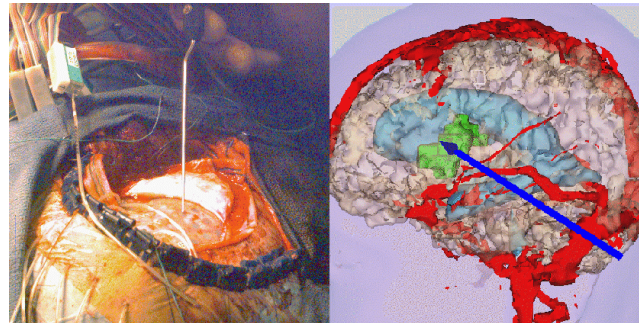
Apo A-I

(Theoretical Biophysics Group,  
University of Illinois at Urbana-Champaign)



Interactive Cutaway Illustrations  
(Microsoft Research)

# Medical imaging

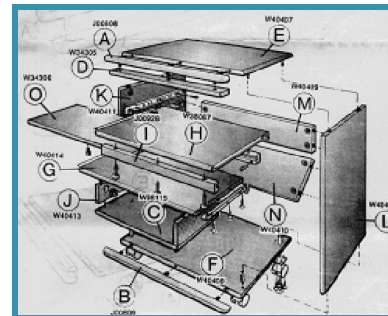


# Applications

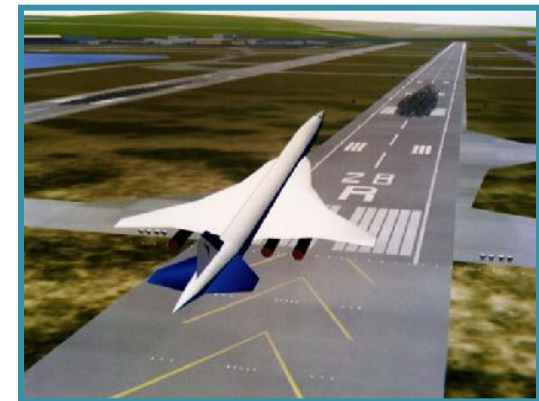
- Entertainment
- Computer-aided design
- Scientific visualization
- • **Training**
- Education
- E-commerce
- Computer art



**Driving Simulation**  
(Evans & Sutherland)



**Desk Assembly**  
(Silicon Graphics, Inc.)



**Flight Simulation**  
(NASA)

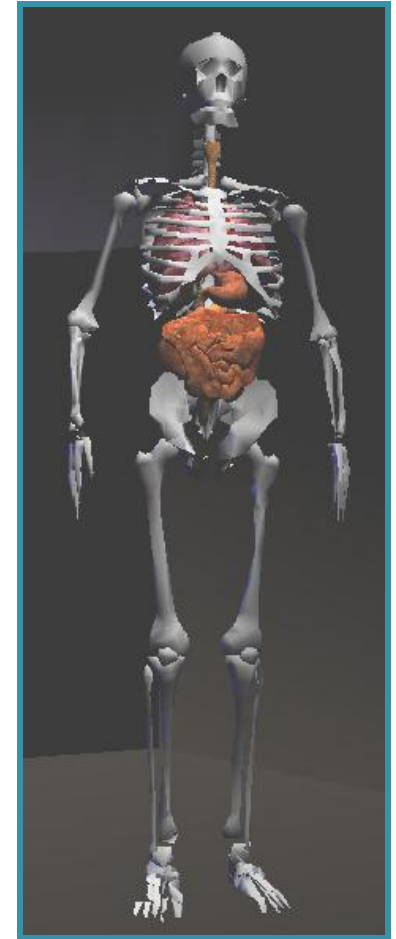
# Applications

- Entertainment
- Computer-aided design
- Scientific visualization
- Training
- • **Education**
- E-commerce
- Computer art



Forum of Trajan

(Bill Jepson, UCLA)



Human Skeleton

(SGI)

# Applications

- Entertainment
- Computer-aided design
- Scientific visualization
- Training
- Education
- • **E-commerce**
- Computer art



Second Life



Virtual Phone Store  
(Lucent Technologies)

# Applications

- Entertainment
- Computer-aided design
- Scientific visualization
- Training
- Education
- E-commerce
- • **Computer art**



**Blair Arch**

*(Marissa Range & Adam Finkelstein,  
Princeton University)c*

וכל התמונות המפוזרות לאורך המצגת...

# סילבוס



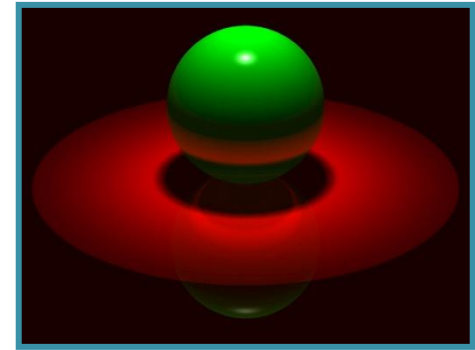
*“The screen is a window through which one sees a virtual world. The challenge is to make that world look real, act real, sound real, feel real.” – Sutherland, 1965*

# סילבוס

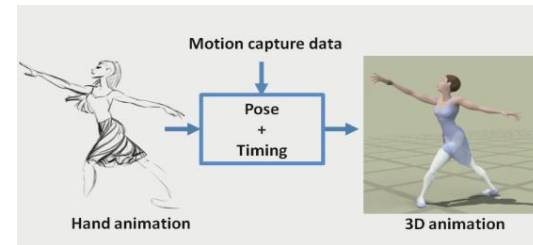
1. Image processing
2. Image manipulation
3. *Rendering*
4. *Modeling*
5. Animation
6. Computer Vision



**Image Processing**  
(Rusty Coleman, CS426, Fall99)

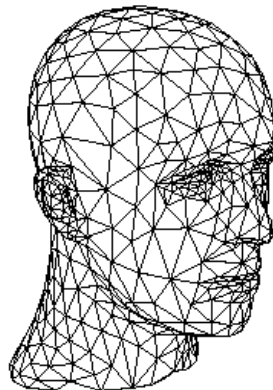


**Rendering**  
(Michael Bostock, CS426, Fall99)

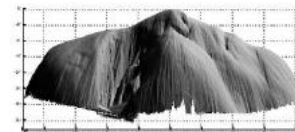


**Animation**  
(Angel, Plate 1)

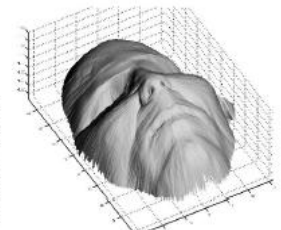
**Modeling**  
(Dennis Zorin, CalTech)



a)



b)



c)

**Computer Vision**



# Image Processing

- Raster Graphics
  - Display devices
  - Color models
- Image Representation
  - Sampling
  - Reconstruction
  - Quantization & Aliasing
- Image Processing
  - Filtering
  - Warping
  - Morphing
  - Composition



**Image Composition**  
*(Michael Bostock, CS426, Fall99)*



**Seam Carving (Shamir, Avidan)**

**Image Morphing**  
*(All students in CS 426, Fall98)*



# Rendering

- 3D Rendering Pipeline
  - Modeling transformations
  - Viewing transformations
  - Hidden surface removal
  - Illumination, shading, and textures
  - Scan conversion, clipping
  - Hierarchical scene graphics
  - OpenGL
- Global illumination
  - Ray tracing
  - Radiosity



OpenGL

*(Chi Zhang, CS 426, Fall99)*

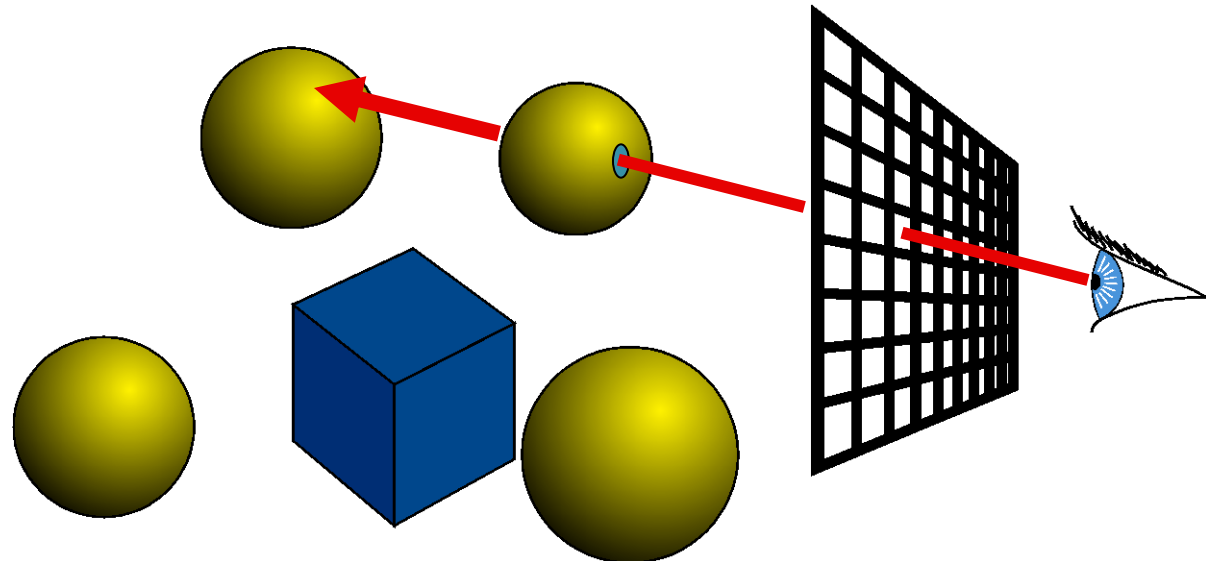


Ray Tracing

*(James Percy, CS 426, Fall99)*

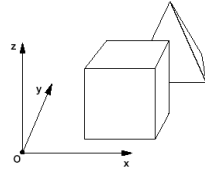
# Ray Casting

- For every pixel  
construct a ray from the eye
  - For every object in the scene
    - Find intersection with the ray
    - Keep if closest

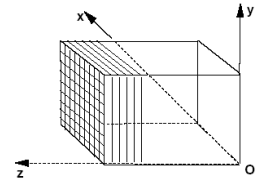
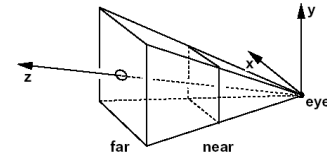


# The Rendering Pipeline

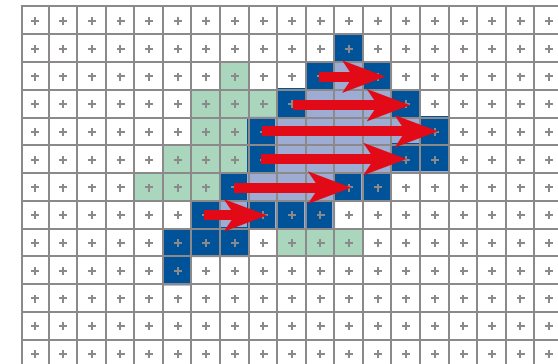
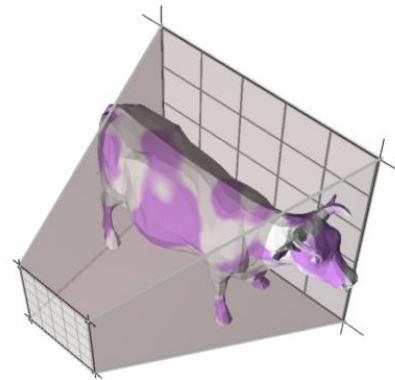
- Transformations



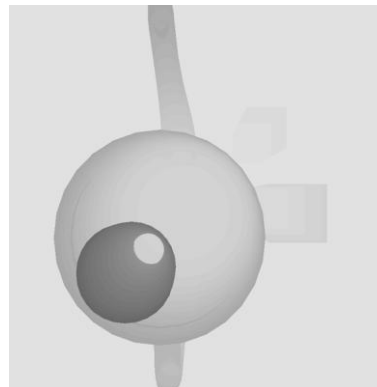
- Clipping



- Rasterization

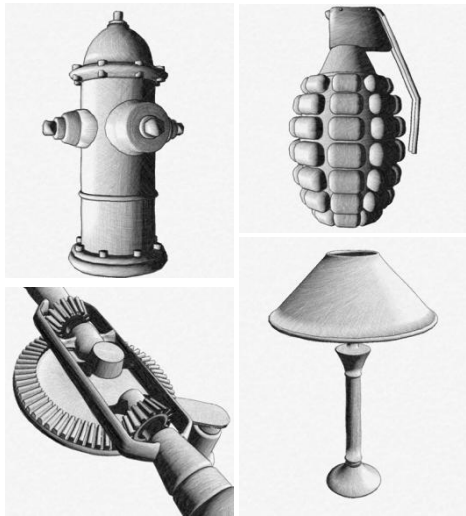


- Visibility

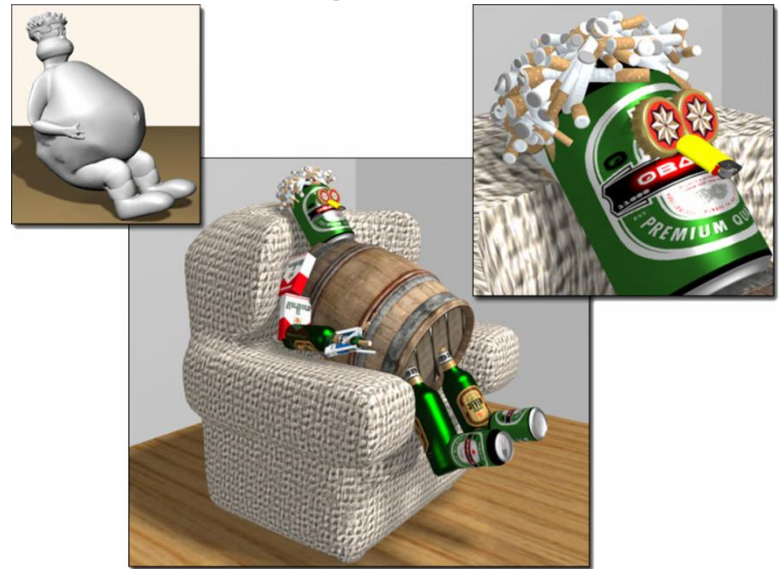


# Rendering - NPR

- Non Photorealistic Rendering



Real-time Pencil Rendering (Lee et al)



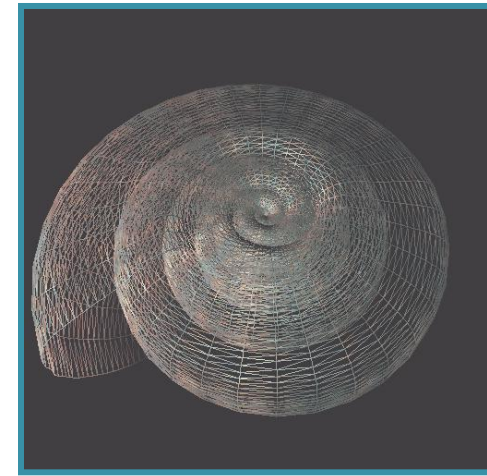
3D Collage (Gal et al)



Zelda the Windwalker  
(Nintendo)

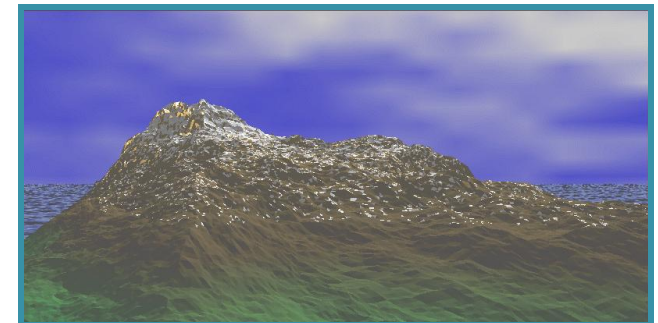
# Modeling

- Representations of geometry
  - Curves: splines
  - Surfaces: meshes, splines, subdivision
  - Solids: Voxels, CSG, BSP
- Procedural modeling
  - Sweeps
  - Fractals
  - Grammars



**Shell**

*(Douglas Turnbull,  
CS 426, Fall99)*

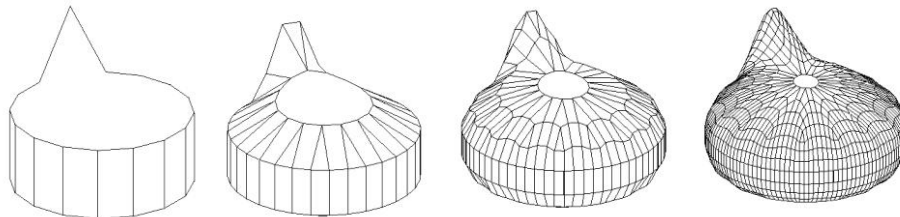
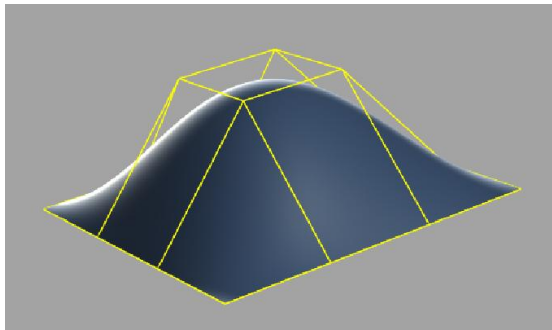


**Scenery Designer**

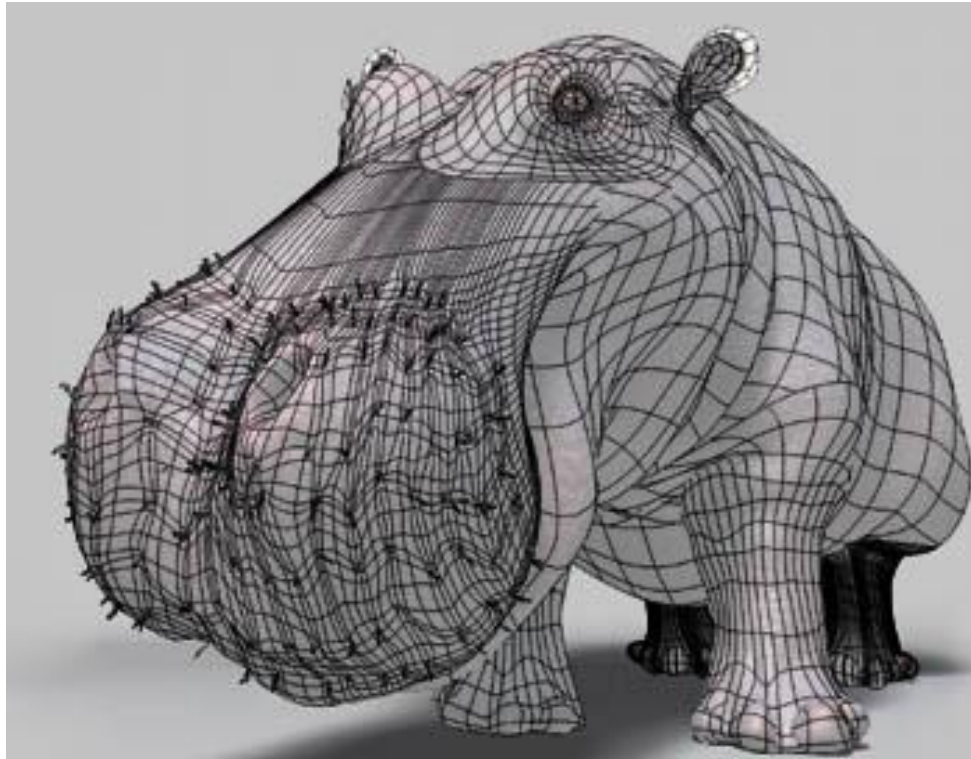
*(Dirk Balfanz, Igor Guskov,  
Sanjeev Kumar, & Rudro Samanta,  
CS426, Fall95)*

# Modeling

- Curved surfaces
- Subdivision surfaces
- Bump Mapping



# Textures and Shading



Just the model



# Textures and Shading



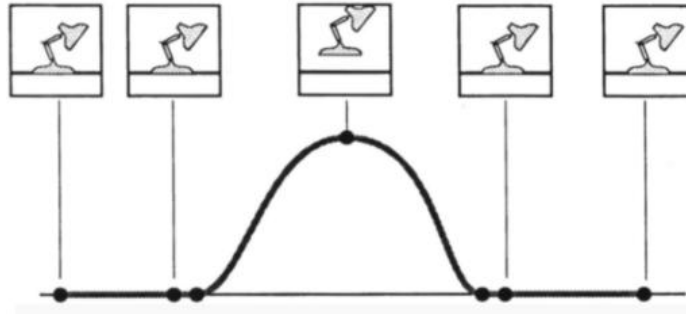
Add a little shading

# Textures and Shading



And sprinkle some textures and shadows

# Animation: Keyframing



ACM © 1987 "Principles of traditional animation applied to 3D computer animation"

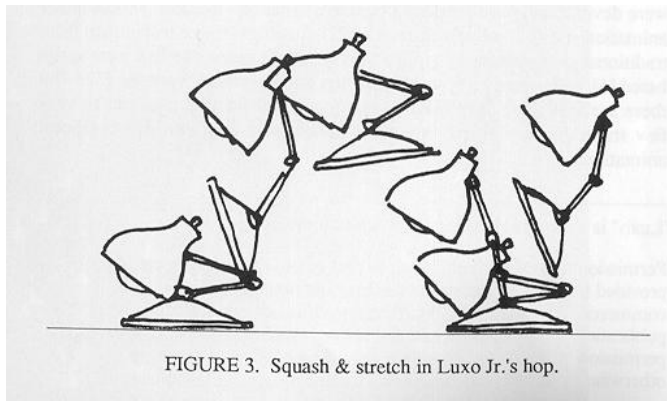


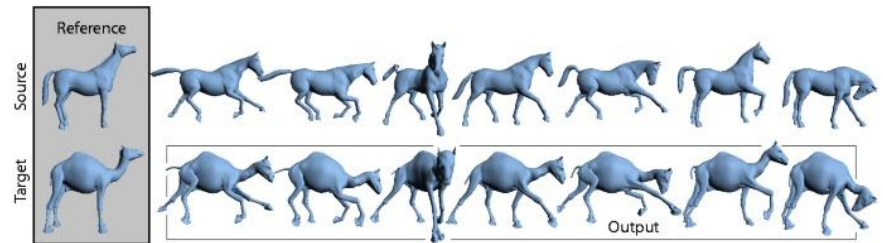
FIGURE 3. Squash & stretch in Luxo Jr.'s hop.

# Animation

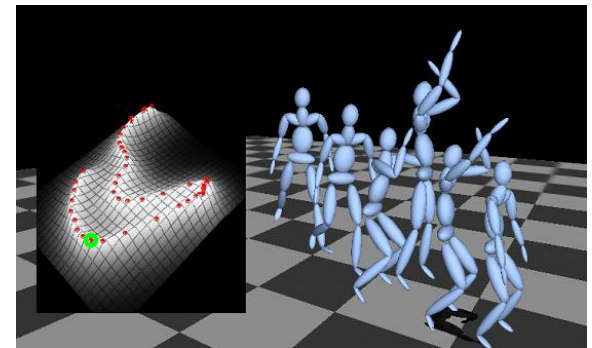
- Keyframing
  - Kinematics
  - Articulated figures
- Motion capture
  - Capture
  - Warping
- Dynamics
  - Physically-based simulations
  - Particle systems
- Behaviors
  - Planning, learning, etc.



Flocking Behaviour 1978 ( Reynolds)



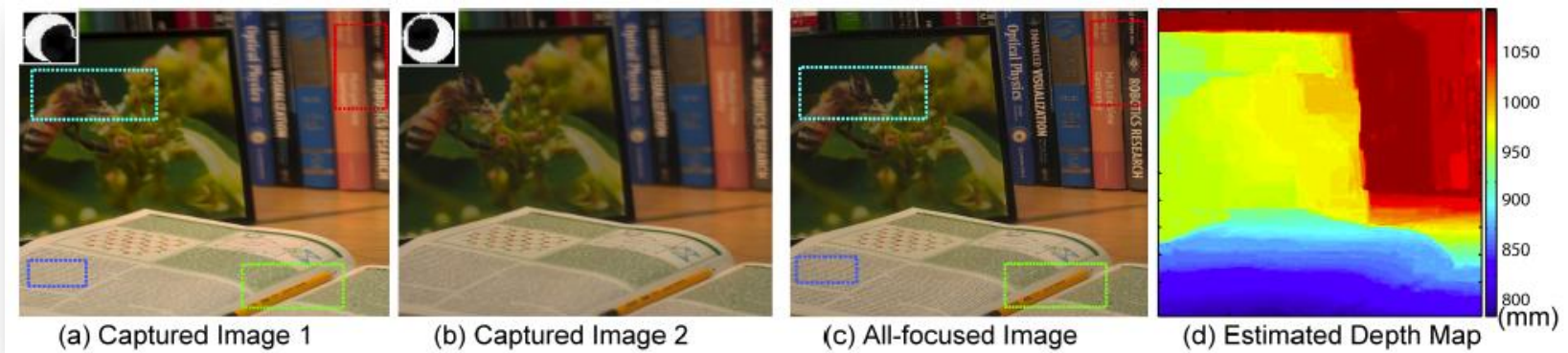
Deformation Transfer (Sumner et al)



Style Based Inverse Kinematics  
(Grochow et al)

# לא בבית ספרנו

- Computational Photography



Coded Aperture Pairs for Depth from Defocus, ICCV 09

# Computer Vision



Building Rome in a day, ICCV 09 ([youtube](#), [project](#))



Human Detection Using Partial Least Squares Analysis, ICCV 09

Introduction to computer vision

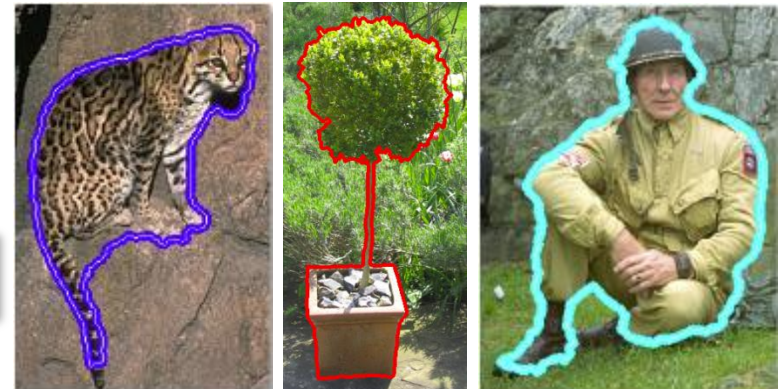
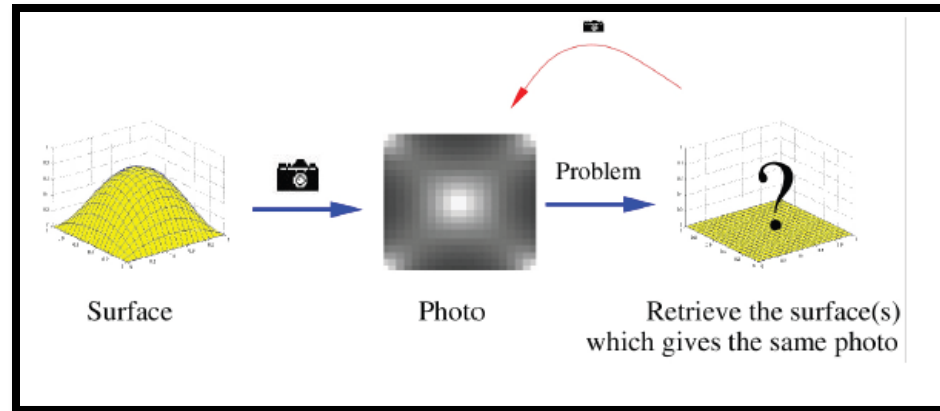


Image segmentation with a Bounding Box Prior, ICC 09

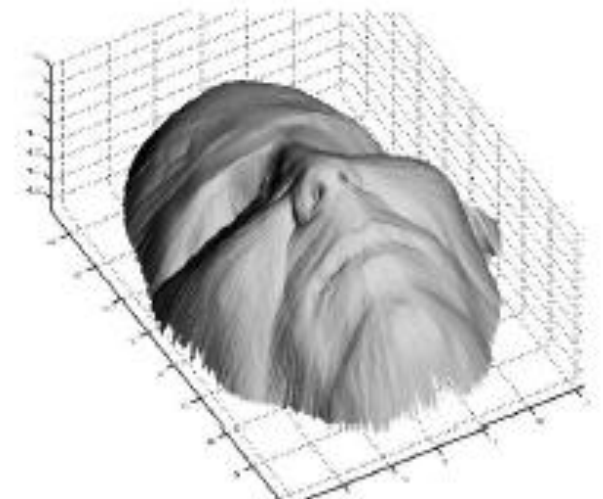
# Shape from Shading



a)

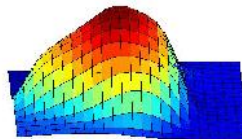
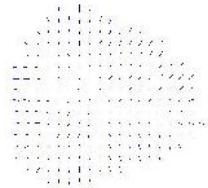
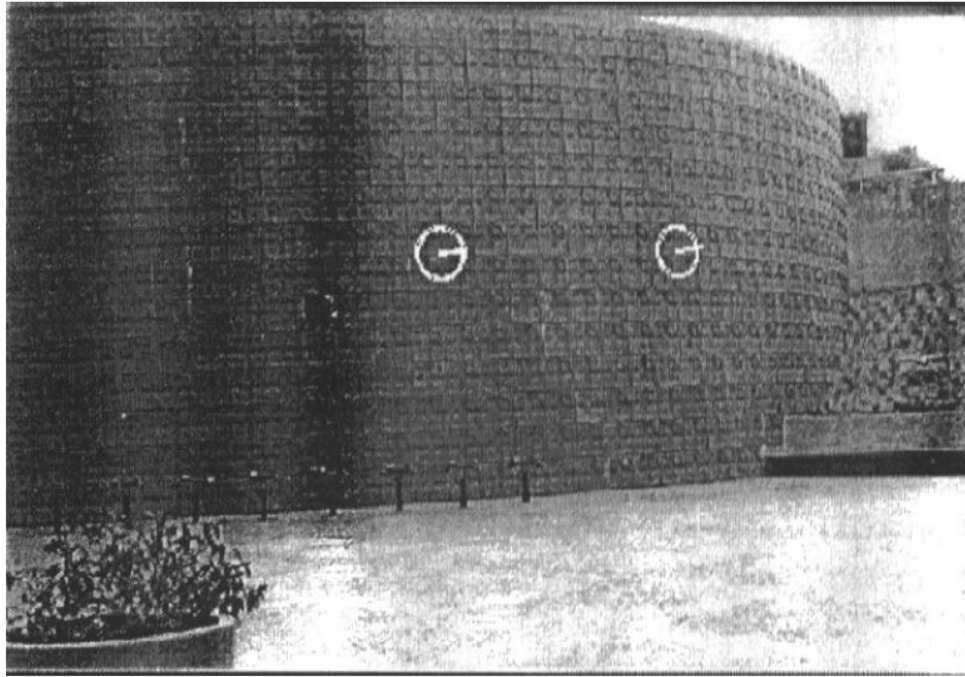


b)



c)

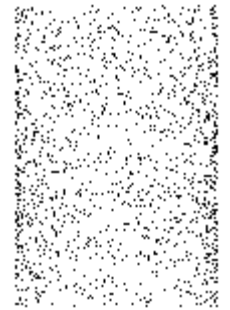
# Shape from Texture



[From [A.M. Loh. The recovery of 3-D structure using visual texture patterns](#)]



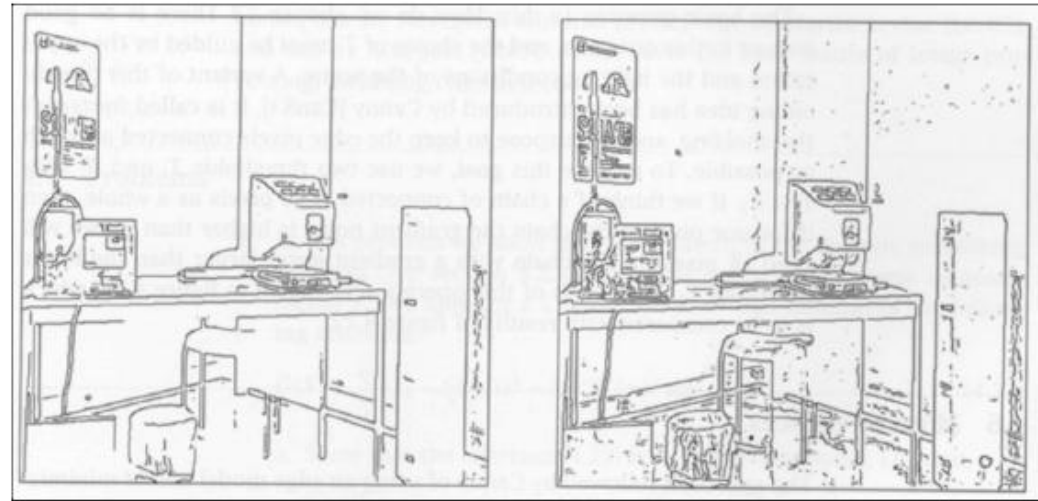
# Shape from Motion



# Stereo pipeline with weak calibration



# Gradients and Edge Detection



T = 15

T = 5

# Optical Flow



# Image-based Rendering

- Use images as inputs and representation
  - E.g. Image-based modeling and photo editing  
Boh, Chen, Dorsey and Durand 2001



Input image



New viewpoint



Relighting

# Graphics, Vision or Image Processing?

- Body Reshape
- Autoscanning

# Course Schedule

Week	Date			Homework
1	20 Feb	<a href="#">Introduction; Raster Graphics</a>	<a href="#">Half-Toning</a>	
2	27 Feb	<a href="#">Vector Quantization</a> + <a href="#">Sampling theory</a>	<a href="#">Colors</a>	
3	6 March	Affine Trans. ( <a href="#">2D</a> )	<a href="#">Seam Carving</a>	<a href="#">Exercise #1</a>
4	13 March	Camera Projections	3D <a href="#">Transformations</a>	
5	20 March	Edge Detection	<a href="#">Interactive Segmentation</a>	
6	27 March	<a href="#">Viewing and Projections</a>	<a href="#">Hidden Surface Removal</a> + <a href="#">BSP-Trees</a>	
7	3 April	<a href="#">Ray-casting</a> (rendering)	<a href="#">Shading</a> + <a href="#">Polygon-shading</a>	<a href="#">Exercise #2</a>
		פסח		
8	24 April	<a href="#">PCA</a>	<a href="#">SVD</a>	
9	1 May	<a href="#">Ray Tracing</a> + <a href="#">Acceleration Data Structures</a>	<a href="#">Line Drawing</a>	<a href="#">Flood-Fill</a>
10	8 May	<a href="#">Textures&amp; Parameterization</a>	Fitting	
11	15 May	<a href="#">Morphing</a>	Alignment	<a href="#">Sand</a>
		יום הסטודנט		
12	29 May	<a href="#">Stereo</a>	Structure from Motion	<a href="#">Exercise #3</a>
13	5 June	<a href="#">Photo-Tourism</a>	<a href="#">Surface Reconstruction.</a>	
14	12 June	<a href="#">MDS-and-SOM</a>	<a href="#">Visibility</a>	<a href="#">Zoom</a>

# דרישות



- השיעורים
  - כל שבוע יתקיים שיעור בן 3 שעות
- התרגילים
  - במהלך הסמסטר יינתנו 3 תרגילים מעשיים
  - התרגילים הינם חובה וייעשו בזוגות
  - משקל התרגילים בציון הוא כ-40% (לא מתחלק שווה בשווה)
- המבחן
  - יתקיים בסוף הסמסטר, משקלו 60%



# התרגילים – מידע נוסף

## • התרגילים

- ייעשו בזוגות (אין אישור לעבוד לבד, אסור יותר מזוג)
- אתם חייבים לכתוב קוד בעצמכם (לא להוריד מהאינטרנט)
- אם אתם משתמשים ברעיונות, ספריות תוכנה עליכם לציין זאת בהגשה ולתת קרדיט.
- לכל תרגיל יינתנו הוראות מפורטות.

## • זה בסדר ל...

- לדבר עם סטודנטים אחרים על גישה, רעיונות וכו'
- לקבל מידע ורעיונות מספרים, האינטרנט וכו'
- להשתמש בספריות עזר (לעיבוד תמונה, הצגת תלת מימד)
- אך עליכם לציין במה השתמשתם

## • זה לא בסדר!

- לשתף קוד עם סטודנטים אחרים
- להשתמש ברעיונות או קוד בלי לציין זאת

# בהצלחה בקורס!



שבוע הבא תרגיל ראשון, תמצאו בן זוג!