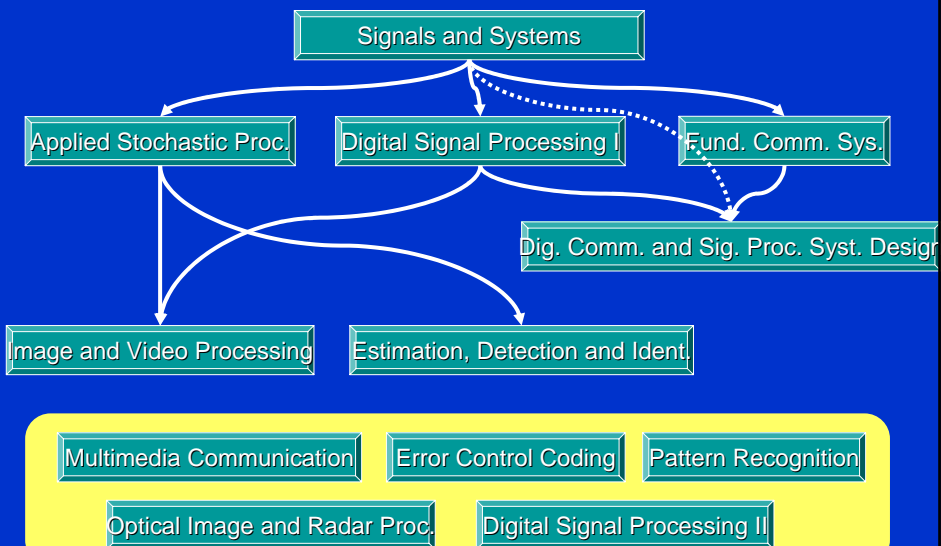


Signals and Systems (18-396),
Image and Video Processing (18-798),
and Life Beyond...



Prof. Tsuhan Chen
tsuhan@cmu.edu

Sample Courses in Signal Processing and Communication



Sound



Digital Audio

	Frequency Band (Hz)	Sampling Rate (kHz)	Bits per Sample	Raw Bitrate (kbits/s)
Telephone Speech	300~3400	8	8	64
Wideband Speech	50~7000	16	8	128
Mediumband Audio	10~11000	24	16	384
Wideband Audio	10~22000	48	16	768

– CD: $44.1 \text{ kHz} \times 16 \text{ bits} \times 2 \text{ channels} = 1.411 \text{ Mbits/s}$

MPEG-1 Audio

- ISO/IEC 11172-3 (1988~1991)
 - First high quality audio compression standard
 - Sampling rates: 32, 44.1, 48 kHz
 - CD quality two-channel audio at ~256 kbits/s
 - CD: $44.1 \text{ kHz} \times 16 \text{ bits} \times 2 = 1.411 \text{ Mbits/s}$
 - YES, this is **MP3!!!**
- Quality demonstration
 - [Stereo 44.1 kHz at 64 kbits/s](#)
 - [Stereo 44.1 kHz at 128 kbits/s](#)
 - [Stereo 44.1 kHz at 192 kbits/s](#)
 - [Stereo 44.1 kHz at 256 kbits/s](#)

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Image



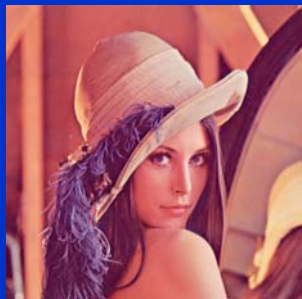
Image

RGB Color

	n			
m	R = 255 G = 200 B = 200	R = 230 G = 120 B = 234	R = 251 G = 200 B = 190	R = 150 G = 170 B = 253
	R = 254 G = 133 B = 200	R = 253 G = 100 B = 120	R = 244 G = 222 B = 214	R = 248 G = 220 B = 242
	R = 151 G = 140 B = 139	R = 204 G = 203 B = 202	R = 0 G = 0 B = 0	R = 149 G = 244 B = 130
	R = 190 G = 170 B = 90	R = 151 G = 148 B = 149	R = 159 G = 149 B = 150	R = 124 G = 110 B = 123

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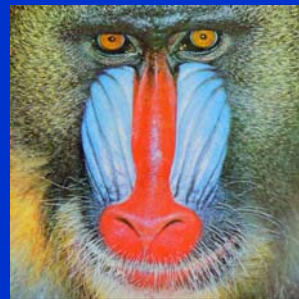
Sample Images



Lena



Pepper



Baboon

$512 \times 512 \times 3$ bytes = 768KB
With JPEG, ~32KB

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Sampling

Spatial Subsampling

Aliasing!!!

Original (256×256)

(64×64)

(32×32)



MSE = 2058

MAE = 24

CR = 16:1

MSE = 3924

MAE = 36

CR = 64:1

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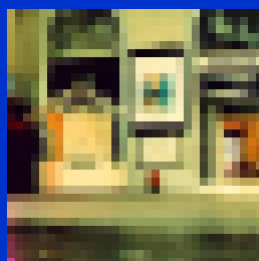
Sampling

Spatial Subsampling w/Averaging

Original (256×256)

(64×64)

(32×32)



MSE = 1010

MAE = 18

CR = 16:1

MSE = 1643

MAE = 26

CR = 64:1

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Quantization

Original (24bit)



(12-bit)



MSE = 9670
MAE = 78
CR = 2:1

(6-bit)



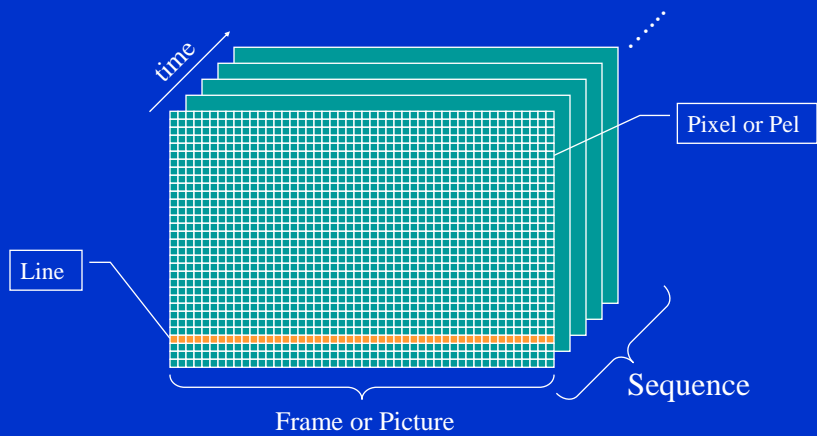
MSE = 10381
MAE = 82
CR = 4:1

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Video



Video



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Video Data

- Video

	Pels/line	Lines	Frames/s	Bytes/pel	Bit rate
Video Telephony (CIF)	352	288	10	1.5	12.2 Mbits/s
Broadcast TV (ITU-R 601 4:2:2)	720	480	30	2	166 Mbits/s
HDTV	~1280	~720	60	2	885 Mbits/s

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Computer Graphics



Face Animation

- Wire-frame mesh model with texture mapping



Demo

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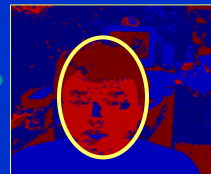
Computer Vision



Face Tracking

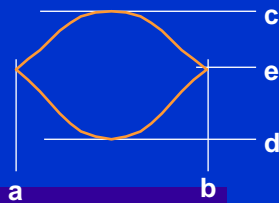
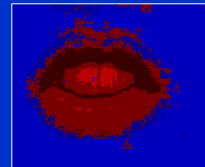
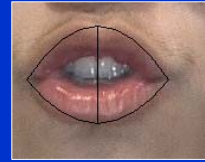
Use color information to segment target vs. non-target pixels

Use deformable template to track the target



Lip Tracking

- Use a Gaussian mixture with three Gaussians to model the color distribution of the mouth
- Template: two parabolas defined by $\lambda = (a, b, c, d, e)$



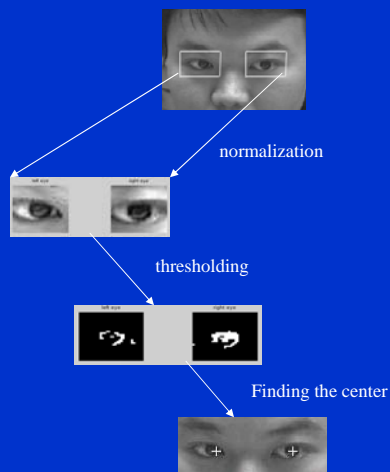
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Hand Tracking



Eye Tracking

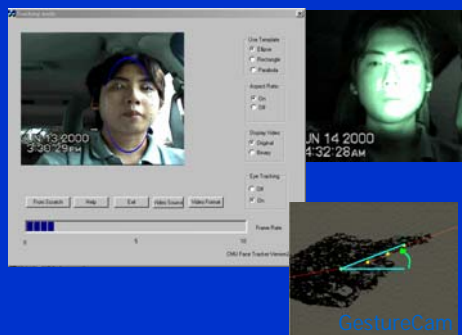
- Find the center of the darkest region in the search window



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CMU-GM Lab

Face/Eye/Hand Tracking:
 . Driver-Vehicle Interfaces
 . Cognitive Overflow Study



Interview Video

Airbag Deployment Control
 Mirror/wheel/panel/seat adjustment



Driver ID and Encryption:
 Security, Safety, User Preference



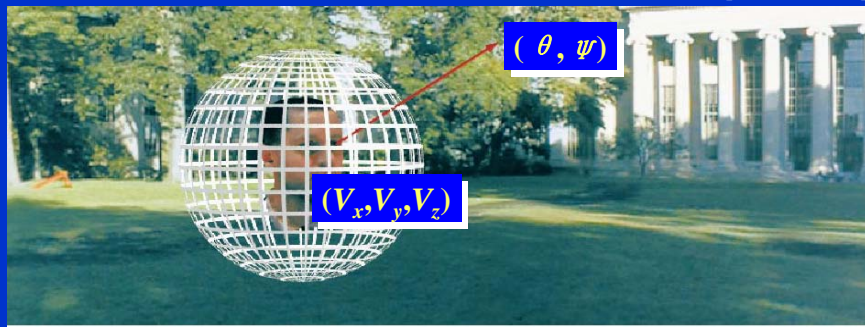
Higher Dimensions?



7D Plenoptic Function

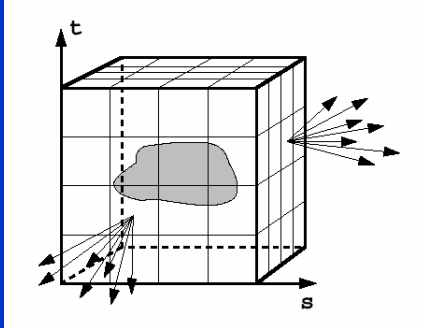
$$f(V_x, V_y, V_z, \theta, \psi, \lambda, t)$$

[Adelson'91]



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Image-Based Rendering



- Plenoptic Function [Adelson'91] [McMillan'95]
- Lumigraph/Lightfield [Gortler/Grzeszczuk'96] [Levoy'96]
- Concentric Mosaics [Shum99]

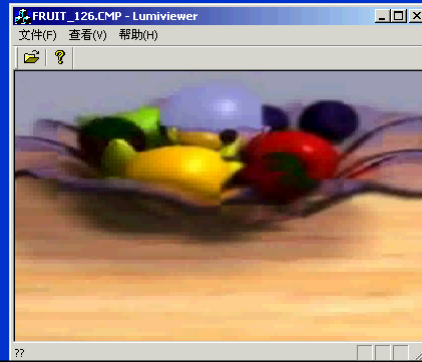
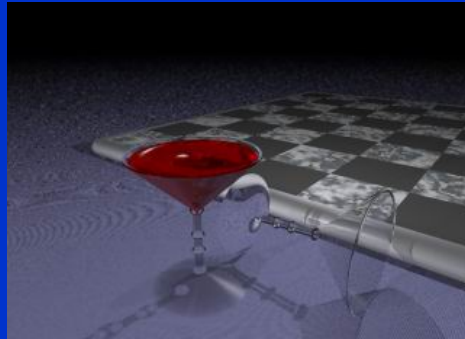


Image-Based Rendering



Demo

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EyeVision



→ 4D IBR
(incl. time)

[Kanade'01]



Before Correction



After Correction

Super Bowl XXXV

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Self-Reconfigurable Camera Array



[Stanford]

[Zhang and Chen, CMU]

[MIT]



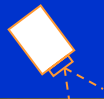
Details

- 48 webcams
 - Embedded processors
 - Sensor network
- 2 step-motors each (translation and pan)
- **Real-time** capturing/calibration/rendering



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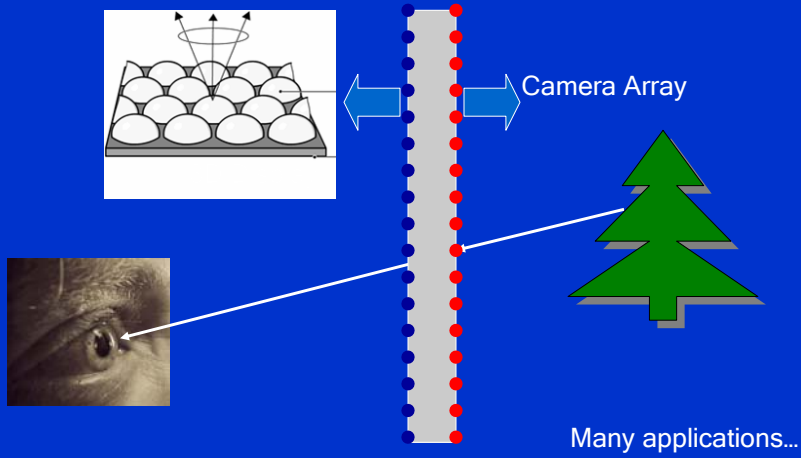
Ongoing: Mirror/Lens Array



This is lightfield/lumigraph!

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Future: "Transparent Material"



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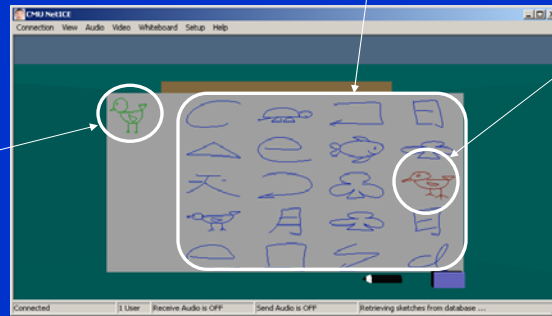
Information Retrieval (Pattern Recognition)



Hand-Drawn Sketch Retrieval



Page stored in Database



Query Sketch

Similar Sketch

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Trademark Retrieval



Retrieved Trademarks

Query

Congratulations! Your query results are shown on the right hand side! You are using "Query" by internal trademark!

To change the query trademark, left click, another thumbnail on the right hand side.

Quick reference

- Click button "Rand" to randomly browse the database, click "Prev." and "Next" to turn pages
- Right click the thumbnail pictures to view the extracted sketch
- Left click reserved for picking up trademarks as queries when query by trademark from inside the database
- Move the sliders toward R (relevant) or NR (nonrelevant) to give the feedback, press the "Feedback:" button to do relevant feedback.

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Trademark Retrieval

Retrieved Trademarks

Hand-Drawn Query

Quick reference:

- Click button "Rand" to randomly browse the database, click "Prev" and "Next" to turn pages
- Right click the thumbnail pictures to view the extracted sketch
- Left click reserved for picking up trademarks as queries when query by trademark from inside the database
- Move the sliders toward R (relevant) or NR (nonrelevant) to give the feedback, press the "Feedback" button to do relevant feedback

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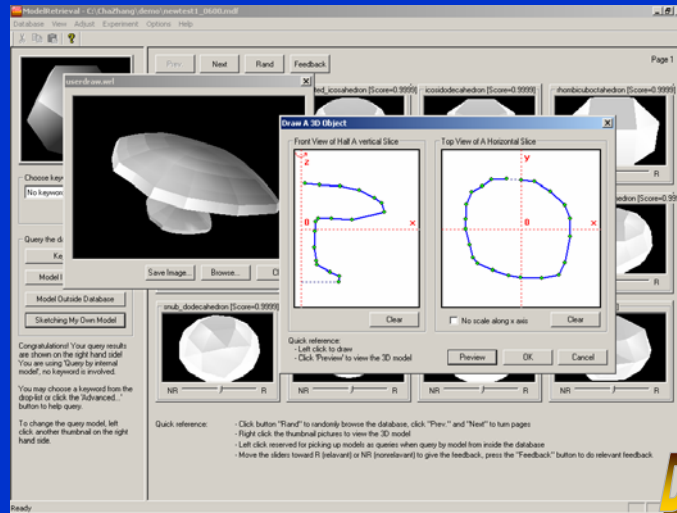
3D Object Retrieval

Quick reference:

- Click button "Rand" to randomly browse the database, click "Prev" and "Next" to turn pages
- Left click reserved for picking up trademarks as queries when query by trademark from inside the database
- Move the sliders toward R (relevant) or NR (nonrelevant) to give the feedback, press the "Feedback" button to do relevant feedback

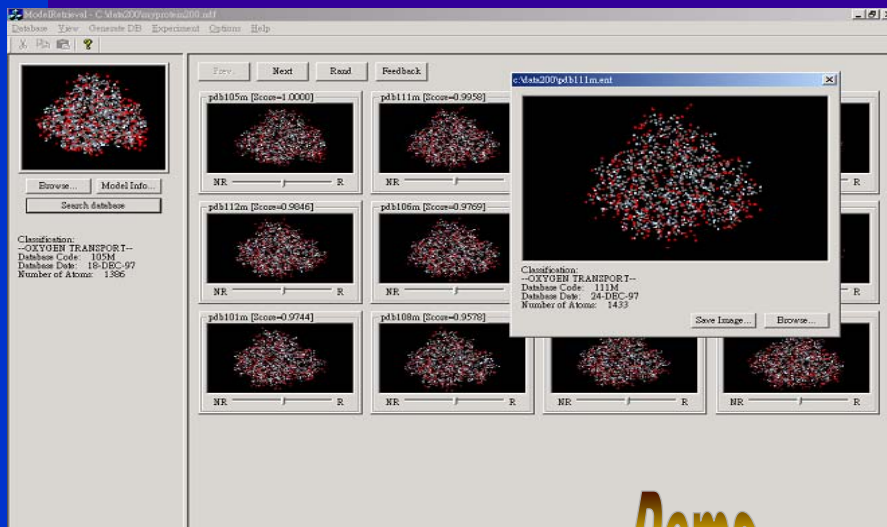
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Sketched 3D Query too...



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3D Protein Structures too...



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Summary

- Signals and Systems
- Image and Video Processing
- Computer Vision
- Computer Graphics
- Pattern Recognition
- Information Retrieval

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