

Image Processing Review

C306,
Review Lecture
Martin Jagersand

Final exam

- Mon Dec 10
- 9:00 in csc B41, 3h
- You may bring 4 single sided (or 2 double sided) 8.5x11in sheets with your own handwritten notes
- Calculator

Main topics covered:

- Image formation/Geometry
- Point processing
- Transforms
- Filtering
- Image enhancement and restoration
- Image and video compression and representations
- Outlook: Human and computer vision.

Continuation:

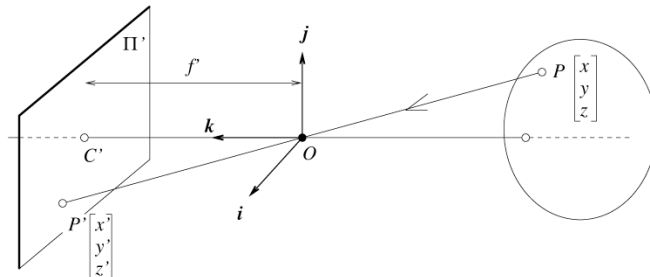
- csc 411, 511 - Introduction to Computer Graphics (Herb, next fall)
- 414 - Introduction to Multimedia Technology .
- 604 - Hand-Eye Coordination and Vision-based Interaction (Martin, next semester, email if interested: jag@cs.ualberta.ca)
- 615 – Artificial and Biological perception systems (Walter, next semester)

The equation of projection

- Cartesian coordinates:

- We have, by similar triangles, that $(x, y, z) \rightarrow (f x/z, f y/z, -f)$
- Ignore the third coordinate, and get

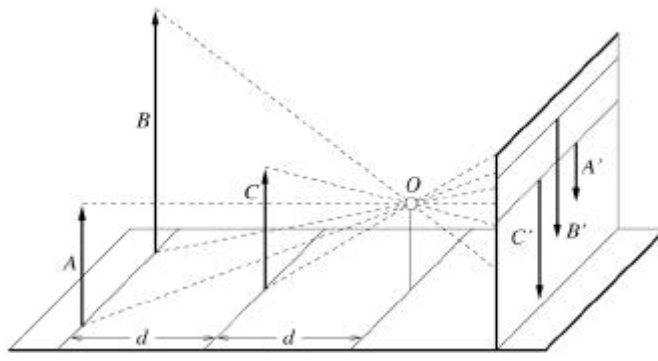
$$(x, y, z) \rightarrow \left(f \frac{x}{z}, f \frac{y}{z}\right)$$



Size illusions

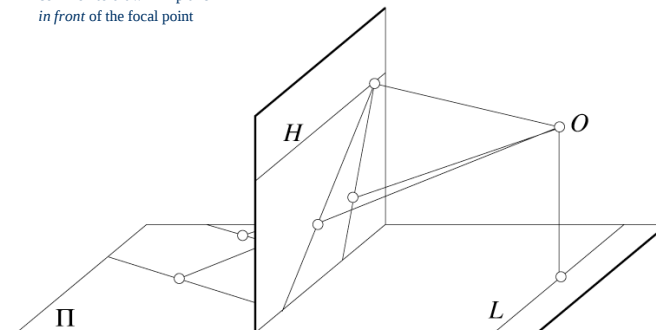


Distant objects are smaller



Parallel lines meet

common to draw film plane
in front of the focal point

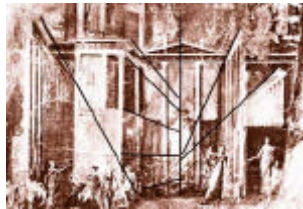


History of Perspective

Prehistoric:



Roman

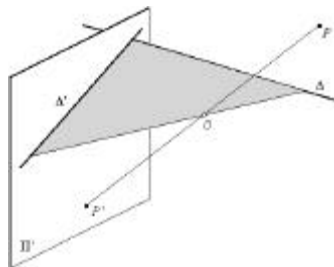


Renaissance Leonardo da Vinci: The last supper



Geometric properties of projection

- Points go to points
- Lines go to lines
- Planes go to whole image
- Polygons go to polygons
- Degenerate cases
 - line through focal point to point
 - plane through focal point to line

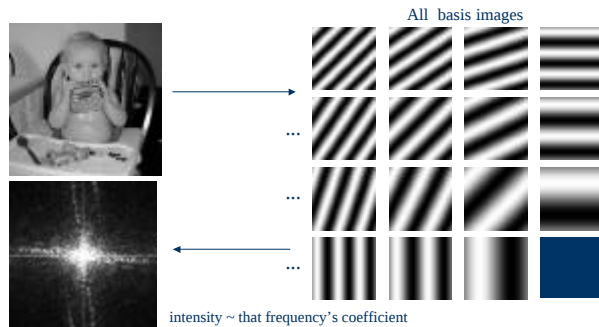


Transforms: Fourier, Cosine, KL

- Can all be written:
 - Forward $F=Af$
 - Inverse $f=A'F$ (' = transpose), where: A is a basis
- Intuition:

$$f = y_1 A_1 + y_2 A_2 + \dots + y_w A_w$$
- Spatial image f is sum of basis images $A_1..A_w$

Representing an image in a new basis



Learn how to relate the matrix form with sum form (Gonzales)

$$F(u) = \frac{1}{N} \sum_{x=0}^{N-1} f(x) e^{j2\pi ux/N}$$

The diagram shows the relationship between the matrix form and the sum form of the Fourier transform. The matrix form is represented as $F(u) = \frac{1}{N} \sum_{x=0}^{N-1} f(x) e^{j2\pi ux/N}$. The sum form is represented as $F(u) = \frac{1}{N} \sum_{x=0}^{N-1} f(x) e^{j2\pi ux/N}$. The diagram includes arrows pointing from the matrix form to the sum form and vice versa.

• Note: $u=A_x$ form!

Put definitions on your crib sheet

Definition KL, PCA, Hotelling transform

- The forward coordinate transform

$$y = B^*(x - m_x)$$

- Inverse transform

$$x = B^*y + m_x$$

Note: $m_y = E[y] = 0$ zero mean

$C = E[yy'] = D$ diagonal cov matrix

Gonzalez

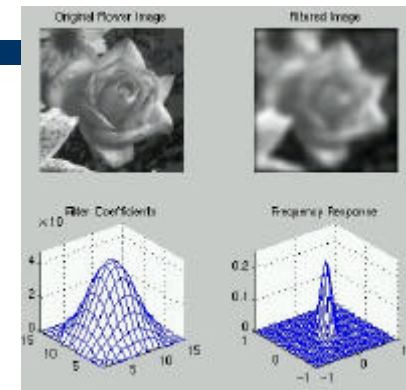
- In addition to the Fourier transform (reading guide and recommended exercises and an additional tutorial given before the midterm, see [www](#))
- Cosine p. 143-156
- KL/Hotelling p 148-156
- Exercises: 3:16-18, 3:22

Filtering

- Filtering can be expressed as a convolution in spatial coordinates, and a pointwise multiplication in frequency coordinates.
- Low pass filtering can suppress noise.
- High pass filtering can enhance detail.

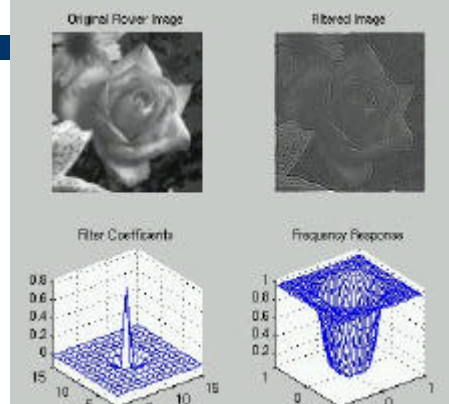
Low pass filtering

- Note: Details disappear
- Note2: Scaling property of F-t



High Pass

- Sharp cutoff frequency
- Why is filtered image so dark??



Special High Pass: Sobel's linefinder

- Most common simple linefinder



$$S_v = \begin{bmatrix} 1 & 0 & 1 \\ 2 & 0 & 2 \\ 1 & 0 & 1 \end{bmatrix}$$

$$S_h = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

- But still not perfect!!
- Linefinding is unsolved problem

Restoration General Solution by Convolution Th



$G(u,v) = F(u,v)H(u,v) + N(u,v)$ in frequency (F-t) coord

Restored: $F_r = G/H = FH/H + N/H = F + N/H \leftarrow$ problem term
when $H=0$

Better: $F_r = \frac{G}{H + a}$ $a = \text{small constant}$

Example: F-t based restoration

- Unfocused image
- Restored image



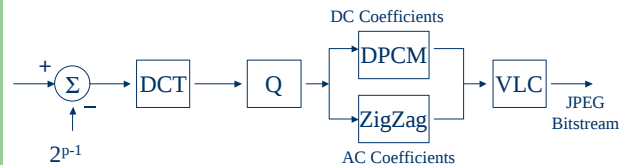
Gonzalez: Readings and exercises

- Filtering: p189-213
- Exc 4.7-8, 4.10-11, 16, 4.14
- Line detection: p413-438
- Exc: 7.3, 7.5, 7.6, 7.10, 7.11
- Restoration: p 253-259, 268-279, 289-303
- Exc: 5.1, 5.3, 5.5, 5.16

Image file formats

- There are many image formats
 - .ppm/pgm (generic unix)
 - .bmp, wmf (PC)
 - .pict (Mac)
 - .tiff (scanned)
 - .psd (Photoshop)
 - .gif, .jpg, .png (Web)
- To deliver images over network, we need
 - cross-platform formats
 - compression

jpeg Compression block diagram

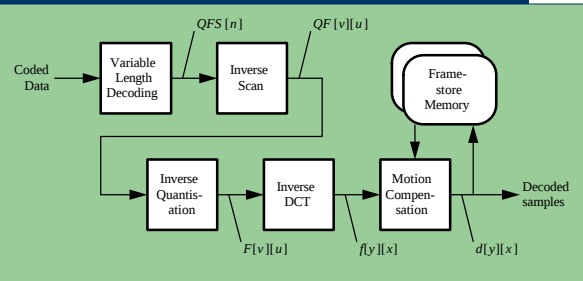


- 2^{p-1}
- 8x8 DCT transform (as defined in the previous lecture)
- Q: Quantization of DCT coefficients
- Predictive coding (DC) or Zig-Zag scan (AC) of Quantized DCT coefficients
- Variable length coding of the quantized AC and DC coefficients
- Decoding performs operations in reverse

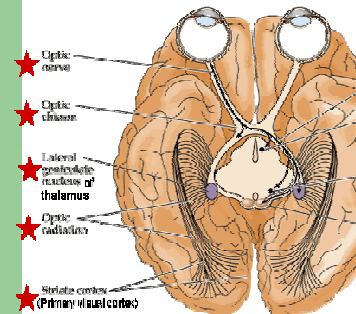
Digital movie encoding

- Now encode time sequences of frames
- Movie compression also based on transform coding like jpeg
- Strong temporal correlation between frames
- Introduces motion-compensated prediction (hybrid coding)
- Predict a frame based on a past frame

Simplified Video Decoding Process



Biological Image Processing Elements and Pathways



- Eye transforms light into nerve impulses
- Optic chiasm splits left and right visual fields
- LGN: Exact function unknown. May have to do with stereo.
- V1 (Striate cortex) performs spatial filtering / coordinate transforms

Computer Vision

The engineering solution.

- 3D model based recognition and location determination solves what & where.

The biological solution.

- What: 2D recognition by pattern matching
- How: 2x 2D image based techniques

Hand-Eye Coordination and Vision-based Interaction

- New exciting course next semester (by yours truly) covering:
 1. **Visual motion**: how to track and analyze it.
 2. **Motor movement**: how to make robots do useful tasks.
 3. **How does the brain do it?** Human visual-motor function, anatomy and physiology.
 4. Putting things together: **Man-Machine interfaces** using vision and physical interaction.

Readings and exercises

- Compression: 307-324, 343-356, 374-387, 395-405
- Exc: 6.1-2, 6.5, 6.14-15, 6.21
- For the Human and Computer vision lectures read the readings on the course WWW page
- Skim rest of Chapters 7-9 in Gonz

Good Luck!

Martin