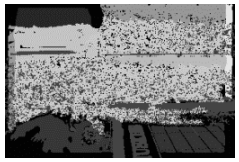
Imaging and Image Representation

- **Sensing Process**
- **Typical Sensing Devices**
- **Problems with Digital Images**
- **Image Formats**
- **Relationship of 3D Scenes to 2D Images**
- **Other Types of Sensors**

Images: 2D projections of 3D

- **The 3D world has color, texture, surfaces, volumes, light sources, objects, motion, …**
- **A 2D image is a projection of a scene from a specific viewpoint.**



Images as Functions

- **A gray-tone image is a function:**

  g(x,y) = val or f(row, col) = val

- **A color image is just three functions or a vector-valued function:**

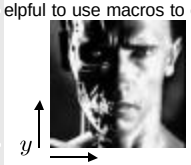
  f(row,col) =(r(row,col), g(row,col), b(row,col))

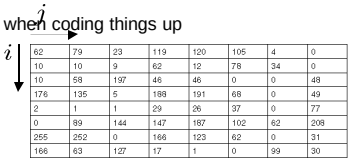
Image vs Matrix

Digital images (or just “images”) are typically stored in a matrix

ifferent coordinate systems (x,y) vs. (i=row,j=column)

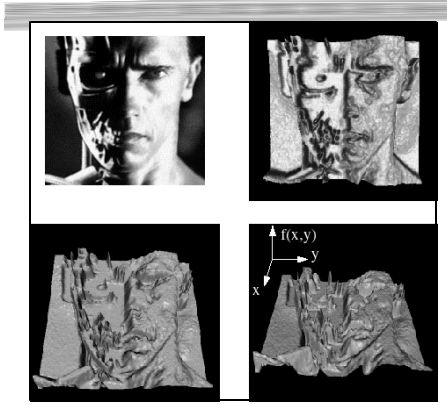
elpful to use macros to convert when coding things up





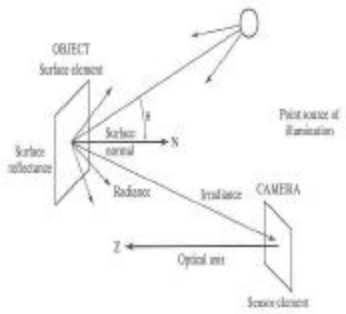
62	79	23	119	120	105	4	0
10	10	9	62	12	78	34	0
10	58	197	46	46	0	0	48
176	135	5	188	191	68	0	49
2	1	1	29	26	37	0	77
0	89	144	147	187	102	62	208
255	252	0	166	123	62	0	31
166	63	127	17	1	0	99	30

Gray-tone Image as 3D Function



Imaging Process

- **Light reaches surfaces in 3D**
- **Surfaces reflect**
- **Sensor element receives light energy**
- **Intensity counts**
- **Angles count**
- **Material counts**



What are radiance and irradiance?

*Radiometry and Computer Vision**

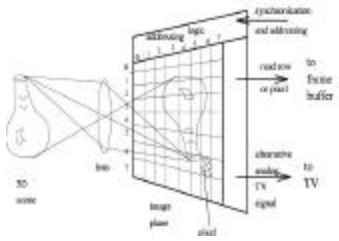
- **Radiometry** is a branch of physics that deals with the measurement of the flow and transfer of radiant energy.
- **Radiance** is the power of light that is emitted from a unit surface area into some spatial angle; the corresponding photometric term is **brightness**.
- **Irradiance** is the amount of energy that an image-capturing device gets per unit of an efficient sensitive area of the camera. Quantizing it gives image gray tones.

•From Sonka, Hlavac, and Boyle, *Image Processing, Analysis, and Machine Vision*, ITP, 1999.

CCD type camera:

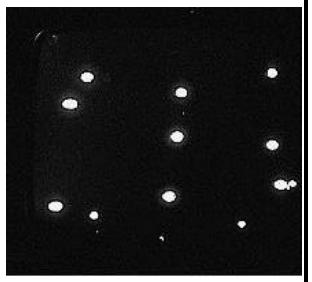
Commonly used in industrial applications

- Array of small fixed elements
- Can read faster than TV rates
- Can add refracting elements to get color in 2x2 neighborhoods
- 8-bit intensity common



Blooming Problem with Arrays

- Difficult to insulate adjacent sensing elements.
- Charge often leaks from hot cells to neighbors, making bright regions larger.

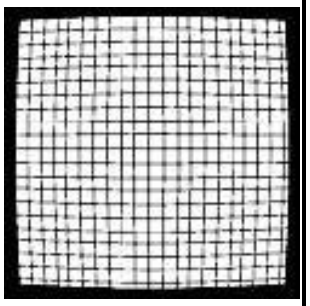


8-bit intensity can be clipped

- Dark grid intersections at left were actually brightest of scene.
- In A/D conversion the bright values were clipped to lower values.

Lens distortion distorts image

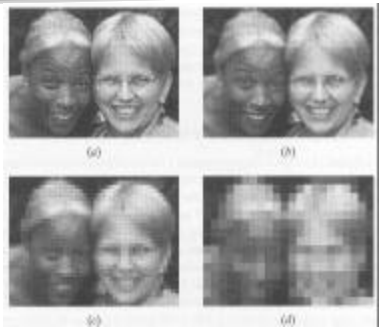
- "Barrel distortion" of rectangular grid is common for cheap lenses ($50)
- Precision lenses can cost $1000 or more.
- Zoom lenses often show severe distortion.



Resolution

- **resolution: precision of the sensor**
- **nominal resolution: size of a single pixel in scene coordinates (ie. meters, mm)**
- **common use of resolution: num_rows X num_cols (ie. 515 x 480)**
- **subpixel resolution: measurement that goes into fractions of nominal resolution**
- **field of view (FOV): size of the scene a sensor can sense**

Resolution Examples



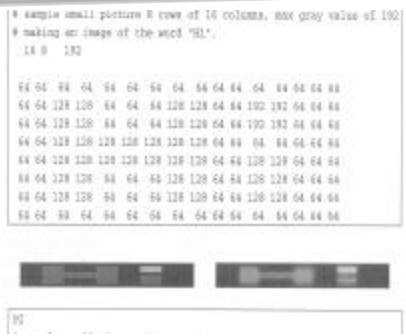
- ✶ Resolution decreases by one half in cases at left
- ✶ Human faces can be recognized at 64 x 64 pixels per face

Image Formats

- ✶ Portable gray map (PGM) older form
- ✶ GIF was early commercial version
- ✶ JPEG (JPG) is modern version
- ✶ Many others exist: **header plus data**
- ✶ Do they handle color?
- ✶ Do they provide for compression?
- ✶ Are there good packages that use them or at least convert between them?

PGM image with ASCII info.

- ✶ P2 means ASCII gray
- ✶ Comments
- ✶ W=16; H=8
- ✶ 192 is max intensity
- ✶ Can be made with editor
- ✶ Large images are usually not stored as ASCII



•*PBM/PGM/PPM Codes*

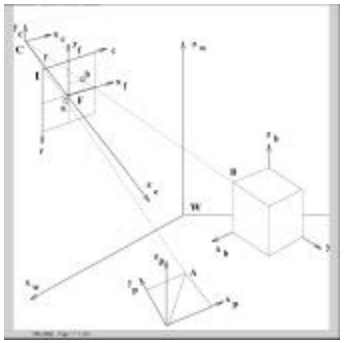
- **P1: ascii binary (PBM)**
- **P2: ascii grayscale (PGM)**
- **P3: ascii color (PPM)**
- **P4: byte binary (PBM)**
- **P5: byte grayscale (PGM)**
- **P6: byte color (PPM)**

JPG current popular form

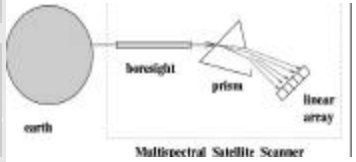
- ✶ Public standard
- ✶ Allows for image compression; often 10:1 or 30:1 are easily possible
- ✶ 8x8 intensity regions are fit with basis of cosines
- ✶ Error in cosine fit coded as well
- ✶ Parameters then compressed with Huffman coding
- ✶ Common for most digital cameras

From 3D Scenes to 2D Images

- **Object**
- **World**
- **Camera**
- **Real Image**
- **Pixel Image**



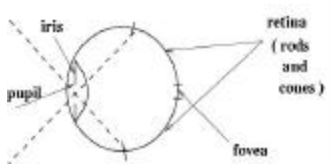
Other Types of Sensors: Orbiting satellite scanner



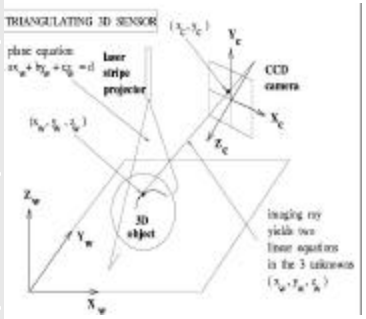
- ✶ View earth 1 pixel at a time (through a straw)
- ✶ Prism produces multispectral pixel
- ✶ Image row by scanning boresight
- ✶ All rows by motion of satellite in orbit
- ✶ Scanned area of earth is a parallelogram, not a rectangle

Human eye as a spherical camera

- ✶ 100M sensing elts in retina
- ✶ Rods sense intensity
- ✶ Cones sense color
- ✶ Fovea has tightly packed elts, more cones
- ✶ Periphery has more rods
- ✶ Focal length is about 20mm
- ✶ Pupil/iris controls light entry

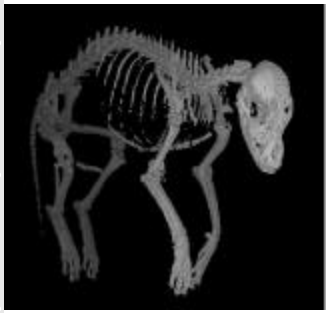


Surface data (2.5D) sensed by structured light sensor



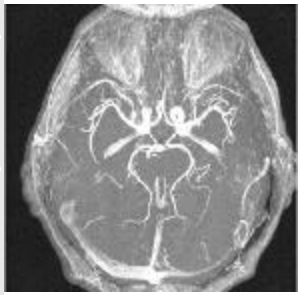
- Projector projects plane of light on object
- Camera sees bright points along an imaging ray
- Compute 3D surface point via line-plane intersection

Magnetic Resonance Imaging



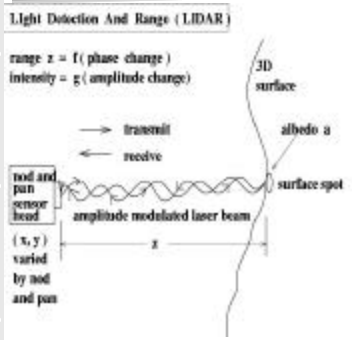
- Sense density of certain chemistry
- S slices x R rows x C columns
- Volume element (voxel) about 2mm per side
- At left is shaded image created by "volume rendering"

Single slice through human head



- MRIs are computed structures, computed from many views.
- At left is MRA (angiograph), which shows blood flow.
- CAT scans are computed in much the same manner from X-ray transmission data.

LIDAR also senses surfaces



- Single sensing element scans scene
- Laser light reflected off surface and returned
- Phase shift codes distance
- Brightness change codes albedo

Other variations

- Microscopes, telescopes, endoscopes, …
- X-rays: radiation passes through objects to sensor elements on the other side
- Fibers can carry image around curves; in bodies, in machine tools
- Pressure arrays create images (fingerprints, butts)
- Sonar, stereo, focus, etc can be used for range sensing (see Chapters 12 and 13)

Where do we go next?

So we've got an image, say a single gray-tone image.

What can we do with it?

The simplest types of analysis is binary image analysis.

Convert the gray-tone image to a binary image (0s and 1s) and perform analysis on the binary image, with possible reference back to the original gray tones in a region.