ANALOG TO DIGITAL

- Analog v. Digital
- Sampling
- Quantization

ANALOG V. DIGITAL

- Analog signals can vary CONTINUOUSLY between two values
- Digital signals vary DISCRETELY, taking only one of any N values at a time
- Analog is like the Real numbers
- Digital is like the Integers

ANALOG

- Examples:
  - violin
  - volume control slider
- Problem: hard to duplicate exactly (can you set the volume exactly the same each time?)
- Problem: Generational loss
**Generational Loss**

- Audio recording: voltage levels vary with time
- copies made by measuring $v(t)$, then recording $v'(t)$
- $v'(t)$ is close but not exactly equal to $v(t)$
- now make a copy of $v'(t)$, $v''(t)$
- in copy of a copy (analog), errors compound

**Analog Copy**

- measure $v$ at $t_i$
- output that measurement
- repeat until done

**Digitizing**

- two steps: sampling and quantization
- sampling: periodic measurements of signal
- quantizing: picking level closest to signal
- signal is now a sequence of discrete levels

**Sampling**

- determine sample size (when to measure, number of measures)
- here we make 4 measurements (sampling frequency)
**Quantize**

- Pick number of levels (2)
  - Level 0 if $0 \leq v < 0.5$
  - Level 1 if $0.5 \leq v < 1$
- Samples from top to bottom, left to right are thus 1,1,0,0

**Result with 2 levels**

- Low sampling frequency doesn’t capture enough detail
- Higher sampling frequency yields more accurate copy
- Higher freq. means more memory

**Quantize**

- Like assigning letter grades based upon number grades (90-100:A, 80-89:B etc.)
- More levels yields more accurate recording of the sample
- More levels require more bits, more memory

**Sampling Frequency Effects**
what determines CCD sampling frequency?
- resolution (ppi)
- number of quantization levels?
- bits per pixel

Digital Images
- CCD resolution = sampling rate
- common number of levels=256
- 0..255, 0 is black, 255 is white (8-bit image)
- color can be done with 3 bytes (24-bit color)
- spatial resolution = sampling
- gray-level resolution = quantization

Why is Digital Better?
- perfectly reproducible
- easily editable/modifiable
- exact copies
- easier processing of signals

Spatial Resolution
- degree of detail representable in image (smallest representable detail)
- line pairs: chart of lines and spaces
- line width = space width
- line pair (lp) is one line and space
- unit is lp/mm
Gray-Level Resolution

- smallest discernible change in level
- unit: number of levels
- low level results in banding

256 Levels

128 Levels