IMAGE CODING

Motivation

- **Large amount of data in images**

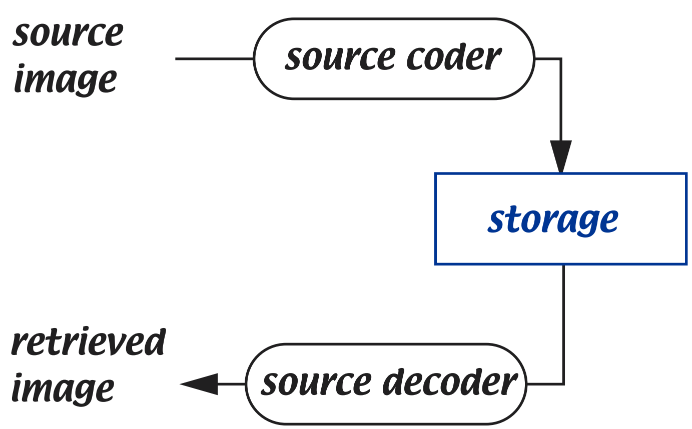
  Color video: 200Mb/sec

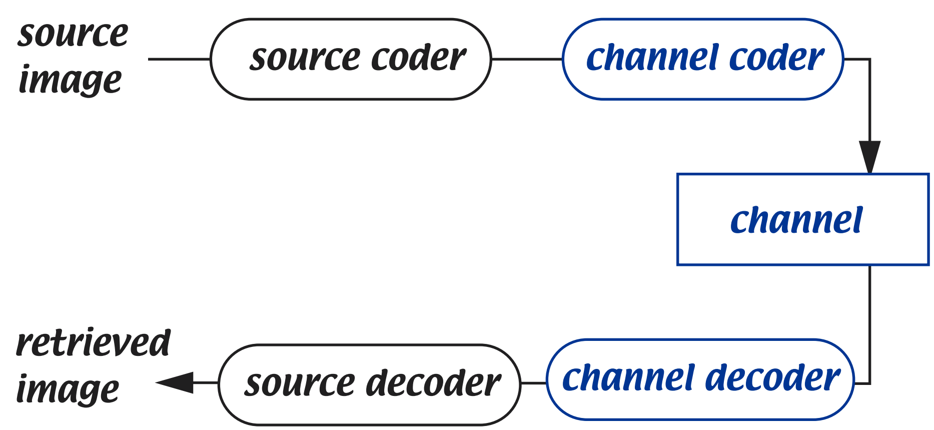
  Landsat TM multispectral satellite image: 200MB

- **High potential for compression**

  Redundancy (aka correlation) in images - spatial, temporal, spectral

storage versus transmission applications





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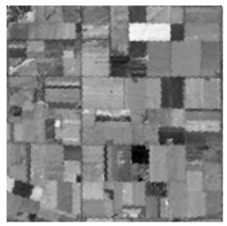
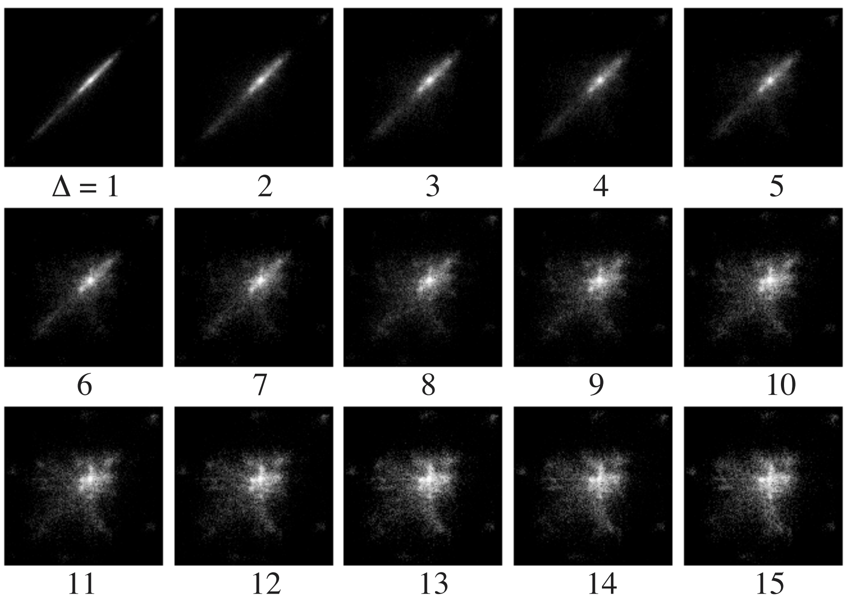
- ***High correlation for close neighbors***
- ***As pixel separation increases, correlation decreases***

Joint probability plots (scattergrams) between pixels with given horizontal spacing





Lossy coding

- **Some acceptable loss of data, without loss of "information"**

- **Error measures**

Mean Square Error	$MSE(DN) = Variance(\hat{f} - f)$
Root Mean Square Error	$RMSE(DN) = \sqrt{MSE}$
Normalized Mean Square Error	$NMSE(\%) = 100(MSE)/Variance(f)$
Signal-to-Noise Ratio	$SNR(dB) = 10\log(100/NMSE)$
Peak-to-peak SNR	$PSNR(dB) = 10\log[(f_{max} - f_{min})^2/MSE]$

- **Problems**

Error measures don't emphasize visually important features such as contrast edges

- Can improve correlation of any of these error measures with visual quality by restricting to "edge pixels" only

How to define and quantify "image quality?"

example with JPEG coding

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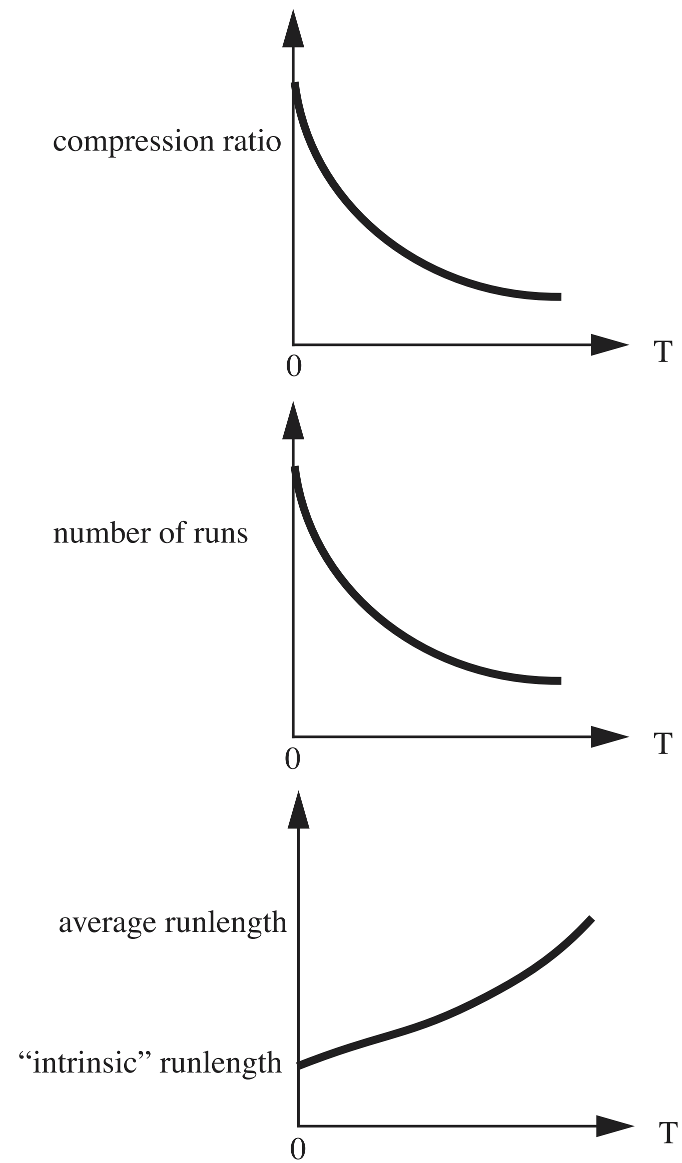
Run-Length Coding

- ***Simple, image domain, lossy compression algorithm***
- ***Exploits neighboring pixel correlation, line-by-line***

  Works best for simple, low-frequency content, near-binary images, e.g. faxes
- ***DN threshold controls quality loss and compression rate***
- ***Look for "runs"***

  contiguous pixels with similar values (within threshold of starting pixel value)
- ***Code starting pixel value (Q bits) and length of line (≤ logN/log2 bits)***

typical behavior (image dependent)



Lossless Coding

- No data loss
- Minimal compression (typically 2:1)
- Example algorithms

  Run-Length (with zero threshold)

  Lempel-Ziv-Welsh (LZW)

  Huffman Coding

Components of source coder

- **Data transformation**

  waveform coder

  transform coder

  image model coder

- **Quantization**

  bits, transform coefficients, or model parameters

- **Codeword Assignment**

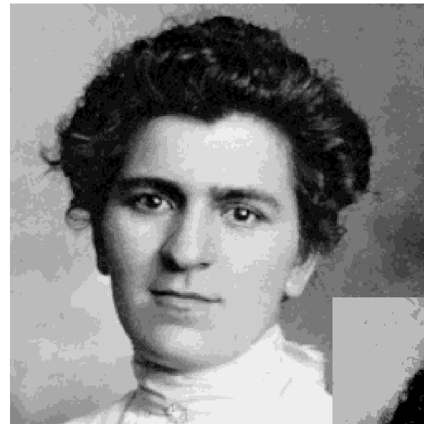
  unique bit string for each quantized parameter

Waveform Coding

- Pulse Code Modulation (PCM)

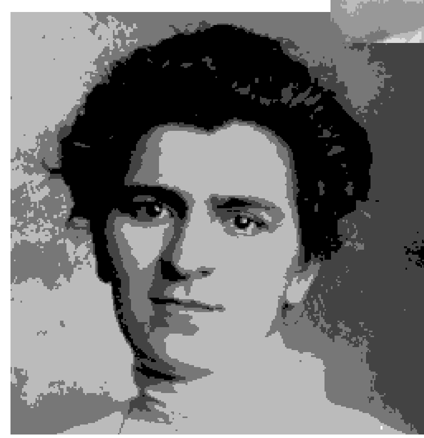
  Image intensity quantized by uniform quantizer

  At low bit rates (typically less than 4 bits/pixel), quantization noise appears as **false contours** in areas of low intensity slope



16 levels

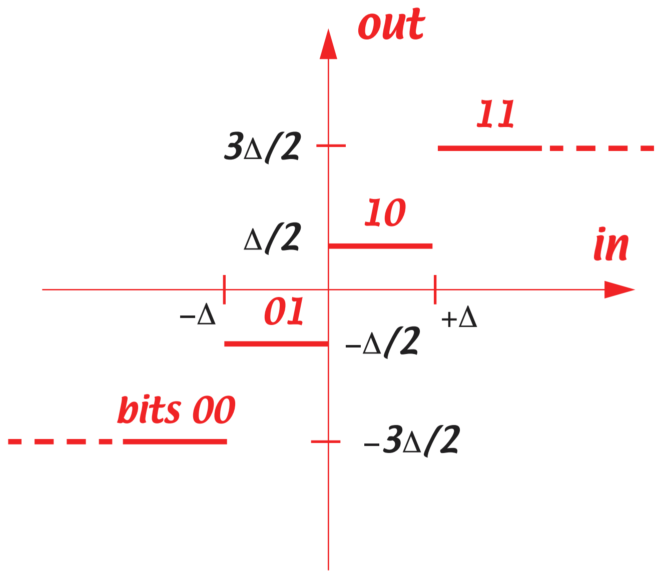
8 levels



4 levels

Example 2-bit uniform quantizer

$\Delta = 1$

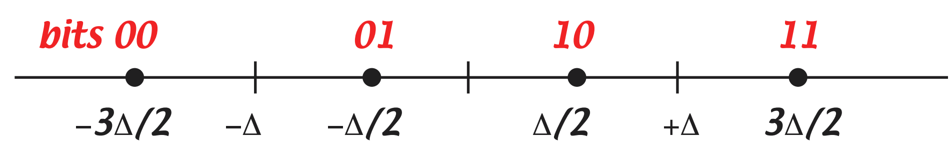


in	codeword	out	error
1.2	11	1.5	-0.3
1.5	11	1.5	0
-2	00	-1.5	-0.5
-0.5	01	-0.5	0
0.5	10	0.5	0
0.6	10	0.5	0.1
-0.75	01	-0.5	-0.25
1.2	11	1.5	-0.3

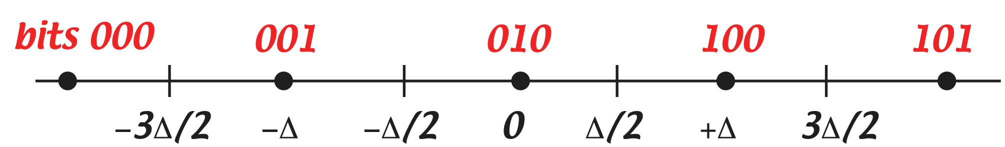
MSE = 0.0628

Alternate representation:

mid-rise uniform quantizer



mid-tread uniform quantizer



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- **PCM with Nonuniform Quantization**

  Assign quantization levels according to image intensity distribution

  Small improvement for typical images

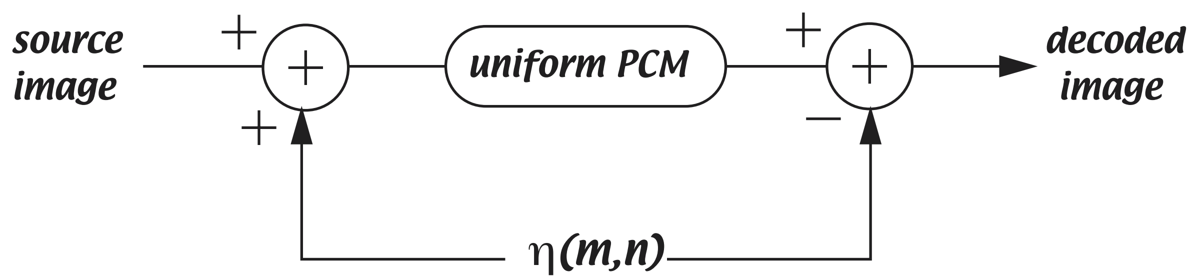
  - *Depends on nonuniformity of image histogram*

  For example, use CDF as nonlinear transform, i.e. histogram equalization

  - *Assigns more levels where there are more pixels*

PCM with Pseudo-noise

- Add random noise to image before PCM
- Subtract same random noise after PCM



- Removes spatial correlation of quantization noise

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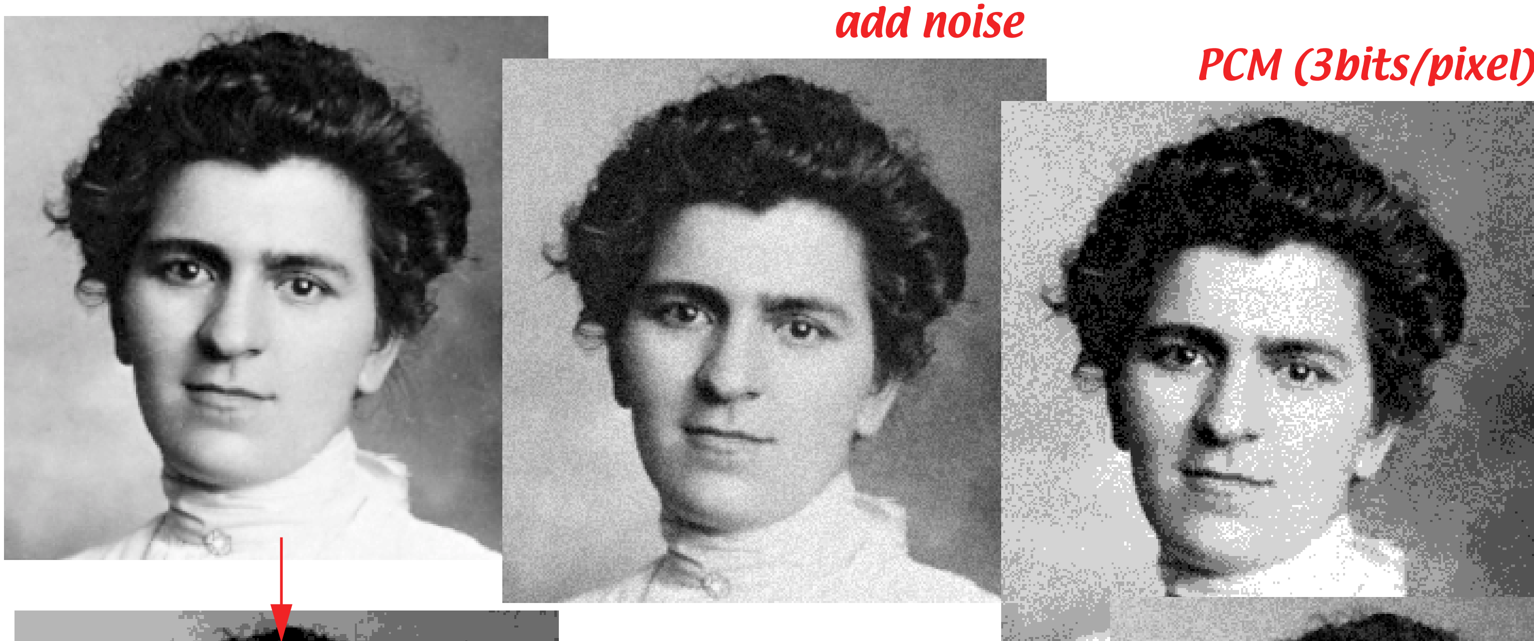
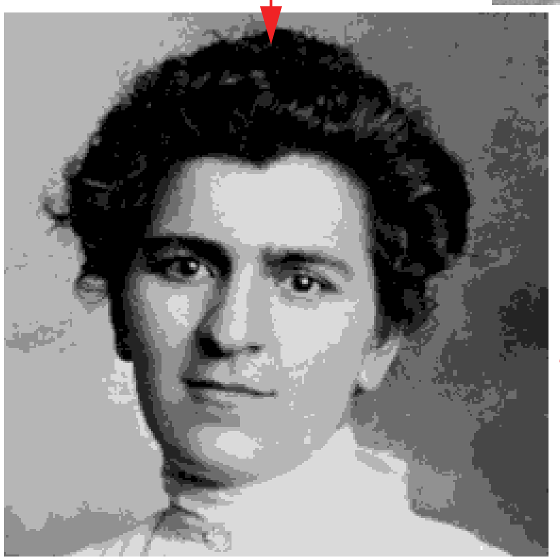
example with 3 bits/pixel and uniform random noise

add noise

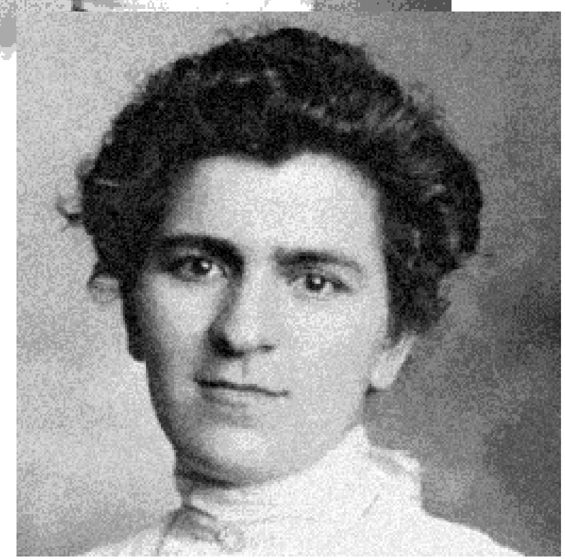
PCM (3bits/pixel)





uniform
PCM (3bits/pixel)

minus noise



Delta Modulation

- Code difference of neighboring pixels with 1 bit

  Assume some “scan” pattern in image

- Reduces spatial correlation before coding

example row-by-row image scan pattern

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Example

image:

6	7	8	8
5	9	10	8
6	8	9	7
7	9	11	9

differences:

6	1	1	0
-4	-1	2	0
1	2	1	-2
-2	-2	2	2

difference ≥ 0: codeword = 1

difference < 0: codeword = 0

in	difference	codeword	out	error
6	6	1	1	-0.3
7	1	1	7	0
8	1	1	8	-0.5
8	0	1	9	0
10	2	1		0
9	-1	0		0.1
5	-4	0		-0.25
6	1	1		-0.3
8	2	1		
9	1	1		
7	-2	0		
9	2	1		
11	2	1		
9	-2	0		
7	-2	0		