Compression II: Images (JPEG)

What is JPEG?

- Works with colour and greyscale images
- Up 24 bit colour images (Unlike GIF)
- Target Photographic Quality Images (Unlike GIF)
- Suitable Many applications e.g., satellite, medical, general photography...
Basic JPEG Compression Pipeline

JPEG compression involves the following:

- Encoding

![JPEG Encoding Diagram]

Figure 46: JPEG Encoding

- Decoding – Reverse the order for encoding
Major Coding Algorithms in JPEG

The Major Steps in JPEG Coding involve:

- Colour Space Transform and subsampling (YIQ)
- DCT (Discrete Cosine Transformation)
- Quantization
- Zigzag Scan
- DPCM on DC component
- RLE on AC Components
- Entropy Coding — Huffman or Arithmetic

We have met most of the algorithms already:

- JPEG exploits them in the compression pipeline to achieve maximal overall compression.
Quantization

Why do we need to quantise:

- To throw out bits from DCT.
- *Example*: $101101 = 45$ (6 bits).
  - Truncate to 4 bits: $1011 = 11$.
  - Truncate to 3 bits: $101 = 5$.
- Quantization error is the main source of **Lossy Compression**.
- **DCT itself not Lossy**
- How we *throw away bits* in **Quantization Step** is Lossy
Uniform quantization

- Divide by constant $N$ and round result ($N = 4$ or $8$ in examples above).
- Non powers-of-two gives fine control (e.g., $N = 6$ loses 2.5 bits)
Quantization Tables

- In JPEG, each F[u,v] is divided by a constant q(u,v).
- Table of q(u,v) is called quantization table.
- Eye is most sensitive to low frequencies (upper left corner), less sensitive to high frequencies (lower right corner)
- Standard defines 2 default quantization tables, one for luminance (below), one for chrominance.

```
16  11  10  16  24   40   51   61
12  12  14  19  26   58   60   55
14  13  16  24   40   57   69   56
14  17  22  29  51   87   80   62
18  22  37  56  68  109  103   77
24  35  55  64  81  104  113   92
49  64  78  87 103  121  120  101
72  92  95  98 112  100  103   99
```

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Quantization Tables (Cont)

- Q: How would changing the numbers affect the picture

  E.g., if we doubled them all?

  **Quality factor** in most implementations is the **scaling factor** for default quantization tables.

- **Custom quantization tables** can be put in image/scan header.

**JPEG Quantisation Examples**

- JPEG Quantisation Example (Java Applet)
**Zig-zag Scan**

What is the purpose of the Zig-zag Scan:

- To group low frequency coefficients in top of vector.
- Maps 8 x 8 to a 1 x 64 vector
Differential Pulse Code Modulation (DPCM) on DC component

- Another encoding method is employed
- DPCM on the DC component at least.
- Why is this strategy adopted:
  - DC component is large and varied, but often close to previous value (like lossless JPEG).
  - Encode the difference from previous 8x8 blocks – DPCM
Run Length Encode (RLE) on AC components

Yet another simple compression technique is applied to the AC component:

- 1x64 vector has lots of zeros in it
- Encode as \((\text{skip}, \text{value})\) pairs, where \(\text{skip}\) is the number of zeros and \(\text{value}\) is the next non-zero component.
- Send \((0,0)\) as end-of-block sentinel value.
Entropy Coding

DC and AC components finally need to be represented by a smaller number of bits:

- Categorize DC values into SSS (number of bits needed to represent) and actual bits.

<table>
<thead>
<tr>
<th>Value</th>
<th>SSS</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-1, 1</td>
<td>1</td>
</tr>
<tr>
<td>-3, -2, 2, 3</td>
<td>2</td>
</tr>
<tr>
<td>-7...-4, 4...7</td>
<td>3</td>
</tr>
</tbody>
</table>

- Example: if DC value is 4, 3 bits are needed. Send off SSS as Huffman symbol, followed by actual 3 bits.
- For AC components (*skip, value*), encode the composite symbol (*skip, SSS*) using the Huffman coding.
- Huffman Tables can be custom (sent in header) or default.
Example JPEG Compression
### Another Enumerated Example

#### Source Image Samples

<table>
<thead>
<tr>
<th>130</th>
<th>144</th>
<th>149</th>
<th>153</th>
<th>155</th>
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</tbody>
</table>

#### Forward DCT Coefficients

<table>
<thead>
<tr>
<th>(a) source image samples</th>
<th>(b) forward DCT coefficients</th>
<th>(c) quantization table</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 0 -1 0 0 0 0 0</td>
<td>240 0 -10 0 0 0 0 0</td>
<td>144 146 149 152 154 156 156 156</td>
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<tr>
<td>-2 1 0 0 0 0 0 0</td>
<td>-24 -12 0 0 0 0 0 0</td>
<td>148 150 152 154 156 156 156 156</td>
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<tr>
<td>-1 -1 0 0 0 0 0 0</td>
<td>-14 -13 0 0 0 0 0 0</td>
<td>155 156 157 158 158 158 158 158</td>
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<td>0 0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0</td>
<td>158 159 161 161 162 161 159 158</td>
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</table>

#### Normalized Quantized Coefficients

<table>
<thead>
<tr>
<th>(d) normalized quantized coefficients</th>
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<tbody>
<tr>
<td>0 0 0 0 0 0 0 0</td>
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#### Denormalized Quantized Coefficients

<table>
<thead>
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<th>(e) denormalized quantized coefficients</th>
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<tbody>
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<td>0 0 0 0 0 0 0 0</td>
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</table>

#### Reconstructed Image Samples

<table>
<thead>
<tr>
<th>(f) reconstructed image samples</th>
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</thead>
<tbody>
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<td>0 0 0 0 0 0 0 0</td>
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</tbody>
</table>
JPEG 2000

- New version released in 2002.
- Based on:
  - discrete wavelet transform (DWT), instead of DCT,
  - scalar quantization,
  - context modeling,
  - arithmetic coding,
  - post-compression rate allocation.
- Application: variety of uses, ranging from digital photography to medical imaging to advanced digital scanning and printing.
- Higher compression efficiency — visually lossless compression at 1 bit per pixel or better.
Further Information

Basic JPEG Information:

- [http://www.jpeg.org](http://www.jpeg.org)
- **Online JPEG Tutorial**