Schemes Supported

- RLE
- JPEG - lossless and lossy
- JPEG-LS - more efficient, fast lossless
- JPEG 2000 - progressive, ROI encoding
- Deflate (zip/gzip) - for non-image objects
In practice mostly ...

- Lossless JPEG for cardiac angio
  - multi-frame 512x512x8, 1024x1024x10
  - CD-R and on network

- Lossless JPEG for CT/MR
  - mostly on MOD media rather than over network
  - 256x256 to 1024x1024, 12-16 bits

- RLE/lossless/lossy JPEG for Ultrasound
  - 640x480 single and multiframe 8 bits gray/RGB, text
But ...

- JPEG lossless not the most effective
- JPEG lossy limited to 12 bits unsigned
- Undesirable JPEG blockiness
- Perception that wavelets are better
- Need for better progressive encoding
- Need for region-of-interest encoding
JPEG Lossless

- Reasonable predictive scheme
  - Most often only previous pixel predictor used (SV1), which is not always the best choice

- No run-length mode
  - No way to take advantage of large background areas

- Huffman entropy coder
  - Slow (multi-pass)
The Medicine Behind the Image

Lossless Compression

<table>
<thead>
<tr>
<th>Format</th>
<th>Compression Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALIC Arithmetic</td>
<td>3.91</td>
</tr>
<tr>
<td>JPEG2000 VM4 5x3</td>
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<tr>
<td>S+P Arithmetic</td>
<td>3.4</td>
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<tr>
<td>JPEG-LS MINE - NO RUN</td>
<td>3.31</td>
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<tr>
<td>NASA szip</td>
<td>3.09</td>
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<tr>
<td>JPEG best</td>
<td>3.04</td>
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</tr>
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<td>PNG</td>
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<tr>
<td>GNU gzip LE</td>
<td>2.39</td>
</tr>
</tbody>
</table>

3,679 grayscale single frame images
The Medicine Behind the Image

JPEG-LS (ISO 14495-1)

- Added to DICOM in CP-174 (25Sep2000)
- Two Transfer Syntaxes
- Lossless
  - Predictive, statistical model, Rice-Golomb, run-length
- Near-lossless
  - Prediction error constrained to limit (0 == lossless)
- Simple, fast, low memory requirement
- Approaches state of the art
Lossless Compression

3,679 grayscale single frame images
JPEG 2000 (ISO 15444-1)

• Added to DICOM in Sup 61 (14Jan2002)
• Lossless
  – Integer wavelet (+/- reversible color transformation)
• Either lossless or lossy
  – Integer or floating point wavelet
• Many features
  – <= 16 bits, signed or unsigned
  – Progressive by contrast or spatial, embedded
  – Region-of-interest coding - fewer bits for background
Lossless Compression

- CALIC Arithmetic
- JPEG2000 VM4 5x3
- JPEG-LS MINE
- JPEG2000 VM4 2x10
- S+P Arithmetic
- JPEG-LS MINE - NO RUN
- NASA szip
- JPEG best
- JPEG SV 1
- PNG
- GNU gzip LE

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JPEG DCT
(Foos, Maui, 1999)
Wavelet
(Foos, Maui, 1999)
JPEG 2000 - More?

- ISO 15444-n
- Transform in 3rd dimension
  - Hyperspectral imaging
  - 3D volumes
- M-JPEG2000 - not applicable to DICOM
- Other 3D initiatives, floating-point
- Interactive protocol (JPIP)
What about MPEG?

- Initially proposed by US for cardiac echo
- Tests: only superior to M-JPEG at > 50:1
- MPEG X? (1, 2, profile/level, frame size)
- How to take advantage of hardware
- Effect on burned in text at low bit rates
- Lost champion/expert, withdrawn
What about waveforms?

- Sup 30 added 26Sep2000
- Audio, ECG, hemodynamic waveforms
- Bulk waveform data in (5400,1010)
  - May be multiple (inside SQ, one per multiplex group)
- Would need new encapsulation mechanism
- Audio specific (".WAV" format question)
- In the interim - use Deflate Transfer Syntax
Deflate Transfer Syntax

- Added in CP 218 (16May2001)
- Goal: compress all attributes
  - 36,112 byte Structured Report -> 3,014 bytes (11.98:1)
  - 62,450 12-lead ECG -> to 26,139 bytes (2.39:1)
- Algorithm used in zip, gzip utilities
  - Deflated bitstream without file header
- **Entire** data-set not just (7FE0,0010)
  - Not the Part 10 meta-header for files, obviously
Lossless Compression

The Medicine Behind the Image

3,679 grayscale single frame images

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Byte All

0 1 2 3 4 5
Other DICOM Initiatives

• Add quality attributes to Query/Retrieve
  – Degree of loss acceptable
  – Contrast and/or spatial resolution required

• Adopt interactive protocol of some kind?
  – DICOM-specific or leverage JPIP?

• Icon images
  – Compressed/not, independent of main image (CP 165)
  – In Query response with compression?
Reality Check

• Industry slow to adopt new schemes
  – Good enough lossless schemes (2.8 vs. 3.8 ?)
  – Lack of market acceptance of lossy schemes
  – Lack of expertise, past bugs/incompatibilities
  – Unwilling to license toolkits/libraries
  – Few true color DICOM applications

• Network applications
  – Ease of negotiation of proprietary schemes

• Media applications
  – Need to limit # of profiles to maximize interoperability
Reality Check

• New pressures
  – Proliferation of creative proprietary schemes
  – Acquisition technology advances
    □ multi-detector CT, MR fluoroscopy, full-field digital mammo
  – Interactive delivery over moderate (DSL) bandwidth

• Media opportunities
  – Take-home patient CD or DVD with built-in viewer
  – DVD-R or -RAM with good lossless compression
  – >25-fold increase in capacity vs. uncompressed CD-R
Finally ....

• DICOM does not, and will never, “approve” compression schemes for any particular use
• Professional practice standards, scientific literature, regulatory approval (product specific)
• Just because it is in DICOM doesn’t mean it is any good; just because it is not, doesn’t mean it isn’t!
DICOM Working Group 4 (Compression)

Wednesday, 27 February

7.00pm -10.00pm, Golden West Room