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An Experiment in Dithering and Texture Compression

Diana Arrieta

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    - What is it?

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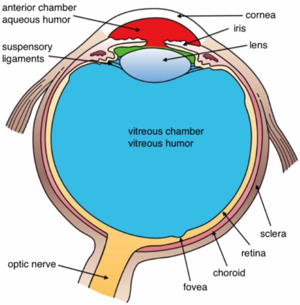
Human Vision

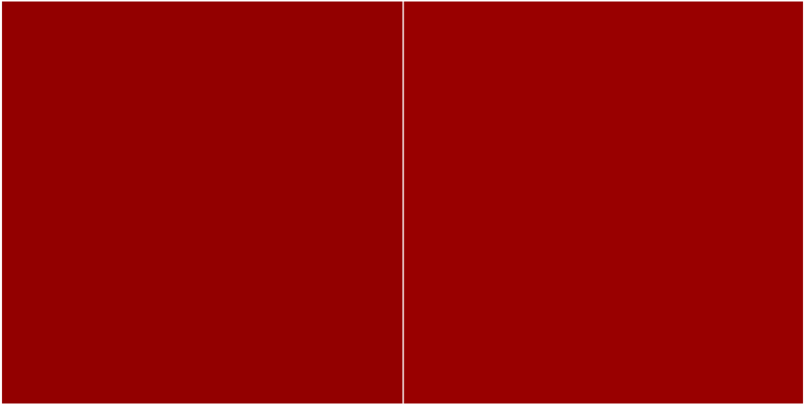
The human eye...



- Can perceive about 10 million colors
  - Compare that to 16.7 million colors on your 24-bit LCD screen!

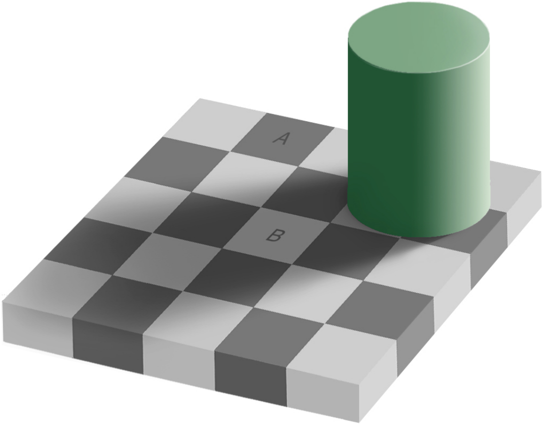
A visual exploit...

- Difficult to differentiate between similar colors.



A different visual exploit...

- Perceived colors are subject to lighting conditions and context.


A
B

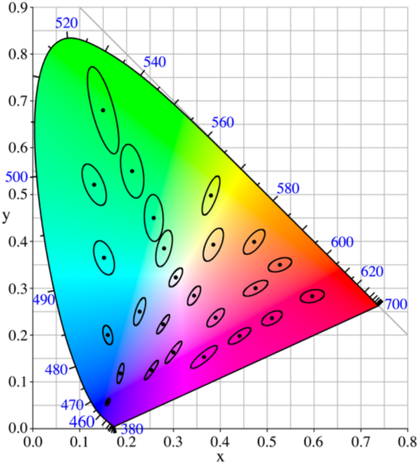


Figure 1 : MacAdam ellipses shown ten times their actual size on the CIE 1931 XYZ color space. Colors inside an ellipse visually match the color in the center.

Dithering

- An optical illusion of color depth in where colors not available in the provided palette are approximated by placing similar colors in a pattern to achieve the desired color.

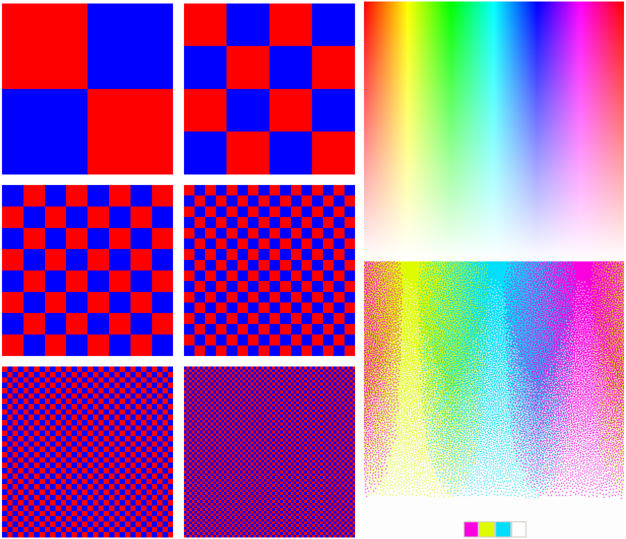


Figure 2 : Using dithering, more colors can be represented using a reduced color palette.

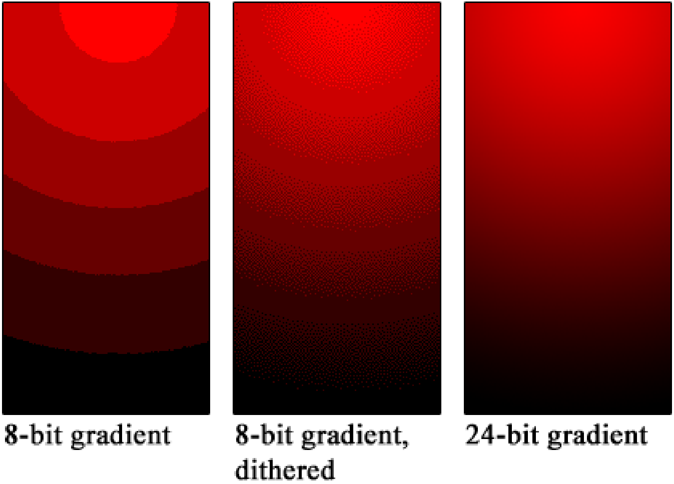


Figure 3 : Banding in a gradient. Banding is reduced when dithering is applied.

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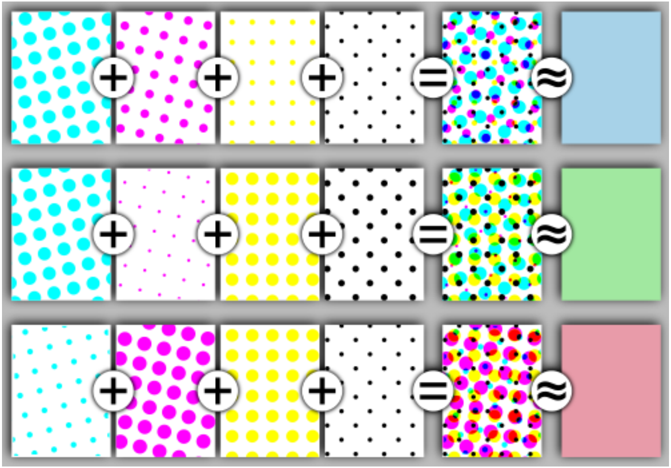

Compression

Involves encoding information into fewer bits than would otherwise be occupied by the original source.

Lossless Compression Methods

Definition: A data encoding method that removes redundancies and uses fewer bits to represent the same data. (Best uses: Text or Archiving.)

Huffman Encoding

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- An entropy encoder that substitutes more common characters with fewer bits, while infrequent characters are encoded with more bits.
- Average Compression: 2.3 to 2.9 bits per character (8 bits)
- Cons: Requires two passes to build variable length codes.
  - You can use pre-built trees to encode rather than building one.

Letter	Frequency	Letter	Frequency
e	0.12702	w	0.02360
t	0.09056	f	0.02228
a	0.08167	g	0.02015
o	0.07507	y	0.01974
i	0.06966	p	0.01929
n	0.06749	b	0.01492
s	0.06327	v	0.00978
h	0.06094	k	0.00772
r	0.05987	j	0.00153
d	0.04253	x	0.00150
l	0.04025	q	0.00095
c	0.02782	z	0.00074
u	0.02758		
m	0.02406		

Figure 4 : Frequency for common letters in the English language.

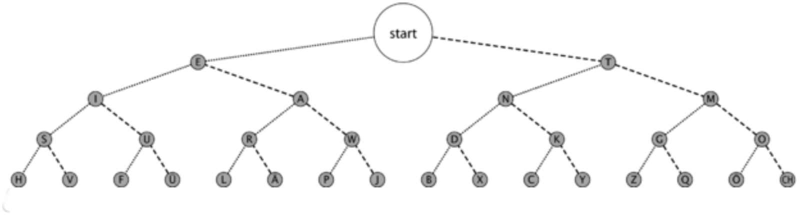

Figure 5 : A Huffman binary tree. This is the tree also used for Morse code.

Lempel-Ziv-Welch

- As the algorithm encounters patterns that it has seen before, it substitutes these with a shorter representation provided that it is already in the dictionary. If not, it creates one on the spot and outputs the corresponding code.

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- Can create substitutions for entire strings rather than single characters.
- In longer files, a better compression ratio can often be achieved since a large dictionary has a better chance of finding matches.
- Tradeoff: A large dictionary can find more matches at the cost of processing time.

```
w = NIL;
   while ( read a character k )
   {
      if wk exists in the dictionary
         w = wk;
      else
         add wk to the dictionary;
      output the code for w;
      w = k;
   }
```

Figure 6 : Pseudo-code for LZW (compression).

```
read a character k;
   output k;
   w = k;
   while ( read a character k )
   /* k could be a character or a code. */
   {
      if k exists in the dictionary
         entry = dictionary entry for k;
         output entry;
         add w + entry[0] to dictionary;
         w = entry;
      else
         output entry = w + firstCharacterOf(w);
      add entry to dictionary;
      w = entry;
   }
```

Figure 7 : Pseudo-code for LZW (decompression).

Lossy Compression Methods

Definition: A data encoding method that discards some data in order to achieve compression. The resulting data is similar enough to the original data. (Best uses: Images, Audio, Video.)

Lossy: Wavelet Transform

- Becomes lossy when coefficients that don't meet the threshold are reduced to zero.
- Is first performed over rows, then columns.
- Most of the resulting data is discarded, with high level data in the upper left, and smaller details to the lower right.

Lossy: Wavelet Transform

```
7   1   6   6   3   -5   4   2

Averages:
(7 +  1) / 2 =  4
(6 +  6) / 2 =  6
(3 + -5) / 2 = -1
(4 +  2) / 2 =  3

Differences:
(7 -  4) = ( 4 -  1) = 3
(6 -  6) = ( 6 -  6) = 0
(3 - -1) = (-1 - -5) = 4
(4 -  3) = ( 3 -  2) = 1

Resulting array:
4   6   -1   3   3   0   4   1
```

Lossy: Wavelet Transform

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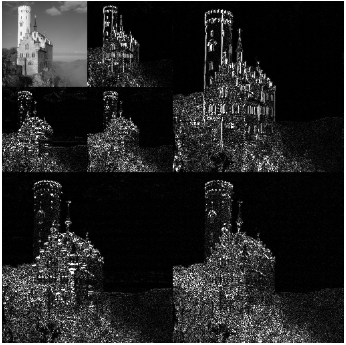

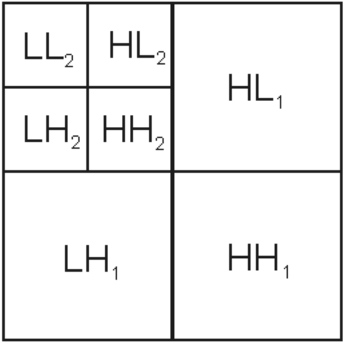

Figure 8 : Image processed with a wavelet transform. Each block contains coefficients to reconstruct the original image.

Lossy: Motion Compensation

Compensates for differences between subsequent frames.

- MPEG-2
  - I-Frame: Initial Frame.

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Lossy: Motion Compensation

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- MPEG-2
    - I-Frame: Initial Frame.
    - P-Frame: Predicted Frame or Delta Frame. Holds changes that occur between frames. Holds less data than a full frame.
    - B-Frame: Bi-directional frame. Contains forward and backward prediction of the closest I-Frame and P-frame.

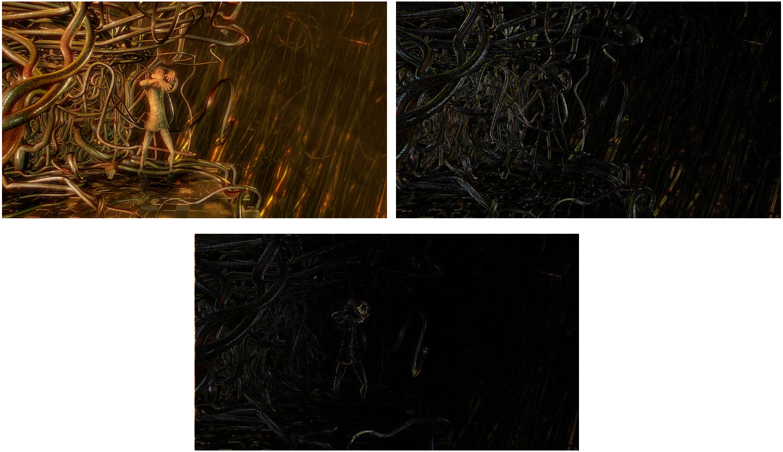

Figure 9 : The original frame, the difference frame, and the motion compensated frame.

Textures

Images that are intended to be mapped to a surface. They are highly compressed using fixed-rate compression algorithms, and are also quick to decompress, either as a whole or just a section.

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- Can contain:
  - Terrain, usually grass, concrete, etc. (Typically flat)
  - Object surfaces, such as boxes, furniture, etc. (Can be irregular)
  - Lighting information, dictating how light interacts with an object.

Texture Atlas

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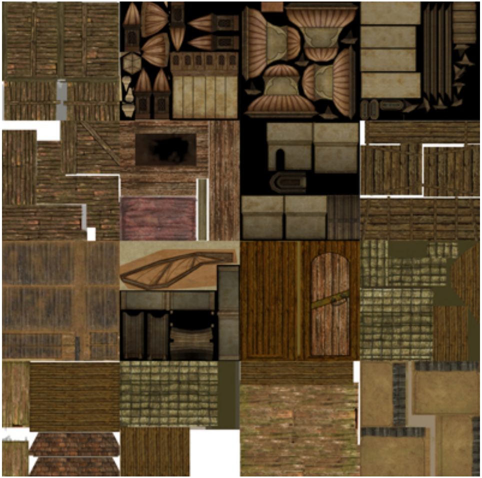

Texture Synthesis

While synthesised textures are a single image that has been stitched to itself repeatedly to a larger resolution.

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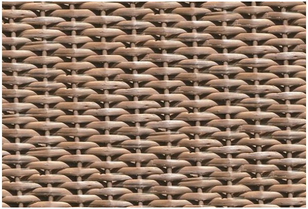
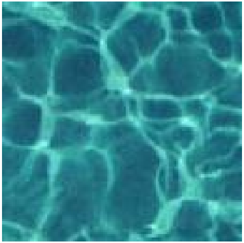


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- Has Constraints:
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  - Allow Random Access to individual blocks (fixed-rate compression).
  - Resulting decompressed images must look relatively similar.

Current Standard: Direct X

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- The current standard under Fixed-Rate Block Compression patent (S3TC).
  - Breaks images down to 4x4 blocks.
  - Finds a best fit line for a set of pixels.
  - Stores indexes of pixels along the line.
- Pros: Fast to decode and results in good compression.
- Con: If a value doesn't have a good fit to the line, it will not be represented accurately.

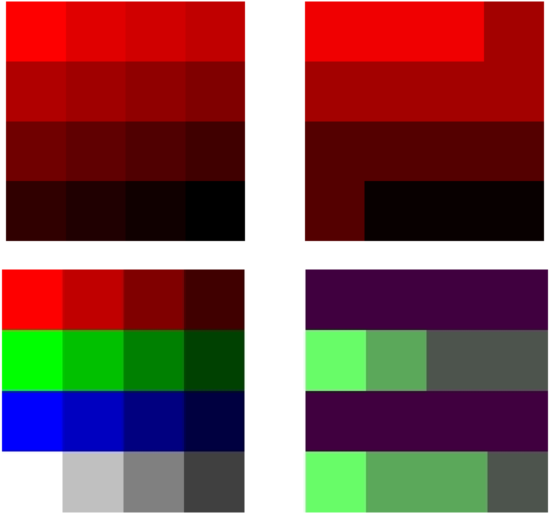

Figure 10 : The errors for gradient textures is shown in the top set of images. The right shows the result of a reduced color palette, which cannot interpolate the original colors at all.

Current Standard: Ericsson

Current standard used for Mobile Phones (notably Android)

- Starts with a 4x4 block...
  - Which is then broken down into a 4x2 or 2x4 block.
  - Each part is given a singel base color (could be 4/4/4 or 5/5/5 RGB).
  - Remaining bits are used to indicate the table used luminance values.

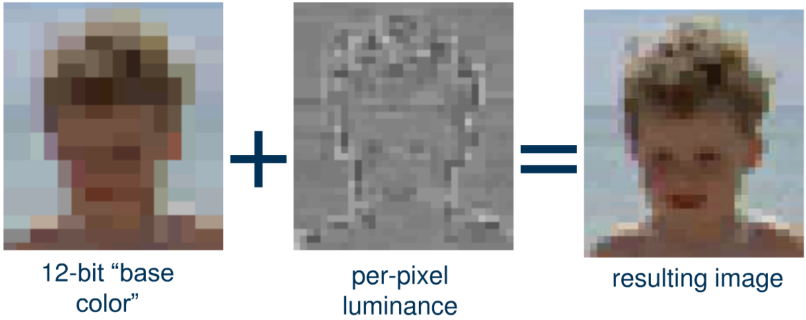

Figure 11 : The base colors are shown for each block on the left image, while luminance modulation is shown in the middle. The final image is the decompressed image.

Project Method

- Relevance Dither
- Relevance Compression

Relevance Dither

```
//Floyd-Steinberg
//          X   7
//      3   5   1

//Jarvis-Judice-Ninke
//          X   7   5
// 3    5   7   5   3
// 1    3   5   3   1

//Mine!
//          X   4  1
//          4   2
//          1
```

Relevance Compression

- Start with a 2x2 block.
- Convert pixel color to indexed color. (Keep count of this!)
- Find the most common indexes.
- Pixels that are not part of the most common indexes are changed to color that is part of this group.
- The best match is found using RGB as a distance coordinate, to find the next closest color.
- Save the most common indexes in the header.

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Pros:

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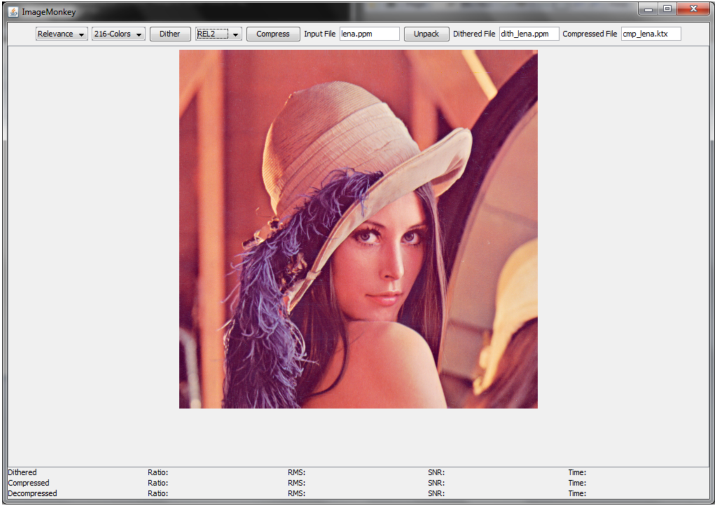
Suggestions:

- Port to a language that doesn't use a virtual machine.
- Index tiles instead of single pixels.

Demo


ImageMonkey
Relevance
216-Colors
Dither
REL2
Compress
Input File lena.ppm
Unpack
Dithered File dith_lena.ppm
Compressed File cmp_lena.ktx
Dithered Ratio: RMS: SNR: Time:
Compressed Ratio: RMS: SNR: Time:
Decompressed Ratio: RMS: SNR: Time:

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