Image Compression based on Non-Parametric Sampling in Noisy Environments

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Objectives

To develop a robust scheme for image compression involving the creation of holes, encoding, transmitting and consequently receiving, decoding and filling these holes.

- Creating holes in an image
- Encode and transmit the image
- Simulate a noisy channel in order to introduce errors
- Identifying and filling the holes appropriately.

System Design

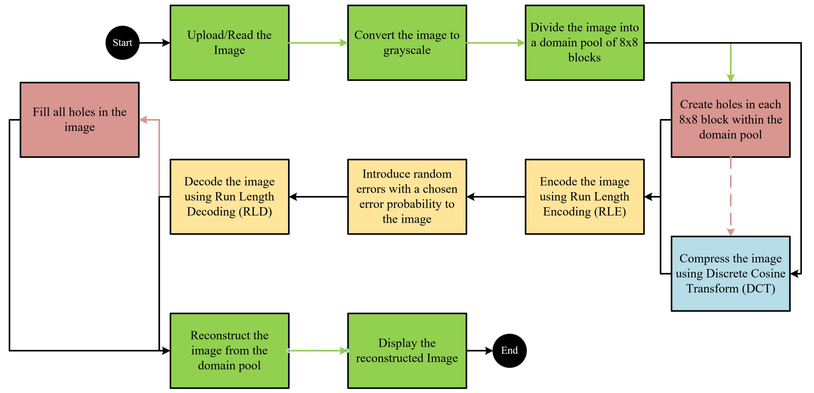


Figure 1: Image compression implementation overview

Algorithms

Algorithm 1 High-level algorithm for creating holes in `8x8` blocks

for every block in the domain pool **do**
  Go to `2x2` square in `8x8` block
  Calculate average of pixels in `2x2`

  for every pixel in the `2x2` **do**
    Check Chebyshev distance between pixels and average
  end for
  if distance between the average and each pixel < 6 **then**
    Go to `4x4` square in `8x8` block
    Calculate average of pixels of `4x4`

    for every pixel in the `4x4` **do**
      Check Chebyshev distance between each pixel
    end for
    if distance between the average and each pixel < 6 **then**
      Go to `6x6` square in `8x8` block
      Calculate average of pixels of `6x6`

      for every pixel in the `6x6` **do**
        Check Chebyshev distance between each pixel and average value
      end for
      if distance between average and each pixel < 6 **then**
        Create hole in `6x6`
      else
        Create hole in `4x4`
      end if

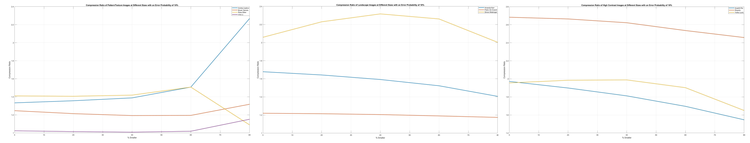
    else
      Create hole in `2x2`
    end if
  else
    Move to next block in domain pool
  end if
end for

Results: Processing

In the figures below, the various steps and processes that the image goes through can be seen.

Results: Simulation

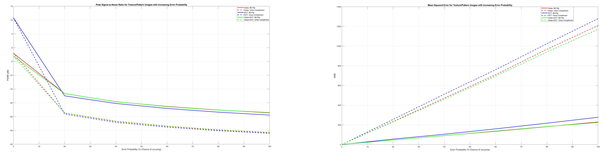
Figure 2 and the subsequent sub-figures test the created *Holes* algorithm on different images. Pattern images are chosen for the repetitive colour and smooth features; landscape images are chosen for the texture features and intense detail; high contrast images are chosen for its combination of both repetitive colour, smooth and texture features.



(a) Pattern Images **(b)** Landscape Images **(c)** High Contrast Images

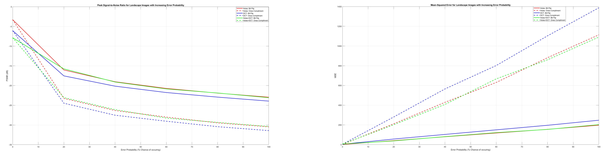
Figure 2: Compression Ratio vs Same Image at Different Sizes

An error analysis is carried out on the different image types calculating the peak signal-to-noise ratio (PSNR) and mean squared error (MSE) of the reconstructed images. The PSNR is a dimensionless number expressed on a logarithmic decibel scale, to identify the perceived errors noticeable by the human vision. The MSE is the cumulative squared error of the compressed image against the original image [1].



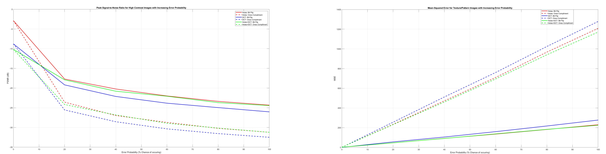
(a) PSNR for all Pattern Images **(b)** MSE for all Pattern Images

Figure 3: Pattern Images Error Analysis



(a) PSNR for all Landscape Images **(b)** MSE for all Landscape Images

Figure 4: Landscape Images Error Analysis



(a) PSNR for all High Contrast Images **(b)** MSE for all High Contrast Images

Figure 5: High Contrast Images Error Analysis

Results: Processing

Formulas

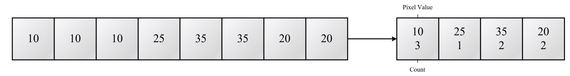
The Discrete Cosine Transform Formula

$$D(i,j) = \frac{1}{\sqrt{2N}} C(i)C(j) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} p(x,y) \cos\left[\frac{(2x+1)i\pi}{2N}\right] \cos\left[\frac{(2y+1)j\pi}{2N}\right] \quad (1)$$

The Chebyshev Distance Formula

$$D(p,q) = \max_i(|p_i - 1_i|) \quad (2)$$

Run Length Encoding



Compression Ratio

$$CR = \frac{No.\ of\ bits\ in\ uncompressed\ image}{No.\ of\ bits\ transmitted\ after\ encoding} \quad (3)$$

Future Work

The designed algorithm for image compression can be improved in numerous ways, including:

- Utilizing parallel computing and programming to speed up the processing time of the algorithm
- A neural network can be trained on multiple images so that holes can be created in the larger picture as opposed to smaller 8x8 blocks within the image
- A neural network trained on multiple images at different compression depths can determine the correct check value
- A trained neural network can ultimately reconstruct an image and improve detail and quality of low-quality images.

Conclusion

This project is more research based, and is proof of concept that multiple compression types can be utilized together for image compression. The

Acknowledgements

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References

[1] Uthayakumar, J. et al; *A survey on data compression techniques: From the perspective of data quality, coding schemes, data type and applications*; Journal of King Saud University - Computer and Information Sciences (2018)