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Course	CSCI 576 Multimedia Systems
Assignment	1 - Aliasing effect & overlay of the original image when control key is pressed

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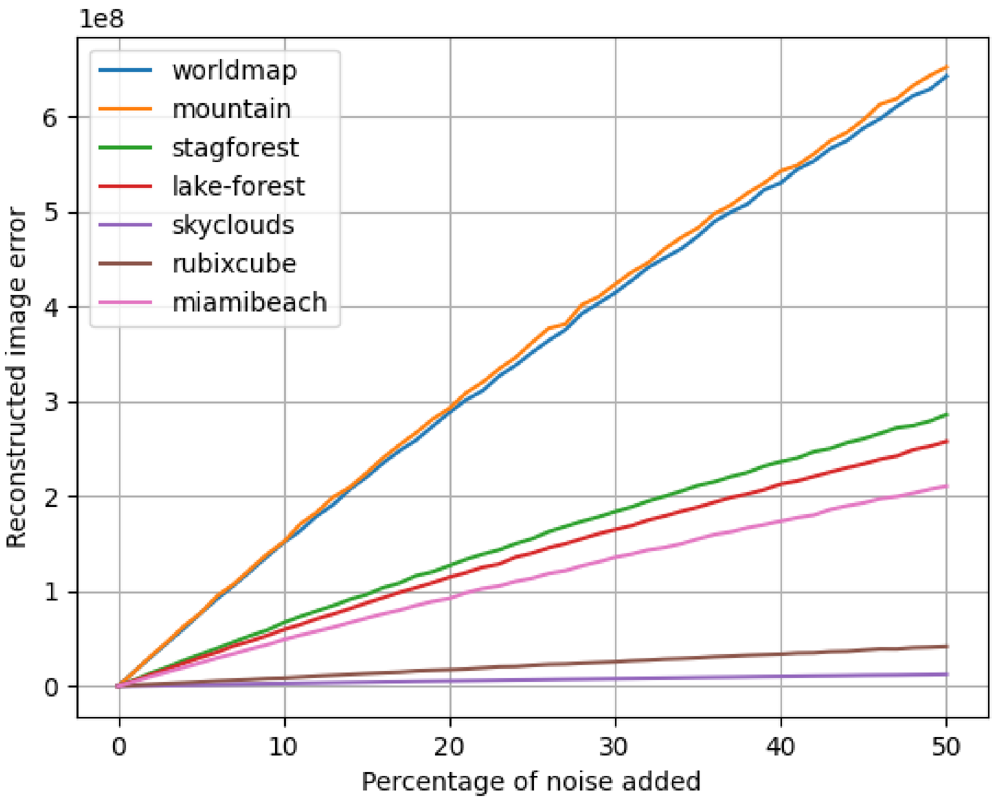
Reconstruction Error Graph



Analysis

Which image has higher errors, and which image has lower errors?

Worldmap and Mountain have a **higher error**. Both of these image contains many fine details, such as country boundaries, coastlines, names of the countries, and various colors in the case of worldmap and the texture of the mountains, trees, and possibly varying shades of colors in the case of mountains. These details make it challenging to compress or reconstruct accurately. As we remove pixels, we lose critical details, leading to a rapid increase in reconstruction error.

Rubrixcube and Skyclouds have **lower errors**. These images are uniform in color with well-defined edges, making reconstructing less complex. There are fewer variations in colors and patterns, which means that even with some pixels removed, the image may remain relatively recognizable.

High reconstruction error example

- **Reconstructed image**

- **Original Image**

Low reconstruction error example

- **Reconstructed image**

- **Original Image**

Quantitative Analysis

Image	x = 5%	x = 25%	x = 35%	x = 50%
Skyclouds	1452620.0	6775402.0	9214843.0	1.2639305E+07
worldmap	7.7093936E+07	3.5159891E+08	4.7390041E+08	6.4249734E+08
rubrixcube	4561434.0	2.1996148E+07	2.9868248E+07	4.1794564E+07
mountain	7.7412688E+07	3.6211427E+08	4.8257209E+08	6.5210522E+08
stagforest	3.3751248E+07	1.5545824E+08	2.1140852E+08	2.8619849E+08
miamibeach	2.4741512E+07	1.1370516E+08	1.5518556E+08	2.1070833E+08
lake-forest	3.03582E+07	1.4015529E+08	1.8853881E+08	2.5782150E+08

Increasing error with more pixel removal: we observe a consistent trend across all images where the reconstruction error increases as a greater percentage of pixels are removed.

Variation in error magnitude: Images vary in their sensitivity to pixel removal, as indicated by the differences in MSE values. Images like Skyclouds and Rubrixcube maintain relatively lower errors even at higher pixel removal percentages, suggesting they are more robust and better at preserving their visual content. In contrast, images like Worldmap and Mountain exhibit significantly higher errors, indicating that they are less resilient to pixel loss due to more intricate visual features.

Complexity and Content Impact: The variation in MSE values underscores the importance of image complexity and visual content. Images with simpler, less intricate content tend to have lower errors, while those with complex patterns and details suffer more from pixel removal, resulting in higher errors.

Why are all the plots different?

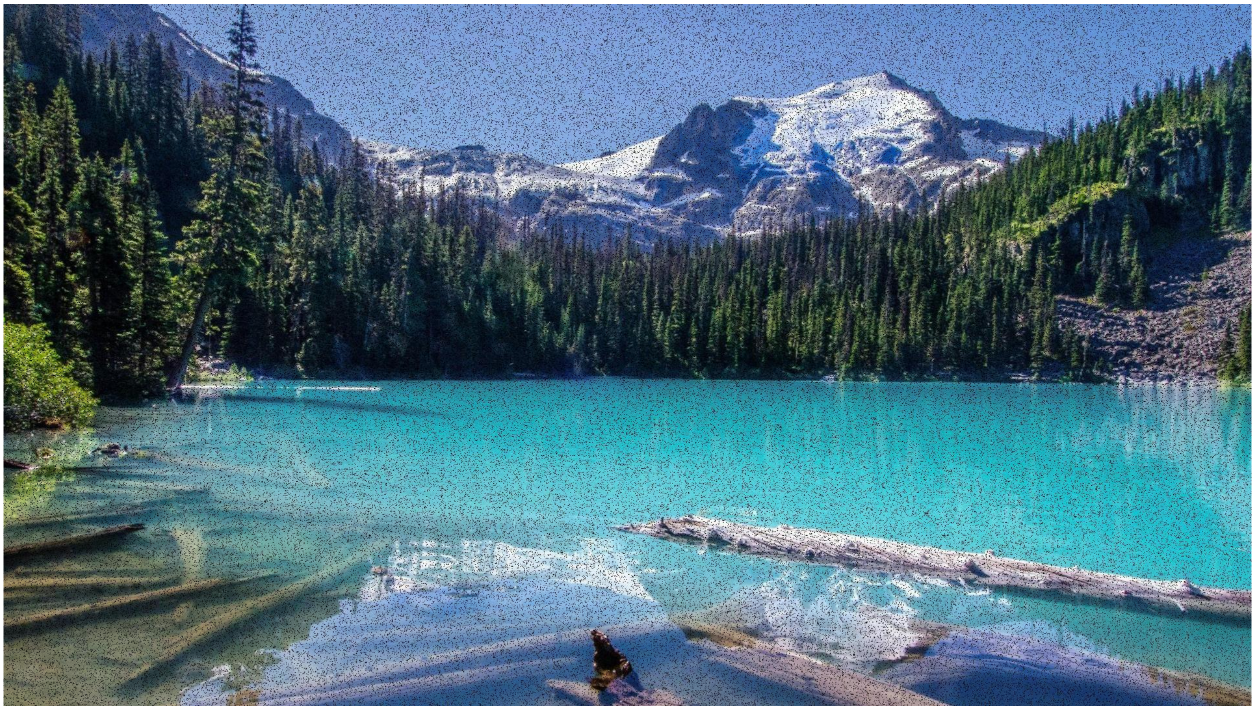
The variation in reconstruction errors between images arises primarily from their inherent complexity and visual content. Intricate images suffer more from pixel removal, while simpler ones withstand it better. Therefore, the extent of reconstruction errors depends on the distinctiveness of a given image's visual features and how well these features can be preserved when pixels are taken away.

From your quantitative analysis, can you qualitatively describe which image will have a higher and which will have a lower error?

Images with lots of details, different colors, and complex patterns will have bigger errors when you take away pixels. This is because they lose important information, and their quality drops more. On the other hand, simpler images with fewer details and the same colors in most parts will have smaller errors when some pixels are removed. They can still look decent even with some missing pixels. So, complex images have higher errors, and simple ones have lower errors when you remove pixels.

More examples - lake-forest.rgb

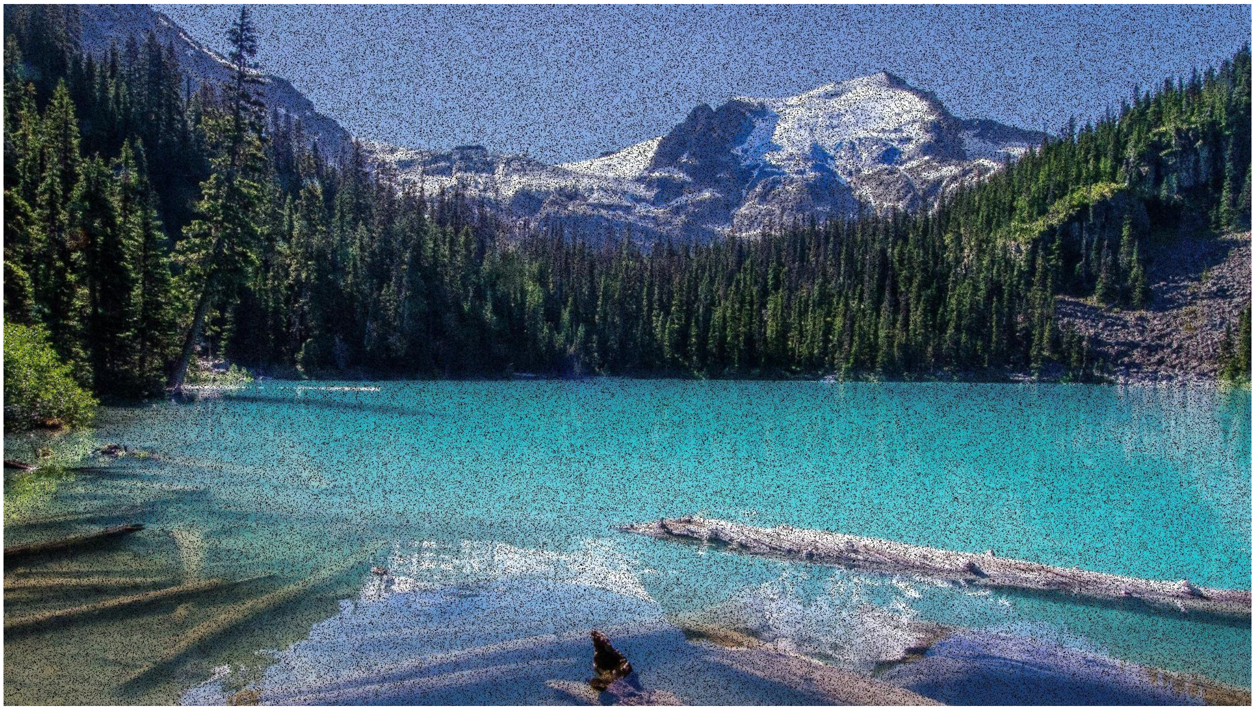
Randomly removed 5% pixels



Noisy image

Reconstructed Image

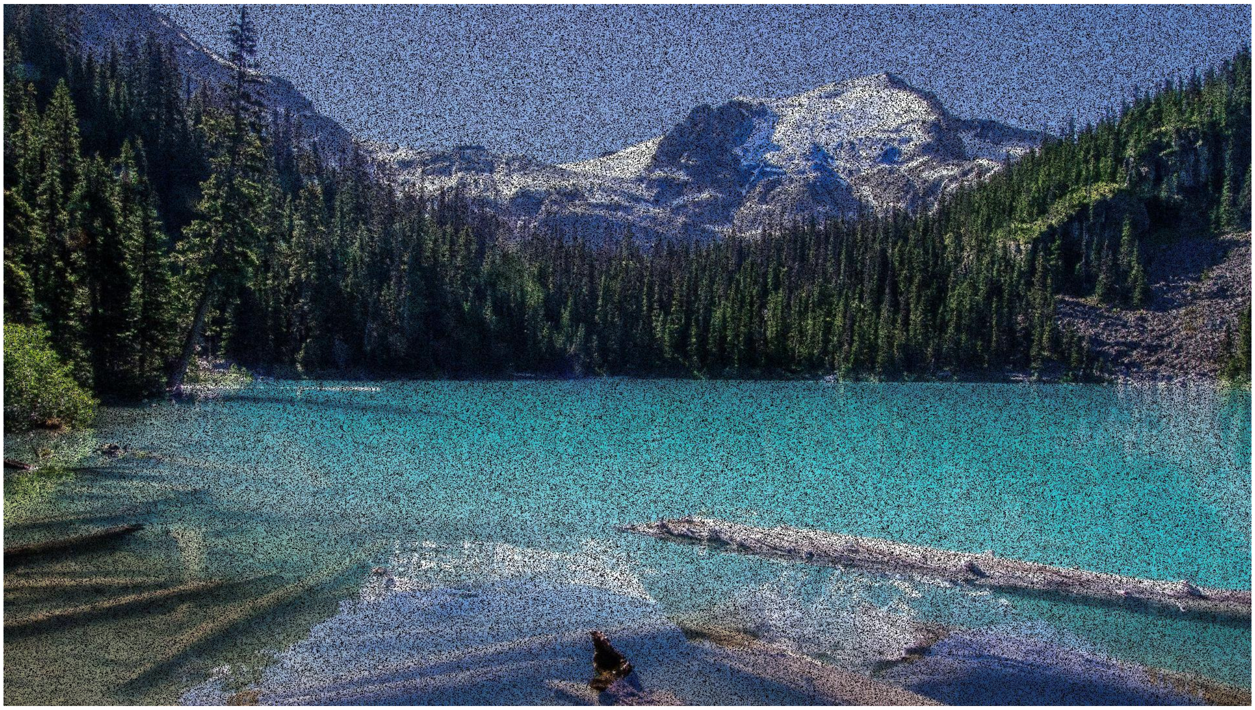
Randomly removed 20% pixels



Noisy image

Reconstructed Image

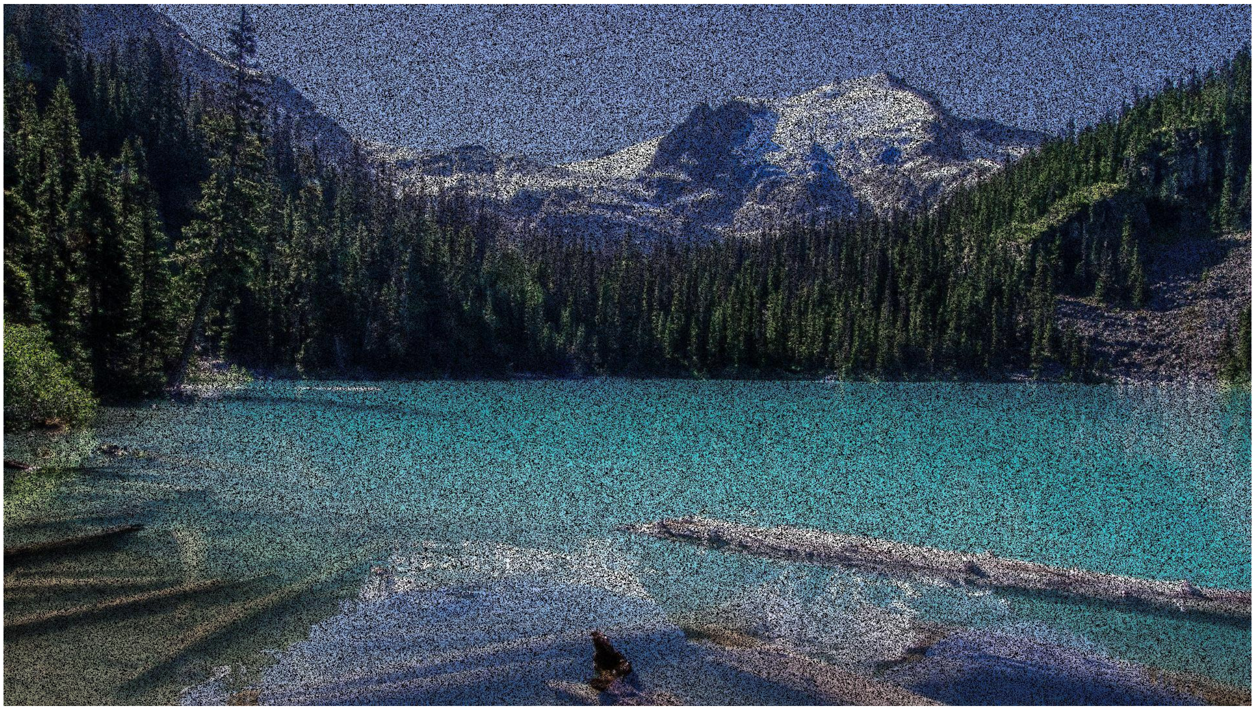
Randomly removed 35% pixels



Noisy image

Reconstructed Image

Randomly removed 50% pixels



Noisy image

Reconstructed Image

Extra Credit Question

Let's assume that the input image has w by h pixels in the input image. Hence, the total pixels would be $w * h$. Let x be the percentage of the pixels that need to be removed. Following the algorithm we used in part 3, let's consider an 3 x 3 neighborhood around every pixel.

Let p_i be the original pixel and p_i' be the reconstructed pixel. If we assume that none of the 8 pixels in the neighborhood of this pixel were removed, we can easily construct the error as follows:

$\mathbb{E}[p] = p' = \frac{\sum_j p_j}{8}$ where j runs from 1 to 8.

Let's assume a scenario where 2 pixels out of 8 neighborhood pixels were also removed along with the center pixel that we want to reconstruct. Now, the probability that 2 out of 8 pixels are removed is:

$$P(2) = \binom{8}{2}(1-x)^6 x^2$$

If we generalize the above equation. The probability of i pixels removed from the neighborhood would be given as follows:

$$P(i) = \binom{8}{i}(1-x)^{8-i} x^i$$

The total ways to remove 2 pixels from the neighborhood is = $\binom{8}{2} = 28$. Now, the total ways of a pixel being selected for removal is $\binom{1}{1} * \binom{7}{1} = 7$. Hence, the total ways when a pixel is definitely a good pixel that can be used to reconstruct the center pixel is $28 - 7 = 21$.

Thus, the expected value of the reconstructed pixel $\mathbb{E}[p_i] = p_i' = \frac{21}{28}\mathbb{E}[p]$.

If we generalize this for all possible cases, i.e., when 2, 3, 4, ..8 pixels are removed, then the expected value of a reconstructed pixel would be given as

$$\mathbb{E}[p_i] = p_i' = \sum_{i=1}^{8} \frac{P(i) * (\binom{8}{i} - \binom{7}{8-i}) * \mathbb{E}[p]}{\binom{8}{i}}$$

Hence, the final reconstructed error of one pixel for one channel, let's say $e_i = (p_i - p_i')^2$. We can now calculate the overall error by summing it for every other possible pixel on all three channels. Since we just need to remove $x\%$ pixels, we need to multiply the final answer with $x\%$.