Digital Image Processing

Assignment 01

Group member:

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Question 1: Which of the digital camera's settings have most probably been adjusted incorrectly to cause the errors 2-4? Why did you come to these conclusions? See Section General Instructions for some hints.

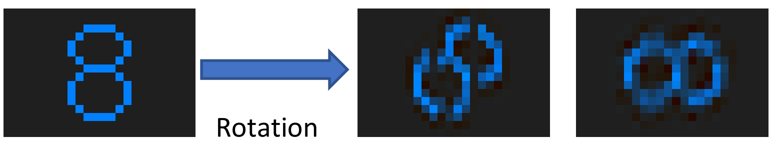
Ans) **Error 2:** Brightness and contrast of the image can be controlled by ISO, aperture, and shutter speed of the camera. The ISO controls the brightness of the image such that greater the ISO the brighter the image and vice versa. Moreover, aperture could also control the amount of light entering the camera depending on the opening. Higher the aperture brighter image will be produced. Likewise, shutter speed also controls the amount of light entering the lens which results in varying brightness. Contrast is the difference between the extreme bright pixel value and dark pixel value. Above mentioned settings also contribute to the contrast of the image such that the more brighter the image is the lesser its contrast will be as it will be washed out and it will be hard to distinguish the edges similarly, the less brighter the image is it will be of low contrast as it is darker and therefore, it'll be hard to distinguish edges. Therefore, there must be a balance between brightness and contrast.

Error 3: Every type of light source has a different light 'temperature'. Incandescent lights have a warmer temperature than fluorescent lighting. The sunlight on a cloudy day is cooler than noon on a cloudless day, which is cooler than the warm temperature of the light coming from the setting sun. This light causes the objects in the image to look a little warmer (orange/red colors) or cooler (blue). Human eyes adjust to the slightly different reflected colors, so we don't notice the difference. Camera can't tell and therefore, it makes a guess. Camera looks at the brightest thing in the image, and assumes that will be the color 'white'. It's a logical assumption. Most outdoor shots have white clouds, and indoor rooms usually have white walls. The camera then calibrates all the colors in that image using the 'white'. However, sometimes the camera gets it wrong. Usually this is because there is no 'white' in the shot and thus no reference point which is also the case in our test image. This causes orange or blue trace. Sometimes camera requires extra information. One way to do this is with white balance settings. When you set your white balance to compensate for a cloudy day, you are telling the camera that the light coming into the lens has a certain temperature. The computer program inside will recognize this and correctly calibrate the photo. Digital cameras come with pre-set white balance modes. It holds different modes like cloudy day, fluorescent, shady, and auto as per the setting and need. So, if the individual is a beginner so it is recommended to use auto white balancing mode.

Error 4: Image noise is random variation of brightness or color information in images, and is usually an aspect of electronic noise. It can be produced by the image sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. There are different types of noises which are caused due to different reasons like Gaussian noise which is caused by inherent noise of sensors, Salt-and-Pepper noise which is caused by ADC errors, shot noise which is caused by the noise of shutter, and periodic noise caused due to electromechanical interference during image capturing process. Moreover, a photo taken at too high ISO will show a lot of grain, also known as noise, and might not be usable. So, brightening a photo via ISO is always a trade-off. You should only raise your ISO when you are unable to brighten the photo via shutter speed or aperture instead (for example, if using a longer shutter speed would cause your subject to be blurry).

Question 2: Why is interpolation needed in the rotation process? How do the different interpolation methods "nearest neighbor", "bilinear interpolation", and "bicubic interpolation" differ?

Ans) Interpolation is a method of estimating the unknown pixel value using the known pixel value. It is performed when an image is resized or distorted/remapped on a new grid such as rotation. For instance, when an image is enlarged i.e. number of pixels are increased then different interpolation methods are applied to estimate the pixel value on new locations such that the quality is not compromised. Similarly, when an image is rotated, interpolation is used to compute the coordinate of a source image point for each destination image pixel. In most cases, the destination pixel does not lie at a source pixel location, but rather lands somewhere between neighboring pixels. The estimated value of each pixel is set in a process called interpolation or image resampling. Figure below shows how geometric transformation of an image could distort the image.



Rotation [2]

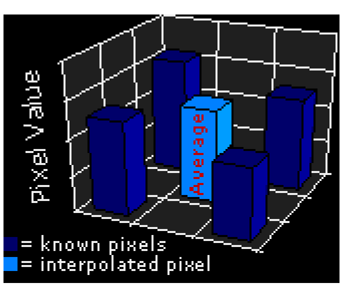
Original 45° rotation 90° rotation

Nearest Neighbor:

Nearest-neighbor interpolation, also known as zero-order interpolation, is the fastest interpolation method, though it can produce image artifacts called jaggies or aliasing error. Nearest-neighbor interpolation simply assigns to point D in the destination image the value of the pixel nearest S in the source image.

Bilinear Interpolation:

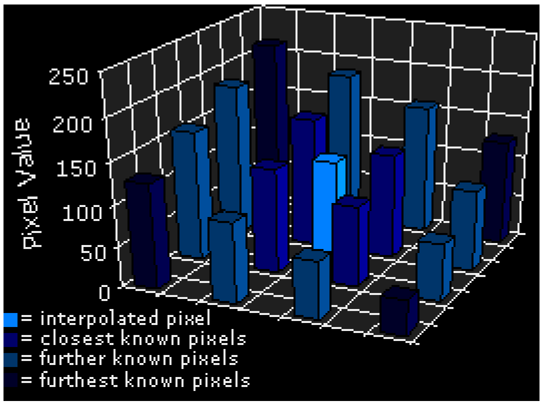
Bilinear interpolation, also known as first-order interpolation, linearly interpolates pixels along each row of the source image, then interpolates along the columns. Bilinear interpolation assigns to Point D in the destination a value that is a bilinear function of the four pixels nearest S in the source image. Bilinear interpolation results in an improvement in image quality over nearest-neighbor interpolation.



[2]

Bicubic Interpolation:

Bicubic interpolation reduces resampling artifacts even further by using the 16 nearest neighbors in the interpolation and by using bicubic waveforms rather than the linear waveforms used in bilinear interpolation. Bicubic interpolation preserves the fine detail present in the source image at the expense of the additional time it takes to perform the interpolation. The bicubic interpolation routine assigns to point D in the destination image a value that is a bicubic function of the 16 pixels nearest S in the source image.



[2]

Question 3: Which preprocessing step is necessary before the size of the image can be scaled down (subsampled) to avoid aliasing?

Ans) Aliasing takes place when the sampling frequency is less than twice the highest frequency present in the image that is when Nyquist Frequency Sampling Frequency is disobeyed. Aliasing causes loss of information and causes fake contours/patterns in the image. Anti-aliasing is applied on the image before it is down sampled to avoid aliasing artifacts. It involves the usage of low pass filter which removes the high frequencies from the image. We set the cut-off frequency equal to half of the maximum sampling rate frequency so that the bandwidth is reduce and when the image is down sampled there will be no aliasing.

Question 4: What other methods than gray world can be used to automatically correct the white balance?

Ans) **White Patch Retinex algorithm (aka white reference)[6]:** It assumes that if there is a white patch in the imaging scene of an image, the maximum value of each channel of the RGB-format image will appear in the white patch. Thus, under the assumption of the presence of white patch, the max values of each R, G, B channel of the image is the illumination color, therefore it is also known as max-RGB algorithm, which utilizes this assumption to compute the maximum responses in either of the three channels R, G and B and sets the color of the light source to this value. We conduct the Max operation in all the separate channels, detecting the maximum of the responses in each channel. It works similar to grey world algorithm; we only replace the mean value by the maximum value of the sensor responses in each channel.

Shades of Grey[6]: It is a more general color constancy algorithm based on Minkowski norm. It computes a weighted average of the pixel values, assigning higher weights to pixels with higher intensities. The weight function is based on the Minkowski-norm.

Cheng's illuminant estimation method[7]: It draws inspiration from spatial domain methods such as Grey Edge, which assumes that the gradients of an image are achromatic. They show that Grey Edge can be improved by artificially introducing strong gradients by shuffling image blocks, and conclude that the strongest gradients follow the direction of the illuminant. Their method consists in ordering pixels according to the norm of their projection along the direction of the mean image color, and retaining the bottom and top percentile. These two groups correspond to strong gradients in the image. Finally, they perform a principal component analysis (PCA) on the retained pixels and return the first component as the estimated illuminant.

Histogram equalization[3]: It is a non-linear transform which maintains pixel rank and is capable of normalizing for any monotonically increasing color transform function. It is considered to be a more powerful normalization transformation than the grey world method. The results of histogram equalization tend to have an exaggerated blue channel and look unnatural, due to the fact that in most images the distribution of the pixel values is usually more similar to a Gaussian distribution, rather than uniform.

Histogram specification[3]**:** It transforms the red, green and blue histograms to match the shapes of three specific histograms, rather than simply equalizing them. It refers to a class of image transforms which aims to obtain images of which the histograms have a desired shape. As specified, firstly it is necessary to convert the image so that it has a particular histogram.

Comprehensive color normalization[3]**:** It is shown to increase localization and object classification results in combination with color indexing. It is an iterative algorithm which works in two stages. The first stage is to use the red, green and blue color space with the intensity normalized, to normalize each pixel. The second stage is to normalize each color channel separately, so that the sum of the color components is equal to one third of the number of pixels. The iterations continue until convergence, meaning no additional changes.

Question 5: Is the correction by white reference better than the conventional gray world assumption? Based on the corrected white balance, at what time of day do you think the image was taken? At dawn or midday?

Ans) Yes, correction by white reference is better than the conventional gray world assumption. Figure 1 from [7], depicts that when gray world is applied it doesn't cover the complete dynamic range and it caused the image to look greenish whereas, white-referencing gives an image with a better contrast. Moreover, since white reference assumes that the scene has a bright(white) patch which reflects the maximum light possible for each RGB whereas, gray world assumes that the average color of the scene is gray therefore, it white referencing will provide the best white balancing.

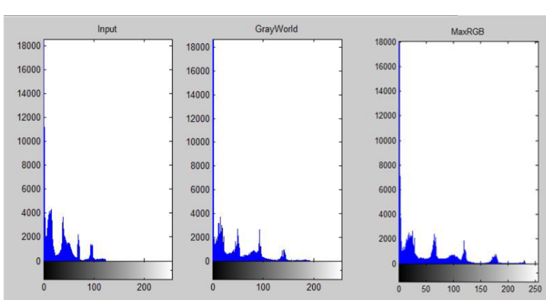


Figure11. Histogram we get after color constancy algorithms Gray World and Max RGB under illuminant ph-ulm. [6]

Question 6: What is the purpose of "intensity transfer function" in contrast enhancement? How does the slope of the transfer function affect the contrast?

Ans) The purpose of "intensity transfer function" is to make changes to the intensities of an image such that the contrast could be enhanced so that it is possible to distinguish objects in an image. To do so we vary the slope of the transfer function. Such that a transfer function with slope greater than one will increases the contrast while, slope less than one will decrease it.

Question 7. What does filter kernel (filter mask) or convolution kernel stand for in spatial filtering? How is the kernel used in practice when performing the filtering? Give an example of a basic Gaussian filter kernel.

Ans) filter kernel or Convolution kernel in spatial filtering refers to a matrix or mask that is slided over an image to perform blurring, sharpening or edge detection. This is done by performing convolution between the image and kernel. The mask is slided over the entire image pixel by pixel and weighted sum of the neighboring pixels is calculated and the resulting value is placed at the same position of the central pixel in a new empty image. Following is an example 3x3 Gaussian filter kernel:

[1/16 1/8 1/16

1/8 1/4 1/8

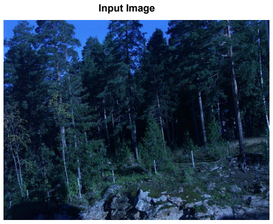
1/16 1/8 1/16]

General description of Tasks:

Following are the description of each tasks:

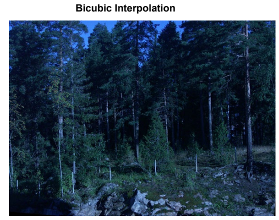
Task 1: First the orientation of the image is fixed by rotating the by 5° in clockwise direction. Rotation produced black regions which were then cropped and different interpolation methods were applied where, Bicubic gave the best results as shown below:

Input Image

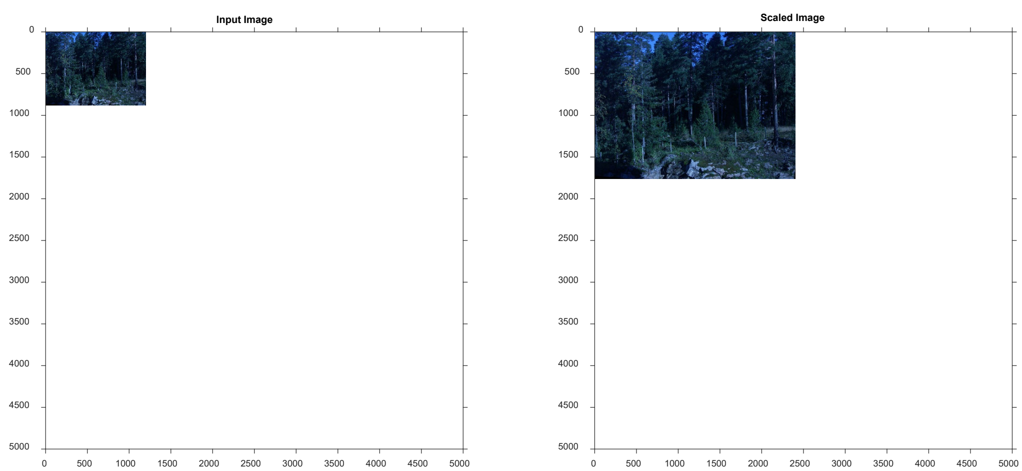


Rotated Image

Bicubic Interpolation



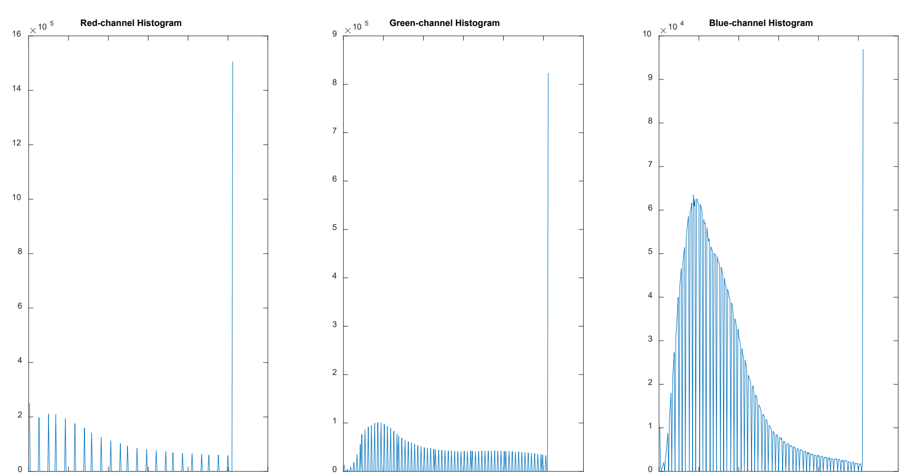
Task 2: Then the image is scaled to the provided scaling factor. For scaling we have created a matrix of the scaled dimensions and then we normalized the row and column position matrix and then performed row-wise and column-wise interpolation. We then mapped the pixel value from original matrix on the scaled matrix based on the positions in row and column position matrix. Result is shown below:



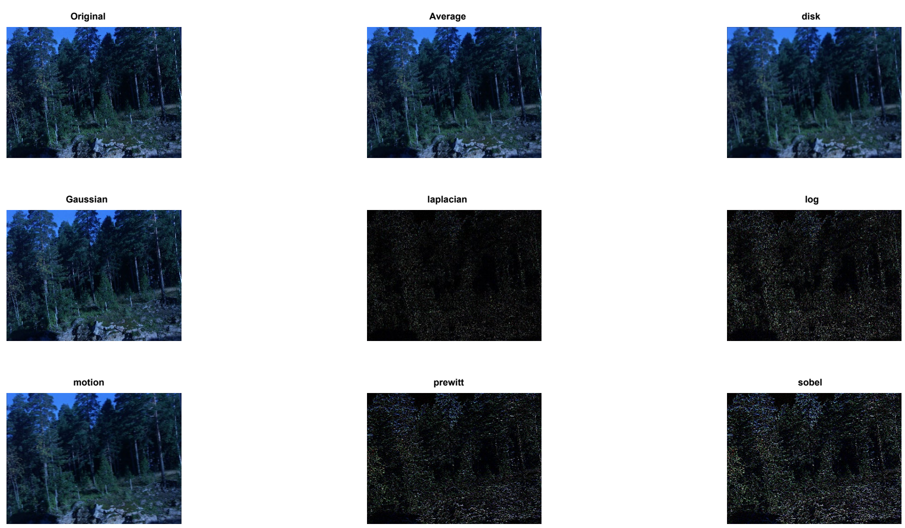
Task 3: Once the image is scaled then we applied the gray world technique for color normalization in which we divided each channel by its average value.

Task 4: Then we used white paper image to calculate the scaling factors such as alpha, beta and gamma which was determined by dividing maximum of each channel of original image with the maximum of respective channel of the white paper and then the resulting factors were multiplied with the respective channels of the original image.

Task 5: Later we improved the contrast of the image to enhance its appearance by implementing two different methods. We first used built-in function that is imadjust which adjusts the histogram of the image to improve the contrast. Then we applied automated method to compare the results. Below are the results from both methods:



Task 6: Lastly, we performed denoising/smoothing on the image to remove noise. We used fspecial to generate a filter which was then applied on the image by imfilter function. Gaussian and averaging filter provided almost the same result so we ended up choosing Gaussian. Following are the results of different filters:



Main Function: The main function reads the test image and applies all the tasks one after the other and finally, we received an enhanced image as shown below:

Result:

Test Image

Final Result

References:

[1] D. Liu, “Comparison analysis of color constancy algorithms,” 2013. [Online]. Available: https://eclipse.github.io/imagen/guide/geom-image-manip/

[2] “Digital image interpolation.” [Online]. Available: https://www.cambridgeincolour.com/tutorials/image-interpolation.htm

[3] “Color normalization,” 2019. [Online]. Available: https://en.wikipedia.org/wiki/Colornormalization

[4] “Image noise,” 2020. [Online]. Available: https://en.wikipedia.org/wiki/Imagenoise

[5] D. Peterson, “Photos too blue? Your white balance might be to blame.” [Online]. Available: https://www.digital-photo-secrets.com/tip/626/photos-too-blue-your-white-balance-might-be-to-blame/

[6] D. Liu, “Comparison analysis of color constancy algorithms,” 2013. [Online]. Available: https://www.diva-portal.org/smash/get/diva2:631476/FULLTEXT01.pdf

[7] Van De Weijer, Joost, Theo Gevers, and Arjan Gijsenij. "Edge-based color constancy." IEEE Transactions on image processing 16.9 (2007): 2207-2214.