7060 Image Sensors & Processing / 4061 Image Processing

Assignment 1

August 2019

(Total Marks: 12%, Due Date: 11:59pm Wednesday 10/04/2019)

Overview

This assignment is intended to give you some hands-on experience with manipulating image data in MATLAB and the basic image manipulation concepts covered in the course up to the end of Week 3.

In this assignment work you will be required to modify several functions which implement basic colour correction, contrast enhancement and noise filtering steps.

IMPORTANT: No routines from the image processing toolbox (such as *histeq*, *medfilt2*, *imfilter*) etc may be used in your assignment solutions unless specifically advised. Using such routines will result in zero marks for that component of the assignment work.

Assignment Submission

Assignments are to be submitted as a standard ZIP archive file (please do NOT use other formats such as 7z, RAR, PKZIP) containing the key MATLAB functions and any test code you have written and a Word (MS Office) or PDF document summarising your results with comments on the performance of the processing steps employed (in 1A-1D) and written answers to questions (1E).

- All submitted materials MUST be your own individual original work.
- Marks will be deducted for late submission or incorrect submission format.

Source Materials

Source code, test functions and example imagery for this assignment is located on the MyUni website (https://www.myuni.adelaide.edu.au). You are welcome to add your own example imagery for testing and reporting purposes.

DO YOU NEED HELP? - The coding required to complete this assignment is not intended to be complicated but it does assume familiarity with MATLAB programming. If you are having problems getting your code working, then please ask questions during the tutorial session or come and see me during my consulting times.

Exercise 1A – (3%) – Colour Balancing using a Reference Chart

Your company is developing a simple enhancement package to be bundled in with its new range of digital cameras. You have been tasked to quickly develop some of the processing steps which will be used in this package. The first is a tool to be used in conjunction with a colour chart to enable people to correct their photographs for the current lighting conditions.

Colour charts such as the one shown below are used by some professional photographers to allow them to colour correct their images after a photographic shoot. The colour chart is photographed under the same lighting conditions and then compared to the original chart.

Above: *An example colour chart and a test photograph containing the test chart*

The differences between the true colour chart and the captured image of the colour chart are used to adjust and therefore correct the colour in subsequent images.

In this exercise you will be required to write three simple functions, the first extracts samples from a 24-colour chart image similar to that shown in the above left. The second function takes two sets of extracted values, one from the true chart and once from a chart collected under less than ideal conditions and calculates the mapping of RGB colours from the less than ideal conditions back to the ideal case. The third function applies this mapping to an image to correct for the colour imbalance.

STEP 1: Modify the supplied function **get_chart_values.m** so that given an image of a colour chart such as that shown above left it returns an 24x3 array of the 24 RGB values corresponding to each patch. The order in which you extract these values is not important. eg:

```
I = imread('exampletestchart.jpg');
values = get_chart_values(I);
```

The supplied image is assumed to contain values in the ranges 0..255, with R,G and B being the first second and third layers of the image respectively.

STEP 2: Modify the supplied function **chart_correction.m** so that given a set of colour chart values from a correct (reference) chart and a set of measurements from a chart captured at a photographic shoot it returns a 256x3 array containing the R,G,B colour corrections required to convert (colour correct) any pixel in an image captured under similar conditions back 'ideal' conditions. Row 1 contains the adjustments for

red, green and blue pixels of value 0 (zero), and row 256 contains the adjustments for red, green and blue for pixels of value 255. eg.

```
chart_image = imread('testchart.jpg');
goodvalues = get_chart_values(chart_image);
bad_chart = imread('badtestchart.jpg');
badvalues = get_chart_values(bad_chart);
RGB_map = chart_correction(goodvalues,badvalues);
```

The two colour charts contain 24 measurements of how each of the red, green and blue image layers differ between the reference and the photo-shoot. These can be used to estimate the correction required for each red, green or blue sample from 0..255.

To calculate this, you can use existing MATLAB functions such as **polyfit** and **polyval** if you like to fit the data and estimate the missing values (recommended). Alternatively, you can set up the problem in the form **Ax=b** and use "\" to find the least squares solution but this takes a little more coding (not recommended). You could also use **interp1** but be aware you may need to handle cases of duplicate samples (see **unique**).

Whichever solution you attempt make sure you enforce the resulting mapping to be integers within the ranges 0..255.

Please refer to the MATLAB documentation (eg 'help polyfit') for information on how to use the suggested functions.

STEP 3: Modify the supplied function **apply_rgb_map.m** so that given an 8-bit RGB image and a (256x3) mapping constructed by **chart_correction.m** it adjusts each RGB value in the map based on the map values. eg.

```
...as before...
badimage = imread('badimage.jpg');
fixedimage = apply_rgb_map(badimage,RGB_map);
```

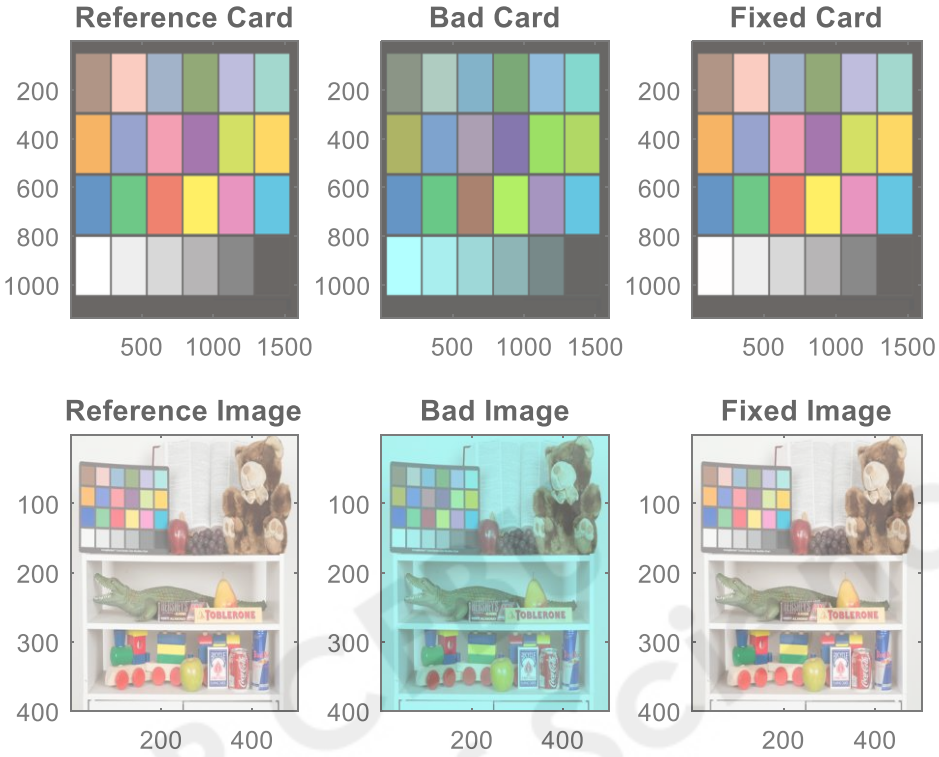
Note that the resulting image must only contain values in the range 0..255.

STEP 4: Test your code using the function **chart_test.m**. Try other variations in colour differences and other imagery. Compare the before and after imagery and note where there are large discrepancies between the 'ideal' and 'corrected' image values.

Write up your results and comments (include example imagery).

An example result produced by **chart_test.m** is shown on the next page.

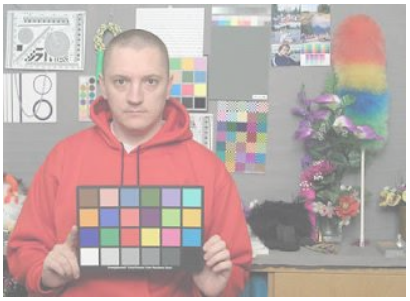
GENERAL NOTE: *the images used here are 8-bit unsigned integers. If required you can convert between this and type double using the conversion functions double() and uint8(). You may need to do this at various times throughout the assignment work.*

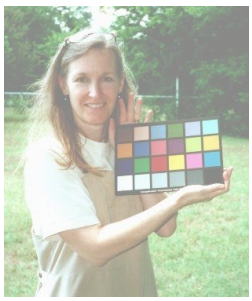


Above: *A simulated example of applying the colour corrections functions. The results on the right are based on the comparison of the reference and 'bad' cards shown above. Note that in practice there is normally no reference image (lower left) and the bad test card samples (top middle) are usually taken from the bad picture (lower middle).*

Comment: *If you are colour blind (or there's chance you may be) then it might be a good idea to get someone else to look over your image results just in case. If in doubt, then ask me to take a look.*

Three images are available for testing:





Exercise 1B – (2%) – Image Contrast Enhancement

STEP 1: Modify the function **histeq_contrast.m** and implement the histogram equalisation steps described in class. You may use the MATLAB inbuilt functions *hist(), sum(), cumsum(), max()* and *min()* (or even *histcounts() in later versions*) to achieve this. For clarity, the equation shown in notes can be written as:

$$m(k) = \begin{cases} 0 & \text{for values below and including the first non - zero entry of } H \\ \dfrac{\left(\sum_{i=1}^{k} H(i)\right) - H_o}{\left(\sum_{i=1}^{n} H(i)\right) - H_o} & \text{otherwise, where } H \text{ is the histogram and } H_o \text{ is the first non - zero entry of } H \end{cases}$$

The call for this function is simply:

```
eq_image = histeq_contrast(input_image);
```

The input image data is assumed to be in the range 0.0 to 1.0. It is recommended you use a histogram with 256 levels. This will allow you to create *m()* as a 256 entry lookup table using the above expression. Values in this table can then be used to replace the original image values by multiplying the image value by 255 and adding 1 (which provides the index into the lookup table).

An example result for histogram equalisation is shown at the bottom of this page. A simple test function **histeq_test.m** has been supplied to help you check your code.

Above: An example histogram equalisation result.

STEP 2: write up your results and include example imagery before and after processing using the equalisation steps (use other images as well as the test example shown above).

Comment: *you can use the function hist() (or histcounts() if you are using a more recent version of MATLAB) in your solution but make sure you read the help information carefully. Do NOT use imhist() etc.*

Exercise 1C – (2%) – A Simple median Filter

STEP 1: Modify the function **median_filter.m** to implement a simple MxN median filter. You may not use functions such as *median(), ordfilt2(), medfilt1(), medfilt2()* etc but you may use *sort()*.

The function **median_filter.m** is called as follows:

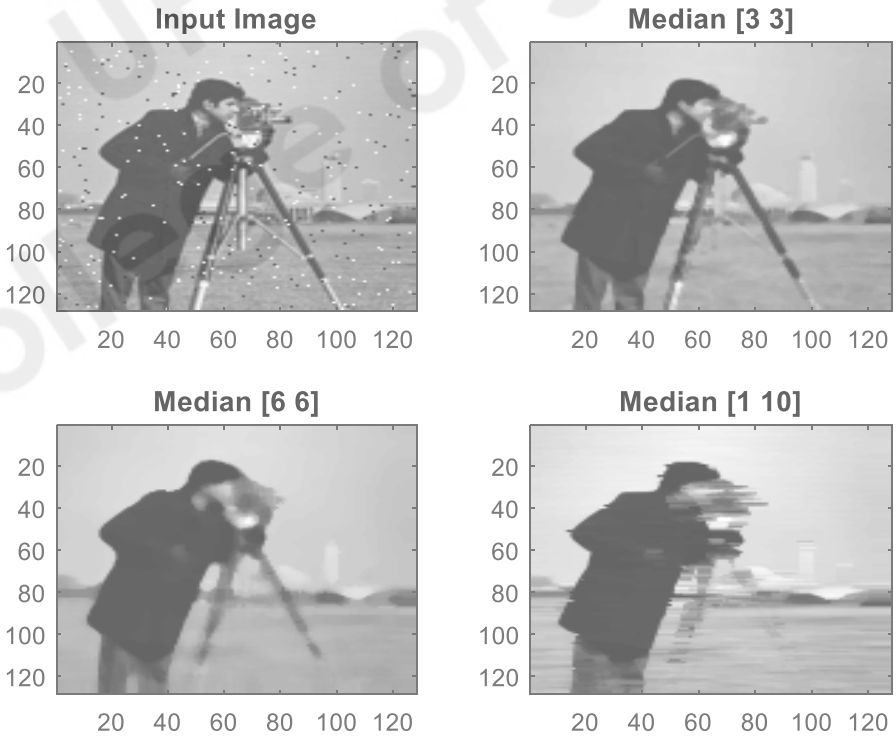
```
med_image = median_filter(input_image,M,N);
```

If the MxN neighbourhood contains an odd number of samples the median is simply the middle value of the sorted list of neighbouring samples. However, if MxN is even the median is the average of the values to either side of the midpoint (eg. the median of [1 2 3 4 5] is 3 and the median of [1 2 3 4] is 2.5).

STEP 2: Use the **median_test.m** function to test your solution. You may use *medfilt2()* as a check of your output but be aware that you may handle pixels near the image boundary differently to how the inbuilt function does.

Try applying your solution to various imagery. As with **median_test.m** you may use *imnoise()* to add salt and pepper noise to imagery of your choosing.

Try increasing the proportion of salt and pepper samples and see what happens.



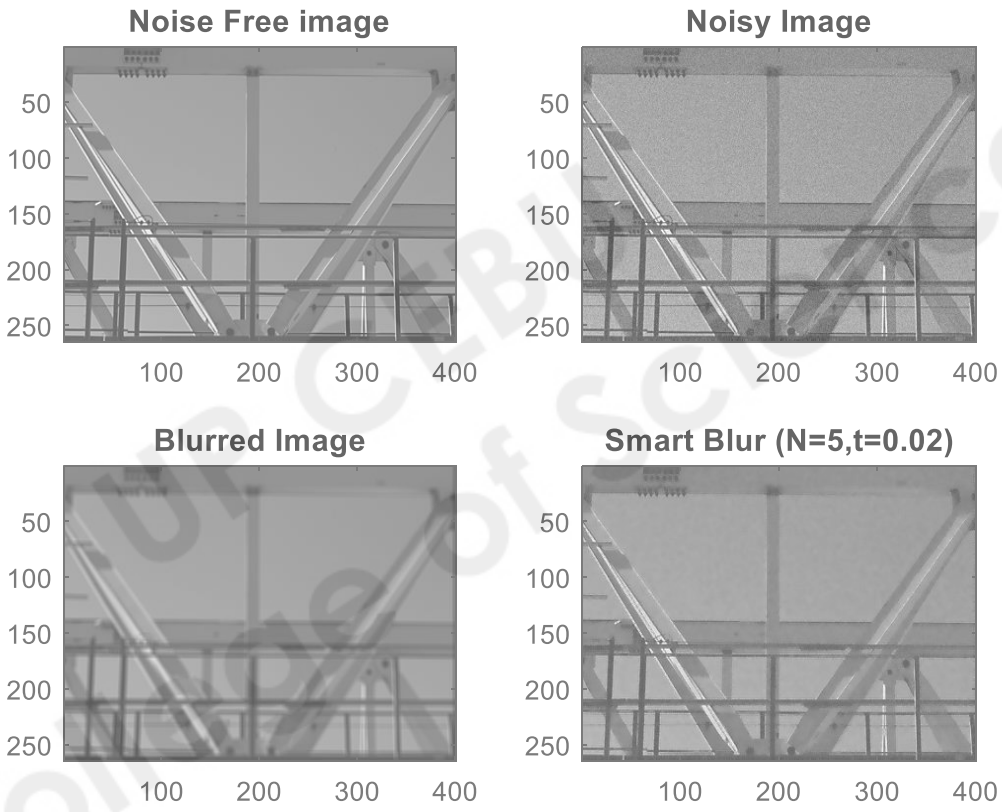
Above: An example median filter test result on the cameraman image. Your solution must be able to handle different filter sizes such as those shown here.

Write up your results including example imagery (some samples have been provided).

Question: Under what noise conditions does the median filter fail?

Exercise 1D – (3%) – A "Smart" Edge Preserving Noise Filter

To reduce the visible effects of image-sensor noise your company has been forced to to implement an averaging filter step. However, as applying an average (blurring) filter to the entire image will also blur details such as edges you have been tasked to implement and test a simple "smart" solution which attempts to preserve edge details where possible. This is achieved by reducing the proportion of the averaged image returned by the filter in areas of the image where the image gradients are large.



Above: *An example of applying a simple edge preserving averaging filter to a portion of a noisy image containing sharp details. The input image (top left) is shown after blurring (top right). The gradient based weights used to combine the blurred and original images are shown (bottom left) with the final "smart" blurred image (bottom right). Note the preservation of details in the hard edges of the structure.*

The proposed smart filter process is as follows:

1. *create a blurred image B using a simple NxN averaging filter*
2. *calculate the x and y image gradients* I_x and I_y *using the following 5x5 Sobel gradient filters:*

$$\frac{1}{240}\begin{bmatrix} -4 & -5 & 0 & 5 & 4 \\ -8 & -10 & 0 & 10 & 8 \\ -10 & -20 & 0 & 20 & 10 \\ -8 & -10 & 0 & 10 & 8 \\ -4 & -5 & 0 & 5 & 4 \end{bmatrix} \quad \textit{and} \quad \frac{1}{240}\begin{bmatrix} 4 & 8 & 10 & 8 & 4 \\ 5 & 10 & 20 & 10 & 5 \\ 0 & 0 & 0 & 0 & 0 \\ -5 & -10 & -20 & -10 & -5 \\ -4 & -8 & -10 & -8 & -4 \end{bmatrix}$$

3. *Compute the gradient image G (where* $G(r,c) = \sqrt{I_x(r,c)^2 + I_y(r,c)^2}$ *)*

4. *For each pixel, compute the weighting function W such that:*

$$w(r,c) = \begin{cases} \dfrac{t}{G(r,c)} & \text{if } \dfrac{t}{G(r,c)} \le 1 \\ 1 & \text{otherwise} \end{cases}$$

   where t is the tolerance value passed into the function

5. *For each pixel, construct the output image as a weighted combination of the blurred and original images using the computed weight values*

$$I'(r,c) = wB(r,c) + (1 - w(r,c))I(r,c)$$

STEP 1: Implement the above algorithm in the supplied function **smart_blur.m**. You may use matlab functions such as *conv2()*, and *min()* to simplify your solutions. Speed is not a concern in your solution.

Note that the function **smart_blur.m** takes 3 parameters and returns an image result. That is:

```
new_image = smart_blur(noisy_image,N,tolerance);
```

Here N specifies the size of the *N*x*N* averaging filter to apply and tolerance is the value *t* used in the above expressions.

STEP2: Test your solutions using the script **smart_blur_test.m** and then experiment with different images and values for the key parameters *N* and *tolerance*.

The matlab function *imnoise()* can be used to add noise to any image if required *(however I suggest you initially used modest levels of noise).*

Write up your results and comments (include example imagery).

Comment: *To make debugging easier I strongly suggest you display the gradients and weights as images during testing. If they don't look right they probably aren't.*

Exercise 1E– (2%) – Written Questions

Write up your answers (in your own words) to the following questions and include them in your assignment report:

1. (1.0%) You have been given a set of imagery from a 256x256 pixel video surveillance camera to analyse. However, to work out roughly how far away objects of known size (eg. people) are from the camera in the footage you need to determine the field of view of the sensor. Using a tape measure as a guide you are able to estimate that a doorway of 2 metres height appears to span around 32 pixels in the imagery when viewed from 10 metres away.

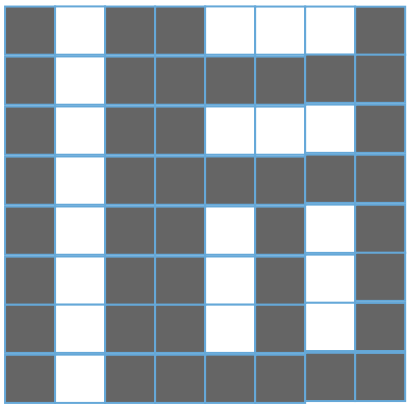
Q: Given the above, what is the likely field of view of the camera? *(you may assume the vertical and horizontal fields of view are the same)*

Q: How far away would a person of height 1.75 metres be if they appeared as a region of height 8 pixels in this imagery?

Hint: this can be worked out using some basic geometry and/or material covered in lecture 1.

2. (1%) Carefully explain how a 'median' and an 'alpha trimmed mean' filter work and describe under what circumstances they are useful (illustrate if required).

Q: Without using a computer, what would be the result of applying a 3x3 and a 5x5 median filter to the following simple image? *(you may assume that white=1, black=0 and that* <u>all</u> *values outside the image boundaries shown here are also black ie. 0)*



Q: Approximately, what would the result be if we instead applied a 3x3 alpha trimmed mean filter with d=3 ?

NOTES / HINTS

- Test routines have been provided to you wherever possible. Use the sample code as a guide to good MATLAB programming. In most cases the solutions only require you to write a few lines of MATLAB code.
- As stated earlier no Image Processing (IP) toolbox functions are to be used in your solutions. If you are unsure about whether a given function is from this toolbox use the '*which*' command (eg. '*which im2double'*). If the pathname includes the word \images\ it probably comes from the IP toolbox.
- Unless specified by the question, the MATLAB inbuilt functions *min max hist linspace sort mean, abs, conv2, cumsum, unique, polyfit* and *polyval* may be useful in your solutions. The function *reshape* can be used to convert to and from arrays and vectors with the same number of elements.
- Remember MATLAB uses (row,column ordering) of arrays as opposed to (x,y) ordering. All references to arrays in this assignment assume (row,column) ordering.
- Your written reports should be around 6-8 pages of result images and short comments. This write-up forms a key part of the assessment so do NOT submit your code solutions without comment. Include example results and comments for the first 3 exercises based on images from the supplied set or on other images of your choice.
- If you get stuck and need help, please ask me in class or come and see me at one of my consulting times. I will also accept email questions although I cannot always guarantee a quick reply.
- **And finally, please remember the Adelaide Universities <u>strict</u> policy on plagiarism and work on your assignments individually…**

Best of Luck - D