CS6640 – Project 1
Assigned Sept. 05, 2012
Due Sept. 19 (Just before midnight)
Instructor: Guido Gerig
TA: Lingbing Jiang, Office MEB 3115, office hours Tue,Thu 3 - 5pm

Goals

The purpose of this project is for you to develop the software platform you will use for the course
(Matlab or C++), to get familiar with the process and expectations for reports, and to write code
and experiment with thresholding and connected components in images.

The second purpose of this assignment is to develop your understanding of image histograms,
histogram equalization and the use of histograms for image segmentation.

1 Build a Histogram

Implement a function or routine, for instance in matlab

```
histogram(I, n, min, max)
```

that takes a 2D array (image) `I` as input (integers or floats) and returns a 1D array of floats
(length `n`) that gives the relative frequency of the occurance of greyscale values in each of the `n`
bins that equally (to within integer round off) divide the range of (integer) values between `min` and
`max`.

Experiment with this function on different images and show graphs or plots, in your report, of
the histogram. Explain how the histogram makes sense for each particular image. For the graphs
you can use whatever software you want, e.g. Matlab plotting routines, MS Excel, Open office.
Document how you did it and show examples.

## 2 Histogram Equalization

1. Implement a Matlab or C++ function:

   ```
   histogram(I, n, min, max)
   ```

   that takes a 2D array (or image) `I` as input and returns a 1D array of floats (length `n`) that
   give the *relative* frequency of the occurance of greyscale values in each of the `n` bins that
   equally divide the range of values between `min` and `max`.

2. Implement a function:

   ```
   histoeq(I, n, min, max)
   ```

   that takes a 2D array (or image) `I` as input (e.g. VISImage¡float¿ in Vispack) and returns
   an image of the same type that has undergone histogram equalization using `n` bins and has a
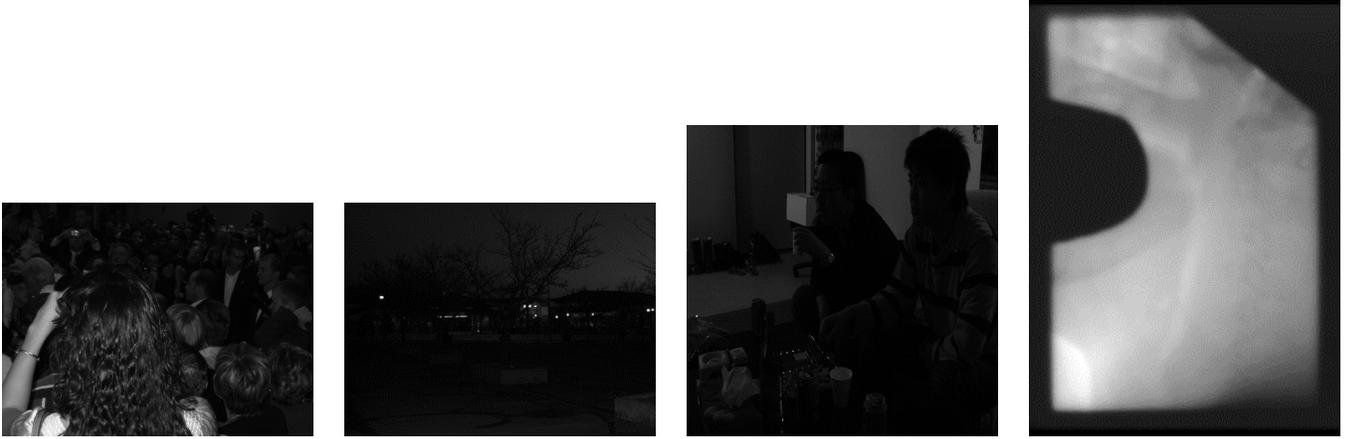   range of outputs that spans the range between `min` and `max`.

4.
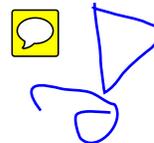
Figure 1: Test images: crowd, university, chang and portal.

3. Use this routine to transform and enhance the following images (see Fig. 1):

   (a) Crowd
   (b) University
   (c) People
   (d) Portal

   In addition, include in your discussion 2-3 of your own greyscale images that you think would be interesting from the point of view of this exercise. I.e. that have bad contrast characteristics and that might be improved by histogram equalization.

5. Show graphs of the histograms of the images before and after equalization and explain their appearance.

6. Discuss (briefly) why histogram equalization is or is not effective for each image.

7. Derive an algorithm that processes an image to return an image with a histogram (pdf) that has at every grey level a value that is a linear blend of the input histogram and a flat histogram. Implement a matlab function

   ```
   histoeq(I, n, min, max, alpha)
   ```

   where `alpha` is a float between 0 and 1 and every bin is (in principle) equal to $\alpha H_{\text{eq}} + (1-\alpha) H_I$. Thus, for a value of `alpha = 0`, the output equals the input and for a value of 1 the output is the same as `histoeq(I, n,)`. Experiment and report results on some of the images listed above. Explain the results you get.

3 Segmentation by Thresholding

As discussed in class, the simplest segmentation is obtained by thresholding of the image. The image histogram may give you a hint on how to choose an optimal threshold but might also be

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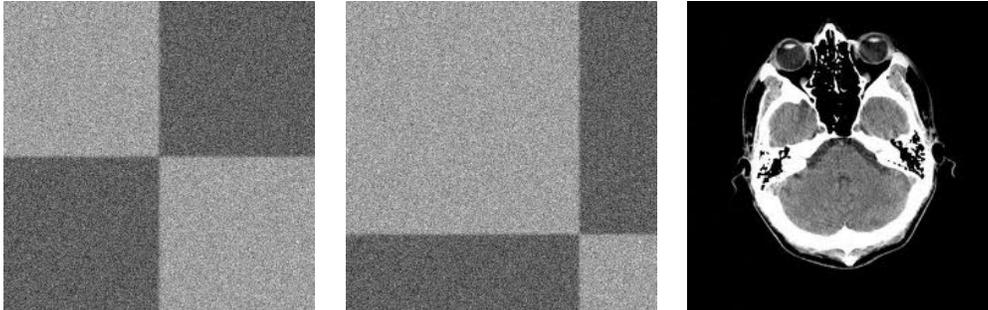misleading. Given the two figures with checkerboard patterns (Figure 3), design a method to find the optimal thresholds. Hint: Remember the class' discussion on the mixed Gaussian model.

The following images (see Fig. 1) are used in this task:

1. checker1

2. checker2

3. CTscan

Checkerboard image segmentation

1. Create and display histograms of the two checkerboard figures.

2. Determine a "valley" in the histograms that might indicate the two region categories.

3. Threshold the images at this value, display results and discuss.

4. Select small regions of interest (e.g. 10x10 patches) in both types of regions and calculate class-specific pdf's for the dark and light gray patches via estimates mean and standard deviation. Compare the results of the pdf's for both images.

5. Design a strategy to select the threshold based on the pdf's for the two categories. Apply this threshold and discuss the resulting images. What is different to above, and why do you expect these differences? You can graph the pdf's by drawing two Gaussians.

6. Given these pdf's and your estimates of the percentage area of the two categories, can you recreate the histogram shapes as actually measured from the original images?

CT scan segmentation

1. The reasoning above is often applied to computer tomography image data (see Fig. 3 right), e.g. to separate bone from soft tissue and then display bony structures as 3D graphics.

2. Create the histogram of the CT image. Would the histogram be sufficient to separate bone from non bone?

3. Estimate pdf's of bone and adjacent soft tissue by selection of small regions and calculation of mean and standard deviations.

4. Determine the best threshold, apply it to the image and discuss.

4 Instructions, Requirements, and Restrictions

1. Please use your name **"NAME"** in all reports and submitted materials to uniquely identify your projects.

2. Your report should summarize your approach to solve the problems, show graphs, images of the results and include a critical evaluation/discussion of the results. Please do not copy the project description into your report, just the title is sufficient. The report can be written with any text program of choice, best is to handin a pdf copy.

3. Write your project code in a single directory, called `project1-NAME`.

4. For Matlab each individual function (including functions you define) should be a ".m" file, and your functions should call one another as necessary.

5. We **do not allow to use Matlab toolbox functions** (e.g. Imaging Toolbox) or other existing image processing libraries in order to give all students the same conditions for code development [1].

6. You should have in your report a short description of each algorithm you used and documentation on how your code is organized. Failure to do this will result in a loss of points. Please remmember to **add your name** to the report title.

7. Your project report will be in the form of an html file called **index.html**, contained in that directory. All links from that file must be relative and all other files necessary to read your report must be in that directory (or subdirectories).

8. You should use examples of images in your report. They should be viewable in the browser when we open your html file.

9. You will submit a single tar file created from from your project directory with the unix command *tar -czf project1-NAME.tgz ./project1-NAME.*

10. Please remember or look-up the honor code and requirement to provide your own solution as discussed in the syllabus.

11. **Please look up the late policy as defined in the syllabus**

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[1]The core MATLAB package comes with several rudimentary functions that can be used to load, save, and perform custom functions on images. Taken from wikibooks

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