Digital Image Processing with MATLAB Taught As an Advanced Computer Application Course for Engineering Graduate Students

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Abstract

The College of Engineering at Southern University Baton Rouge (SUBR) has a Master of Engineering Program. Advanced Computer Application for Engineers (ELEN 530) is a core course taught in this program. This is an interdisciplinary course being offered to students with undergraduate degrees in Civil Engineering, Electrical Engineering, Electronic Engineering Technology and Mechanical Engineering. . It was a challenge to choose material for this course with students from these different backgrounds. After four years of experience, we found Digital Image Processing with MATLAB to be an appropriate topic, a topic welcomed by the students. Since images are matrix files, we have found that this course provides excellent material for the writing and application of advanced algorithms to solve engineering problems. Many of the algorithms involve statistical concepts, thus providing an excellent foundation for research. The instructor of the course, two graduate students and two undergraduate students are presently performing research on an image processing project sponsored by the Air Force Research Laboratory.

1. Introduction

Image processing courses are offered in many engineering colleges, such courses being offered at different levels. Such a course can provide students with a rich computing experience. There are currently about 50 students in the Master of Engineering Program in the College of Engineering at Southern University Baton Rouge. These students are from four different disciplines: Civil Engineering, Electrical Engineering, Electronic Engineering Technology and Mechanical Engineering. All students are required to take the core course, Advanced Computer Application for Engineers (ELEN 530). It was a challenge to select suitable material for the course with students from such a wide range of backgrounds. After four years of experimenting, we found Digital Image Processing with MATLAB to be an excellent subject, one that was welcomed by the students. As an outline for this course, it begins with a review of MATLAB fundaments to include programming assignments. Imaging theory is introduced with some

simple imaging algorithms. More in-depth imaging concepts are then introduced to include practical exercises with digital image perception, image acquisition, enhancement, filtering, restoration, and compression. After this foundation is laid, students are assigned projects to demonstrate their competency in writing and executing meaningful algorithms. Digital Image Processing is a popular research area. Imaging has a wide range of civilian, military and security applications. Many image files, such as those collected by satellite, are very large. Comprehensive imaging algorithms that can swiftly and efficiently process and retrieve information from huge image data sets as the data accumulates is needed[2,7]. With the exposure given to Image Processing in this class, as of date, three master students have chosen research topics in Digital Image Processing as their master theses. The students gained an appreciation for the wide range of Digital Image Processing applications. Several faculty members are now performing research in this area and will be providing added research opportunities for both graduate and undergraduate students. This paper presents the basic material covered in the ELEN 530 course. The plans are to introduce some of the fundamental material in the undergraduate Engineering Use of Computer course. We hope that the approach to choosing material for this interdisciplinary course will serve as an example for choosing material for other interdisciplinary courses. This paper is organized as follows: It first gives the course over review, followed by several course projects, and then some concluding remarks.

2. Course Over View

Advanced Computer Application for Engineers (ELEN 530) covers algorithm development, and practical solutions to digital image perception, acquisition, enhancement, filtering, restoration, and compression. The students gain an understanding of algorithm design, the use of mathematical tools, and practical implementations of various digital image applications. The students will learn how to use MATLAB programming software to implement digital image applications. The prerequisites include basic data structures and their implementation, senior-level understanding of statistics, probability theory and stochastic processes, and senior-level understanding of linear systems and transformations. Many students have the perception that this pre-requisite material is difficult to comprehend and that the underlying theoretical tools are counter-intuitive. They often have difficulty with the concepts of time and space complexity, as well as with properties of advanced data structures. The lack of an intuitive understanding not only makes the comprehension of the material more difficult but it also leads to less material being retaining at the end of the course. In contrast, with image processing, having images to manipulate makes algorithm design and execution more intuitive. In this course, students are made aware of the interdisciplinary nature of Image Processing. For Civil Engineers, imaging is widely used for mapping. For Mechanical Engineers, imaging is used to detect cracks in welds. Electrical and Electronic Engineers provide support in a wide range of imaging applications, to include industrial, medical, military, etc.

3. Course Projects and Student Work

The course included several projects. Some of the typical projects are listed below. The project description is given, followed by comments on the student work.

The **first project** familiarized the student with grey-tone image manipulation techniques reducing the number of gray levels in an image. The image is shown as Figure 1, below. The requirements were first to use MATLAB commands to read and display the image. Then, write a MATLAB program to reduce the number of gray levels in the image from 256 to 2, in integer powers of 2. The desired number of gray levels was to be a variable input to the program.

Comments on student work: Most students had no previous experience with images. The students received a review of MATLAB programming techniques. This project accomplished the goal of familiarizing the student with the first necessary step of using MATLAB, to read an image file and to display the image. It familiarized the student with the various MATLAB image formats and techniques of manipulating images. All students successfully completed the first project and became more interested in the course.

The purpose of the **second project** was to introduce students to additional grey-tone image manipulation techniques such as brightness, contrast adjustment, gamma correction, and histogram equalization. The MATLAB operations used were (a) Image negatives: (b) Histogram Equalization; and (c) Power-law transformations at c=1, gamma =0.2 and c=1, gamma=5.
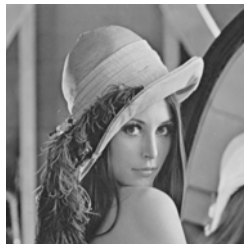

Figure 1: Lena image for project 1& 2

Comments on student work: This project emphasized several basic theories taught in image processing. The students we excited to see how they could make changes in images. They were especially excited to see that MATLAB had the capability of improving the appearance of an image.

The **mid-term project** was to integrate several theoretical concepts to make improvements to the "bad" image of Figure 2. The student had the liberty to choose an image enhancement transformation. The MATLAB transformation was to change the dark area (below the red lines) so that more information on the image would be revealed, while at the same time keeping the area above the red lines unchanged.

Figure 2: Image for mid term project

Comments on student work: The midterm project provided an opportunity for students to demonstrate their algorithm design capability by making improvements on a real "bad" or faulty image. The design process included the student selecting from a number of different possible methods. Several students had good solutions. Two such examples will be given.

```
% ELEN530_midterm student one's MATLAB code

clear;
I = imread('T:\My Documents\other courses\Fall 2005\ELEN
530_f05\Elen530_midterm.jpg');
 imview(I)

gamma=0.5
L=im2double(I);
N_1=L;
N_2=L;

n_x=length(L(:,1));
n_y=length(L(1,:));
 for j=1:1:125;
    for i=floor((524-468)*(j-1)/(125-1)+468):1:n_x;
       N_1(i,j)=(L(i,j))^gamma;
    end;
 end;

 for j=126:1:356;
    for i=floor((398-525)*(j-126)/(356-126)+525):1:n_x;
     N_1(i,j)=(L(i,j))^gamma;
    end;
 end;

 for j=357:1:681;
    for i=floor((613-399)*(j-357)/(681-357)+399):1:n_x;
     N_1(i,j)=(L(i,j))^gamma;
    end;
```

```
% ELEN530_midterm student two's MATLAB code
clear;

clc  %Clear memory
clear  %Clear screen
%---------------------------------------------------------------

datay = [468 524 398 613 785 785 468];
datax = [0 125 356 681 776 0 0];

%---------------------------------------------------------------

I = imread('T:\My Documents\other courses\Fall 2005\ELEN
530_f05\Elen530_midterm.jpg');
%I=imread('Berkeley.jpg');
figure;
imshow(I);
hold on;
u = plot(datax,datay, 'r','LineWidth',1);  %add the boundary lines to
it.

%---------------------------------------------------------------

immatrix = I;
L = 255;    %Maximum number of gray-levels.
[n,m] = size(immatrix);   %Get dimensions of image matrix

imd =im2double(immatrix);    % Make image matrix a double
matrix
```

```
end;

for j=682:1:776;
   for i=floor((781-614)*(j-682)/(776-682))+614):1:n_x;
     N_1(i,j)=(L(i,j))^gamma;
   end;
end;

figure, imshow(N_1)
hold;
x=[1 125 368 681 776]';y=[468 524 398 613 781];
plot(x,y,'r')

for j=1:1:600;
   for i=400:1:n_x;
     N_2(i,j)=(L(i,j))^gamma;
   end;
end;

imview(N_2)
```

```
I_he=histeq(imd);

g = roipoly(I,datax,datay);  %Distinguish inner from outer
boundary
g = im2double(g);

I_0=immultiply(I_he,g);
%This is for logical operation on matrices

gw=imcomplement(g);
%-----------------------------------------------------------------------

I_1=immultiply(imd,gw);

H=imadd(I_0,I_1);
%-----------------------------------------------------------------------
imview(H);

imshow(H);
u = plot(datax,datay, 'r','LineWidth',1);
```


The aim of **project number four** was to filter the noise from corrupted images. Two corrupted images are shown in Figure 3. The first image is corrupted by Gaussian noise and second image is corrupted by salt & pepper noise. The students were to choose methods from the textbook to filter the noises in the images.
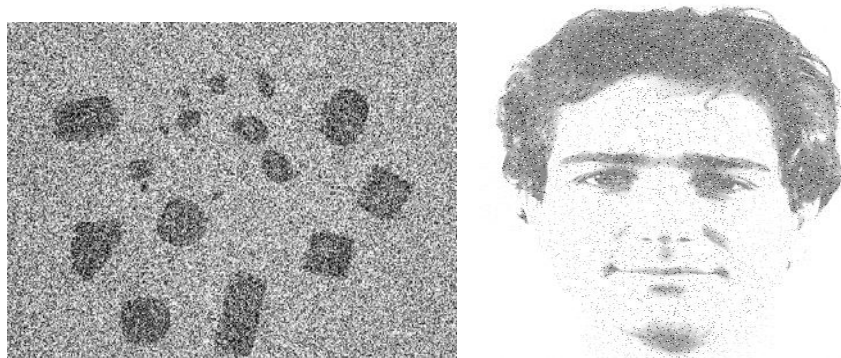
Figure 3a: Images for project 4. The left image is corrupted by Gaussian noise. The right image is corrupted by Salt & Pepper noise.

Comments on student work: This project required that the students understand the functions of different type of filters for image processing and to use the best type of filter to smooth the noise. The image on the left was corrupted by Gaussian noise and a mean filter was used. A median filter was used for the image on the right which was corrupted by Salt & Pepper noise. The result of one student's work is shown below.
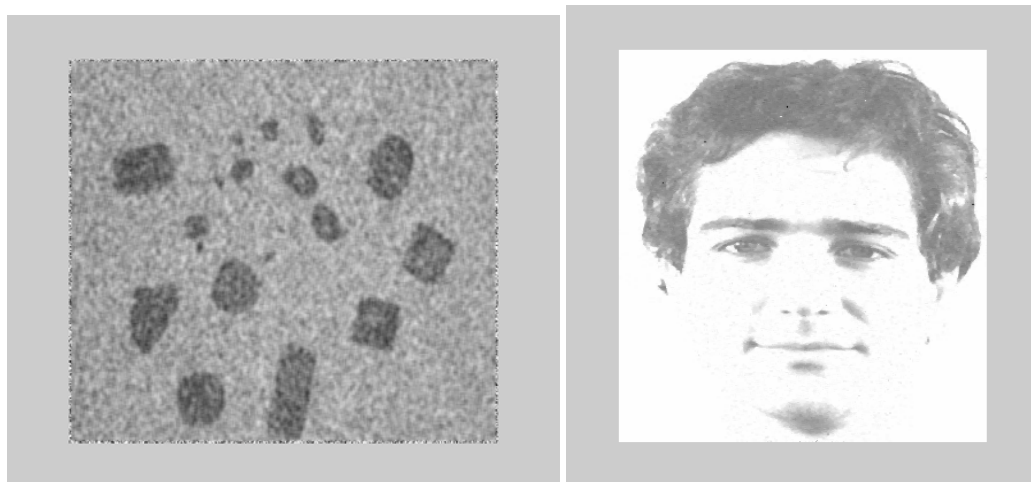

Figure 3b: The result of one student's work for project four.

In the **final project**, there were three groups of images: light images, dark images and other images with noise. The 11 images used are shown in Figure 4. Students were required to take at least one image from each group to do the project. They were to select suitable MATLAB color image transformations and write algorithms to produce improved images.
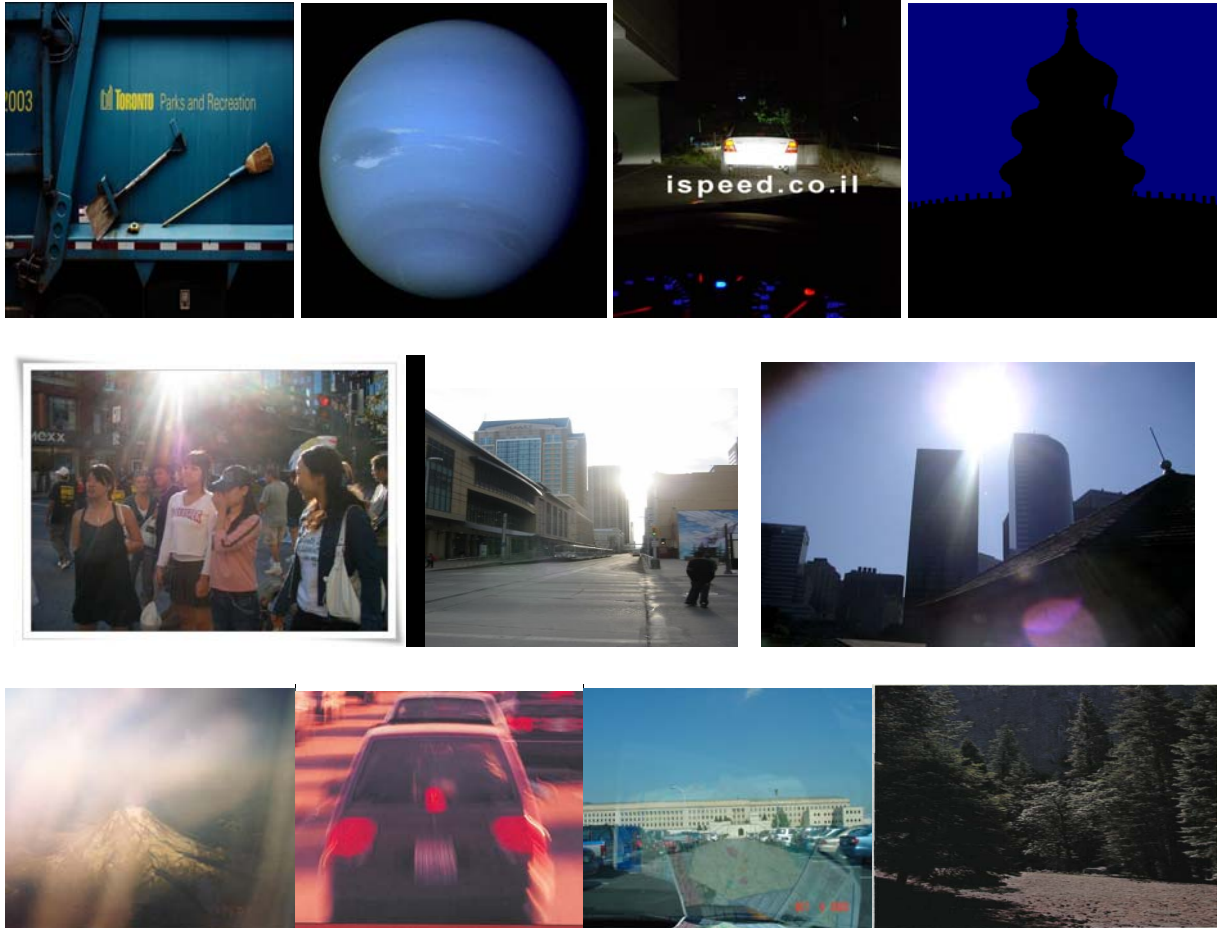
Figure 4: Images for the final projects. The first row shows four dark images. The second row shows three light images. The last row shows four other noisy images.

Comments on student work: This final project accomplished the goals of checking students' understand of image processing theories and developing and implementing MATLAB algorithms for typical imaging problems. The students worked in groups and acquired programming skills crucial in advanced computer applications. Furthermore, the students learned to combine several algorithms and data structures for designing efficient applications.

The selection of assignments for the course was designed for the students to gain competency in MATLAB programming. The students were required to submit reports with performance graphs and answers to related questions. The reports included empirical results and a comparison of the observed program running time with the expected asymptotic behavior. In addition, the students wrote summaries of their project experiences, indicating the most difficult part of the assignments.

4. Conclusions

We have described a series of assignments used to teach Image Processing as the basic for our Advanced Computer Application for Engineers course. Since visual data are now an integral part of many computer applications, image manipulation is likely to become an important skill for engineers. Most students enjoyed the hands-on style of learning and enjoyed their experience with visual data. The course accomplished its objective of providing the students the computational skills needed for research. It especially provided the fundamental skills to perform research in the area of Image Processing. The authors of this paper are presently performing research for the Air Force Research Laboratory involving the recognition of images in the presents of interferences such as fog and other obstructions. Several students are performing research on this project.

References

1. Jiecai Luo and Kenneth W. Tobin, "A novel method based combined color features for large-scale spatial image data retrieval," 37th Southeastern Symposium on System Theory (SSST), 2005, Tuskegee University, Alabama.
2. Jiecai Luo, "Automated Image Retrieval Based Large-scale Spatial Data Management and Analysis" 2003 Technique Report, Oak Ridge Institute for Science and Education and Image Science & Machine Vision Group at ORNL, ORNL/ORAU HBCU and MEI Summer Faculty Research Program
3. Jiecai Luo, "Content-Based (Unsupervised) Image Segmentation for Large-scale Spatial Images (with MATLAB)," 2004 Technique Report, Oak Ridge Institute for Science and Education and Image Science & Machine Vision Group at ORNL, Faculty and Student Teams (FaST) Summer Program.
4. Zhengmao Ye, Jiecai Luo, Pradeep Bhattacharya, Hamid Majlesein, "Processing of Slow Motion Images Out Of Underwater, Ground and Aerial Vehicles", Proceedings of 2005 IEEE Canadian Conference on Electrical and Computer Engineering (CCECE05) (To Appear).
5. Zhengmao Ye, "Artificial-Intelligence Approach for Biomedical Sample Characterization Using Raman Spectroscopy", IEEE Transactions on Automation Science and Engineering, PP.67-73, Vol.2, Issue 1, Jan. 2005.
6. B. B. Maxwell, "Teaching computer vision to computer scientists: issues and a comparative textbook review," Int. J. Pattern Recognition and Artificial Intelligence 12, 8 (1998) 1035{1051.
7. Eugene Fink and Michael Heath, "Image-processing projects for and algorithms courses," International Journal of Pattern recognition and artificial Intelligence Vol. 15, No. 5 (2001) 859 – 868.

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