Innovating Engineering Education:

Teaching Image Processing In Texas

ASEE-GSW CONFERENCE, 3/26/2015, SAN ANTONIO, TX

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Brief Course Description

Introduction to Digital Image Processing (DIP). Understand how images (pictures) are represented in a way that computers can deal with them. Examine the different operations that computers use to manipulate (process) images. Use scientific computing software such as Matlab® programming language and interactive environment to process images. The following image processing operations will be studied: enhancement, filtering, reconstruction, compression, object detection, and classification.

Program Overview

- Course Offering Process
- Selecting Participant Schools
- Requirements for Career and Technical Education (CTE) Course
- Administrative Course Logistics
- University of Texas San Antonio (UTSA) Teaching Team
- High School Teacher Training and Research Program
- Program Schedule
- Examples of Course Content
- Classroom Methodology
- Teaching Tools

Additional Content

- Brief Justification of the Course Innovation
- General Knowledge and Skills
- Specific Student Needs this Course is Designed to Meet
- Major Resources and Instructional Materials Required
- Required Activities and Sample Optional Activities
- Recommended Qualifications of Teachers

Course Offering Process

- Submission of the Innovative Course Application to the Texas Education Agency (TEA)
  - Our submission was Jan. 23, 2014
  - There was no submission deadline in 2014
- Approval of the Innovative Course Application by the TEA Education Department with the authority of the Commissioner
  - Our application was approved July 9, 2014
- Key person at TEA:
  - John Ellis, Statewide CTE Coordinator, Curriculum Division,
    - PH: (512) 463 – 9581 FAX: (512) 463 – 8057
    - John.ellis@tea.state.tx.us

General Application Content	Our Application Content
County District Number	01519
Superintendent	Dr. Brian T. Woods (NISD)
PEIMS Course Number	N1303766
Course Name	Digital Image Processing
Course Subject	Career and Technical Education
Grade levels to be served	11 & 12

Table 1. Contents of general and DIP Innovative Course Application

Selecting Participant Schools

- San Antonio high schools provide close proximity to UTSA
- There is a need for one or two teachers with competency in mathematics
  - Programming competency is desirable but not required
- Willingness of teachers and administration to participate
- Current Target High Schools:

Brackenridge	Burbank	Edison	Highlands
Houston	Jefferson	Lanier	Navarro

Table 2. Current target SAISD High Schools

Requirements for Career and Technical Education (CTE) Course

- Requires the SBOE to adopt rules that allow elective credit requirements to be met by successful completion of advanced CTE courses, including those that lead to a certification or an associate degree
  - CTE courses must lead to a student certification to be added to a pathway
  - MathWorks Certified MATLAB Associate is a possible certification under consideration
    - Working with the MATLAB user interface, Entering commands and creating variables, Analyzing vectors and matrices, Visualizing vector and matrix data, Working with data files, Working with data types, Automating commands with scripts, Writing programs with logic and flow control, Writing functions

MathWorks®
CERTIFIED MATLAB®
ASSOCIATE

  - Certification is desirable to increase longevity of this DIP course

Administrative Course Logistics

- UTSA teaching team members would be part of the SAISD CTE program and classified as a "classroom" teacher
  - Generally a classroom teacher is a full-time position
- Could courses be offered after typical school hours? Yes, but getting students to participate is difficult and you would be dealing with additional staff to keep the school open during those hours
  - An additional option is to bus students to UTSA for class time, but this draws away from the high schools receiving any computing resources supplied through the program for the course
- Scheduling flexibility is difficult because there is no flexibility in the school schedule. The time the class(es) would be offered could have some flexibility, but that would need to be part of the master schedule which is completed by late June.
  - The last period of the day or a lunch time period is probably most practical for accommodating professional schedules
- Are teachers required to hold "office hours?" Teachers have conference period built into the schedule during the day in lieu of "office hours."
- If granted, the position would begin the first day of school.

UTSA Teaching Team

Dr. Artyom Grigoryn

Associate Professor of Electrical & Computer Engineering

Teaching Interests: Network Theory, Signals and Systems, Digital Signal & (Biomedical) Image Processing

Short list of classes taught: *Biomedical Imaging Advanced Signal Processing, Signals and Systems 1&II, Network Theory, Statics and Dynamics, Applied Engineering Analysis 1&II*

Dr. Sos Agaian

Peter T Flawn Distinguished Professor of Electrical and Computer Engineering

Teaching Interests: Digital Signal Processing, Signals & Systems, Wavelet Transforms, Computer Vision, Pattern Recognition, Medical Imaging, Multimedia Security, Digital Filters

Short list of classes taught: Digital Signal Processing, Orthogonal Transforms Wavelets and Fractals with Applications, Digital Filtering, *Signals and Systems*

John Jenkinson

PhD student: Electrical and Computer Engineering

Teaching Interests: Signals and Systems, Digital Image Processing, 3D Modeling

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UTSA Electrical and Computer Engineering

UTSA Teaching Team

- A professor with 10 or more years of teaching experience at the university level may bypass the Texas teacher certification
- Student teachers will train to become certified Texas teachers
  - A+ Texas Teachers is an expedited 3rd party certification program which is the current platform for our certification training
  - A+ is self-paced, and requires approximately 180 hours of course work
  - The cost is $5,000, with $300 at the time of training completion and the remaining amount due once a teaching position has been secured
- Pending the success of the pilot program year, graduate students and pre-service K-12 teachers will be recruited to participate in the program
  - Recruitment procedures are to be determined

High School Teacher Training and Research Program

- During the pilot year, the resident high school teacher(s) will train and research with the UTSA teaching team
  - Training will involve the completion of UTSA's Digital Image Processing Course during the first semester
    - In the future, offering a UTSA course dedicated to this training is a possibility
  - A 6 week research project will be conducted by the teacher(s) during each of the pilot year semesters
    - The completed work will be integrated into the high school DIP course the following year
  - Teacher(s) will meet with the UTSA teaching team monthly to discuss classroom methodology for the course and lessons learned
  - Post training completion, the teacher(s) will return to their resident school(s) to assume teaching DIP for all subsequent years

Research Project Topics

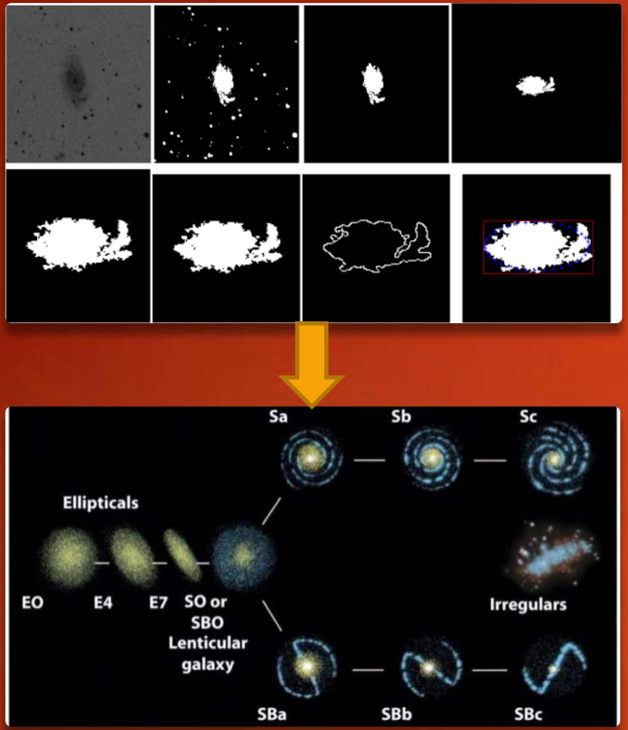

Figure 1. Galaxy image preprocessing for classification

Figure 2. Rider image enhanced by Discrete Quaternion Fourier Transform based Alpha-rooting method

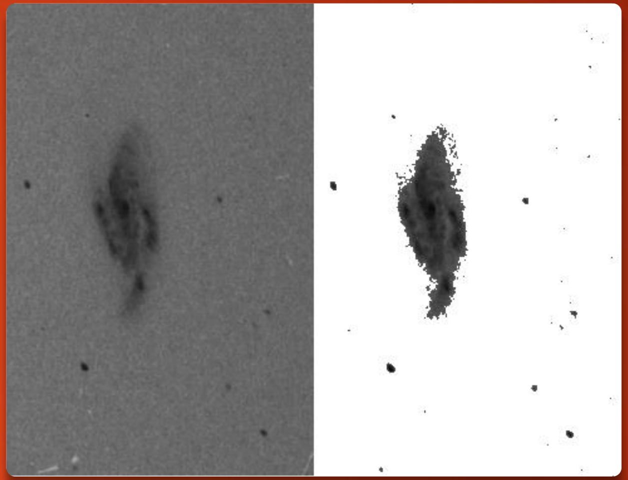

Figure 3. Galaxy background subtraction by the Heap transform

Image Classification

Fluorescence In Situ Hybridization, Galaxy, Diabetic Retinopathy, etc..

Image Enhancement

Histogram equalization; Alpha-rooting; Discrete quaternion Fourier transform

Image Segmentation

Galaxy, Diabetic Retinopathy, Traffic, Surveillance, Surgical, etc..

Program Schedule: 1st year timeline

Spring & Summer 2015

- Course materials development
- Graduate student teacher certification
- School district networking – selection of pilot program year participants occurs
- Funding procurement is sought

Fall 2015 (round 1)

- Pilot year semester 1 begins
- UTSA teaching team begins teaching at two San Antonio High Schools
- Resident high school teachers begin and complete training at UTSA in DIP course
- First research collaboration begins and completes
- Publication of research findings occurs
- Curriculum is updated with findings from research collaboration
- Supplemental funding procurement is sought
- Monthly 1 hour program meetings occur to address difficulties, solutions, and suggestions
- Garner interest regarding Summer 2016 teacher training program offering

Spring 2016 (round 1)

- Second research collaboration begins and completes
- Publication of research findings occurs
- Curriculum is updated with findings from research collaboration
- Round 1 program trainees graduate
- Supplemental funding procurement is sought
- School district networking – selection of second program year participants occurs
- Monthly 1 hour program meetings occur to address difficulties, solutions, and suggestions
- Supplemental funding procurement is sought

Example 1 Course Content: Methods of Image Enhancement

- Spatial Transformations:
  - Negative
    $T_n: f(x,y) \rightarrow g(x,y) = M - f(x,y)$
  - Logarithmic
    $T_l: f(x,y) \rightarrow g(x,y) = c_0 \log(1 + f(x,y))$
    $T_s: f(c,y) \rightarrow g(x,y) = c_0 \sqrt{1 + f(x,y)}$
  - Power Law
    $T_\gamma: f(x,y) \rightarrow g(x,y) = c_\gamma (1 + f(x,y))^\gamma$

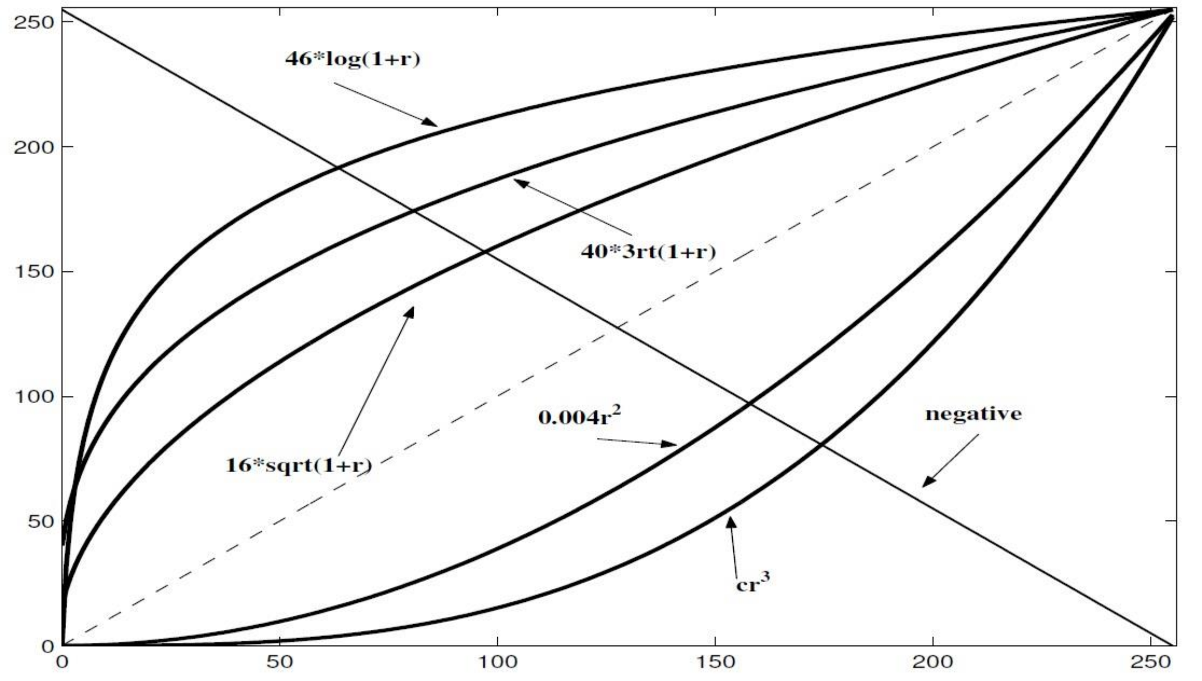

Figure 4. Spatial enhancement transformation functions

Example 1 Course Content: Continued

Contents


```
% call: spatialEnhancement.m
%
% For Digital Image Processing.

% s_dir = pwd;
% cd images
fc = imread('gotska_beach.jpg');
ic = imread('haft_seen.jpg');
% cd(s_dir)

f = rgb2gray(fc);
i = rgb2gray(ic);
f = double(f);
i = double(i);
[N M] = size(f);
[P Q] = size(i);
```

Negative Transformation

```
mx = max(f(:));
mx = double(mx);
gn = mx-f;

% Plot result
fig1 = figure;
colormap(gray(255))
set(fig1,'Name','Negative Transformation','Menubar','None');
subplot(121)
image(f); axis image; title('Gotska image');
subplot(122)
image(gn); axis image; title('Gotska negative');
```

Logarithmic and n-th Root Transformations

```
mxi = max(i(:));
mxi = double(mxi);
cLog = mxi/log(1+mxi);
gLog = cLog*log(1+i);

% Square root transformation
cSqrt = mxi/sqrt(1+mxi);
gSqrt = cSqrt*sqrt(1+i);

% 3rd root transformation
c3rd = mxi/(1+mxi)^(1/3);
g3rd = c3rd*(1+i).^(1/3);

% Plot result
fig2 = figure;
colormap(gray(255))
set(fig2,'Name','Logarithmic and n-th Root Transformations',...
    'Menubar','None');
subplot(221)
image(i); axis image; title('Half-Seen image');
subplot(222)
image(gLog); axis image; title('Log transformation');
subplot(223)
image(gSqrt); axis image; title('Square root transformation');
subplot(224)
image(g3rd); axis image; title('3rd root transformation');
```

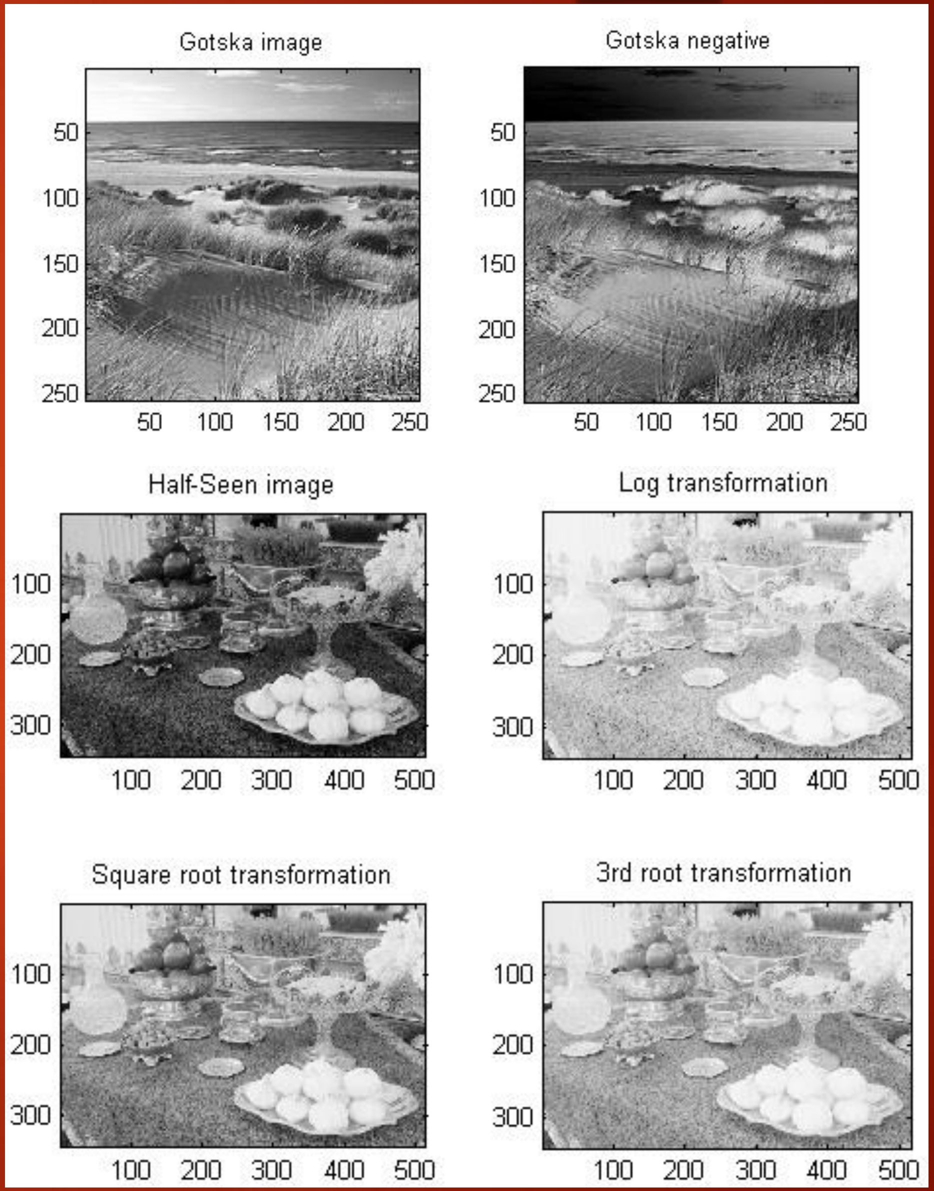

Figure 5,6,7. Left to Right: Input code and negative transform code, log transform code, and Matlab published results of image enhancement

Example 2 Course Content: Mathematical Morphology

- Erosion
  $E(A,B) = A \ominus B = \{x: B + x \subset A\}$
- Dilation
  $D(A,B) = A \oplus B = \cup\{A + b: b \in B\}$
- Opening
  $O(A,B) = D\big(E(A,B)\big) = (A \ominus B) \oplus B$

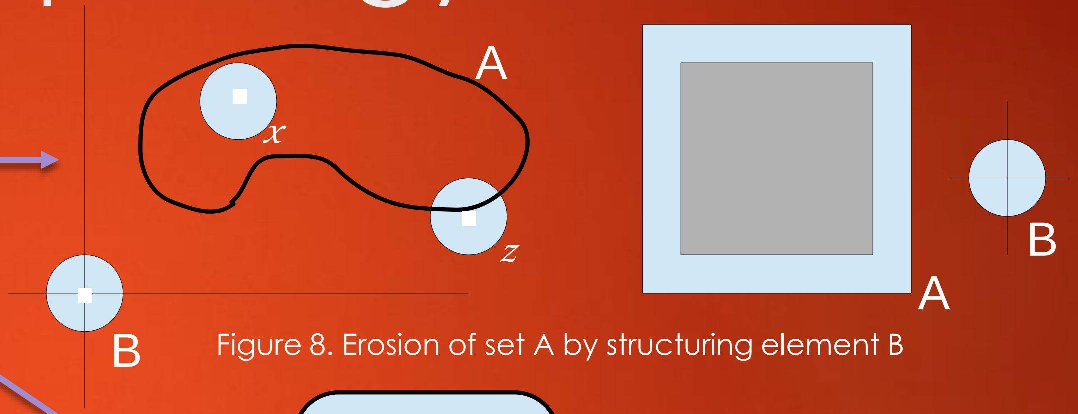

Figure 8. Erosion of set A by structuring element B

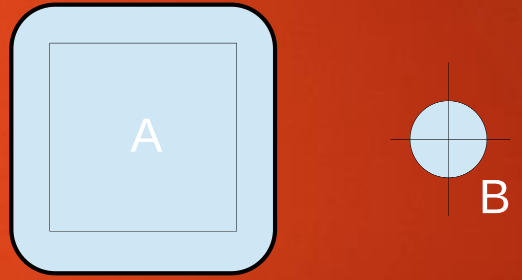

Figure 9. Dilation of set A by structuring element B

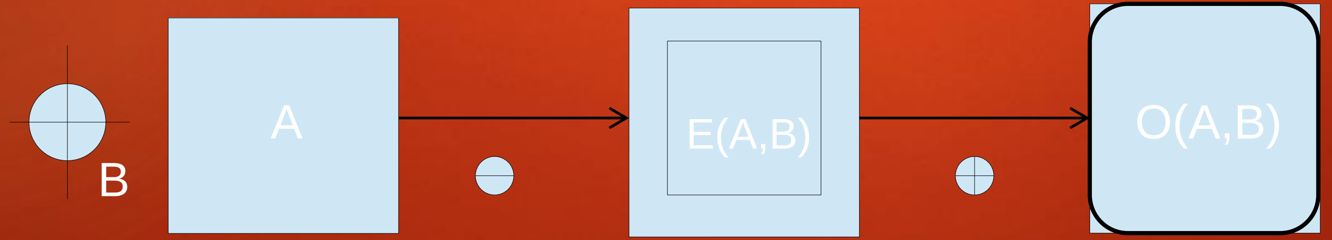

Figure 10. Morphological opening of set A by structuring element B

Figures were drawn with the intent to replicate the figures 2.1, 2.2, 2.6 and 2.8 in "*An Introduction to Nonlinear Image Processing*" by Edward R. Dougherty and Jaakko Astola.

Example 2 Course Content: Continued


```
% Example 1 of Matlab function BWAREAOPEN.
% BWAREAOPEN Remove small objects from binary image.
% BW2 = BWAREAOPEN(BW,P) removes from a binary image all connected
% components (objects) that have fewer than P pixels, producing another
% binary image BW2.  This operation is known as an area opening.
% Binary matrix with objects represented as true.
BW = [1 1 1 0 0 0 0 0 0 0;
    0 1 1 0 0 0 0 0 0 0;
    0 1 1 0 1 1 0 0 1 0;
    0 1 0 0 1 1 0 0 1 0;
    0 0 0 1 1 1 0 1 1 1;
    0 0 0 0 1 0 0 1 1 1;
    0 0 1 1 1 1 0 0 1 0;
    0 0 0 1 1 0 0 0 1 0;
    0 0 0 0 0 0 0 0 0 0;
    0 0 0 0 0 0 0 0 0 0];
% Set the value of object area to preserve.
p = 10; % objects with >=p pixels will be kept.
% Connectivity is between conn neighbors.
conn = 8; % default connectivity for 2-Dimensional arrays.
% Find connected components in BW with conn connectivity.
CC = bwconncomp(BW,conn);
% Calculate the area of each connected component as the number of pixels
% contained in the object.
area = cellfun(@numel, CC.PixelIdxList); % numel gives the vector length
% Remove objects with area <=p.
idxToKeep = CC.PixelIdxList(area >= p);
idxToKeep = vertcat(idxToKeep{:}); % concatenate all idxToKeep values vertically
% Create output matrix.
bw2 = false(size(BW));
bw2(idxToKeep) = true;
```

BWAREAOPEN

```
bw2=bwareaopen(bw,2048);
% cc=bwconncomp(bw2); %use for more than 1 object
% L=labelmatrix(cc);
% L(L~=2)=0;
% L=double(L);
% imshow(L,[])
% X=double(A);
% g=L.*X;
imshow(bw2,[]); %colormap(gray(65535))
X=double(A);
g=bw2.*X;
imshow(g,[]); %colormap(gray(65535))
```

IMOPEN

```
se = strel('disk',7);
Opened = imopen(bw,se);
X=double(A);
Opened2 = Opened.*X;
imshow(Opened2,[])

figure;
subplot(211)
imshow(g,[]);title('BWAREAOPEN for object removal')
subplot(212)
imshow(Opened2,[]);title('IMOPEN for object removal')
```

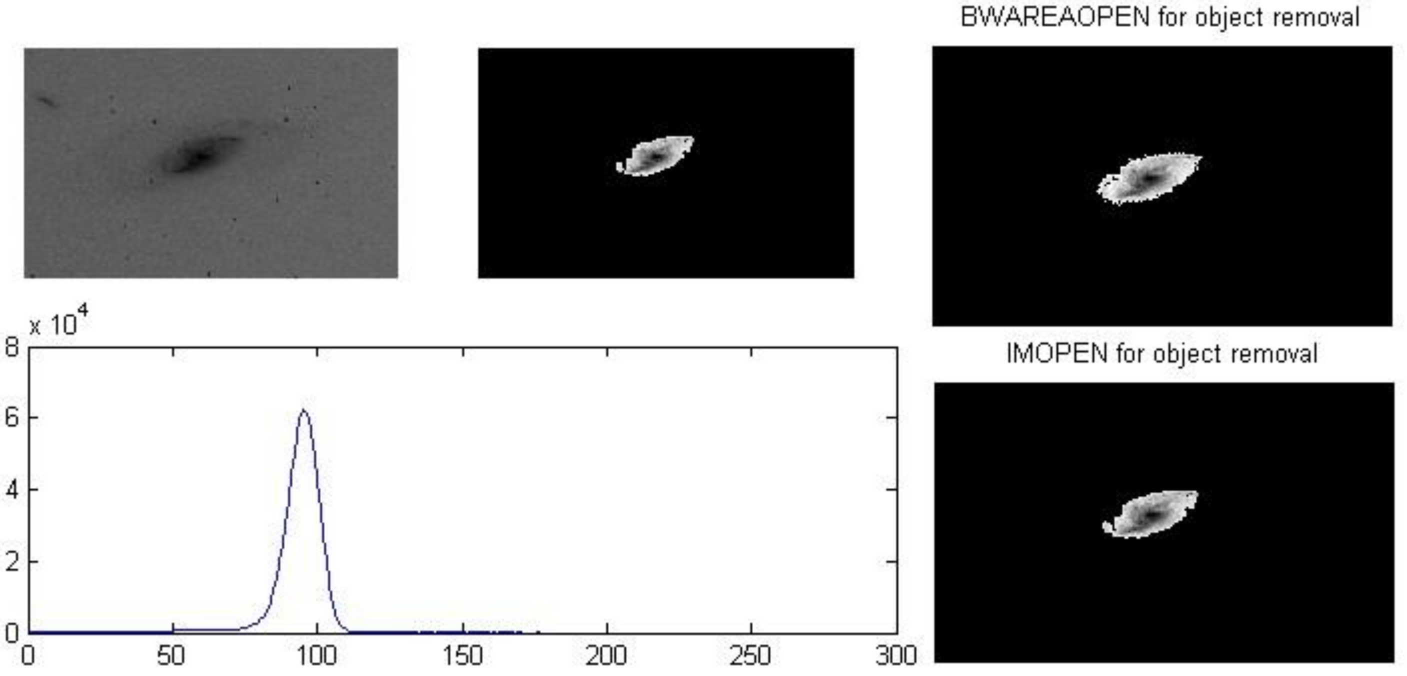

Figure 11,12. Left to Right, Top to Bottom: Function bwareaopen example code, galaxy image processed by bwareaopen and imopen, and the results of processing with original image and histogram

Classroom Methodology

- Semi-flipped classroom
  - Alternating schedule of lecture classes and programming classes
  - Week 1: 3 days lecture, 2 days programming
  - Week 2: 2 days lecture, 3 days programming
  - Recorded videos of selected lecture content will be assigned for homework, and following class periods will be reserved for implementation
- Evaluation methods include:
  - In class assignments,
  - homework programming projects
  - in-class exam consisting of a programming portion and a written analysis portion

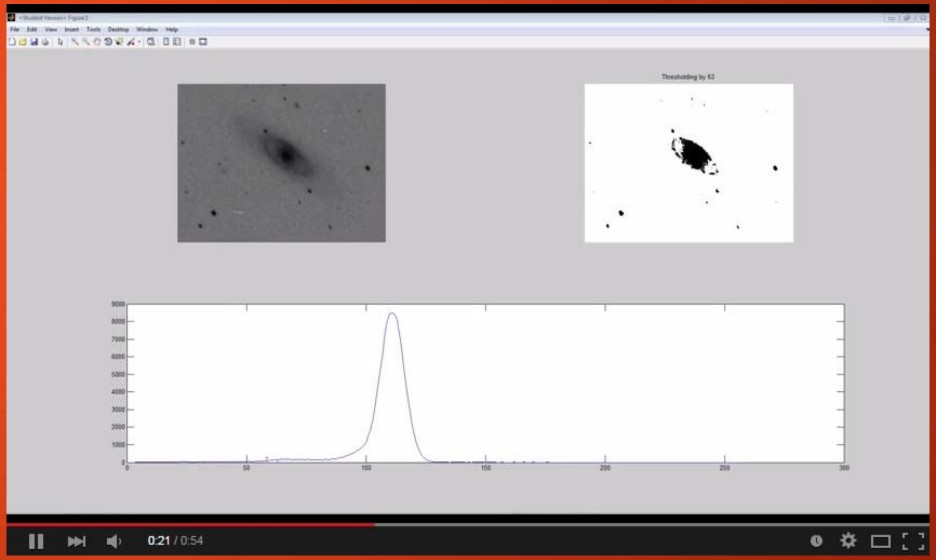

Figure 13. Screen shot of YouTube channel playing lecture video content

Teaching Tools

MATLAB

Interactive programming environment

YouTube

Resource for storing and viewing recorded lectures

GitHub

Storage and collaboration tool for instructor and student codes

Brief Justification of the Course Innovation

This subject is not currently taught at the high school level, and it was not until the 1950s, with the advent of the digital computer, that the field of digital image processing (DIP) began to form. DIP at the high school level will combine mathematics and programming through the application of processing images in the fields of biomedicine, astronomy, geology, and more, to provide the student with an understanding of where image processing technology exists in society and how it is being used for our advancement. Whether being a mobile application like Instagram or a biomedical application like MRI, digital image processing has become an integral part of emerging technologies and an early introduction of this space to high school students is then innovative.

General Knowledge and Skills 1

- (a) General requirements. This course is recommended for students in Grades 11-12. Prerequisites:
- Algebra I, Geometry, and Algebra II.
- (b) Introduction.
- 1. Digital image processing (DIP) is the field that is concerned with achieving the best representation of images for human visual analysis and for the storage, transmission, and representation of images in automated machine perception. It implies the processing of any two-dimensional (2-D) data by a digital computer.
- 2. An image can be defined mathematically as a function of two variables, f(x,y), where a value of light intensity is defined for every coordinate point (x,y) in a Cartesian plane. This establishes a basis for DIP to draw from a rich mathematical theory for solving the problems of image capture, representation, storage, transmission, and interpretation. This course will use concepts and tools that students have learned in previous mathematics courses for solving problems.
- 3. Every technical field is impacted by DIP. In nuclear medicine for example, patients are injected with a radioactive isotope that emits gamma rays at it decays. Complete bone-scan images are produced from the emissions collected by gamma ray detectors. Such images are used to locate sites of bone pathology, such as infections or tumors.

General Knowledge and Skills 2

- (c) Knowledge and skills.
- (1) The student will use advanced mathematics, general scientific principles, and computer applications for solving practical engineering problems. The student is expected to:
- (A) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, Algebra II, Statistics, and Calculus relevant to digital image processing;
- (B) understand the fundamentals of image formation, quantization, and resolution of images;
- (C) demonstrate the main methods of gray-scale transformations for image enhancement;
- (D) calculate the histogram of an image and apply histogram equalization to a given histogram;
- (E) demonstrate the main methods of edge and contour detection by different gradient operators;
- (F) calculate the 2-D convolution, window-filtering, and correlation of images;
- (G) investigate concepts, properties, and applications of the 2-D Fourier transform;
- (H) calculate the 2-D Fourier transform of an image;
- (I) apply the 2-D Fourier transform of an image for filtration, analysis, and multiresolution;
- (J) calculate enhancement performance measure (EME) to determine the quality of transform-based enhancement methods;

General Knowledge and Skills 3

- (K) develop an understanding of the linear model of image degradation;
- (L) calculate the error resulting from optimal linear filtration for image restoration;
- (M) develop an understanding of the optimal windowed linear filters for image restoration;
- (N) demonstrate the main concepts of mathematical morphology for image processing;
- (O) demonstrate the 2-D median-type filters and their application for degraded image restoration;
- (P) calculate the projection of objects in an image for use in image reconstruction;
- (Q) understand the fast methods of image reconstruction by back-projections and fast paired transforms; and
- (R) apply the concepts of image reconstruction from projections and fast paired transforms
- to computerized tomography.
- (2) The student will gain experience in programming scientific software in Matlab®, develop an intuition for results produced by the software that the student develops, and present the software and its results in a way that is effective for conveying ideas and results to management and clients in industry. The student is expected to:

General Knowledge and Skills 4

- (A) apply theory developed during the course to program image processing solutions;
- (B) describe the process and result of the program execution in a written report; and
- (C) describe the process and result of the program execution in an oral presentation.
- (3) The student will understand how image processing requires working effectively in multidisciplinary teams. The student is expected to:
- (A) understand where image processing is being applied in industry, and how the problems in image processing are often defined by people in other disciplines;
- (B) establish lines of communication with industry experts and investigate multidisciplinary team environments that have been experienced by industry professionals; and
- (C) propose a mock written proposal to government scientific agencies of how multidisciplinary efforts related to work and research involving image processing necessitate government funding.
- (4) The student will understand the impact of engineering solutions in global and societal contexts.

General Knowledge and Skills 5

- The student is expected to:
- (A) investigate a specific application of digital image processing, which company or academic institution developed the application, and how the application has benefited mankind; and
- (B) make a oral presentation of the research conducted.
- (5) The student will understand the need for continuing professional education in image processing.
- The student is expected to:
- (A) conduct an interview of a digital image processing professional, either in industry or academia, and write a report on the professional's continued education and the benefits received from it; and
- (B) investigate the hardware used in the development and implementation of digital image processing and report how continuing education benefits industry professionals by providing them with new tools to work with.

Specific Student Needs this Course is Designed to Meet

Exposure to current hot fields of work and research are needed by our youth. A course in DIP serves this purpose. Basic and intermediate programming in scientific programming software such as Matlab® serves to improve students' computer proficiency and build a skill set in computing that is transferable to multiple computer related industries. Critical thinking and analysis will strengthen the student's problem solving ability as they see current and past problems in imaging as well as their solutions. High levels of organization and attention to detail are required for image processing programming, and contributions will be made to the student in this area through the course.

Major Resources and Instructional Materials Required

Each student will need access to:

- A computer during class time and outside of class to work on assignments.
- Scientific computing software such as Matlab®. One textbook for digital image processing will be required. Textbooks are currently available for the subject, but our team at UTSA is developing a textbook specifically to be used for this high school image processing course, which will reduce the rigor, typically at the undergraduate or graduate level, to be readable by high school students.

Required Activities and Sample Optional Activities

In class, programming of image processing algorithms will be required. Field trips to both university labs and industry settings where image processing is being applied in a way that is effective to demonstrate to high schools will be optional. Blackboard theoretical development will be provided and then programmed in scientific computing software. Optional special project will be given to address a student's individual interest in a specific area of DIP which will allow the student to investigate the area, produce a small result, and present the results in either in a written or oral report. A team project is an optional activity where the students will be grouped together in small groups (three or four students per group) and will work together to produce a new idea for the field of image processing. Each group will have the option to produce a new result or study and present a result that has already been discovered in the field. This will foster teamwork in computing and creativity in developing new results.

Recommended Qualifications of Teachers

- The local education agency (LEA) will assign certified teachers. The teacher will hold a valid Texas Teacher Certificate in one or more of the following subject areas. In addition, a teacher with a Bachelor's degree of Science in Electrical Engineering, Computer Science, Mathematics or a related field and 1-3 years of image processing with scientific programming software such as Matlab® programming experience should serve as the basis for teacher qualifications of this course. Digital Image Processing for High School Instruction (DIPHI) training course is also recommended.

- (1) Master Science Teacher (Grades 8-12).
- (2) Mathematics/Physical Science/Engineering: Grades 6-12.
- (3) Mathematics/Physical Science/Engineering: Grades 8-12.
- (4) Physical Science: Grades 6-12.
- (5) Physical Science: Grades 8-12.
- (6) Physics/Mathematics: Grades 7-12.
- (7) Physics/Mathematics: Grades 8-12.
- (8) Science: Grades 7-12.
- (9) Science: Grades 8-12.
- (10) Science, Technology, Engineering, and Mathematics: Grades 6-12.
- (11) Secondary Industrial Arts (Grades 6-12).
- (12) Secondary Industrial Technology (Grades 6-12).
- (13) Secondary Physics (Grades 6-12).
- (14) Secondary Science (Grades 6-12).
- (15) Secondary Science, Composite (Grades 6-12).
- (16) Computer Science: Grades 8-12

Conclusion

- Early exposure
- Fostering technical interest
- Leveraging modern technology

Through offering DIP at the high school level, even gaining the interest of a single student to pursue a career in this field, the student can leverage experience attained through the course to enter the field soon. It would be great if our graduates could begin rigorous Summer internships in the field after their Freshman year at university.