

Recycling Graduate Coursework to Introduce Freshmen to Engineering Fields

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ABSTRACT: *The great technological advances of the last fifty years have increased the complexity of engineering education. Students have to make choices about their areas of concentration early in their studies. It becomes necessary to present introductory material about the different areas of work during the freshman year, and many universities have created special courses to accomplish this.*

This article describes a process in which class-work from a graduate-level course has been used to introduce engineering college freshmen to the areas of imaging and computer vision. For this purpose, graduate students taking a computer vision course were asked to prepare the courses' homework, practical exercises and final projects in a way compatible with the format of tutorials. This material was collected and organized into a coherent document and presented to freshman students taking a hands-on, introductory course in the department's "Tools and Toys Laboratory." The tutorial introduces basic concepts, provides an interface to run programs illustrating these ideas, and suggests simple exercises for further learning. Besides providing an effective, hands-on way of introducing entry level students to the different areas of study in their chosen profession, this type of activity can give new meaning to the work performed in graduate courses.

The article discusses the structure of the graduate and undergraduate courses, the tutorial organization, the topic selection and our future plans.

1 INTRODUCTION

This article describes a novel educational experience in which a tutorial was developed to introduce engineering college freshman to the field of computer vision. Students enrolled in a graduate-level Computer Vision course were asked to do their homework and laboratory exercise reports in html format. This material was then complemented and organized in a coherent document. The final result is an interactive tutorial which will be presented to freshman students taking a hands-on, introductory engineering course in the University of Puerto Rico's Electrical and Computer Engineering Department. The course, which is fully described in [J. Colom et al, 2003], was created to introduce electrical and computer engineering to freshman students; it consists of one-hour lecture followed by a two hour lab experience once a week. The students are introduced to five areas of specialization through the discussion of basic concepts in class and real life applications in the laboratory. The laboratory experiments are focused in five specialization areas: Power, DSP and Communications, Control Systems, Electronics, Applied Electromagnetics, and, with the integration of the tutorial described here, Computer Vision and Imaging.

The laboratory activities are carefully designed to provide students with an understanding of the different application areas of their chosen field of study early in their college career. In addition to the familiarization with basic laboratory equipment (multi-meters, oscilloscopes, signal generators, etc.), students are introduced to other important software tools such as MATLAB®, Excel®, Powerpoint®, and CoolEdit®. The students also attend seminars on effective oral and poster presentations as part of the requirements of the course.

The tutorial offers an introduction to computer vision. It describes the main components of a computer vision system, overviews algorithms that are often used to process images, and provides some

practical application examples. MATLAB© is used as the computational engine. Sample applications are overviewed and hyperlinks are included to allow students to run the corresponding code from the html document. Because these examples include source code, students can use them as a starting point to develop their own machine vision applications.

The rest of this paper is organized into three sections: first a section describing the graduate course, then an overview of the tutorial organization, and finally conclusions and plans for future work.

2 MACHINE VISION COURSE

Computer vision consists of the use of electronically acquired images to automatically perform some specific task. The images are acquired by an electronic camera, transferred to the computer and processed using a program to isolate the objects of interests. Once the objects are located, the program estimates the quantities of interest and performs appropriate actions based on the results.

The Computer Vision graduate course covered the fundamentals of computer/machine vision and the design of vision systems for different applications such as industrial automation. The structure and organization of this course was based on [J. Ramesh et al, 1995] and is as follows:

1. Machine vision systems: digital images; image acquisition and frame grabbers; cameras and CCD; image geometry; lenses.
2. Introduction to Geometrical Optics: lens equation; image resolution; depth of field; exposure.
3. Binary Image Processing: image binarization; object geometry; image moments; component labelling; binary algorithms; thinning, expanding and shrinking; morphological operations.
4. Image Regions: segmentation; region representation; region split and merge; region Growing
5. Image filtering: linear filters; median filter; Gaussian smoothing
6. Edge detection: gradient operators; Laplacian operators; Gaussian edge detection; detector performance.
7. Contours and region representation: curve fitting; poly-line representation; line detection and Hough Transform
8. Shading: Image irradiance; illumination and reflectance; surface orientation; reflectance map
9. Stereo Vision: stereo imaging; matching; range imaging
10. Photometric stereo
11. Camera calibration

To implement the course's exercises, graduate students had free access to the laboratory, which is equipped with personal computers, *Matrox Meteor II* frame grabbers and video cameras. A MATLAB© C-language interface was developed to allow capturing images directly from and into MATLAB©. Once the image is acquired, it can be conveniently processed using a combination of scripts developed by the students and MATLAB©'s Image processing toolbox algorithms.

Several laboratory exercises and a final project were required as part of the course. As noted earlier, the reports were collected in html format and were used as the basis for the tutorial. A brief description of these exercises follows.

2.1 Automatic License Plate Recognition

This exercise used previously acquired images of vehicles. The student's task was to develop a prototype license plate recognition system (LPRS), an algorithm to find the vehicle's license plate on the image and then recognize the numbers and letters. The algorithm consists of the following steps:

1. Open a previously captured car's image,
2. Isolate the license plate in the image,
3. Recognize license plate characters to identify the vehicle.

To determine the portion of the image that contains the license plate, the different objects present in the image are labelled. To facilitate the labelling process, the image is segmented according to a threshold level Q . This technique takes the greyscale image and produces a binary image whose pixels assume the values 0 and 1. The labelled objects are then analyzed and those that possess geometrical characteristics similar to those previously established for license plate characters, such as width and height, are selected. The distance between the selected objects is then calculated to verify that it is compatible with the distance between plate characters. If this is successful, the region of the image containing the license plate

has been identified, and the characters can be extracted. If attempts to find the region containing the plate fail, the segmentation threshold would have to be modified and the whole procedure performed again. This process would continue until satisfactory results are obtained or, if a maximum number of iterations are reached, the image is ignored because it is assumed that it does not contain a license plate.

To recognize the plate characters, template matching is used. It is based on comparing character patterns in a predefined set and those in the image being analyzed in order to select the one with maximum correlation.

An example of the final result of this procedure is shown in figure 1.

2.2 Finding Hand Orientation using Computer Vision

The objective of this exercise was to determine the position and orientation of a hand. The algorithm can be used in the development of computer games and novel human-computer interfaces. The algorithm used is as follows:

1. Capture an image using the frame grabber and camera.
2. Use Otsu's method [N. Otsu, 1979] to segment the image.
3. Label the regions in the image.
4. Select the region with largest area as the hand.
5. Use the region's moments [X. Liao et al, 1996] to calculate its centre of mass and inclination angle.
6. For this exercise, a rectangle was superimposed on the image to indicate the result.

This algorithm is repeated continuously. Figure 2 shows a sequence of 3 images acquired and processed in this way.

2.3 Detection of coins using Hough Transform

The exercise's objective was to detect coins in an image using edge detection techniques and Hough Transform [D.H. Ballard, 1981] for circle detection. The algorithm used is as follows:

1. Acquire an image.
2. Detect the edges in the image.
3. Use the circular Hough Transform and the edges to identify circles with a predefined coin radius.
4. Once the test is done for the radius of each coin, calculate and show the total value of the coins in the image.

To calculate the edges, two methods were tried. The first was a Canny detector. In the second method, the morphological operations of dilation and erosion were applied to the binarized image, and the resulting arrays subtracted. Figure 3 shows results obtained using the Canny edge detector. The recognized circles are painted with red contours.

2.4 Barcode reading

The objective with this project was decoding the bar codes (UPC) using computer vision algorithms. These codes consist of a combination of black bars separated by white spaces. The bar/space pattern corresponds to a unique code corresponding to the type of product, manufacturing and specific product. These barcodes are used in the automation of product inventory, determination of an article's price, and to keep a data base up-to-date. Commonly the decoding is based on interpreting the pattern of light reflected when the bars are illuminated using photo-diodes. In this exercise, an algorithm was designed to read and decode a barcode using a camera. Figure 4 shows the result for a barcode decoding.

2.5 Integrated Circuits identification

Modern quality inspection systems in printed circuit board (PCB) assembly lines use automatic methods to detect defective items. This project used different machine vision methods to detect Integrated Circuits on boards. Several algorithms, such as the line-Hough Transform, distance between centroids and auto-correlation, were tested. All these techniques were found to be very sensitive to the lightning conditions prevalent during the acquisition of the images. Figure 5 shows the result obtained with these methods.

3 TUTORIAL

The exercise and project material was collected and combined with complementary information to produce a coherent interactive HTML tutorial. The main html page of the document is shown in figure 6. It's organized in 5 sections which have a sequential order that allows for easy exploring and studying. The first 4 sections contain basic information about of computer vision systems. Section 5 shows the applications and projects developed within the graduate course.

The tutorial starts with a brief introduction to the Computer Vision field and suggests additional readings to complement the information contained in the document. The next section describes the components of a machine vision system. Specifically, the components available in the "Tools and Toys" laboratory to be used in this tutorial are described. A survey of fundamentals of the computer vision field is discussed in section 3. Basic digital image and image processing concepts are introduced there. In section 4, algorithms for image processing are discussed and programs are used to illustrate each algorithm. The student can run the programs from the html document. Once a program is run, a dialog window appears with an introduction of the algorithm that the student wishes to use. The programs will open windows to display results and to interact with the student, asking him or her to select an algorithm or open an image when appropriate. Figures 7 through 9 show results from some of the algorithms.

The last section of the tutorial shows the exercises and projects of the Computer Vision course described in the previous section. Each project was documented and all of the algorithms and principles used to reach the solution explained.

4 CONCLUSIONS

The homework and projects developed by graduate students in a Computer Vision course served as the basis for the preparation of a tutorial in order to introduce this area to first year electrical and computer engineering students. Besides providing an effective and efficient way of producing a tutorial, this process had the added advantage of providing extra incentives to the graduate students. In addition, because the same equipment was used for both the graduate course and the freshmen tutorial, a higher quality educational experience was obtained at a lower cost. In the future, we plan to use the same process to create similar tutorials for other areas of electrical and computer engineering.

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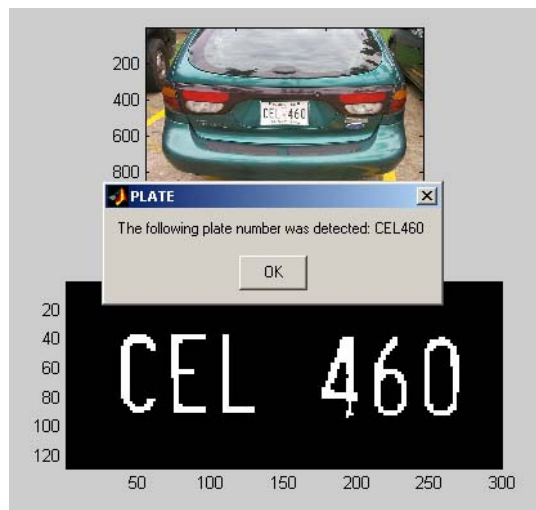


Figure 1 – License plate recognition example.

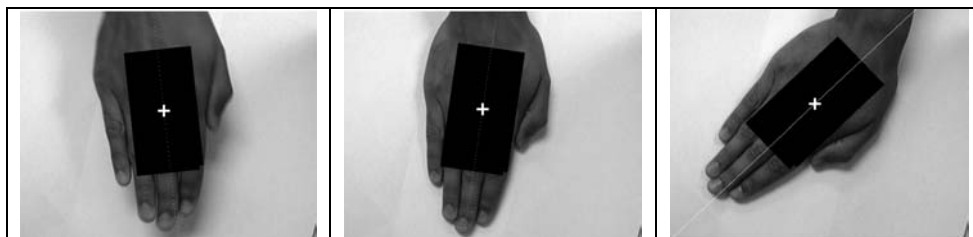


Figure 2 – Sequence of images showing the hand orientation algorithm results.



Figure 3 – Detected coins using a Canny edge detector.

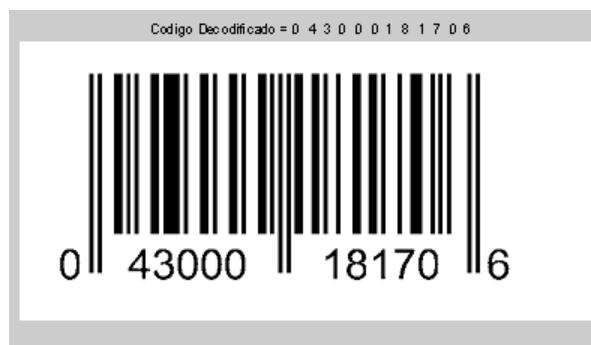


Figure 4 – Barcode identification using computer vision

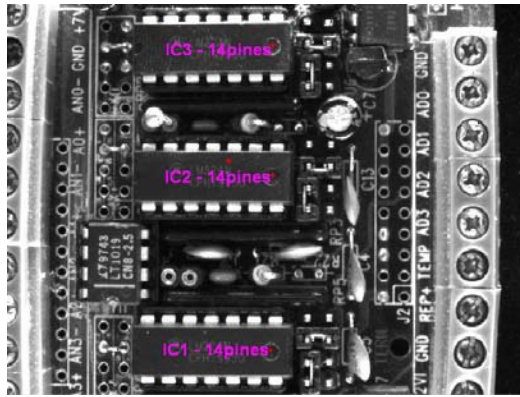


Figure 5 – IC detection example.

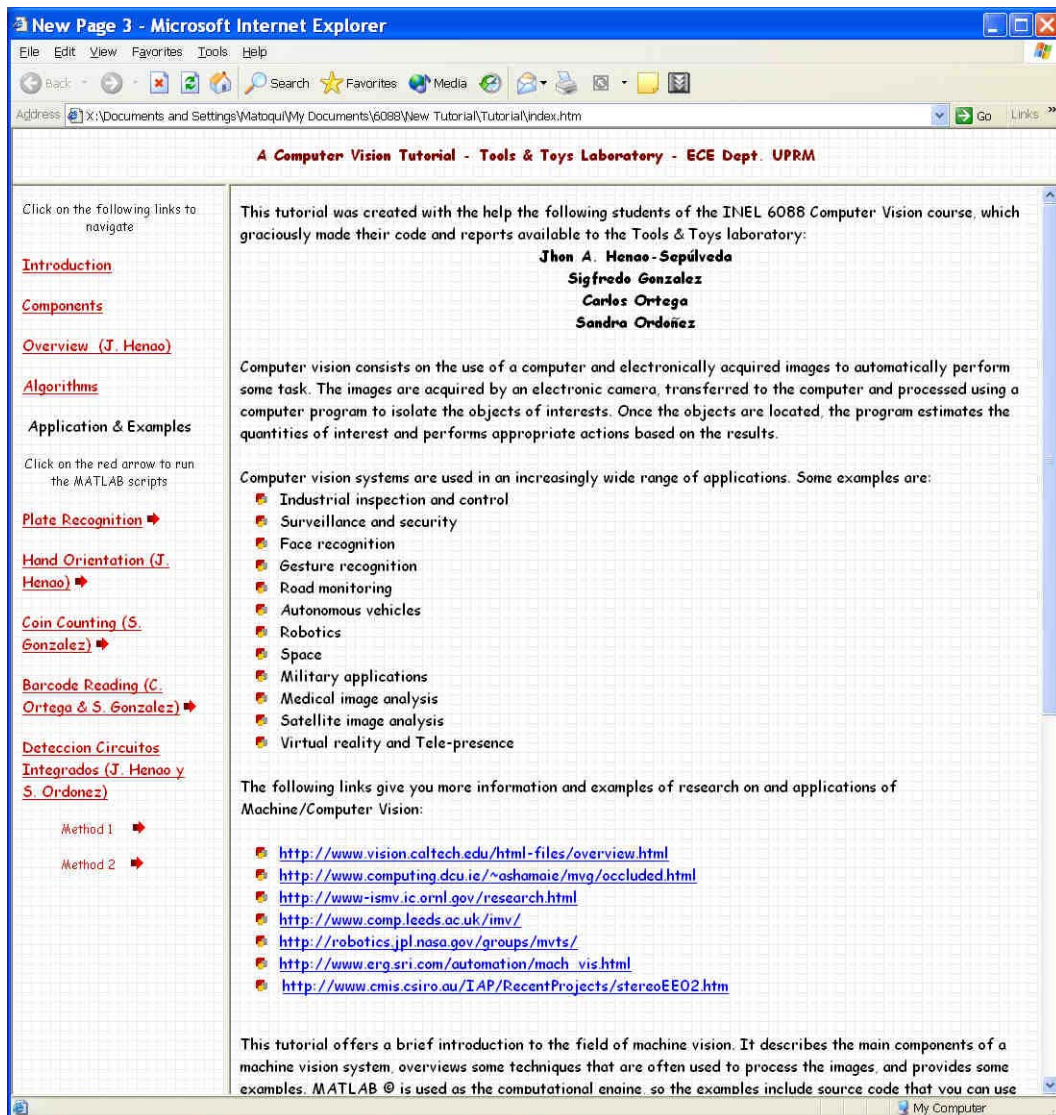


Figure 6 – Main tutorial html page.



Figure 7 – Image binarization example

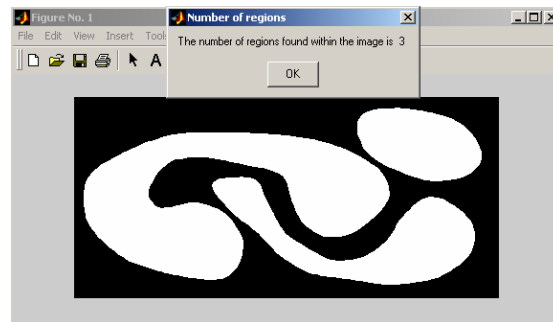


Figure 8 – Image labeling example

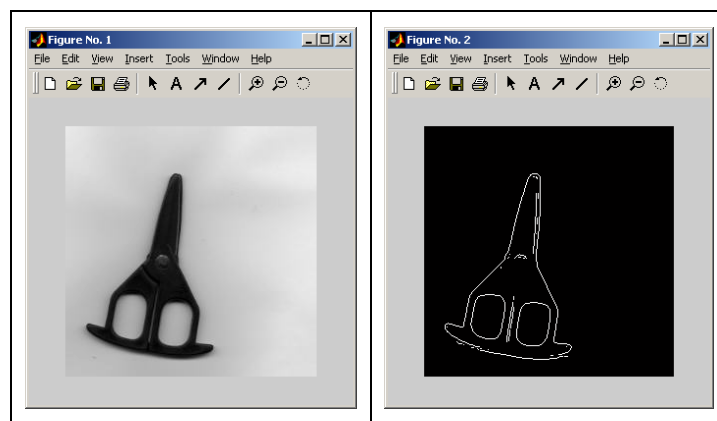


Figure 9 – Edge detector on an image