

# Computer Imaging: A Project for Pattern Classification With Range Images

SCOTT E. UмбаUGH, ROBERT LEANDER, PATRICK SOLT,  
AMIT KHARBANDA, PRADYNA DEOKAR

*Computer Vision and Image Processing Laboratory, Southern Illinois University Edwardsville, P.O. Box 1801,  
Edwardsville, Illinois 62025-1801*

Received 26 February 2007; accepted 23 August 2007

**ABSTRACT:** A series of three laboratory exercises were developed to introduce undergraduate students specializing in computer vision and image processing to three-dimensional imaging. These lab exercises were consolidated into a term project in the Image Analysis and Computer Vision course at Southern Illinois University Edwardsville. The difficulty encountered in introducing undergraduate students to 3-D imaging was the expense of the equipment. Because equipment expense placed a limitation on the number of 3-D cameras available and consequently, the number of students that could use the equipment, the image database used in this project was captured by graduate students only. At the end of the term, the students evaluated the effectiveness of the project. Eighty eight percent of the students *strongly agreed* or *agreed* that they “gained insight into the process of developing algorithms for automatic object classification via images.” Additionally, 83% of the students *strongly agreed* or *agreed* that “this project is an excellent enhancement to the in-class lectures.” © 2009 Wiley Periodicals, Inc. *Comput Appl Eng Educ*; Published online in Wiley InterScience (www.interscience.wiley.com); DOI 10.1002/cae.20183

**Keywords:** computer imaging; pattern classification; range images; digital image processing

---

## INTRODUCTION AND OVERVIEW

The introduction of images containing three-dimensional information into our computer vision

and image processing (CVIP) curriculum specialization, here at SIUE, presented one difficulty. The prohibitive cost of the equipment disallowed the provision of multiple cameras, making us reluctant to allow undergraduates complete access to the hardware. We solved the problem by having graduate students capture a database of images to be used by *all* the students.

---

Correspondence to S. E. Umbaugh (sumbaug@siue.edu).  
© 2009 Wiley Periodicals Inc.

We chose to introduce students to 3-D imaging via range (or “depth”) images which measure object-to-camera distances. Using the range images, we developed lab exercises which culminated in a pattern classification project. The project, in addition to enlisting range-image exercises, is suitable for a final project in a computer vision or image analysis course.

## MATERIALS AND METHODS

### Images

Images were captured using Canesta’s DP205 camera, which outputs a range image, as well as a brightness image. A “range image” is two-dimensional array of pixels where each pixel value quantifies the distance from the focal plane of the camera sensor to the surface of the object within the camera’s field of view.

The camera outputs images in 16-bit-per-pixel (bpp), TIF format which were converted to 8-bpp TIF images for use in Computer Vision and Image Processing Tools (CVIPtools) [1–4]. The image database that was captured consisted of forty images of five kinds of objects—a bowl, a cup, a fork, a plate, and a spoon. There were eight images of each object (class). The entire image database was further divided into two equally sized sets: a training set and a test set.

### Software

The CVIPtools software was used to investigate and analyze the images. The primary tools used included *Analysis → Segmentation*, *Analysis → Features*, and *Analysis → Pattern Classification*. Figure 1 shows the *Analysis → Segmentation* window in CVIPtools. The *Features* (-extraction) window is shown in Figure 2. The pattern classification tools that are available in CVIPtools include various normalization

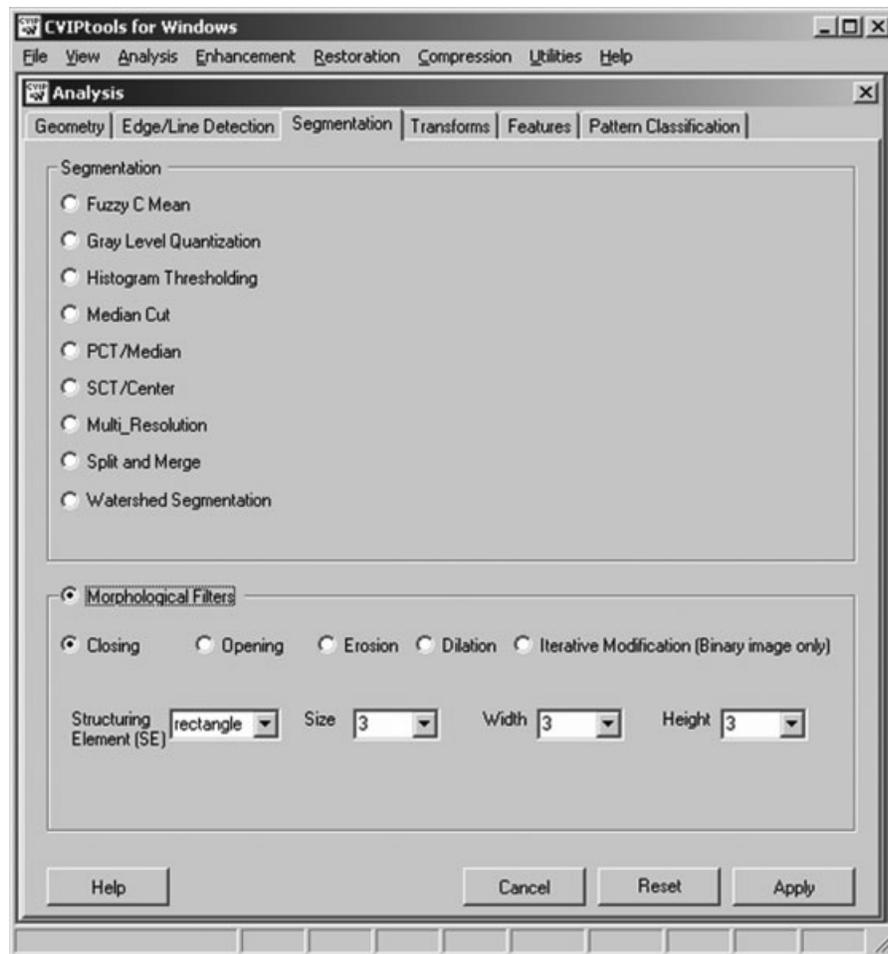


Figure 1 Segmentation window in CVIPtools.

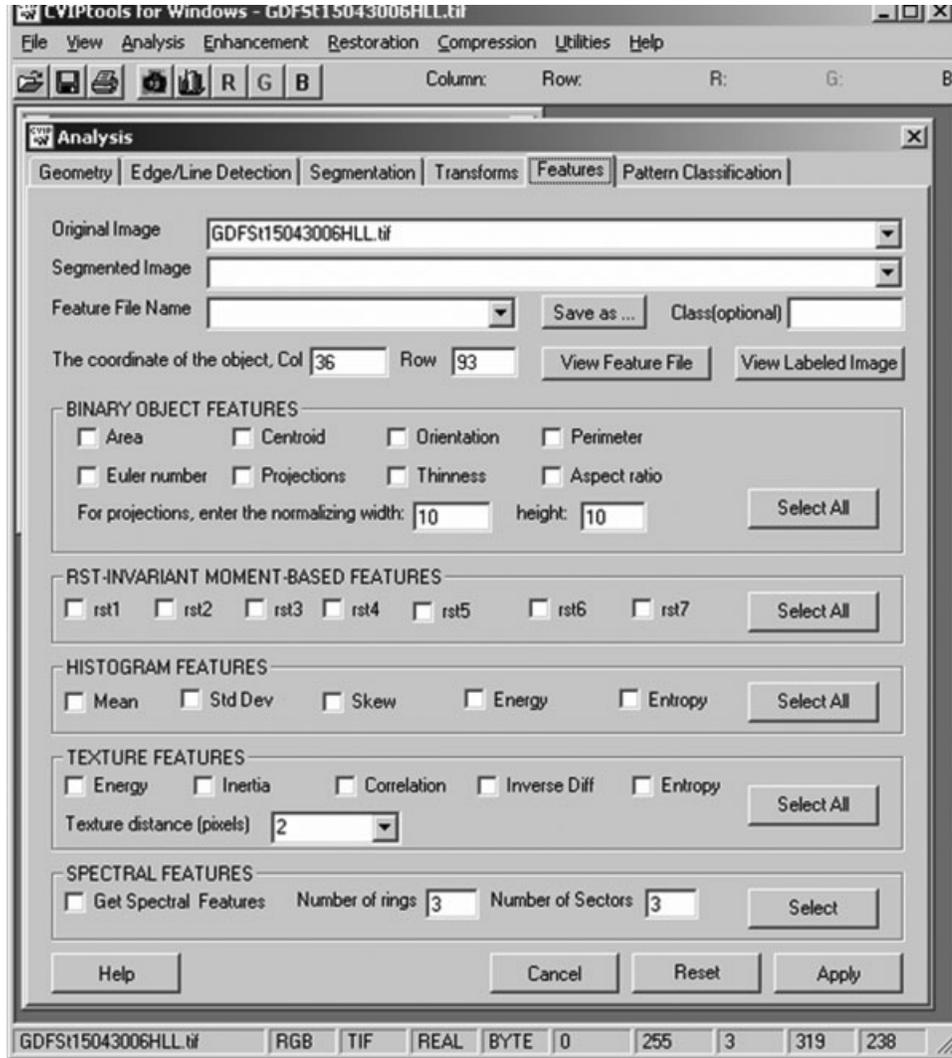


Figure 2 Feature extraction window in CVIPtools.

methods, distance and similarity measures and three classification methods (see Fig. 3).

### Three-Dimensional Imaging Background

There are many types of 3-D imaging methods. One standard method is to use multiple cameras to create a stereo image, similar to the way the human visual system does. This method requires more hardware and special calibration techniques which may be time consuming. Another method, which is applied using a number of techniques, infers shape from the shading or texture of objects in an image. However, these techniques are computationally intensive. Implementing structured lighting is also a useful method for acquiring 3-D image information, but requires specialized equipment, environment and processing [5].

We took the approach that uses a camera that acquires brightness and range images using a single integrated circuit. This approach requires no specialized environment or processing. The camera's sensor chip, called the *Equinox*, works similar to the way radar does. It sends out infrared light pulses and calculates the time it takes the photons to reach and return from the objects in the field of view. The chip includes an IR LED, whose light is modulated to create the signal that is transmitted from sensor chip [6].

After the range images are acquired, there are many techniques available for analyzing their objects as three-dimensional objects. A number of the more sophisticated approaches found in the literature employ various techniques that construct photo-realistic, three-dimensional models of physical objects [7], or techniques that recognize free-form

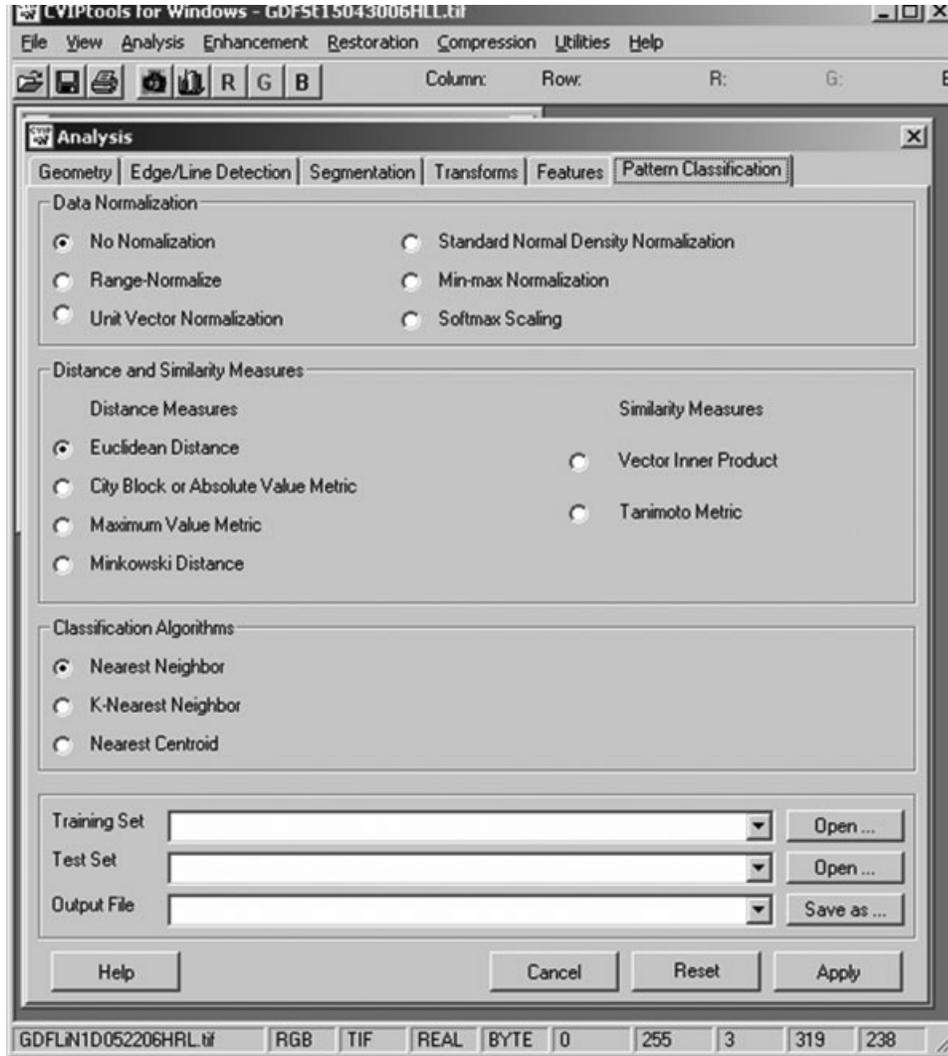


Figure 3 Pattern classification window in CVIPtools.

objects in range images, using local-feature histograms [8]. Our approach simply treated the range images as standard images, but using the brightness levels corresponding to the distances of portions of objects in the scene to capture features of depth.

### THE PROJECT: OBJECT RECOGNITION USING RANGE IMAGES

Students performed two introductory laboratory exercises which culminated in the following project:

#### Do the Following

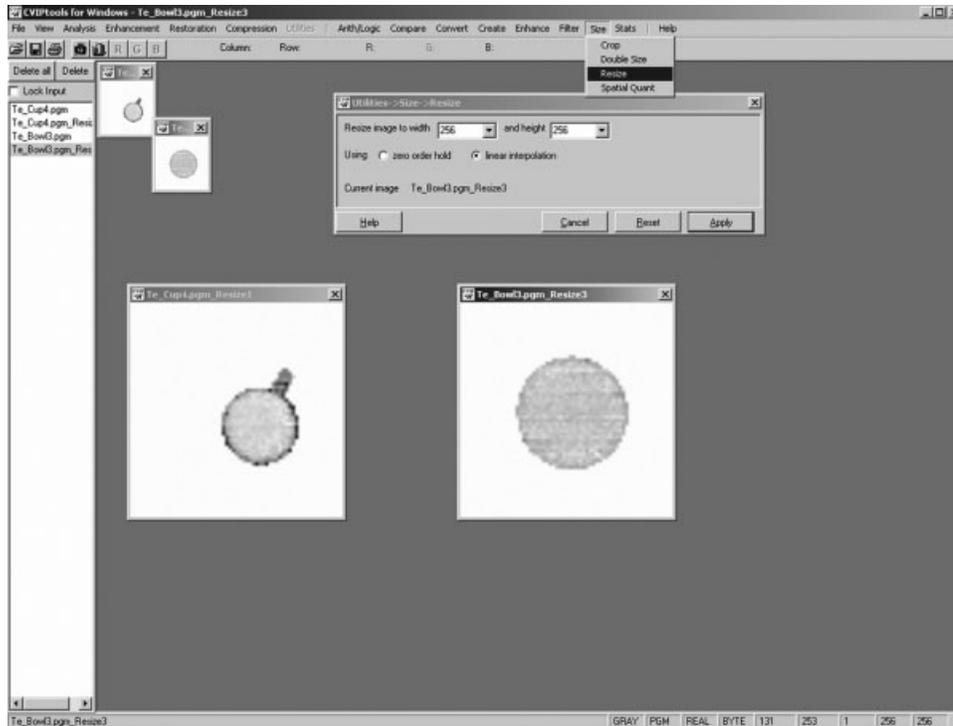
Develop an algorithm to recognize objects using range images. In a range image, each pixel expresses the

distance between a known reference frame and a visible known point.

Create an algorithm with the following steps:

1. Image resize—resize to  $256 \times 256$ .
2. Segmentation.
3. Morphological filtering.
4. Feature analysis and extraction.
5. Pattern classification.

The image database consists of forty images of five kinds of objects: bowl, cup, fork, plate, and spoon. The object types will be the *class*. There are eight images of each object (*class*). The entire image database is further divided into two equal-sized sets: Training set and Test set. The training set and the test set images are on the ECE 438 Syllabus web site. The



**Figure 4** Resizing the Images in CVIPtools.

images' names in the training set are prefixed with "Tr\_" like Tr\_cup, Tr\_bowl and the images' names in the test set are prefixed with "Te\_" like Te\_cup, Te\_plate.

Initially, the first three stages of the algorithm—image resize, segmentation, and morphological filtering—are performed on all the 40 images in the training set and the test set to find the most appropriate procedure.

The next stage—feature extraction—requires the creation of two separate feature files—one for the training set and one for the test set. These files are then used for pattern classification.

### Do the Following

- Download the images from the web site ECE 438 syllabus.
- Read the 40 training and test images into CVIPtools. Resize them one at a time as you load them (see the descriptions and illustrations below).

Develop your algorithm as described on the following pages.

**Image Resize.** This stage is performed on all forty images. The images obtained from the 3-D camera are

64 pixels by 64 pixels. To facilitate further processing, first resize the images, using the *Resize* option in CVIPtools (*Utilities* → *Size* → *Resize*), with the linear interpolation method. The images are to be resized to a width and height of 256 and 256 respectively. This is shown in Figure 4.

**Segmentation.** Experiment with various segmentation methods, and select one that you think will work the best for this application. The goal is to find a method that will clearly separate the object outline from the background. Then apply it to all forty images.

**Morphological Filtering.** Experiment with various morphological filtering methods, and select one that you think will work the best for this application. The goal is to fill in any holes and smooth out object boundaries, so that the shape of any class of objects is fairly consistent. Then apply it to all forty images.

**Feature Analysis and Extraction.** Initially, extract features for all 20 images in the training set. Select the features that you think will help differentiate the various image classes: bowl, cup, fork, plate, and spoon. The images in the training set are prefixed with "Tr\_." Then extract features in a separate file for all

**Table 1** Summary of Student Evaluations

Survey question	Number of students				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
These three laboratory exercises and the project increased my knowledge of range images	13	9	1	0	0
The level of technical detail provided was appropriate	9	13	1	1	0
The laboratory handouts and image database are well-organized, and I can find the information I need easily	9	12	2	1	0
The length of the project labs was appropriate	10	11	3	0	0
I believe that by performing this project, I gained insight into the process of developing algorithms for automatic object classification via images	8	13	3	0	0
I believe this project is an excellent enhancement to the lectures	13	7	1	0	0

twenty images in the test set. The images in the test set are prefixed with “Te\_.” Note that there are eight images for each class: four in the training set and four in the test set. Be sure you put the training set and test set features into separate files; this is necessary for the next step.

**Pattern Classification.** Pattern classification is used to classify objects based on the features in the feature files. Experiment with various normalization methods, distance/similarity measures and classification methods. The results will be in the specified *Output File* from CVIPtools. At the end of the output file there will be a table containing the success rates from the test set. Your goal is to get 100% success for all classes in the test-set images. If you cannot get the success that you want, feel free to go back to any of the previous steps and modify your algorithm.

### Postlab

- Describe your methods, that is, your five-step algorithm, in detail; include all parameters that you used with each process. Show the images resulting from each step.
- List your success results for each class. Include the training- and test-set feature files, as well as the output file from the pattern classification.
- Discuss the relationship between your results and your methodology.
- Summarize your results and draw conclusions based on your Discussion.

### STUDENT EVALUATION

Table 1 summarizes the results of student evaluations of the 3-D-imaging-pattern-classification project, assigned during the Fall term 2006, at SIUE.

### CONCLUSION

For our Image Analysis and Computer Vision course, we developed a set of laboratory exercises to introduce 3-D imaging to undergraduate and graduate students. An image database of range and brightness images was created using Canesta’s DP205 camera. The exercises culminated in a pattern classification project using those range images and provided an effective introduction to 3-D imaging. Results from students’ evaluations of the exercises and project were that 88% of the students *strongly agreed* or *agreed* that they “gained insight into the process of developing algorithms for automatic object classification via images;” and that 83% of the students *strongly agreed* or *agreed* that “this project is an excellent enhancement of the lectures.” These results verify that the labs and project are educationally effective and valuable for teaching 3-D imaging and pattern classification in an image analysis and computer vision course at the advanced-undergraduate/graduate level.

### ACKNOWLEDGMENTS

This project was partially funded by an Excellent in Undergraduate Education Grant from Southern Illinois University Edwardsville, Grant #06-52, Real-time single chip 3-D imaging, FY06.

### REFERENCES

- [1] The CVIPtools Web Site, <http://www.ee.siue.edu/CVIPtools>.
- [2] S. E. Umbaugh Computer imaging: digital image analysis and processing, The CRC Press, Boca Raton, FL, 2005.

- [3] M. Zuke and S. E. Umbaugh, CVIPtools: a software package for computer imaging education, *Comput Appl Eng Educ* 5 (1997), 213–220.
- [4] A. Mani, R. Swamisai, and S. E. Umbaugh, Web site for Computer Imaging Education, *Comput Appl Eng Educ* 8 (2000), 61–71.
- [5] E. R. Davies (Ed.), *Machine vision: theory, algorithms and practicalities*, 3rd edition, Morgan Kaufman, New York, 2005.
- [6] Canesta Electronic Perception SDK Reference Manual, Version 2.0, Rev. 4, Canesta, 965 West Maude Ave., Sunnyvale, CA, 2005. [www.canesta.com](http://www.canesta.com).
- [7] J. Park and G. N. DeSouza, 3D Modeling of Real-World Objects Using Range and Intensity Images Innovations in Machine Intelligence and Robot Perception (Edited by: S. Patnaik, L.C. Jain, G. Tzafestas and V. Bannnore), February 05, 2004.
- [8] G. Hetzel, P. Levi, B. Leibe, and B. Schiele, 3D Object Recognition from Range Images using Local Feature Histograms, IPVR, University of Stuttgart, D-70565 Stuttgart, Germany, Perceptual Computing and Computer Vision Group, ETH Zurich, CH-8092 Zurich, Switzerland.

## BIOGRAPHIES



**Scott E. Umbaugh** is currently a Professor in Electrical and Computer Engineering at Southern Illinois University at Edwardsville, where he is the Graduate Program Director and directs activities in the Computer Vision and Image Processing (CVIP) Laboratory. He received the BSE degree with honors from Southern Illinois University at Edwardsville in 1982, the MSEE in 1987 and PhD in 1990 from the University of

Missouri-Rolla, where he was a Chancellor's Fellow. He worked in industry as a computer design engineer from 1981 to 1986, and as a computer-imaging consultant since 1986. He currently serves on the editorial board for the *Pattern Recognition* journal; as well as being a reviewer for numerous IEEE publications. His professional interests include computer vision and image processing and engineering design education. He has authored numerous papers, co-authored two book chapters and two textbooks. The most recent book, published by the CRC Press, is *Computer Imaging: Digital Image Analysis and Processing*. Dr. Umbaugh is also the primary developer of the CVIPtools software package. He can be reached at the Department of Electrical and Computer Engineering, Southern Illinois University Edwardsville, Edwardsville, IL 62026-1801, or [sumbaug@ee.siu.edu](mailto:sumbaug@ee.siu.edu).



**Robert LeAnder** is currently an Assistant Professor in Electrical and Computer Engineering at Southern Illinois University at Edwardsville. He completed his bachelor's and master's degrees in electrical engineering ('97, '98) at Southern Illinois University Edwardsville, specializing in computer imaging. He received his doctoral degree in bioengineering from the University of Illinois Chicago ('02) specializing in bioelectromagnetics and functional electrical stimulation of

the retina using retinal implants. Dr. LeAnder's most recent work involves using image processing and computer vision for the automatic differentiation of skin tumors in dermoscopic images and the automatic segmentation of blood vessels in images of the retina.



**Patrick Solt** is currently a PhD candidate in Engineering Science at Southern Illinois University Edwardsville. He received his BS degree in Computer Engineering, summa cum laude, from Southern Illinois University Edwardsville in 2000. From 1999 through 2004, Pat worked as a software engineer, designing software for embedded control systems. He received the MS degree in Computer Science in 2007 from SIUE. His

professional interests include computer vision and image processing, pattern recognition and machine learning. He can be reached at [psolt@siue.edu](mailto:psolt@siue.edu).



**Mr. Amit Kharbanda** received his Bachelor of Science in Computer Engineering from the University of Pune, India in 2002 and the Master of Science in Electrical Engineering from Southern Illinois University Edwardsville in 2006. His research projects include developing labs for computer vision and image processing courses, designing and incorporating pattern classification in CVIP-tools, and developing algorithms to aid in the

classification of skin tumors. Amit's work, with Dr. Slattery of the SIUE Construction Department, on utilizing web camera technology to monitor steel construction was presented at the 1st International Conference on Construction Engineering and Management in 2005. Currently, Amit is working as a SAP consultant. Contact: [kharbandaamit@yahoo.com](mailto:kharbandaamit@yahoo.com).



**Pradnya Deokar** received her Bachelors Degree in Electrical Engineering from Pune University in 2002. Following completion of her undergraduate degree she was employed with Infosys, India's leading IT company, for one year. In 2004, Pradnya joined the Department of Electrical and Computer Engineering at Southern Illinois University Edwardsville and completed her Master of Science degree in Electrical Engineering in

2006. While at SIUE she worked on range image segmentation methods. Pradnya Deokar is currently employed as an Engineer with Digital Concepts, St. Louis, Missouri, an engineering manufacturer of electronic assemblies for the fitness and leisure markets.