

A MULTIMEDIA TUTOR FOR DIGITAL IMAGE PROCESSING FOR REMOTE SENSING

Krishna Mohan BUDDHIRAJU¹, S. KARTHIK, Vijendra NAYAK and G. ANU

Centre of Studies in Resources Engineering
Indian Institute of Technology, Bombay
Powai, Mumbai - 400076, INDIA
Corresponding author's email: bkmohan@csre.iitb.ac.in

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ABSTRACT:

The advances in remote sensing and geographic information systems technologies make it possible to deploy them in diverse applications for planning, resources management, environmental monitoring, and optimal urban/rural development activities. At the same time, the lack of availability of trained manpower in these areas is a concern, that can impede the penetration of these technologies. In particular, the high resolution digital imagery generated by sensors onboard spaceborne platforms require knowledgeable users to exploit their potential. One of the recent approaches to provide digital image processing training is based on detailed educational content along with other tools on CD-ROM or on web-servers for self-paced learning. The other tools include demonstrations, interactive exercises, case studies, software package to support most of the techniques discussed, sample datasets, glossary and bibliography. Such resources also help the teaching and training institutions, where even the instructors can benefit from the teaching aids in the form of CD-ROM and web-based tools. Students can benefit from access to lecture notes, software, exercises, short descriptions in the form of glossary and pointers to further reading through bibliography. In this paper, a CD-ROM and web-based digital image processing tutor DIPTORS (Digital Image Processing Tutor for Remote Sensing) developed at the Centre of Studies in Resources Engineering, Indian Institute of Technology, Bombay is described.

1. INTRODUCTION

Recent advances in remote sensing and geographic information systems technologies are immensely beneficial in diverse applications for planning, resources management, environmental monitoring, rural and urban development programs. At the same time, the lack of availability of trained manpower in these areas is a concern, that can impede the penetration of these technologies. In particular, the high resolution digital imagery generated by sensors onboard spaceborne platforms require knowledgeable users to exploit their potential. This is particularly true in developing countries, where maps at large scales (1:10,000 and above) are not easily available to the resource managers and planners, and such products need to be generated by interpreting and analyzing remotely sensed images. Further, many colleges in the developing countries may not have extensive teaching aids for instructors, or multiple licenses of expensive commercial packages to deploy in teaching laboratories while providing senior sophomore or Master's level education in the area of digital image processing for remote sensing.

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Many approaches are adopted in practice in this context to train manpower including classroom based short intensive courses, distance education through telecast/webcast programs among others. One of the recent approaches is to provide a software with sample images with image processing books so that readers can also experiment with the images to get a feel of the algorithms implemented. Mather (2004) is a classic example in this context, where he provides a software package, sample data, case studies, links to useful web pages etc. to supplement the material in the book. However, the material in the book is static, in the sense that there is very little interactivity while reading a hard copy. Another problem with books is that they may be without much mathematical detail (in the context of image processing algorithms) as can be seen in Mather (2004), Jensen (2004), Richards and Jia (1999) or full of mathematical content (e.g. Haykin, 1999 on neural networks) that may be too involved for a remote sensing student. An electronic reader can be designed to enable the user to select content, multimedia demonstration and explanation, interactive exercise, mathematical details etc.

¹ Corresponding author

while reading about any topic. This is the approach in DIPTORS that we developed on digital image processing for remote sensing at CSRE, IIT Bombay.

2. BRIEF REVIEW OF EDUCATIONAL MATERIALS

Gan and Kuo (2006) developed teaching content to teach Digital Signal Processing Software Development where various issues in implementation using fixed point arithmetic was discussed. Sarkar and Craig (2006) adopted a Wireless-Fidelity (Wi-Fi) project based approach to teach wireless communication and networking concepts to students. More attempts can be seen in Kuo and Miller (1996), Gan (2002), Lopez-Martin (2004) discussing the educational aspects of digital signal processing, random signals and noise. Abdel-Qader et al. discuss the curriculum for undergraduate signal processing courses. Rogers et al. (1995) discussed a multimedia tutor for manufacturing education that was used at Boeing company. Woolf et al. (1996) at the University of Massachusetts built Design for Manufacturing (DFM) computer modules which instruct students on efficient procedures for designing parts for manufacture. The intended use of these modules is to provide the student with the knowledge of design as well as the actual injection moulding and stamping. Cho et al. (2003) discuss the development of a multimedia tutor to teach microcontroller principles to students of bio-medical engineering. The tutor included movie clips, narration, animations, graphics and text to communicate the concepts.

Venkatachalam et al. (2001) developed a basic tutor on Geographic Information Systems whose framework was adopted in major part of the content development here. They divided the tutor into several parts:

- Subject Content (more than 15 topics briefly discussing the introduction to GIS, components of a GIS, concepts of map, spatial data models and data structures, spatial analysis, raster analysis, cartography, and GIS applications)
- Animated Demonstrations (to illustrate for principle of a few selected GIS operations)
- Case Studies (to demonstrate potential of GIS in real world applications)
- Glossary (of common technical terms used in GIS and remote sensing)
- Bibliography (list of useful websites, books and journals)

The early version of this tutor does not have any bundled software for the user, nor any interactive facilities.

3. DESIGN OF DIPTORS

The design of the tutor can be captured in Fig. 1 that illustrates the entire philosophy, structure and components. The most important component of the tutor is the subject content, divided into 35 topics covering both the basic and advanced areas of digital image processing for remote sensing.

3.1 Topics

The topics covered in the tutor include introduction to digital images, remote sensing, preprocessing and enhancement, up to classification and accuracy assessment.

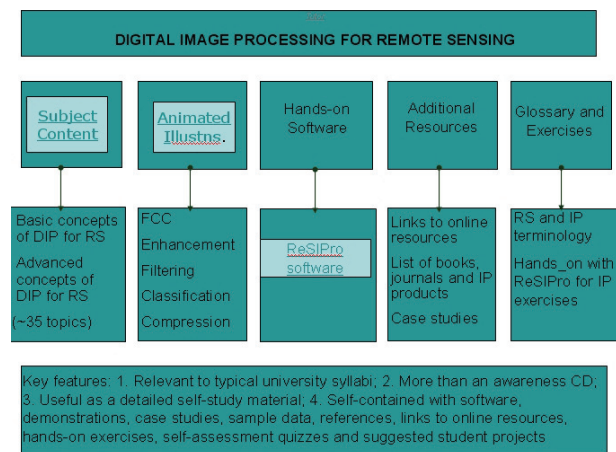


Fig. 1 Layout of the DIPTORS

Coverage of basic topics

Introduction to remote sensing and international remote sensing programs
 Image acquisition by imaging sensors
 Resolution
 Distortions in remotely sensed images and image corrections
 Image Enhancement and transforms
 Introduction to texture analysis
 Feature selection
 Image classification and accuracy assessment

The advanced topics predominantly discuss image segmentation and classification, with additional coverage including image compression, data compression and mathematical morphology.

Coverage of advanced topics

Neural networks and fuzzy logic
 Genetic algorithms

SAR image processing and interferometry
 Image segmentation principles
 Thresholding
 Edge and texture based segmentation
 Mathematical morphology and region segmentation
 Contextual classification and refinement
 Image compression
 Image data fusion
 Support Vector Machines

The content can be covered over a period of two semesters, where the advanced topics may be of interest to those students who are mathematically well equipped. The subject content is supplemented by links to interactive illustrations and experiments where the student can actually verify some of the basic operations using a hand-held electronic calculator on small (8x8 or 16x16) datasets or by executing programs to see the original and processed images one by the side of the other. Certain tasks such as are illustrated with automatic / user-controlled animations so that the results are easily understood. The authors feel that once the basic concepts are understood, then the advanced topics are easily handled. An example of the above is shown in Fig. 2, where the linear contrast enhancement is defined, and explained. The user has links to an example that can be hand-calculated for verification, and a demonstration where the enhancement can actually be executed on an image.

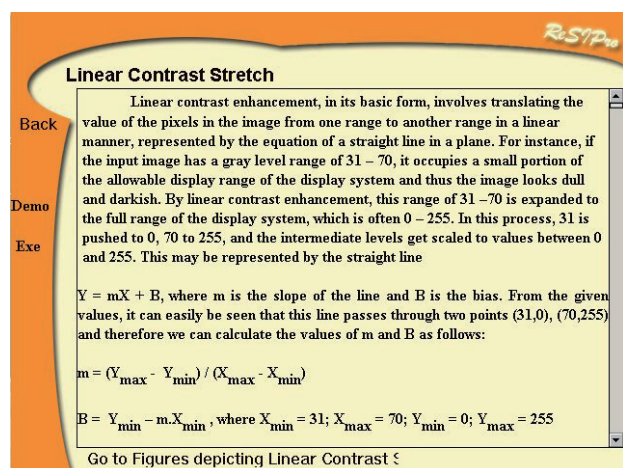


Fig. 2 View of the coverage of the content

Where figures are present, there are links to another page so that the main screen is not cluttered with too much text and figures.

The content is developed in such a manner that those well equipped with mathematical background can benefit from the mathematical equations to gain a better understanding of the actual computations involved, while

others can skip the mathematics and yet understand the underlying principles. It is our view that one of the shortcomings with current textbooks on digital image processing is the absence of enough mathematical detail to attract students of electrical engineering, computer science and such disciplines for whom the theory of image processing and analysis are of greater interest compared to the applications. It is therefore necessary to develop the tutor that can provide material to address the needs of both types of students. At the same time, we make no pretensions to building a comprehensive tutor that has equal coverage of digital image processing for remote sensing and applications to natural resources management and environmental monitoring. Some of this material can be found in the Case Studies part of the tutor. Also, the bibliography section has pointers to a wide range of books and papers addressing this aspect.

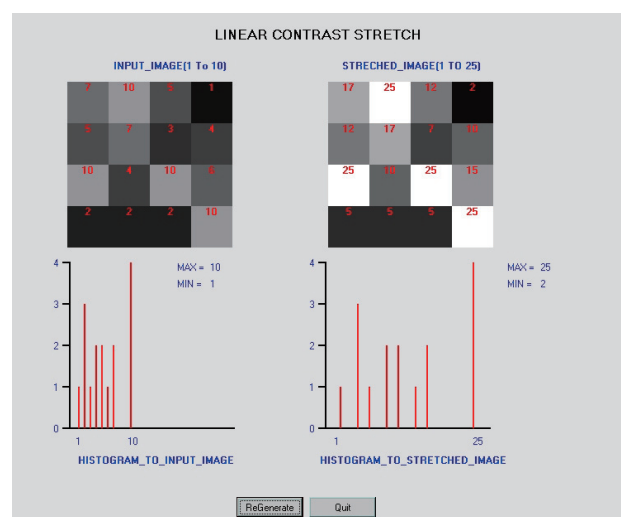


Fig. 3. Interactive example for Contrast Stretch

The entries in the above example are generated using random numbers, and by clicking on the “regenerate” button, the user can repeatedly generate new sample matrices and evaluate the technique manually. Similar functions are built for image display, enhancement, filtering, band arithmetic, parallelepiped and minimum distance from mean classification methods.

Once the concept is understood using small numerical examples, the student can use the program to display the input image and process it using the embedded executable programs (based on ActiveX). This example is shown in Fig. 3. This example illustrates the interactive tool where the user is able to choose one from among a few images available, choose the size of the window, and perform the median filter operation on the image. The filtered image can optionally be saved on the

disk. The user can vary the size of the window, and in each case view the degree of smoothing introduced by the filter. Using similar principle, a large number of executables are embedded into the tutor so that the examples, demonstrations can be taken right at the point where the content is browsed in the tutor.

In this manner, the user is assisted in understanding the image processing concepts based on simple hand-verifiable examples, followed by their visual impact on real images.



Fig. 4a. Original Image



Fig. 4b. Median Filtered Image

4. ReSIPRO SOFTWARE PACKAGE

The tutor is accompanied by a software package ReSIPRO (Remotely Sensed Image PROcessing) that is a standalone desktop image processing software package, that can be invoked from inside the tutor or externally. This package is used to enable the student to actually try out numerous image processing and analysis operations, such as:

Image geo-referencing – geometric transformation and resampling using nearest neighbor / bilinear / cubic colvolution

Contrast Enhancement – linear / logarithmic / exponential / histogram equalization

Filtering – Mean filtering / Median Filtering / Edge enhancement using Sobel / Prewitt / Laplace

Transforms – Principal Component Transform / RGB-HIS transform / NDVI / DFT / DWT

Band arithmetic – band difference / band ratio / band multiplication / band addition

Supervised classification – maximum likelihood / minimum distance from mean / parallelepiped / multiplayer perceptron neural network classifiers

Unsupervised classification - conventional k-means and fuzzy c-means clustering

Texture analysis – Cooccurrence matrix based texture feature extraction

Contextual classification – probabilistic relaxation labeling

Segmentation – Canny operator based edge detection, morphological watershed segmentation

Connected Component labeling – to label all the regions in an image after segmentation / classification

A limited number of images are provided along with the software to enable the user to gain experience in image processing.

Some of these programs are too involved to be built into the tutor through ActiveX and therefore the standalone software package is provided along with a few images. This package is simple to use and functionally rich, yet it is not meant to be used as a substitute for commercial products like Geomatica and ERDAS Imagine. The interface of this software is shown in Fig. 4. The package is developed in Microsoft Windows environment using

Visual C++ compiler. The tutor itself is built using Macromedia Authorware software. Macromedia Flash software is used for the animations. Most of the subject content discussed in this tutor is actually covered by the first author as part of two Master's level courses taught at IIT Bombay to the students of M.Tech. Natural Resources Engineering (NR-607 and NR-602; see www.csre.iitb.ac.in) for details.

5. OTHER TOOLS

The other tools present in this tutor include detailed glossary of remote sensing and image processing terms (alphabetically organized) and bibliography of books on remote sensing and image processing, references to key papers on each of the topics discussed, important websites of courses taught at different universities, webpages of commercial products, and links to useful resources on internet. The instructor's resources in the tutor include presentations on most of the lectures, suggested student projects, and brief notes for laboratory sessions. Another interesting feature here is a collection of case studies on the use of image processing techniques in different remote sensing applications.

A set of question papers is provided to help the instructor to test the understanding of the students. The questions are of three types: a) objective type questions that can be answered in one line b) short questions that can be answered briefly in 2-3 sentences and c) problems that need to be worked out based on a clear understanding of the concepts covered in the content.

Key websites such as the Canada Centre of Remote Sensing, the famous Remote Sensing Online Tutorial by Nicholas Short, Remote Sensing Core Curriculum website at the University of British Columbia, Paul Mather's website at the University of Nottingham are among those included in the tutor to help the reader to get access to material not covered in this tutor.

6. MULTIMEDIA PRESENTATIONS

In order to supplement the textual and graphical content in the tutor, selectively audio / video content is provided where certain concepts are explained by a human tutor. For instance, the concept of edge enhancement is explained using the text and graphics illustrating the intensity gradient and the edge, while the commentary through audio / video emphasizes the relationship between the intensity gradient and the location of the edge. Beginners to the field do not realize the fact that the intensity gradient is perpendicular to the orientation to the edge, and therefore high gradient magnitude in a given orientation points to the presence of edge in an

orientation orthogonal to the gradient direction. Further, edge magnitude is adequate to get an edge map, while edge orientation is required for analysis purposes, as well as to improve the edge map using the principle of edge connectivity, thinning, filling etc. Similarly the concept of histogram equalization as a tool for image enhancement also requires some explanation, since the process of reassignment of gray levels is tricky. Users who click on the appropriate button in a software tool to equalize the image often do not understand how the equalization occurs, or may not appreciate the fact that sometimes histogram equalization can lead to loss of detail in the tails of the histogram, leading to excess contrast than necessary.

7. CONCLUSIONS

We presented an image processing tutor specifically for remote sensing applications, and along with it a framework for a collection of tools to make it self-contained, catering to the needs of working professionals as well as Master's level students. For a full-time student, this tutor is a useful supplementary learning aid, while for the professional who cannot take time off to undergo classroom training, this can help as an introductory learning tool, till he is able to receive training by an expert in the field. The instructors can take advantage of ready teaching material, instructor's resources and software that can be used by each student for hands-on purposes in case expensive commercial tools are unavailable. The tutor is evolving, and we propose to continue working on this for several years to come, continuously refining the content, software, and ancillary tools discussed above. Our plans include development of a matlab version as well as a platform independent version using Java. The first author may be contacted regarding access to the tutor materials.

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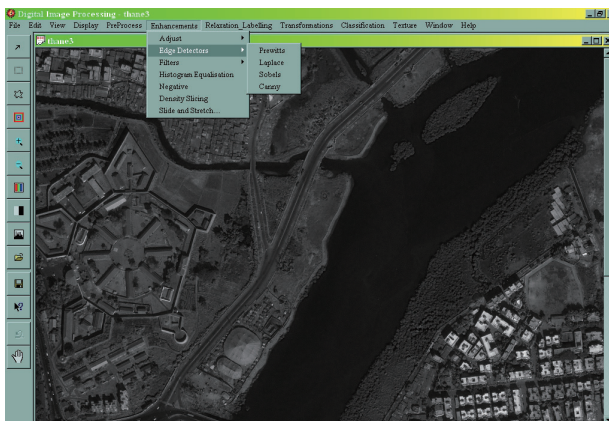


Fig. 5. Layout of ReSIPRO image processing software

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