

1 Introduction

1.1 Mission Statement

This two-semester lecture is designed for students, who want to treat images quantitatively. The first semester discusses the basics of image recording, image enhancement and image analysis. This will be done with examples and exercises. In the second semester the reconstruction of noisy images and the assessment of three-dimensional structures will be discussed.

1.2 Motivation

Following few image examples demonstrate the power of image processing.

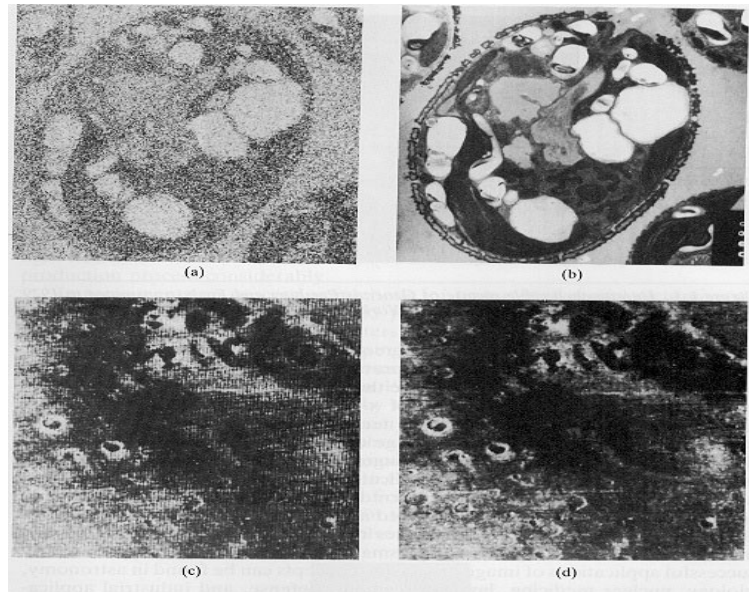


Figure 1-1 a) image of a cell heavily corrupted by electronic noise;
b) averaging several noisy images
c) Moon surface image corrupted during transmission by interference lines;
d) lines removed.

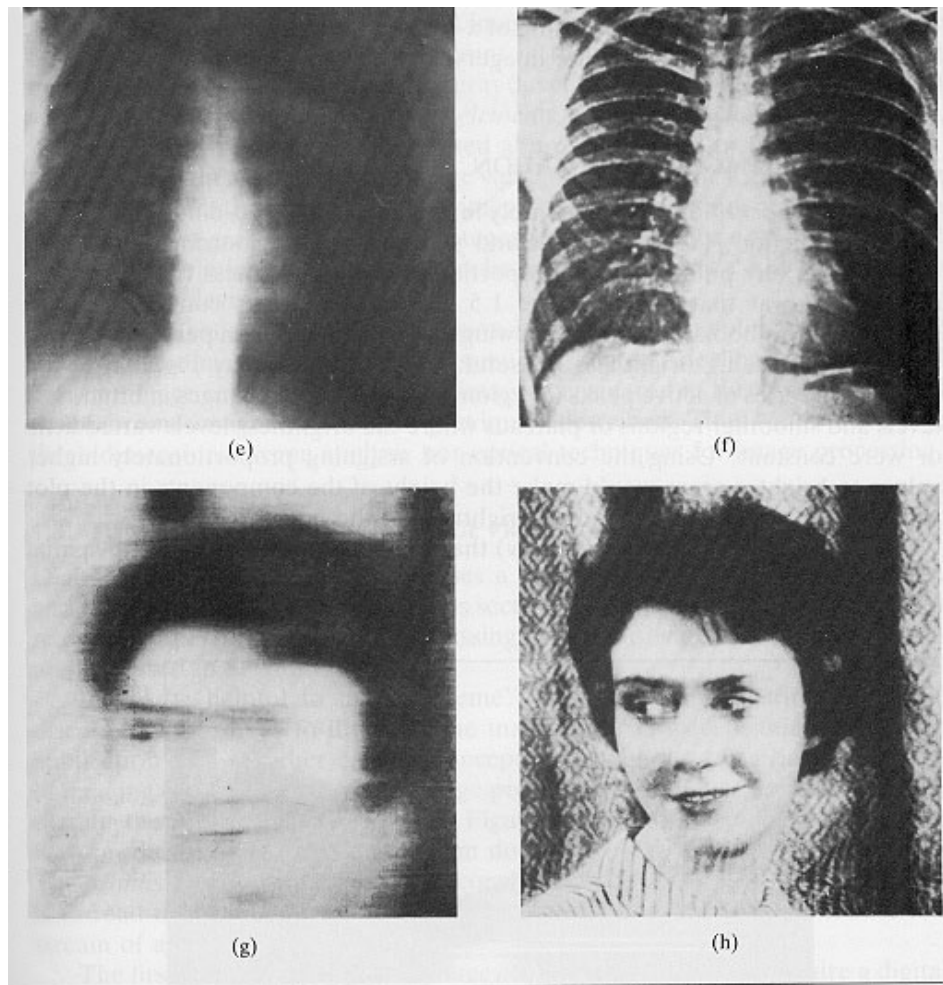


Figure 1-2 a) X-ray image; b) improved by edge and contrast enhancement
c) image blurred by uniform motion; d) result after deblurring algorithm applied.

Example:

Classification of Landsat Satellite images (test site Beckenried); 900km above sea level; July 1985
From K.I. Itten, et.al (University of Zürich)

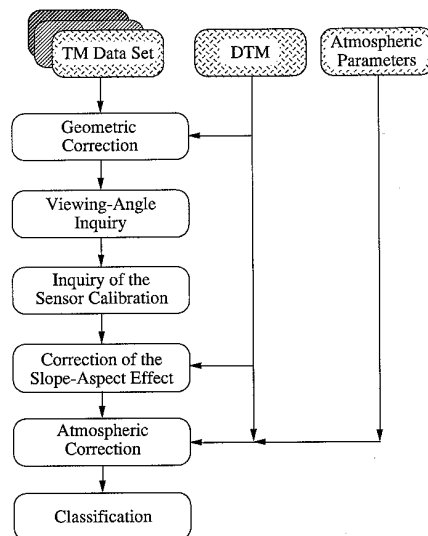


Figure 1-3 Flowchart of all (pre) processing steps

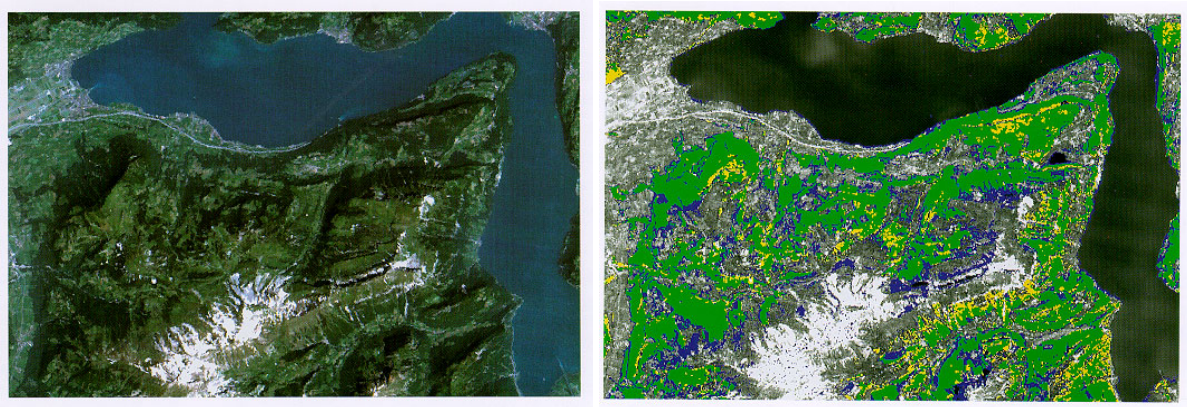


Figure 1-4 Forest vs. non forest classification
(green: correctly classified forest, blue: non forested areas classified as forest, yellow: forested areas classified as non forest)

Digital Phase - Measurement Technique:

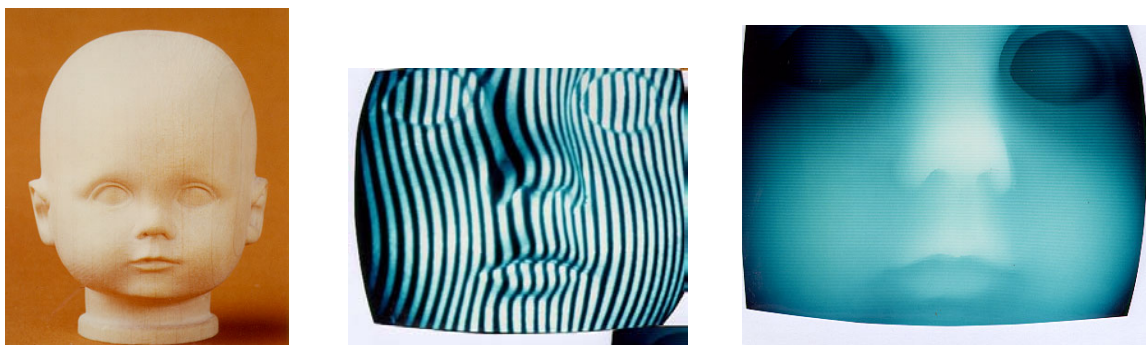


Figure 1-5 3D-Digitization of Surfaces (left to right: model, projected contour lines, calculated x/y/z map)

1.3 Applications of Digital Image Processing

Digital image processing techniques can be used to analyze a digital image or to process it to a new, improved image. Any situation requiring the enhancement, restoration, analysis, or creation of a digital image is a candidate for these techniques. Here are some of the major applications of digital image processing technology in use today.

With declining costs of general computing equipment and of specific devices for digital image acquisition, processing, and display, new applications emerge daily. Digital image processing is, and will be, the key technology for many innovations yet to come.

Biological Research

Bioresearch and biomedical laboratories use digital techniques to visually analyze components of a biological sample. In some cases, digital image processing techniques provide totally automated systems for specimen analysis.

- Image enhancement: various techniques for improving the visibility of features that are not evident or clear in the original image, such as contrast balancing and edge sharpening.
- Bone, tissue, and cell analysis: automatic counting and classification of cell structures and other objects meeting prescribed characteristics.
- DNA typing: analysis, classification, and matching of DNA material.

Defense / Intelligence

The military has made widespread use of digital image processing techniques for various applications. Defense and intelligence agencies of the United States, and of other governments, have poured vast resources into the research and implementation of the technology.

- Image enhancement: various techniques for improving the visibility of features that are not evident or clear in the original image, such as contrast balancing and edge sharpening.
- Reconnaissance photo interpretation: automated interpretation of earth satellite imagery to look for sensitive targets or military threats such as airports, sea vessels, missile launches, or military installations.
- Target acquisition and guidance: recognizing and tracking targets in real-time for smart bomb and missile-guidance systems.

Document Processing

Acquisition and processing of documents and drawings have helped to automate many industries that were classically paper driven, such as banking (check processing) and insurance-claim processing.

- Scanning, archiving, and transmission: converting paper documents to a digital image form, compressing the image, and storing it on magnetic or other media for archiving.
- Document reading: automatically detecting and recognizing printed characters so that documents like bank checks, tax forms, and so forth can be intelligently processed by computer.

Factory Automation

Vision systems in the manufacturing environment provide automated quality inspection and process monitoring. These systems free the human operator and inspector, while improving overall process accuracy and reliability.

- Visual inspection: automatically analyzing predetermined features of manufactured parts on an assembly line to look for defects and process variations.

Law Enforcement Forensics

Law enforcement agencies process large volumes of images for mug shots, evidence, and fingerprints. Various forms of digital enhancement, archiving, and classification processing are part of the modern operation.

- Image enhancement: various techniques for improving the visibility of features that are not evident or clear in the original image, such as contrast balancing and edge sharpening.
- Fingerprint feature analysis: automated fingerprint classification and identification operations.

- DNA matching: biological material analysis and matching between multiple samples.

Materials Research

Multidisciplinary laboratories involved in materials research use digital image processing techniques to visually analyze components of a material sample.

- Image enhancement: various techniques for improving the visibility of features that are not evident or clear in the original image, such as contrast balancing and edge sharpening.
- Material feature analysis: automatic counting and classification of objects, such as impurities and grain sizes meeting prescribed characteristics.
- Surface and structural rendering: creating three dimensional surface and internal structure renderings for visualization of features.

Medical Diagnostic Imaging

Medical radiological imaging looks at the internal components of the human body. X-ray imaging and computed tomography techniques make intensive use of digital image processing.

- Image enhancement: various techniques for improving the visibility of features that are not evident or clear in the original image, such as contrast balancing and edge sharpening.
- Digital subtraction angiography: enhancing blood vessel imagery by subtracting a baseline X-ray image from a second image with an X-ray opaque liquid in the bloodstream.
- Computed tomography-creating images using multiple image projections. This method is used in CT, MRI, and PET scanners.

Photography

Digital image processing techniques have augmented and, in some cases, replaced methods used by the photographer for image composition and darkroom processing.

- Image enhancement: various techniques for improving the visibility or artistic rendering of features that are not acceptable or clear in the original image, such as contrast balancing, edge sharpening, color balancing, or retouching of defects.
- Multiple-object scene compositing: adding and subtracting objects to and from a scene to create illusions that did not originally exist.
- Special effects: warping, blending, and other visual effects to convert existing imagery into new visual forms.

Publishing / Prepress

The desktop publishing and prepress industries use digital image processing techniques to enhance and lay out digital images for publication. Most publications use digital image and typography techniques.

- Image enhancement: various techniques for improving the visibility or artistic rendering of features that are not acceptable or clear in the original image, such as contrast balancing, edge sharpening, color balancing, or retouching of defects.
- Layout compositing: mixing of image, text, and graphical elements into final film suitable for printing.
- Color separation: creating cyan, magenta, yellow, and black film separates for the four-color printing process.

Remote Sensing/Earth Resources

Orbiting satellites image every square mile of the Earth's surface on a regular basis for resource management purposes. This image data is used to analyze crop yields and damage due to disease, early frost, and other factors.

- Landcover analysis: measuring various vegetation features such as water content, temperature, chlorophyll absorption characteristics, and geometric features.
- Terrain rendering: creating three-dimensional Earth terrain renderings for analysis, based on elevation data returned by remote sensing satellites.

Space Exploration /Astronomy

Digital imaging systems are used almost exclusively on board exploratory spacecraft and earthbound telescopes. This equipment makes extensive use of digital image processing techniques to enhance, restore, and analyze extraterrestrial imagery.

- Image enhancement: various techniques for improving the visibility of features that are not evident or clear in the original image, such as contrast balancing and edge sharpening.
- Imaging system deficiency correction: techniques for correcting known and unknown defects in the

original image, such as sensor response non linearities, geometric distortions, image noise, and motion blur.

- Automatic event detection: detecting features that are changing over time, such as solar activity and other cosmic events.
- Terrain rendering: creating three-dimensional planetary terrain renderings based on elevation data returned by exploratory satellites and space vehicles.

Video/Film Special Effects

The video and film production industries use various digital image processing techniques for creating and hiding artifacts of special visual effects.

- Multiple-object scene compositing: adding and subtracting objects to and from a scene to create illusions that did not originally exist.
- Scene creation: fabricating synthetic imagery when physical creation would be costly or impossible.
- Special effects: warping, blending, and other visual effects to convert existing imagery into new visual forms.

Video Programming Distribution

Methods for reducing the data size of images improve both video archiving and transmission processes. The television program distribution industries such as cable television, direct-broadcast satellite, and electronic video movie distribution can all benefit greatly from image compression techniques.

- Video archiving and transmission: removing redundant information from a digital image or sequence of images; this reduces data size, making transmission faster, archiving more efficient, and both processes less expensive.