VIEWING NOTES

Correction and Enhancement of Digital Image Data

by Paul E. Anuta

VIDEOTAPE SERIES

Introduction to Quantitative Analysis of Remote Sensing Data

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PREFACE

Remote sensing helps provide up-to-date information critical to the management of earth resources on a regional, national, and international level. As data collection and communication techniques are refined, as computational and analysis technologies evolve, and as sophisticated output devices become more economical, remote sensing will play an ever larger role as a source of information. The videotape you are about to see is one in a group of educational programs developed at Purdue University to keep scientists and administrators abreast of this rapidly evolving technology.

Purdue University has long been a leader in the development of remote sensing technology through the Laboratory for Applications of Remote Sensing (LARS). For over fifteen-years, the interdisciplinary staff, from the schools of agriculture, engineering, and science, has been responsible for much of the development in remote sensing and has gained world-wide recognition through these accomplishments. Today, activities at the Laboratory include both fundamental research and applications research, with additional major emphasis on training people in the use of quantitative remote sensing systems and developing educational materials to foster understanding of the technology.

Several key aspects of remote sensing technology are addressed in these videotapes, which make up the series Introduction to Quantitative Analysis of Remote Sensing Data. The tapes focus on such topics as scene radiation, data collection and preprocessing, and data analysis -- from both theoretical and applications perspectives -- and each from the perspective of a single scientist who is recognized as an expert in the field. In this way, when you view each tape, you are able to share personally in the insights and judgements offered on this increasingly important technology.

Videotape presentations in the series include the following titles:

The Role of Numerical Analysis in Forest Management by Roger M. Hoffer, professor of forestry.
The Role of Pattern Recognition in Remote Sensing by Philip H. Swain, associate professor of electrical engineering.
The Remote Sensing Information System by David A. Landgrebe, professor of electrical engineering and associate dean of engineering.
Correction and Enhancement of Digital Image Data by Paul E. Anuta, research engineer.
Spectral Properties of Soils by Marion F. Baumgardner, professor of Agronomy.

Level and Prerequisites

The videotape series was prepared for graduate and advanced undergraduate students and professionals new to the field of remote sensing. Before viewing this tape, you should already have a basic understanding of remote sensing and its related terminology, such as can be gained through any of a number of introductory texts or through studying selected minicourses in the series Fundamentals of Remote Sensing (Purdue University, 1976, 1980).

Despite the mathematical and statistical nature of some aspects of the technology, the videotapes have been prepared with non-mathematical audiences in mind. Whenever possible mathematical relationships are illustrated graphically and described verbally. You may wish to consult the textbook Remote Sensing, the Quantitative Approach, edited by Philip H. Swain and Shirley M. Davis (McGraw-Hill Book Company, New York, 1978), for in-depth explanations of many of the concepts presented.

About the Author

Paul E. Anuta is associate program leader for data handling research at Purdue University's Laboratory for Applications of Remote Sensing. Mr. Anuta is responsible for research and evaluation of remote sensor data preprocessing techniques, with particular emphasis on image registration, geometric correction and resolution enhancement of satellite multispectral imagery. He has been principal investigator for several NASA and NSF grants to develop methods for multivariate preprocessing and for analysis of geophysical data.

Acknowledgements

Others at Purdue University who contributed to this videotaped program were Shirley M. Davis, senior education and training specialist; James D. Russell, associate professor of education; Neil Sydor, producer-director; Susan L. Ferringer and Kathleen Z. Barash, visual designers; Sara Jane Coffman, instructional developer; and Luis A. Bartolucci, program leader for technology transfer, LARS. Opening music by Richard K. Thomas. Viewing notes were prepared by Shirley Davis and James Tilton.

Appreciation is also expressed to Earthsat Corporation for supplying examples of enhanced imagery.

Funds supporting the development of the videotaped programs and viewing notes were provided by the Continuing Education Administration, Purdue University. The authors express special appreciation to Mr. G.W. O'Brien for his generous support of this project.

Time: 28 minutes

Correction and Enhancement of Digital Image Data
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Synopsis

Digital image data, such as that collected by multispectral scanners, often undergoes a series of mathematical operations that improve the data for subsequent analysis. The operations are intended to correct the data to remove defects or to enhance it to make it easier to analyze. Two commonly performed types of corrections are geometric corrections and radiometric corrections. The purpose of geometric corrections is to remove distortions in image geometry, such as skew, scale and rotation--distortions which have been caused by variations in the position or angle of the scanner relative to the earth below. Radiometric corrections reduce errors in the data caused by detector noise and environmental variations; many of these errors can be corrected in a preprocessing step prior to analysis. Data enhancements are performed to improve the quality of digital images or to emphasize certain properties of the scene. Examples of data enhancement are ratioing two images, edge enhancement, principal components transformations, and two-dimensional Fourier transformations. The product of each of these transformations, whether geometric or radiometric correction or enhancement, is a new digital-image data set. Effective use of correction and enhancement techniques requires an understanding of the alterations made in the data.

Objectives

Upon completion of this videotape, you should be able to:

1. Explain in general terms why corrections and enhancements are performed on image data.

2. State at what point during the data handling process image data corrections and enhancements may be performed.

3. List several sources of geometric and radiometric errors.

4. Give the affine transformation and state the six geometric errors it can correct.

5. Explain, with the aid of a sketch, a method for correcting shading error due to large view angles.

6. Describe three methods of image enhancement (band ratioing, gradient and principal components) and state the main effect of each enhancement.

-- TURN PAGE --

-- BEGIN VIEWING THE TAPE --

I. Basic Definitions

"Image corrections are performed to remove defects caused by data-collection or data-transmission."

"Image enhancements are done either to improve the visual appearance of the scene or to make the data analysis more efficient."

II. Geometric Corrections

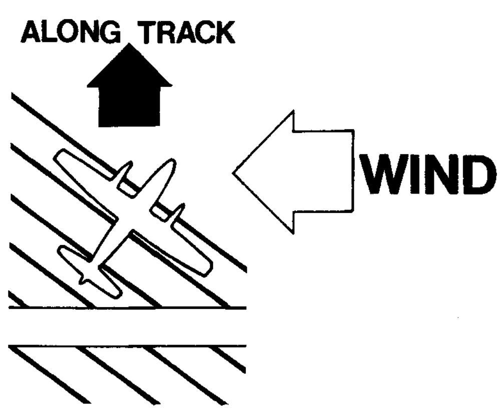
A. Sources of Geometric Distortions

1. Angular Variables
   a. Pitch is the up and down movement of forward moving end of the sensor platform.
   b. Roll is the side to side rolling of the sensor platform.
   c. Yaw is the turning of the sensor platform to the left or to the right of the straight ground track.

2. Positional Variables
   a. "Along track" or "x-movement" irregularities.
   b. "Cross track" or "y-movement" irregularities.
   c. "Vertical" or "z-movement" irregularities.

3. Additional Sources of Geometric Distortions in Landsat Data
   a. Skew distortions are caused by the rotation of the earth beneath the satellite.
   b. Rotation distortions of the data happen because the satellite follows a track about 12° off of north to south at the equator. (Strictly speaking rotation at the equator is not a distortion. Rotation must be corrected only to create a conventional north-south orientation for the final image.)
   c. Scaling distortions occur because the sensor views slightly elongated ground areas for each measurement.

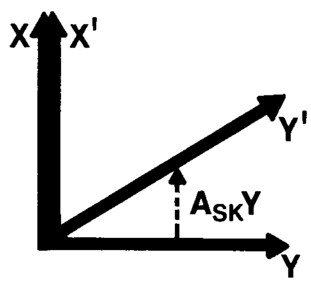
4. An Example: Skew caused by aircraft yaw.



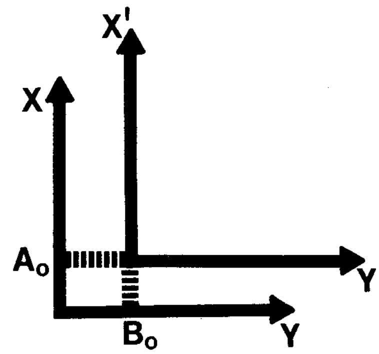
(Note that skew can also occur in satellite data due to the earth's rotation.)

B. Geometric correction formulas

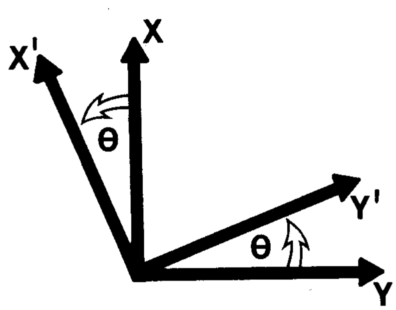
Skew correction: $X' = X + A_{sk}Y$
$Y' = Y$



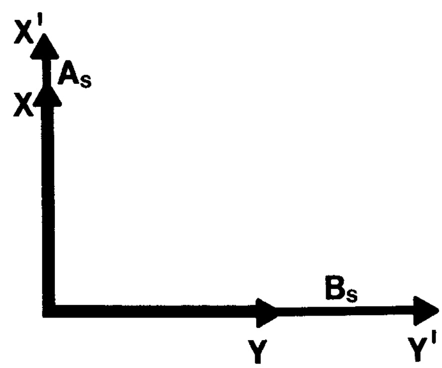
Translation correction: $X' = A_o + X$
$Y' = B_o + Y$



Rotation correction: $X' = X\cos\theta - Y\sin\theta$
$Y' = X\sin\theta + Y\cos\theta$



Scaling correction: $X' = A_sX$
$Y' = B_sY$



"and when all are combined into a single expression, we have an <u>affine transformation</u>."

Affine Transformation: $X' = A_0 + A_1X + A_2Y$
$Y' = B_0 + B_1X + B_2Y$

C. Geometric Correction of Landsat Data

The affine transformation can be used to correct up to about a quarter of the Landsat frame. (Something less than a quarter of the Landsat frame is shown on the videotape.)

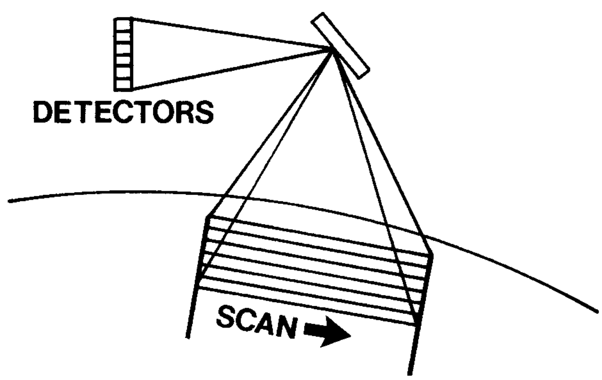
> "A full frame of Landsat MSS imagery, covering approximately a 100-mile square, can be corrected to sub-pixel positional accuracy using [a] fifth-degree polynomial in both directions."

> "For high precision in geometric correction, clearly identifiable control points must be selected in the imagery--such as an intersection of two major roads. [In order to evaluate the coefficients of the correction polynomial,] twenty to forty points must be used for correcting a full frame of Landsat data."

III. Radiometric Corrections

A. Detector Related Sources of Radiometric Error

> "For the Landsat MSS system, six matched detectors in each wavelength band scan the scene in one sweep. Therefore, successive sets of six contiguous scan lines create a single-band image of the scene."

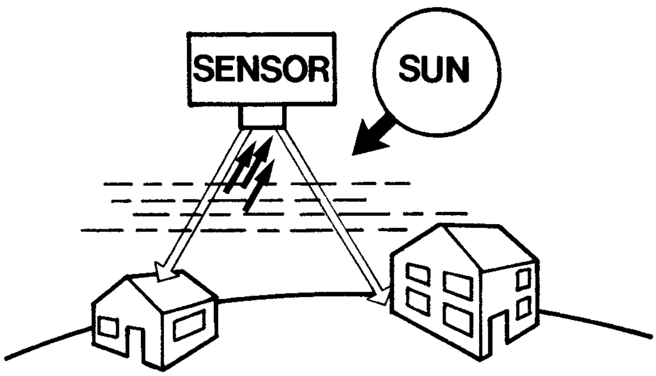


> "Variations among the individual detectors can cause...striping...."

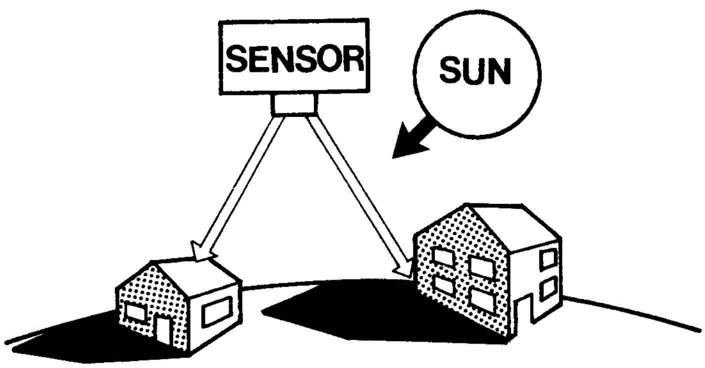
> "...other radiometric variations may derive from...power supply [variations], temperature variations, or aging of the equipment."

> "Filtering techniques are used to remove [detector] noise...."

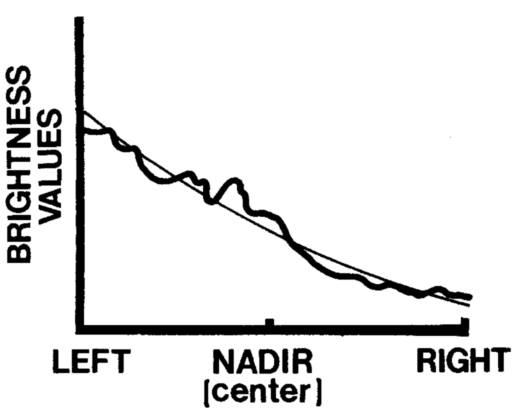
B. Environmentally Related Sources of Radiometric Error



"A radiometric effect--which is called backscattering--occurs when...some of the energy that reaches the sensor has been reflected to it by the water vapor in the atmosphere, and not by the earth."



"[Shadows cause] objects which should have the same reflectance [to] yield very different measurements."

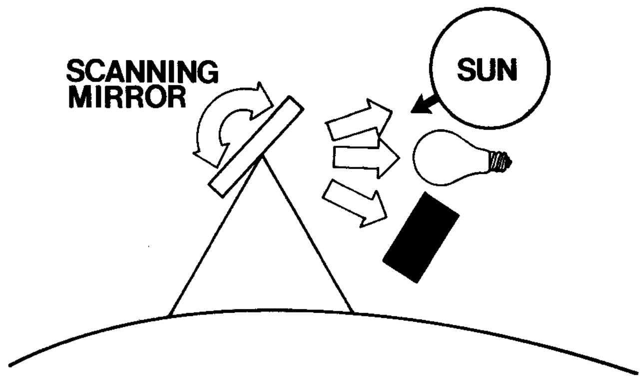


"It is possible to plot the statistical means of the brightness values of vertical strips of imagery; and then, by smoothing the curve,...correct the brightness of the data across the entire image."

"The atmosphere also causes radiometric errors; changing the radiation passing through it by absorping and scattering the energy, often randomly. The biggest problem is clouds,...[data affected by clouds] cannot be improved by correction."

C. Calibration of Scanner Data

Calibrating the data to a reference standard gives the data specific quantitative meaning.



"For the Landsat MSS, calibration is possible since, with each swing of the sensing mirror, the sensors measure the radiance of an incandescent reference lamp of known intensity... Some scanners also use the sun and a black plate for obtaining calibration data."

IV. Image Enhancements

A. Enhancement by Band Ratioing

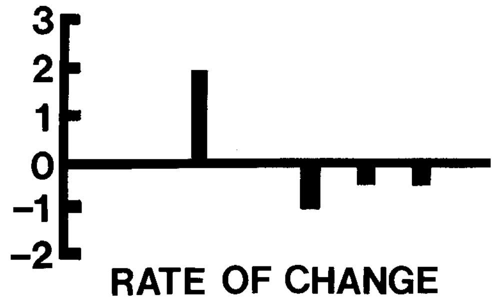
An enhanced image can be created by ratioing, i.e. "by dividing the values in one band, pixel-by-pixel by the corresponding values in an adjacent band."

"The ratioing essentially cancels out the shadows."

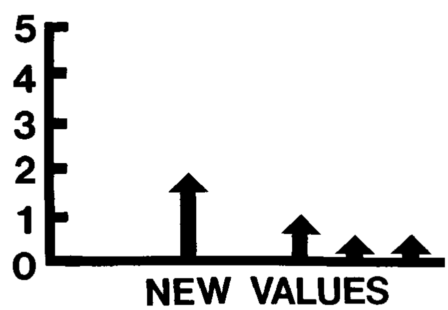
B. Gradient Enhancement

"...gradient enhancement...emphasizes linear features in specific directions as well as the edges between objects in the scene."

"The transformation for this enhancement involves comparing brightness values along orthogonal directions in the image,



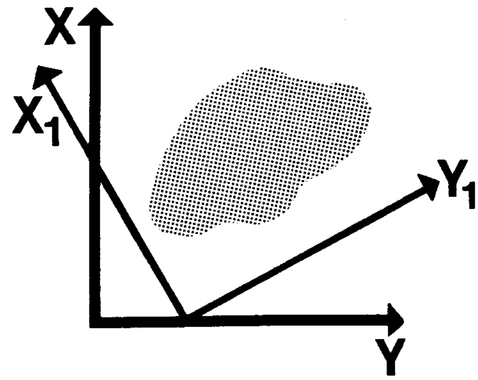
"calculating the rate of change in gray level values



"and then creating new pixel values to show the magnitude of the rate of change."

C. Enhancement by the Principal-Components (Karhunen-Loève) Transformation.

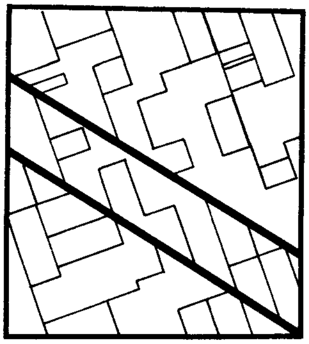
> "The principal components transformation reduces...redundancy[of information in scanner image channels] by compressing the information into fewer channels."



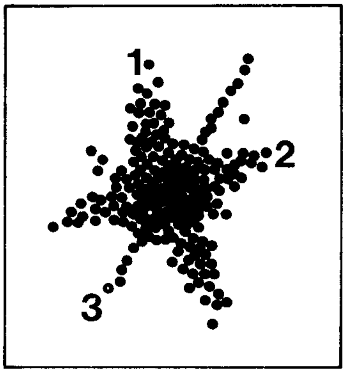
> "The basis of this transformation is that a multidimensional data set, here represented by values along the x and y axes, acquires new values that describe its spread along a new set of axes, x_1 and y_1, in this two-dimensional example."

D. The Two-Dimensional Fourier Transform

"Another transformation which is also used to analyze spatial characteristics is the two-dimensional Fourier transformation."



ORIGINAL DATA



FOURIER TRANSFORM

"The strongest line in the transformation, line 3, is caused by the highway and canal."

"The Fourier transformation is also useful for detecting geological lineaments which may be too subtle to be seen on the original scene."

V. Summary

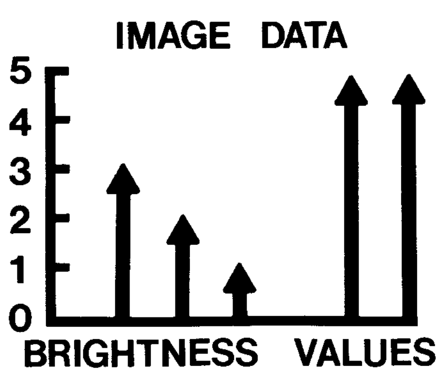
"Correction and enhancement of digital image data are powerful tools, but, because these techniques actually replace original data with new values, they require an analyst who understands the nature of the data being analyzed. The three subjects illustrated in this videotape, geometric correction, radiometric correction, and image enhancement provide a basic survey of both the required and the optional operations."

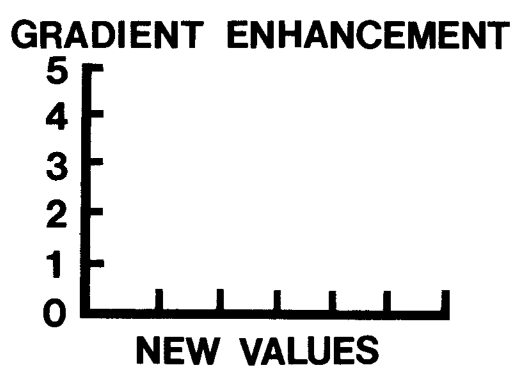
SELF-CHECK QUESTIONS

1. List six sources of geometric distortion and three sources of radiometric error.

2. State the effects band-ratioing, gradient and principal-components enhancements have on image data.

3. Given the image brightness values graphed below, use the gradient enhancement to find new pixel values and plot on the graph provided.





CHALLENGE QUESTIONS

1. A 20-channel MSS was flown by an aircraft in early morning through a strong crosswind. Describe the characteristics you would expect the data to have. State which corrections and enhancements would be appropriate to use on this data and why. Describe how each correction and enhancement is performed.

2. Write the coefficients of the affine transformation (A_0, A_1, A_2, B_0, B_1, B_2) in terms of the coefficients of the six basic geometric corrections (A_{sk}, A_0, A_1, $\cos\theta$, $\sin\theta$, A_s, B_s).

ANSWERS TO SELF-CHECK QUESTIONS

1. The sources of geometric distortion listed should include six of the following: pitch, roll, yaw, along track (x-movement) irregularities, cross track (y-movement) irregularlities, vertical (z-movement) irregularities, rotation of the earth, flight or orbit track off of north-south (or east-west) and scale differences. The three sources of radiometric error are variations in the detector(s), atmosphere effects such as backscattering and shadows.

2. The band ratioing enhancement essentally cancels out the shadows. The gradient enhancement emphasizes linear features. The principal components enhancement reduces redundancy of information in scanner image channels by compressing the information into fewer channels.

3.