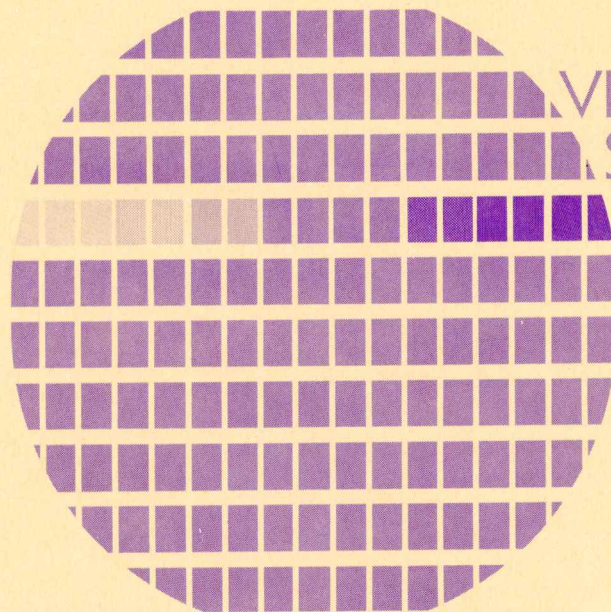


VIEWING NOTES

The Role of Pattern Recognition in Remote Sensing

by Philip H. Swain



VIDEOTAPE
SERIES

Introduction to Quantitative Analysis
of Remote Sensing Data

Inquiries about the VIDEOTAPE SERIES may be directed to:

CONTINUING EDUCATION ADMINISTRATION
116 Stewart Center
Purdue University
West Lafayette, Indiana 47907 (USA)

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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

Philip H. Swain is associate professor of electrical engineering at Purdue University and is program leader for data processing and analysis research at the Laboratory for Applications of Remote Sensing. A widely known lecturer and teacher, Professor Swain is frequently invited to make both tutorial and research-related presentations in this country and abroad.

He has organized several advanced-level remote sensing short courses and workshops and has developed educational materials in this field, including a textbook, Remote Sensing: The Quantitative Approach, for which he is co-editor and contributing author.

Since 1966, Professor Swain's research has focused primarily on the application of pattern recognition theory to the analysis of remote sensing 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; Sara Jane Coffman, instructional developer; Susan L. Ferringer, visual designer; and Luis A. Bartolucci, program leader for technology transfer, LARS. Opening music by Richard K. Thomas. Viewing notes were prepared by Shirley M. Davis and Philip H. Swain.

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Synopsis

Pattern recognition is a natural approach for classifying unidentified elements, such as pixels, into discrete classes. Multi-dimensional measurement space can be carved into decision regions by using training samples representative of the classes of interest. Computer-based pattern recognition uses mathematical expressions called discriminant functions to decide on class membership. Since the classes we would wish to discriminate among do not always occupy distinctly separate portions of the measurement space, we must deal with some uncertainties in classification. By using a statistical decision-making strategy, the maximum-likelihood decision rule, we improve our chances of being correct.

Objectives

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

1. Describe in general terms how pattern recognition is used in the analysis of remote sensing data.
2. State functional, remote sensing-related definitions for the following pattern recognition terms: measurement vector, measurement space, decision region, decision surface, training samples, discriminant functions.
3. Draw a sketch that shows how decision surfaces carve up the measurement space to differentiate among spectral classes of data.
4. Given a set of discriminant functions, decide on the probable class membership of a specific measurement vector.
5. Describe how a player in the Funny Dice Game uses a statistical approach to improve decision making in the face of uncertainty.

-- TURN PAGE --
-- BEGIN VIEWING THE TAPE --

I. Applicability of Pattern Recognition in Remote Sensing

|| "When we want to classify pixels into discrete classes, such as crop species in an agricultural scene, pattern recognition is a natural approach."

II. Terminology of Pattern Recognition

- a) Measurement vector: an ordered set of measurements from an object (or ground area), represented by a column of numbers or a point in measurement space.
- b) Measurement space: a multidimensional coordinate system in which each axis corresponds to one of the sensor channels.
- c) Decision regions: the regions of measurement space identified with each of the classes of interest.
- d) Decision surface: surfaces which divide the measurement space into decision regions.
- e) Discriminant functions: mathematical functions which indicate in which decision region any given measurement vector lies.
- f) Training samples: data vectors of known identity, representative of the classes of interest and used to determine a suitable set of discriminant functions.

III. An Example: "Funny Dice"

One possible set of discriminant functions for classifying the dice:

$$G_1(X) = x_1 - 2x_2 + 10 \quad (\text{std.})$$

$$G_2(X) = 3x_1 - x_2 - 10 \quad (\text{aug.})$$

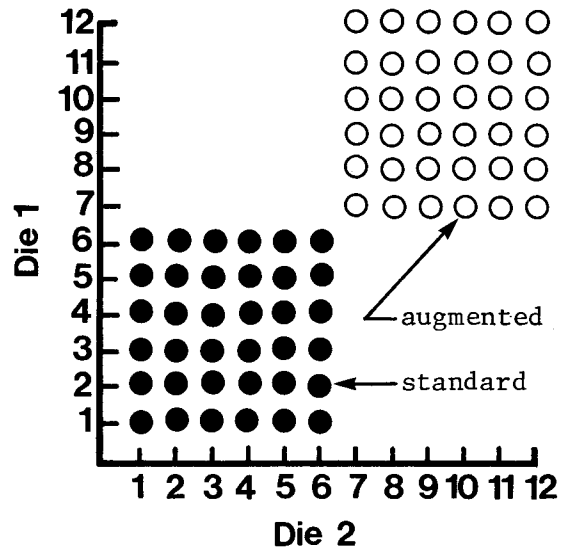
When evaluated at (5,4), i.e., die 1 is 5, die 2 is 4:

$$G_1(5,4) = 5 - 2(4) + 10 = 7$$

$$G_2(5,4) = 3(5) - 4 - 10 = 1$$

$$G_1(5,4) > G_2(5,4)$$

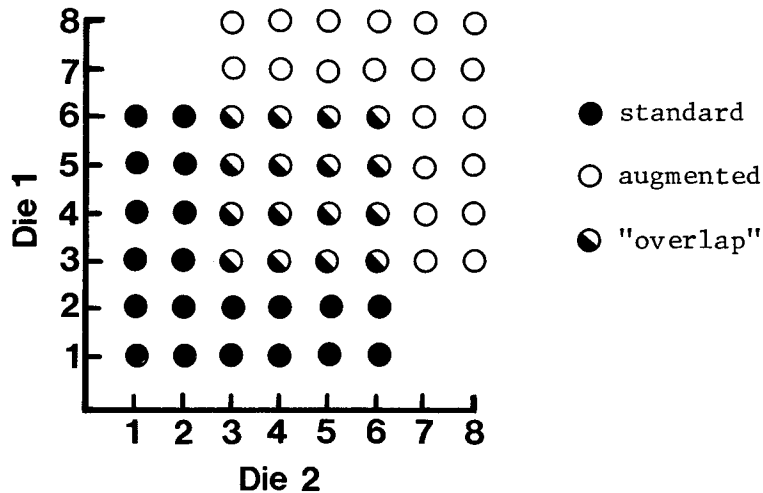
•• If a 5 and 4 are rolled, the dice must be the standard set.



Measurement space for two pairs of "Funny Dice":
"standard" and "augmented"

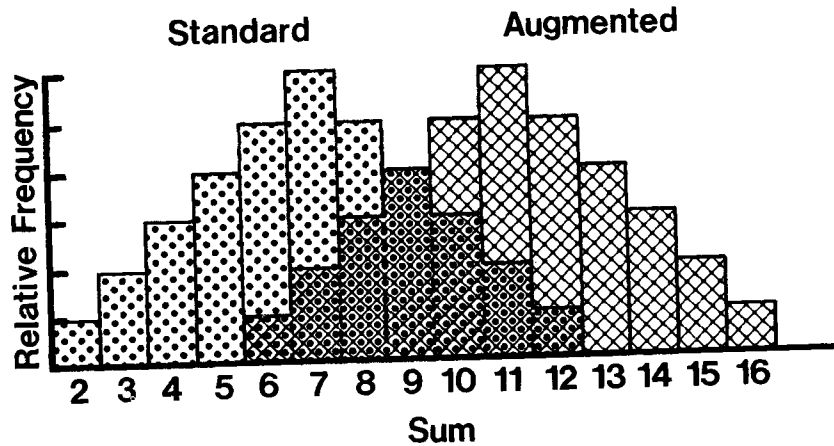
IV. Classification in the Face of Uncertainty

"Only rarely do all of the classes we'd like to discriminate occupy distinctly separate portions of the measurement space. In other words, measurements from different classes sometimes look the same! And so, in classifying such remote sensing measurements, we must deal with some uncertainty with respect to the correct classification."



Overlapping situation for standard pair and second pair of "Funny Dice."

"If we study the frequencies with which different combinations occur for each set of dice, we can get enough information about how the dice differ in their behavior to allow us to make an educated guess....the odds of being right will be in our favor."



Decision regions lie on either side of boundary defined by values of equal frequency.

Discriminant functions:

$$G_1(X) = x_1 + x_2 + 9$$

$$G_2(X) = 2x_1 + 2x_2$$

Example: (2,3)

$$G_1(2,3) = 2 + 3 + 9 = 14$$

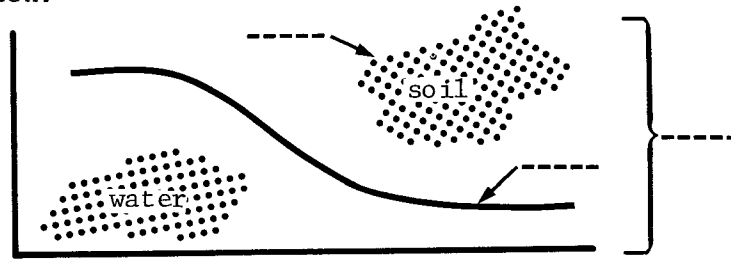
$$G_2(2,3) = 4 + 6 = 10$$

∴ Decide standard set.

"In remote sensing there are several possible sources of uncertainty....We can observe the relative frequencies of the measurements associated with these cover types and, by applying our statistical decision strategy, tip the odds in our favor. We can make maximum-likelihood decisions which have a higher probability of being right than of being wrong."

SELF-CHECK QUESTIONS

1. Fill in the four blanks in the figure below with the letter of the term that defines each.



$$\left. \begin{aligned} G_1(X) &= x_1 + x_2 + 2 \\ G_2(X) &= 2x_1 + 2x_2 \end{aligned} \right\} \text{---}$$

- | | |
|-----------------------|---------------------------|
| a) measurement vector | d) decision surface |
| b) measurement space | e) discriminant functions |
| c) decision region | f) training samples |

2. A three-dimensional measurement

$$X = \begin{bmatrix} 3 \\ 4 \\ 6 \end{bmatrix}$$

is to be classified by the following set of discriminant functions:

$$G_1(X) = x_1 + 0.5x_2 + 2x_3 + 1$$

$$G_2(X) = 2x_1 + x_2 + 0.5x_3$$

$$G_3(X) = 3x_1 + 2x_2 - 4x_3 - 3$$

To which class does X belong?

3. Describe how the player in the Funny Dice Game uses statistical decision-making to improve the chances of winning.

CHALLENGE QUESTIONS

1. Based on the description of pattern recognition given in this tape, what are the steps involved in using pattern recognition in remote sensing?

2. Explain how a pattern-recognition system will go about classifying pixels in the area which belong to classes not represented in the training classes. How might this situation be remedied?

Answers to both of these Challenge Questions may be found in the first reference cited on the next page.

FURTHER READING

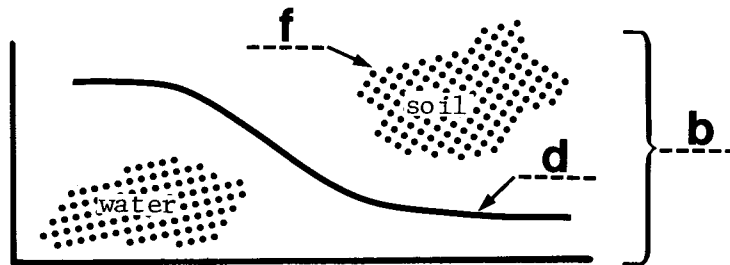
Swain, P.H. and S.M. Davis, eds. Remote Sensing: The Quantitative Approach, McGraw-Hill Book Company, New York, 1978. Pages 136-148.

Lindenlaub, J.C. and P.H. Swain, "Pattern Recognition in Remote Sensing" in the minicourse series Fundamentals of Remote Sensing, Purdue Research Foundation, W. Lafayette, Indiana, 1976.

Lintz, J., Jr. and D.S. Simonett, eds. Remote Sensing of Environment Addison-Wesley Publishing Company, Inc., Reading, Mass. 1976. pp. 353-371.

ANSWERS TO SELF-CHECK QUESTIONS

1.



$$\left. \begin{aligned} G_1(X) &= x_1 + x_2 + 2 \\ G_2(X) &= 2x_1 + 2x_2 \end{aligned} \right\} \text{--- e ---}$$

2. Class 1

3. The player calculates the probabilities of occurrence of each of the sums and then uses this information to improve the chance of guessing class membership correctly.