COLLOQUIUM TALK

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# PATTERN RECOGNITION TECHNIQUES IN FILM DATA ANALYSIS

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## I. Introduction

I should like to take this opportunity to tell you about some pattern recognition techniques that have been found to be applicable in practical problems of analysis of film data. I should say at the onset that the theoreticians upon seeing the success of their theories, will say - "Of course, we knew it all along". An experimentalist, on the other hand, might fairly ask the theoretician to tell him, before the fact, which of these techniques will work on what problems. (Feynman anecdote).

It is hardly necessary to emphasize the importance of both theoretical and experimental work on machine methods for processing graphic data. A great deal of data acquired in the course of experiments in many fields of science come to us quite naturally in graphic form. In fact, almost every discipline is engaged in experimental research that yields graphic data - to name a few: Optical Astronomy yields film data on cell structure and cell processes such as chromosome subdivision; radiological biology makes use of film data in the study of bone tissue; medical research in areas such as hematology make use of graphic data; chemical and metallurgical engineering record patterns in photostress analysis; metallurgy and solid state physics yeild electron microscope pattern for measurement and analysis; and high-energy particle physics yields photographs of tracks and particle interactions in spark chambers and bubble chambers. In these examples, quantitative as well as qualitative analysis is made of the film data, thus calling for techniques for measuring as well as scanning.

There are areas of utilization of film data that are grossly more qualitative, such as fingerprint analysis; aerial photographic surveys, handwriting analysis, voice analysis, aircraft identification for navigational purposes, and character recognition.

There are also active areas wherein GRAPHS of various kinds are used to represent structures and processes, and development of machine methods for processing these data is an interesting problem in itself.

I keep referring here to film data, but I should like to point out that the methods used here are not specialized to film data. The important feature is for the computer to be presented the same sort of parameters whatever the source of data. In the case of spark chamber data, for example, there is a lot of current interest and successful work on filmless chambers. With small modifications, the same programs can be used. Generally speaking, we are interested in deducing various topological relationships of events that have taken place and the method of transducing and recording the information is not critical to the methods.

II. The Problem

The particular problem posed to us here is the development of machine methods for scanning, measuring and associating into tracks, sparks or bubbles that have been generated by nuclear particles in spark chambers or bubble chambers, respectively.

Once these spark images or bubble images have been associated into tracks and lists of their three space coordinates generated, there already exists programs which do the fitting to yield kinematic parameters, such as momentum and scattering angle. The fitting programs are followed by event summarizing programs whose functions are to generate histograms and carry out hypothesis testing. The kinematic analysis and event summarizing programs have been in use for many years processing data generated by manual or semi-automatic scanning and measuring systems. Although there are still some quite important problems remaining in this area, they are not the subject of this talk.

Since I do not intend to present a summary of data processing in high-energy physics, I shall "get on" with the main part ofthe talk. I intend here, in the introduction, only to put into perspective the role of the scanning, measuring, and association into tracks part of the work. I shall also specialize this discussion to spark chamber events.

Let me first describe the overall physical problem. I shall then present a parallel description of the mathematical problem(s) and show what each mathematical step provides physically.

The first two slides (#145-504-A) and #145-504-B) show two 18° stereo views of an event in a spark chamber composed of about 90 gaps. The spark chamber is located in a magnetic field. The presence of the magnetic field causes the tracks of the charged particles to be curved. These pictures were not taken with automatic processing in mind, a fact which greatly complicated the scanning algorithm. You can see that gap edges are prominent and fiducials are not easily identified. The film is relatively complicated from the viewpoint of the chamber but relatively simple from the viewpoint that not many unwanted particles are present. The next slide (#145-694) shows two views on one slide of another event and also shows some odd sparks and noise in the film. Much of the film we are handling is more complex, i.e., noisier than this.

The problem is to develop a machine method that will present to the geometrical reconstruction and kinematic analysis programs a list of the three space coordinates of the centroids of spark images that are properly associated into tracks. This is to be done without human intervention and, needless to say, in a reasonably short time.

III. The Scanning and Measuring

About a year ago, I described in some detail the CHLOE film scanning and measuring device and the system aspects of its incorporation into theArgonne computer network. I shall not describe this aspect of the problem. It will suffice to say that CHLOE is a cathode-ray tube scanner controlled by a small computer that scans a 4096x4096 raster on an area about 1.25 in X 1.25 in, covering almost the full field of a 35 mm frame. CHLOE and its scanning program AROMA generate all the film coordinate information for all sparks for both stereo views. Actually, many cells that are not sparks are also digitized. One of the problems is deciding which cells are sparks and which are not.

The next slide (#145-699) depicts in one figure the kind of scans that can be performed and shows how cells are constructed from line segments generated by the scanning algorithm in the AROMA program. The top half of the next slide (#145-693 Rev) shows the output of AROMA. It really shows you that the computer can digitize and reconstruct the original photo. This output corresponds to the second slide I showed (#145-694).

The next slide (#145-700) shows the relationships of the various hardware and software components. It is the AIRWICK Program that I wish to discuss and rather than discuss AROMA, I shall simply indicate, when necessary, what information AROMA provides.

## IV. Classification of Paired Sparks

PREPOS, the next program encountered after AROMA, sorts sparks by gap and chamber, removes optical distortions from the data, and transforms CHLOE film coordinates into real space coordinates on the top surface of the chamber. We now have a list of the centroids of the points of intersection of the top surface of the chamber with the rays joining the sparks to the camera lens - the elements of the list have been ordered by gap and chamber. We have two such lists - one for each view.

The traditional approach on manual scanning tables and in other automatic scanning efforts at this stage is to next associate these spark images into tracks in each view and then combine the tracks to yield curves in space. It appeared to us that, if we could reconstruct the sparks in space first without any <u>a priori</u> knowledge of the picture's topology, linking would proceed with far fewer ambiguities.

Following this approach, physically our next step is to identify the corresponding spark images in the two stereo views and to reconstruct them in space. After this, we must decide which of these reconstructed sparks belong to a track. These two operations are executed by two programs called PAIR and LINK which I shall now describe mathematically. PAIR picks out the corresponding spark images in the stereo views and LINK picks out the reconstructed sparks that belong to a track.

From the ordered list of spark images presented by AROMA, we construct a two-dimensional <u>relationship array</u> for each gap of the chamber. The number of dimensions of the <u>relationship array</u> is equal to the number of stereo views we have, and the number of entries we have for a given dimension is the number of spark images seen for the gap being investigated. A two-view relationship array might look like the figure shown in the next slide (#WM-100).

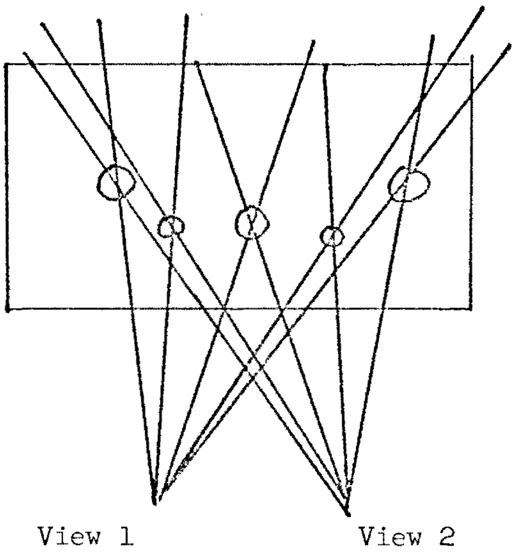
Recall that the images are ordered and that we may have hidden sparks, etc., so that we shall not, in general, have the same number of images in each view.

We make entries according to

$M(i,j) = 1$ if the spark reconstructed from images i and j would be in the chamber

$= 0$ otherwise

Top View of Chamber




(Slide WM-101)

j → View 2

↓ i View 1

| | | | | |
|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 1 | 1 |

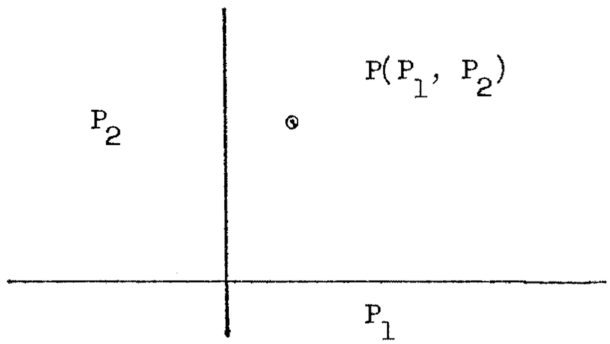
(Slide VM-102)

Sparks at the points of the circles shown in the top view above would generate a relationship array of block diagonal form as shown.

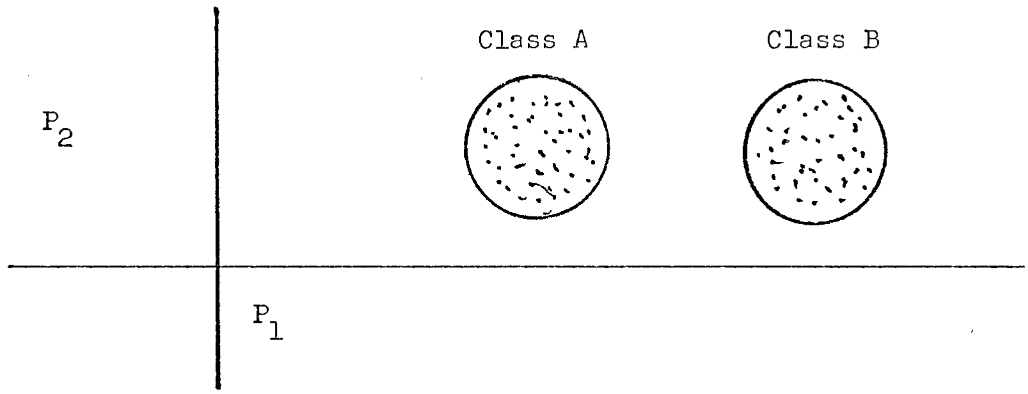
This block diagonal form, which arises because of the ordering of the sparks in the gaps, permits us to concentrate on each subblock in the pairing. Within a subblock, we should like to find a classification technique that will classify the paired images. That is, we should like to find a technique that will remove the ambiguities in the relationship array.

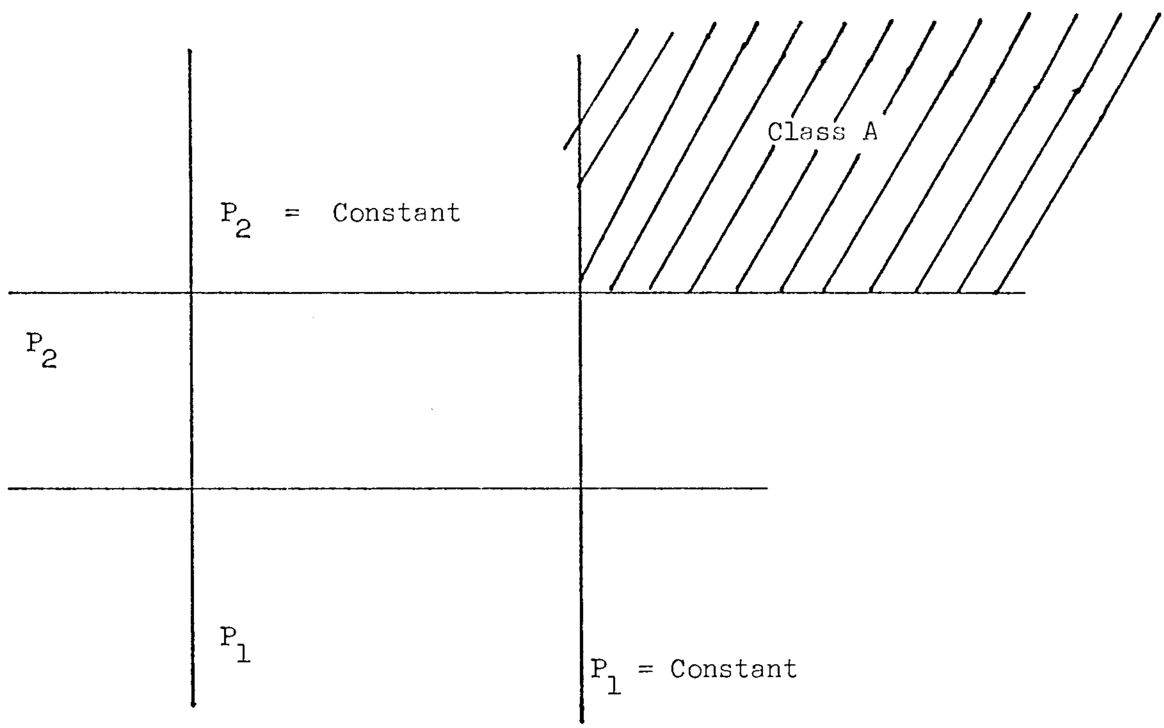
Now let me review some of the features of the classification problem in pattern recognition problem of which classification is one important aspect. If one utilizes the statistical decision theoretic approach to the classification problem, one poses the problem as follows:

A set of parameters are measured for each of the set of things to be classified. Each measurement, then, yields a point (vector) in an n-dimensional parameter space. The fundamental assumption




made, is that one can find a characteristic set of parameters, such that the set of measurements on the objects or events which belong to the same class will lie in a characteristic region of the parameter space.

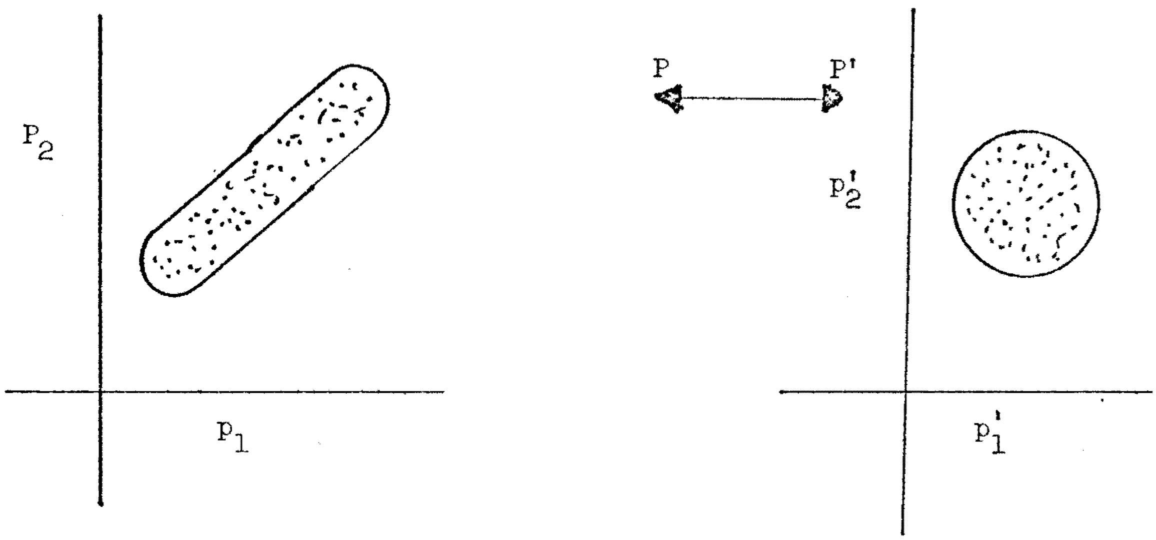



The principal underlying mathematical theory is that of statistical decision theory. I shall not discuss that theory here. Clearly, then, the statement that a measurement can be classified as belonging to a certain class, is a probabilistic statement.

As previously stated, there are several aspects to the general pattern recognition problem - particularly to the development of machine methods for pattern recognition - to name a few: learning, classification matching, filing and retreiving, etc., In the particular problem at hand, we developed a machine method only for the classification. The learning part was provided by the investigators. The learning part here consists of finding the set of parameters that can be masured and will lead to classification.

There is one more theoretical consideration to be discussed. In order to have a quantative basis for classification of points in the parameter space, it is necessary to find a metric $d(\vec{P}_1, \vec{P}_2)$ which is small for points in the same class. Alternately and equivalently, we can seek transformations on the parameter space that will lead to clustering in the sense that the Euclidean metric is small for any two points of the same class.



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