PATTERN RECOGNITION

Human and Mechanical

Satosi Watanabe

PATTERN RECOGNITION: HUMAN AND MECHANICAL

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PATTERN RECOGNITION: HUMAN AND MECHANICAL

To
Dorothea
for her patience and cheerful encouragement

Preface

This book is an elementary introduction to a new domain of science commonly called pattern recognition, excluding, however, its subfield called picture processing. It addresses two kinds of readers: those of the non-scientific audience who do not like mathematical formulas and those specialized students of science who have been exposed to mathematical theories on pattern recognition but do not understand what they are really doing with those sharp quantitative tools.

Although the current interest in pattern recognition stems obviously from the possibility of its partial simulation and replacement by the computer, the subject of the present study is primarily the human cognitive capabilities, ranging from concrete object perception to abstract theory building. The title originally considered for this book was: "Form, Figure, Feature," implying that our task here lay in explication of the general concept (Form) in terms of class-characteristics (Feature) derived from the intuitive image (Feature) of a class as suggested by class-samples (paradigms). The study of this mental activity is, however, at present forced to be reformulated under the impact of the recent developments of psychology and neurophysiology. The present book, includes, beside the mathematical modeling, both non-mathematical, historical descriptions (Chapters 1-4) and a currently developing new vista over the entire field of cognition (Epilogue).

Before finalizing the manuscript, I also considered a subtitle: "An Epistemometrical Foundation of Pattern Recognition." The term

epistemometry, which was used in the preface of my earlier book, *Knowing and Guessing* [W-10], designates an attitude developed during our series of research on the problem of knowledge and concept formation. It may be characterized as follows:

1. Represents a new natural extension of a branch of philosophy, epistemology.
2. Represents an empirical science--a quantitative theory based on empirical facts about the process of knowing. It is not a branch of the traditional philosophy, nor of mathematics, nor, least of all, of statistics. It is an independent discipline by itself.
3. Does not side with the so-called empiricist camp in the classical empiricist-rationalist battle. It recognizes the fact that innate ideas are necessary in making "knowing" possible, but, at the same time, maintains that these innate ideas are the results of the philogenetic outgrowth, through evolution, of the interaction between life and its environments.
4. Corrects the overemphasis of the "digital-linguistic-logical-deductionist" approach prevalent among researchers in cognitive sciences, simply because the basic cognitive capabilities are present already in the prelingual animals and human infants (Section 10.5 and E-3).
5. Maintains that the formation of concepts is possible only with the help of a value-oriented ponderation (Chapter 4). As such it has affinity with the epistemological relativism held by such philosophers as Feyerabend, Putnam, Kuhn, the ontological relativity maintained by Quine, and the inductive relatively pointed out by Goodman [F-5, G-3, K-8, P-11, Q-1]. We think, however, that a more cautious attitude is required than in the popular epistemological relativism with regard to the arbitrariness of historical developments of natural science [W-17, W-32].
6. Considers mental description as well as physical description as experimental facts.

The identify theory of mind-body relation à la Feigl is assumed, but only in an approximate sense [F-3, W-34] (see also Section E-3).

7. Makes a clear distinction between deductive and inductive processes, without losing sight of the fact that a real process of thinking is an interplay of deduction and induction. At variance with R. Carnap and his followers, we should abide by the old definition of deduction as a derivation of particular proposition from a general proposition and the definition of induction as the reverse process [C-5, W-10]. Pattern recognition is an inductive process [W-24].
8. Locates the vital essence of science in its inductive theory-building. The axiomatization and programmation of a theory is a cadaver of a science. Despite the final deductive expositions of their results, the true creative logicians and mathematicians are strong inductionists.
9. Takes the view that induction is never free of inductive ambiguity. In the presence of inductive ambiguity, what propels a science is a heuristic principle which is neither unique nor necessary. It does not guarantee success.
10. Believes that the study of human pattern recognition as a science is beneficial to and benefited from the development of mechanical applications of pattern recognition as a technique. The totality of scientific-technological efforts to unravel and simulate the process of pattern recognition, in the broadest sense of the word, is tantamount to the entire epistemometry. See Epilogue for a discussion of the unbridgeable gap between the present-day computer and the human brain.

An epistemometrical point of view, as characterized above, can be said to have started in 1959 when Professor Brand Blanshard, then chairman of the philosophy department of Yale University, asked me, an IBM physicist, to take over course on

"inductive logic," which Professor Arthur Papp had been scheduled to give. I am certain that the philosophical level of my course was nothing comparable to the one that the famous young-deceased philosophical genius would have attained. But, one thing notable of mention was that in my course the inductive ambiguity was traced back to the asymmetrical application of symmetrical conditional probabilities, and the idea of the theorem of the Ugly Duckling was introduced as another expression of inductive ambiguity. This theorem was announced in a session organized by Professor Russell Hanson but was not published [W-18, W-19].

About the same time (1960) my research at IBM Research Laboratory became more and more concentrated on pattern recognition. In the past twenty years, the materials included in this book have been topics of my courses at the University of Hawaii, Yale University, Columbia University, Rutgers University, Fordham University and Sophia University (Tokyo) and subjects of lectures at various institutions and conferences in Europe, the United States, and Japan. As a consequence, it contains some earlier results in pattern recognition, but is entirely rewritten in the spirit of the new ideas about heuristics which have been reformulated quite recently [W-46, W-47]. There is a certain amount of duplication of my earlier book, *Knowing and Guessing* [W-10], but an independent reading is entirely possible, although some cross-references are made for possible usefulness.

I witnessed and modestly participated in the genesis and development of pattern recognition in the United States, and the contents of this book owe greatly to the works of my colleagues and contemporary experts in this field. But, at the same time, this book may be more truthfully described as a record of my reactions as a non-American-trained researcher, non-engineer, and non-mathematician, to these important achievements of technology, which have been brought about mostly by American-trained researchers, engineers, and mathematicians. I hope the reader will tolerate an autobiographic overtone in order to make this self-styled textbook more readable and more vivid.

I am indebted to many friends and colleagues who made this book possible, and to two young collaborators who have worked closely with me from my

Yale years on, Dr. Tsuguchika Kamimura and Dr. Casimir Kulikowski. I am indebted greatly to Dr. Francis W. Dauer for exciting discussions and for his tutorial efforts in philosophical problems although I was not always a docile student. Others who have inspired and assisted me in scholarly research are mentioned in the appropriate places in the text.

Being interspersed at different junctures with innovative yet unorthodox ideas, this book has to expect at best a controversial acceptance. The courageous decision on the part of Miss Beatrice Shube of John Wiley and Sons, Wiley-Interscience Division, to publish this book is highly appreciated by the author. The first manuscript was typed up by Mrs. Alberta Smith. The second much revised typescript was prepared by Mrs. Ethel Shintaku and assistants. The final accurate camera-ready copy was typed by Ms. Susan Yamane and Ms. Glenna Sumiye. This book owes its birth in the present elegant form greatly to Mrs. Barbara Whitehouse-Jones, who edited the manuscript and coordinated efforts for the production of camera-ready copy.

Satosi Watanabe

Honolulu
September, 1984

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CHAPTER 1
Pattern Recognition as Seeing-One-In-Many

1.1 PATTERN AND RECOGNITION

The intellectual enterprises usually grouped under the name of pattern recognition are so diversified and comprehensive that many people are tempted to introduce a neologism, more general or more dignified than pattern recognition. But, I myself have no objection to the rubrique: pattern recognition. Although this name emphasizes only one aspect of this group of intellectual activities, it is neither too abstract nor too concrete, neither pompous nor overly modest. This term is particularly convenient because it serves well the purpose of extricating the essential common nature underlying the various activities in this general area. In addition to this advantage, the terminology is neutral as to the question whether we are talking about the human activities such as sensation, perception, cognitive judgement, or about their mechanical simulation by the computer. As was the case with cybernetics, the technique of mechanization is advanced by a study of human prototypes, and the biomedical and psychological understanding profits from our efforts in developing methods of mechanical simulation. It is, therefore, often convenient to use a common terminology to cover these two areas, although it is on the other hand also important not to overlook a deep-lying crevasse between them.

Now, what is a pattern? When do we speak of a pattern? For instance, when iron filings are scattered on a sheet of paper they spread out more or less uniformly and there is no pattern to speak of. But, by some accident, perhaps due to an irregular deviation of the paper from a perfect horizontal plane, the density of filings may become relatively high at certain places, and, a pattern appears. It

may look like a river, or a dog's head. In another case, because of a magnet positioned under the paper, the filings may show something like what we learn in physics as magnetic lines of force (see Fig. 1.1.1). In such cases, we say that a pattern has appeared. Be it a blob or lines of force or something without name, a pattern is the opposite of chaos; it is an entity, vaguely defined, that could be given a name--i.e. a something. It is important to notice, when we see a river, a dog's head or lines of force, that we are somehow associating the present particular case before the eyes to other cases of

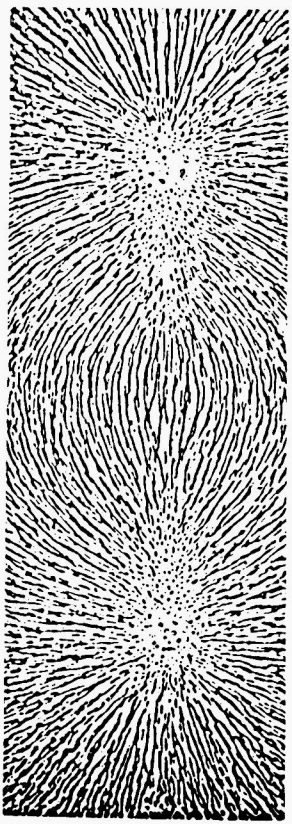

Figure 1.1.1 A collection of pieces of broken line segments seen as a set of lines of force of a magnetic field.

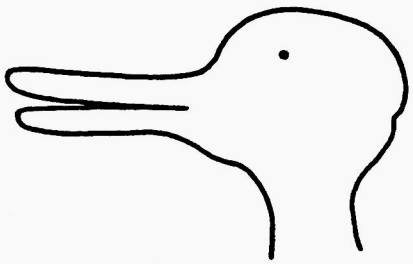

Figure 1.1.2 An example of double meaning: Wittgenstein's duck-rabbit. Either a duck or a rabbit is seen but not both simultaneously.

rivers, dogs' heads and lines of force, recognizing similarity.

The situation may be regarded as a special case of what Wittgenstein said about "seeing something$_1$ as something$_2$" [W-14]. The verb "see" has two usages, according to him, such as "I see this rose" and "I see this picture as a rabbit" (see Fig. 1.1.2). What we call "pattern" corresponds to something$_2$ in this formulation. Something$_2$ as such does not exist in the same level of language as something$_1$ in the picture. It can be seen by our mind's eye. It is an ideal construction. Sometimes, something$_2$ has a name; sometimes, it has no name. In some cases, we have to describe the structure of the nameless thing by mentioning the known constituent building blocks and how they are put together in some familiar, definable way.

In cases exemplified by Wittgenstein's duck-rabbit, there can be two, or even more, somethings recognizable, and the most conspicuous fact is that when one pattern is recognized the other one disappears at that time and vice versa (see Fig. 1.1.2). It is the same in many examples of figure-ground switching of Gestalt psychologists, and a similar thing can be said about Rorschach inkblots. There is no mixture, no co-existence (see Fig. 1.1.3, Fig. 1.1.4). Yet it is not true if we say that only one of them is the true reality. This is somewhat like Bohr's complementarity. In any event, what is important here is that something$_2$ is a result of cooperation of external stimuli and a certain kind of

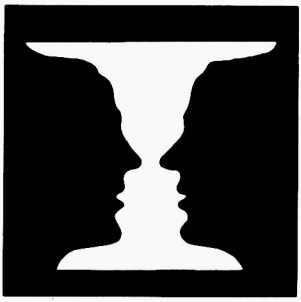

Figure 1.1.3 A favorite example of double meaning used by Gestalt psychologists--a flip-flop alternation of figure and ground.

mental activity of associating one case with other similar, or at least related, cases.

Now if we substitute "recognize" for "see" and "pattern" for "something$_2$" in the phrase "to see something$_1$ as something$_2$," we can talk more specifically about pattern recognition. Let us consider a few examples out of ordinary conversation: "I recognize this flower as plumeria"; "I recognize this tartan as Gordon." These sentences contain perfectly normal usages of the word "recognize" in the sense of recognizing a pattern. They share one important common feature, i.e., the idea of different individual objects belonging to the same class. The plumeria flower I have in my hand is not the same plumeria flower I have previously seen, but I recognize this one as a member of the same family as the earlier samples of plumeria. The necktie I have in my hand at this moment is an entirely different object from the kilt I saw yesterday, and the dimension of weave pattern on the tie is smaller, yet I consider these two to belong to the same class as far as the arrangement of colors is concerned.

Thus, we may say that recognition usually means identification of an object as a member of a family which we already know, or we are familiar with, thereby reducing many to one. Before going into the examination of the meaning of the word "family" or "class," we may ask ourselves if it is necessary for us to know already, or to be familiar with, the class when we use the word recognize. The answer is no.