Pattern Recognition with Neural Networks

Introduction

What is a pattern? A pattern is essentially an arrangement or an ordering in which some organization of underlying structure can be said to exist. We can view the world as made up of patterns. Watanabe [1985] defines a pattern as an entity, vaguely defined, that could be given a name.

A pattern can be referred to as a quantitative or structural description of an object or some other item of interest. A set of patterns that share some common properties can be regarded as a pattern class. The subject matter of pattern recognition by machine deals with techniques for assigning patterns to their respective classes, automatically and with as little human intervention as possible. For example, the machine for automatically sorting mail based on 5-digit zip code at the post office is required to recognize numerals. In this case there are ten pattern classes, one for each of the 10 digits. The function of the zip code recognition machine is to identify geometric patterns (each representing an input digit) as being a member of one of the available pattern classes.

A pattern can be represented by a vector composed of measured stimuli or attributes derived from measured stimuli and their interrelationships. Often a pattern is characterized by the order of elements of which it is made, rather than the intrinsic nature of these elements. Broadly speaking, pattern recognition involves the partitioning or assignment of measurements, stimuli, or input patterns into meaningful categories. It naturally involves extraction of significant attributes of the data from the background of irrelevant details. Speech recognition maps a waveform into words. In character recognition a matrix of pixels (or strokes) is mapped into characters and words. Other examples of pattern recognition include: signature verification, recognition of faces from a pixel map, and friend-or-foe identification. Likewise, a system that would accept sonar data to determine whether the input was a submarine or a fish would be a pattern recognition system.

1.1 Pattern Recognition Systems

For a typical pattern recognition system the determination of the class is only one of the aspects of the overall task. In general, pattern recognition systems receive data in the form of “raw” measurements which collectively form a stimuli vector. Uncovering relevant attributes in features present within the stimuli vector is typically an essential part of such systems (in some cases this may be all that is required). An ordered collection of such relevant attributes which more faithfully or more clearly represent the underlying structure of the pattern is assembled into a feature vector.

Class is only one of the attributes that may or may not have to be determined depending on the nature of the problem. The attributes may be discrete values, Boolean entities, syntactic labels, or analog values. Learning in this context amounts to the determination of rules of associations between features and attributes of patterns.

Practical image recognition systems generally contain several stages in addition to the recognition engine itself. Before moving on to focus on neural network recognition engines we will briefly describe a somewhat typical recognition system [Chen, 1973].

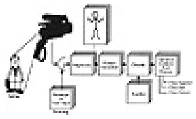

Figure 1.1 Components of a pattern recognition system.

Figure 1.1 shows all the aspects of a typical pattern recognition task:

Preprocessing partitions the image into isolated objects (i.e., characters, etc.). In addition it may scale the image to allow a focus on the object.

Feature extraction abstracts high level information about individual patterns to facilitate recognition.

The *classifier* identifies the category to which the pattern belongs or, in general, the attributes associated with the given pattern.

The *context processor* increases recognition accuracy by providing relevant information regarding the environment surrounding the object. For example, in the case of character recognition it could be the dictionary and/or language model support.

Figure 1.2 shows the steps involved in the design of a typical pattern recognition system. The choice of adequate sensors, preprocessing techniques, and decision-making algorithm is dictated by the characteristics of the problem domain. Unlike the expert systems, the domain-specific knowledge is implicit in the design and is not represented by a separate module.

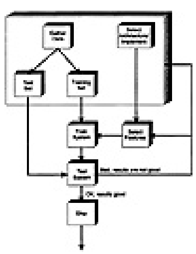

Figure 1.2 A flow chart of the process of designing a learning machine for pattern recognition.

A pattern classification system is expected to perform (1) supervised classification, where a given pattern has to be identified as a member of already known or defined classes; or (2) unsupervised classification or clustering, where a pattern needs to be assigned to a so far unknown class of patterns.

Pattern recognition may be static or dynamic. In the case of asynchronous systems, the notion of time or sequential order does not play any role. Such a paradigm can be addressed using static pattern recognition. Image labeling/understanding falls into this category. In cases of dynamic pattern recognition, where relative timing is of importance, the temporal correlations between inputs and outputs may a major role. The learning process has to determine the rules governing these temporal correlations. This category includes such applications as control using artificial neural networks or forecasting using neural nets. In the case of recognizing handwritten characters, for example, the order in which strokes emerge from a digitizing tablet provides much information that is useful in the recognition process.

The task of pattern recognition may be complicated when classes overlap (see Figure 1.3). In this case the recognition system must attempt to minimize the error due to misclassification. The classification error is significantly influenced by the number of samples in the training set. Several researchers (for example, see Jain and Chandrasekaran [1982], Fukunaga and Hayes [1989], Foley [1972]) have addressed this issue.

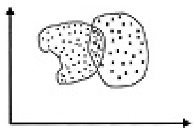

Figure 1.3 Two categories of patterns plotted in the pattern space. Patterns belonging to both classes can be observed in the overlapping region.

The three major approaches for designing a pattern recognition are (1) statistical, (2) syntactic or structural, and (3) artificial neural networks. Statistical pattern recognition techniques use the results of statistical communication and estimation theory to obtain a mapping from the representation space to the interpretation space. They rely on the determination of an appropriate combination of feature values that provides measures for discriminating between classes. However, in some cases, the features are not important in themselves. Rather the critical information regarding pattern class, or patterns attributes, is contained in the structural relationships among the features. Applications involving recognition of pictorial patterns (which are characterized by recognizable shapes) such as character recognition, chromosome identification, elementary particle collision photographs, etc. fall into this category. The subject of syntactic pattern recognition deals with this aspect, since it possesses the structure-handling capability lacked by the statistical pattern recognition approach. Many of the techniques in this field draw from the earlier work in mathematical linguistics and results of research in computer languages. A large body of literature exists in this field which includes Watanabe [1972], Fu [1974, 1977], Gonzalez and Thomason [1978].

Despite the existence of a number of good statistical, syntactic (grammar-based), and graphical approaches to pattern recognition, we limit the scope of this book to the discussion of the various artificial neural network based modules. However, where statistical methods are strongly related to corresponding neural network techniques, the applicable statistical methods are discussed. Additionally, it should not be overlooked that neural recognizers can and have been used in combination with other types of recognition engines such as elastic pattern matchers.

1.2 Motivation For Artificial Neural Network Approach

The development of a computer as something more than a calculating machine marked the birth of the field of pattern recognition. We have witnessed increased interest in research involving use of machines for performing intelligent tasks normally associated with human behavior. Pattern recognition techniques are among the most important tools used in the field of machine intelligence. Recognition after all can be regarded as a basic attribute of living organisms. The study of pattern recognition capabilities of biological systems (including human beings) falls in the domain of such disciplines as psychology, physiology, biology, and neuroscience. The development of practical techniques for machine implementation of a given recognition task and the necessary mathematical framework for designing such systems lies within the domain of engineering, computer science, and applied mathematics. With the advent of neural network technology a common ground between engineers and students of living systems (psychologists, physiologists, linguists, etc.) was established. We would like to point out that mathematical operations used in theories on pattern recognition and neural networks are often formally similar and identical. Thus, there is good mathematical justification for teaching the two areas together.

Recognizing patterns (and taking action on the basis of the recognition) is the principal activity that all living systems share. Living systems, in general, and human beings, in particular, are the most flexible, efficient, and versatile pattern recognizers known; and their behavior provides ample data for studying the pattern recognition problem. For example, we are able to recognize handwritten characters in a robust manner, despite distortions, omissions, and major variations. The same capabilities can be observed in the context of speech recognition. Humans also have the ability to retrieve information, when only a part of the pattern is presented, based on associated cues. Take, for example, the cocktail party phenomena. At a party you can pick up your name being mentioned in a conversation all the way across the hall even when most of the conversation is inaudible due to a clutter of noise. Similarly, you can recognize a friend in the crowd at a distance even when most of the image is occluded.

Decision-making processes of a human being are often related to the recognition of regularity (patterns). Humans are good at looking for correlations and extracting regularities based on them. Such observations allow humans to act based on anticipation which cuts down the response time and gives an edge over reactionary behavior. Machines are often designed to perform based on reaction to the occurrence of certain events which slows them down in applications such as control.

The nature of patterns to be recognized could be either *sensory recognition* or *conceptual recognition*. The first type involves recognition of concrete entities using sensory information, for example, visual or auditory stimulus. Recognition of physical objects, characters, music, speech, signature, etc. can be regarded as examples of this type of act. On the other hand, conceptual recognition involves acts such as recognition of a solution to a problem or an old argument. It involves recognition of abstract entities and there is no need to resort to an external stimulus in this case. In this book, we shall be concerned with recognition of concrete items only.

The real problem of pattern recognition, however, is to generate a theory that specifies the nature of objects in such a way that a machine will be able to robustly identify them. A study of the way living systems operate provides great insight into addressing this problem. The image in Figure 1.4 indicates the complexity of the type of problem we have been discussing. The image in Figure 1.4(a) shows the face with distinct boundaries between pixels. Thus an image understanding/pattern recognition algorithm, which labels areas with different intensities as parts of different surfaces, would have difficulties in recognizing this pattern of a face. On the other hand, for a human observer it is easier to see that blurring of the boundaries between pixels, as shown in Figure 1.4(b), would result in a easily recognizable face. The ability may be attributed to the existence of interacting high and low spatial frequency channels in the human visual system.

Otmane El Rhazi, is a Moroccan national residing in Essex, England. He is an alumni of Ecole Nationale des Ponts et Chaussées and Université Pierre and Marie Curie Paris VI.