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Different Approaches in Pattern Recognition

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Abstract The objective of this paper is to discuss and compare some aspect of pattern recognition, among the various framework in which pattern recognition has been traditional formulated. The primary goal of pattern recognition is supervised or unsupervised classification. More recently, neural network techniques and methods imported from statistical learning theory have been receiving increasing attention. The design of a recognition system requires careful attention to the following issues: definition of pattern classes, sensing environment, pattern representation, feature extraction and selection, cluster analysis, classifier design and learning, selection of training and test samples, and performance evaluation.

Keywords Statistical Pattern Recognition, Classification, Clustering, Feature Extraction, Feature Selection, Error Estimation, Classifier Combination, Neural Networks

1. Introduction

Pattern recognition is the study of how machines can observe the environment, learn to distinguish patterns of interest from their background, and make sound and reasonable decisions about the categories of the patterns. In spite of almost 50 years of research, design of a general purpose machine pattern recognizer remains an elusive goal.

Ross[2] emphasizes the work of Nobel Laureate Herbert Simon whose central finding was that pattern recognition is critical in most human decision making tasks: "The more relevant patterns at your disposal,the better your decisions will be. This is hopeful news to proponents of artificial intelligence, since computers can surely be taught to recognize patterns. Indeed, successful computer programs that help banks score credit applicants, help doctors diagnose disease and help pilots land airplanes depend in some way on pattern recognition We need to pay much more explicit attention to teaching pattern recognition". Our goal is to discuss and compare pattern recognition as the best possible way

2. What is Pattern Recognition?

Automatic (machine) recognition, description,classification, and grouping of patterns are important problems in a variety of engineering and scientific disciplines such as biology, psychology, medicine, marketing, computer vision, artificial intelligence, and remote sensing. A pattern could be a fingerprint image, a handwritten cursive word, a human-face, or a speech signal. Given a pattern, its recognition/ classification may consist of one of the following two tasks: 1) supervised classification (e.g., discriminant analysis) in which the input pattern is identified as a member of a predefined class, 2) unsupervised classification (e.g., clustering) in which the pattern is as

signed to a hitherto unknown class. The recognition problem here is being posed as a classification or categorization task, where the classes are either defined by the system designer (in supervised classification) or are learned based on the similarity of patterns (in unsupervised classification).These applications include data mining (identifying a "pattern", e.g., correlation, or an outlier in millions of multidimensional patterns),document classification (efficiently searching text documents), financial forecasting, organization and retrieval of multimedia databases, and biometrics. The rapidly growing and available computing power, while enabling faster processing of huge data sets, has also facilitated the use of elaborate and diverse methods for data analysis and classification. At the same time, demands on automatic pattern recognition systems are rising enormously due to the availability of large databases and stringent performance requirements (speed, accuracy, and cost). The design of a pattern recognition system essentially involves the following three aspects:

1) data acquisition and preprocessing,
2) data representation, and
3) decision making.

The problem domain dictates the choice of sensor(s), preprocessing technique, representation scheme, and the decision making model. It is generally agreed that a well-defined and sufficiently constrained recognition problem (small interclass variations and large interclass variations) will lead to a compact pattern representation and a simple decision making strategy. Learning from a set of examples (training set) is an important and desired attribute of most pattern recognition systems. The four best known

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approaches for pattern recognition are: 1) template matching, 2) statistical classification, 3) syntactic or structural matching, and 4) neural networks.

2003(Sergios Theodoridis,) Pattern recognition is a scientific discipline whose aim is the classification of the objects into a lot of categories or classes. Pattern recognition is also a integral part in most machine intelligence system built for decision making.[10]

1) Supervised classification (e.g., discriminant analysis) in which the input pattern is identified as a member of a predefined class,

2) Unsupervised classification (e.g., clustering) in which the pattern is assigned to a hitherto unknown class.

Note that the recognition problem here is being posed as a classification or categorization task, where the classes are either defined by the system designer (in supervised classification) or are learned based on the similarity of patterns (in unsupervised classification).

Picard[1] has identified a novel application of pattern recognition, called affective computing which will give a computer the ability to recognize and express emotions, to respond intelligently to human emotion, and to employ mechanisms of emotion that contribute to rational decision making.

Recently a lot of area comes under pattern recognition due to emerging application which are not only challenging but also computationally more demanding (see table 1).

Table 1. Example of Pattern Recognition Applications

Problem Domain	Application	Input Pattern	Pattern Classes
Bioinformat ics	Sequence Analysis	DNA/Protein Sequence	Known types of genes patterns
Data Mining	Searching for meaningful patterns	Points in multi- dimensional space	Compact and well separated clusters
Document image analysis	Reading machine for the blind	Document image	Alphanume ric characters, words
Multimedia database retrieval	Internet search	Video clip	Video genres(e.g. action, dialogue,et c.)
Biometric recognition	Forcasting crop yield	Multispectral image	Land use categories, growth pattern of crops
Speech recognition	Telephone directory enquiry Without perator assistance	Speech waveform	Spoken words

that the available features are not usually suggested by domain experts, but must be extracted and optimized by data- driven procedures.

The four best known approaches for pattern recognition are:

1)Template matching,

2) Statistical classification,

3) Syntactic or structural matching, and

4)Neuralnetworks

These models are not necessarily independent and sometimes the same pattern recognition method exists with different interpretations.

A brief description and comparison of these approaches is given below and summarized in Table 2.

Table 2. Pattern Recognition Models

Approach	Representati on	Recognition function	Typical criterian
Template matchin	Sample, pixels,curves	Correlation, distance measure	Classificat ion error
Statistical	Features	Discriminant function	Classificat ion error
Syntactic or structural	Primitives	Roles, grammar	Acceptanc e error
Neural networks	Samples,pixe ls, features	Network function	Mean square error

3. Template Matching

One of the simplest and earliest approaches to pattern recognition is based on template matching. Matching is a generic operation in pattern recognition which is used to determine the similarity between two entities (points, curves, or shapes) of the same type. In template matching, a template (typically, a 2D shape) or a prototype of the pattern to be recognized is available. The pattern to be recognized is matched against the stored template while taking into account all allowable pose (translation and rotation) and scale changes. The similarity measure, often a correlation, may be optimized based on the available training set. Often, the template itself is learned from the training set. Template matching is computationally demanding, but the availa bility of faster processors has now made this approach more feasible. The rigid template matching mentioned above, while effective in some application domains, has a number of disadvantages.

For instance, it would fail if the patterns are distorted due to the imaging process, viewpoint change, or large intraclass variations among the patterns. Deformable template models[6,9] or rubber sheet deformations[5] can be used to match patterns when the deformation cannot be easily explained or modeled directly.

4. Statistical Approach

In the statistical approach, each pattern is represented in terms of d features or measurements and is viewed as a point in a d- dimensional space. The goal is to choose

those features that allow pattern vectors belonging to different categories to occupy compact and disjoint regions in a d-dimensional feature space. The effectiveness of the representation space (feature set) is determined by how well patterns from different classes can be separated. Given a set of training patterns from each class, the objective is to establish decision boundaries in the feature space which separate patterns belonging to different classes. In the statistical decision theoretic approach, the decision boundaries are determined by the probability distributions of the patterns belonging to each class, which must either be specified or learned[6,7].

One can also take a discriminant analysis-based approach to classification: First a parametric form of the decision boundary (e.g., linear or quadratic) is specified; then the "best" decision boundary of the specified form is found based on the classification of training patterns. Such boundaries can be constructed using, for example, a mean squared error criterion. The direct boundary construction approaches are supported by Vapnik's philosophy[14]: "If you possess a restricted amount of information for solving some problem, try to solve the problem directly and never solve a more general problem as an intermediate step. It is possible that the available information is sufficient for a direct solution but is insufficient for solving a more general intermediate problem".

5. Syntactic Approach

In many recognition problems involving complex patterns, it is more appropriate to adopt a hierarchical perspective where a pattern is viewed as being composed of simple subpatterns which are themselves built from yet simpler subpatterns[4],[11]. The simplest/elementary subpatterns to be recognized are called primitives and the given complex pattern is represented in terms of the interrelationships between these primitives. In syntactic

pattern recognition, a formal analogy is drawn between

the structure of patterns and the syntax of a language. The

patterns are viewed as sentences belonging to a language, primitives are viewed as the alphabet of the language, and the sentences are generated according to a grammar. Thus, a large collection of complex patterns can be described by a small number of primitives and grammatical rules. The grammar for each pattern class must be inferred from the available training samples. Structural pattern recognition is intuitively appealing because, in addition to classification, this approach also provides a description of how the given pattern is constructed from the primitives. This paradigm has been used in situations where the patterns have a definite structure which can be captured in terms of a set

of rules, such as EKG waveforms, textured images, and shape analysis of contours[4]. The implementation of a syntactic approach, however, leads to many difficulties which primarily have to do with the segmentation of noisy patterns (to detect the primitives) and the inference of the grammar from training data. Fu[4] introduced the notion of attributed grammars which unifies syntactic and statistical pattern recognition. The syntactic approach may yield a combinatorial explosion of possibilities to be investigated, demanding large training sets and very large computational efforts[12].

6. Neural Networks

The main characteristics of neural networks are that they have the ability to learn complex nonlinear input-output relationships, use sequential training procedures, and adapt themselves to the data. The most commonly used family of neural networks for pattern classification tasks[2] is the feed-forward network, which includes multilayer perceptron and Radial-Basis Function (RBF) networks. Another popular network is the Self-Organizing Map (SOM), or Kohonen-Network[3], which is mainly used for data clustering and feature mapping. The learning process involves updating network architecture and connection weights so that a network can efficiently perform a specific classification/clustering task. The increasing popularity of neural network models to solve pattern recognition problems has been primarily due to their seemingly low dependence on domain-specific knowledge and due to the availability of efficient learning algorithms for practitioners to use. Artificial neural networks (ANNs) provide a new suite of nonlinear algorithms for feature extraction (using hidden layers) and classification (e.g., multilayer perceptrons). In addition, existing feature extraction and classification algorithms can also be mapped on neural network architectures for efficient (hardware) implementation. An ANN is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems.

An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons.

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rithms can also be mapped on neural network architectures for efficient (hardware) implementation. In spite of the seemingly different underlying principles, most of the wellknown neural network models are implicitly equivalent or similar to classical statistical pattern recognition methods (see Table 3). Ripley[13] and Anderson et al.[8] also discuss this relationship between neural networks and statistical pattern recognition. Anderson et al. point out that “neural networks are statistics for amateurs... Most NNs conceal the statistics from the user.” Despite these similarities, neural networks do offer several advantages such as,

unified approaches for feature extraction and classification and flexible procedures for finding good, moderately nonlinear solutions.

Table 3. Links Between Statistical and Neural Network Methods

Statistical Pattern Recognition	Artificial Neural Network
Linear discriminant Function	Perceptron
Principal component Analysis	Auto-Associated Network, and various PCA networks
A Postoriori Probability Estimation	Multilayer Perceptron
Nonlinear Discriminant Analysis	Multilayer Perceptron
Parzen Window Density-based Classifier	Radial Basis Function Network
Edited K-NN Rule	Kohonen’s LVQ

7. Conclusions

It is the goal that most parts of the paper can be appreciated by a new comer to the field of pattern recognition based on the above discussion and can easily understand the basic concept of pattern recognition and can compare between the most used concept of this field. This paper is helpful for the researcher who is willing to pursue their research work in pattern recognition field.

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