Recognition by Computers : Technology and Applications in Real Life Problem Solving

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Recognition is one of the very basic attributes of human beings and other living beings. It is a process by which we can identify objects in our daily lives. Any object we recognize can be described by a pattern. So pattern is something that distinguishes an object from others of different kinds. Thus we can define pattern as any distinguishable interrelation of data, events or concepts.

We are performing the task of pattern recognition at every instant of our daily lives. We can recognize a friend by looking at his/her face or by hearing his/her voice over telephone; we can read books by distinguishing one character from the others; we can identify somebody by looking at his/her handwriting or signature or by analyzing his/her fingerprint; we are also able to distinguish between gestures of happiness from that of anger.

The process of recognition by computers is similar to that of the human being. Actually the human brain can be considered a super processor which possesses a superior pattern recognition capability. But this capability of human being was not with him from birth. A new born baby learns how to recognize its mother, father and other objects or patterns. The very basic step of learning is attaining the ability to make a difference. This ability is attained by psycho physiological processes that make a copy of each pattern received via physical stimulus into brain memory cells. As more and more patterns are perceived by a child, initially it tries to identify all of them as separate entities. But from experience it knows that some of the objects are of a certain category and some others are of different category and so on. Then it tries to categorize them into classes and refines the recognition process by storing a replica of each category. This process is called learning. When we perceive a pattern, we try to make an inference by associating this perception with some concept that has been developed in memory from past experiences. So, human recognition system tries to associate each input pattern to a set of statistical population whose nature depends on past experience. Thus the problem of pattern recognition may be regarded as the process of discriminating the input data or pattern awong populations, a process made possible by search of common features among the members of a population.

Recognition by machines are similar in many respects because the process of human recognition is simulated in the pattern recognition systems. The discrimination, that is done in the human brain memory cells, is tried to be imitated in computer based pattern recognition systems. Of course this does not mean that machines are as much capable of recognizing things as human beings are. Each recognition system has its limitations and generally it is applicable to a specific domain of patterns. For example, a recognizer that is designed for identification of English characters will not work for identification of flowers from their machine representations. In any case, classification of patterns can be considered a major step in the pattern recognition process. This classification depends on the statistical distribution of patterns in the relevant domain. But in early days, when the concepts of classification were applied to fields such as biological taxonomy, classification of planetary objects etc., no concepts of statistics, such as significance analysis, probability models or optimal procedures, were used. Some simple but useful methods like sorting, searching, joining, splitting etc. were used primarily for such classification purposes.

Obviously, the human recognition system is very fast and accurate. But still it has some limitations. When the complexity and domain size of the problem is huge, the human recognition system may not work satisfactorily. Also in some cases the human sensory organs cannot detect any pattern at all. For example, very low and ultra high frequencies cannot be detected by human ear; infra red and ultra violet region of the spectrum are invisible to human eye. And in such a situation, we want a machine to do the job for us. In many fields of application of pattern recognition the human sensory organs are found to be unfit. For example, to identify the position of a naval submarine, the sound signals coming from the submarine are to be detected out of a large number of other marine signals and noises. Another example of complex recognition is the identification of a person from his fingerprint or speech sounds etc. Many such examples can be cited where we are forced to depend on machines for greater capacity, reliability and accuracy. An interesting biomedical application is the classification of tumor cells in the midst of other kind of normal and abnormal cells. This information is extracted from Magnetic Resonance Images. Weather prediction is done as an output of the recognition processes. Here data are collected via different sensory devices and used to produce a weather map. This map is then analyzed by machines for significant features, whose classification leads to a forecast.

For recognition of a pattern by machine we must give the pattern a machine understandable i.e., numerical form. This form comes out to be a vector consisting of numerical measures of the significant features of the entity concerned. Thus it is very crucial to identify the features which will constitute the pattern vectors. For example, the pattern class "English Characters" may be represented by features such as vertical stroke, horizontal stroke, open face, curvature of face, lake, bay etc. Too few or poorly selected features may not characterize the patterns in question. On the other hand, too many features may unnecessarily complicate the processing involved, and in many cases give rise to undesired results. However, there is no general rule which provides clues regarding how to select the features to be included in a pattern. This depends entirely on past experience and general intuition of the designer of a classifier. So the extraction of effective features from input data is a very important task and in technical literature this is called preprocessing of feature vectors or reduction of dimensionality of pattern vectors.

The general approach to solve a pattern recognition problem may be described by the block diagram in Fig.1. Here the input is some representation of the input object, e.g., a scanned photograph, an MRI image, a database record etc. The first phase analyses the input to extract essential features, i.e., features of interests to construct an n-dimensional pattern vector, $x = \{x_1\ x_2\ ..x_n\}$. This task is called the preprocessing of features. If the input data is in the form of a wave signal, as shown in Fig.2, which may be represented as a continuous function of some variable t, then the function can be sampled at n discrete points $t_1, t_2, ..., t_n$, to get the individual components of the feature vector as $x_1 = f(t_1)$, $x_2 = f(t_2)$,. ..,$x_n = f(t_n)$. The next part, i.e., the decision generator is the most important part. One or more functions are evaluated to determine the class membership of an object. The highest response of the input vector to the objective function relevant to a class determines the membership of the input. In Fig. 1, the term O_i represents the value of the i^{th} objective function. The output is just the class identified in the process.

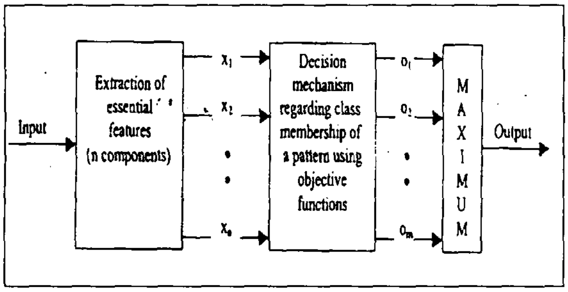

Fig. 1 : *Block diagram of a general pattern recognition system*

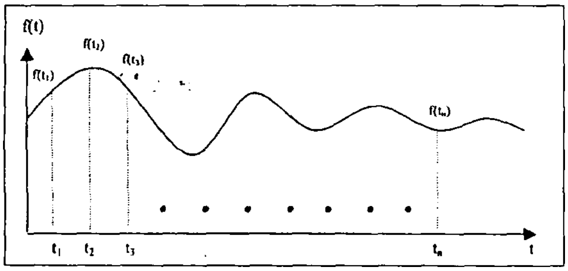

Fig. 2 : *Sampling method for generation of pattern vectors*

An automatic pattern recognizer can be designed in different ways depending on the nature of the feature space. When the feature space is simple enough and individual features are standard and not distorted heavily, then a template matching system will be sufficient. If all the features of a pattern class can be determined from a set of sample patterns, then the system may simply be reduced to a common feature matching one. In other situations, the concepts of clustering is employed. Clusters are subsets of patterns that have enough similarity among themselves. Clusters may be disjoint or conjoint. For the latter, not all the features of different classes are distinguishable. Here the concept of fuzziness is employed for classification. As the degree of fuzziness increases, the patterns become less and less distinguishable. Concepts of fuzziness are extremely important in pattern recognition because most of the patterns that have biological origins such as voices, handwriting etc., are essentially fuzzy in nature. Nowadays sophisticated systems employing artificial neural networks are being used in association with fuzzy logic to solve complex recognition problems.

The artificial neural networks essentially attempt to mimic the behaviour of the human sensory system. Here a number of processing elements are connected in a number of layers. Information flows from one layer to another, just as in human neural system stimuli are transmitted via a chain or mesh of neural bodies viz., axon and dendrite. After processing the stimuli in brain the knowledge obtained is transmitted to the neural bodies again as a part of learning process. This learning process is responsible for generation of reflex action. This reflex action enables us to respond to a particular object or event promptly. In artificial neural networks, this process of learning is imitated, where processing elements are made to learn from past experience by updating the information stored in them as newer and newer patterns are received as input. In Fig.3, a very basic artificial neural network is shown. In this diagram, X_j is the j^{th} input vector, i.e., $\{x_{j1} x_{j2} \ldots\ldots x_{jn}\}$, Y_i is the i^{th} output category, W_{ki} is the weight of the k^{th} path leading to the i^{th} output node. The output function is :

$$Y_i - \max_j \{\Sigma_k x_{jk} * w_{ki}\}$$

The weight vector is the learning factor. The weight vector component for the i^{th} processing unit at time instant (t+1) can be, in terms of the same vector component at time instant (t), defined as follows :

$$w_i (t+l) = w_i(t) + \Delta w_i(t)$$

where $\Delta w_i(t)$ is the change in the weight vector component. The magnitude of this change in the weight vector may be thought of as the amount of learning acquired by the system at any instant t. Generally this amount reduces with increase in time t, which is quite reasonable.

Though in Fig.3 only one level for learning is shown, it is possible to maintain multiple levels depending on the complexity of the learning or, in general, the recognition process. At each level, the learning factors are updated at each instance a new pattern is being input to the system. In the given diagram, the basic system is shown only; and in reality, when implementing a recognizer, the implementor may incorporate a more complicated set of interconnections between levels or within the nodes of the same level. The modified architecture then reflects the nature of information exchange between levels and nodes. In Pattern Recognition terminology, the modified architectures are often called feedforward and feedback connections depending on the direction of information flow. These modified systems are generally called adaptive recognition models. Adaptive models are of course the most suitable for their capability to adapt to any changes in the environment in relation to noise, deviation etc.

In this article, our aim is to view the basic architecture of the state-of-the-art artificial recognizers. A detailed technical description is out of scope. The ideology behind the development of a recognizer, that can imitate the human recognition process, is our main concern. It is expected that this simple presentation will encourage the enthusiastic reader to think of a system of his own, and provide instincts to design a recognizer for a certain real life application.

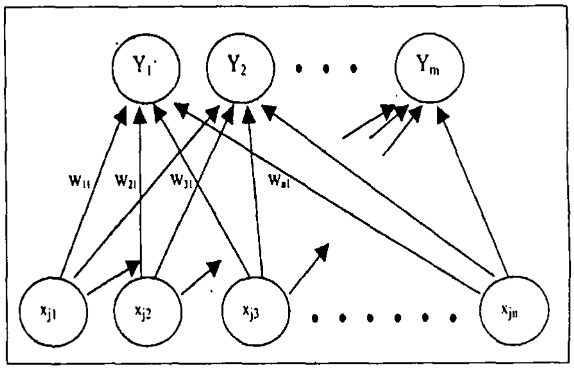

Fig. 3 : *A basic two layer artificial neural network*

Pattern recognition is a subject of interest to scientists and researchers due to its wide range of applications. By making a machine able to recognize objects, one essentially makes the machine more intelligent. Developing machine intelligence is a very interesting and challenging task. Pattern recognition is an interdisciplinary subject. Scientists from different branches of education are involved in the development of such systems. An amount of general commonsense, a little knowledge of computer programming and a great insight into the human recognition system can lead one to the development of an automatic recognizer. Advancements in computer technology and power of recently developed soft computing tools like evolutionary programming, simulated annealing, fuzzy logic etc. direct us to explore the supremacy of machines in the field of pattern recognition.

"Those who dare to discover will find endless possibilities for progress in life"