A Fast-Efficient Multi Class Pattern Recognition Method

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Abstract: ***This work presents a novel method for multi class pattern recognition. The feature space is classified with minimum hardware complexity and maximum speed using straight lines, circles, parabolas etc. RK algorithm-based devices (RKD) and mathematical functional blocks classify the feature space very rapidly after learning pattern classification with a fewer numbers of training sets compared to other statistical and artificial neural network (ANN) methods. RKDs are self-learning and fast responding devices and which manipulate a single variable at a time. The RK algorithm is used for learning the range of a variable. A set of sample variable and their corresponding responds are given for learning. The mathematical functional blocks manipulate one or more variables or attributes to perform mathematical functions and the outputs of these blocks are fed to RKDs. Finally, the RKDs perform the classification functions. The classification using straight lines or curves depends upon the mathematical functional block.***

Keywords: Pattern recognition, RK algorithm, Multi class pattern classification, Logical pattern recognition.

I. INTRODUCTION

Fast efficient Pattern recognition has many applications including object recognition, speech recognition, hand written character recognition, driverless vehicles and control systems. Conventional pattern recognition methods include ANN and statistical methods. In ANN method multi-layer Perceptron are used. Each Perceptron is a processing element. If the feature space is complex, ANN requires a large number of processing elements for classification.

A. ANN has the following disadvantages:

• ANN requires huge number of training sets [1-2], compared to RK algorithm-based devices. ANN learns to compute the weights between layers using trial and error method.

• The structure of ANNs requires processors with parallel processing power [1]. For this reason, the realization of it depends on application of ANN. High speed applications require parallel structures.

• Unexplained behavior of the network is the most important problem of ANN. If ANN produces a probing solution, it does not give information of how it solves the problem. This reduces trust in the network [2,3].

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• There is no specific rule for determining the structure of ANN. Appropriate network structures are achieved through experiences and trial and error method [4].

• ANNs can work only with numerical information. Problems have to be translated into attributes before being introduced to ANN and they are not directly solved by ANN [5].

• Since the adaptive duration of the network is unknown, the network is reduced to a certain value of the error on the sample and it means that the training has been completed. This value does not give us optimum results [6,7].

The RK algorithm-based systems require lesser number of training sets compared to neural networks. It is because of RK algorithm manipulate a single variable at a time. The hardware complexity of the RK algorithm is very less compared to ANN hardware complexity. The RK algorithm doesn't require complicated processing like addition, multiplication etc. All the activities in an RK algorithm-based system are predictable. The attribute values are also editable. There are rules for selecting RKD networks for different applications. The problems can be directly given to an RKD network. The network sizes can be determined by the user in order to obtain optimum results.

Mapping of an input feature space to an output space having more than two pattern classes is called as a multi class pattern recognition [8]. In this work an RKD based multi-class pattern recognition is presented. Section 2 includes the theory and methodology of RKD and multi-class pattern recognition methods, section 3 includes results and discussion, and section 4 concludes the work.

II. THEORY AND METHODOLOGY OF RKD FOR PATTERN RECOGNITION

The RKD is a self-learning device based on RK algorithm. It learns high and low values of a continuous variable X when the pair of this variable Y is high. The variable Y is in digital form. The function of RK algorithm is learning of these high and low values of X if a set of (X, Y) pairs are given. Fig.1 shows an RKD circuit which mainly consists of two op-amps, three AND gates, and two memory locations H and L for storing the high and the low values of the particular variable respectively. The op-amps work as comparators and the AND gates enable the memory locations. Thus, they produce test output after training and the H and L memory locations store the variables k' and k respectively. Thick lines indicate analog signal paths and thin lines indicate digital signal paths

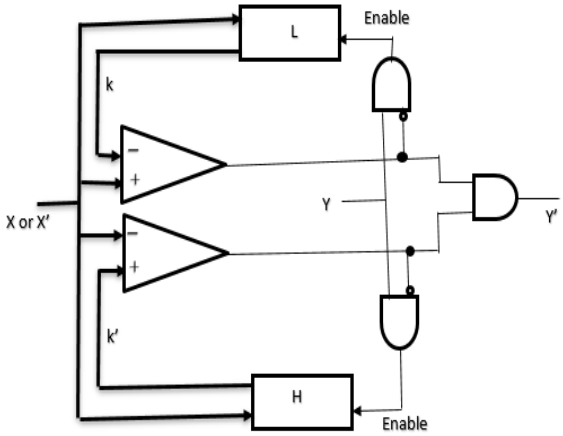


Fig.1 Circuit diagram of the RKD

The training algorithm of the RKD is given below.

A. RK algorithm for learning

1.initialize k = X_{max} and k` = X_{min}

2. m^{th} training step: check whether Y_m = 0 or 1

If Y_m = 1 and k >= X_m store X_m to the location L

If Y_m = 1 and k` <= X_m store X_m to the location H

3. Go to step 2 until the learning process is completed
4. decrease k = k - ΔX and increase k` = k` + ΔX

End

Processing time of the RKD is very low because this device does not perform arithmetic operations

B. Multi-class pattern Recognition

Multi-class pattern recognition has different kinds of applications[9-11]. A multi-class, denoted as K-class, classification problem can be described formally as follows. For a given d-dimensional feature space, Ø, and a training data set $Ø_{tr} \subset Ø$, where each element or attribute .x in $Ø_{tr}$ is associated with a class label cl, cl ∈ Class_Labels = $\{cl^1, cl^2, \ldots, cl^K\}$, where $cl^j \neq cl^h$ for all h ≠ j and K > 2, an ANN system F can be trained on $Ø_{tr}$ such that for any given feature vector .x ∈ Ø, F(.x) ∈ Class_Labels. F can be a system of ANN or a single ANN whose weights are determined by a neural learning algorithm.

Fig.2 is an illustration of a feature space having two features and an optimal classification boundary that separates all six classes in the feature space. The classification is using 9 straight lines. Multiple ANNs are combined using a decision block [8] for classifying these 6 classes.

Feature space classification problems can perform using mathematical functions like equation of straight line, parabola, circle etc. Using mathematical functions one can obtain the following advantages to reduce number of training sets and predict the behavior of the system. There are rules for selecting the RKD networks in which adaptive networks are possible. Other systems can edit the attribute values of RKD network.,

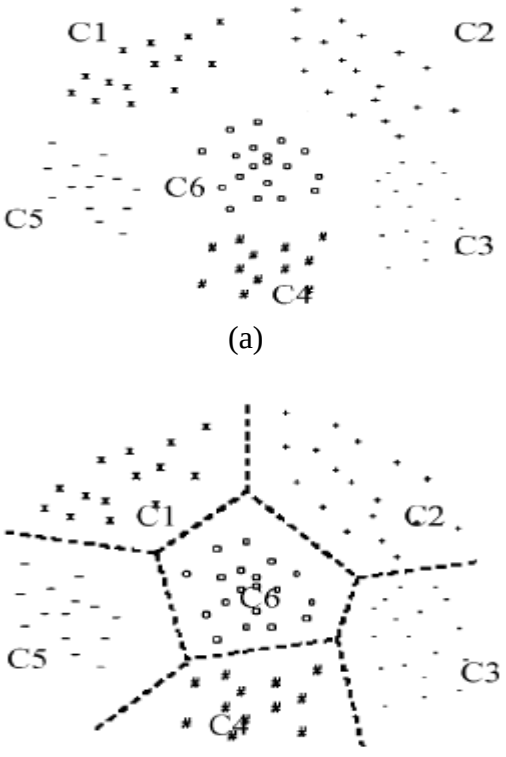


Fig.2 Illustration of feature space and classification, (a) the feature space, (b) an optimal classification boundary by which separates all six classes in the feature space

Fig.3 illustrates the feature space classification using mathematical shapes. Straight lines, circles and parabola are used for classifying six classes

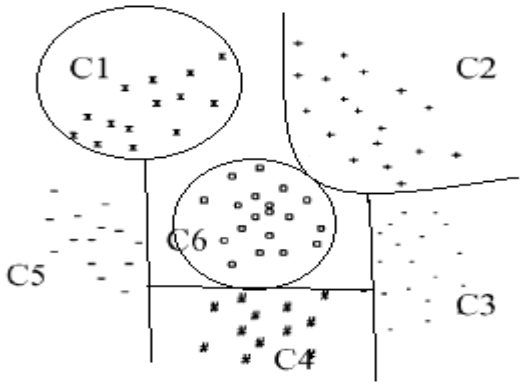


Fig.3 Illustration of feature space classification using mathematical shapes

C.Multi-class pattern Recognition using RKD

Equation of a line can be written as ax + by + c=0 in a Cartesian coordinate system, where x and y are the coordinates, a/b is the slope and c/b is the y coordinate intercept value.

Fig. 4 illustrates three classes C1, C2 , and C3 using two straight lines A and B which are parallel lines with same slopes. The only parameter changes here is c/b .

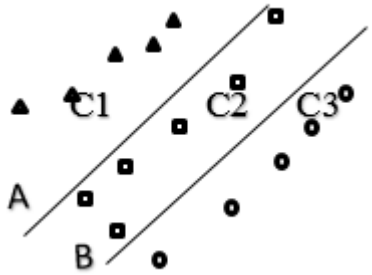


Fig.4 Illustration of feature space classification using straight lines

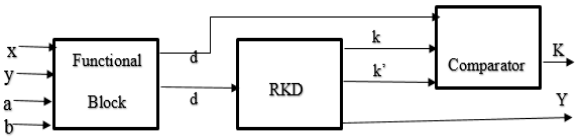


Fig.5 Diagram of a straight line based multi-class pattern recognition using an RKD

Fig.5 shows the diagram of a straight line based multi-class pattern recognition. It consists mainly a functional block, an RKD, and a comparator. Functional block manipulates mainly four variables x, y, a, and b. The slope a/b is taken as a constant for simplicity. Now the straight lines become parallel. The functional block produces an output d, where d = -c/b. The RKD is used to learn the range of this d by learning the lower limit k and upper limit k' for an optimum classification as shown in Fig. 4..

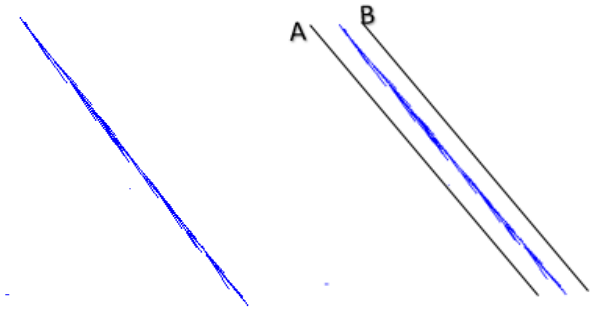
The comparator compares the values of d with k and k' while testing.

if $(d < k) \& (d < k')$ K=0 Y=0 Class C1
if $(d \geq k) \& (d \leq k')$ K=0 Y=1 Class C2
if $(d > k) \& (d > k')$ K=1 Y=0 Class C3

Similarly, equations of circle, parabola, ellipse are used for multi-class pattern recognition using RKDs. By combining different functional blocks, complicated multi-class patterns recognition is possible.

III.RESULTS AND DISCUSSION

Hough transform is the conventional method for straight line segment extraction and parallel Hough transform is used for high speed applications [12,13]. One of the main problems in high speed line segment extraction is the coincided lines with the original line. The original line is the longest line among the coincided lines as shown in fig.6 in which fig. 6(a) shows straight lines with number of coincided lines and fig. 6(b) shows two straight lines A and B with different values of d.

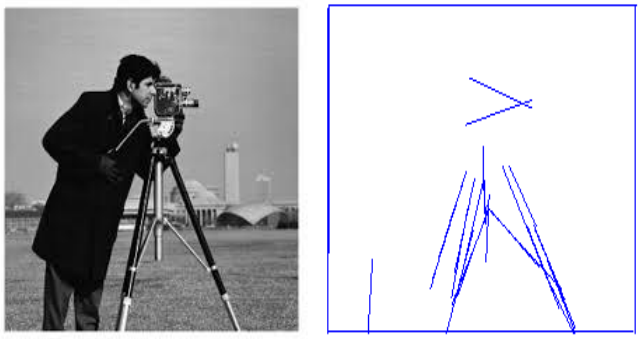


(a) (b)

Fig.6 (a)A straight line with a number of coincided lines, (b) two straight lines A and B with different values of d

Straight line-based pattern recognition employing RKD is used to extract the original line segment. When the pattern recognition problem shown in Fig.4 is considered, the original line segment among the coincided lines belongs to class 2.

Fig.7 shows the extracted straight lines from a camera man image using this method. Fig 7(a) is the original image and fig. 7(b) is the extracted straight lines from the image



(a) (b)

Fig.7 (a) original image: (b) extracted straight lines

The RKDs are used in multi-class pattern recognition problems for high speed object recognition applications. The RKD network manipulates a large number of features. Each feature is trained by an RKD. The entire RKDs are logically ANDed while testing. If the output of the AND gate is high the object belongs to that particular class. These processes are repeated by changing the feature values for classifying a large number of objects. The accuracy of pattern recognition depends on the number of features used. Table 1 shows comparison of accuracy with neural network methods and RKD network method

Table 1 Comparison of accuracy

Works	Data representation	Resolution	Dataset	Accuracy
[14]	Point cloud	1024	ModelNet40	89.2%
[15]		1024	ModelNet40	91.9%
[16]		5000	ModelNet40	93.4%
RKD network (present work)		512	Set of colored images with straight lines	99%

IV. CONCLUSION

The RKD networks are fast learning networks and they require lesser number of training data compared to other methods. The RK algorithm manipulates a single variable at a time. Different kinds of RKD networks are possible with lesser hardware complexity. Unlike neural networks the processing parameters are observable and editable by another system if erroneous predictions are observed. The RKD is a logical device and mathematical functional blocks can be added to the network. The speed and accuracy of pattern classification have been observed as high when feature space is large. It is a fast and accurate object recognition method.

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