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A Novel Neural Net based Off-line English Character Recognition System

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Abstract—

Handwriting recognition has been one of the active and challenging research areas in the field of image processing and pattern recognition. In this paper, Off-line Handwritten English Character recognition is done using Artificial Neural Network (ANN). Artificial Neural Network (ANN) with its inherent learning ability offers promising solutions for handwritten character recognition. Each image character is comprised of 10×10 pixels. We have applied feature extraction technique for calculating the feature. Features extracted from characters are directions of pixels with respect to their neighboring pixels. These inputs are given to a back propagation neural network with hidden layer and output layer. We have used the Back propagation Neural Network for efficient recognition where the errors were corrected through back propagation and rectified neuron values were transmitted by feed-forward method in the neural network of multiple layers. In this learning process, training and testing of characters is done.

Keywords— Handwritten Character Recognition; Feature Extraction; Back propagation network; Training, classification

I. INTRODUCTION

Hand written Character Recognitions, an area of pattern recognition that has been the subject of considerable research since last some decades. Many forms and applications are filled in English language and sometimes those forms have to be scanned directly. If there is no HCR system, then image is directly captured and there is no option for editing those documents. Handwritten character recognition (HCR) is a process of automatic computer recognition of characters in optically scanned and digitized pages of text. The main objective of an HCR system is to recognize alphabetic characters, which are in the form of digital images, without any human intervention. [1]

In general, handwriting recognition can be classified into two major categories, namely off-line and on-line hand writing recognition methods. In the on-line system, the two dimensional coordinates of successive points are represented as a function of time and the order of strokes made by the writer are also available. In the off-line recognition, the writing is usually captured optically using a scanner and the completed writing is available as an image. The on-line methods have been shown to be superior to their off-line counterparts in recognizing handwritten characters due to the temporal information with formal. Off-line handwriting recognition is comparatively a difficult task, as different people exhibit different handwriting styles. Off-line handwriting recognition refers to the process of recognizing words that have been scanned from a surface (such as a sheet of paper) and are stored digitally in grey scale format. After being stored, it is conventional to perform further processing to allow superior recognition. Optical Character Recognition (OCR)/Image Character Recognition (ICR) engines have been primarily developed for recognizing machine printed and hand printed texts, while the recognition of handwritten documents entails special consideration as it involves recognizing the characters written with varying styles.

The steps in any handwritten recognition system are pre-processing followed by segmentation, feature extraction and classification. Pre-processing shapes the

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input image into a form suitable for segmentation. This includes filtering, morphological operations, noise modeling and normalization. In the segmentation, the input image is segmented into individual characters and then, each character is resized into m x n pixels towards the training network. Segmentation includes external and internal segmentation. External segmentation decomposes page layout into logical units. While internal segmentation decomposes words into characters.

Feature extraction is a method widely used in pattern recognition. Feature extraction determines the important properties such as Aspect Ratio, Percent of pixels above horizontal half point, Percent of pixels to right of vertical half point, Number of strokes and Average distance from image center. This approach provides the recognizer more control over the properties used in identification. However, certain methods of modeling can incorporate both the feature extraction and classification stages together for simplifying the process of recognition.

II. Artificial Neual Network

An Artificial Neural Network (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. ANNs, like people, learn by example. 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. This is true of ANNs as well.

An Artificial Neural Network is a network of many very simple processors ‘units’, each possibly having a small amount of local memory. The units are connected by unidirectional communication channels ‘connections’, which carry numeric as opposed to symbolic data. The units operate only on their local data and on the inputs they receive via the connections. The design motivation is what distinguishes neural networks from other mathematical techniques: A neural network is a processing device, either an algorithm, or actual hardware, whose design was motivated by the design and functioning of human brains and components thereof.

There are many different types of Neural Networks, each of which has different strengths particular to their applications. The abilities of different networks can be related to their structure, dynamics and learning methods. Fig1.1 shows the architecture of Multilayer neural network

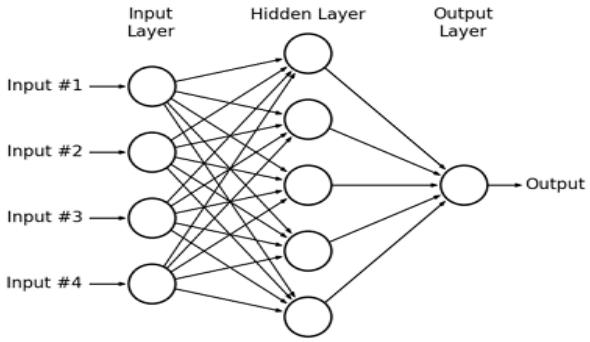

Fig1.1 Architecture of Multilayer neural network [10]

III. Problems in Character Recognition Steps

A handwritten character may appear differently from picture to picture due to the image transformations of size, orientation, or location. In addition, the diversity of writing styles results in vast variations in the appearances of characters. A handwritten character presented in the image plane should be correctly recognized by the system in spite of these circumstances. These problems are prescribed in detail in the following sections

A. Image Transformations

One of the recognition problems encountered due to image transformations is the scaling of the object in the image plane. This problem results from the change of size of the object image. As such a change is very common in handwritten documents; it should be overcome by the recognition system. For example, the three upper case A's with different sizes in Fig (2.1a) and Fig (2.1b) should be recognized as the same one. One way of dealing with this problem is performing an image normalization, so that all and written characters presented in the two dimensional image plane are of the same size before recognition. Another way is to extract from the character unique features which are invariant to scaling, so that the system responds strongly to the selected features, no matter what size the character is. In recognition system, once the features of a character are detected by the system, the character can be correctly identified.

Fig (2.1a) ’A’ with different font sizes

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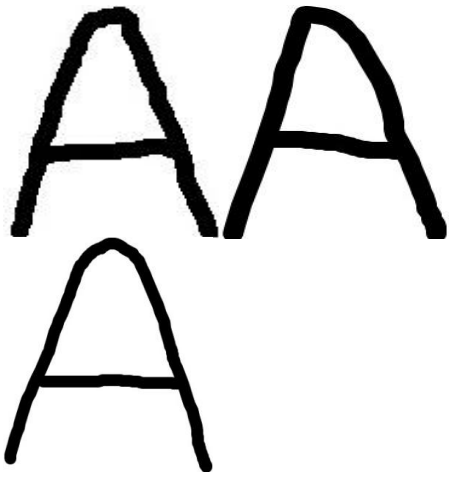

Fig (2.1b) Normalized images

B. Object Location

In addition to the problems described above, the change of the object location in the image plane may also cause a false recognition. The location of a character image is important for the systems which perform the recognition on low level images, such as raw images. In this case, each pixel in the image plane is supposed to give some image information. For a 20×20 binary image, the image vector contains 400 elements each of which is a pixel value. Character image change in location results in a new image vector, which may be quite different from its original. In high level image recognition, the problem can be solved by edge detection techniques which detect the object boundary, and the system uses the object boundary for recognition task. However, the boundaries of handwritten characters are not all the same, and size normalization must be employed.

C. Variations of Writing Style

Great shape variations of handwritten characters due to different writing styles yield another recognition problem. Handwritten characters have a very wide range of variations from their prototypes. Different people writing the same character may produce incredibly different images. Thus, a handwritten character recognition system must have the flexibility to recognize the various writing appearances of the same character without losing the accuracy of distinguishing different characters which have similar appearances

D. Noise in digital image

Noise is the errors occurred during the image acquisition process that results in pixel values that do not reflect the true intensities of the real scene. Digital images are prone to be corrupted by a variety of types of noises. Common types of noises include salt and pepper noise and Gaussian noise. Salt and pepper noise contains randomly distributed occurrences of both black and white impulses. Gaussian noise contains intensity variations that are drawn from a Gaussian distribution and is a very good model for many kinds of sensor noises caused by camera electronics errors. These noises can hinder the performance of the whole system. Thus it is required to remove these noises. Hence pre-processing is required to be carried out on the acquired image. Fig .2.2 shows the different types of noise presents in digital Image.

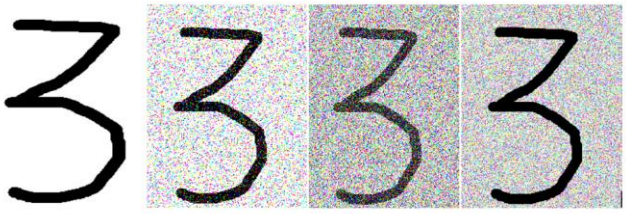

Fig 2.2 (a) Original Image (b) salt and pepper noise (c) Gaussian noise (d) Speckle noise

IV. Character Recognition System

Fig.3.1 shows the basic steps of character recognition system.

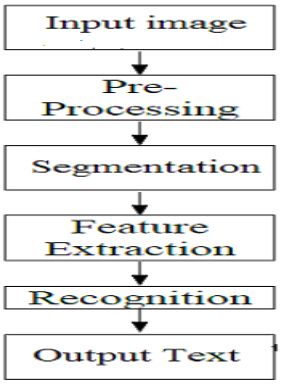

Fig. 2. Character recognition steps [2]

A. Pre-Processing

The pre-processing stage yields a clean document in the sense that maximal shape information with maximal compression and minimal noise on normalized image is obtained. It includes noise removal and location identification

B. Noise Removal

We can use linear filtering to remove certain types of noise. Certain filters, such as averaging or Gaussian filters, are appropriate for this purpose. Median filtering is similar to using an averaging filter, in that each output pixel is set to an average of the pixel values in the neighborhood of the corresponding input pixel. However, with median filtering, the value of an output pixel is

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determined by the median of the neighborhood pixels, rather than the mean. The median is much less sensitive than the mean to extreme values (called outliers). Median filtering is therefore better able to remove these outliers without reducing the sharpness of the image. To remove noise, adaptive filter applies a Wiener filter (a type of linear filter) to an image adaptively, tailoring itself to the local image variance. Where the variance is large, little smoothing is performed. Where the variance is small, more smoothing is performed.

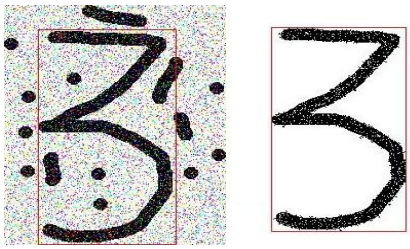

Fig.3.1:(a) Shows a character '3' with both the types of noise. Fig 3.1(b) character '3' after noise removal

C. Image Segmentation

The term image segmentation in the areas of conventional image processing is used for the process that partitions an image into regions of different categories. In neural network applications, it is the task that extracts individual objects which are contained in an image, so that only one object is in a sub-image. In other words, segmentation is to separate individual objects in an image from each other, so that the recognition system can process them individually. Images of handwritten characters are obtained by applying image segmentation to picture images of survey sheets, A threshold process then operates on each character image to obtain the binary image form in which the object pixels and the background pixels are assigned 1s and 0s, respectively. The resolution of the binary image is 20×20, which means that a binary image is in a 20×20 matrix form. After the image segmentation, the binary images of objects are ready for feature extraction.

D. Feature Extraction

The image is stored in matrix form. Character is written only on some of the portion of the image. This Character must be found out and that portion is cut from the image. Now a suitable matrix is extracted from the image as input to the neural network. This is called feature extraction. Feature extraction includes some step by step processes to be performed on the image.

- *RGB to grayscale image conversion*: Input RGB image into gray scale image. The aim is to formulate a Matlab based program that implements the use of a trained neural network to recognize.
- *Gray scale to binary image conversion*: the gray scale image into binary image. In a gray scale image there are 256 combinations of black and white colors where 0 means pure black and 255 means pure white. This image is converted to binary image by checking whether or not each pixel value is greater than255•level (level, found by Otsu's Method). If the pixel value is greater than or equal to 255•level then the value is set to 1 i.e. white otherwise 0 i.e. black. Figure 3.2(a) is showing a gray scale image with 0-255 level of histogram and figure 3.2(b) is showing a BW or binary image with two level of histogram.

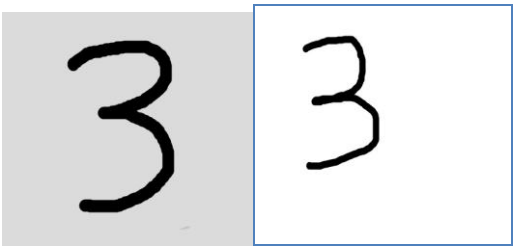

Fig3.2(a) RGB Image Fig 3.2 (b)Binary Image

- *Find the Object Location:* Characters can be written anywhere on the page and with any size and width of pencil. For this reason the location of character must be find out and the remaining porting of the page must be cropped. In this project The character is found out and a square is drawn such that it fits the boundary of the character.

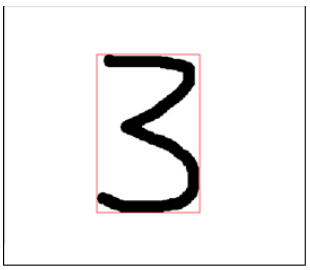

Fig 3.3 Find location of a character

- *Cropping:* After the character is found out and the square is drawn on the boundary of the it, the remaining portion of the image must be cropped .The advantage of cropping is that any sized character can be normalized after to get data from it. Now the cropped portion of image in resized to standard size.

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- *Normalization:* Due to the nature of handwriting with its high degree of variability and imprecision obtaining these features, is a difficult task, So different characters have different size and same for cropped images. To get same number of features for all images, we must need to convert images in the same dimensions

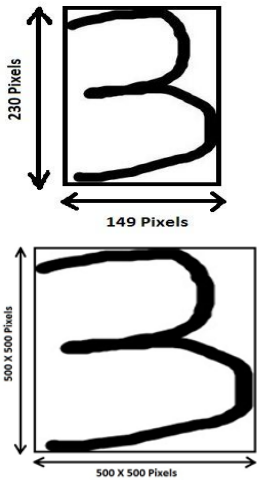

Fig 3.4 Normalization

- *Database creation:* Database is like the heart for the recognition system. It is the collection of all the types of patterns to which the system will be designed to work. For the character recognition system we need to have English alphabets (both upper case and lower case) and numerical data (0 to 9) as the database. Database usually consists of different fonts in case of printed recognition system or predefined handwritten characters in handwritten character recognition system. Many samples of each character are taken to create a database.

E. Recognition or classification

The classification stage performs the recognition based on the knowledge from the learning phase. A test sample is compared to all the cluster centers generated in the learning phase, and the classification decision is made in accordance with the classification criteria. The decision made on a test sample is either to recognize or to reject this sample. The rejection is made when a sample cannot be assigned to a unique object class. Otherwise, the classification is made. In multiclassifier systems, samples which are rejected by a single classifier may still be subject to the recognition process in other parts of the system.

V. EXPERIMENTATION

The images stored by Matlab are binary matrices, and as such, not suitable for direct use in a neural network. So, we have to somehow extract features from each image that we can subsequently use for classification. This is the most important design decision in the procedure, since without a good feature set we cannot expect to see good results.

In feature extraction stage each character is represented as a feature vector, which becomes its identity. The major goal of feature extraction is to extract a set of features, which maximizes the recognition rate with the least amount of elements.

Our main target is to find a vector from the image. So image is processed and then binary image is created. So we have only 2 types of data on the image. Those are 1 for the white space and 0 for the black space. Now we have to pass the following steps for creating 625 length vectors for a particular character or image.

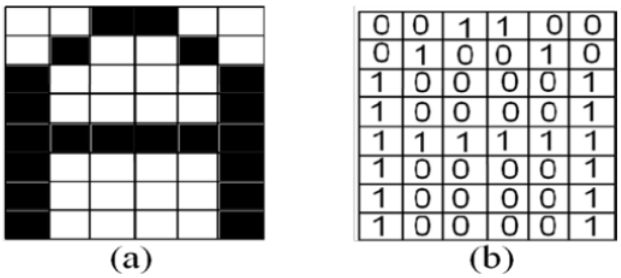

Fig 4.1 (a) English Character pixels (b) Extracted Pixel [8]

Extraction of information vectors

We sample the entire image into a specified portion so that we can get the vector easily. We specified an area of 10 X 10 pixels. For this we need to convert the 500 X 500 image into the 50 X 50 area. So for each sampled area we need to take 10 X 10 pixels from binary image.

To understand how the training matrix is created, consider table (0) to (5).Table (0) to (5) shows a matrix of 5x5 matrix of '0' to '5' respectively. These matrices are then converted into the 25x1 matrix. Table (A) shows that such matrices (25 x 1) of 0 to 3 are joined to make 25x6 matrix.

But in this project, instead of 5 x 5 matrix, 50x50 matrix for each image is generated, so the final matrix is 2500x1.To train the NN total 10 images of each character is used and there are 26 alphabets and 10 numeric digits. So we have training matrix of 2500x360(2500 x260 + 2500 X 100). This matrix is used to train the net.

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0	1	1	1	0
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
0	1	1	1	0

Table 0

0	0	1	1	0
0	1	1	1	0
0	0	0	1	0
0	0	0	1	0
1	1	1	1	1

Table 1

0	1	1	1	0
1	0	0	1	0
0	0	1	1	0
1	1	0	0	0
1	1	1	1	1

Table 2

1	1	1	1	0
0	0	0	1	1
0	0	1	1	1
0	0	0	1	1
1	1	1	1	0

Table 3

0	0	1	1	0
0	1	0	1	0
1	1	0	1	0
0	1	1	1	1
0	0	0	1	0

Table 4

1	1	1	1	1
1	1	0	0	0
1	1	1	1	0
0	0	0	0	1
0	1	1	1	0

Table 5

In Table 'A' column C0 is vector for character '0' which is obtained by converting 5 x 5 matrix of table 0 into matrix of 25 x 1. Same for C1, C2, C3, C4 and C5. Such a matrix for all the numerical and alphabets are formed to create input matrix for neural net.

Output Matrix

In table 'B' Column 1 shows output vector for '1' .If first element of vector is '1' than the recognized image is '1'. If the second element of vector is '1' than the recognized image is '2' and so on. The output value we are getting may not perfect '1' or '0'. It is because of some errors.

C0	C1	C2	C3	C4	C5
0	0	0	1	0	1
1	0	1	1	0	1
1	1	1	1	1	1
1	1	1	1	1	1
0	0	0	0	0	1
1	0	1	0	0	1
0	1	0	0	1	1
0	1	0	0	0	0
0	1	1	1	1	0
1	0	0	1	0	0
1	0	0	0	1	1
0	0	0	0	1	1
0	0	1	1	0	1
0	1	1	1	1	1
1	0	0	1	0	0
1	0	1	0	0	0
0	0	1	0	1	0
0	0	0	0	1	0
0	1	0	1	1	0
1	0	0	1	1	1
0	1	1	1	0	0
1	1	1	1	0	1
1	1	1	1	0	1
1	1	1	0	1	1
0	1	1	0	0	0

Table 'A'

1	2	3	4	5	6	7	8	9	0
1	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0
0	0	0	0	1	0	0		0	0
0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	1

Table 'B'

V. RESULTS

Here, the output layer has same no. of neurons as the no. characters to be recognized. Results show that for character '1', the first neuron has value 1 and others have value 0. Thus '1' is recognized. Similarly for other characters are also recognized.

Test Image	Output	Target
	0.99981; 0.00086311; 6.4674e-005; 0.0001896	1 0 0 0
	[0.00086996; 0.99993; 0.00010702; 0.0010854]	0 1 0 0
	[0.00025829; 0.0032607; 0.99332; 0.00024777]	0 0 1 0
	[0.0042078; 0.0011849; 0.00011399; 0.9998]	0 0 0 1

Such tests are performed on different alphabets .The alphabets are recognized correctly. Few alphabets

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which are similar to numerical characters (like alphabet 'O' and number '0') are difficult to differentiate.

Neural Network is trained Performance graph is given below in Fig5.1, Fig5.2 and Fig5.3.

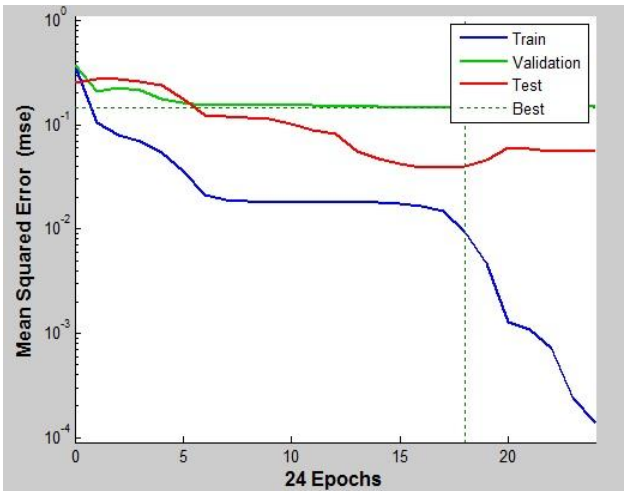

Fig 5.1 Mean Square Error vs. Epochs

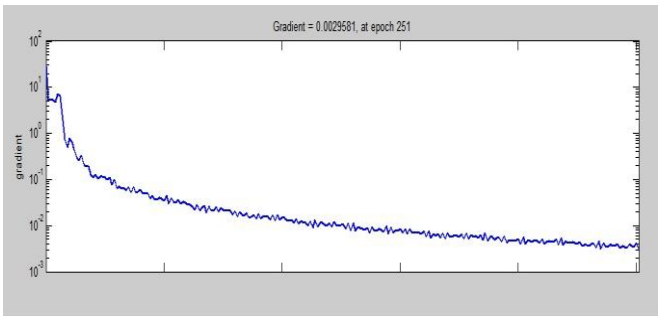

Fig 5.2Training States: Gradient vs. Epochs

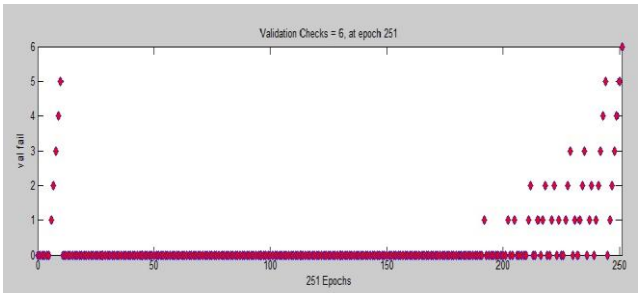

Fig 5.3Training States: Validation vs. Epochs

VI. Conclusion and Future Scope

A. *Conclusion*

An optical character recognition program has been implemented using neural network tool. The character recognition processes performed using matrix of 2500x1 as inputs to a self-organizing map neural network. The neural network is capable of distinguishing 62 characters of the English language (both uppercase and lowercase letters, together with numerals 0 - 9).

For simulation and training multi-layer Perception neural network with back propagation functions has been used. In fact, trained back propagation neural networks are able to recover unknown data (correct data entry) from the database. If a set of input patterns repeatedly presented to it, the ability to detect these patterns brings. One of the major problems in designing long-term problem of how to sample detection machine to cope with changes in position and shape distortion in the input patterns. Network proposed in this project is a partial solution for this problem.

B. *Future scope*

In this thesis, we mainly focused our research on the image invariants from the perspective of the image transformations of scale, and translation. The evaluation of the invariant property of these image invariants under the transformation of shear will be of great interest for the future work; because it is very common that the angle of the scanned paper image acquisition. Find out the angle range to keep the property of the image invariants will make the character recognition system more flexible and reliable.

Another research interest will be on the images degraded or blurred by various reasons. In this thesis, we researched the salt and pepper, Gaussian and speckle affected images. But as the image acquisition process can be affected by other factors such as diffraction, lens aberration, wrong focus and atmospheric turbulence, the degraded image can be of various formats. Exploration of the blur-invariant image features based on these image invariants or some other algorithms will make the recognition systems more reliable and robust.

Further, here the output layer has same no. of neurons as the no. of characters to be recognized. The output may also be ASCII value of the character. So the output from the neural net can be directly used by the computer for further manipulation.

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