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Feature Vector of Binary Image using Freeman Chain Code (FCC) Representation based on Structural Classifier

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Abstract

This paper presents a recognition system for English Handwritten that utilized Freeman Chain Code (FCC) as data representation. There are 544 features were extracted from character images that used six techniques to extract the features. Before extracting the features, thinning algorithm was applied to the original image to produce a Thinned Binary Image (TBI). A feed forward back propagation neural network was used as classification. National Institute of Standards and Technology (NIST) database are used in the experiment. The accuracy yielded from the system is 87.34%.

Keywords: *Handwritten Character Recognition (HCR), Thinning Algorithm, Freeman Chain Code (FCC), Feature Extraction, Artificial Neural Network (ANN)*

1 Introduction

Handwritten Character Recognition (HCR) or automatic offline reading system still a challenge task among researchers nowadays even there are almost four decades people working on it. A lot of successful works have been reported before with variety of methods. There are two types of HCR which are online and offline system. Offline HCR system is more complex because human handwritten has unique properties that causing infinite variety of style among the writers. Due to this wide range of variability, it is difficult to recognize by a machine [1]. A robust system need to be created to solve this problem.

An automated character recognition system is a solution that can interpret characters automatically. The automatic recognition of characters can be extremely useful where it is necessary to process large volume of handwritten characters. HCR can be classified into three stages, which are pre-processing, feature extraction and classification. Pre-processing is involving operation to produce a clean character image and can be used directly and efficiently by the feature extraction. In feature extraction, effective and efficient features are to be selected for use in classification stage. The last stage is the classification that is the end of HCR where image character is being recognized. The success rate of the system is depending on the entire stages.

This paper is divided to six sections. Section 2 describes literature review and previous works. Section 3 describes research methodology in HCR which are pre-processing, feature extraction and classification. Section 4 describes proposed framework, Section 5 describes result and discussion and Section 6 describes conclusions, limitations and future research.

2 Literature Review

The goal of offline HCR system is to recognize and interpret input which usually optically captured from a scanner and it will available as an image. A lot of practical applications in HCR are used nowadays such as cheques processing without human involvement, reading aid for blind, automatic text entry into computer for desktop publication, library cataloguing, health care, ledgering, automatic reading of city names and addresses for postal mail, document data compression, natural language and processing investigation forms or the automatic reading of postal addresses [2, 3].

In addition, different style of writing will produce different data even though based on the same character. There are many databases used by researchers in HCR, for example English databases such as CENPARMI [4], CEDAR [5] IRONOFF [6] for French database; Indian database ISI [7]; Japanese database [8]; Kanji database [9]; Chinese database [10, 11]; Persian/Arabic database [12]; Bengali database [13] and Tibetan database [14] Figure 1 shows the different styles of handwriting.

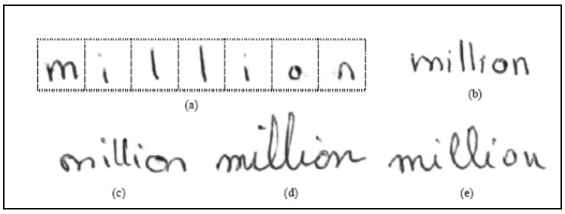


Figure 1: Different Styles of Handwriting

As we mentioned above, a HCR system usually has pre-processing, feature extraction and classification stages. The purpose of pre-processing is removing or minimizing the noise of the image before move to the next stage. Besides, the point of pre-processing is for data standardization to make it feasible to the recognition algorithms and to reduce data complexity. Feature extraction plays the most important rule of a HCR system which that the accuracy of the system is depending on this. The selected features will act as feature vector and will be the input for the classifier. Classifier is functioning to rate the accuracy of HCR system.

2.1 Pre-processing and FCC Extraction as Data Representation

Thinning algorithm is a process used on binary images to eliminate specific foreground pixels. Thinning structure consists of two elements namely ‘1’ as the foreground pixels and ‘0’ representing the background pixels.

Chain code representation gives the code of the boundary of character image, the codes that is representing the direction of where is the location of the next pixel and correspond to the neighbourhood in the image. Two types of boundary description algorithm are repeatedly applied for binary image: chain code based and run-length based algorithms [15]. Usually used in image compression, the run- length algorithm works by listing the successive ‘runs’ of similar objects and background pixels [15]. On the other hand, chain code based algorithm of a character image first through a binary image as input. Binary image is a representation with only two possible gray values for each pixel, such as “0” and “1”. Frequently, binary images attended in two types categories are the foreground is represented by 1 and the background is represented by 0. An 8-direction FCC is used for descriptions of object borders in image field because of simple and compact form of data representation and its suitability for fast processing. This paper utilizes 8-neighbourhood in extraction of characters as shown in Figure 2.

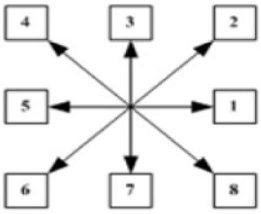


Figure 2: 8-Neighbourhood FCC Direction.

Freeman Chain Code (FCC) will be generated using Randomized based Algorithm which obtained the shortest computation time [1]. The randomized-based algorithm is an algorithm that makes random (pseudo- random) choices. The advantage of randomized algorithm is the one that comes with a very high probability of correct computed results [16]. Randomized-based algorithm is one of Heuristic technique. A heuristic is defined in [17] as a technique which attempts to seek or find good solutions to a difficult model. Heuristic is an optimization problem that is concentrated on space complexity and time. Time complexity is referred to the running time of the program whereas space complexity is referring to the amount of computer memory required during the program execution. The amount of time and space are needed to solve the computation of complexity theory.

In this paper, features vectors were created from six methods to increase the accuracy. There were source image properties, pixel density calculation and transition, vector distance count, cross corner feature extraction and standard deviation and zone centroid average distance.

2.2 Classification

After features that represent the raw input data are extracted, classification stage would use the data to recognize the feature class based on the properties in the features. There are two kinds of classifier, one that needs to be trained to be familiarized with the input data pattern, and which that try to conclude the grouping independently. The former is termed as supervised learning while the latter is unsupervised learning. The learning process included in classification consists of supervised and unsupervised learning. Supervised learning is where the definitions of classes are done by the researcher and learning process is based on training data, formed by pairs of input object and desired outputs. On the other hand, unsupervised learning, which the input pattern is assigned to an unknown class so the determinations of the classes are based on the similarities of the features. After a pattern is mapped (represented), the next stage is classification.

ANN has been developed as generalizations of mathematical models of human cognition or neural biology, based on the following assumptions [18]:

i. Information processing occurs at many simple elements called neurons.
ii. Signals are passed between neurons over connection links.
iii. Each connection link has an associated weight, which, in a typical neural net, multiplies the signal transmitted.
iv. Each neuron applies an activation function (usually nonlinear) to its net input (sum of weighted input signals) to determine its output signal.

ANN is a supervised learning process. Supervised learning is when the input and desired output are provided. ANN can be classified into feed forward or recurrent depend on their connectivity. An ANN is a feed forward network if an arbitrary input vector is propagated forward through the network and caused an activation vector to be produced in the input layer. On the other hand, a recurrent network if the output vector is propagated backward to the previous layer. Single-layer perceptron, multi-layer perceptron and radial basis function nets are the examples of feed forward networks while for recurrent networks are competitive networks, kohonen's SOM, Hopfield network and Adaptive Resonance Theory (ART) model. This paper only concentrates on feed forward network with multi-layer architecture.

2.3 Previous Works

There are a lot of previous works on HCR discussed in Table 1. These works were using Roman scripts in their system. Various pre-processing and feature extraction techniques had been presented. The result was discussed in detail for all works. Majority of the works are done with all three stages. Binarization, noise reduction, normalization and thinning are often used as pre-processing in their work prior goes to feature extraction. Variety of feature extraction methods are applied in their work and all showed excellent result which is 90% and above. In this section, neural network is used as classifier to recognize the handwritten character.

Similar to our work, skeletonization or thinning had been done in [20] in their pre-processing stage. In addition, this work was done on NIST numeral database. A combined classifier was used and yielded excellent result. As discussed above, this work also used a lower quantity of training and testing samples. There was another work done by [21] that used lower quantity of testing and training samples. They used profile projection technique to extract the features. The accuracy achieved was high that reached 95.33%. Table 1 shows the previous works done by several researchers.

Table 1: Literature Review and Previous Works

Authors	**Pre-processing**	**Feature Extraction**	**Classification**	**Accuracy**
[19]	Segmentation, binarization, noise removal	Diagonal Feature Extraction Method Produced 54 features of each character	ANN	98.54%
[20]	Binarization and skeletonization	Complex Wavelet Features produced 772 features	ANN	99.25%
[21]	Noise removal and resizing	Vertical, Horizontal, Left Diagonal and	ANN	95.33%.

		Right Diagonal directions produced 94 features		
[22]	Binarization, resizing, thinning	Cross-corner feature extraction method produced 88 features	ANN	97%
[23]	Normalization	Zoning based features, upper and lower character profile projections features, left and right character profile projections features, distance based features produced 325 features	ANN	99.03%
[24]	Noise reduction	Structural features and the statistical features	ANN	100%
[25]	Binarization and segmentation produced 88 features	Transition Feature, Sliding Window Amplitude Feature, Contour Feature	ANN	92.32%.
[26]	Binarization and segmentation	Transition features	ANN	92%.
[27]	Not specify	Speeded Up Robust Features (SURF)-Upgraded SIFT	ANN	93.8%
[28]	Scaling and slanting deformation	Chain code features	RBF-NN and SVM	>99%

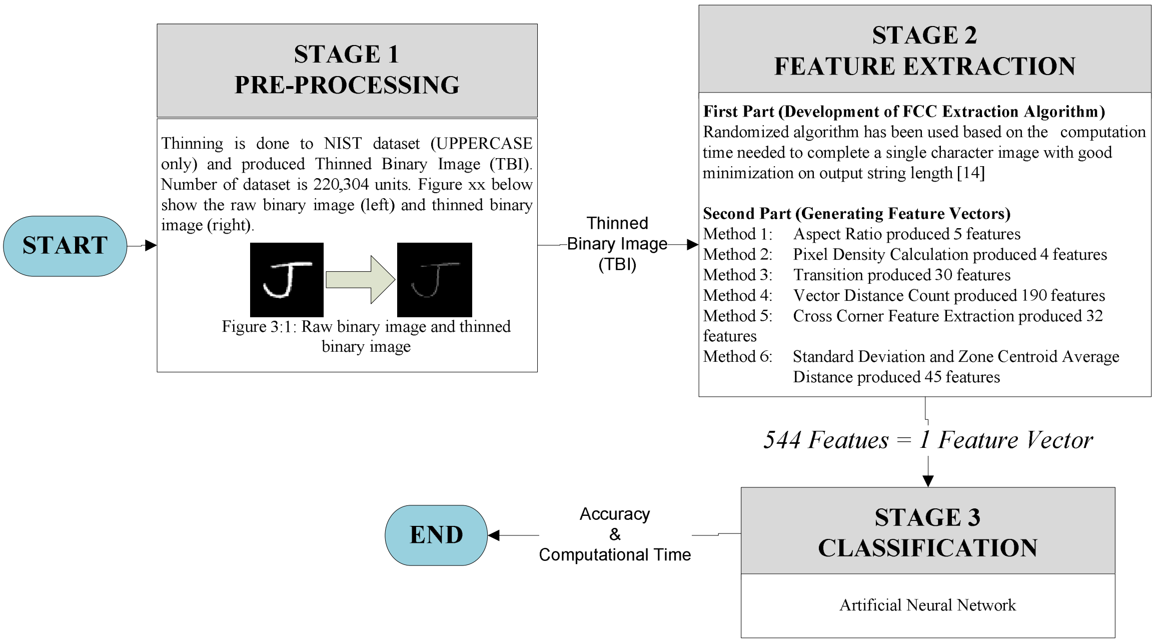
3 Research Methodology

There are three major issues related to the problems that are HCR and its problem; pre- processing particularly thinning algorithm in image processing; and FCC as data representation. In feature extraction and selection, proposed randomized-based algorithms to generate the FCC and followed by feature selection is to be distinguished. Continuing on the process is the problem and description of ANN as classifier to classify image characters. The process of problem identification is done by referring to the previous literatures in published papers and journals. After the problem identification and specification is completed, the next step is data definition and collection.

3.1 Data Definition and Collection

Data definition is a process of defining the type of data used, deciding the sources of dataset, checking the validity of the dataset, and categorizing the dataset for testing and validation. In the other hand, data collection means having the input data extracted or built from the original source and gathered into a compilation of huge numbers of input. Therefore, data collection is gathering relevant information in order to develop, testing, validating and analyzing the algorithms. For NIST dataset, the data is collected from the publisher [29]. In data collection for the purpose of validating and analyzing the algorithm, a function is created in the Matrix Laboratory (MATLAB) program so that the data such as route length and time are tabulated as output from the program.

This section presents the general information of research framework that describes the whole activity in this paper. The research framework is demonstrated in Figure 3. It shows the detail of the process involved in the research framework. In HCR, input data is defined and collected so that it can be manipulated in achieving the objective. NIST database was used in the experiment. Hence, which character image dataset to be used is identified and selected to be the input source in further progression. First stage is pre-processing. Pre-processing is the process to prepare and transform raw original data from the database to suit through the thinning process. Randomized-based algorithm is used to extract Chain Code (FCC). Further development of feature extraction to identify effective and efficient features from available data material and character classification algorithms are done in Stage 2. The classification algorithm is built as ANN implementations to generate the features then classify the image characters are presented in Stage 3. The outputs of this stage are accuracy and computation time.



Thinning is done to NIST dataset (UPPERCASE only) and produced Thinned Binary Image (TBI). Number of dataset is 220,304 units. Figure xx below show the raw binary image (left) and thinned binary image (right).

Figure 3:1: Raw binary image and thinned binary image

First Part (Development of FCC Extraction Algorithm)
Randomized algorithm has been used based on the computation time needed to complete a single character image with good minimization on output string length [14]

Second Part (Generating Feature Vectors)
Method 1: Aspect Ratio produced 5 features
Method 2: Pixel Density Calculation produced 4 features
Method 3: Transition produced 30 features
Method 4: Vector Distance Count produced 190 features
Method 5: Cross Corner Feature Extraction produced 32 features
Method 6: Standard Deviation and Zone Centroid Average Distance produced 45 features

Figure 3: The proposed research framework

3.2 Pre-processing and Randomized-based Algorithm in FCC Extraction

In pre-processing stage, the raw image is converted to Thinned Binary Image (TBI) by using established thinning function inside the MATLAB tools. The chain code will be extracted from TBI by using randomized-based algorithm. The general structure of the applied algorithm is to follow the routes in the image character while keeping track the route that is already used [29][33]. The starting or first node to begin chain code tracing is selected randomly. There are two options for this, whether by "node method" or "end node method". The former is to find any node based on its position at each "corner" such as left upper, right upper, left lower and right lower. As for the latter, the aim is to find any character that only has one neighbour. Three types of neighbours will be used: not visited,

visited and taboo neighbours. These types will be used to check the neighbourhoods during the route tracing process. Finally, the algorithm will sort and list of shortest route can be formed using existing routes between nodes. The pseudo-code of FCC extraction by randomized-based is shown in Figure 4. The randomized-based algorithm is influenced by its parameter values. The parameters are the maximum string displayed and maximum route. Maximum string displayed is the number of line of generated FCC string that would be displayed in each session. Maximum route is to limit the maximum number of node count passed for each route. In addition, the input binary image is processed to generate more efficient data structure to be used in the iterations. The selection of the shortest route length from the list of FCC is by choosing the chain code string with the minimum route length. If there are many minimums of route length found, the string is selected by the first time it found in the list.

```
1.    Initialize data
2.    Locating Starting Node (select first node randomly which are
"node method" or "end   node method")
3.    Visiting node and generating list of FCC
      while (number of visited node < number of       node)
            if there are not visited neighbours
                  select one node randomly
            elseif there are visited neighbours
                  select one node randomly
            elseif there are taboo neighbours
                  select one node randomly
            endif
      endwhile
4. Selecting shortest route length from the list of FCC until
stopping criterion is achieved
```

Figure 4: Pseudo-Code of applied randomized-based algorithm [29]

3.3 Feature Identification and Development of Classification Algorithms

Assembly of a feature vector is the target of feature identification as input for the classification stage. 544 features contained in a single vector is a combination of 2 feature parts. The first part is features extracted from FCC and the second part is extracting global features from the character image. Feature vectors formed from character images in NIST database are then compiled into a input for classification phase.

4 Proposed Framework

As mentioned in previous section, the proposed framework of the system consist pre-processing, feature extraction and classification stages. In pre-processing, thinning algorithm is used. There are two parts involved in feature extraction stage. The first part is FCC extraction and second part is generating feature vector by using six methods which are aspect ratio, pixel density calculation, translation, vector distance count, cross corner feature extraction and standard deviation and zero centroid average distance. Finally, ANN is used as classifier to measure the accuracy and computation time.

4.1 Pre-processing: Thinning Algorithm

In converting raw binary image to TBI, thinning function in Image Processing Toolbox of MATLAB software is used respectively. The thinning algorithm for NIST dataset is parallel thinning algorithm using neural network approach. Original image dimension of 128x128 pixels is transformed into 32x32 to avoid the resulting chain code to represent the image becomes too long. Finally, the raw binary images of single character are obtained. For NIST dataset, manipulation from the raw binary image to TBI is using ‘bwmorph’ function in the Image Processing Toolbox in MATLAB. The result of TBI will be copied automatically in a directory that is determined earlier into two types of extension: text format (.txt file) and image format (.png file) for easier use and viewing. Figure 5 is the flowchart of the pre-processing stage.

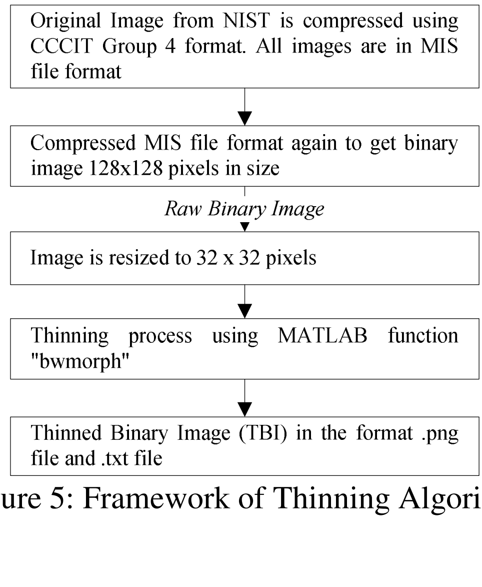

Original Image from NIST is compressed using CCCIT Group 4 format. All images are in MIS file format
Compressed MIS file format again to get binary image 128x128 pixels in size
Raw Binary Image
Image is resized to 32 x 32 pixels
Thinning process using MATLAB function "bwmorph"
Thinned Binary Image (TBI) in the format .png file and .txt file

Figure 5: Framework of Thinning Algorithm

4.2 Feature Extraction

As discussed before, randomized algorithm is chosen to generate feature vector created from extracted FCC to be the input to the classification stage later. A thinning process is needed to shape the numeral image toward a skeleton form before the tracing of the whole numeral skeleton is carried out to extract the heuristic features step by step. Figure 6 shows a sample feature for the first part of feature extraction which were FCC and the five features from source image properties. Generated string of FCC is divided into four divisions to enable feature count normalization for this data type and to represent the directional properties of the character sample. For every chain code division, appearance frequency for every FCC directional code is calculated. Thus, number of occurrence of a specific FCC directional code in a single division is divided with total chain code length, producing 4 division x 8 directional code frequency per division = 32 features from this data type.

```
-1 0.52631579 0.54285714 0.47142857 0.59375000 1
  0.15000000 0.02500000 0.00000000 0.00000000
  0.00000000 0.02500000 0.00000000 0.07500000
  0.05000000 0.02500000 0.07500000 0.07500000
  0.05000000 0.00000000 0.00000000 0.00000000
  0.12500000 0.02500000 0.00000000 0.02500000
  0.05000000 0.02500000 0.00000000 0.02500000
  0.20000000 0.02500000 0.00000000 0.00000000
  0.00000000 0.00000000 0.00000000 0.00000000
```

Figure 6: Sample Features of Character 'J' in Part 1 Feature Extraction

In the second part of feature extraction, the first method which is Method 1 is aspect ratio calculation. There were five features extracted from source image in the first part of feature extraction. First data type which is based on image is further expanded to five features, with all calculations for feature values using cropped image to its foreground marker defining the character for image height and width unless original image specification is stated otherwise. In other words, dimension between actual character image and its original source are differentiated [29]. In general, the five aspect ratios were calculated as formulas below.

a. Height-Width Ratio = Character Height / Character Width
b. Upper Ratio = Upper Region Marker / Total Foreground
c. Right Ratio = Right Region Marker / Total Foreground
d. Height Ratio = Actual Height / Original Image Height
e. The fifth feature is the total count of character segment in a single image.

Next, pixel densities are calculated for four different zones of the image and the number of pixels counted is used as the features of the character [24]. In this Method 2, the image will be divided to four frames that produced four features of each character. “frameres1” is declared as refers to window/frame count [frameX,frameY] which pixel inside the frame is to be counted. Frame count is the feature count since it was a feature per frame, feature count will be frameX*frameY, which is total frame for x-axis multiplied with frame count for y-axis.

Transition feature which is Method 3 as in [31] described that as the image is a binary image both return one of the three values 0, 1 or -1. 0 indicate no transition 1 means white to black transition and -1 indicate transition from black to white. Total 30 features extracted from this method. “gridQt2” is declared as refers to grid line count in which a feature will be generated per line. As such, total feature for this method will be line count for x-axis + line count for y-axis. In this very simple but effective, feature extraction technique the use of four different profiles, horizontal, vertical, and two diagonals, is suggested [32]. Feature extraction Method 4 is counting foreground pixel count per pattern line intersection. Below is the formula of the feature count. As we know the size of the image is 32 x 32 pixels, therefore, the feature count equals to:

Feature count = 3 * (img.dimH+img.dimW) - 2
= 3 * (32+32) – 2
= 190 features

Method 5 which is cross corner feature extraction is the same with Method 2 except the foreground pixels is counted diagonally. As usual, the image will be divided to 16 equal frames. Since the pixel is counted two times which is right diagonal and left diagonal, so the number of features is 2 x 16 equals to 32 features. Number of left diagonal line is one feature and number of right diagonal line is another feature in each zone [22].

Image will be divided to equal nine zones in Method 6 to calculate the zone centroid distance and standard deviation [30]. First, the centroid is obtained. 45 features produces from average distance, standard deviation, average angle, average distance from zone centroid to pixels present in the same zone and average angle from zone centroid to pixel present in the same zone. Each produced 9 features reflected to 9 zones of an image. Below is a sample feature for the second part of feature extraction. Figure 7 shows the sample features of character J to be used as input for ANN. Since all features must be defined in the row, zero feature values are also included as the input. Features from Part 1and Part 2 will be combined as a feature vector to be an input to ANN.

```
0.000 0.000 0.000 0.000 00 0.000 0.000 00 0.375 0.469 02 0.344 0.406 00
0.500 0.469 00 0.656 0.250 02 0.438 0.312 01 0.406 0.562 00 0.281 0.688 00
00 00 00 00 00 00 00 00 00 00 00 08 07 02 01 01 04 02 02 05 03 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 01 02 02 02 02 02 02 02 02 03 04 04
01 01 01 01 01 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 01 01 03 03 01 02 01 04 02 02 03 02 04 03
03 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 04 03 02
01 00 01 01 03 00 02 02 03 03 01 01 00 01 01 01 01 01 01 01 01 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 05 05 09 11 09 05 04 05  0.000
0.000 +0.000  0.000  0.000  0.000  0.000 +0.000  0.000  0.000  0.000  0.000
+0.000  0.000  0.000 10.357 12.701 +2.880  1.007 -0.426 13.351 14.013 -0.402
3.975 -0.391 10.093 13.352 -0.460  1.200  1.257  0.000  0.000 +0.000  0.000
0.000  5.812  8.189 +1.965  0.667  1.047  0.000  0.000 +0.000  0.000  0.000
```

Figure 7: Sample Features of Character 'J' in Part 2 of Feature Extraction Phase

4.3 Artificial Neural Network (ANN) as Classifier

From the experiment, some of the characters are not tested due to low quality of the image or broken character. In the experiment, several adjustment of parameter setting is used. Table 2 and Figure 8 describe the parameter setting and the pseudo-code of generating features values for ANN. Assembly of a feature vector is the target of feature identification as input for the classification stage. 544 features contained in a single vector is a combination of two feature parts. Feature vectors formed from character images in NIST database are then compiled into input dataset for character classification stage.

Table 2: Information and Parameter Setting of ANN

Network	Feed forward Back Propagation	
Layer	3 (Input, hidden and output)	
Layer details	Neurons	Training Function
Input	180	Tansig
Hidden	80	Tansig
Output	26	Pure Linear
Back propagation training function	trainrp	
Back propagation bias learning function	learngdm	
Performance function	MSE	

```
1. Specify input/output folder

2. Divide data into n parts, for the sake of n-fold cross-validation, where the data division = 5

3. Specify number of parts for FCC division, making number of features = (4 * n) +5+ 512, where that FCC division number = 4

4. Generate FCC using randomized-based algorithm
    4.1   Character segmentation based on pixel connectivity
    4.2   Generate feature vector using five methods as mentioned
    4.3   Generate FCC based on method specified earlier
    4.4   Save result to specified folder
    4.5   Calculate frequency of chain code occurrence in chain code string
```

Figure 8: The Pseudo-code of Generating Features Values for ANN

5 Experimental Results and Discussions

In this experiment, we chose uppercase characters from NIST database to run in the system. The number of tested characters from NIST dataset is 208,568 characters out of 220,304 characters.

Table 3: Dataset of NIST for ANN

Character Class	Original Data NIST	Dataset After Features Generation	Training Set	Testing Set
Upper-case	220,304	208,568	208,568	208,568

As discussed in previous section, we were choosing three divisions of FCC which were 4, 8 and 16 to compare the performance of ANN. Table 4 and Figure 9 showed the trend of the result according to the increasing of chain code division. As we can see below as the chain code division increasing, the accuracy dropped while the computation time increased. The highest accuracy obtained is 87.34% with lowest chain code division and shortest computation time.

Diagonal feature extraction was one of the techniques that had been reported in [19]. This off-line handwritten alphabetical character recognition system using multilayer feed forward neural network. Based on the training and testing databases used, there was a big difference in term of quantity compare to NIST database we had used. Lower quantity of character testing may caused high accuracy.

Similar to our work, skeletonization or thinning had been done in [20] in their pre-processing stage. In addition, this work was done on NIST numeral database. A combined classifier was used and yielded excellent result. As discussed above, this work also used a lower quantity of training and testing samples. There was another work done by [21] that used lower quantity of testing and training samples. They used profile projection technique to extract the features. The accuracy achieved was high that reached 95.33%.

A lot of previous works used a self collection database. In [22], only 650 samples are used in their experiment. There were 70,000 sample handwritten digits from NIST database were used in [23]. They divided to 60,000 for training and 10,000 for testing. The result yielded was very high with an accuracy of 99.03%. However, the sample quantity was still lower than ours. This also happened in [24, 25, 26, 27, 28] which their sample quantity used in the experiment was lower than our sample. The highest sample quantity was 20,000 and the lower was 200.

As mentioned before, the quantity of samples we used were 220,304 which was a larger amount compare to previous work discussed in Section 2.3. The accuracy may affect due to high sample quantity. All the previous works had used lower sample quantity that made their accuracy became higher.

Table 4: Accuracy and Computation Time based on Chain Code Division

Chain Code Division (n)	Accuracy (%)	Computation Time (minutes)
4	87.34	44.60
8	79.07	49.25
16	75.64	56.68

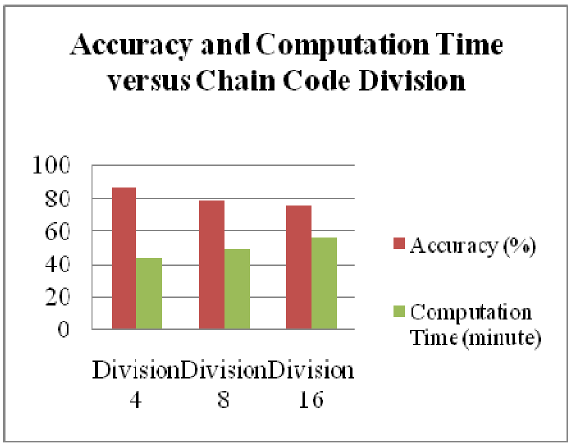


Figure 9: Accuracy and Computation Time versus Chain Code Division

5 Conclusions, Limitations and Future Research

This paper presents a recognition system for English Handwritten that used Freeman Chain Code (FCC) as data representation. There are 544 features were extracted from the original image. Thinning algorithm was used. A feed forward back propagation neural network was used as classification. The accuracy yielded from the system is 87.34% with shortest computation time which is 44.6 minutes.

From the experiment, not all NIST uppercase character database can be used due to broken and low quality images. There were 11,736 cannot be analyzed in the experiment.

In the future works, this experiment will be done to all character classes. Besides, the experiment can be done to other biometric databases such as signature to test the recognition performance. Lastly, the selection of features vector as input for classification stage is important to reach higher accuracy with application of other classifier such as SVM and hybrid classifier.

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