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A Review of Various Handwriting Recognition Methods

Salma Shofia Rosyda[1] and Tito Waluyo Purboyo[2]

[1,2] Department of Computer Engineering, Faculty of Electrical Engineering, Telkom University, Bandung, West Java, Indonesia
ORCIDs : [1]0000-0002-5920-7124, [2]0000-0001-9817-3185

Abstract

One of the computer-related problems that are being sought and researched is how an image can be recognized and classified. How computers can recognize images like humans who recognize the image. One that can be recognized from an image is handwriting, handwriting recognition can help with human work such as check analysis and for handwritten form processing. In image recognition, the angle of view, light conditions, and whether the captured image is clear or not will affect the process of recognizing the image. There are several methods to be discussed in this paper, in this paper to be discussed is a method that can be used for handwriting recognition.

Keywords: Handwritten method, Image Recognition, Image Classification,

INTRODUCTION

One of the many computer-related problems that are sought and researched is how images can be recognized and classified. How a picture is recognized as a human who recognizes the image. Image recognition is an important process for image processing [27]. In image recognition, the angle of view, light conditions, and whether the captured image is clear or not will affect the process of recognizing the image [1]. Handwriting recognition is one of the most sought after and studied issues, since handwriting can help humans do some work such as post-exposure, bank check analysis, and handwritten processing on forms.

The recognition of images for handwriting is more challenging because each person must have a different handwriting form. In addition to writing handwriting is not always straight sometimes there is a sloping up and there is a downward slant, so handwriting will be more difficult to detect than computer writing that already has a definite form [2]. Handwriting detection definitely has more factors that will influence the successful recognition of a handwriting. Because a misinterpretation will be more handwriting than computer writing that is certain to have a fixed form depending on the type. For handwriting recognition, there are several methods that can be used that will be discussed in the next section.

IMAGE RECOGNITION METHODS

CONVOLUTIONAL NEURAL NETWORK

Convolutional Neural Network (CNN) is one of the most widely used methods for handwriting recognition. Before entering into Convolutional Neural Network the image must go through pre-processing first. The following are the steps of Pre-processing :

1) Input the image you want to recognize [1, 5].
2) Do cropping or warping. The goal is that the image part that does not want to be recognized is lost [1].
3) Set the image size. Image size should be all the same [1, 7, 10].

In figure 1 is an example Diagram Recognition of Handwritten [6].

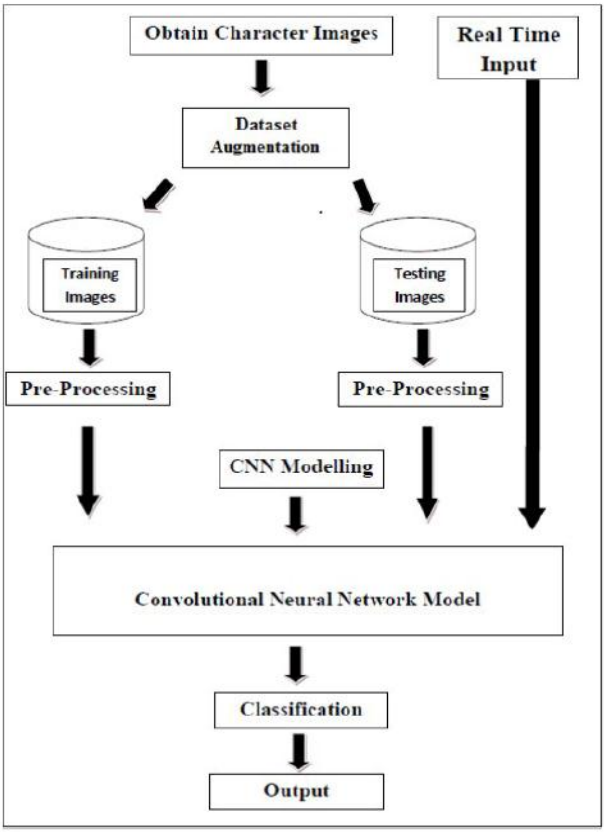

Figure 1: example Diagram Recognition of Handwritten [6]

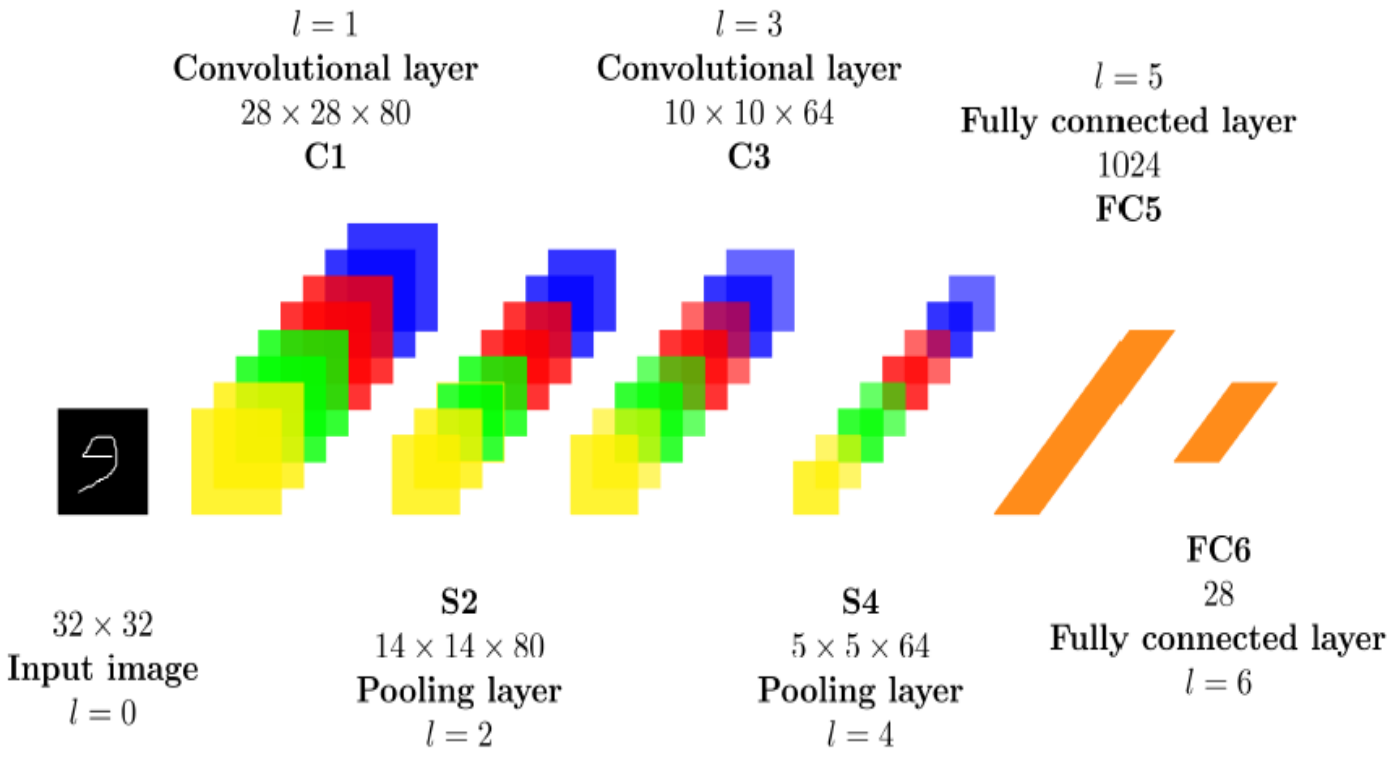

Figure 2: The example of CNN architecture [5]

CNN generally consists of three layers: convolutional layer, sub-sampling layer, and fully connection layer. But it can also be inserted another layer like softmax layer. Each layer linked to the previous layer [1]. The softmax layer works to improve the accuracy of image detection. In Figure 2 is an example of CNN architecture without inserted an additional layer. The number of layers applied to CNN is not always the same, depending on the need. Differences in recognizable handwriting language also affect what layers will be used and how many layers [3, 5, 6]. Additional layers inserted on CNN are optional. If an additional layer is inserted on CNN there will be an effect, for example, if the softmax layer is inserted into CNN then the handwriting recognition accuracy will be higher than CNN which is not inserted the softmax layer.

Below are the layers in the Convolutional Neural Network (CNN):

1) Convolutional Layer

Convolutional layer is the basic layer that builds a CNN. In this layer, the convolution process is performed. The convolution operation of this image serves to extract the input image feature [9]. The final convolution layer to maintain the spatial position and gray level information of the convolution feature map [4, 5].

2) Subsampling Layer

Pooling Layer (Subsampling). Serves to change the input feature into a representation of statistical results of the features around it, so the resulting feature size will be much smaller than the previous feature [1]. Most of the subsampling on CNN uses Max pooling [5].

3) Fully-Connected Layer

As a classifier on CNN, this layer is a CNN architecture consisting of input layer, hidden layer, and output layer [1].

4) Softmax Layer

The softmax layer is the last layer on CNN [11]. Softmax Layer is used to present output to the form of probability. Very useful for classification. The softmax layer is used to classify characters. The softmax function has a value between 0 and 1. The class with the maximum value will be selected as the class for the image, while the smaller value means not including the main image to be detected [6, 7, 1]. Here is the equation [8]:

$$f_i(x) = \frac{e^{x_i}}{\sum k^{e^{x_k}}}$$

Where xi is the input value, k is the number of kernels, and x is a vector of scores [8]. Where fi is the element to i at f

The stages of the CNN method for image recognition in writing as below:

1) Pre-Processing: The image is resized, if too large then the calculation will be high or too small will be difficult to adjust to large networks. Larger images are cut and padding will be applied to smaller images to get the standard size [1, 6].

2) Creation of datasets: If no open source dataset is

available for handwriting characters to be detected, it must be built in a new dataset, but if a dataset is available then an existing dataset can be used [6].

3) Final Data Determination: A large dataset is required to train CNN. To achieve this, the images that have been obtained are modified and changed to get a large number of variations [6].

4) Classification: The CNN end layer is the Softmax layer and the softmax layer is used to classify the given input image [1, 6].

5) Testing: The test module is related to the test image. The test images were obtained by splitting the randomly enlarged dataset [6, 9, 10].

SEMI INCREMENTAL RECOGNITION METHOD

This semi incremental method differs from the pure incremental method. In this semi incremental method, the waiting time will not be too visible [12]. The pure incremental method of seeing only the current scratches alone does not see the previous scratches associated with the current scratches, while the semi incremental considers the latest stroke and previous segment, this is because the previous strokes are related to the current stroke [12]. This method focuses on handwriting calculations [13].

1) Strategy of local processing

Introduction with semi incremental method is done after several new strokes entered. Incoming scars before new strokes appear also affect the outcome of the introduction. That's why strokes before new strokes come in and new strokes both must be both processed. To know the best recognition, by tracing from the first stroke [13,14].

2) Processing Flow

I In the semi incremental method, the process in a pure incremental method is performed again by a semi incremental method, but in addition to using existing processes in pure incremental methods, another process is performed that is the process of correcting wrong segmentation and correcting recognition errors [12].

Figure 3 is a semi-incremental recognition diagram, a few sentences after this will briefly explain the diagram. As shown in Figure 3, from the user's handwriting, a new stroke is inserted [13, 14]. The end result is reused for the next processing cycle [12, 13, 14].

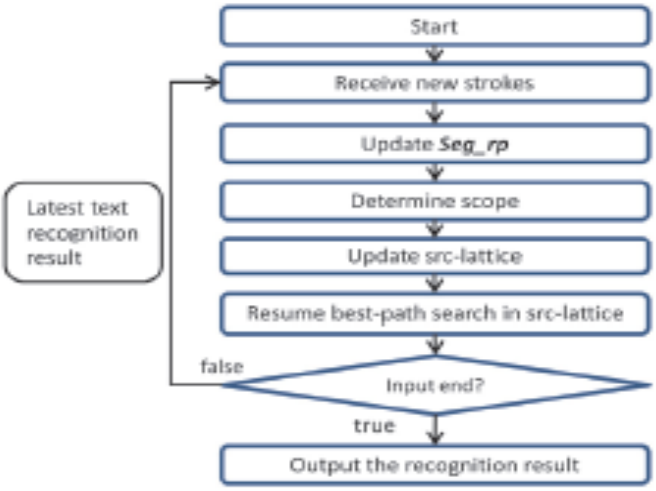

Figure 3: Flow of semi incremental recognition [13]

3) Determination of scope

To determine the scope used the result of the segmentation process. Stroke segmentation before and after the system receives a new stroke and then compared to each other. If the detected offstroke classification is considered to be scratched before start [13].

4) Seg_rp and segmentation point determination

Seg_rp is determined from SP off-strokes. From the result of the recognition of the text up to the last scope, that is the best path to the latest scope in the src lattice, a stroke between two recognizable characters can be considered SP. Among off-strokes, Seg_rp selection is performed based on the number of characters from each off-stroke until the last character in the acknowledgment. If this number is equal to N_CHAR, then the off-stroke will be determined as new Seg_rp. N_CHAR itself is the number of fixed characters needed to define a new Seg_rp [13, 14].

5) process examples

Figure 4 is an example image to determine the scope. The latest scope with the result of segmentation and text recognition in Figure 4. Then, a new scratch filled with red color is added. Segmentation of Seg_rp in Figure 5.Off that changes in Figure 6. The discovery of the character block between or shortly before this off-stroke and the scope space shown in Figure 7.

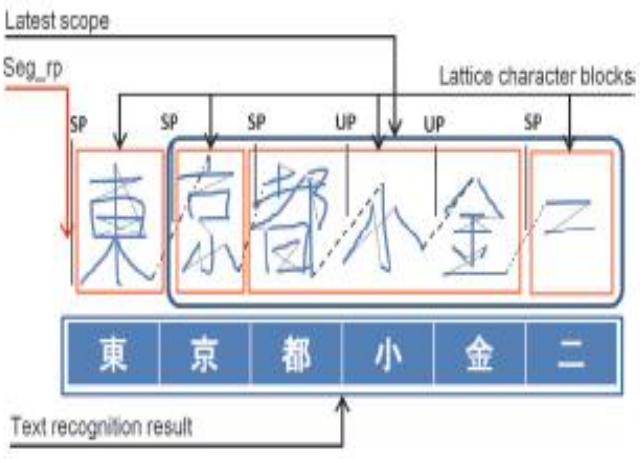

Figure 4: The latest scope with the result of segmentation and text recognition [13]

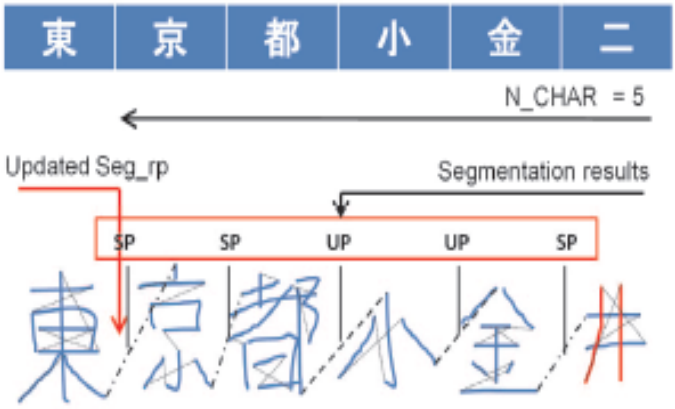

Figure 5: New scratch filled with red color is added. Segmentation of Seg_rp [13]

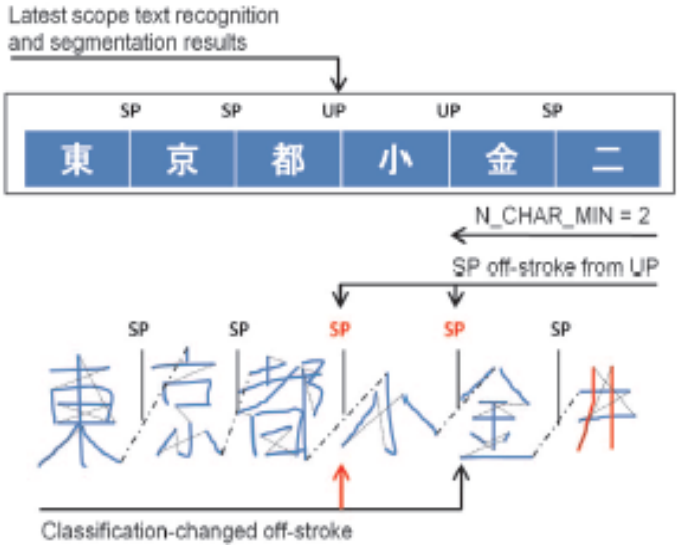

Figure 6: Determining UPs to SPs and finding classification-changed offstrokes [13]

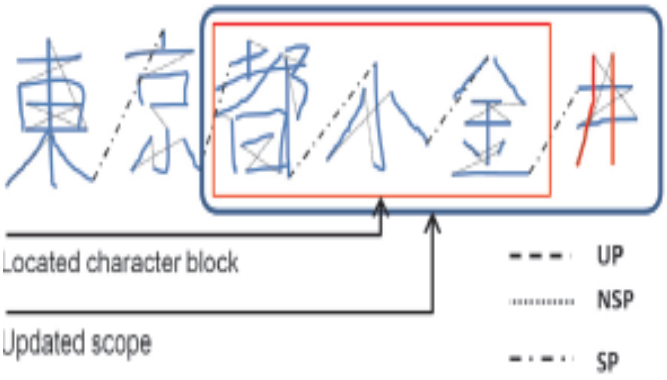

Figure 7: An example of determining scope [13]

6) Update of src-lattice

To update the src lattice in the latest scope, in order to maximize the reuse of the src grid in the previous scope, the lattice candidates were previously built in the previous scope. From the scope initial, the method finds SP offstrokes and subsequently divides the candidate character block by the SP off-stroke. Each SP off-stroke divides the candidate character block into two parts: the previous and the next sections. The src grid in this grid block will be checked if any candidate character pattern is already in the previous scope. If there is, we get it from the previous scope, if it does not exist then it must be rebuilt [13, 14].

7) Resuming best-path search and recognition

From the first character grating block in the current scope, continue the best path search and get text recognition results [13, 14].

INCREMENTAL RECOGNITION METHOD

Incremental method is one method that can be used for handwriting recognition. Incremental methods can not only be applied to busy recognition but can be applied to lazy recognition as well [15]. This incremental pure method only sees the strokes just enter, in this method the previous strokes are not seen [15]. The process is also illustrated in Figure 8. Figure 8 further clarifies the flow from the initial process to the final process. Here is a process done on the incremental method [12, 15]:

1) Receive a new stroke

The stroke inputted comes from the user.

2) Update of geometric feature

The newly received stroke belongs to the geometric feature. Based on the recently received information, the current geometric feature average value is updated immediately.

3) Symbol candidates recognition

Each symbol hypothesis is recognized by a combination of online and offline recognition. The online method is great for stroke connections, while offline will not be impacted by irregular strokes or duplicate strokes.

4) CYK update table

The CYK table only needs to be expanded, the existing table does not need to be changed anytime it receives a new stroke. Figure 8 is a diagram of the incremental process described above.

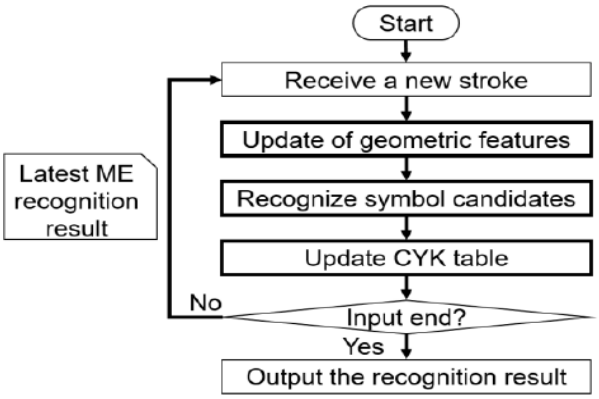

Figure 8: Flow of incremental recognition [12]

Structure Relation

The structure or relationship between symbols is ambiguous, even in some cases ambiguous to humans. The delimiter is used to represent the main position and size of the symbol. Figure 9 is a feature of structural relations [12, 15]. In figure 9 Features H, Dy, and O classify the horizontal, superscript and subscript relationships in Group 2 by another SVM. Below is the calculation [12, 15]:

$$D_x = \frac{p_{x2} - p_{x1}}{w_1} \qquad D_y = \frac{p_{y2} - p_{y1}}{w_1}$$

$$H = \frac{h_2}{h_1} \qquad O = \frac{S_{overlap}}{h_2 - h_1}$$

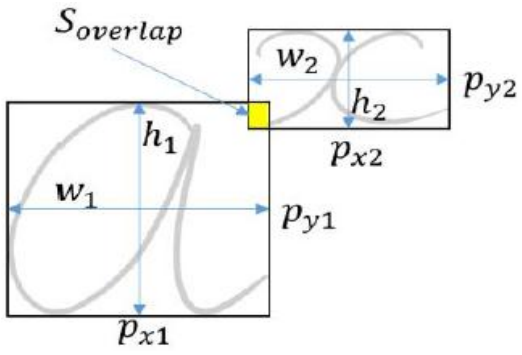

Figure 9: Structural Relation [15]

LINE AND WORD SEGMENTATION

Handwriting segmentation is a difficult problem in handwriting recognition [28]. Even in recognition, handwriting is harder to recognize than computer writing. One factor is everyone has different handwriting forms. The other factor is the slope factor of a writing. In the recognition of handwriting, the word segmentation into letters is a usable approach. The word segmentation is complex, but it is even more complicated if this method has to recognize the dial. A Line and Words Segmentation Approach for Printed Documents to project a powerful process [16]. A writing can be segmented based on line, word, and character. On line segmentation is detected by scanning the written image that has been inputted horizontally [17, 18]. The description of this step method is shown in Figure 9. The following is a step by step of the method [16, 17]:

1) View scanned images and crop imagery to find areas of interes [16, 17]t.
2) Remove existing noise in image using subtraction method. To remove the noise on the image inputted pre-processing done. The size of the image that has been inputted adapted its size. Then the resized image is subtracted from the blank image for a noise-free image [16,17].
3) The image is converted to binary by way of mining text and removing the background [16]. Change the grayscale image to binary image. Where 0 is black and 1 is white.
4) Correction and skew detection using Hough Transform. Skew's handwriting image is inevitable. Therefore, a change of tilt is a serious thing. Hough Transform is used to know the slope accurately by mapping the dot on the cartesian space (x, y) to the sinusoidal curve [16,17].

$$\rho = x\cos\theta + y\sin\theta$$

Skew is defined by θ. For Correction skew in a direction in the opposite direction of the same angle.

5) The use of 'bwmorph' morphology function for thinning process. The morphological process applied here is Thinning. Thinning is used to remove marked pixels marked from binary images, much like erosion [16].
6) Horizontal Projection Profile is used for line segmentation. In the histogram of a handwriting, a peak and valley indicate the writing and space between each line [16].
7) Use of dilation and Vertical Projection Profile word segmentation is done [17]. Figure 10 is a block diagram of the word and line segmentation methods, whose steps have been mentioned previously.

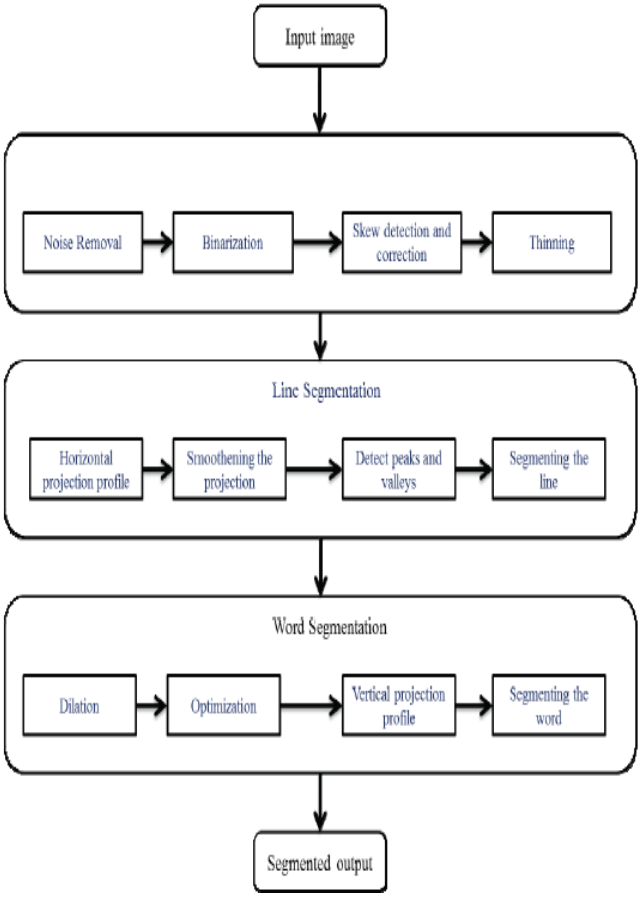

Figure 10: Block Diagram Line and Word Segmentation [16]

PART-BASED METHOD

Part-Based methods have been used to recognize an object. Below are the properties of the part-based method [19]:

1) Use multiple keypoints to represent a single image.
2) In evaluating the similarity of global features is often overlooked, this leads to an increase in resistance to object display variations.
3) Image similarity depends on whether or not the image with keypoint, if the same then the image will be considered to be in the same class as Keypoint.
4) Each class is sometimes represented by a collection of key points extracted from several (different) class images for many variations.

The following are the benefits of the Part-Based method [20]:

1) Characters can still be recognized although difficult to normalize with preprocessing.
2) It does not depend on the global structure, therefore, if there is a line or curve of writing, it is still recognizable.
3) Equivalent to the most unconstrained image distortion model, each local part is disturbed around its original position to represent deformation. As a result, it is very powerful to serve deformation.
4) Can be directly applied to cursive script because it can recognize its component character. This relaxes the difficulty of segmentation.
5) Can be applied to scenery images to detect the characters in the image.

Part-based character recognition methods are organized in two steps, the first step of the training and the second introductory step. Here, the steps are [20]:

1) Training Step

   The keystrokes will be detected on each training pattern using the SURF key detector. The square area around each keypoint is represented as a 128-dimensional SURF feature vector (reference vector), then stored into a database (dictionary). Figure 11 is a picture of the SURF feature vector that has been briefly described in this step training.

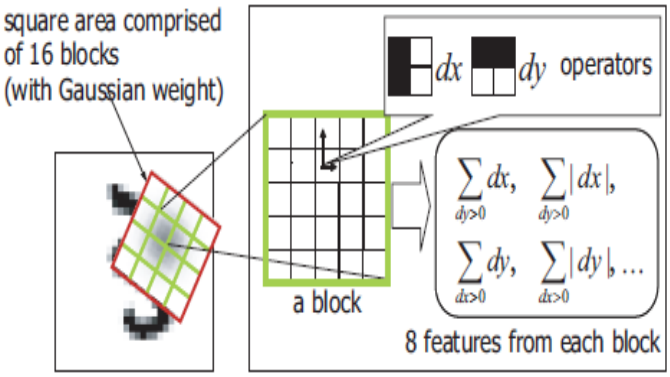

Figure 11: Describing a local part as a 128-dimensional SURF feature vector. [20]

2) Recognition Step

   The next recognition step consists of two sub-steps, namely the feature-level and character-level recognition.

SLOPE AND SLANT CORRECTION METHOD

Slope and slant correction in handwriting is used to reduce the style variation in writing. When writing variation is simple it will help the recognition process. Careful slope correction not only makes the segmentation process simpler but also the accuracy of the writing recognition itself [21].

Slope Correction Method

In the proposed method, the slope of the word text can be estimated based on the slope of the baseline. Ascenders and descenders have no contribution to the initial formation, they are thrown out as much as possible and then the best straight line as expected from the remaining part of the word [22]. The basic slope is found then the slope corrected by rotating the

word about with the angle of the slope. The slope of the word is estimated from the slope of the baseline. First, select the core area of the word and then determine the best load line from the bottom area of the core. Then the selected part is divided into small pieces. To reduce as much as possible the effect of slope on a post, the skewed correction must be performed before segmentation, feature extraction, training, and classification stages [31]. The initially slanted writing will become upright [31]. Leverage is the value of deviation from the variable mean. Leverage is the average of Li. here is the equation of Li [21]:

$$L_1 = \frac{1}{N} + \frac{(y_i - \bar{y})^2}{\sum_{i=1}^{N}(y_i - \bar{y})^2}$$

N = Total number of Centroid

y_i = Vertical Coordinate

$\bar{y}$ = Mean of y_i

Slant Correction Method

Directed textures can be detected and analyzed efficiently by using Gabor filters. This capability is attached to the Gabor filter because it can provide bank filters depending on the length variations as well as the angle parameters [21]. The resemblance of the image can be improved. The slope is estimated and considered as the slope of the original image. Finally, using a sliding transform, the slope of the original image is corrected [23]. Below is a function of the slant correction method:

$$h(x,y) = g(x,y)s(x,y)$$

$s(x,y)$ = Complex sinusoidal Know

$g(x,y)$ = 2D Gaussian-shaped

ENSEMBLE METHOD

The ensemble method is a new classifier, proposed in the machine learning field. The feature of the ensemble method is to generate multiple classifiers from one base class base automatically [24]. In this method, classifier selects one feature which is the best recognition level. [25]. The purpose of the ensemble method is to improve the predictive performance of static learning techniques or fitting models [26]. Below is an explanation of the Ensemble method [25]:

1) Feature Search Ensemble Method

   Algorithms known for feature selection can be used. The necessary modification is to prevent the feature selection algorithm returning the same feature subset over and over again.

2) Feature Selection Ensemble Method

   When adding a new classifier to an ensemble, all feature subsets will be considered. This method does not work for pattern recognition issues with high-dimensional feature vectors because the number of feature sets may be increased.

3) Heuristic Version of feature search and feature selection ensemble method

   The simulation method is defined by N. The higher the N value will result in a more accurate simulation, but the complexity of the simulation will be higher. Figure 12 is an example of the ensemble method.

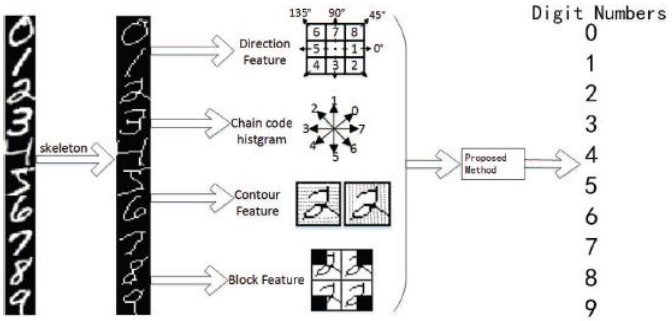

Figure 12: examples of ensemble methods as a whole [26]

ZONING METHOD

Zoning is a method that can be used for handwriting recognition. The pattern image is divided into several zones that provide regional information. The zoning method is quite successfully applied to handwriting recognition. There are two methods of zoning, static and dynamic. The following is an explanation of the Zoning method:

1) Static Zoning

   In this static zoning, zones are distributed evenly (uniformly), so that the zones of one and the other are the same [29]. The more zones in an image then the accuracy of the image will be higher [30]. Figure 13 is a description of the uniformity of zone divisions.

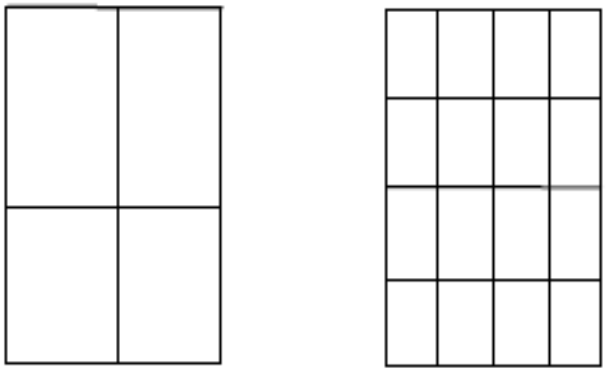

Figure 13: Static Zoning [29]

2) Dynamic Zoning

In dynamic zoning, the number of zones dividing from a large image is not the same. In figure 14 it shows the non-uniform zone division, the magnitude is different.

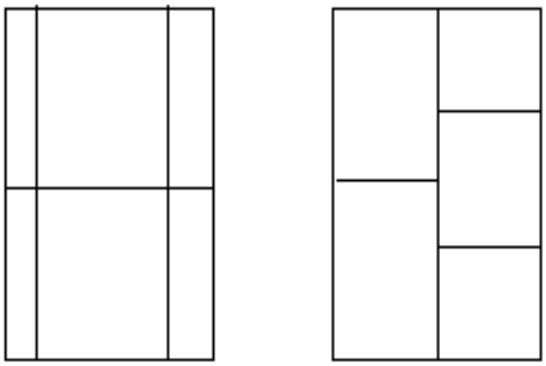

Figure 14: Dynamic Zoning [29]

The optimization problem is where the discriminating ability of a zone is estimated by Shannon's entropy (E) defined as [29]:

$$E = \sum_{i=1}^{n} p_i \,.\, \log_2 \frac{1}{p_i}$$

n = number of classes

pi = probability

The following is the stage of image recognition using the zoning method [29]:

1) Database

The collected database consists of handwriting. Once handwriting is collected it will then be made into a database. For example from each letter taken several samples to be used as a database.

2) Pre-Processing

Preprocessing is applied to remove noise in the image as well as to simplify the feature extraction procedure. The preprocessing steps include binarization, resizing, median filtering and morphological operations such as Thinning. The colored image is converted to grayscale. After it is converted to binary.

3) Feature Extraction

Zoning method is one method to extract the features. Feature extraction itself is the most important thing in detecting a post. As already explained above there are two zoning methods of static zoning and dynamic zoning.

4) Classification

Classification is the step to make a decision. The feature vector of the feature extraction process is assigned to the classifier for training and testing purposes.

COMPARISON OF DIFFERENT METHODS

As mentioned above, handwriting recognition can be done by various methods. Several methods have been discussed above.

Here is a table that compares methods that can be used in writing recognition, especially handwriting. In the table, the discussion is the shortcomings and advantages of each method.

Table 1: The advantages and disadvantages between methods

No	Method	Advantages	Disadvantages
1.	Convolutional Neural Network Method	1) When CNN is trained then the image recognition will be accurate 2) It has been proven successful used for many handwriting and computer recognition	1) In order for high accuracy in the training process should use many Samples. 2) Long training time.
2.	Semi Incremental Method	1) Waiting time will not be too visible 2) Considers the latest strokes and previous segments	1) Should be accompanied by other methods can not only semi incremental only. 2) The way it works is more complicated than the pure incremental method.
3.	Incremental Method	1) The recognition stage is simpler than semi-incremental, one of the simplest factors that makes it simpler is because it only sees the lat	1) There is a problem with the segmentation process
4.	Line and Word Segmentation Method	1) Line and Words Segmentation Approach for Printed Documents to project a powerful process	1) Can't detect pattern
5.	Part-Based Method	1) Reliable enough for writing recognition because of low accuracy.	1) In order for high accuracy in the training process should use many Samples.

No	Method	Advantages	Disadvantages
6.	Slope and Slant Correction Method	1) Segmentation process simpler and the accuracy of the writing recognition.	1) Not maximal for handwriting recognition.
7.	Ensemble Method	1) Accuracy results are quite high.	1) Line seg-mentation components affect accuracy.
8.	Zoning Method	1) Accuracy results are quite high.	2) The number of zones in an image must be many, because if a little then the accuracy will be smaller.

Table 1 continued….

DISCUSSION

There are eight methods discussed. First, Convolutional Neural Network (CNN), Semi-Incremental Segmentation, Incremental, Lines and Words, Parts, Slope and Correction Slant, Ensemble, Zoning. These eight methods can be used to write recognition, especially handwriting.

Of the eight methods discussed above, CNN is a method often used for writing recognition, including handwriting. The accuracy of CNN is high in almost every case. Zonation methods, Line and word segments, Ensemble methods, and Part-Based methods are quite reliable in writing recognition. Simple or not a method does not specify that method would be good for handwriting recognition. In handwriting recognition should be accompanied by a training process and more samples will be better.

Each method has its weaknesses and advantages. In the Convolutional Neural Network (CNN), the time required for long training due to CNN is included in the deep learning study, but CNN has good accuracy for handwriting recognition because more CNN training will result in more accurate writing recognition. For the zoning method, the disadvantage is that in the picture there should be many zones because otherwise the identification accuracy level will be smaller. In incremental methods, the disadvantage is that there is a problem in segmentation, the advantage of this process is simpler than the Semi-Incremental method. For other methods can be seen in the table above.

CONCLUSION

Image recognition is an important process for the image processing. Image feature extraction has several constraints such as differences in image capture position and different lighting conditions when the image is taken. The image recognition in handwriting is more challenging because everyone has different handwriting forms, so that on the detection also handwriting will be more difficult to detect compared writings from computers that already have a definite standard form. There are seven methods discussed and which have the highest accuracy is the Method of Convolutional Neural Network (CNN). The method of the lowest accuracy is Slope and Slant Correction Method.

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