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Image processing method in implementation of handwriting identification for Japanese katakana characters

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Abstract. Japanese is one of the popular languages and is spoken in international world. Japan ranks fourth out of ten commonly used languages in the world. Pattern recognition techniques have developed over the time and often used to solve problems. Pattern recognition technique is used for identification of handwriting, images, etc. Japanese Katakana handwriting with all the complexity turns out to have strict rules in writing. In its application, there is an inaccuracy in the writing of Katakana letters. This is caused by the many variations and procedures of writing Katakana. The procedure of writing Katakana letters has its own rules especially regarding the number of scratches. Therefore, in this research, authors implemented Recurrent Neural Network to identify the words based on the Katakana handwriting.

1. Introduction

According to list of languages used according to the number of native speakers, Japanese is ranked 9th after Chinese, Hindi, Spanish, English, Bengali, Arabic, Russian and Portuguese [1]. Human has various ways in learning foreign language. As example, self-taught, actively speaking the language and taking courses. Foreign language can also be learnt digitally through computer. Therefore, machines (computers) are required to master every character in all languages to ease the human in learning the foreign language. Pattern recognition techniques are used for handwriting recognition, images, etc. Pattern recognition aims to perform identification process of an object (e.g. handwriting) into a particular class, based on particular pattern [2]. Artificial neural network is one of the artificial intelligence of human brain which always tries to stimulate the learning process of the human brain. The term artificial is used because this neural network is implemented using a computer program that is able to process a number of calculation during the learning process [3]. Recurrent Neural Network (RNN) is a neural network with feedback facilities to neurons, so that the information flow of the inputs has multiple directions [4]. Recurrent Neural Network is a network that has at least one feedback loop. RNN has excellent depiction capabilities and can address the weaknesses feedforward [5].

Katakana with all its complexity turns out to have strict rule in its writing [6]. The rule is called a stroke order or a sequence of scratches. Because the writing technique, in addition to the beautiful writing, is also very useful as a method of memorizing the Katakana letters, which certainly saves memory in our brain. Artificial neural networks have the ability to identify letters based on handwriting. Therefore, in this research, the authors utilized artificial neural network of recurrent
neural networks to identify letters based on handwriting Katakana letters. In the implementation, there is an inaccuracy in the writing of Katakana letters. This is caused by the many variations and procedures of writing Katakana. The procedure of writing Katakana letters has its own rules especially regarding the number of scratches. Therefore, an approach is needed to identify Japanese writing Katakana letters.

There have been numerous information technology researches on identification field, such as Artificial Neural Network Implementation of Back Propagation Method in Japanese Katakana and Hiragana Handwriting [1] and research entitled Diagonal Feature Extraction Based Handwritten Character System Using Neural Network [7]. Another previous research that applied Recurrent Neural Network method entitled Nonlinear Identification Using Recurrent Neural Network and Kalman Dead-Zone Filter [5]. Although numerous researches in word identification have been conducted, it still needs further development on research in the field of speech recognition, especially in writing Katakana.

2. Methodology

2.1. Image

Image is a two-dimensional media which composed by group of pixels that are the smallest part of the image. In general, the image is formed from regular square squares so that the horizontal and vertical distances between pixels are the same in all parts of the image [2]. Image as the data recording system output can be: optical in the form of photographs, analogue in the form of video signals such as images on television monitors, and digital that can be directly stored on a magnetic tape.

Digital image is the visual representation of an object after experiencing numerous data transformations from various forms of numeric sequence [8]. Feature Extraction is the process of measuring data that has been normalized to generate a feature value. The feature value is used by the classifier to identify the input unit with the output target unit and facilitate the classification because it is easy to distinguish [7]. In general, the feature is all the measurement results that can be obtained. The feature can also illustrate the characteristics of the monitored object [8]. An example of a low-level feature is signal intensity. Features can be symbolic, numeric or both.

2.2. Dataset

Sample data used is 46 Katakana letters written on A4 size paper using black-ink markers. Sample data were acquired from 13 people who understand Katakana letters. The writing procedure of data sample is 10 people wrote 46 Katakana letters in one try for training data and the other 3 wrote for testing data. Total sample data used is 460 sample data images used as training data and 138 sample data images used as testing data. Writing sample of Katakana letters is shown in Figure 1.

![Figure 1. Katakana handwriting sample](image)

2.3. Recurrent neural network

Recurrent Neural Network (RNN) is neural network a neural network with feedback facilities to neurons, so that the information flow of the inputs has multiple directions [4]. Recurrent Neural Network is a network that has at least one feedback loop. RNN has excellent depiction capabilities and can address the weaknesses feed-forward [5]. RNN Output depends not only on the current input, but also on the neural network input of the past. This condition is intended to accommodate past events to be included in the computation process.
2.4. Letter identification process
Several phases performed in identification process of Katakana letters, namely:

- The first stage in image processing is to convert the color image into a grayscale image. So it obtained result as image shown in Figure 3. The process of changing the color image (RGB) into a grayscale image can be calculated using formula:

  \[
  grayscale = 0.299R + 0.587G + 0.114B \\
  or \\
  grayscale = 0.333R + 0.333G + 0.333B
  \]

- The next step is to resize all the images to be the same size of 60 x 90 pixels. The result of resizing process can be seen in Figure 4. The purpose of resizing in this image pre-processing is to change the resolution or the vertical and horizontal size of an image. This image size conversion aims to ease the process of image pre-processing.

- Normalization is a part of radiometric correction, which is to eliminate the difference between two or more different images of time or location by referring to the image that is considered the best and the right one. In other words the function of normalization is to get data with mean zero and standard deviation that is equal to one. The result of normalization is shown in
Figure 5.

![Normalized image](image)

Figure 5. Normalized image

- Thinning is a morphology operation used to remove the selected foreground pixels from binary image. It is usually used for the process of finding the bones of an object (Skeletonization). Thinning aims to reduce the size of an image while maintaining the value or characteristics of the image. Thinning result can be seen in Figure 6.

![Thinned image](image)

Figure 6. Thinned image

- After image pre-processing process, then performed feature extraction phase. The feature extraction used was Diagonal Based Extraction Featured. Feature extraction was performed to get the feature value as an input for Recurrent Neural Network input layer. Diagonal Based Feature Extraction is a process of writing characters identification using offline methods in the process [7]. Every image of a character, has the size of 60 x 90 pixels, is then divided into 54 equal zones, and each zone measures 10 x 10 pixels. Figure 7 shows the detail of zone partition.

![Zone partition](image)

Figure 7. Zone partition of 6 columns and 9 rows

The explanation of Figure 7 is as follows:

- Calculate the diagonal histogram of each zone. Diagonal histogram is the number of black pixels of each diagonal in one zone. Each zone has 19 diagonal histogram values called Histds, where $1 \leq d \leq 19$
• Calculate feature value of each zone, which is the average histogram of each zone called \( Z_n \) where \( 1 \leq n \leq 54 \)

\[
Z_n = \frac{\sum_{d=1}^{19} histd}{19}
\]

• Calculate the average zone value of each line called \( B_i \), where \( 1 \leq i \leq 9 \)

\[
B_i = \frac{\sum_{d=1}^{5} Z_{((i-1) \times 5 + d)}}{6}
\]

• Afterwards, the classification process of the handwriting image that has been extracted its feature value by using the Recurrent Neural Network was performed. The flow chart of the Recurrent Neural Network of this research can be seen in Figure 8

![Recurrent neural network flowchart](image_url)

**Figure 8.** Recurrent neural network flowchart

The explanation of Figure 8 is as follows:

• Initial input is image acquired from image pre-processing stage and its feature extraction value has already acquired.

• State vector input. State Vector is the desired target from the training image and testing image. State vector can be calculated using formula:

\[
x(k) \in \mathbb{R}^n
\]

• Calculate the weight of initial value using the equation:

\[
W_1, k, W_2, k \in \mathbb{R}^{mxn}
\]

• Calculate the value of hidden layer using formula:

\[
V_1, k, V_2, k \in \mathbb{R}^{mxn}
\]
• Calculate value of $\phi$ and $\sigma$ using sigmoid function below:

$$\phi(\mu) = \frac{0.2}{1 + e^{-0.2 \mu}} - 0.05$$

$$\sigma(\mu) = \frac{2}{1 + e^{-0.2 \mu}} - 0.05$$

• Calculate the value of network output using the equation:

$$A\mu(k + 1) = A\mu(k) + V1, k\sigma[w, k\mu(k)] + V2, k\phi[W, 2\mu(k)]$$

3. Result and analysis
The number of Katakana letters image that have been trained is 460 images, they consist 10 samples image for each of 46 Katakana letters. In this section, all the test result of the 3-testing data of each letter will be presented. It is shown in Table 1. From the test result, the accuracy rate can be calculated using the equation below:

$$\text{Accuracy rate} = \frac{\text{Number of identified character}}{\text{Number of total character}} \times 100\%$$

$$\text{Accuracy rate} = \frac{123}{138} \times 100\% = 86.1952\%$$

It can be concluded that the accuracy rate of pattern recognition for the tested characters is 86.1952\%.

Table 1. Test result of test data

| Image Name | Sample 1 | Sample 2 | Sample 3 |
|------------|----------|----------|----------|
| A          | ✔        | ✔        | ✔        |
| Chi        | ✔        | ✔        | ✔        |
| E          | ✔        | ✔        | ✔        |
| Fu         | ✔        | ✔        | ✔        |
| Ha         | ✔        | ✔        | ✔        |
| He         | ✔        | ✔        | ✔        |
| Hi         | ✔        | ✔        | ✔        |
| Ho         | ✔        | ✔        | ✔        |
| I          | ✔        | ✔        | ✔        |
| Ka         | ✔        | ✔        | ✔        |
| Ke         | ✔        | ✔        | ✔        |
| Ki         | ✔        | ✔        | ✔        |
| Ko         | ✔        | ✔        | ✔        |
| Ku         | ✔        | ✔        | ✔        |
| Ma         | ✔        | ✔        | ✔        |
| Me         | ✔        | ✔        | ✔        |
| Mi         | ✔        | ✔        | ✔        |
| Mu         | ✔        | ✔        | ✔        |
| N          | ✔        | ✔        | ✔        |

4. Conclusion and future research
Based on the literature, implementation and testing that have been conducted, it can be concluded as follows:
• Identification of Katakana handwriting using Recurrent Neural Network method can be classified as a moderate success.

• The accuracy rate of pattern recognition of trained characters is 89.1304%.

• The accuracy rate of pattern recognition of the tested character using Recurrent Neural Network is 86.1952%

Leap Motion Controller can be used as a tool in Bekel game application development.

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