Probabilistic Neural Network to Classify Image of Children’s Face with Down Syndrome

R F Rahmat¹, S Budiarti¹, S Faza¹, I Fawwaz² and U Andayani¹

¹ Department of Information Technology, Faculty of Computer Science and Information Technology, Universitas Sumatera Utara, Medan, Indonesia
² Department of Information Technology, Faculty of Computer Science and Information Technology, Universitas Sumatera Utara, Medan, Indonesia

Email: romi.fadillah@usu.ac.id

Abstract. Down Syndrome is a condition of the physical and mental underdevelopment of a child due to chromosomal development abnormalities. This condition has different facial symptoms. Although Down syndrome has a unique feature on the face, they have a similar face with their parents and siblings, so it is quite complex to tell the difference. These symptoms contain specific information for facial recognition. In this research, the proposed method consists of five stages. The first stage is the input image. The second stage is pre-processing which composed of grayscale and CLAHE processes. The third stage is the image segmentation to bring up the special features of the image. The process continued with feature extraction that will generate an invariant moment. The final stage is the classification process to determine the type of face such as mosaic, trisomy 21 or without syndrome. The test result using the test data of 22 images showed that the system has an accuracy rate of 91% with the success percentage for recall and precision is at 88%.

1. Introduction

Digital image processing is a process that aims to manipulate and analyze an image with the help of a computer. Image processing has several functions to improve the quality of an image so that the human eye can more easily interpret it. It can also be used to process the information contained in an image for automatic object recognition.

Today technology is very developed, and the recognition system is mandatory to minimize errors. Digital image processing is one of the techniques to solve the problem of image processing. The image will be processed in such a way that the image can be more accessible to process and converted into information. The facial recognition of Down syndrome through facial image is necessary considering many of the characteristics look different from non-syndrome faces.

Down Syndrome is a collection of symptoms as a result of chromosomal abnormalities; usually the chromosome 21 failed to separate during the division resulting in individuals with 47 chromosomes. Genetic abnormalities occurred on the chromosome 21 can be identified by looking at a typical clinical manifestation. Abnormalities in the underdeveloped growth of physical and mental were first recognized in 1866 by Dr. John Longdon Down. Due to the seemingly different characteristics such as the relatively short height, the smaller head, and the flat nose, resemble the Mongoloid, it often known as Mongolism at that time.
Although Down syndrome has distinctive features on their faces, they have similarities with their parents and relatives in appearance rather than with other people's Down syndrome so it is complicated enough to tell the difference. It can be simplified using image processing. This study was conducted for early identification of facial types of Down syndrome suffered by the children.

Symptoms that arise from the Down syndrome may vary, ranging from no visible sign to a very distinctive sign. Although Down syndrome has special facial features, they have a similar face with their parents and relatives, so it is quite difficult to distinguish the facial type of Down syndrome children. Therefore, an approach is required for early facial identification of Down syndrome suffered by children.

Various studies for Down syndrome facial classification have been previously conducted. Saraydemir performed a study on Down syndrome facial image using kNN and SVM method by examining non-syndrome children with Down syndrome aged 1-12 years where there are 15 facial images of Down syndrome and 15 non-syndrome facial images [1]. Keikhayfarzaneh also conducted research on the development of fuzzy interface system to diagnose the Down syndrome by matching 300 images of 250 non-syndrome facial images and 50 down syndrome images. The system is the basis of one fuzzy rule optimized with genetic algorithms. Problems will occur in facial detection if the output of both systems is positive in one skin region [2]. Zhao implemented Support Vector Machine (SVM) Algorithm to detect the face of Down syndrome using landmark on the facial model and then using geometric features and texture features in local binary patterns. The result of the study is quite satisfactory with a high accuracy of 97.92% [3]. The research was then re-examined by combining SVM and Radial Basis Function (RBF) methods, but the result gave a lower success rate at 94.6%.

Pandit et al. applied Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) for feature extraction and implemented neural network as the classification method on the classification of the facial image of congenital disabilities with abnormal faces. The study obtained an accuracy level of 87% [4]. Another research was conducted by Saraydemir using Gabor Wavelet Transformation (GWT) as feature extraction method, while SVM and K Nearest Neighbor (KNN) served as the classification methods to classify the effect of the training set size on facial recognition of the Down syndrome using 6 different facial expressions. The result stated that SVM generated a better result compared to KNN [5]. Burcin used 20 facial samples including ten images of Down syndrome children and ten non-syndrome facial images for training data. After the training data set were specified, LBP was applied in feature extraction for every data. Euclidean distance and Changed Manhattan distance served as the classification methods for regular facial images and Down syndrome respectively. The system can identify different facial expressions, different races with extras contained on faces such as glasses, hair, and others [6].

2. Methodology

The method proposed by the authors to classify the face down Syndrome consists of several processes. The processes will be performed as follows: The inputted image will be cropped first, then it will go through the pre-processing phase. In this process, the image will experience grayscale process and CLAHE (Contrast Limited Adaptive Histogram Equalization) which produces a black and white image with sharper contrast and easy to recognize the edges. The process continues to image segmentation where each image will show its distinctive traits. The next step is to extract the features or characteristics of an image. In this research, Invariant moment served as the feature extraction method. The final step is image classification using PNN algorithm. The implementation of the Probabilistic Neural Network (PNN) method aims to recognize any forms that contain unique features of Down syndrome face, and the final result will be more accurate with the application of this algorithm. The general architecture of this method is shown in Figure 1.
2.1. *Image Input*

The facial image for the input is an image that holds one face. The input images are the facial images that are facing the camera.

2.2. *Training Data*

In the process of image training, the training data amounted to 30 facial images. These images will be the reference for data testing. The facial images in this research had the size of 300 x 300 pixels and stored on the local hard disk.

2.3. *Test Data*

Test data are the data used to test the system. There is 3 facial type for the system to be identified by comparing the images with the training data. Total of the test data is 22 images.

2.4. *Image Pre-Processing*

Image pre-processing is an early stage of this study. This stage aims to process the input to be converted into a better-quality image for further processing. The stages in the image pre-processing consisting of the grayscale process and CLAHE (Contrast Limited Adaptive Histogram Equalization).

2.4.1. *Grayscale*
The grayscale process is the process of changing the color of red, green, blue (RGB) to the gray level. This process is to facilitate the system to determine the value and to ease the next process that is CLAHE.

2.4.2. Contrast Limited Adaptive Histogram Equalization (CLAHE)

After the grayscale process, the image will enter the CLAHE stage that will change the image color to black and white with sharper quality.

2.5. Image Segmentation

Segmentation is a process that divides an image into the essential elements of an image. The main purpose of segmentation is to detect the lines and edges to separate the desired part. Gabor filter is a process to bring up the special features of an image that have been convoluted to the kernel so that the main elements of the image are visible. Gabor Kernel 2D applied as a filter which obtained by modulating 2D sine wave at a specific frequency and orientation using the Gaussian envelope.

2.6. Feature Extraction

Feature extraction of the image objects is generally based on two-pixel characteristics of similarity and the difference of pixel values. In other words, how the discontinuities of the gray pixel values are treated and when the intensity values changes based on certain criteria are appropriate to indicate a boundary between different image features [7]. In this research, authors applied the invariant moment method. To get the result of this method is to calculate the moment value. Conventionally, the moment invariant is computed based on information provided by shape boundaries and interior regions [8] which can be calculated using the equation below.

\[ m_{pq} = \sum_{x=0}^{H-1} \sum_{y=0}^{W-1} x^p y^p f(x,y) \]

The result of this method is seven values that will be used for the next process.

2.7. Identification using PNN Algorithm

The Probabilistic Neural Network (PNN) is an artificial neural network that uses the theories of classical probability such as Bayes classification and Parzen density approximation. PNN algorithm has faster processing time when compared to Backpropagation Neural Network (BNN). The accuracy of the PNN classification is primarily determined by the value of \( \sigma \) and the training pattern. If the value of \( \sigma \) applied to PNN is precise, then the classification accuracy will be close to or reach 100%. If the value of \( \sigma \) applied is not accurate, then the PNN classification accuracy will decrease [9].

In this research, the total image for test data is 22 images. The images were acquired from one of the special schools that have numerous students with special needs, and others were sourced from the internet. After the values of the invariant moment were obtained, the next process will be identification phase using Probabilistic Neural Network algorithm to generate more accurate results which can be calculated using equation as follows:

\[ fA(X) = \frac{1}{(2\pi)^{p/2} \sigma^p} \frac{1}{m} \sum_{i=1}^{m} \exp\left[-\left(\frac{(X - XAi)^t(X - XAi)}{2\sigma^2}\right)\right] \]

Where:
- \( i \) = Number of pattern
- \( m \) = Number of training pattern
- \( XAi \) = Training pattern to i-th of 0A category
- \( \sigma \) = stabilizer parameter
- \( p \) = size dimension
Note that $f_A(X)$ is a simple summation of small multivariate Gaussian distributions centered on each training sample. However, the numbers are not limited to being Gaussian. This may occur, in fact, the estimation of probability function has a subtle density. There are apparent similarities between parallel analogue networks that classify multiple patterns using density probabilities (PDF) and feed-forward neural networks applied to other training algorithms [10].

3. Experimental Results

The results for the facial classification of down syndrome using the test dataset are as follows.

3.1. Image Capturing

The result of image capturing is a facial image taken from human face only with the .jpg format. The example of this stage can be seen in Figure 2.

![Fig 2. Sample of the image capturing result](image)

3.2. Pre-Processing

The results of this stage are the images that have been through the processes of saturation, grayscale and thresholding. The sample of a pre-processing stage can be seen in Table 1.

| Grayscale | CLAHE |
|-----------|-------|
| ![Sample of pre-processing](image) |

3.3. Image Segmentation

Image segmentation is the process of partitioning a digital image into several segments. The main purpose of segmentation is to simplify or to change the representation of the image into information and easy to analyze [11]. Image segmentation is commonly used to find objects and line boundaries, curves, many more. [12]. Gabor filter is a process to showcase the special features of an image that has been convoluted to the kernel so that the main elements of the image are visible. Gabor Kernel 2D served as a filter by modulating 2D sine wave at a particular frequency and orientation using the Gaussian envelope. The sample of image segmentation is shown in Figure 3.

![Fig 2. Sample of Gabor filter](image)
3.4. Feature Extraction

The next stage is feature extraction. At this stage, each segmented image will be processed to produce seven invariant moment values for the classification process using Probabilistic Neural Network (PNN) algorithm. The results of this process can be seen in Table 2.

Table 2. Calculation result of Invariant Moment value

| φ   | A1          |
|-----|-------------|
| φ₁  | 7.281682493741887 |
| φ₂  | 20.15958074150991 |
| φ₃  | 32.37096911552964 |
| φ₄  | 32.0137957182342 |
| φ₅  | 65.9153207589105 |
| φ₆  | 42.09494889894795 |
| φ₇  | 64.18951252347178 |

3.5. Identification using PNN Algorithm

The values obtained from feature extraction were used as the input in the Neural Network process. In this PNN stage, the invariant moment values of the test data will be compared with the invariant moment value of the training data stored in the database, making it easier for the system to recognize the images. The result of the process will obtain the value of \( f_A(X) \), a simple summation of small multivariate Gaussian distributions centred on each training sample. The results of the Probabilistic Neural Network process are described in Table 3.

Table 3. Sample of PNN calculation

| Gabor | Fmosaic (X) | Ftrisomy21 (X) | Fnonsyndrome (X) |
|-------|-------------|----------------|-----------------|
|       | 1.57857     | 2.33259        | 1.60667         |

Thus, the results will be compared to the values of fmosaic(X), ftrisomy21(X) and fnonsyndrome(X). If the value of the fmosaic (X) is greater than ftrisomy21 (X) and fnonsyndrome (X), then the image will be classified as mosaic and so on. It can be concluded that a more significant result is the determinant.

3.6. System Accuracy

In this study, the Gaussian value is set at 0.9 because it is the most accurate value based on the test results. The result of the system test obtained an accuracy value of 91%. The calculation of the accuracy percentage is as follows:

\[
\text{Accuracy Percentage} = \frac{\text{Correctly identified data}}{\text{Total of test data}} \times 100\%
\]

\[
= \frac{20}{22} \times 100\%
\]

\[
= 91\%
\]
3.7. Analysis of Precision and Recall

In pattern recognition and information retrieval, precision and recall are the two calculations that are widely used to measure the system performance. Precision is the corresponding level of the information requested by the user with the answers given system. A recall is the success rate of the system in rediscovering information. Precision and recall in this study are used to measure the performance of Probabilistic Neural Network (PNN) algorithm in the facial classification of Down syndrome using 22 test data. System test results can be seen in Table 4.

Table 4. Sample of PNN calculation

| Category     | Relevant (a) | Irrelevant (b) | Total (a+b) | Not Found (c) | Total (a+c) | Recall [a/(a+c)] x100% | Precision [a/(a+b)] x100% |
|--------------|--------------|----------------|-------------|---------------|-------------|------------------------|---------------------------|
| Mosaic       | 5            | 1              | 6           | 1             | 6           | 83,4 %                 | 83,4 %                    |
| Trisomy 21   | 11           | 0              | 11          | 0             | 11          | 100 %                  | 100 %                     |
| Non-syndrome | 4            | 1              | 5           | 1             | 5           | 80%                    | 80%                       |

According to Table 6, the recall and the precision values are at 88%. The effectiveness level is divided into two parts, which is effective if the value is above 50% and ineffective if the value is below 50%. The ideal condition of the effectiveness of a classification system is when the ratio of recall and precision is equal (1:1) [13]. Thus, it can be concluded that the system is effective since the ration of recall and precision of this study is 1: 1.

4. Conclusion

Based on the results, it can be concluded that the Probabilistic Neural Network (PNN) algorithm can classify the face of Down syndrome. An accuracy rate of 91% supports this. The factor that affects the accuracy rate is the level of image density or pixels. It can also be concluded that poor image quality will provide a higher risk of system failure. Further research can be developed by examining other parts. Furthermore, additional features, such as texture and shapes in feature extraction could boost the system accuracy. The execution environment also can be improved by implementing cloud computing technology [14].

5. References

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