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Design of Facial Expressions Recognition for Academic Presence by Using Backpropagation Artificial Neural Networks Based on Principal Components Analysis

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ABSTRACT

There are 4,004 universities in Indonesia where each university needs data to find out student activities, one of which is through attendance. Some universities in Indonesia still use manual attendance systems and attendance systems through the website. This system has several obstacles that require solutions. The problems are loss or damage of data, time-consuming process, inaccuracy and inputs errors, and the students can abuse the manual attendance. This research aims to make a design to make academic presence for students by using neural network. There are many methods that can be used to create this system including using Principal Component Analysis (PCA) based on Backpropagation Neural Network (BNN) because it can help the system perform faster and more accurately without losing important information. The result of this research is design of facial expressions recognition. The results are step to make detection process, then extraction process, and finally the face can be recognized.

Keywords: artificial neural networks; backpropagation; principal component analysis.

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1. Introduction

As time progresses, followed by global changes, the world becomes increasingly modern in various fields, especially technology. Many new technologies have been developed that make human activities easier. Human facial recognition technology is one of the detection technologies that has received a lot of attention from researchers (Aini & Irmawati, 2017). Face recognition is a field of computer vision which is a process to identify a person from different kinds of facial images that have different expressions. (Mahmud et.al, 2015). On the other hand, facial recognition is a promising technology with a great application potential and broad prospects for development (Huang, 2019). The face itself is one of the most basic things in recognizing identity. Because the face is a part of the body that cannot be duplicated (Win, 2021). Much research has been carried out on human facial recognition, with certain advantages and disadvantages. One of the advantages of research on facial recognition is that

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it can be applied to determine student attendance every day (Abuzneid, 2018).

Based on data from the Central Statistics Agency (BPS) in 2022, it is recorded that there are 4,004 universities in Indonesia. Most universities require data on student activity, one of which can be obtained through student attendance on campus every day. The student attendance data collection system at each campus is different, some still use manual attendance (signatures) which in this case may not necessarily be proven to be accurate due to fraud committed by students. One type of fraud that is often committed is when students entrust their absences to fellow students who attend the same lecture class. In other words, there are students who help fill in their friends' attendance lists. Then there are also those who use the attendance system via the campus website which fills in online. This has several obstacles, including taking time, being hampered by weak networks, and students forgetting to fill in attendance. Therefore, a more concise system is needed to assist students in filling out attendance. There are many methods that can be used to analyze facial shape recognition, but in this research it is only limited to the use of the Principal Component Analysis (PCA) method based on Backpropagation Artificial Neural Networks (ANN) because it can help system performance more quickly and accurately without losing important information (Hijriah, 2020).

Principal Components Analysis (PCA) is used to reduce the dimensions of a set or image space so that a new basis or coordinate system can better describe the typical model of the set. In this case the desired model is a collection of trained faces (training faces). The new base will be formed through linear combination. The components of this facial space basis will not be correlated with each other and will maximize the differences in the original variables (Kashem, 2021).

Neural networks have seen an explosion of interest over the last few years and are being successfully applied across an extraordinary range of problem domains in areas as diverse as finance, medicine, engineering, geology and physics (Cilimkovic, 2015). Artificial neural networks (ANN) are a simplified model of biological nervous systems as an alternative computing system (Frenza & Mukhaiyar, 2021). Backpropagation is a general algorithm for artificial neural networks. In the learning process, the backpropagation algorithm is included in the category of supervised learning method. Training methods using this algorithm can produce a balance between the network's ability to recognize patterns used during training and the network's ability to provide correct responses to input patterns that are similar but not the same as the patterns used during training (Octariadi, 2020).

There are several studies that have used the Backpropagation Neural Network algorithm and the Principal Components Analysis (PCA) method. Such as research conducted by Harizayu in 2021, regarding "Facial Expression Recognition Based on Backpropagation Neural Networks using the Principal Component Analysis Method". In their research, they analyzed the accuracy in recognizing facial expressions with various expressions, and obtained accurate results. Furthermore, research conducted by Anniza and friends in 2021, regarding "New Method for Locker Doors with Facial Security Systems using the Backpropagation Algorithm". In their research they created a facial recognition program for locker door security. In their research, the program created was able to work well, only the faces that could be recognized had to be in normal condition (Rofii, 2017).

The challenges of manual attendance at universities can include the following:

1. Loss or Damage of Data: Attendance forms or sheets can be lost, damaged, or illegible, leading to the loss of attendance data.
2. Time-Consuming Process: Collecting and checking manual attendance takes longer, both for students and lecturers, especially in large classes.

3. Inaccuracy and Input Errors: Human errors can occur when signing the attendance list, such as duplicate signatures, signing for someone else, or forgetting to sign, resulting in inaccurate data.
4. Abuse: Students may ask friends to sign in on their behalf, leading to fraudulent attendance records, making manual systems more prone to misuse.

A digital attendance system is expected to address most of these issues. Based on several studies that have applied the Backpropagation Artificial Neural Network (ANN) method and the Principal Components Analysis (PCA) method, it is proven that this method is an accurate method for recognizing faces. In this study we aim to design a facial recognition system for student attendance at the Faculty of Mathematics and Natural Sciences.

2. Research Method

In the problem of identification process in this research, the steps arranged in the flow diagram below are carried out.

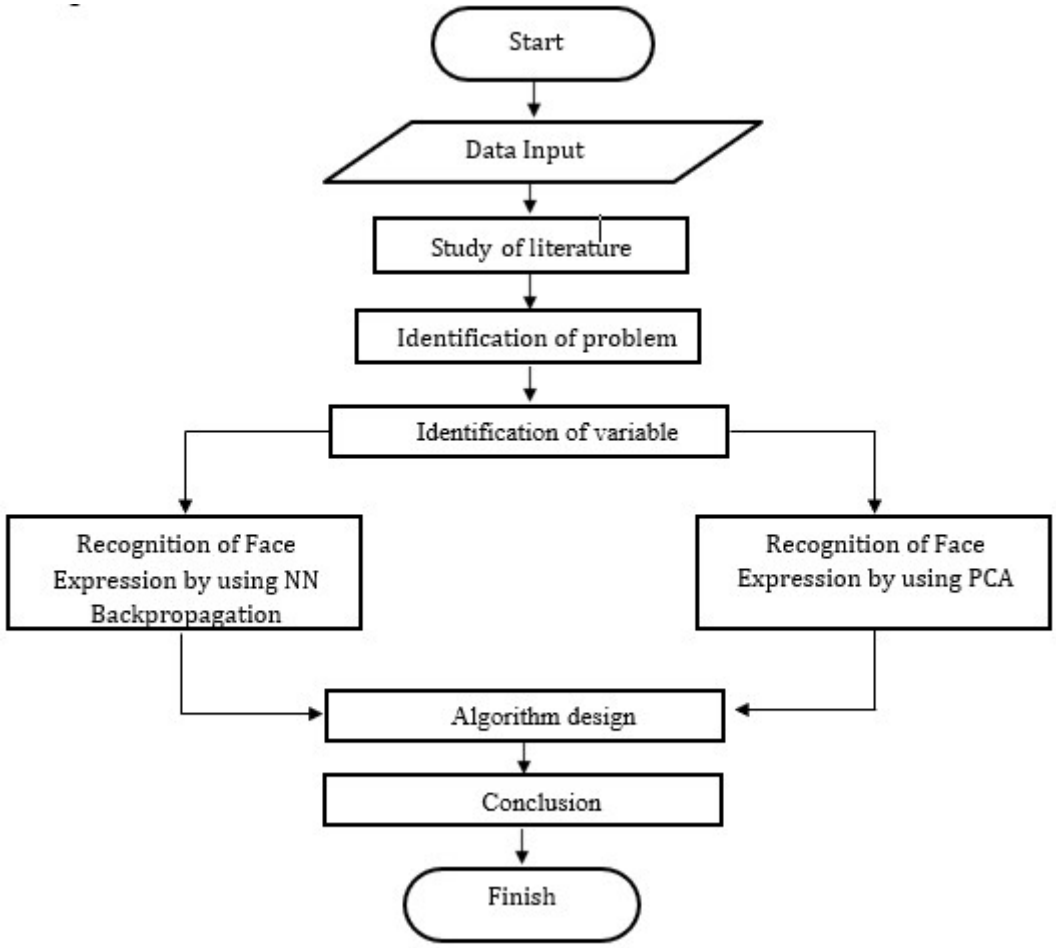

Figure 1. flowchart of research

Based on the figure 1, we can describe the step on the following below.

- Data Input
  In this section, facial images will be collected by the mathematics students in Department of Mathematics, Faculty of Mathematics and Natural Sciences, University of Mataram.
- Study of literature
  In the literature study, important stages will be studied that will be used to solve research problems.
- Identification of problem

After obtaining information from the literature study, conditions in the field will then be reviewed to determine the solution to the problem being studied.

- Identification ofvariables
  In this section we will identify various facial expressions that will be used as values for the matrix.
- Recognition of face image expressions with PCA
  In this process the expected results will be obtained.
- Results
  In this section, results will be obtained in the form of a program design for student attendance.
- Conclusion
  After carrying out a series of steps in creating this program, a conclusion will be produced regarding the research objectives created by the data and applying PCA.

3. Results and Discussion

Principal Component Analysis (PCA) or also called Hotelling Transform (HT) or Karhunen-Loeve Transform (KLT). PCA is used to reduce dimensions, usually effective in image reduction or Signal Processing. PCA reduces the size of the vectors used for object recognition and object grouping problems. PCA can be implemented using EVD (Eigenvalues Decomposition) and SVD (Singular Values Decomposition). However, this journal focuses on using EVD. Implementation of PCA on the following

- Suppose we have n images $(x_1, x_2, \dots, x_n)$ of size $M \times N$.
- First, the 2D image will be converted to 1D size. so, the image can be represented as a 1D vector with size $1 \times MN$
  $$X = [x_1\ x_2\ x_3\ \cdots\ x_n\ ] = [x_{11}\ \cdots\ x_{1MN} \vdots \ddots \vdots\ x_{n1}\ \cdots\ x_{nMN}\ ].$$
  The size of the matrix X is $n \times MN$.
- After that, determine the mean m of the matrix data X. $(m = \underline{X})$.
- Mean subtraction m of row X
  $$X_m = X - m,$$
  (average of middle data with size $n \times MN$).
- Find the covariance of the matrix X_m
  $$Q = \left(\frac{X_m^T . X_m}{n-1}\right).$$
  The size of Q is $MN \times MN$ which is very large.
- Matrix Q will be diagonalized with the help of matrix P, so that
  $$P^{-1}QP = \Lambda,$$
  for an orthogonal matrix P, the above equation can be written
  $$P^TQP = \Lambda,$$
  where Λ is the diagonal of the matrix measuring $MN \times MN$ which contains the eigenvalues (λ) of the matrix Q
  $$\Lambda = [\lambda_1\ \ \ddots\ \ ].$$
- Matrix P can be found using the eigenvectors of Q. Because the size of matrix Q is $MN \times MN$, there will be as many as MN eigenvectors with size $MN \times 1$ which are mutually perpendicular
- $P_1 = [P_{11}\, P_{12}\, \cdots\, P_{1MN}\ ], P_2 = [P_{21}\, P_{22}\, \cdots\, P_{2MN}\ ], \dots, P_{MN} = [P_{MN1}\, P_{MN2}\, \cdots\, P_{MNMN}\ ]$, if the eigenvectors are arranged, a matrix P will be produced.
- $P = [P_1\ P_2\ P_3 \dots\ P_{MN}] = [P_{11}\, P_{12}\, \cdots\, P_{1MN}\ \ P_{21}\, P_{22}\, \cdots\, P_{2MN} \dots\ \ P_{MN1}\ \ P_{MN2}\ \ \cdots\ P_{MNMN}]$,
  so the size of the matrix P is $MN \times MN$.

- This matrix P is used to decorrelate data set X. This transformation can be written as $T_{n\times MN} = [X_m]_{n\times MN} \cdot [P]_{MN\times MN} = [X - m]_{n\times MN} \cdot [P]_{MN\times MN}$.
- It can be seen that the transformed data set T is of size $n \times MN$. Which means no reduction is obtained because we take all parts of the matrix P to be transformed. If all eigenvectors represent all principal axes, then dimensionality reduction is not achieved. Therefore, to achieve dimensionality reduction several columns (eigenvectors) of P are used. Chosed is a vector eigen (column of P) as L is a the biggest eigen value (λ).
- The new measure of metric reduction $PPCA$ is $MN \times L$. Then, the transformation becomes

$$T_{n\times L} = [X - m]_{n\times MN} \cdot [P_{PCA}]_{MN\times L} \quad (1)$$

with L measuring $20 - 50$ and MN measuring thousands, you will get a large dimension reduction from the data set $\{[X_{n\times MN}] > T_{n\times L}\}$.
- As is known, the matrix column $Xn\times MN$ contains 1 image with a size of $1 \times MN$. After transformation, the data matrix $Xn\times MN$ is reduced to $Tn\times L$. Where each row of the matrix $Tn\times L$ represents one image with size $1 \times L$.
- An image of (I) size will be transformed $M \times N$ ke PCA

$$I_{(1\times L)} = [I - m](1\times MN)[P_{PCA}](MN\times L). \quad (2)$$

Recognizing facial image expressions using ANN Backpropagation is a learning algorithm to reduce the error rate by adjusting the weights based on the difference between the output and the desired target. Backpropagation is also a systematic method for training multi-layer ANN because Backpropagation has three layers in the training process, namely the input layer, hidden layer and output layer, where Backpropagation is the development of a single layer network which has two layers, namely the input layer and the output layer. Having a hidden layer in backpropagation can make the error rate in backpropagation lower than the error rate in a single layer network because the hidden layer in backpropagation functions as a place for updating and adjusting weights.

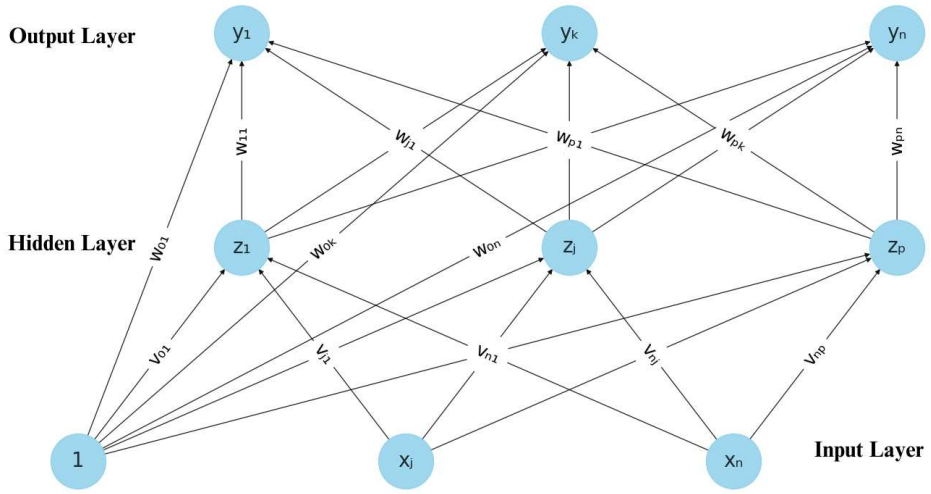

Figure 2. backpropagation neural network architecture

Information:

Vij : weight on hidden layer
Voj : blur on hidden layer
Z : hidden layer
Wij : weight on output layer

Woj : blur on output layer
X : iInput layer
Y : output layer

The architecture of a backpropagation neural network has functions including, the input layer is tasked with forwarding input while the hidden layer and output layer function to carry out computations. The number of neurons in the input layer is equal to the number of features or attributes in the pattern to be recognized, while the number of neurons in the output layer is equal to the number of pattern classes.The design of face expressions recognition as a result of this research is shown by the explanation on the following.

3.1 Recognition of facial image expressions using ANN Backpropagation

After the system design has been carried out, the results of the Backpropagation algorithm will be obtained. This is done in order to find out the system's ability to recognize faces, and how accurate the system created is in carrying out processing.

1. Main view

   The main page on the system that has been created will appear when you first open the system. On this page, researchers must store image data of students who will later use this system, the aim is that the student's face is registered in the system which will facilitate the testing process.
2. Final view

   In this display, all data that has been saved on the home page will be tested. At this stage it will be shown whether the data that has been saved will match the data to be trained.
3. Face detection

   After selecting images by the system that are suitable for what will be trained, the system will separate images of faces from non-faces to facilitate face detection and make it easier to proceed to the next stage.
4. Grayscale

   At this stage, the image that has gone through the face detection process will enter the grayscale stage, that is, the face image will be changed from previously colored to gray.
5. Filter mean

   This part is a process that will remove noise in the image, so that it will reduce the error rate during the next process.
6. Find Face Features

   In this section the system will recognize and find images that match what is being searched for, the system will recognize the shape of the eyes, count and mouth.
7. Threshold

   At this stage the image that has been found will be converted into binary form. And you will get a threshold point.
8. Face feature distance table

   After getting the results from the previous process, the next feature distance calculation will be carried out. Distance will be measured based on points in the previous process using the Euclidean method.
9. Training of data

   After going through all the previous processes and the data has been saved, data training will be carried out. The goal is as a learning process for the backpropagation algorithm in recognizing faces and will enter it into the backpropagation database. The training process may not be able to be done just once, it may take several times until data that matches what is stored and what is entered is found.
10. Testing

    This process is the final process in recognizing faces. In this section testing will be carried out where in this section it will be known whether the image that has been

saved and trained is the same as the image that comes out during testing.

3.2 Recognition of facial image expression with PCA

After the system design has been carried out, the results of the Principal Component Analysis will be obtained. This is done in order to find out the system's ability to recognize faces, and how accurate the system created is in carrying out processing. There are several steps you can take, some of which are as follows

1. Detection Process

   The process involves equalizing the light intensity of the training data so that the conditions of the training image are the same and converting it into a grayscale image.
2. Extraction Process

   After successfully detecting facial skin for all data. The results of facial skin extraction are represented in the form of facial matrices. This uses calculations to find the eigenfaces of the face.
3. Face Recognition

   At this stage, PCA will calculate the covariance matrix from the collection of training face images. The eigenface will be the basis for calculating face distance which represents the individual weight values representing one or more facial images. This weight value is used to recognize the test face image by finding the distance between the weight value of the test face image and the weight value of the training face image.

4. Conclusion

Based on the preparation steps in designing a student attendance system, it can be formed in several steps in 3.1 and 3.2. In order to the system to run using a backpropagation neural network, it requires facial image data which will go through the processing, training and testing stages. Meanwhile, face recognition using the PCA method uses data with the same resolution in each image. Then, the image will go through three stages, namely detection, extraction and recognition.

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References

[1] Aini, N., & Irmawati, I. (2017). Implementasi Metode Fisherface pada Presensi Wajah Karyawan Studi Kasus PT. Illuminati Metamorphosis Makassar. SEMNASTEKNOMEDIA ONLINE, 5(1), 1-2. https://ojs.amikom.ac.id/index.php/semnasteknomedia/article/view/1606

[2] F. Mahmud, S. Afroge, M. A. Mamun and A. Matin, "PCA and back-propagation neural network based face recognition system," 2015 18th International Conference on Computer and Information Technology (ICCIT), Dhaka, Bangladesh, 2015, pp. 582-587. https://doi.org/10.1109/ICCITechn.2015.7488138

[3] Huang, Q., Limin, C., (2019). Design and Application of Face Recognition Algorithm Based on Improved Backpropagation Neural Network. Academic Journal. https://doi.org/10.18280/ria.330105

[4] Win, E. A. (2021). Model Pengenalan Wajah dengan Principal Components Analysis dalam Perancangan Perangkat Lunak. Jurnal Global Multicom Tifo, 1(1), 35-39. https://dx.doi.org/10.9744/informatika.2.2.pp.%2057-61

[5] Abuzneid, M. A., & Mahmood, A. (2018). Enhanced human face recognition using LBPH descriptor, multi-KNN, and back-propagation neural network. *IEEE access*, *6*, 20641-20651. https://doi.org/10.1109/ACCESS.2018.2825310

[6] Hijriah, A., Fauziyah, M., & Dewatama, D. (2020). Implementasi JST Backpropagation pada Face Recognition untuk Percepatan Proses Sistem Presensi.Jurnal Elkolind: Jurnal Elektronika dan Otomasi Industri, 1(1), 14-22. http://dx.doi.org/10.33795/elkolind.v1i1.29

[7] Kashem, M. A., Akhter, M. N., Ahmed, S., & Alam, M. M. (2021). Face recognition system based on

principal component analysis (PCA) with back propagation neural networks (BPNN). *Canadian Journal on Image Processing and Computer Vision*, *2*(4), 36-45. https://www.ijser.org/viewPaperDetail.aspx?JUN1119

[8] Cilimkovic, M. (2015). Neural Networks and Back Propagation Algorithm. Institute of Technology Blanchardstown. https://api.semanticscholar.org/CorpusID:18592533

[9] Frenza, D., & Mukhaiyar, R. (2021). Aplikasi Pengenalan Wajah dengan Metode Adaptive Resonance Theory (ART). Ranah Research: Journal of Multidisciplinary Research and Development, 3(3), 147-153. https://doi.org/10.38035/rrj.v3i3.392

[10] Octariadi, B. C. (2020). Pengenalan Pola Tanda Tangan Menggunakan Metode Jaringan Syaraf Tiruan Backpropagation. Jurnal Teknoinfo, 14(1), 15-21. https://doi.org/10.33365/jti.v14i1.462

[11] Kholis, I. & Rofii, A. (2017). Analisis Variasi Parameter Backpropagation Artificial Neural Network Pada Sistem Pengenalan Wajah Berbasis Principal Component Analysis. Jurnal Kajian Teknik Elektro, 2(1), 1-12. https://doi.org/10.52447/jkte.v2i1.548