Effect of MinMax Normalization on ORB Data for Improved ANN Accuracy

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Article Info
Received Aug 10, 2023
Revised Aug 23, 2023
Accepted Aug 31, 2023

ABSTRACT
This study investigates the impact of employing MinMax normalization on Oriented FAST and Rotated BRIEF (ORB) data as inputs for an Artificial Neural Network (ANN). The primary goal is to compare the accuracy of an ANN model using two types of input data: raw ORB data and MinMax-normalized ORB data. The findings emphasize the vital role of MinMax normalization in significantly enhancing the performance of the ANN model. Through comprehensive experiments, it becomes evident that MinMax-normalized ORB data consistently outperforms raw ORB data in terms of accuracy, reaching an impressive highest accuracy of 76.6%, whereas using raw ORB data only achieves a maximum accuracy of 51.1%. This improvement validates MinMax normalization’s effectiveness in mitigating the challenges posed by varying scales within raw data. As a result, the ANN benefits from improved pattern recognition capabilities and heightened predictive accuracy, ultimately addressing the research problem and showcasing the importance of preprocessing techniques in optimizing data input for neural network models.

Keywords:
MinMax Normalization
ORB
Artificial Neural Network
Data Preprocessing
Accuracy Enhancement

1. INTRODUCTION
In the rapidly advancing era of technology, the use of robots is becoming increasingly widespread, including in the field of computer vision, which is a crucial component of Artificial Intelligence (AI) development. Computer vision technology enables computers to possess visual capabilities akin to humans, allowing them to perceive, recognize, and interact with objects in their surroundings. With this capability, computers can analyze images and respond with actions based on acquired information.

One of the primary focuses in computer vision development is enhancing the accuracy and precision of image analysis. This involves the development of methods and techniques for interpreting images, recognizing patterns, and understanding their meanings. One significant method in this regard is the Oriented FAST and Rotated BRIEF (ORB), an algorithm for feature extraction from images. ORB boasts high efficiency and employs an approach based on centroid orientation intensity in its analysis.

However, data resulting from ORB feature extraction may exhibit significant scale variations, which can impact their use in the development of artificial neural networks (ANNs). To address this, the MinMax data transformation method is employed, normalizing the data range to ensure scale consistency. This research aims to analyze the influence of applying the MinMax data transformation to ORB feature extraction data on the performance of ANNs in object classification. It is anticipated that the MinMax transformation will ensure data scale consistency and enhance the ANN's ability to better recognize and classify objects, thereby contributing to the development of computer vision technology across various practical applications.

2. METHOD
2.1. Research Methodology
1. Literature Review
A literature study involves the process of seeking and gathering information/data and delving into supporting theories from various sources, both offline and online. Data can be obtained from diverse sources such as articles, journals, datasheets, verified web pages, and books related to image classification utilizing ORB and ANN.

2. Experiment
In the context of this research, an experimental method is employed to analyze the accuracy and performance of Artificial Neural Networks (ANN) using an approach that varies the input data. This approach involves testing focused on ORB data before and after undergoing MinMax normalization. In
the initial phase, ANN is evaluated using raw ORB data without normalization. Subsequently, MinMax normalization is applied to the ORB data to reconfigure the value range. In the final phase, ANN is re-evaluated using the normalized ORB data. This approach aims to gain a profound understanding of the impact of MinMax normalization on the accuracy and performance of the ANN model. This analysis also allows for a performance comparison of ANN under two different data conditions, aiding in identifying the influence of normalization on model effectiveness.

The research method used in this study is described in a flowchart as outlined in Figure 1 as follows:

Figure 1. General Research Flowchart

Figure 1 illustrates that the initial step in this research involves processing image data using ORB. After processing the data using ORB, it will then be normalized using the MinMax Normalization method, while the data before normalization will be retained. Once the normalization process is complete, an Artificial Neural Network (ANN) model is created for the purpose of conducting the learning process. Subsequently, testing procedures are carried out. The testing process aims to determine the accuracy values when using both non-normalized and normalized data. Following the acquisition of results, an analysis is performed, leading to conclusions drawn from the study.

2.2. Artificial Neural Network

Artificial Neural Network (ANN) is a model inspired by the way neurons in the human brain operate. Each neuron in the human brain is interconnected and shares information with each other. There are 4 (four) essential components in ANN, namely:
1. Feedforward Algorithm
2. Activation Function
3. Backpropagation
4. Confusion Matrix

Each of these four components is responsible for different aspects of the classification process [6], [7], neuron activation [8], ANN learning [6], and the accuracy achieved by the ANN [9].

2.3. Oriented FAST And Rotated BRIEF (ORB)

ORB (Oriented FAST and Rotated BRIEF) is a binary descriptor used in image analysis. It rapidly detects and characterizes essential features by combining FAST and BRIEF techniques.

Both computers and humans share the similarity of interpreting data through multiple dimensions, where spatial information holds significance [10]. In image processing, the initial step involves converting the image’s color format to grayscale, simplifying subsequent analyses [11].

The FAST technique rapidly identifies keypoints—specific locations where pixel intensity changes occur, indicating potential features such as corners or edges. Simultaneously, the BRIEF technique generates
concise binary representations of these keypoints. The true strength of ORB lies in its seamless integration of FAST-based keypoint detection and BRIEF-based description processes [12], offering a clear advantage in terms of significantly enhanced efficiency compared to Scale-Invariant Feature Transform (SIFT) across various contexts.

In conclusion, ORB plays a pivotal role in identifying and describing critical image features. By adeptly merging FAST and BRIEF techniques, ORB demonstrates proficiency in feature recognition, with adaptability to rotation and robustness against noise [13].

2.4. Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a statistical analysis method used to transform initially correlated variables into a set of new variables that are uncorrelated with each other. The main objective of PCA is generally to reduce the data dimensions. PCA is a useful solution in situations where there are many variables in a data collection. By using this method, fewer new variables can be generated while still explaining the variance of the existing data [14], [15].

2.5. MinMax Normalization

MinMax normalization is a method in data processing used to transform values within a dataset into a specific range, typically between 0 and 1. The main objective of this normalization is to achieve a uniform scale for all features (variables) in the dataset, thereby preventing excessive dominance or influence from features with larger values on the analysis or models utilizing the data.

MinMax normalization is beneficial in various data analysis and model-building applications, such as image processing, pattern recognition, as well as algorithms that compute distances or similarities between data points. However, it's important to note that this normalization is not always necessary or suitable for all types of data and usage scenarios. This normalization technique will transform the range of the obtained input data into 0 – 1 using Equation (1) as follows:

\[
v_{\text{norm}_i} = \frac{v_i - v_{\text{min}}}{v_{\text{max}} - v_{\text{min}}}\]

Equation (1)

Explanation:
- \(v_{\text{norm}_i}\) = Normalization value of data \(v\) at index \(i\)
- \(v_i\) = Value of data \(v\) at index \(i\)
- \(v_{\text{max}}\) = Maximum value of the data group \(v\)
- \(v_{\text{min}}\) = Minimum value of the data group \(v\)

2.6. Research Variables or Data

The research variables or data include the learning rate variable to determine the speed at which the ANN reaches the global minimum point, the number of neurons in the hidden layer variable to find the optimal number of neurons during ANN learning, and the learning time variable to determine the duration of time needed in the learning process, measured in seconds (s).

2.7. Result Analysis

The analysis was conducted using a quantitative method with an experimental approach. The testing results consist of accuracy data when the training data has and does not have background, as well as the testing data that also has and does not have background and the duration time for ANN to learn. The testing results are presented in tabular form.

- **Accuracy**
  Measuring the Success Rate of the System in Recognizing Dogs and Cats Based on the Number of Learning Rates and Neurons in the Hidden Layer.

\[
\text{accuracy} = \frac{d_{tp} + d_{tn}}{n} \times 100\%
\]

Equation (2)

Explanation:
- \(\text{accuracy}\) = The accuracy value
- \(d_{tp}\) = The number of data included in the true positive block
- \(d_{tn}\) = The number of data included in the true negative block
- \(n\) = The number of testing data
3. RESULT AND DISCUSSION

3.1. Result

In this study, an exploration is conducted by varying the number of neurons in the hidden layers as well as the learning rate within an Artificial Neural Network (ANN). The aim is to enhance the accuracy level generated by the ANN during the testing process.

By doing so, the research seeks to uncover distinctive characteristics of each tested ANN composition. It is important to note that differences in the number of neurons in the hidden layers and the learning rate can have significant impacts on the performance of the ANN, and these variations may provide insights into how the ANN adapts to different input data.

Furthermore, a comparison is made by testing the ANN in two distinct situations: using input data before and after MinMax normalization. This approach allows for observing the achieved accuracy improvements and assists in identifying and understanding how the characteristics of the ANN change when confronted with these two different types of input data. MinMax normalization is a process that transforms data values into a specific range (e.g., 0 to 1), enabling more effective processing of the data by the ANN.

Through this exploration, significant differences in the performance of the ANN are expected to emerge when applied to normalized and non-normalized data. This can provide a deeper insight into how the ANN responds and adapts to data manipulations.

Overall, this exploration aims to shed light on how the ANN’s performance can be optimized in different scenarios. It’s important to note that the selection of the number of neurons in the hidden layers and the learning rate is not always linear or deterministic, and further experimentation and analysis may be required to fully understand how these factors interact to influence the ANN’s performance.

The combination of neurons in the hidden layer and learning rate can be seen in the following Table 1:

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Number of Neuron</th>
<th>Learning Rate</th>
<th>Test Number</th>
<th>Number of Neuron</th>
<th>Learning Rate</th>
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<th>Number of Neuron</th>
<th>Learning Rate</th>
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<td>80</td>
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</tr>
</tbody>
</table>

The accuracy test results using raw input data without undergoing MinMax Normalization can be seen in Figure 2 below:
The results of the accuracy test using input data that has undergone MinMax Normalization can be seen in Figure 3 below:

The comparison of accuracy test results using raw input data without undergoing MinMax Normalization with the accuracy test results using input data that has undergone MinMax Normalization can be seen in Figure 4 below:
3.2. Discussion

In Figure 2, it's evident that the accuracy achieved from all tests, as per the composition outlined in Table 1, falls short of the intended target accuracy for this study (60%). None of the conducted tests managed to reach this desired threshold, with the highest accuracy obtained being 51.4%. Conversely, Figure 3 illustrates that after implementing the composition specified in Table 1, the achieved accuracy for the ANN does meet the study's target accuracy. The majority of these tests achieved an accuracy of 60% or higher, with the peak accuracy reaching 76.6%.

Figure 4 displays distinct differences in the obtained accuracy results. The results of tests using raw input data without MinMax Normalization are consistently below the desired target accuracy. In contrast, tests conducted with input data that underwent MinMax Normalization exhibit a mixed pattern: some surpass the target accuracy, while others fall below it.

4. CONCLUSION

In conclusion, this study unequivocally establishes the efficacy of MinMax normalization in enhancing the accuracy of an ANN model utilizing ORB data. The achieved results underscore the transformative impact of this preprocessing technique, as MinMax-normalized ORB data consistently outperformed raw data, achieving a significant accuracy improvement of over 25%. These findings firmly establish the critical role of data preprocessing, particularly MinMax normalization, in refining input data quality and elevating the reliability and performance of models.

ACKNOWLEDGEMENTS

The author extends gratitude to the academic community of the Faculty of Engineering, Tanjungpura University, for their constant guidance and support. May the results of this research be beneficial for both the author and the readers.

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