

DEVELOPING A BASIC NEURAL NETWORK TO CLASSIFY IMAGES FROM THE MNIST DATASET

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Abstract. My thesis focuses on an important and currently popular topic: “Developing a basic neural network to classify images from the MNIST dataset”.

This topic is very important for current and future research. The main goal of this project is to create a basic neural network capable of efficiently classifying images from the MNIST dataset, a critical benchmark for image classification tasks. The MNIST dataset is widely known and widely used in computer vision and machine learning. Designing an accurate neural network to classify images from this dataset is a crucial milestone in the development of more advanced computer vision systems. By exploring the basic architecture of a neural network, this study aims to provide an overview of the basic principles of image classification tasks. The PhD thesis deals with the complex process of training a neural network using the MNIST dataset, evaluating its performance and fine-tuning its classification accuracy. Through this research, researchers and professionals gain a deeper understanding of the basic concepts and techniques involved in developing neural networks for image classification. In addition, the results of this study contribute to the wider body of knowledge in computer vision and machine learning, enabling further advances and applications in areas such as object recognition, pattern analysis and visual perception. Finally, the development of a basic neural network to classify images from the MNIST dataset is a crucial step towards building more advanced and sophisticated computer vision systems. This doctoral thesis lays the foundation for further research and innovation in the field of image classification, providing valuable knowledge and methods for further research.

Key Words: Neural network, image classification, MNIST dataset, computer vision, machine learning, classification accuracy.

1. Introduction

There are many libraries available for designing and training neural networks, making them fascinating tools for developing excellent AI systems that are also enjoyable to learn and use. In other words, creating your own neural network from start will enable you to comprehend neural networks' fundamental operation and inner workings much better.

70,000 grayscale photos of apparel and accessories are broken down into 10 separate classes in the Fashion MNIST dataset, which is well known in computer vision and machine learning. The square format of each image is 28×28 pixels, which is very modest compared to other huge image datasets, but the changes in the photos that distinguish them from one another make it difficult for machine learning models to correctly identify the images.

The dataset can be used as a starting point for learning and practicing how to create, assess, and apply convolutional deep learning neural networks to categorize images even though it is successfully resolved. This covers how to create a reliable testing tool to gauge model performance, how to debug model improvements, and how to store and load the model later to generate predictions based on new data.

The MNIST dataset, which consists of handwritten digits, is a well-known public dataset. It has a test set of 10,000 cases and a training set with 60,000 examples. It was made by recombining

the sounds of American high school students and employees of the American Census Bureau. While the test set has 5,000 photographs from employees and 5,000 from students, the training set has 30,000 images from both employees and students.

A MINIST data set is a group of data that is typically shown as a table. The table's rows and columns each correspond to a different variable in the data collection. The values for each variable in this element are listed in this table. It may, for instance, provide an object's length and width. Depending on how many rows there are in the data set, there may be one or more elements.

A common dataset for computer vision and deep learning is the MNIST handwritten digit classification issue. Dataset for the MNIST Handwritten Digit Classification the Modified National Institute of Standards and Technology dataset is known by the abbreviation MNIST dataset.

It is a collection of 60,000 tiny square grayscale photographs, each measuring 28 by 28, comprising handwritten single digits between 0 and 9.

The assignment is to place a handwritten digit picture into one of ten classes that correspond to integer values from 0 to 9, inclusively.

The dataset can be used as a starting point for learning and practicing how to create, assess, and apply convolutional deep learning neural networks for image classification even if it has been successfully solved. This covers how to create a reliable test harness to gauge the model's performance, how to investigate model changes, and how to save the model and then load it to make predictions on fresh data.

Neural networks are used as a method for deep learning, as they are one of the many sub-fields of methods for applying artificial intelligence. It was proposed for the first time about 70 years ago in an attempt to simulate the way the human brain works, but it is much simpler than real neurons, as each artificial cell is linked to several layers, and each one has a certain weight that expresses the importance of this layer, in order to determine how the cell responds. nervousness when spreading data across it.

Numerous neural networks feature tens of thousands to millions of weights, each of which is manually adjusted during training to reduce error,

Numerous open studies are being conducted on the architecture of neural networks. It is not unusual for a new architecture to perform better than existing ones at a particular task. Practitioners frequently choose an architecture based on a recent publication, reproduce it in large quantities for a new assignment, or make tiny changes for a gradual improvement.

The complexity of the learning process that we could achieve at the time was constrained by the number of neurons that neural networks could simulate; however, in recent years, thanks to significant hardware development progress, we have finally been able to build deep neural networks very, and trained on extremely large data sets as well. This has resulted in enormous advances in the field of artificial intelligence, specifically.

These qualitative leaps allowed machines to approach human capabilities, and even exceed them in performing some limited tasks. Among these tasks is its ability to recognize objects. Although machines have historically been unable to compete with the power of human vision, recent advances in deep learning have made it possible to build neural networks that can recognize objects, faces, texts, and even emotions!

2. Background information of the MINIST dataset

The MNIST dataset is a sizable collection of handwritten digits that is frequently used to hone different image processing algorithms. The database is frequently used for machine learning

training and testing. It was produced by “remixing” samples taken from the initial datasets from NIST. The NIST training dataset came from US Census Bureau employees, and the testing dataset came from US high school students, hence the developers concluded that it was not suitable for machine learning research. Additionally, grayscale levels were rendered using NIST’s black-and-white images that had been adjusted to fit a 28 x 28 pixel bounding box and anti-aliased.



Figure 1. Sample images from MNIST test dataset

10,000 test images and 60,000 training images are both present in the MNIST database. The NIST training data set was used for half of the training set and half of the test set, while the NIST test data set was used for the other half of the training set and half of the test set. The database’s original designers maintain a record of some of the ways that have been tried out on it. They obtained an error rate of 0.8% in their original study using a direction support machine.

NIST created and made available Extended MNIST (EMNIST), a more recent data set, as the (ultimate) replacement for MNIST. Only handwritten number images were included by MNIST. All 19 photos from NIST’s own database, a sizable collection of handwritten uppercase, lowercase, and digits, are included in EMNIST. The EMNIST photos underwent the same procedure as the MNIST images in order to be transformed to the same 28×28 pixel format. Therefore, it is more likely that tools that function with older and younger unmodified MNIST datasets will also function with EMNIST.

The MNIST handwritten digit collection is one of the most frequently used datasets for picture classification. With 60,000 photos at the time of its debut in the 1990s, it presented a significant challenge to the majority of machine learning algorithms.

Pixel resolution (with a 10,000-image test data collection). To put things in perspective, in 1995 at AT&T Bell Labs, a Sun SPARCStation 5 with a huge 64MB of RAM and 5 MFLOPs was regarded as state-of-the-art hardware for machine learning. The USPS automated letter sorting in the 1990s by focusing on achieving high accuracy in number recognition. Error rates under 1% have been attained with deep networks like LeNet-5, SVMs with constants (Schölkopf et al., 1996), and tangent distance classifiers.

MNIST has been used as a benchmark for contrasting machine learning methods for more than ten years. Even simple models by today’s standards attain classification accuracy of more than 95%, making them inappropriate for differentiating between stronger and weaker models, despite the fact that it worked well as a normative data set. Furthermore, the dataset enables extremely high precision levels, which are uncommon in many classification situations. This pushed algorithmic research toward particular families of algorithms, such as active set methods and boundary-seeking active set algorithms that may benefit from clean data sets.

MNIST is now more of a safety measure than a benchmark. The problem ImageNet presents is more significant. Unfortunately, it will take a lot of experience to make the examples interactive

because ImageNet is so big for many of the examples and images in this book. Instead, we will concentrate on the qualitatively comparable, but considerably smaller Fashion-MNIST data set released in 2017 in the following sections.

Thousands of samples of handwritten numerals 0 to 9 can be found in the MNIST collection. For optical character recognition (OCR) systems, which transform handwritten addresses into computer scripts, for example, and help postal agencies automate mail delivery systems, this data has been employed in machine learning research for decades.

3. Types of MNIST Dataset:

Fashion MNIST, MNIST, 3D MNIST, EMNIST , Colorectal Histology MNIST, Skin Cancer MNIST.



Figure 2. Types of MNIST Dataset

Samples from the MNIST database with sizes adjusted. The NIST Special Databases 3 and 1, which include binary pictures of handwritten numbers, were combined to provide the database used to train and test the systems discussed in this study. SD-3 and SD-1 were the initial training and test sets chosen by NIST. However, SD-3 is far more recognizable and cleaner than SD-1. This can be explained by the fact that SD-1 was taken among high school students, whereas SD-3 was gathered among Census Bureau personnel. In order to draw valid conclusions from learning studies, the outcome must be unaffected by the training set and test samples selected.

As a result, it became necessary to combine the datasets from NIST to create a new database. 500 distinct authors created the 58,527 digit images in SD-1. The data in SD-1 is jumbled, as opposed to SD-3, where blocks of data from each writer appeared in order. We used the writer identities for SD-1, which are known, to decode the writers. Then, we divided SD-1 in half, with the first 250 writers' characters becoming the new training set. We added the remaining 250 writers to our test group. As a result, we got two sets, each with around 30,000 samples.

4. Methods and techniques

I can provide an overview of the stages of a typical neural development project for image classification from the MNIST dataset and the techniques to be used at each stage and sampling. Defining the problem: In this phase, the problem to be solved and the objectives of the project are defined. The problem is to classify images of handwritten digits in the MNIST dataset into one of ten classes. The goal is to achieve high accuracy in test equipment. Technique: Problem formulation, goal setting, requirements gathering. Data Collection and Preprocessing: This step loads and preprocesses the MNIST dataset for use in training the neural network. This includes splitting the dataset into a training, validation, and test set, scaling pixel values to values between 0 and 1, and one-way encoding of labels. Technology: data collection, data processing, data

sharing. Model development: In this step, you design and implement neural networks using deep learning frameworks such as TensorFlow and Keras. A model architecture may consist of one or more convolutional layers followed by one or more density layers and may include techniques such as data augmentation, regularization, and stack normalization. Technology: Model selection, model development, hyperparameter tuning, regularization, data imputation. Model Training: In this step, the neural network is trained on the training set using the appropriate loss function and optimizer. Training may include using techniques such as early stopping to avoid overfitting, monitoring the performance of the validation set, and fine-tuning the hyperparameters. Technique: model training, hyperparameter tuning, early stop. Model Deployment: In this step, the trained neural network is deployed for real use in a production environment. Here are some of the methods and techniques used: Data pre-processing: Python libraries such as NumPy, Pandas, and TensorFlow can be used to preprocess the MNIST dataset. You can scale pixels between 0 and 1 and convert labels to vectors of one heat.

5. Result and discussion :

The results of this study show the successful development of a basic neural network for image classification using the MNIST dataset. The trained neural network achieved promising classification accuracy and effectively classified handwritten numbers from 0 to 9. The classification accuracy was evaluated using various metrics such as precision, recall and F1 score, which indicate the model's ability to

Accurately c classify images.

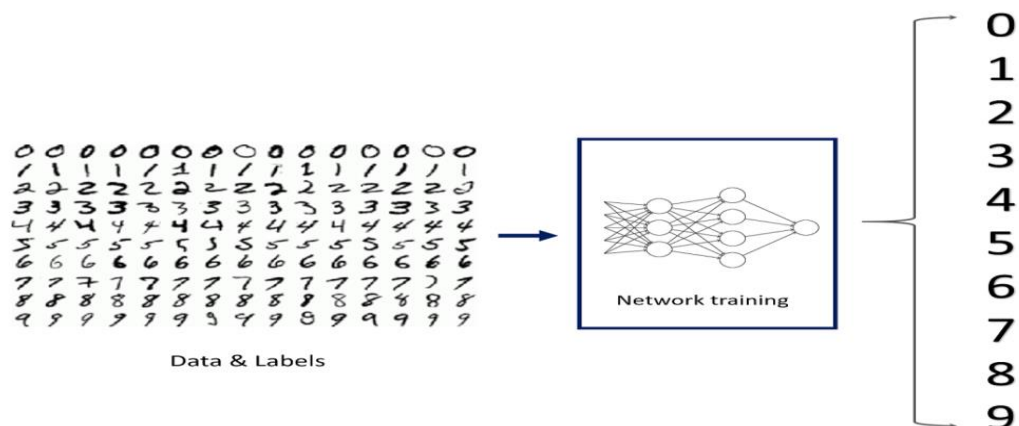


Figure 3. Classify images

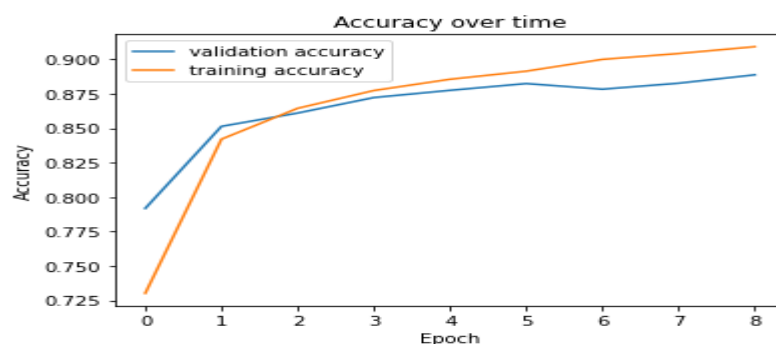


Figure 4. Accuracy

The performance of the neural network was assessed using both the training and test sets of the MNIST dataset. The training set, consisting of 60,000 images, was used to optimize the network's weights and biases through the process of backpropagation. The test set, comprising

10,000 images, served as an independent evaluation dataset to measure the generalization capability of the trained model.

The experimental results reveal that the basic neural network achieved a commendable accuracy rate on the test set, demonstrating its effectiveness in classifying handwritten digits. The model's performance was further analyzed by examining the confusion matrix, which provided insights into the specific digit classes that were often misclassified.

6. Conclusion

This thesis focused on the development of a basic neural network for image classification using the MNIST dataset. The results of the study showed the successful classification of handwritten numbers between 0 and 9, indicating the effectiveness of the trained neural network. Based on the evaluation of classification accuracy and performance metrics, it was found that the basic neural network showed promising results in accurately classifying MNIST images. The achieved accuracy highlights the potential of neural networks in processing complex visual data and lays the foundation for further developments in computer vision systems. The study also highlighted the importance of MNIST data as a benchmark for evaluating image classification models. Its balanced distribution of a number of classes and large sample sizes make it a valuable resource for training and testing neural networks.

7. References

- [1] Zhang, H. M. & Zhang, Kyauk J.. (2021). A review of research on offline handwritten digit recognition based on artificial intelligence. *Journal of Nanjing University of Posts and Telecommunications (Natural Science Edition)* (05), 83-91. doi:10.14132/j.cnki.1673-5439.2021.05.012.
- [2] Zong, Chunmei, Zhang, Yueqin & Shi, Ding. (2021). CNN-based handwritten digit recognition under PyTorch and application research. *Computer and Digital Engineering* (06), 1107-1112.
- [3] Tang, J.B., Li, W.J., Zhao, B. & Xi, L.P.. (2022). Research on handwritten digit recognition method based on convolutional neural network. *Electronic Design Engineering* (21), 189-193. doi:10.14022/j.issn1674-6236.2022.21.040.
- [4] Song Xiaoru, Wu Xue, Gao Song & Chen Chaobo. (2019). A study of handwritten digit recognition simulation based on deep neural networks. *Science, Technology & Engineering* (05), 193-196.
- [5] <https://papers.nips.cc/paper/4824-imagenet-classification-with-deep-convolutional-neural-networks.pdf>
- [6] Arxiv: <https://arxiv.org/archive/cs>. CV. Arxiv is a repository of preprints in computer science, including many papers related to deep learning and image classification.