# AUTHENTICATION OF BANK NOTES AND IMAGE CLASSIFICATION THROUGH ARTIFICIAL AND CONVOLUTIONAL NEURAL NETWORK

**BY**

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This Report Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science in Computer Science and Engineering

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# APPROVAL

This thesis titled **"Authentication of bank notes and image processing through Artificial and Convolutional Neural Network"**, submitted by **Md. Touhidul Islam** to the Department of Computer Science and Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of M.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on May 07, 2018.

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# DECLARATION

I hereby declare that, this project has been done by only me under the supervision of **Dr. Sheak Rashed Haider Noori, Associate Professor and Associate Head, Department of CSE,** Daffodil International University. I also declare that neither this thesis nor any part of this thesis has been submitted elsewhere for award of any degree or diploma.

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# ABSTRACT

This paper focuses on two common applications of image processing done with the help of neural network. At first, it gives a solution for detection of counterfeit bank notes using Artificial Neural Network with the structured image dataset of the corresponding bank notes provided by the UCI Machine Learning Repository. In the second part, the emphasis is on solving the unstructured image classification problem through Convolutional Neural Network and using the famous Kaggle dataset. Both problem include a common Artificial Neural Network architecture. However, in the second problem, on top of Artificial Neural Network, two convolutional layers are added. Two classifications discussed here are non-linear in nature and they have some inherent differences. This paper also discuss the common pitfalls and possible improvement techniques in the future implementation of this strategy along with a detailed discussion.

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## List of Abbreviations

| | |
|---|---|
| ANN | Artificial Neural Network |
| CNN | Convolutional Neural Network |
| MLP | Multi Layer Perceptron |

# Chapter 1: Introduction

## 1.1 Introduction

Image classification has been a hot topic for quite some time. Its overwhelming applications in modern technologies and daily life have been the motivation for continuous research. Now-a-days from social media to medical imaging the applications of image processing are completely evident. A new type of application is also finding its way to become completely integral to our life – that is ensuring security. Bank notes authentication is one of the implementation of this kind of application.

These days, automatic machines accepting banknotes are developed to meet numerous demands and functions. These machines acknowledge banknotes fed to them by finding the design or value of the banknotes. It is extremely essential for such machines to authenticate the banknote to differentiate it between real and counterfeit ones [1]. In general, authentication is more difficult than recognition, because the differences in designs or values are deliberately designed to be readily distinguished, while forgeries are deliberately created for intended purposes to be inseparable from real ones.

To tackle this issue several methods are being used but the technology getting exponentially developed the forgeries are becoming had to detect. One blessing of the recent colossal growth of computational power has enabled the use of Artificial Intelligence in this situation. Specifically Neural Network can be deployed to detect the counterfeit notes if large amount of training dataset can be provided.

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Banknotes are not designed to be used fundamentally with automatic identification purposes. Normally the attributes of the banknotes which are used for identification by those techniques have to be selected on a pragmatic basis. This means, that there is usually no simplified algorithm by which these attributes can be combined to find if the banknotes are authentic or not.

In contrast to previous scenario, Convolutional Neural Network is the modification of the Artificial Neural Network which does not use raw data directly, rather collects the important feature at first and then process it. Convolutional Neural Network can be effectively used to classify unstructured image data. The convolution layer plays a very crucial part to detect the important features out of the image. Then the max-pooling layer conserves the useful information while reducing the size. The key here is to manipulate the architecture of the network by tweaking between the number and orientation of the convolution layer.

Before the implementation of the proposed network some considerations must be taken including the quality of the images taken and number of it. As these two points play a very important part in achieving the desired accuracy. The convolution Neural Network can be combined with Recurrent Neural Network to add temporal dimension to the spatial one of the convolution stage. Using these two in a combination can give us lots of information which can be used to automate and predict important hidden features [3]. So it can be safely said that the proposed methodologies with this research can be modified accordingly to be used in versatile applications.

## 1.2 Motivation

With the recent advancement of the computational power, the frontiers of newest technologies are running almost haywire. This computational power growth is often characterized by Moore's Law. Along with this opportunity the Artificial Intelligence has become dominant and is being used in almost every sector. So why not use this chance to solve image classification problems which are very crucial in our modern day sustainability. From the facial recognition in the Facebook to medical imaging in the health sector the image classification is becoming dormant day by day. Due to this present scenario it is essential that the research in image processing must go hand in hand.

On the other hand, forger are becoming more expert too which poses a huge challenge to the authority to ensure security of the bank notes. Traditional techniques often fail because of the sophisticated scanner machines are used to produce counterfeit notes. If we can leverage the current big data analytics along with neural network, it can surely solve this ever growing problem. As abundant of data is available machine can easily learn the difference between real and fake notes [4]. So, from this perspective continuation of novel research in this field is required.

Lastly, Image classification from large unstructured data pose different kinds of challenge where machine need to recognize something given a lot of variation in the input dataset. In this case, the underlying challenge is to implementation of a proper architecture which will facilitate both the result and the accuracy. Moreover, the mega projects from the likes of Google's deep mind are providing the necessary computational packages which can be accessed by the mass people who can easily implement their methods to test if and validate their results. With that note it is completely evident that the novel research in this exciting field can open new doorways for our future.

### 1.3 Rationale of the study

Though one can think there are already a bunch of study and techniques are available which can solve a lot of problems, the real consideration is if this will be enough for the future. As I previously said, the technology is getting sophisticated and so do the challenges. Consider a scenario, when a driverless car is going to be populated in all of the major countries, what the risk will come along with it. Proper image recognition is a must to ensure smooth maneuver and security. Those kinds of complex situation demands every bit of research done in advance to be properly handled. As I mentioned the situation is very unique, to solve the most complicated problems the most sophisticated arsenal we have is our brain. So it completely makes sense to develop the newer form of neural network architecture as it the best thing which can mimic the human brain.

Now the main challenges are the formation of some common architectures which can solve the general problems. It is a huge task as the real life scenario can be quite unique and at the same time paradoxical. For example, images can be sometimes hard to distinguish even for human. In order to implement an efficient neural network simultaneous study of the human brain must go hand in hand. At the same time the new findings should be implemented through neural networks to justify and validate those findings.

On the other hand, the existing image processing techniques must be optimized and fine-tuned so that continuous production of the results can be maintained [6]. Specifically, the bank note authentication require lots of study to classify and differentiate the inherent uncertainty. All these things demands that the current research must go on to find the solutions of the newest problems and along with it to enhance the existing technologies. The methods presented here will also need further research as both artificial neural network and convolutional neural network are still in the infant stage. The hyper parameters tuning and a perfect architecture will never become possible unless lots of studies are done.

### 1.4 Research Questions

This paper focuses on two distinct yet related problems of non-linear image classification. At first, the authentication of bank notes requires few questions to be answered to successfully solve the problem. How the data of the bank notes will be collected gives us few options. Turns out this is the part which defines what kind of neural network should be used for the solution of the problem. To analyze the big data from recent colossal growth the proper computation platform is needed. Additionally to choose between the proper libraries to handle the computation can be dwelling too. Whatever the platform or libraries it will require a lot of calculation. How these computation can be done efficiently in terms of time and power is equally important. On the other hand, image classification problem will be implemented through finding the proper classification of cats and dogs from a set of given dataset. This problem is unique in the sense that this dataset is completely unstructured. How to relate between the dependent and independent variables and at the same time with efficacy is the crucial part of the solution. Even with the proper choice among these options, the design of architecture will always need consideration.

Both of the problems require an efficient neural network architecture and flexibility of the computation process. The proper activation functions for both the forward propagation and backward propagation are essential part of designing a neural network. This state normally involves lots of mathematics and statistical methods. Although some pretty useful algorithms are already in existence, the accuracy and efficiency can always get better with the fine-tuning of the hyper parameters and network architecture.

At last from the findings of the results a long term study should be conducted to select between the computation platform, parameters tuning and inherent mathematical methods. Also the connection between the studies may help to bring some new ideas which in turn can be beneficial for the future. The most important questions for both of the problems may be if we should be confined to the existing solution strategies or we should develop some new strategies which can face the ever growing complexities of the image classification.

### 1.5 Expected Outputs

From the study in this paper, two efficient solutions from the existing technologies will be found. In terms of bank note authentication, the dataset will be made structured from the raw image data. A proper exploratory analysis can reveal the underneath structure among the data itself. Then with a successful implementation of the Artificial Neural Network through python codes and libraries will distinguish between authentic and counterfeit bank notes. The efficiency of the classification will depend on the input dataset. If the dataset contains great amount of noise, it may make some mismatch. Other than that the classification should be pretty impressive as the Artificial Neural Network is very efficient to classify the structured dataset. Though it might give us an excellent result, we should be always careful to cross check our results in case of any discrepancies among the dataset.

On the other hand, the image classification of cats and dogs should give us a good division among the class too if the network is properly trained. The computation should take long time if GPU based computation is not available for the execution process. Other than that the number of examples can limit the accuracy and loss of our model while performing classification. So with the effective implementation of the algorithm and architecture both of our problems should be efficiently classified.

### 1.6 Report Layout

This report will first start with the theoretical background of Artificial Neural Network and Convolutional Neural Network and its relevance to this research. Then a brief overview of the current and relevant works will be discussed. After that a comprehensive methodologies will be presented along with detailed description how to perform the task. At first bank note authentication and later image classification of cats and dogs will be addressed. Consequently, the resulting findings will be shown in corresponding graph and a detailed discussions of the results will be presented. In the end, further improvement and potential recommendations will be suggested.

# Chapter 2: Background

### 2.1 Theoretical Background

Artificial neural networks are the mimicry of human brain where lots of inter-connected neurons process the computation thus can identify complex pattern which is normally possible for humans. ANNs learn through adjusting its weights and biases which requires a huge amount of data [7]. Neurons are normally arranged in a layered structure. The supreme accuracy and prediction power becomes possible for the complex and connected links among neurons. The characteristics of a neural network mostly depends on the internal organization, activations functions in each layer and its parameters and hyper parameters. The weights and biases are also called as hyper parameter of the neural network because these are not depended on the input data. The neurons in each layer only fire if the weighted sum of the inputs cross a threshold value. During training the internal weights and biases are optimized until the error becomes acceptable. The variety of activation functions makes it possible to do non-linear classifications [2]. Overall accuracy of the artificial neural network is ensured normally using the back propagation algorithm.

The back-propagation algorithm is a technique which implements the chain rule of differential calculus from the very last steps found from the feed-forward propagation [3]. It is particularly useful for feed-forward neural networks. Feed-forward network is the network which has no loop that means it has no feedback opportunity. In order to make the back-propagation algorithm work the activation functions have to be differentiable. Back-propagation is basically deployed to estimate the gradient of error for the network in accordance to its weights and biases. This gradient is fundamentally used in a simple stochastic gradient descent algorithm to match weights that gives minimum error for the network and also to avoid local minima. Stochastic gradient is implemented using a batch learning which means after a batch of inputs are processed, the weights are updated. It is crucial to consider that back-propagation networks are usually multilayer perceptron with many layers.

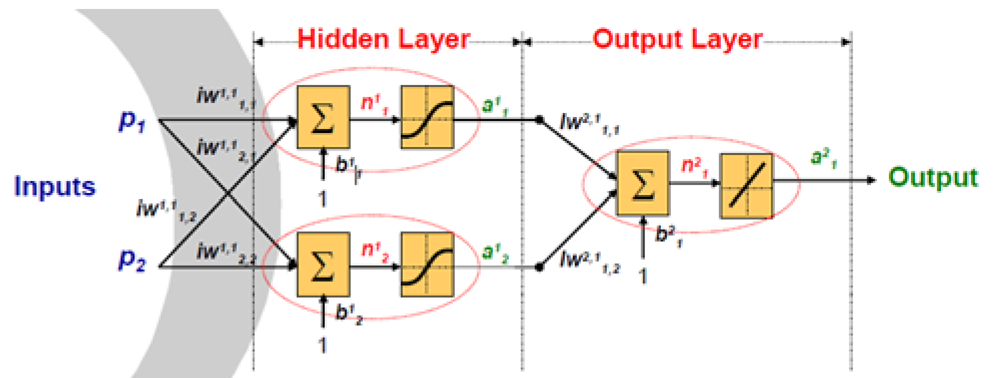


Figure 2.1: Architecture of Artificial Network

The test data can only be classified by the neural network only after the training is done properly. The characteristics of a network depends upon its architecture and activations functions. In recent years numerous types of neural network have been designed most of which are still under subject to research. An artificial neural network can solve supervised, unsupervised and reinforcement algorithmic problems. Within these categories there are linear regression, logistic regression, random forest, support vector machine and so on. Each type of model can solve unique problems efficiently, however some of them can be equally good for other categories in a particular situation. Supervised learning is basically used for classification and unsupervised for clustering. Reinforcement learning can be useful if the agent is directly interacting with the environment. It does not require additional data for learning rather it learns from getting individual reward for its decision and next time analyzing those outcomes. However, in this research the focus is on supervised learning of Artificial Neural Network.

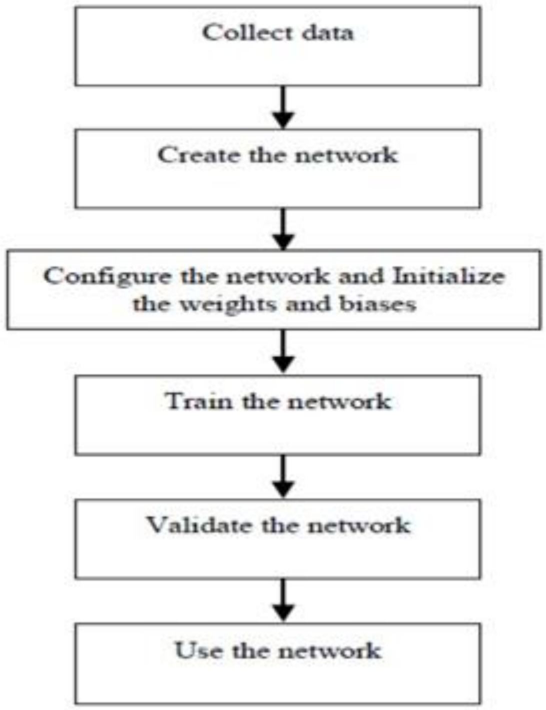


Figure 2.2: Flow diagram of training algorithms for MLP network architecture

On the other hand, Convolutional Neural Networks are deep artificial neural networks that are used primarily to classify images, cluster them by finding commonalities and perform object recognition [8]. They are the algorithms and architectures which can differentiate individual faces, street signs, tumors, platypuses and many other aspects of visual data. Convolutional neural network has a built-in facility to incorporate additional convolutional layers which collects important features while reducing a great amount of size. These architecture can be greatly manipulated to increase the accuracy.

The superior performance of convolutional network in image classification is one of the most prominent reasons why the recent trend is picking overwhelming use of it. This is the main driving force in computer vision which in turn the key factor to successfully implement self-driving cars, robotics, drones, security, medical diagnoses, and treatments for the visually impaired. The interesting fact is that it start from a very simple image classification to very complicated pattern detection. Though there are some difficulties while using convolutional neural network.

The working principle of Convolutional Neural Network can described in following ways. At first input vector of images are put into convolution layer. There are numerous feature detectors which grabs the specific features from the input data and thereby reducing the size of the image. In the next step, convoluted features are passed through the max-pooling layers which just grabs the most important features of the convoluted data. Here the size of the images are significantly reduced but the features are not lost because from every max-pooling filter the most important features are conserved. Thus it ensures if the test image comes in different orientation it can still detect the inherent features. After the max-pooling layer dataset are flattened into a long single vector which is the input of the adjacent Artificial Neural Network. One thing to note here that the hidden layers of this type of network is fully connected thereby it is also called fully connected layer. The main benefit here the input of the ANN is already a refined vector which maximize the efficiency.

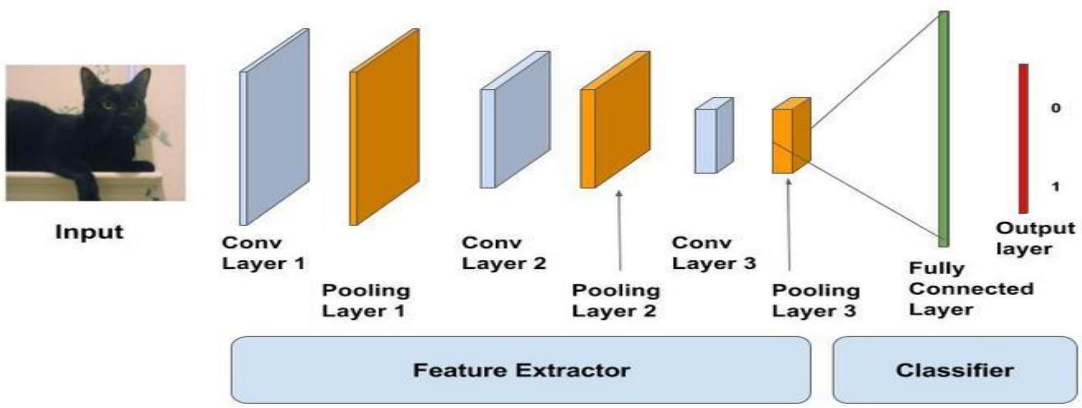


Figure 2.3: CNN image classification pipeline

## 2.2 Related Works

Artificial Intelligence particularly Simple Perceptron was first developed in 1957 at the Cornell Aeronautical Laboratory by Frank Rosenblatt. Rosenblatt showed how a binary classification problem can be automated with the use of simple perceptron. Since then lots of research have been conducted in the field of artificial intelligence. Neural Network became very popular in 1980's when the renowned godfather of neural network Geoffrey Hinton found some breakthroughs. Along with him some other researchers made some remarkable contributions but the idea while envisioned at first slowly died off in the 1990's. As neural network need large dataset to train the input data to maximize the result, the technology at that time did not permit the large scale implementation of neural network. But as the recent growth in the computational power, the idea of neural network has been revitalized and has created difference in a very short span of time.

However, the latest research is on mostly combining multiple neural network framework to create a hybrid platform that can perform complex tasks which otherwise seems impossible. Google's deep mind is one of the sophisticated example of this kind of hybrid network which can automatically identify a person's face and tag them. Especially combining convolutional layer with recurrent layer gives a huge boost because recurrent layer adds temporal dimension in addition to convolutional layer's spatial dimension. Some of the examples are – making movie subtitles, describing an image completely which means what is the image and what is going on in that image too. Even this hybrid network can be used to develop precision medicine and genome sequencing. Last but not the least, if we want to implement full scale driverless cars in our road, we need to find a complete efficient hybrid network of convolutional and recurrent layers.

### 2.3 Research Summary

The main purpose of this research is to implement two types of neural network which is Artificial Neural Network and Convolutional Neural Network and while doing so effectively classify image data mainly. After the successful implementation some challenges and inherent scope for improvement are found. To address these issues while the research is being done and also keeping those for the future works is crucial. Especially the profound complexity associated with the fine-tuning of neural network and tackling these challenges to get excellent results are the outcomes of this research.

### 2.4 Scope of the Problem

Both of our problems are very simplistic in nature, at least considering how much complexity a neural network can contain. So the main target is to classify structured image data in Artificial Neural Network and unstructured image data in Convolutional Neural network. After that analyzing the results from the corresponding graphs and numerical results are also considered with equal importance. In addition, what tweaks and tricks can be used to make the networks more efficient and effective and also getting expected results after analyzing those aspects are addressed. However, developing new algorithms or mathematical equations and conducting novel experiments are not in the scope of this research.

### 2.5 Challenges

The main challenges associated with the research are as follows-

- ✓ Getting good quality datasets with needed attributes.
- ✓ Preprocessing of the datasets for the effective analysis.
- ✓ Corresponding exploratory data analysis to visualize the nature of the datasets.
- ✓ Choosing a proper programming platform and corresponding libraries.
- ✓ Incorporating GPU computing along with CPU computing to reduce time complexity.
- ✓ Choosing proper initial hyper parameters and tweaking them while programming.
- ✓ Finding the optimal number of convolutional layers in CNN implementation.
- ✓ Getting enough data to train the neural network properly.
- ✓ To choose the correct activation functions in both hidden and output layers.
- ✓ To avoid over fitting in Convolutional Neural Network.

# Chapter 3: Research Methodologies

## 3.1 Introduction

The research of this paper will follow an organized strategy to solve two non-linear classification problems. At first two datasets for two problems will be collected from two different sources. Preprocessing will be done for the authentication of bank notes and will not be required for the image classification of cats and dogs. Preprocessing is conducted for the standardization of the input datasets. Data exploration will be done for Artificial Neural Network afterwards for the first problem. Then the networks will be initialized and datasets will be split accordingly. Consequently, the training of the networks will be done with the given training data. Then the right class of the test datasets will be predicted with the test data. For Convolutional Neural Network some additional steps will be required. First of all, image augmentation will be needed to avoid over fitting and then on top of Artificial Neural Network there will be corresponding initialization of the convolutional layer, max-pooling layer and flattening layer. After that Classifier objects will be run to get the results and analyze them in respective graphs to find the overall scenario and pitfalls.

The detailed explanation of bank note authentication is as follows-

### 3.1.1. Image Acquiring

Images can be taken with high quality camera or scanner. All of the features of the images should be conserved. In case of ensuring the quality industrial camera may be used.

### 3.1.2. Gray Scale Transformation

Image stored in the previous step is too large to process. Additionally, color information is not needed though the indices of the colors are. Then RGB image is converted into their corresponding pixel values and then gray scale image is transformed with 660 dpi.

### 3.1.3 Wavelet Conversion

It is the basic requirement in image processing. Wavelet Transform tool are utilized to extract attributes from images [9]. The data feature information:

- ✓ Variance of Wavelet Transformed image (continuous)
- ✓ Skewness of Wavelet Transformed image (continuous)
- ✓ Curtosis of Wavelet Transformed image (continuous)
- ✓ Entropy of image (continuous)
- ✓ Class (integer)

### 3.1.4. Image Partition

In this step images are segmented in accordance with their properties and nature. For example, Monochromatic images will be partitioned according to intensity and shape.

### 3.1.5. Output

Outputs are meticulously analyzed to find the failed cases to measure the networks accuracy so that it can be used in the future to design the algorithm and select the model more accurately.

## 3.2 Research Subject and Instrumentation

The research subject is basically non-linear image classification. This research will be conducted with two neural networks – Artificial Neural Network and Convolutional Neural Network and two data sets. One from UCI Machine Learning repository and the other is from Kaggle datasets. The overall process involves collecting, analyzing and presentation of the results obtained from neural network implementation of two different kinds.

### 3.3 Data Collection Procedure

Bank note dataset has been collected from taking images thousands of real bank notes. From the raw data of the image four features will be selected to make a structured data frame. Though the structured data have been taken from UCI machine learning repository which is open source but the requirement is that whoever takes this data for research purpose has to give proper citation [10]. The bank note dataset selected for this research contains 1372 instances. On the other hand, the dataset for cats and dogs image classification has been collected from Kaggle machine learning dataset which is also open source but the citation credit has to be given. It contains 25000 images of cats and dogs but in this experiment to reduce the computation time 8000 are selected. To be able to connect independent variables which are just numerical values in this case with the dependent variable which is the classes of cats and dogs two distinct folders are created in working directory labeling the classes properly. So in this paper both of the required datasets are collected from open source platforms.

### 3.4 Statistical Analysis

The collected data should be statistically fit to process in the neural network. Normally the data is made standardized so that the numerical value fit into a closer range. The data should also be uniform or normally distributed some of the time to get desired results. In this case, the data is already statistically processed so no addition steps had to be done.

### 3.5 Implementation Requirements

The research subjects of this paper are datasets of bank note from UCI machine learning repository and images of cats and dogs from Kaggle. The programming platform needed to analyze the data is Python and its deep learning libraries – Tensorflow, Contrib.Learn and Keras. Additionally for exploration Matplotlib and Seaborn will be used. To perform efficient and avoid time complexity GPU enabled computing system will be needed.

# Chapter 4: Experimental Results and Discussions

## 4.1 Introduction

The accuracy of the bank note authentication is very accurate. It classifies all of the data correctly while the accuracy level of the image classification of cats and dogs is nearly 80%. Also the data of the bank note authentication is almost separable that is the reason for excellent accuracy. On the other hand, image classification in the second experiment is much more complex. Due to added convolution layer and the size of the data the computation time is much larger. However, the results are quite satisfactory but still leaves room for improvements.

## 4.2 Experimental Results

The results found after performing the computation of the bank notes are as follows-

| | Image.Var | Image.Skew | Image.Curt | Entropy | Class |
|---|---|---|---|---|---|
| **0** | 3.62160 | 8.6661 | -2.8073 | -0.44699 | 0 |
| **1** | 4.54590 | 8.1674 | -2.4586 | -1.46210 | 0 |
| **2** | 3.86600 | -2.6383 | 1.9242 | 0.10645 | 0 |
| **3** | 3.45660 | 9.5228 | -4.0112 | -3.59440 | 0 |
| **4** | 0.32924 | -4.4552 | 4.5718 | -0.98880 | 0 |

Figure 4.1: Independent and Dependent Variables

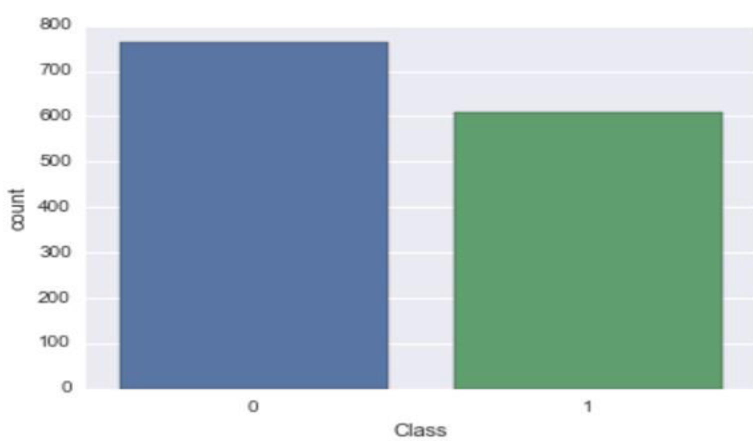


Figure 4.2: Splitting of Authentic (0) and Counterfeit (1) notes

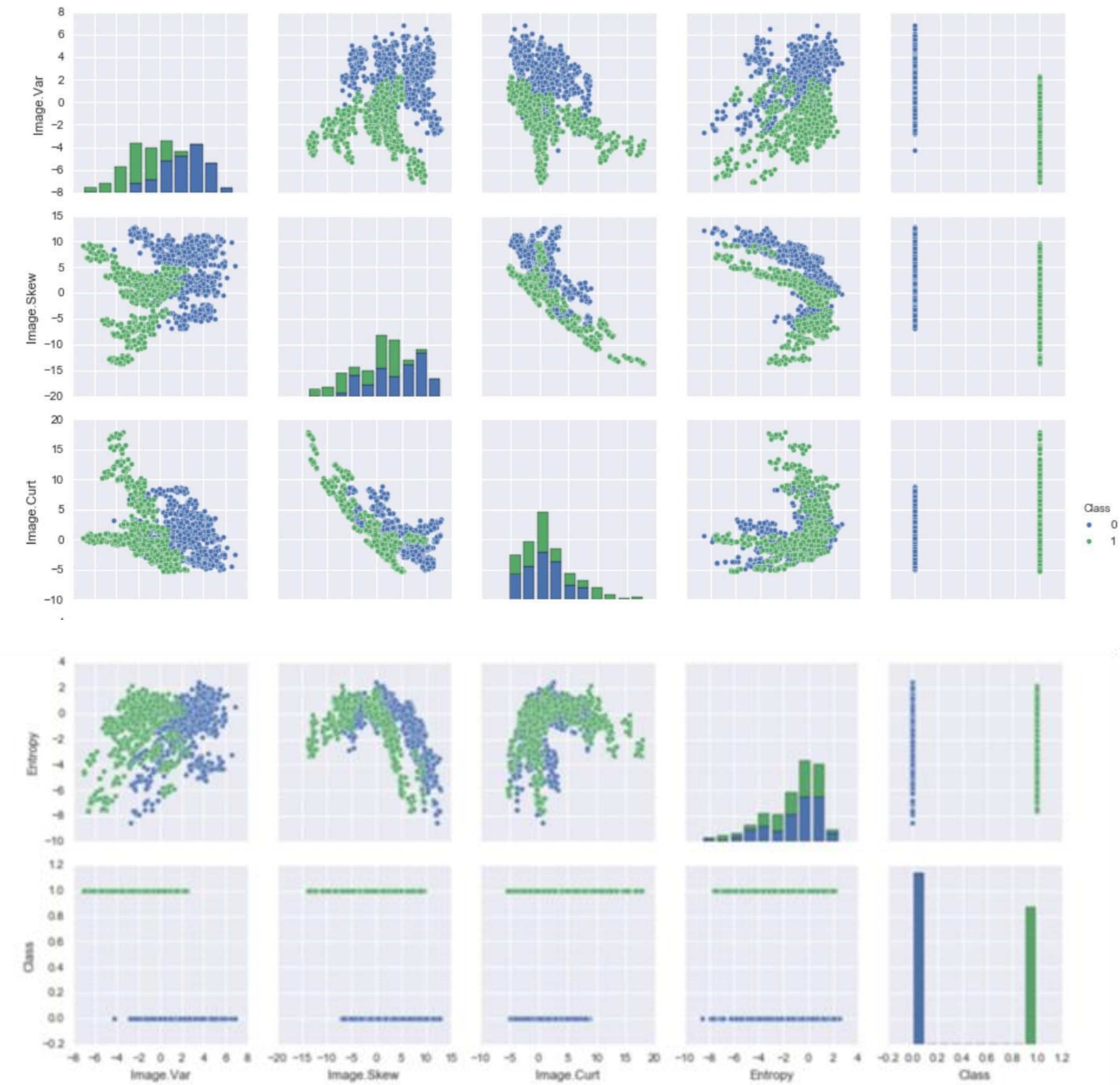


Figure 4.3: Distribution of the data set

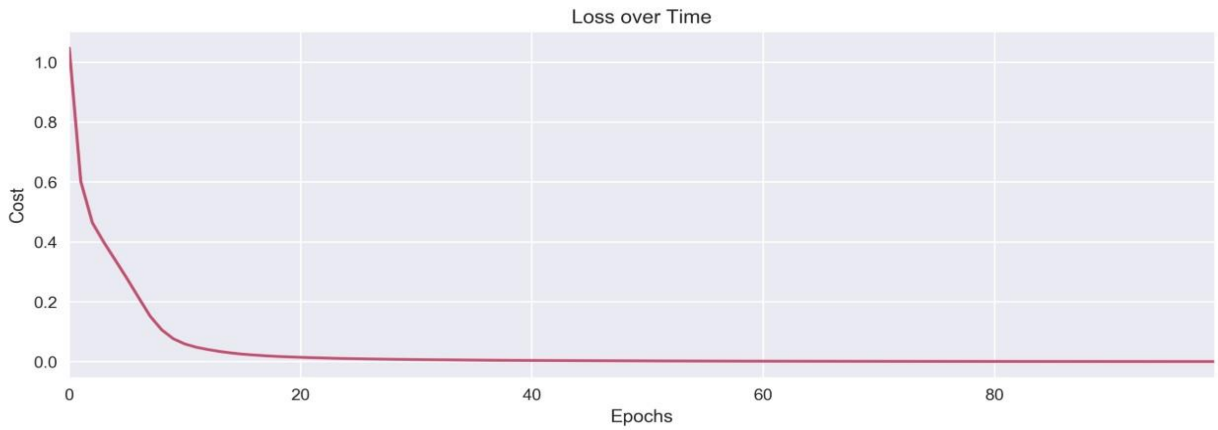


Figure 4.4: Performance of the ANN model

**Confusion Matrix:**

[[237 0]

[ 1 174]]

**Performance Metrics**

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| 0 | 1.00 | 1.00 | 1.00 | 237 |
| 1 | 1.00 | 0.99 | 1.00 | 175 |
| avg / total | 1.00 | 1.00 | 1.00 | 412 |

The results from the cats and dogs image classification are as follows-

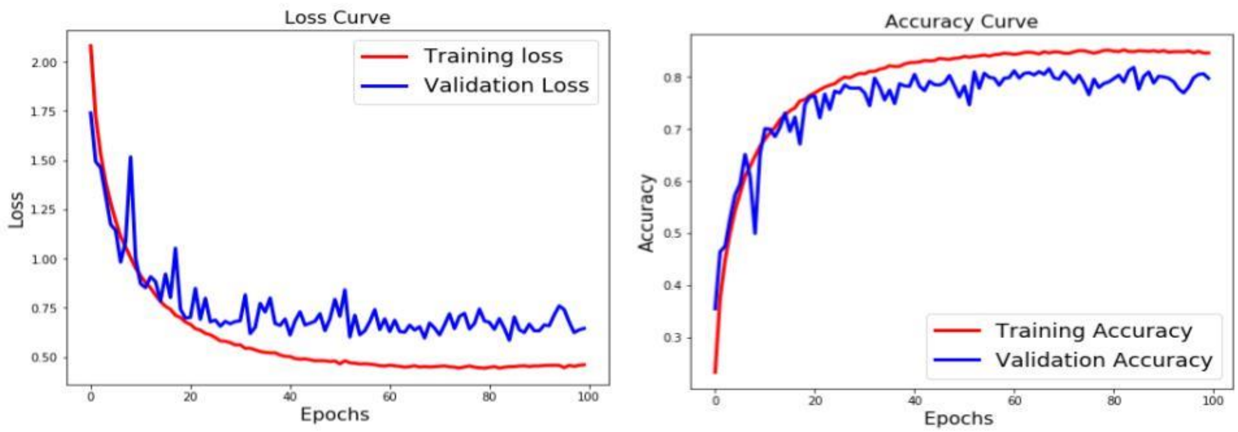


Figure 4.5: Accuracy and Loss Curves of the CNN model without image augmentation.

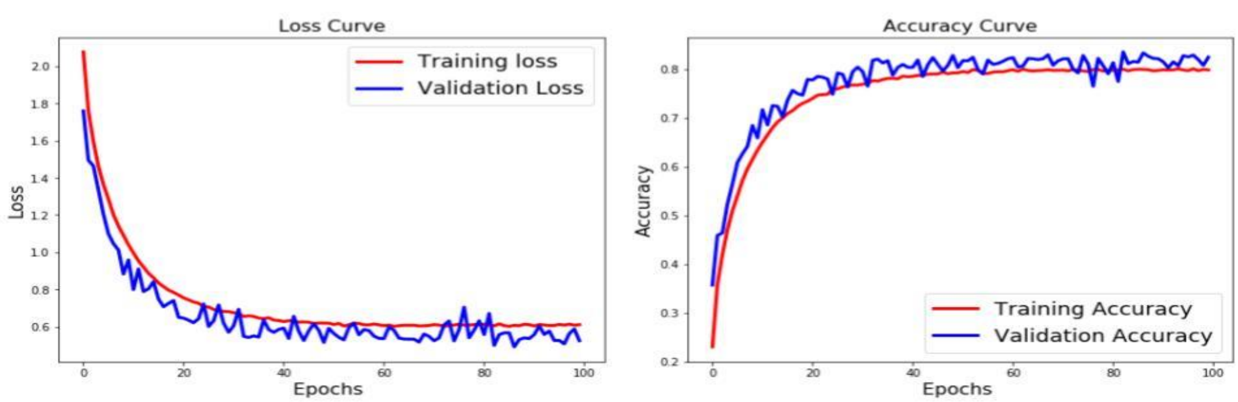


Figure 4.6: Accuracy and Loss Curves of the CNN model with image augmentation.

### 4.3 Descriptive Analysis

From figure 4.1 it is evident that the range of the values in the bank note dataset is very close. So it does not require standard scaling. However to be in the safe side this experiment considers standardizing the dataset. While figure 4.2 represents the count plot of the dataset. From the corresponding count plot we can see that almost 760 of the total 1372 instances are authentic notes and the rest are counterfeit. Then figure 6 gives us the pair plot of the dataset. From this figure it is evident that the independent variables are quite separable from each other. However, there are some overlaps in curtosis and entropy regions. This conspicuous separation yields to a very good results. After that standard scalar function is used to standardize the data. Then a set of 70% training data and 30% test data is split. After that in Tensorflow a classifier object is created. Using step size of 200 and batch size of 20 the training data is made fit into the model. Now model evaluation is done to predict the result and the results are shown in the corresponding classification report and confusion matrix. Figure 4.4 shows the cost function over time. It is seen that the cost function quickly reduces to a minimum value and become stable. With this finding we can conclude that our model was a good selection for Artificial Neural Network for bank note classification. Now from confusion matrix the supremacy of the model is complexly obvious as it classifies all of the real notes correctly just one wrong prediction in the counterfeit note which is acceptable. From the performance matrix the accuracy of the model is known and we can see that the test set was of size 412 and it identifies all 237 real notes correctly and 174 out of 175 counterfeits correctly.

Now the performance of the Convolutional Neural Network will be discussed from figure 8 and 9 which are generated with the help of matplotlib library. Our CNN model cannot outperform the ANN model in this case because ANN models had fewer and structured data while CNN had 8000 of instances which are also totally unstructured. Nonetheless, the result is quite satisfactory for CNN with a accuracy of 80%. Though this accuracy was obtained using additional convolutional and max-pooling layer. But from last two figure an interesting phenomena is noticed. In figure 4.5 both the loss and the accuracy in the test set cannot match the training results. It somehow reduces for the loss function and increases in the accuracy function nevertheless shows a constant fluctuation. This is because of the over fitting caused by the lower number of instances in the training set. What happens is that the machine memorizes the training data very well due to lower in number and that's why it cannot generalize the pattern. Ultimately when an unknown test set is given it cannot classify properly. On the other hand, in figure 4.6 the test set matches the training set both in terms of loss and accuracy. The reason is in first case image augmentation was not used while in the second case it was used. Image augmentation is the process where the images in the training set is randomly transformed linearly to create multiple instances within the training set. This enables us to increase the number of examples which helps the machine to learn properly.

### 4.4 Summary

Both of the neural networks perform quite well and effectively find the solutions for our non-linear classification problems. Still there are rooms for improvements by tweaking some parameters and hyper parameters of the networks. The computation time for the Convolutional Neural Network is a big issue if GPU computing is not used. Fortunately in our case the availability of GPU computing enabled us to choose a bigger epoch size and thereby making the learning process easier and accurate for the networks. In bank note authentication 411 instances out of 412 were successfully classified and in the cats and dogs image classification almost 80% of the time the network was correct in guessing the right class.

## Chapter 5: Conclusion, Recommendation and Implication for the future

### 5.1 Conclusion

This thesis paper was particularly divided into two different problems for Artificial Neural Network and Convolutional Neural Network. The proposed methodologies successfully generated the desired results with some interesting observations. These observations intrigued a myriad of recommendations and scope of future study regarding neural network as a whole.

### 5.2 Recommendations

For bank note authentication –

- ✓ Experiment on the initialization of weights and biases in the network
- ✓ Splitting training and test data properly and standardization of the dataset.

For image classification of cats and dogs-

- ✓ Using deeper Convolutional Neural Network.
- ✓ In some cases adding additional fully connected layers.

- ✓ Adding extra feature detectors in the subsequent convolutional layers.

### 5.3 Implication for Further Study

The revitalization of the neural network has been a true hope for an intelligent future. The limited resources we have cannot ensures the sustainability of our future. Proper implementation and research of Neural Networks can help us fully deploy intelligent machine to work on our behalf. With this note two of the supervised neural network model has been the subjects of our study but lots of other variants of the networks still deserves proper and in depth research. The manipulation of the mathematical models and algorithms can give birth to new types of networks. Especially, combining convolutional and recurrent neural network is the next big thing which can solve some of the complicated real life problems. Also an meticulous look at the reinforcement learning is of no lesser importance.

# Appendix

### Appendix A: ANN Python Implementation

```
# Using pandas to read in the bank_note_data.csv file

import pandas as pd

data = pd.read_csv('bank_note_data.csv')

#Checking the head of the Data

data.head()

#Import seaborn and set matplolib inline for viewing

import seaborn as sns %matplotlib inline

#Creating a Countplot of the Classes (Authentic 1 vs Fake 0)

sns.countplot(x='Class',data=data)

#Creating a PairPlot of the Data with Seaborn, set Hue to Class

sns.pairplot(data,hue='Class')
```

#Standard Scaling

from sklearn.preprocessing import StandardScaler

#Create a StandardScaler() object called scaler.

scaler = StandardScaler()

#Fitting scaler to the features.

scaler.fit(data.drop('Class',axis=1))

StandardScaler(copy=True, with_mean=True, with_std=True)

#Use the .transform() method to transform the features to a scaled version.

scaled_features = scaler.fit_transform(data.drop('Class',axis=1))

#Convert the scaled features to a dataframe and check the head of this dataframe to make sure the scaling worked.

df_feat = pd.DataFrame(scaled_features,columns=data.columns[:-1])

df_feat.head()

#Train Test Split

Create two objects X and y which are the scaled feature values and labels respectively.

X = df_feat

y = data['Class']

#Using the .as_matrix() method on X and Y and reset them equal to this result. We need to do this in order for TensorFlow to accept the data in Numpy array form instead of a pandas series.

X = X.as_matrix()

y = y.as_matrix()

#Using SciKit Learn to create training and testing sets of the data:

from sklearn.cross_validation import train_test_split

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)

#Importing Contrib.learn

Import tensorflow.contrib.learn.python.learn as learn

import tensorflow.contrib.learn.python.learn as learn

Create an object called classifier which is a DNNClassifier from learn. Setting it to have 2 classes and a [10,20,10] hidden unit layer structure:

classifier = learn.DNNClassifier(hidden_units=[10, 20, 10], n_classes=2)

#Now fitting classifier to the training data. Use steps=200 with a batch_size of 20.

classifier.fit(X_train, y_train, steps=200, batch_size=20)

/Users/marci/anaconda/lib/python3.5/site-packages/tensorflow/python/ops/array_ops.py:1197: VisibleDeprecationWarning: converting an array with ndim > 0 to an index will result in an error in the future

result_shape.insert(dim, 1)

DNNClassifier()

#Model Evaluation

Using the predict method from the classifier model to create predictions from X_test

note_predictions = classifier.predict(X_test)

Now creating a classification report and a Confusion Matrix.

from sklearn.metrics import classification_report,confusion_matrix

print(confusion_matrix(y_test,note_predictions))

print(classification_report(y_test,note_predictions))

**Appendix B: CNN Python Implementation**

from keras.models import Sequential

from keras.layers import Convolution2D

from keras.layers import MaxPooling2D

from keras.layers import Flatten

```
from keras.layers import Dense

#initializing the CNN

classifier = Sequential()

#Convolution

classifier.add(Convolution2D(32,kernel_size=(3,3),input_shape=(64,64,3),data_format="
channels_last",activation ='relu'))

#MaxPooling

classifier.add(MaxPooling2D(pool_size=(2,2)))

#Flatterning

classifier.add(Flatten())

#Full Connection

classifier.add(Dense(units=128,activation='relu'))

classifier.add(Dense(units=1,activation='sigmoid'))

#Compiling the CNN

classifier.compile(optimizer='adam',loss = 'binary_crossentropy',metrics=['accuracy'])

#Fitting the CNN to the image

from keras.preprocessing.image import ImageDataGenerator

train_datagen = ImageDataGenerator(

    rescale=1./255,

    shear_range=0.2,

    zoom_range=0.2,

    horizontal_flip=True)

test_datagen = ImageDataGenerator(rescale=1./255)

training_set = train_datagen.flow_from_directory(

    'dataset/training_set',
```

```
        target_size=(64, 64),
        batch_size=32,
        class_mode='binary')
test_set = test_datagen.flow_from_directory(
        'dataset/test_set',
        target_size=(64, 64),
        batch_size=32,
        class_mode='binary')
classifier.fit_generator(
        training_set,
        steps_per_epoch=8000,
         epochs=20
        validation_data=test_set,
        validation_steps=2000)
```

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