Mini-Project 3: Network Intrusion Detection

Version 1.0

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Contents

1. Problem Statement

This project aims to build a network intrusion detector, a predictive model capable of distinguishing between bad connections, called intrusions or attacks, and good normal connections.

2. Methodology

Here we are using dataset containing a wide variety of intrusions simulated in a military network environment. We have implemented Sklearn models for Logistic Regression, SVM, Gaussian Naïve Bayes, KNN, TensorFlow models and CNN.

- We are using the entire dataset.
- The dataset lacked column headers, so we manually added them.
- We normalized numeric features and encoded categorical features.
- We dropped rows with missing values.
- We encode the Outcome column with 0 for normal connection and 1 for all the other intrusion.
- We then split the data for training and testing.
- We implemented the Sklearn models for Logistic Regression, SVM, Gaussian Naïve Bayes, KNN.

- We created three Tensorflow models with activation function ReLU, Sigmoid and Tanh.
- We also used Early Stopping and checkpointing and 4 hidden layers in these models.
- We implemented CNN model to handle numeric data.
- Here we transformed the shape of the data to make it look like an 2D image to be used for Conv2D.
- We plotted the Confusion Matrix and ROC curve for each model to analyze the performance of the models for the given data.
- We obtained the accuracy, recall, precision and F1-score of all the models, and the comparison can be seen in the table below.

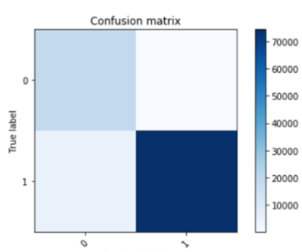
3. Experimental Results and Analysis

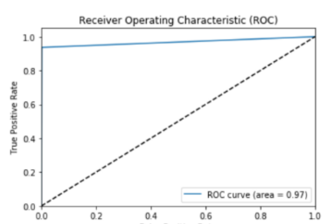
- We observed that when we consider the full data set, for every model that we run, we got 99% accuracy.
- We tried to analyze whether it is because of the model tuning or the redundancy in the data set.
- We are showing below the confusion matrix and the ROC curve of the Gaussian Naïve Bayes and CNN.
- The confusion matrix and ROC curve of all the other models are like CNN.

Model & Tuning	Accuracy	Precision	Recall	F1 Score
Logistic Regression	0.9946257236549128	0.9946828323036672	0.9946257236549128	0.9946408290044061
KNN	0.9995546738998421	0.9995549353996092	0.9995546738998421	0.9995547520894394
SVM	0.9983300271244079	0.9983315628157213	0.9983300271244079	0.9983305969065448
Gaussian NB	0.9489089510546131	0.9593017637420566	0.9489089510546131	0.9509965159983609
Fully Connected NN				
ReLU + adam + early stopping and checkpoint + 4 hidden layers	0.9992814056111089	0.999281343572176	0.9992814056111089	0.9992813705348386
Sigmoid + sgd + early stopping and checkpoint + 4 hidden layers	0.9949394761345695	0.9950494730768633	0.9949394761345695	0.9949616324501922
Tanh + adagrad + early stopping and checkpoint + 4 hidden layers	0.9992510424679163	0.9992514105204905	0.9992510424679163	0.9992511739686027
CNN conv2d_1 (41 , ReLU, (1,3), (1,1))+ conv2d_2 (82 , ReLU, (1,3))+ max_pooling2d_1(1,2) + dropout_1 (0.25)+ flatten_8 + dense_1 (164, ReLU) + dropout_2 (0.5) + dense_2 (2) output.	0.9994129792316101	0.9994134960875988	0.9994129792316101	0.999413128064702

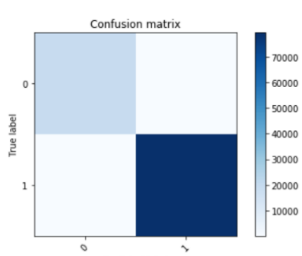
Confusion Matrix and ROC

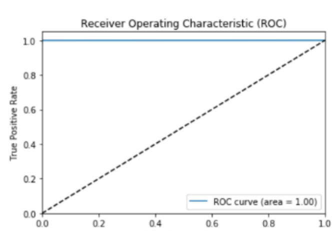
- Gaussian Naïve Bayes





- CNN





4. Task Division

4.1. Chandini Nagendra:

- Logistic Regression
- Gaussian NB
- Fully Connected Neural Networks
- Report

4.2. Siddharth Chittora

- SVM
- KNN
- CNN
- Report

Discussed together on how to improve the model and came up with the solution discussed in the additional features section.

5. Project Reflection

- All the models have an outstanding accuracy of 99%.
- We tried to remove null values and found out that there were no null values in the dataset.
- We removed redundancy which reduced the dataset significantly.
- Even after the removing redundancy the accuracy stayed at 99%.
- Though the accuracy remained the same we observed that the dataset with redundant record are highly skewed towards intrusion or attacks as an outcome.
- After the removal of redundant records, we observed that maximum of the connections was normal.
- Since we did not have complete domain knowledge, we researched existing papers on data mining for network intrusion detection.
- We were surprised to find that features suggested in the papers were almost similar to the features selected after Feature Importance Analysis using tree-based estimators.
- It was challenging to perceive the data as an image, whether to use it as greyscale image of size 1X41 or color image of size 1X1 with 41 channels.
- Therefore, we chose to go with the feature selected by the tree-based estimator.
- We experimented with a new CNN architecture to see how it would impact the accuracy of the model, because every other model that we worked with gave 99% accuracy.

6. Additional Features

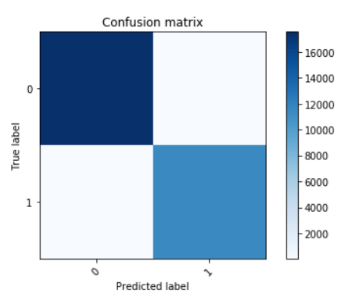
- The data set had a lot redundancy which skewed the results.
- We removed redundancy from the entire dataset and ran all the models.
- We performed feature importance analysis using tree-based estimators which computes the feature importance
- We coupled it with the Sklearn feature selection meta-transformer to discard the irrelevant features and reduced the number of features to train the models.
- We also researched to see if there was an existing proven CNN architecture for this type of problem.
- We found an architecture which we have implemented in the additional features section.
- The implemented model has sixteen layers, which is a mix of eight Conv2d layers, three Max-pooling layers, one flatten layer, two hidden layers and one dropout layer.

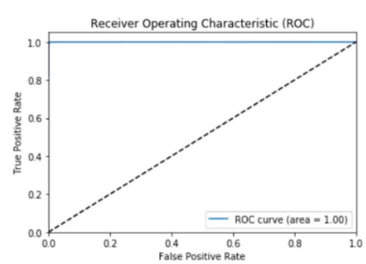
Model & Tuning	**Accuracy**	**Precision**	**Recall**	**F1 Score**
Redundancy Removal				
Logistic Regression	0.9876360888827832	0.9876555198142505	0.9876360888827832	0.9876232148457863
KNN	0.9983514785177044	0.9983514386974491	0.9983514785177044	0.9983513798219226
SVM	0.9922038671566439	0.9922025866386067	0.9922038671566439	0.9922020510243128
Gaussian NB	0.918295154033726	0.926633232685079	0.918295154033726	0.9163503763232373
Fully Connected NN				
ReLU + adam + early stopping and checkpoint + 4 hidden layers	0.9985231995054435	0.9985233281256618	0.9985231995054435	0.9985230557019816
Sigmoid + sgd + early stopping and checkpoint + 4 hidden layers	0.986331009375966	0.986336941032662	0.986331009375966	0.9863197626089032
Tanh + adagrad + early stopping and checkpoint + 4 hidden layers	0.9980767249373218	0.9980766831171078	0.9980767249373218	0.998076580954231
CNN conv2d_1 (41 , ReLU, (1,3), (1,1))+ conv2d_2 (82 , ReLU, (1,3))+ max_pooling2d_1(1,2) + dropout_1 (0.25)+ flatten_8 + dense_1 (164, ReLU) + dropout_2 (0.5) + dense_2 (2) output	0.9994129792316101	0.9994134960875988	0.9994129792316101	0.999413128064702
Feature Selection based on Feature Importance Analysis				
Logistic Regression	0.9837208503623313	0.9837784158032781	0.9837208503623313	0.9836938095343001
KNN	0.9981110691348697	0.9981118993313256	0.9981110691348697	0.9981107146517584

SVM	0.9805268399903836	0.9809747688267506	0.9805268399903836	0.980447975698628
Gaussian NB	0.9782944671497751	0.9785952641646312	0.9782944671497751	0.9782192710782204
Fully Connected NN				
ReLU + adam + early stopping and checkpoint + 4 hidden layers	0.997458529381461	0.9974605511391783	0.997458529381461	0.9974589455556856
Sigmoid + sgd + early stopping and checkpoint + 4 hidden layers	0.9869148607342789	0.9869227666119975	0.9869148607342789	0.986903789403367
Tanh + adagrad + early stopping and checkpoint + 4 hidden layers	0.9970463990108871	0.9970511600234251	0.9970463990108871	0.9970471884585685
CNN conv2d_1 (41 , ReLU, (1,3), (1,1))+ conv2d_2 (82 , ReLU, (1,3))+ max_pooling2d_1(1,2) + dropout_1 (0.25)+ flatten_8 + dense_1 (164, ReLU) + dropout_2 (0.5) + dense_2 (2) output	0.9977332829618436	0.9977349414187415	0.9977332829618436	0.997733620522209
Experimental CNN Architecture				
CNN 8 Conv2d layers + 3 Max-pooling layers + 1 flatten layer + 2 Dense hidden layers + 1 dropout layer	0.9986605762956349	0.9986607317324747	0.9986605762956349	0.9986604458692393

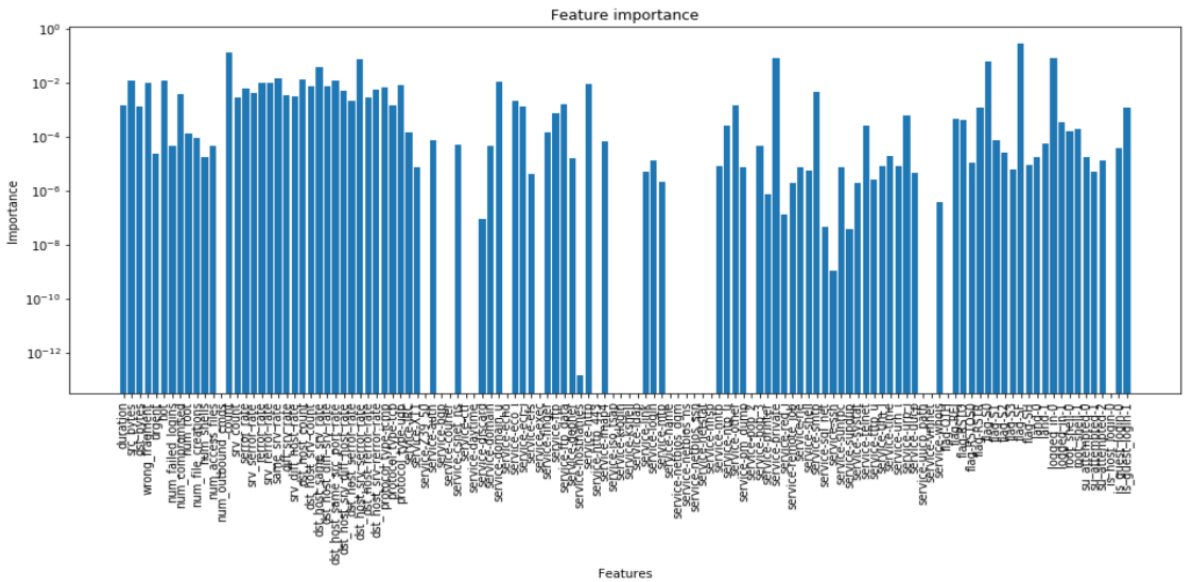
Confusion Matrix and ROC

- CNN after Redundancy Removal

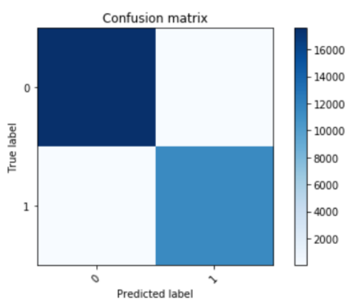


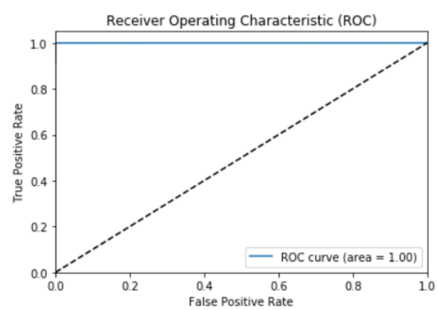


- Feature Importance Analysis Plot



- CNN after Feature Selection





7. References

[1] Md Moin Uddin Chowdhury and *et. al.*“A Few-shot Deep Learning Approach for Improved Intrusion Detection”, IEEE UEMCOM 2017, October 2017