MACHINE LEARNING MODEL

COMPARISON BASED ON SOME METRICS

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I. SUPPORT VECTOR MACHINE

Kernels = linear, poly, rbf, sigmoid

C = 1, 2, 3, 4, 5

Degree = 1, 2, 3, 4, 5, 6

Gamma = scale, auto

Decision function shape = ovo, ovr

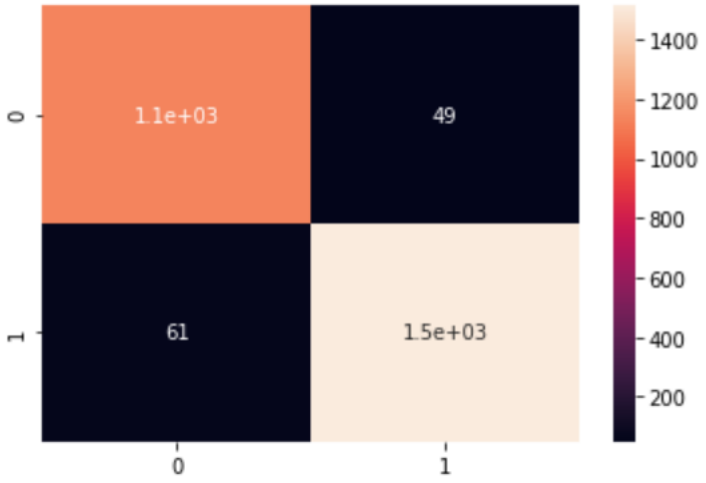
A. Results of SVM:

Best performed kernel: rbf

Worst kernel kernel: sigmoid

Linear: %93.31, Poly: %95.84, RBF: %95.01, Sigmoid: %83.73

The Average Score of SVC is %92.16 over 480 different model combinations. Best performed combination is “kernel = poly, C = 3, degree = 5, gamma = scale, decision function shape = ovo” with %97.53 accuracy.



II. LINEAR SUPPORT VECTOR MACHINE

Losses = hinge, squared hinge

Penalty = l2

C = 1, 2, 3, 4, 5

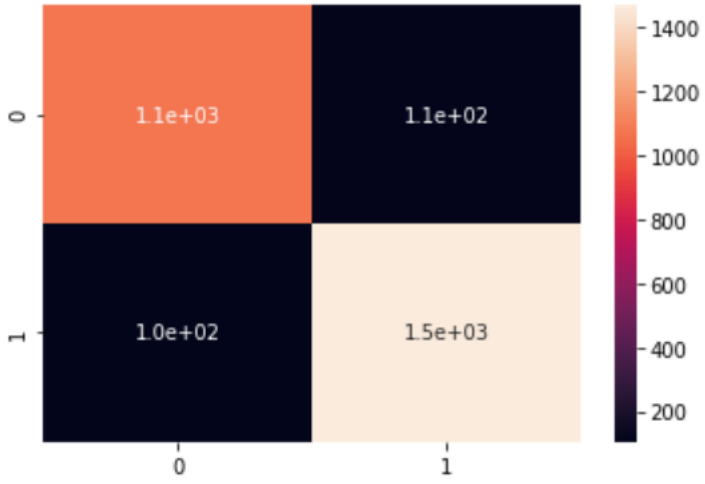
Multi Class = ovr, crammer singer

A. Resultf of Linear SVC:

Best performed loss function: squared hinge

Hinge: %93.10, Squared Hinge: %93.12

The average score of Linear SVC is %93.11 over 20 different models. Best performed combination is "loss function: hinge, penalty: l2, C: 1, Multi Class: ovr" with the accuracy of %93.198.



III. K – NEAREST NEIGHBORS

K = 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24

Weights = uniform, distance

Metric = euclidean, manhattan, chebyshev, minkowski, wminkowski, mahalanobis, seuclidean.

A. Results of KNN:

K-1: %96.28, **K-2**: %95.18, **K-3**: %95.21, **K-4**: %95.12, **K-5**: %95.17,

K-6: %95.26, **K-7**: %95.29, **K-8**: %95.14, **K-9**: %95.19, **K-10**: %95.04,

K-11: %95.07, **K-12**: %94.69, **K-13**: %94.77, **K-14**: %94.66,

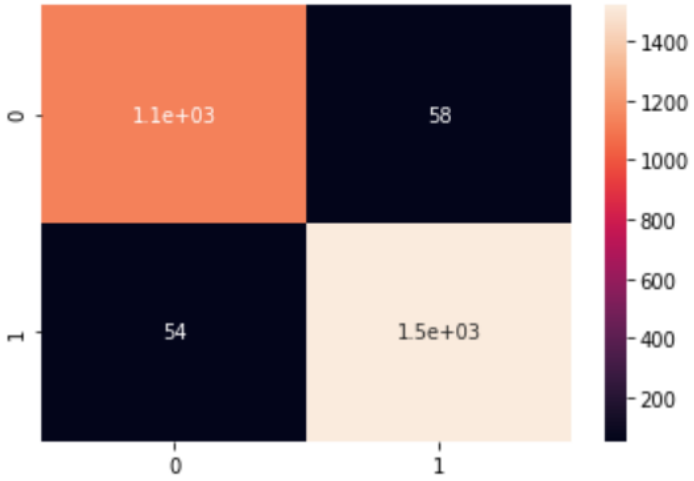
K-15: %94. 75, **K-16**: %94.59, **K-17**: %94.36, **K-18**: %9431,

K-19: %94.25, **K-20**: %9421, **K-21**: %94.20, **K-22**: %94.18,

K-23: %94.19, **K-24**: %94.16

Best performed k is 1 with %96.28.

The average accuracy of K-NN is %94.80 over 1344 model combinations. Best performed K-NN combination is “k: 6, weights: distance, algorithm: auto, metric: euclidean” with the accuracy %96.41.



IV. DECISION TREE CLASSIFIER

Max features = None, auto, sqrt, log2

Criterion = gini, entropy

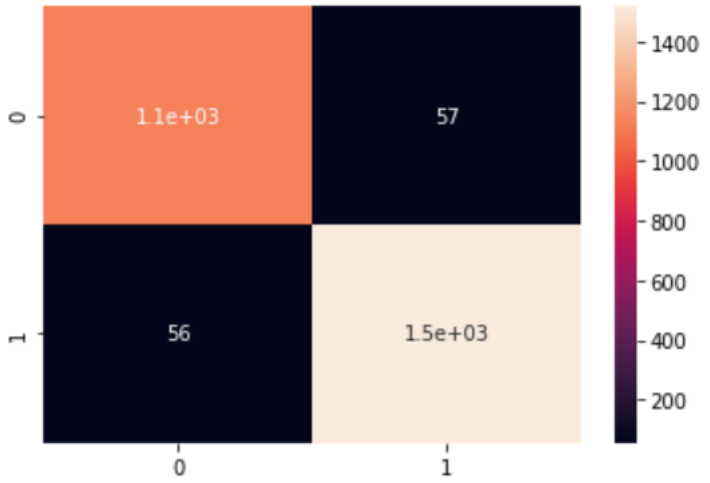
Splitter = best, random

A. Result of Decision Tree Classifier:

Best performed combination is “max_features = None, criterion = entropy, splitter = random” with accuracy of %96.52.

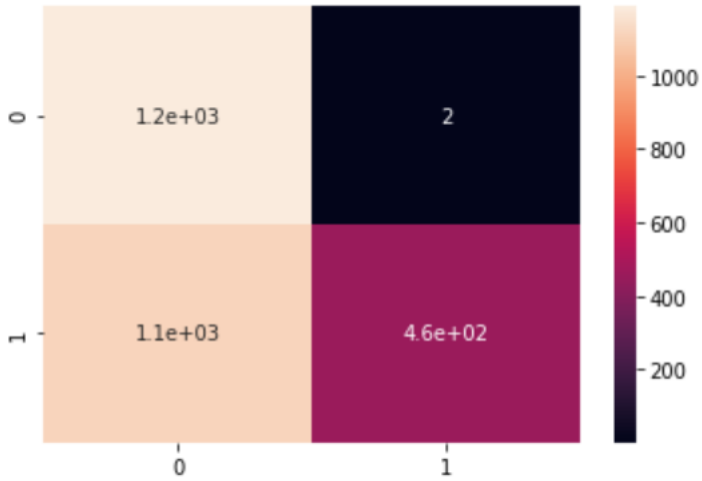
Worst performed combination is “max_features = log2, criterion = gini, splitter = random” with accuracy of %94.21.

The average accuracy of Decision Tree Classifer is %95.65 over 16 different model combinations.



V. GAUSSIAN NAIVE BAYES CLASSIFIER

The accuracy score of Gaussian Naive Bayes is %60.89.



VI. NAIVE BAYES CLASSIFIER

The accuracy score of our Naive Bayes classifier is %56.54.

A. Bernoulli Naive Bayes Classifier:

Alpha = 0, 1, 2, 3, 4, 5, 7, 9, 11

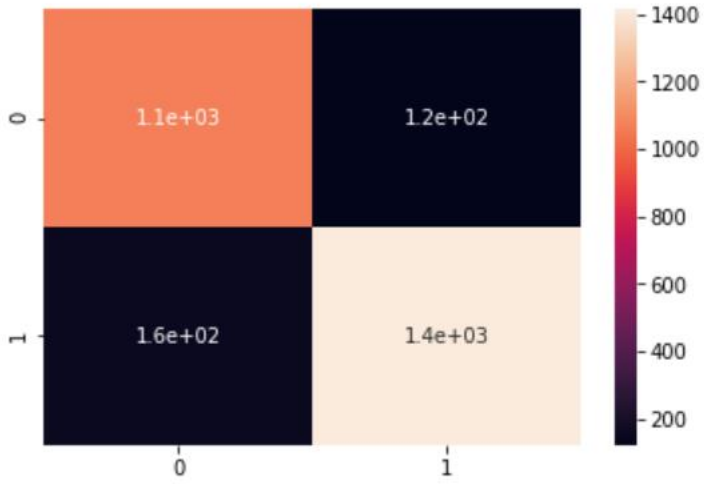
Binarize = 0, 1, 2, 3, 4, 5, 7, 9, 11

Fit prior = True, False

B. Results of BernoulliNB:

Best performed alpha value: 0,1,2 performed same accuracy value of %60.36; 3 and 4 performed %60.36; 5, 7 and 9 performed %60.35 accuracy; 11 performed %60.34 accuracy. As we can see the accuracy tends to perform worse as the alpha value increases.

The average performance of BernoulliNB is %60.36 over 162 different models. The best performed combination is “alpha = 0, binarize = 0, fit prior = True” with the accuracy of %90.95.



VII. SUPPORT VECTOR MACHINE

The accuracy of Support Vector Machine is %38.72 on testing set.

A. Random Forest Classifier:

Max features = None, auto, sqrt, log2

Criterion = gini, entropy

Class_weight = None, balanced, balanced_subsample

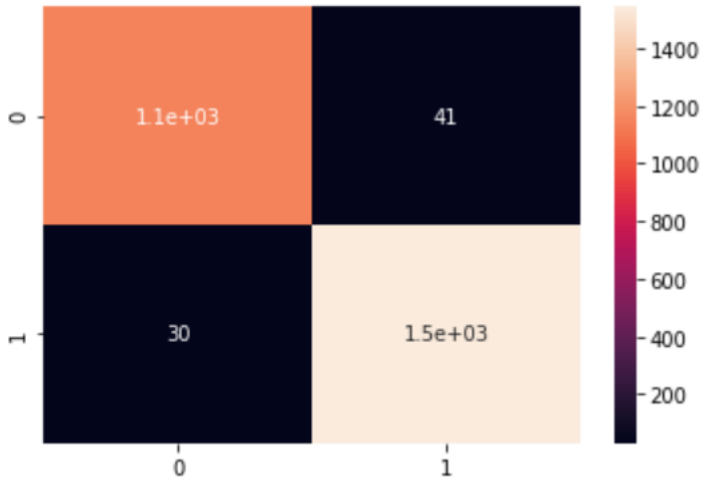
Warm start = True, False

B. Result of Random Forest Classifier:

Best performed combination is “max_features = log2, criterion = entropy, class_weight = balanced_subsample, warm_start = True” with accuracy of %96.96.

Worst performed combination is “max_features = auto, criterion = gini, class_weight = balanced, warm_start = False” with accuracy of %96.12.

The average accuracy of Random Forest Classifier is %96.60 over 48 different model combinations.



VIII. DEEP LEARNING WITH TENSORFLOW

Input Layer: Flatten (input_shape = (30,2))

Deep Layers: Dense (64, activation = relu), Dense (128, activation = relu), Dense (128, activation = relu)

Output Layer: Dense (1, activation=softplus)

Optimizers = 'sgd', 'rmsprop', 'adam', 'adadelta', 'adagrad', 'adamax', 'nadam', 'ftrl'

Loss = 'binary_crossentropy', 'categorical_crossentropy', 'hinge', 'squared_hinge', 'huber'

A. Results of the Deep Network:

Best performed combination is “optimizer = rmsprop, loss = huber” with the accuracy of %76.59 on validation set.

Worse performed combination is “optimizer = adam, loss = categorical_crossentropy” with the accuracy of %43.45 on validation set.

The average accuracy over 45 different models is %53.43 on validation set with this architecture of the network.

IX. DATA SET FEATURES

1. *Using the IP Address:*

Rule: *IF* $\begin{cases} \text{If The Domain Part has an IP Address} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

2. *Long URL to Hide the Suspicious Part*

Rule: IF $\begin{cases} URL\ length < 54 \rightarrow feature = \text{Legitimate} \\ else\ if\ URL\ length \geq 54\ and\ \leq 75 \rightarrow feature = Suspicious \\ otherwise \rightarrow feature = \text{Phishing} \end{cases}$

3. *Using URL Shortening Services “TinyURL”*

Rule: IF $\begin{cases} \text{TinyURL} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

4. *URL’s having “@” Symbol*

Rule: IF $\begin{cases} \text{Url Having @ Symbol} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

5. *Redirecting using "//"*

Rule: IF $\begin{cases} \text{ThePosition of the Last Occurrence of "//" in the URL} > 7 \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

6. *Adding Prefix or Suffix Separated by (-) to the Domain*

Rule: IF $\begin{cases} \text{Domain Name Part Includes } (-) \text{ Symbol} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

7. *Sub Domain and Multi Sub Domains*

Rule: IF $\begin{cases} \text{Dots In Domain Part} = 1 \rightarrow \text{Legitimate} \\ \text{Dots In Domain Part} = 2 \rightarrow \text{Suspicious} \\ \text{Otherwise} \rightarrow \text{Phishing} \end{cases}$

8. *HTTPS (Hyper Text Transfer Protocol with Secure Sockets Layer)*

Rule: IF $\begin{cases} \text{Use https and Issuer Is Trusted and Age of Certificate} \geq 1 \text{ Years} \rightarrow \text{Legitimate} \\ \text{Using https and Issuer Is Not Trusted} \rightarrow \text{Suspicious} \\ \text{Otherwise} \rightarrow \text{Phishing} \end{cases}$

9. *Domain Registration Length*

Rule: IF $\begin{cases} \text{Domains Expires on} \leq 1 \text{ years} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

10. *Favicon*

Rule: IF $\begin{cases} \text{Favicon Loaded From External Domain} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

11. *Using Non-Standard Port*

Rule: IF $\begin{cases} \text{Port \# is of the Preffered Status} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

12. The Existence of "HTTPS" Token in the Domain Part of the URL

$$\textit{Rule: IF}\begin{cases}\text{Using HTTP Token in Domain Part of The URL} \rightarrow \text{Phishing}\\ \text{Otherwise} \rightarrow \text{Legitimate}\end{cases}$$

13. Request URL

$$\textit{Rule: IF}\begin{cases}\%\text{ of Request URL} < 22\% \rightarrow \text{Legitimate}\\ \%\text{of Request URL} \geq 22\% \text{ and } 61\% \rightarrow \text{Suspicious}\\ \text{Otherwise} \rightarrow \text{feature} = \text{Phishing}\end{cases}$$

14. URL of Anchor

$$\textit{Rule: IF}\begin{cases}\%\text{ of URL Of Anchor} < 31\% \rightarrow \textit{Legitimate}\\ \%\text{ of URL Of Anchor} \geq 31\% \text{ And} \leq 67\% \rightarrow \text{Suspicious}\\ \text{Otherwise} \rightarrow \text{Phishing}\end{cases}$$

15. Links in <Meta>, <Script> and <Link> tags

$$\textit{Rule: IF}\begin{cases}\%\text{ of Links in "} < \text{Meta} > \text{","} < \text{Script} > \text{" and "} < \text{Link>"} < 17\% \rightarrow \text{Legitimate}\\ \%\text{ of Links in } < \text{Meta} > \text{","} < \text{Script} > \text{" and "} < \text{Link>"} \geq 17\% \text{ And} \leq 81\% \rightarrow \text{Suspicious}\\ \text{Otherwise} \rightarrow \text{Phishing}\end{cases}$$

16. Server Form Handler (SFH)

$$\textit{Rule: IF}\begin{cases}\text{SFH is "about: blank" Or Is Empty} \rightarrow \text{Phishing}\\ \text{SFH Refers To A Different Domain} \rightarrow \text{Suspicious}\\ \text{Otherwise} \rightarrow \text{Legitimate}\end{cases}$$

17. Submitting Information to Email

$$\textit{Rule: IF}\begin{cases}\text{Using "mail()" or "mailto:" Function to Submit User Information} \rightarrow \text{Phishing}\\ \text{Otherwise} \rightarrow \text{Legitimate}\end{cases}$$

18. Abnormal URL

This feature can be extracted from WHOIS database. For a legitimate website, identity is typically part of its URL.

Rule: IF $\begin{cases} \text{The Host Name Is Not Included In URL} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

19. *Website Forwarding*

Rule: IF $\begin{cases} \text{ofRedirect Page} \leq 1 \rightarrow \text{Legitimate} \\ \text{of Redirect Page} \geq 2 \text{ And} < 4 \rightarrow \text{Suspicious} \\ \text{Otherwise} \rightarrow \text{Phishing} \end{cases}$

20. *Status Bar Customization*

Rule: IF $\begin{cases} \text{onMouseOver Changes Status Bar} \rightarrow \text{Phishing} \\ \text{It Does't Change Status Bar} \rightarrow \text{Legitimate} \end{cases}$

21. *Disabling Right Click*

Rule: IF $\begin{cases} \text{Right Click Disabled} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

22. *Using Pop-up Window*

Rule: IF $\begin{cases} \text{Popoup Window Contains Text Fields} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

23. *IFrame Redirection*

Rule: IF $\begin{cases} \text{Using iframe} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

24. *Age of Domain*

Rule: IF $\begin{cases} \text{Age Of Domain} \geq 6 \text{ months} \rightarrow \text{Legitimate} \\ \text{Otherwise} \rightarrow \text{Phishing} \end{cases}$

25. *DNS Record*

Rule: IF $\begin{cases} \text{no DNS Record For The Domain} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$

26. Website Traffic

$$\textit{Rule: IF}\begin{cases}\text{Website Rank} < 100{,}000 \rightarrow \text{Legitimate}\\ \text{Website Rank} > 100{,}000 \rightarrow \text{Suspicious}\\ \text{Otherwise} \rightarrow \text{Phish}\end{cases}$$

27. PageRank

$$\textit{Rule: IF}\begin{cases}\text{PageRank} < 0.2 \rightarrow \text{Phishing}\\ \text{Otherwise} \rightarrow \text{Legitimate}\end{cases}$$

28. Google Index

$$\textit{Rule: IF}\begin{cases}\text{Webpage Indexed by Google} \rightarrow \text{Legitimate}\\ \text{Otherwise} \rightarrow \text{Phishing}\end{cases}$$

29. Number of Links Pointing to Page

$$\textit{Rule: IF}\begin{cases}\text{Of Link Pointing to The Webpage} = 0 \rightarrow \text{Phishing}\\ \text{Of Link Pointing to The Webpage} > 0 \text{ and} \leq 2 \rightarrow \text{Suspicious}\\ \text{Otherwise} \rightarrow \text{Legitimate}\end{cases}$$

30. Statistical-Reports Based Feature

$$\textit{Rule: IF}\begin{cases}\text{Host Belongs to Top Phishing IPs or Top Phishing Domains} \rightarrow \text{Phishing}\\ \text{Otherwise} \rightarrow \text{Legitimate}\end{cases}$$