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:

Test Size: 15%

Best Accuracy = 96.44%

Best Combination = “poly, 5, 5, scale, ovo”

Worst Accuracy = 82.64%

Worst Combination = “sigmoid, 5, 1, scale, ovo”

Average Accuracy = 91.42%

Test Size: 30%

Best Accuracy = 98.10%

Best Combination = “poly, 5, 6, scale, ovo”

Worst Accuracy = 83.78%

Worst Combination = “sigmoid, 3, 1, scale, ovo”

Average Accuracy = 92.42%

Test Size: 35%

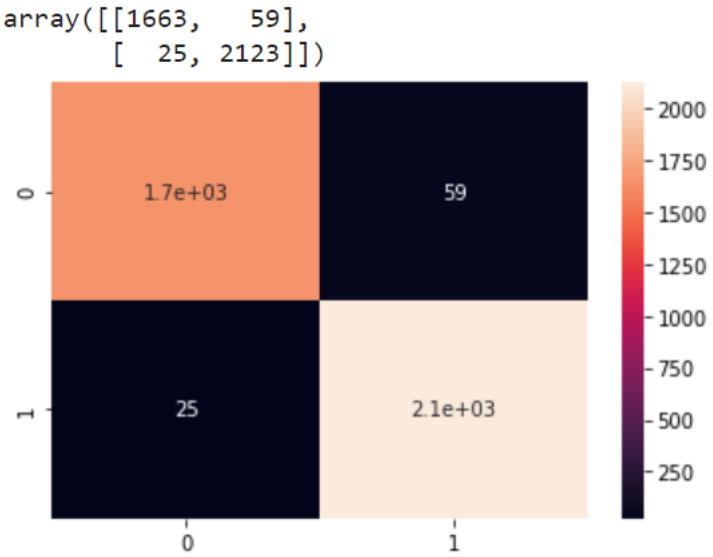
Best Accuracy = 98.03%

Best Combination = “poly, 5, 6, scale, ovo”

Worst Accuracy = 82.79%

Worst Combination = “sigmoid, 3, 1, scale, ovo”

Average Accuracy = 91.98%



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:

Test Size: 15%

Best Accuracy = 92.40%

Best Combination = “squared_hinge, l2, 1, ovr”

Worst Accuracy = 92.22%

Worst Combination = “hinge, l2, 1, ovr”

Average Accuracy = 92.33%

Test Size: 30%

Best Accuracy = 93.15%

Best Combination = “hinge, l2, 5, ovr”

Worst Accuracy = 93.03%

Worst Combination = “hinge, l2, 4, ovr”

Average Accuracy = 93.08%

Test Size: 35%

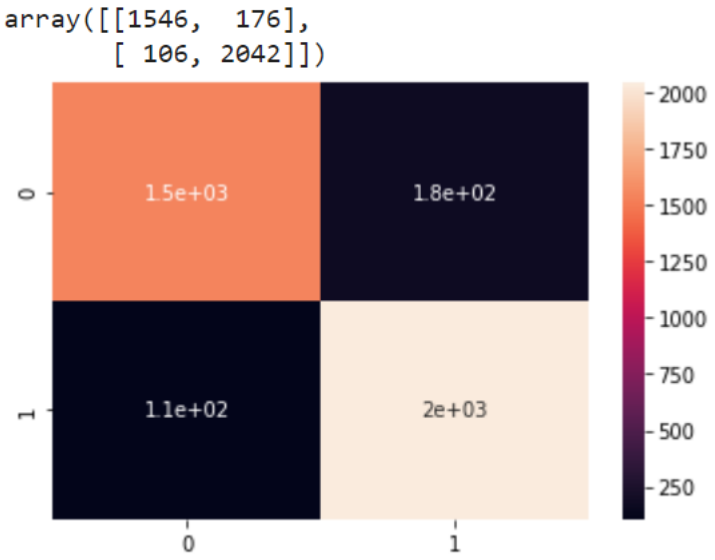
Best Accuracy = 92.97%

Best Combination = “squared_hinge, l2, 1, ovr”

Worst Accuracy = 92.79%

Worst Combination = “hinge, l2, 1, ovr”

Average Accuracy = 92.83%



III. K – NEAREST NEIGHBORS

K = 1,2,3,4,5,6,7,8,9,10

Weights = uniform, distance

Metric = euclidean, manhattan, chebyshev, minkowski

A. Results of KNN:

Test Size: 15%

Best Accuracy = 96.14%

Best Combination = “8, disctance, brute, manhattan”

Worst Accuracy = 71.18%

Worst Combination = “8, uniform, auto, chebyshev”

Average Accuracy = 91.86%

Test Size: 30%

Best Accuracy = 98.52%

Best Combination = “5, distance, auto, manhattan”

Worst Accuracy = 78.17%

Worst Combination = “8, uniform, auto, chebyshev”

Average Accuracy = 95.99%

Test Size: 35%

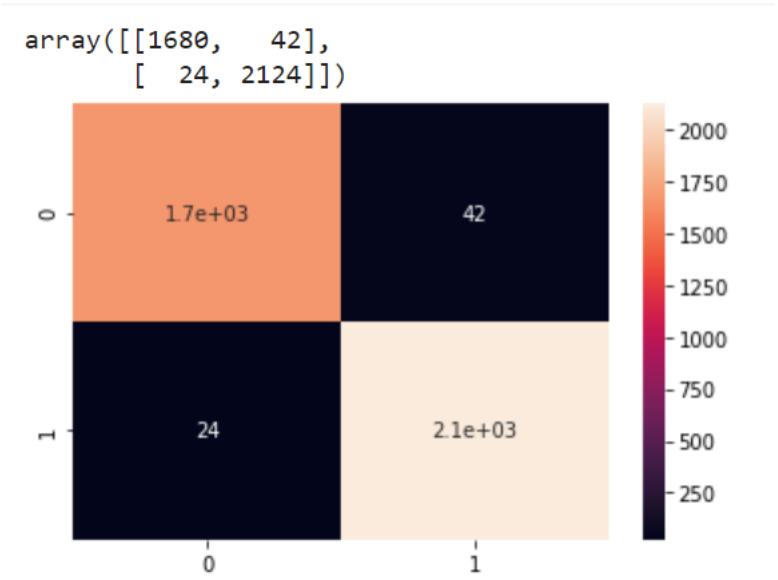
Best Accuracy = 98.44%

Best Combination = “5, distance, auto, manhattan”

Worst Accuracy = 77.08%

Worst Combination = “8, uniform, auto, chebyshev”

Average Accuracy = 95.85%



IV. DECISION TREE CLASSIFIER

Max features = None, auto, sqrt, log2

Criterion = gini, entropy

Splitter = best, random

A. Result of Decision Tree Classifier:

Test Size: 15%

Best Accuracy = 96.92%

Best Combination = “None, None, entropy, random"

Worst Accuracy = 93.91%

Worst Combination = “None, log2, gini, random”

Average Accuracy = 95.64%

Test Size: 30%

Best Accuracy = 95.96%

Best Combination = “None, None, entropy, random”

Worst Accuracy = 94.33%

Worst Combination = “None, log2, gini, random”

Average Accuracy = 95.37%

Test Size: 35%

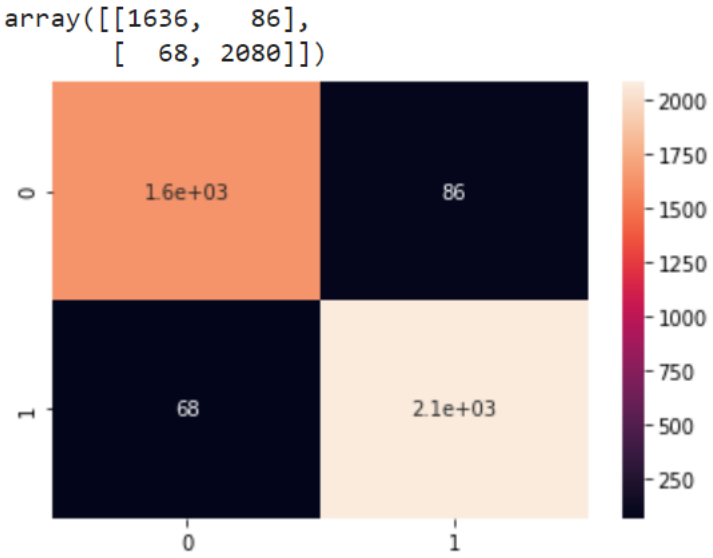
Best Accuracy = 95.86%

Best Combination = “default parameter”

Worst Accuracy = 94.03%

Worst Combination = “balanced, log2, entropy, random”

Average Accuracy = 95.18%



V. GAUSSIAN NAIVE BAYES CLASSIFIER

Test Size: 15%

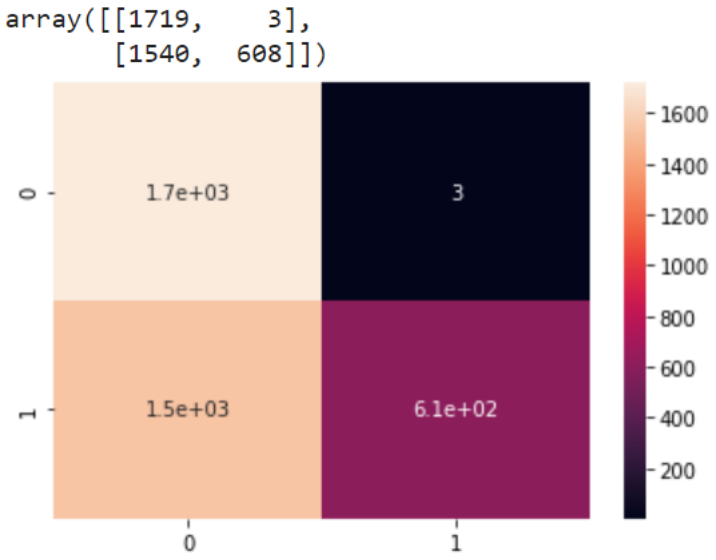
Accuracy = 59.25%

Test Size: 30%

Accuracy = 60.47%

Test Size: 35%

Accuracy = 59.94%



VI. BERNOULLI 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:

Test Size: 15%

Best Accuracy = 89.93%

Best Combination = “0, 0, true”

Worst Accuracy = 56.60%

Worst Combination = “0 1.0 true”

Average Accuracy = 60.07%

Test Size: 35%

Best Accuracy = 90.86%

Best Combination = “0, 0, false”

Worst Accuracy = 56.01%

Worst Combination = “0, 1.0, true”

Average Accuracy = 60.07%

Test Size: 35%

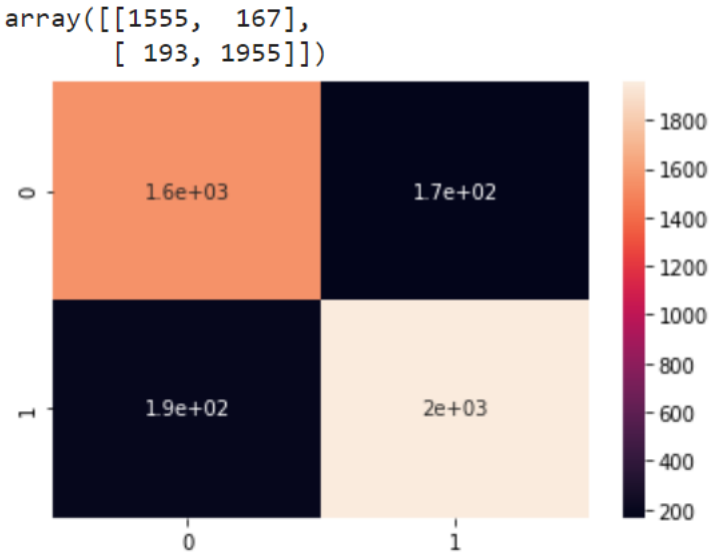
Best Accuracy = 90.08%

Best Combination = “3.0, 0, true”

Worst Accuracy = 55.50%

Worst Combination = “0, 1.0, true”

Average Accuracy = 59.61%



VII. RANDOM FOREST CLASSIFIER

Max features = None, auto, sqrt, log2

Criterion = gini, entropy

Class_weight = None, balanced, balanced_subsample

Warm start = True, False

A. Result of Random Forest Classifier:

Test Size: 15%

Best Accuracy = 97.34%

Best Combination = “None, auto, entropy, false”

Worst Accuracy = 96.68%

Worst Combination = “balanced, none, entropy, true”

Average Accuracy = 97.00%

Test Size: 30%

Best Accuracy = 96.95%

Best Combination = “None, log2, entropy, false”

Worst Accuracy = 96.50%

Worst Combination = “balanced_subsample, none, entropy, true”

Average Accuracy = 96.72%

Test Size: 35%

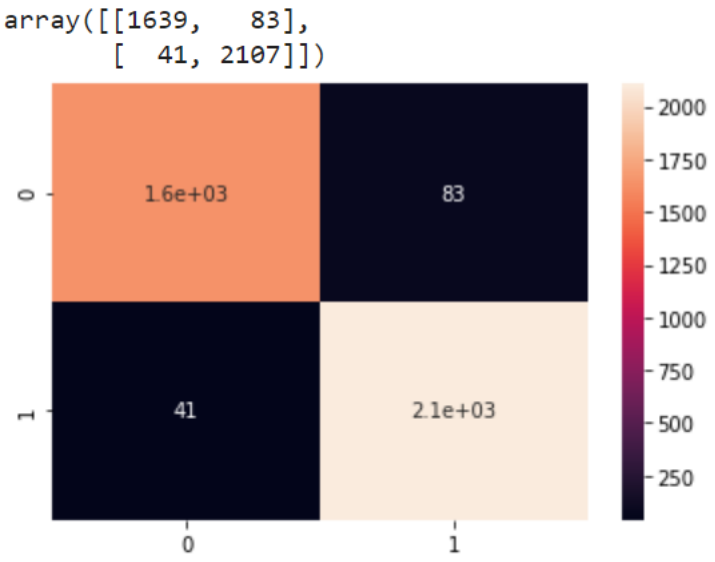
Best Accuracy = 96.89%

Best Combination = “None, log2, gini, true”

Worst Accuracy = 96.50%

Worst Combination = “None, None, gini, true”

Average Accuracy = 96.72%



VIII. DEEP LEARNING WITH TENSORFLOW

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

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

Activation = 'softplus', 'softsign', 'selu', 'elu', 'exponential', 'tanh', 'sigmoid', 'relu'

A. Results of the Deep Network:

Input Layer: Dense (32, , activation = relu, input_shape = (30,2))

Deep Layers: Dense (64, activation = relu), Dense (32, activation = relu)

Output Layer: Dense (1, activation=softplus)

Test Size: 15%

Best Accuracy = 55.98%

Best Combination = “softplus, adamax, huber”

Worst Accuracy = 44.04%

Worst Combination = “softplus, sgd, huber”

Average Accuracy = 52.92%

Input Layer: Dense (64, kernel_regularizer=l2, activation = relu, input_shape = (30,2))

Deep Layers: Dense (128, kernel_regularizer=l2, activation = relu), Dense (256, kernel_regularizer=l2, activation = relu), Dense (512, kernel_regularizer=l2, activation = relu), Dropout(0.3)

Output Layer: Dense (1, activation=softplus)

Test Size: 15%

Best Accuracy = 54.74%

Best Combination = “softplus, adagrad, huber”

Worst Accuracy = 45.12%

Worst Combination = “softplus, sgd, huber”

Average Accuracy = 50.73%

Input Layer: Dense (64, activation = relu, input_shape = (30,2))

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

Output Layer: Dense (1, activation=softplus)

Test Size: 15%

Best Accuracy = 75.76%

Best Combination = “softplus, adamax, binary_crossentropy”

Worst Accuracy = 44.35%

Worst Combination = “softplus, sgd, huber”

Average Accuracy = 69.04%

Test Size: 35%

Best Accuracy = 75.54%

Best Combination = “softplus, adamax, binary_crossentropy”

Worst Accuracy = 44.31%

Worst Combination = “softplus, sgd, huber”

Average Accuracy = 69.19%

Input Layer: Dense (64, kernel_regularizer=l2, activation = relu, input_shape = (30,2))

Deep Layers: Dense (128, kernel_regularizer=l2, activation = relu), Dense (128, kernel_regularizer=l2, activation = relu),

Output Layer: Dense (1, activation=softplus)

Test Size: 35%

Best Accuracy = 76.20%

Best Combination = “softplus, nadam, huber”

Worst Accuracy = 44.55%

Worst Combination = “softplus, sgd, huber”

Average Accuracy = 69.62%

Input Layer: Dense (64, kernel_regularizer=l2, activation = relu, input_shape = (30,2))

Deep Layers: Dense (128, kernel_regularizer=l2, activation = relu), Dense (128, kernel_regularizer=l2, activation = relu), Dense (128, kernel_regularizer=l2, activation = relu), Dense (256, kernel_regularizer=l2, activation = relu),

Output Layer: Dense (1, activation=softplus)

Test Size: 35%

Best Accuracy = 75.40%

Best Combination = “softplus, adamx, binary_crossentropy”

Worst Accuracy = 44.34%

Worst Combination = “softplus, sgd, huber”

Average Accuracy = 68.96%

Input Layer: Dense (64, kernel_regularizer=l2, activation = relu, input_shape = (30,2))

Deep Layers: Dense (128, kernel_regularizer=l2, activation = relu), Dense (128, kernel_regularizer=l2, activation = relu), Dense (128, kernel_regularizer=l2, activation = relu), Dense (256, kernel_regularizer=l2, activation = relu),

Output Layer: Dense (1, activation=softplus)

Test Size: 15%

Best Accuracy = 75.79%

Best Combination = “softplus, adam, huber”

Worst Accuracy = 44.16%

Worst Combination = “softplus, sgd, huber”

Average Accuracy = 69.29%

Input Layer: Dense (64, kernel_regularizer=l2, activation = relu, input_shape = (30,))

Deep Layers: Dense (128, kernel_regularizer=l2, activation = relu), Dense (128, kernel_regularizer=l2, activation = relu), Dense (128, kernel_regularizer=l2, activation = relu),

Output Layer: Dense (1, activation=softplus)

Test Size: 15%

Best Accuracy = 98.78%

Best Combination = “softplus, adamax, huber”

Worst Accuracy = 44.65%

Worst Combination = “softplus, sgd, hinge”

Average Accuracy = 82.89%

Best Optimizers = rmsprop, adam, adamax, adadelta, adagrad, nadam

Worst Optimizers = SGD, ftrl

Best Activation Functions = softplus, sigmoid, selu, elu, exponential, tanh, softsign

Worst Activation Functions = relu

Best Combinations = selu, adamax, binary_crossentropy; %98.86

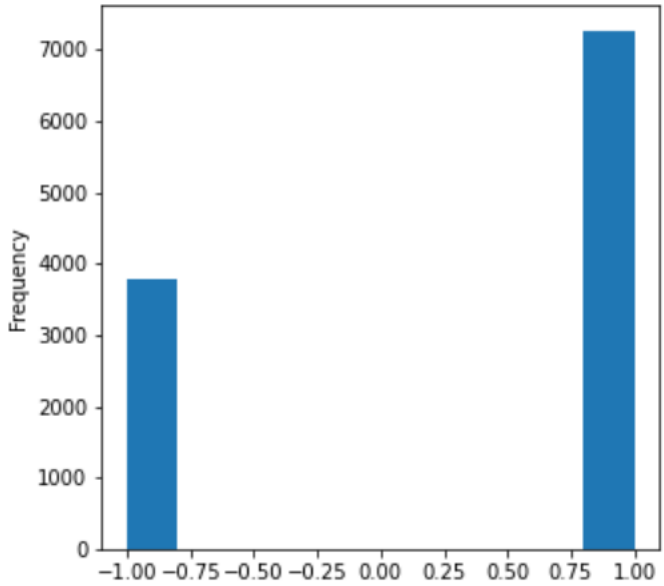
Worst Combinations = softplus, sgd, huber; %44.41

Average Accuracy = %81.42

IX. DATA SET FEATURES

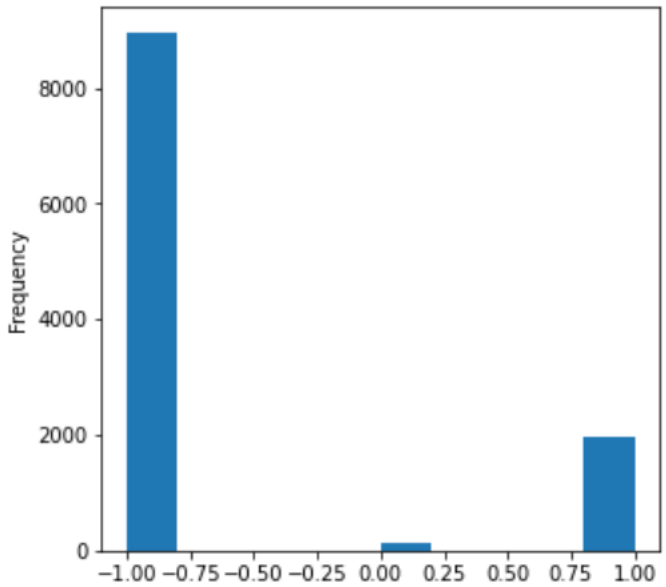
1. Using the IP Address

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



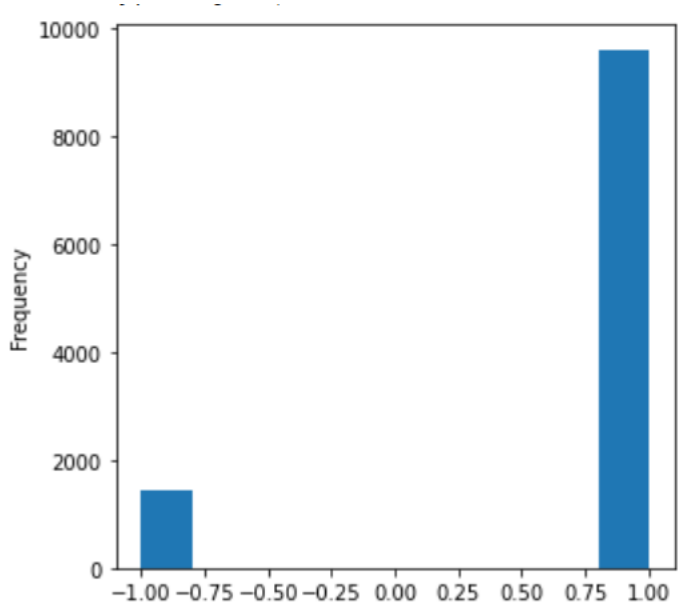
2. Long URL to Hide the Suspicious Part

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



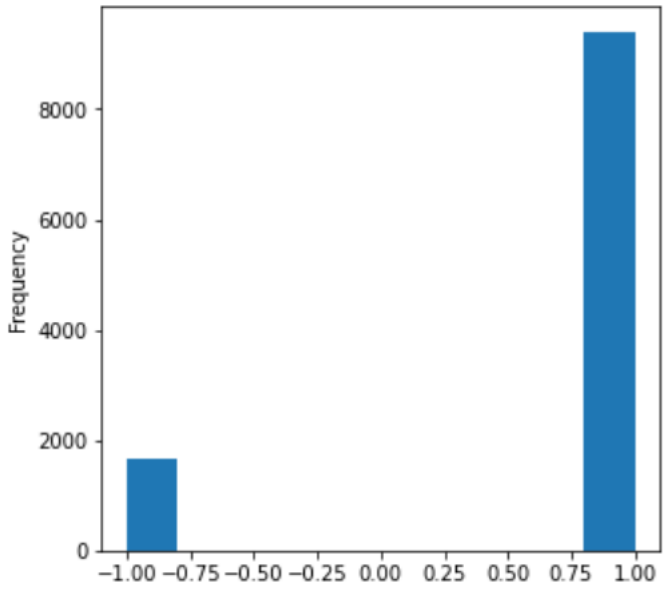
3. Using URL Shortening Services "TinyURL"

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



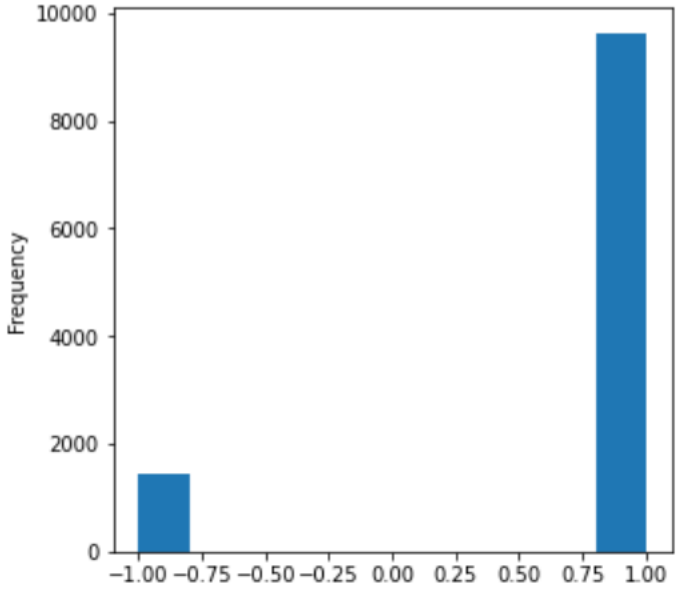
4. URL's having "@" Symbol

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



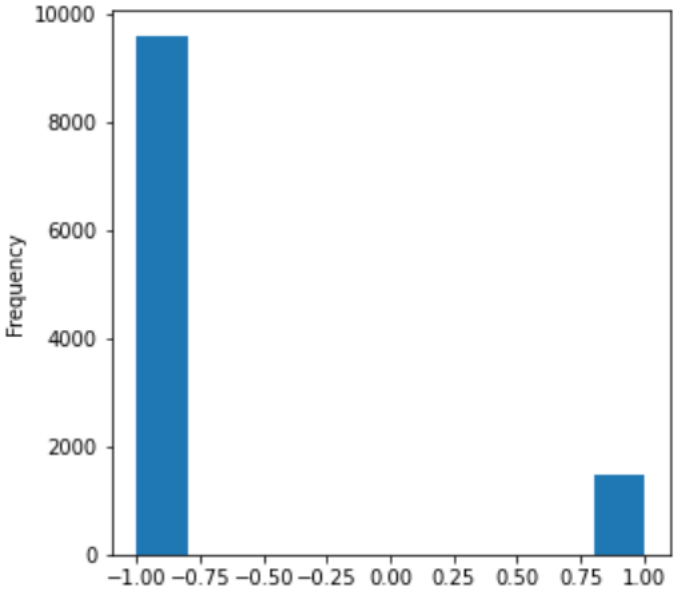
5. Redirecting using "//"

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



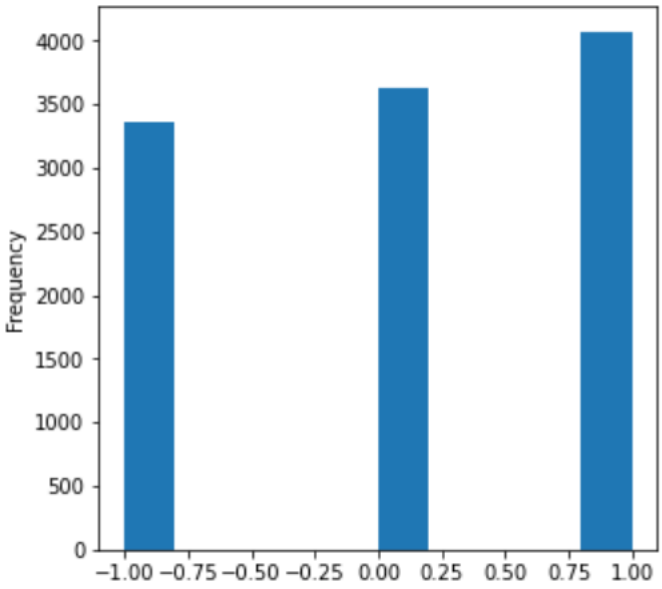
6. Adding Prefix or Suffix Separated by (-) to the Domain

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



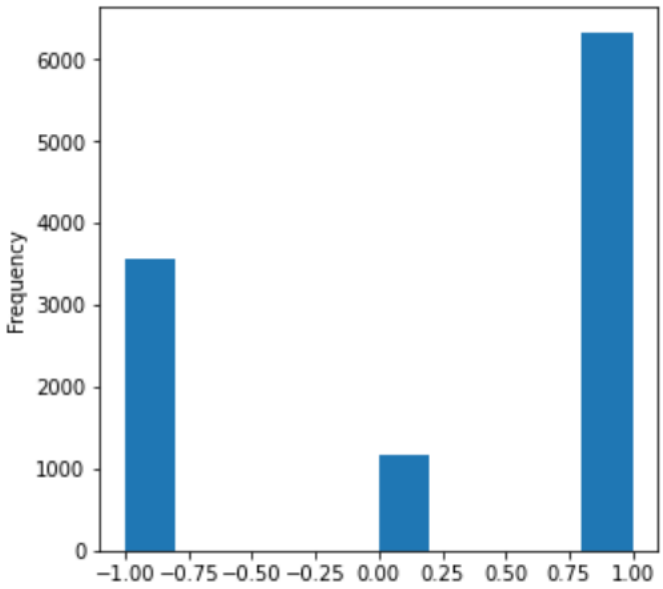
7. Sub Domain and Multi Sub Domains

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



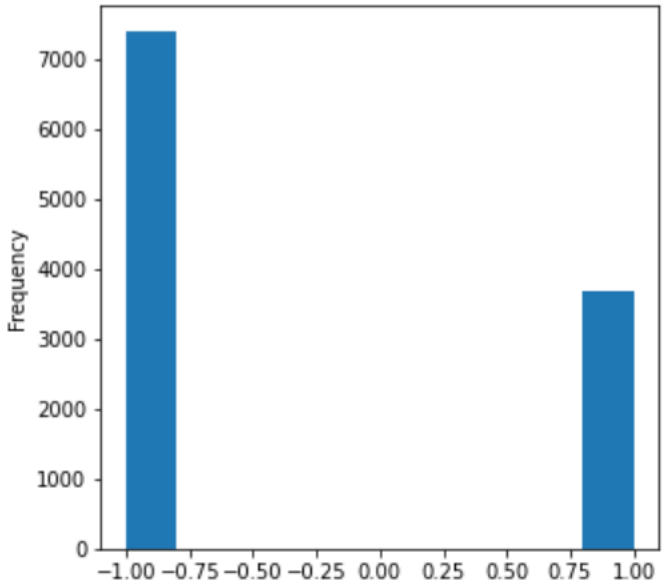
8. HTTPS (Hyper Text Transfer Protocol with Secure Sockets Layer)

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



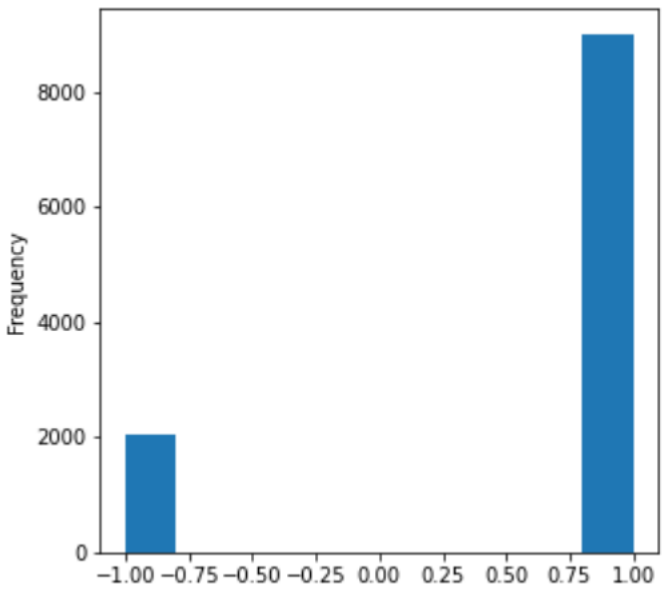
9. Domain Registration Length

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



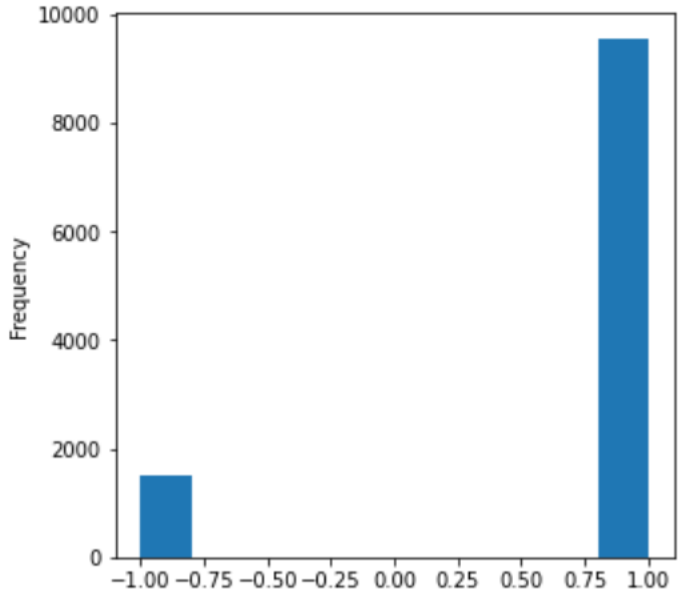
10. Favicon

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



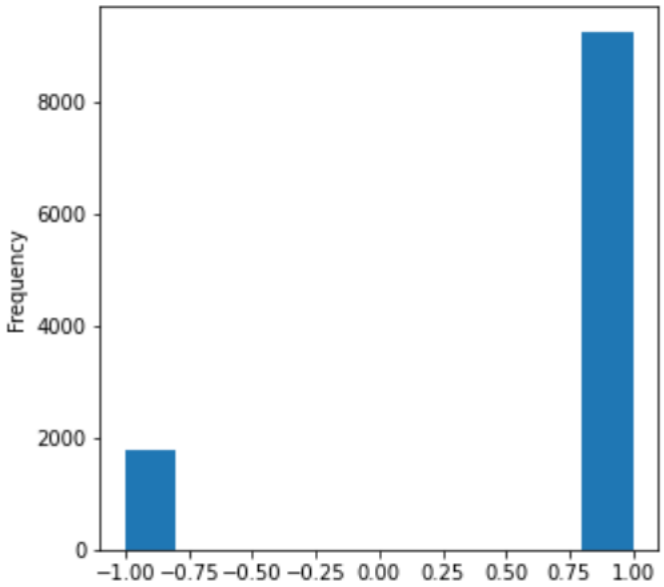
11. Using Non-Standard Port

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



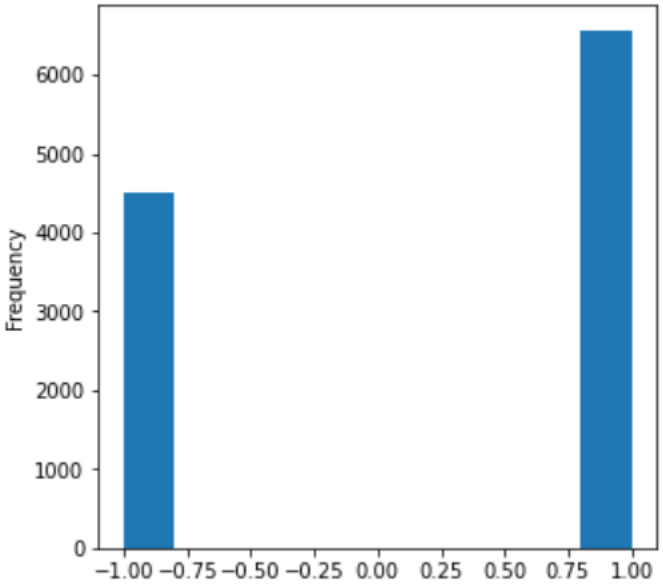
12. The Existence of "HTTPS" Token in the Domain Part of the URL

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



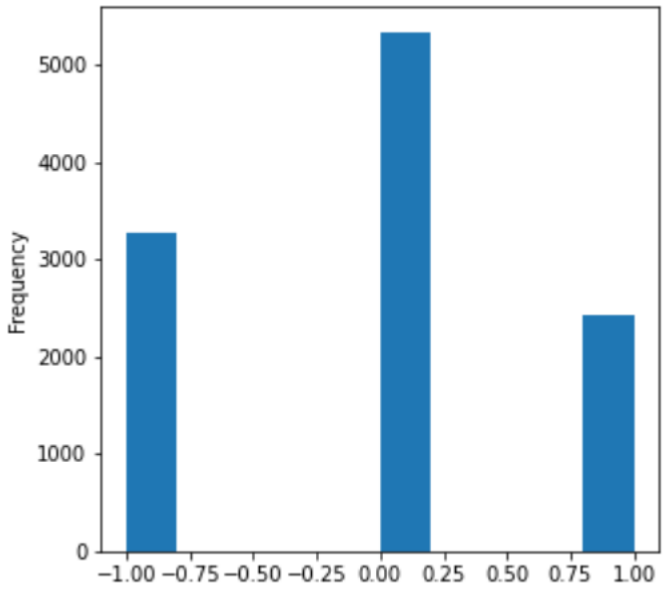
13. Request URL

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



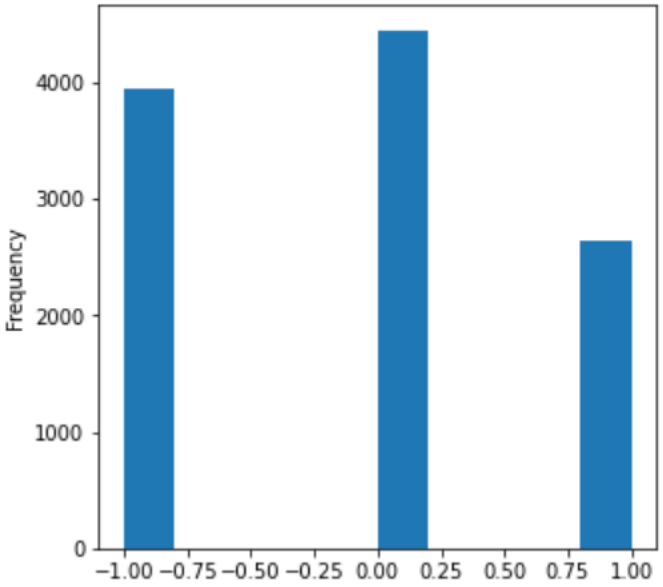
14. URL of Anchor

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



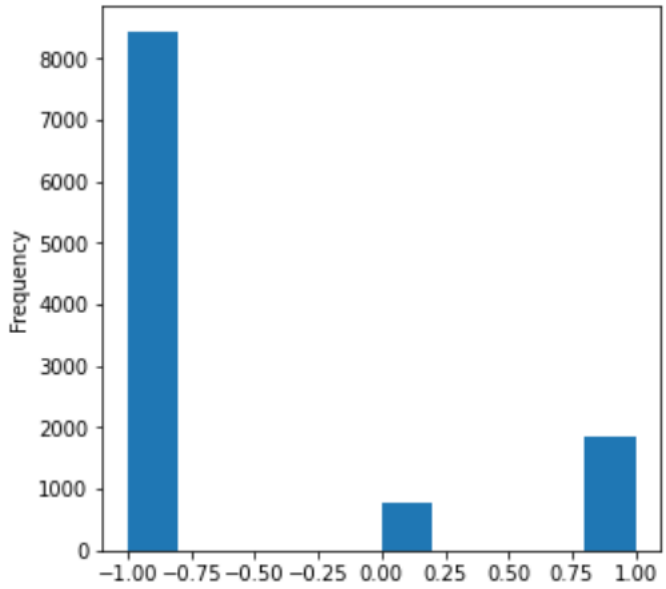
15. Links in <Meta>, <Script> and <Link> tags

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



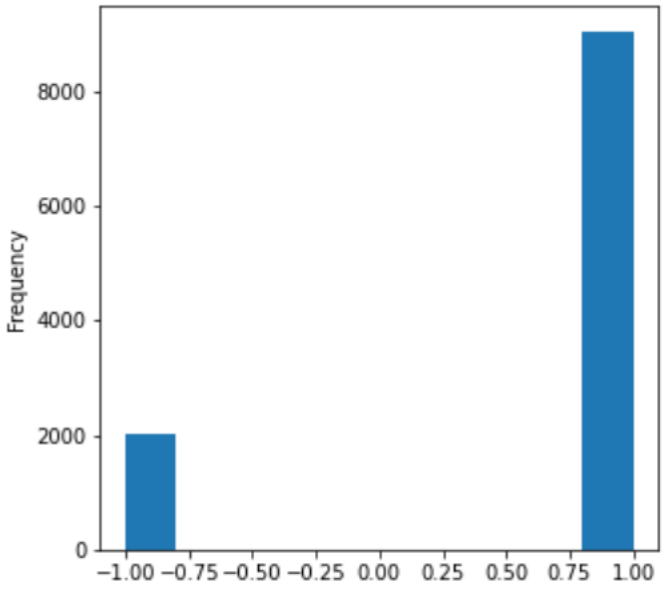
16. Server Form Handler (SFH)

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



17. Submitting Information to Email

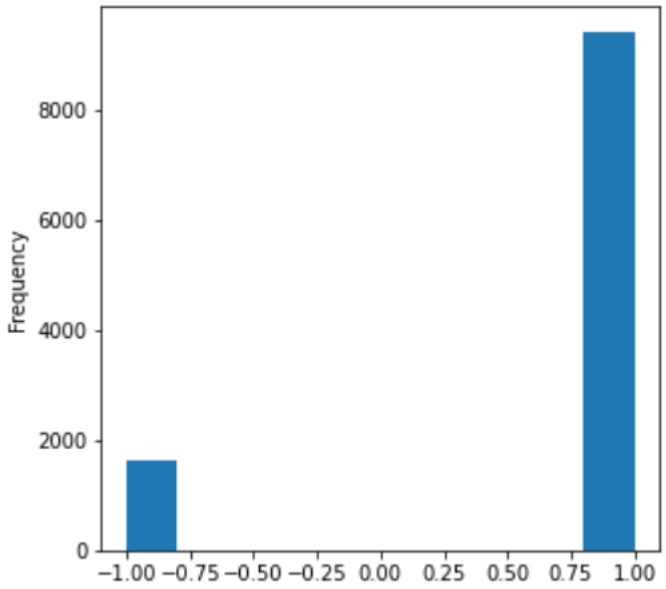
Rule: IF $\begin{cases} \text{Using "mail()" or "mailto:" Function to Submit User Information} \rightarrow \text{Phishing} \\ \text{Otherwise} \rightarrow \text{Legitimate} \end{cases}$



18. Abnormal URL

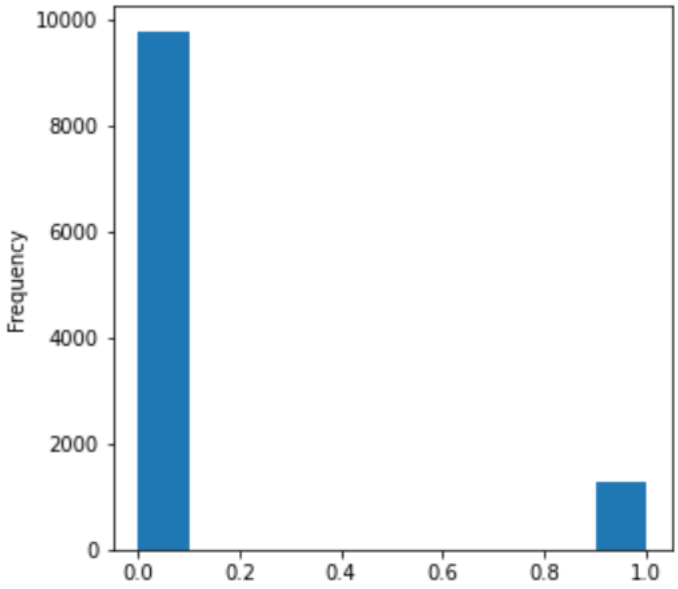
This feature can be extracted from WHOIS database. For a legitimate website, identity is typically part of its URL.

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



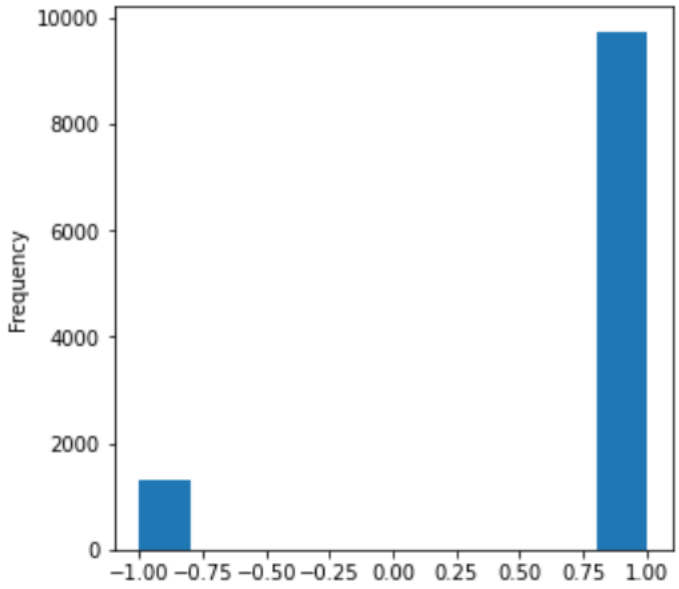
19. Website Forwarding

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



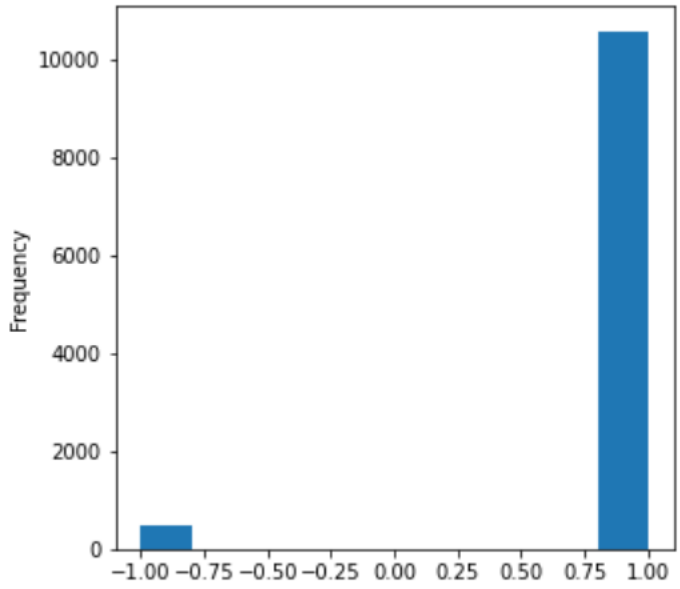
20. Status Bar Customization

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



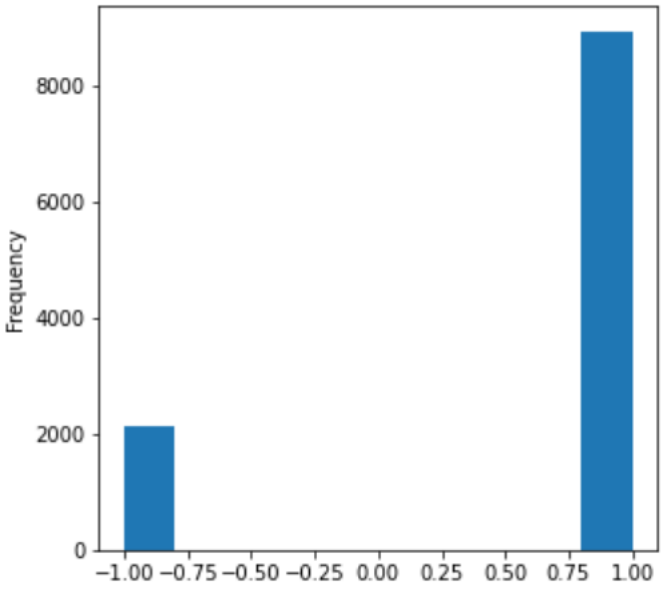
21. Disabling Right Click

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



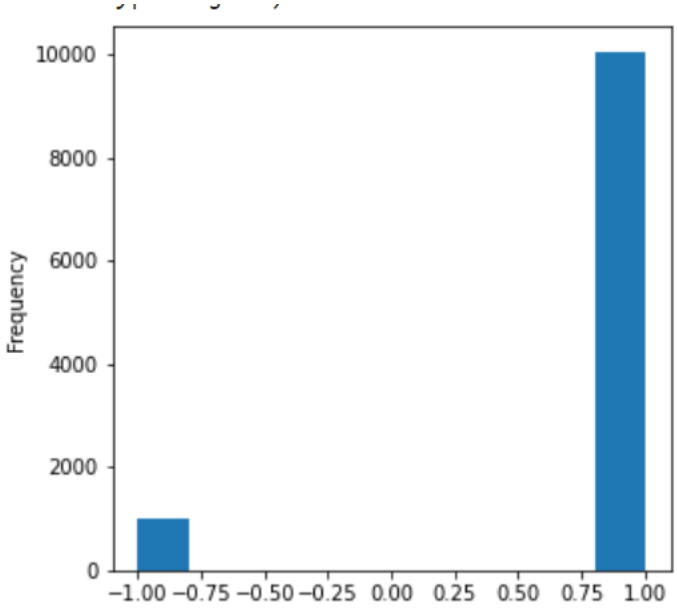
22. Using Pop-up Window

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



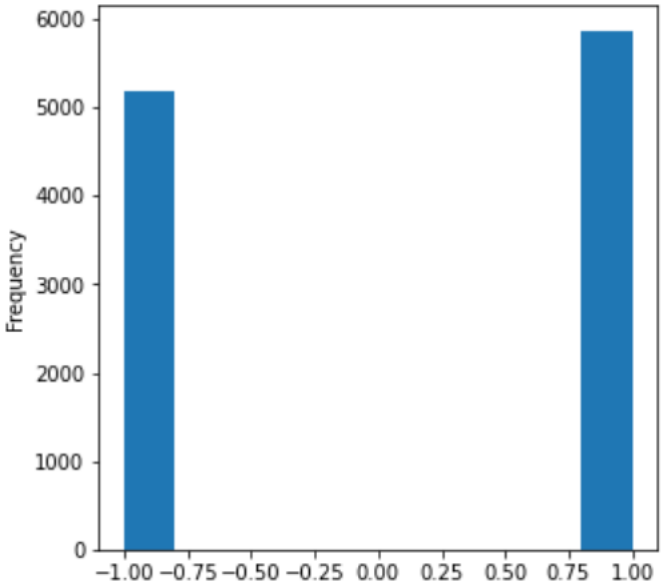
23. IFrame Redirection

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



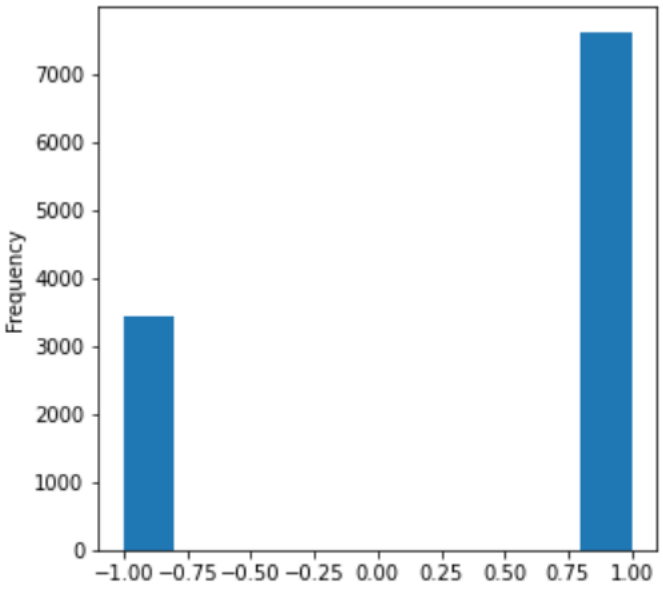
24. Age of Domain

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



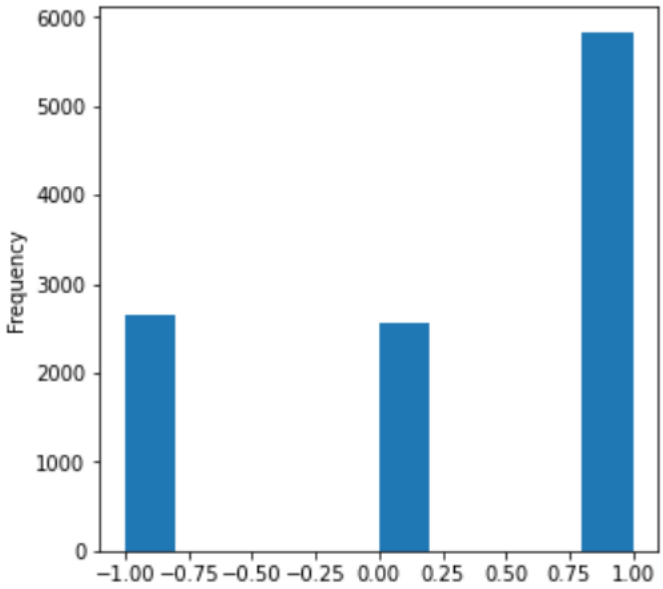
25. DNS Record

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



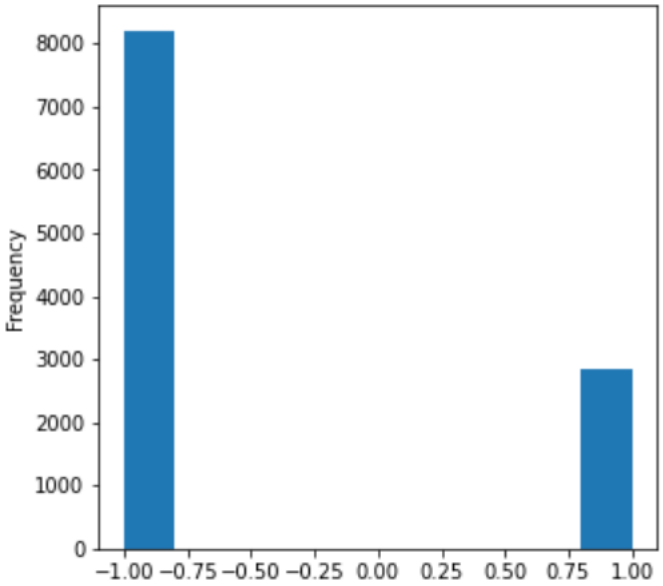
26. Website Traffic

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



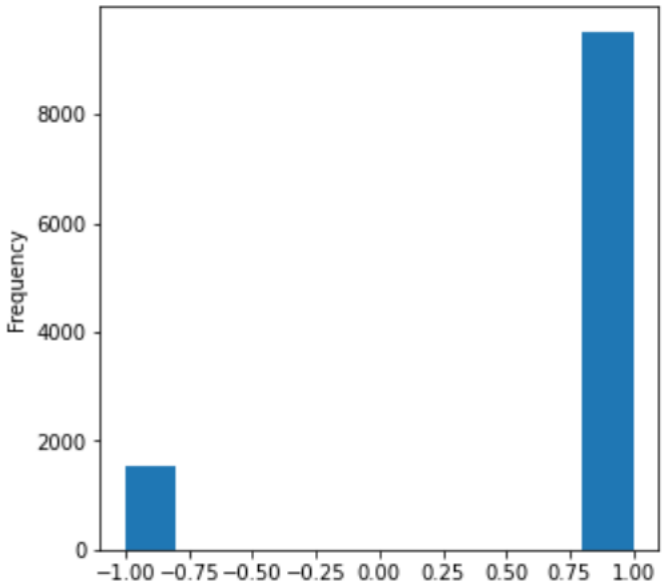
27. PageRank

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



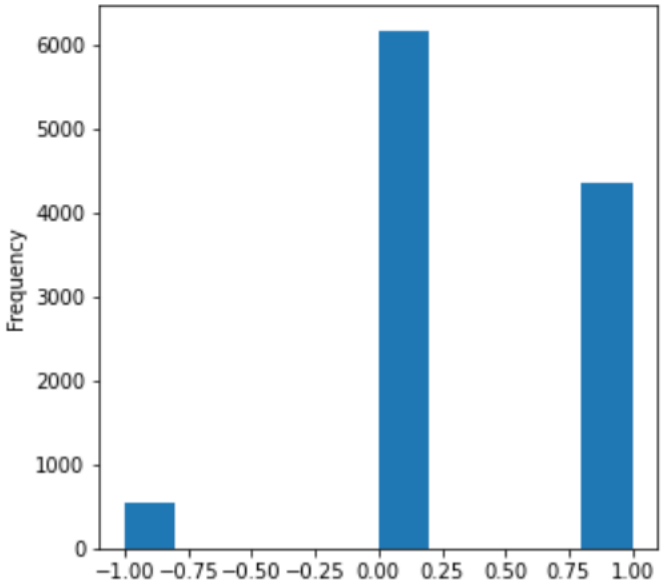
28. Google Index

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

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

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