Phishpedia: A Hybrid Deep Learning Based Approach to Visually Identify Phishing Webpages

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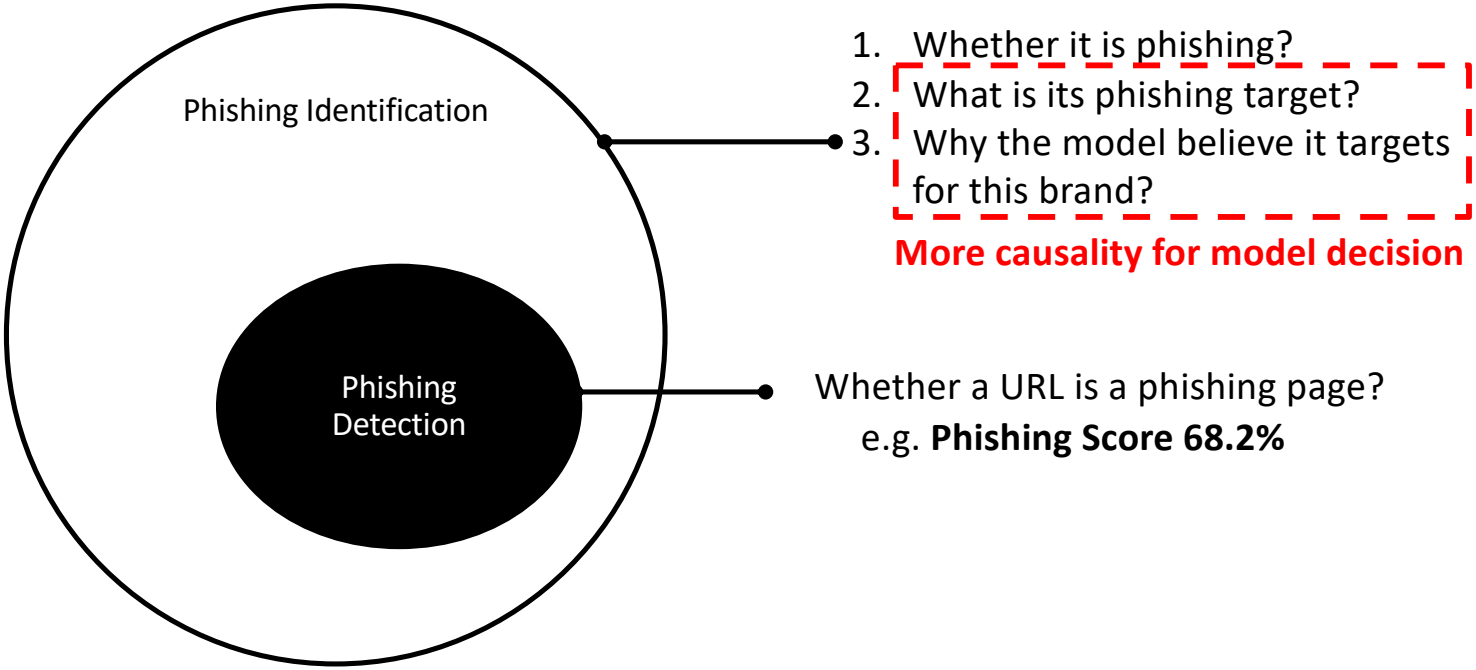
Presenter: Ruofan Liu

Introduction: Phishing Attack

- Definition:
  - A type of cybercrime which steal users credential information by **disguising itself as legitimate entity**

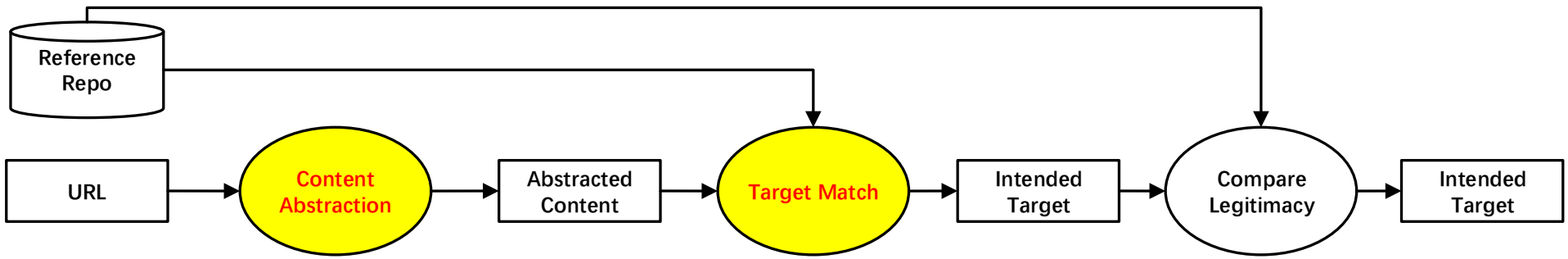
Research Problem

- Accurately **identify** phishing **websites**



Typical Framework for Phishing Identification

- Key components:
  - A reference repo to store targeted brands webpage signature
  - An approach to abstract webpage content
  - An approach to compare with reference repo



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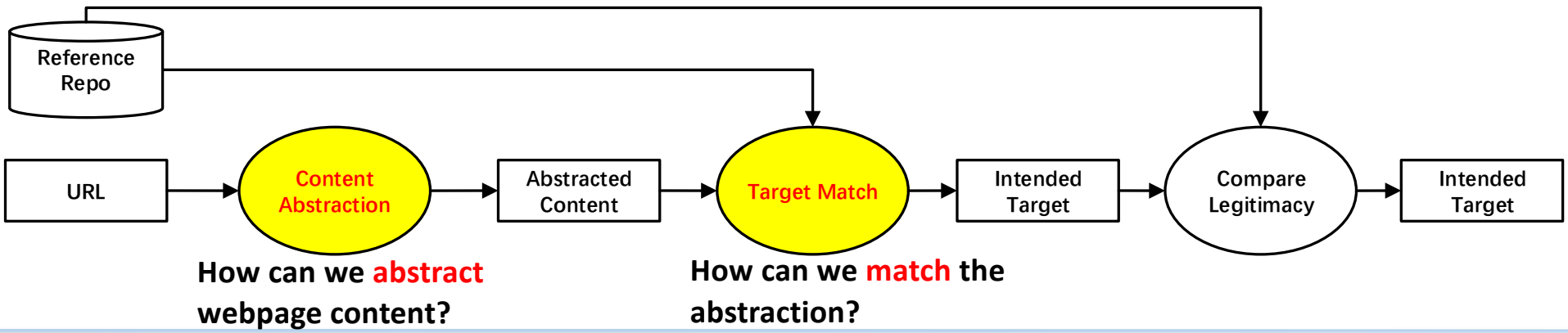
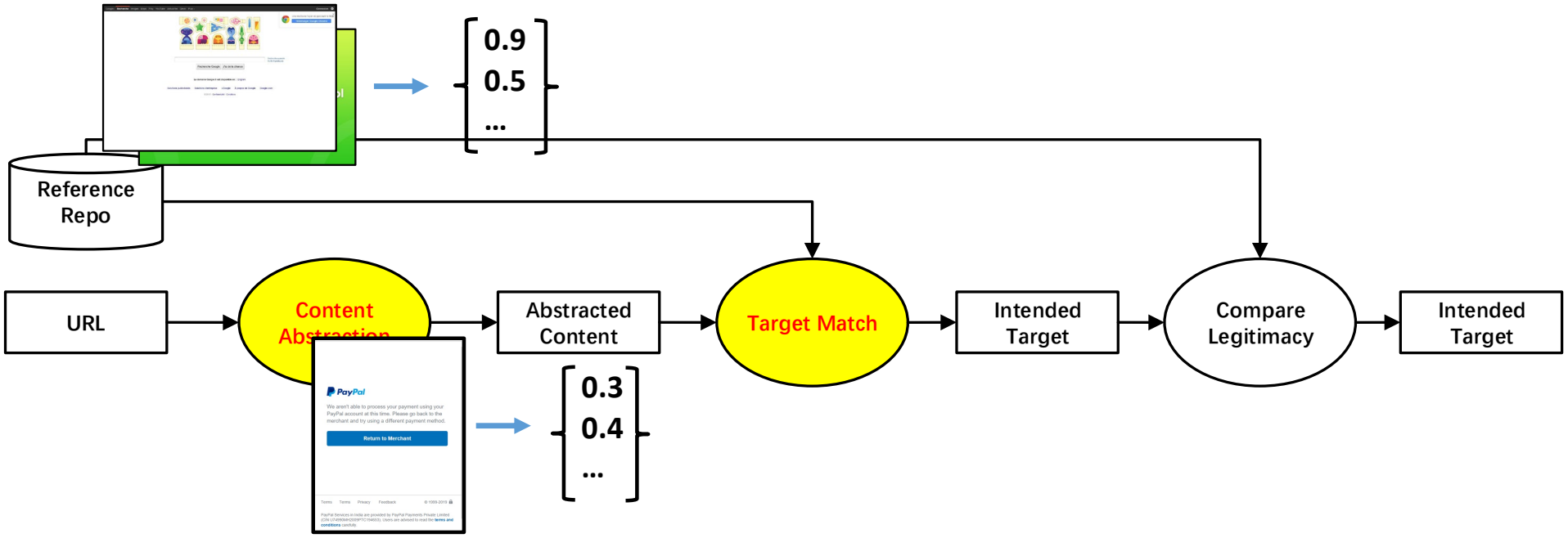


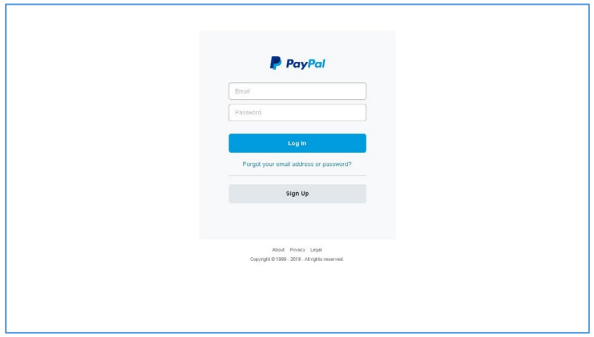
Existing Work 1: EMD [1]



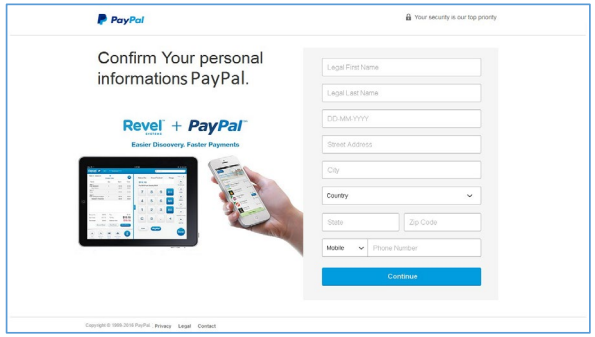
[1] Fu, A. Y., et al. (2006). "Detecting Phishing Web Pages with Visual Similarity Assessment Based on Earth Mover's Distance (EMD)." IEEE Transactions on Dependable and Secure Computing **3**(4): 301-311.

Problem of EMD

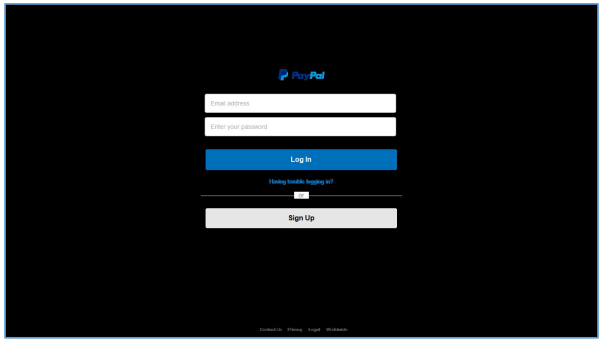
- EMD compares colour distribution of two screenshots
  - Screenshot usually changes from time to time, causing a lot of false negatives



Reference screenshot



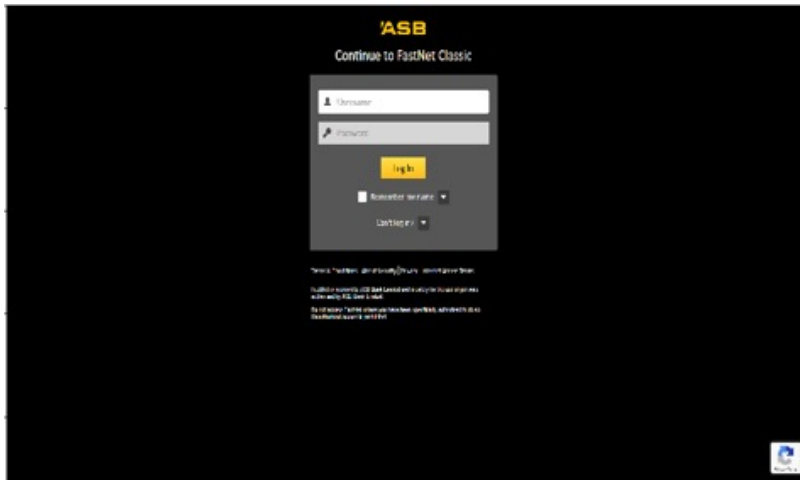
False negatives (change in layout)



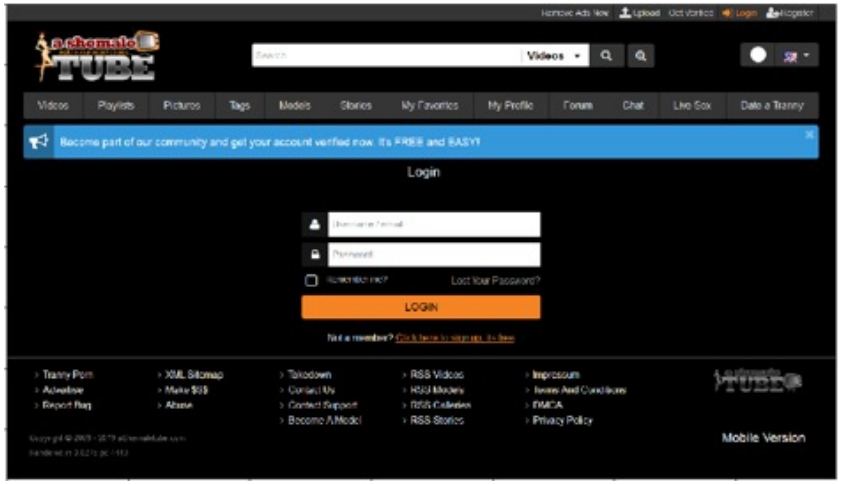
False negatives (change in colour scheme)

Problem of EMD

- EMD compares colour distribution of two screenshots
  - Report false positives as long as colour distributions are similar

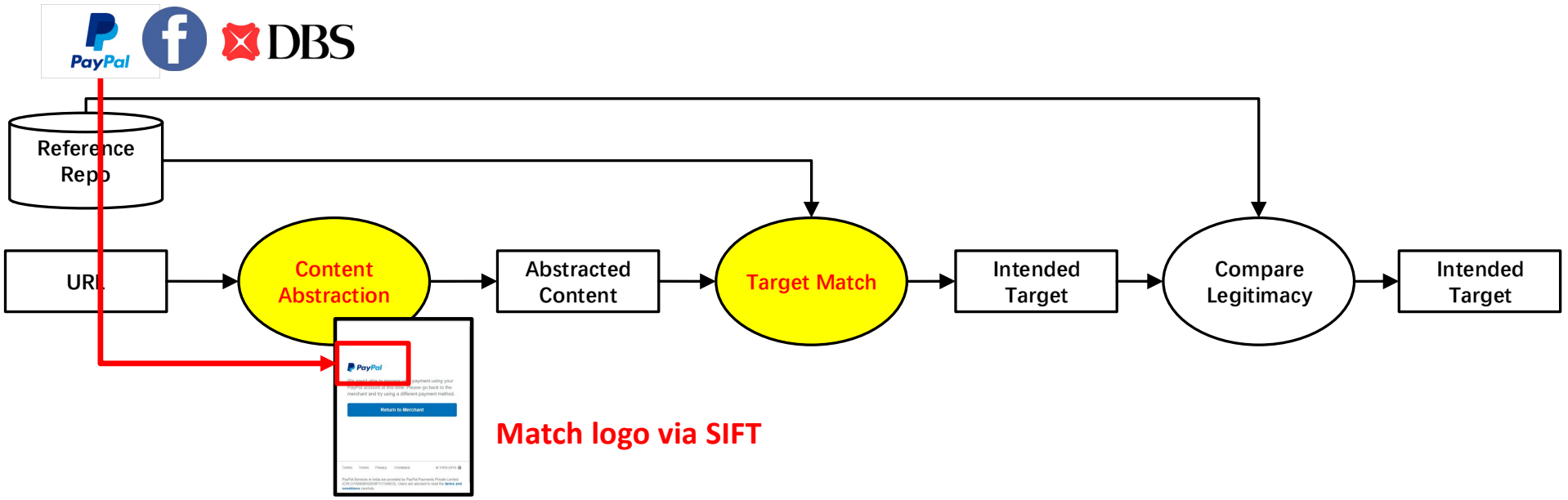


Reference screenshot



False positive

Existing Work 2: PhishZoo[2]

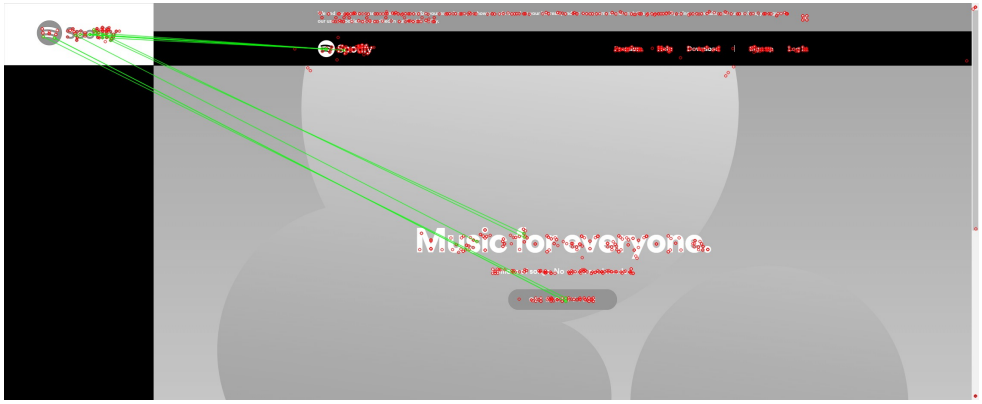


[2] Afroz, S. and R. Greenstadt (2011). PhishZoo: Detecting Phishing Websites by Looking at Them. 2011 IEEE Fifth International Conference on Semantic Computing.

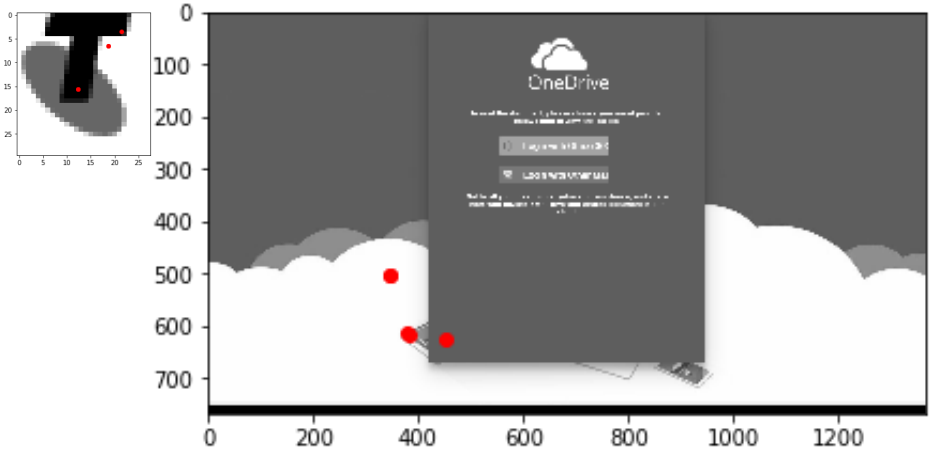
Problem of PhishZoo

- SIFT extract feature points to match a logo on screenshot, but with miss and incorrect matching

Matching ratio: 0.4, miss-match



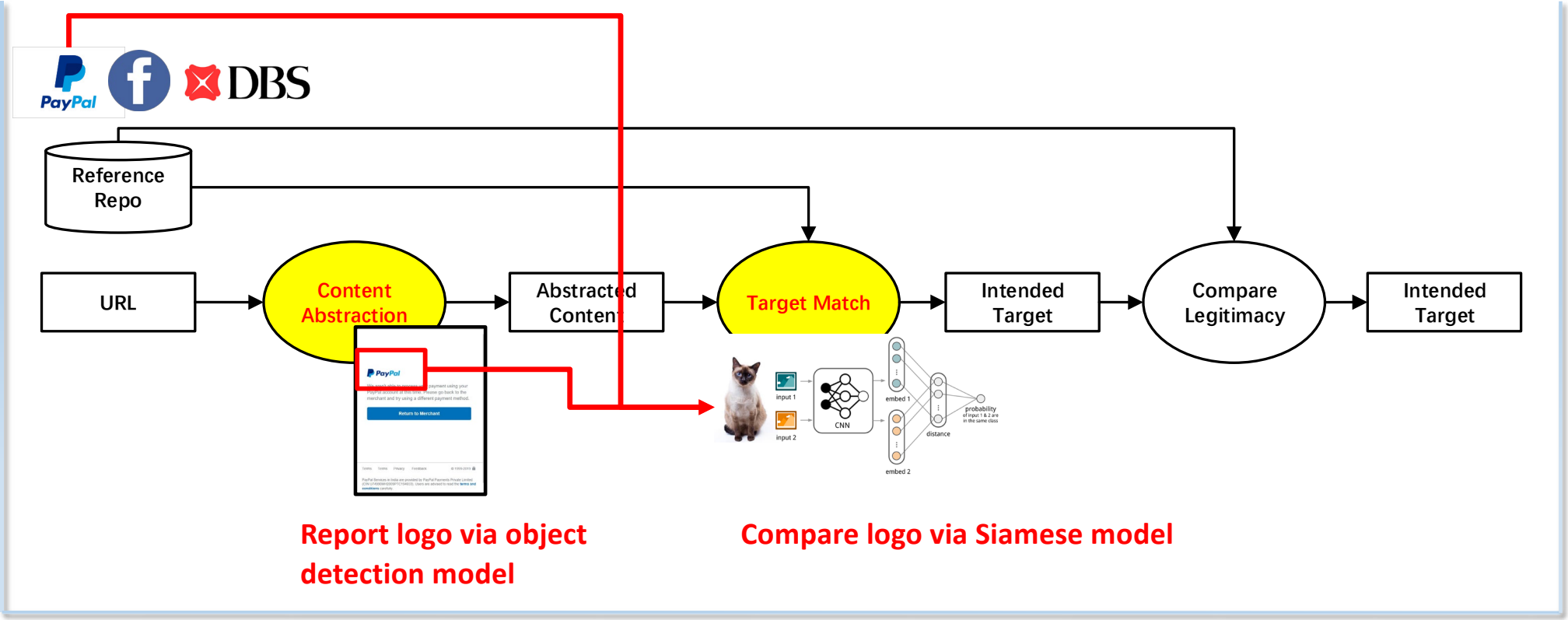
Matching ratio: 0.83, incorrect-match



Problem of PhishZoo

- SIFT extract feature points to match a logo on screenshot, but with long running time (On average 18 seconds per URL webpage)

Phishpedia Approach Overview



Phishpedia: Explainable Annotation

Phishpedia

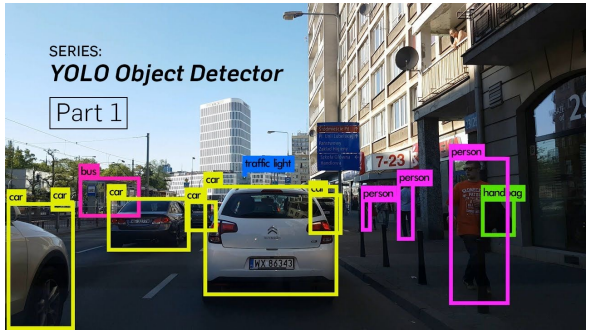
- **Perfect logo identification** with customized object detection approach.
- **Low runtime overhead** even with visual analysis.
- **Low bias in phishing dataset**, no need to train on any pre-collected phishing datasets.
- **Visualization annotation** on phishing screenshot, improving user confidence.

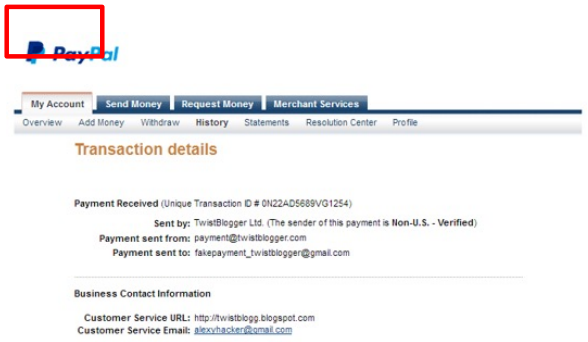
Challenges of Phishpedia

- Identifying perfect logo
- Training model to learn similar logos: representation learning

C1: Identifying perfect logo

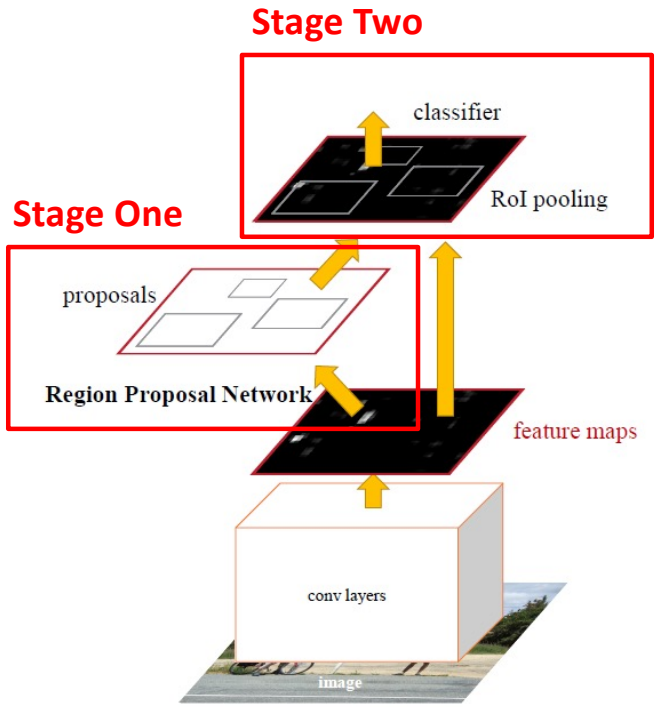
- Logo detection as an object detection problem.
- Off-the-shelf one-stage object detection face challenges of sometimes **generating only partial logo**.





Two-stage Object Detection Model

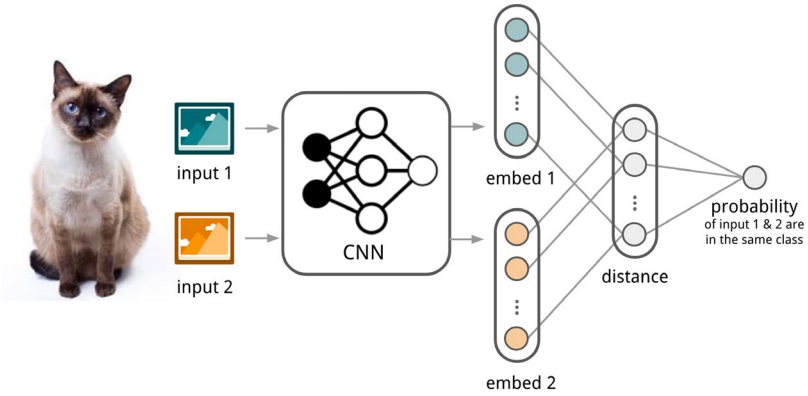
- Stage one:
  - Detect **region** containing objects (i.e., logo and input) on the screenshot first.
- Stage two:
  - Refine the reported region
  - Classify the region content
    - Logo
    - Input

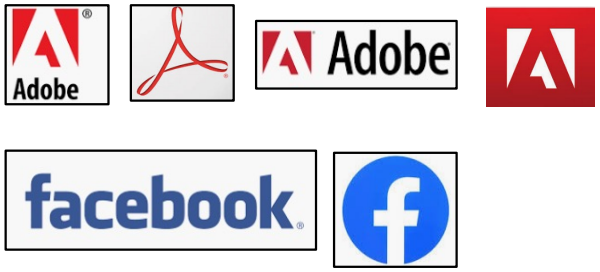


[3] Ren, S., et al. (2015). Faster r-cnn: Towards real-time object detection with region proposal networks. Advances in neural information processing systems.

C2: Training model to learn similar logo

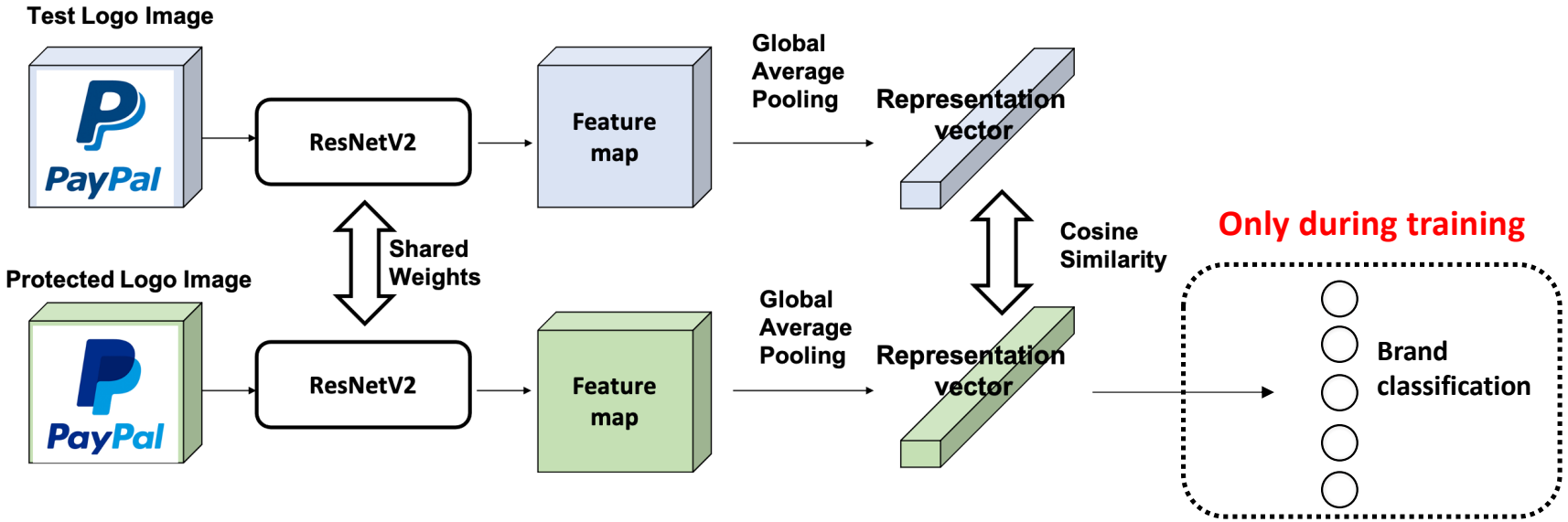
- Traditional way of training Siamese model does not work.
  - Logo variants are very different to generalize.
  - Forcing the model to train different logo variants end up overfitting





Training Siamese Model

- Train model in classification way
- Use the model in Siamese style

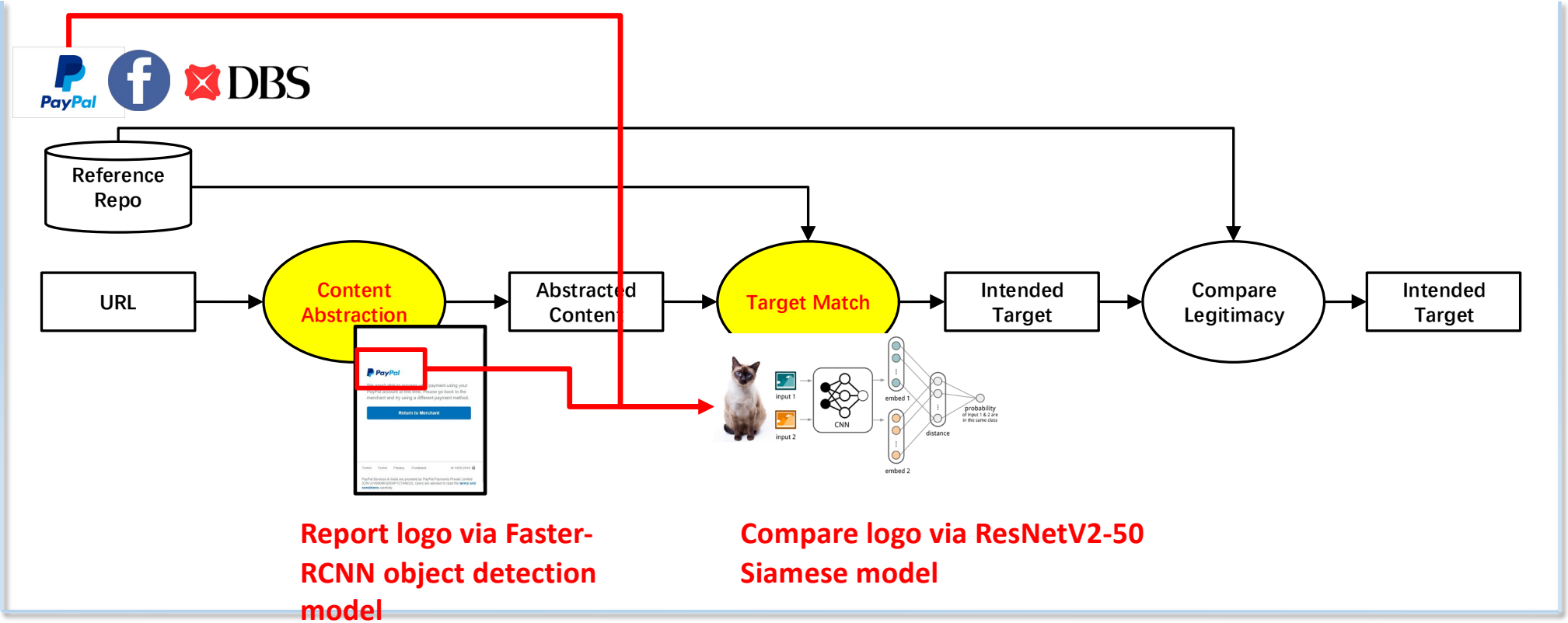


Training Siamese Model

- Use ResnetV2-50 [4] model architecture.
- Apply two-stage training:
  - Stage 1: pretrain a ResnetV2-50 classification model to classify 2341 brand of logos on Logo2K+ dataset [5].
  - Stage 2: finetune the pretrained model to classify 181 target brands.

[4] He, K., Zhang, X., Ren, S., & Sun, J. (2016). Identity mappings in deep residual networks. In *European conference on computer vision* (pp. 630-645). Springer, Cham.
[5] Wang, J., Min, W., Hou, S., Ma, S., Zheng, Y., Wang, H., & Jiang, S. (2020). Logo-2K+: A large-scale logo dataset for scalable logo classification. In Proceedings of the AAAI Conference on Artificial Intelligence (Vol. 34, No. 04, pp. 6194-6201).

Phishpedia Approach Overview



Experiment

- RQ1: Whether Phishpedia can identify the phishing URL effectively?
- RQ2: How good is the performance for individual component (i.e. Logo detector and Siamese)?
- RQ3: Whether Phishpedia can catch more phishing in the wild?

Experiment Setup

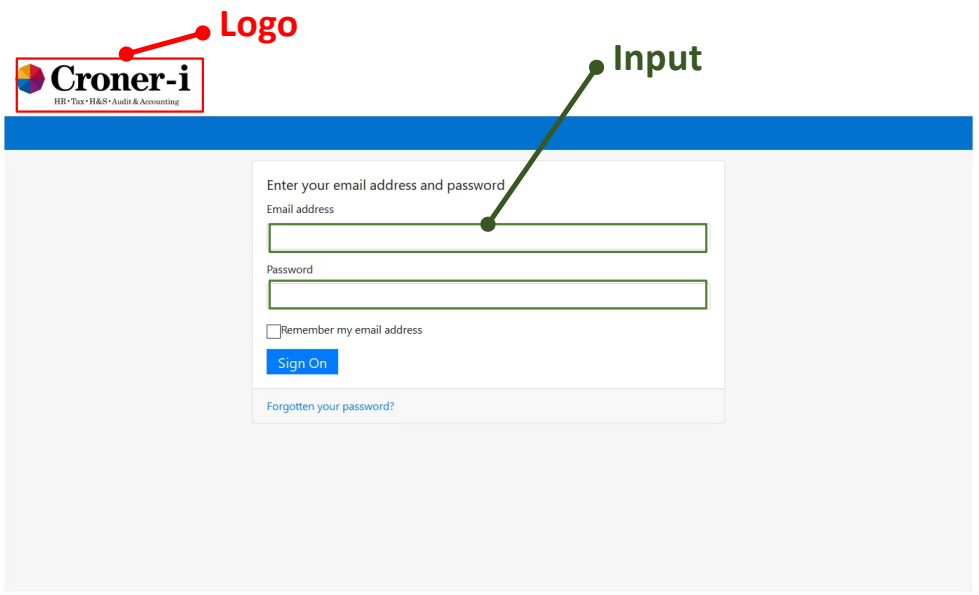
- 29,496 phishing webpages
  - From Openphish
- 29,951 benign webpages
  - Top Alexa
- For each phishing/benign page, we collect
  - Meta-data (i.e. phishing target)
  - Screenshot
  - HTML code

Experiment Setup

- Reference logo database
  - Cover top 181 brands that are mostly attacked from Openphish data
  - Used in Siamese training

Experiment Setup

- 30649 labelled legitimate website (logo & input box annotation)
  - Used in object detector training



RQ1: Overall Phishpedia Performance

Approach	Detection Accuracy		Identification Accuracy	Runtime Overhead (s)
	Precision	Recall		
EMD (*TDSC'06*)	52.0%	76.2%	27.7%	0.19
PhishZoo (*ICSC'11*)	68.9%	81.8%	28.5%	18.2
LogoSense (*Computers & Security*)	20.5%	26.9%	37.8%	27.2
Phishpedia	**98.2%**	**87.1%**	**99.2%**	**0.19**

RQ2: Individual component performance

- Logo detector

Object Class	Logo	Input Boxes	Overall (mAP)
Training AP	52.7	73.5	63.1
Testing AP	49.3	70.0	59.7

- Siamese matching accuracy
  - 93.5%

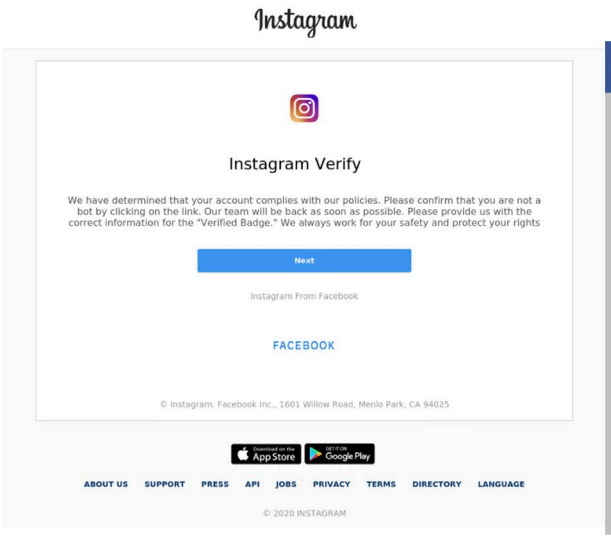
RQ3: Whether Phishpedia can catch more phishing in the wild?

- We deploy Phishpedia on emerging domains fed from CertStream for one month
- Phishpedia report **1820** as phishing, out of which **1704** are real phishing, **1133** are zero-day
- Other tools report too many false positives

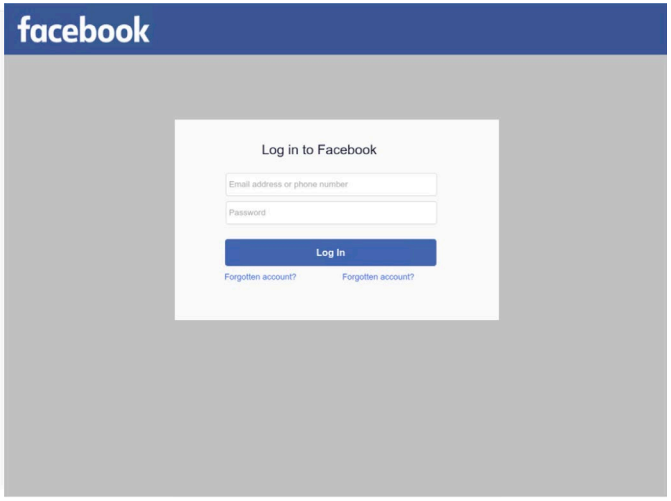
Tool	Category	#Reported Phishing	#Top Ranked Samples	#Real Phishing	#Zero-day Phishing
EMD	Identification	299,082	1000	3	2
Phishzoo	Identification	9,127	1000	8	5
Phishpeida	Identification	1,820	1000	939	623

RQ3: Whether Phishpedia can catch more phishing in the wild?

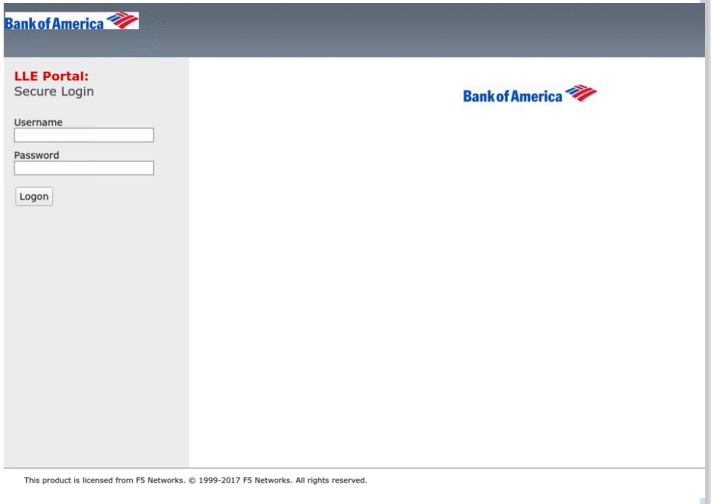
- Found phishing examples



verifiedbadgeforInstagram.ml



www.grab-pay.xyz



www.accountmgmtpl2.bamlqa.com

Takeaways

- Phishpedia is a phishing identification technique helping explain phishing causality.
  - **Visualization annotation**
- Technically, Phishpedia makes the following contributions:
  - **Perfect identity logo identification**
  - **Accurate logo matching model**
  - **Low runtime overhead**
  - **Low bias in phishing dataset**


THANK YOU!