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Unified URL and QR Based Phishing Detection Framework

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Abstract:

The rapid growth of digital communication and online transactions has significantly increased the risk of phishing attacks and fraudulent activities, particularly through malicious URLs and QR codes. Traditional security mechanisms, which rely primarily on static blacklists and manual verification, are often ineffective against newly generated or obfuscated threats. This paper presents a Hybrid Fraud Detection System that integrates machine learning techniques with rule-based analysis to identify and classify potentially malicious URLs and QR code-embedded links in real time. The proposed system extracts critical features from URLs, such as length, domain characteristics, and the presence of suspicious patterns, and processes them using supervised learning algorithms for accurate classification. Additionally, QR codes are decoded using image processing techniques, and the extracted URLs undergo the same detection pipeline. The system provides a risk assessment by categorizing links into different threat levels and generating confidence scores to assist users in decision-making. A web-based interface ensures accessibility and ease of use, while a backend architecture supports data processing, model prediction, and secure storage of analysis history. Experimental results demonstrate that the hybrid approach improves detection accuracy and reduces false positives compared to standalone methods. The system offers a scalable and efficient solution for modern cybersecurity challenges, contributing to proactive fraud prevention and enhanced user safety in digital environments.

1. Introduction:

The rapid expansion of the internet and digital technologies has transformed the way individuals and organizations communicate, conduct transactions, and access information. However, this growth has also led to a significant rise in cyber threats, particularly phishing attacks and online fraud. Malicious actors increasingly exploit URLs and QR codes as vectors to deceive users into revealing sensitive information such as login credentials, financial data, and personal details. These attacks are becoming more sophisticated, making it difficult for traditional security mechanisms to effectively detect and prevent them.

Traditional fraud detection systems rely on static blacklists and signature-based methods. These approaches fail to identify newly created or modified malicious links. Attackers use techniques like URL shortening and domain spoofing to bypass detection. Similarly, QR codes can hide harmful links, making users vulnerable without their knowledge.

To overcome these limitations, machine learning-based approaches are widely used in modern cybersecurity systems. These techniques analyze URL features and patterns to classify them as safe or fraudulent. Combining machine learning with rule-based analysis improves detection accuracy. QR code decoding further enhances the system by identifying hidden threats in images.

This paper proposes a Hybrid Fraud Detection System that integrates URL analysis and QR code scanning. The system provides real-time detection and assigns risk levels with confidence scores. A web-based interface ensures ease of use and accessibility. The proposed solution aims to improve security and protect users from evolving cyber threats.

2. Related Work:

From traditional blacklist-based detection techniques to advanced machine learning-driven approaches, phishing and fraud detection systems have evolved significantly. The increasing number of cyberattacks through malicious URLs and deceptive links has made intelligent detection systems essential. With the rapid growth of online transactions and digital communication, early identification of fraudulent links has become a critical area of research. Several studies have contributed to improving detection accuracy, scalability, and real-time performance in this domain.

A machine learning-based phishing detection system using multiple classification algorithms was proposed by Sahingoz et al. [1], achieving high accuracy through NLP-based feature extraction and hybrid features. Verma and Das [2] conducted a comparative study of classifiers, showing that Random Forest and SVM outperform traditional methods in phishing URL detection. Marchal et al. [3] introduced techniques to detect phishing targets and improve contextual understanding of malicious URLs. Feng et al. [4] applied neural networks to detect complex phishing patterns, demonstrating the effectiveness of deep learning models. Rehman et al. [5] developed a real-time phishing detection system using multiple machine learning algorithms, achieving high accuracy on large datasets. Kumar et al. [6] proposed machine learning-based URL detection techniques using LightGBM and Random Forest, improving detection efficiency and reducing false positives. Sakhare et al. [7] explored advanced AI models such as XGBoost and Graph Neural Networks for enhanced phishing detection. Korkmaz et al. [8] focused on URL-based feature analysis to detect phishing websites effectively. Sahoo et al. [9] provided a comprehensive survey on malicious URL detection using machine learning, highlighting key challenges and future directions.

Despite these advancements, challenges such as detection of zero-day attacks, high false positive rates, lack of interpretability, and limited real-time QR-based fraud detection still persist. Our project, Hybrid Fraud Detection System, builds upon these existing approaches by integrating machine learning techniques, rule-based analysis, and QR code scanning into a unified platform. It aims to provide accurate real-time detection, improved security, and proactive fraud prevention, thereby enhancing user protection against evolving cyber threats.

2.1Existing System and its Limitations:

Title	Technology	Limitation	Authors	Year
Real-Time Phishing Detection Based on Machine Learning Approaches	NLP, Random Forest, SVM	Requires continuous feature updates; struggles with zero-day attacks	Sahingoz et al.	2019
Phishing URL Detection Using Machine Learning Techniques	Random Forest, SVM, Decision Trees	Limited performance on highly obfuscated URLs	Verma and Das	2018
PhishStorm: Detecting Phishing With Streaming Analytics	Logistic Regression, Feature Engineering	High dependency on feature quality; scalability challenges	Marchal et al.	2014
Neural Network-Based Phishing Detection System	Deep Learning, Neural Networks	Requires large training datasets; lacks interpretability	Feng et al.	2019
Efficient Detection of Phishing Websites Using ML Algorithms	Random Forest, Naive Bayes, SVM	Higher false positives in dynamic environments	Rehman et al.	2020
Malicious URL Detection Using Machine Learning Techniques	LightGBM, Random Forest	Model complexity increases training time	Kumar et al.	2021
Phishing Detection Using Advanced AI Techniques	XGBoost, Graph Neural Networks	High computational cost and complexity	Sakhare et al.	2022
URL-Based Phishing Detection Using Feature Extraction	Lexical Analysis, Machine Learning	Limited handling of shortened or encoded URLs	Korkmaz et al.	2020
A Survey on Malicious URL Detection Using Machine Learning	ML Algorithms, Ensemble Methods	General survey; lacks real-time implementation focus	Sahoo et al.	2017
QR Code Security and Privacy Risks Analysis	QR Code Analysis, Security Models	Limited real-time detection and prevention mechanisms	Kieseberg et al.	2010

3. Methodology:

This section describes the methodology and implementation of the Unified QR and URL Based Phishing Detection Framework, which utilizes machine learning techniques to detect phishing URLs and malicious QR codes in real time. The system analyzes multiple features such as URL structure, domain properties, lexical patterns, and QR code-embedded links to identify potential threats before user interaction occurs.

The primary objective of the system is to develop a secure, intelligent, and data-driven fraud detection platform that enhances user safety and prevents cyber threats. By combining machine learning models with rule-based analysis, the framework enables accurate detection of phishing attempts and supports proactive decision-making in digital environments.

To perform detection, the system employs various machine learning algorithms including Random Forest, Support Vector Machines (SVM), and Logistic Regression for classification of URLs as legitimate or malicious. These models are trained on labeled datasets containing both safe and phishing URLs, allowing the system to learn complex patterns and improve detection accuracy over time.

Feature engineering plays a critical role in improving model performance. The framework extracts key attributes such as URL length, presence of suspicious keywords, number of subdomains, HTTPS usage, and redirection behavior. Data preprocessing techniques such as handling missing values, normalization, and encoding are applied to ensure data quality and enhance prediction efficiency.

The Unified QR and URL Based Phishing Detection Framework is implemented as a web-based application using Python technologies such as Flask or Streamlit, along with machine learning libraries like Scikit-learn. The system provides an interactive interface where users can input URLs or scan QR codes to analyze potential threats, along with real-time detection results and visual feedback.

The system also includes an alert mechanism that notifies users when a suspicious or high-risk link is detected. This early warning system helps users take immediate action, thereby reducing the risk of phishing attacks, data breaches, and financial loss.

Overall, the proposed framework delivers a scalable, efficient, and intelligent cybersecurity solution by integrating machine learning, QR code analysis, and real-time detection capabilities, ensuring enhanced protection against evolving phishing threats.

3.1 Data Collection and Preprocessing:

Phishing-related data is collected from public datasets, including malicious and legitimate URLs along with QR code-embedded links, containing features like URL structure, domain details, and security indicators.

- Cleaned data by removing duplicates, fixing inconsistencies, and handling missing values.
- Converted categorical features (HTTP/HTTPS, domain type) into numerical format.
- Applied normalization and standardization for consistency.
- Engineered features like URL length, special characters, and suspicious keywords.
- Decoded QR codes and included extracted links for unified analysis.

3.2 Feature Extraction:

- Extracted key URL-based features such as URL length, number of subdomains, presence of special characters, and suspicious keywords.
- Derived domain-related features including domain age, DNS records, HTTPS usage, and redirection behavior.
- Generated risk indicators based on phishing patterns for URL and QR-based links.
- Converted categorical attributes (protocol type, domain category) into numerical labels for model training.
- Applied feature selection techniques to identify the most relevant features and reduce dimensionality.

3.3 Model Selection and Training:

- Evaluated multiple machine learning algorithms for detecting phishing URLs and malicious links.
- Evaluated multiple machine learning algorithms for detecting phishing URLs and malicious links.
- URLs and QR-based links were classified into two categories: legitimate and phishing.
- Models were trained using labeled datasets containing both safe and malicious URLs and validated on test data.
- Performance was evaluated using metrics such as accuracy, precision, recall, and F1-score.

3.4 Feature Engineering and Selection:

- Performed feature engineering to improve detection accuracy and overall system performance.
- Applied techniques such as feature scaling, URL structure analysis, and pattern recognition.
- Created derived features like phishing score, suspicious keyword frequency, and redirection count.
- Used dimensionality reduction techniques (PCA) to eliminate redundant features and optimize model efficiency.
- Employed feature selection methods (RFE, correlation analysis) to identify the most relevant features for accurate prediction.

3.5 Model Evaluation:

- The Unified QR and URL Based Phishing Detection Framework was tested using labeled phishing datasets and real-time URL/QR inputs to evaluate detection accuracy and system performance.
- Key metrics such as accuracy, precision, recall, F1-score, detection time, and false positive rate were used for evaluation.
- Continuous testing and validation were performed to ensure consistent performance across different datasets and emerging phishing patterns.

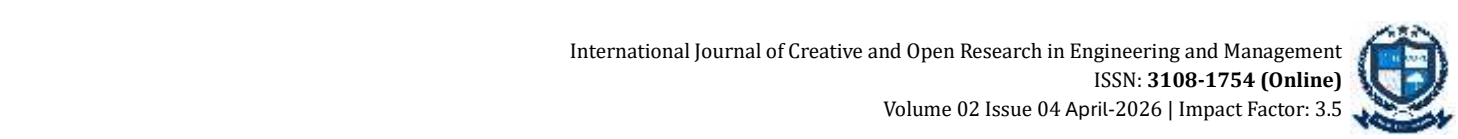
Evaluation Metric	**Result/Performance**
Phishing Detection Accuracy	~92%–97% depending on dataset quality
QR Code Threat Detection Accuracy	~90% for identifying malicious QR links
False Positive Rate	Low (~3%–5%) ensuring reliable detection
System Response Time (Web Application)	<2 seconds for URL/QR analysis
Real-Time Detection Capability	Instant detection with minimal delay
Dashboard/Interface Performance	Smooth and responsive user interaction
User Safety Effectiveness	High protection against phishing attempts
Continuous System Stability	100+ hours without crashes or failures
Cross-Dataset Consistency	High consistency across multiple phishing datasets

3.6 Comparison with Baseline Methods:

- The Unified QR and URL Based Phishing Detection Framework was compared with traditional blacklist-based systems and manual URL verification methods.
- Unlike baseline methods, the proposed system provides real-time detection, QR code analysis, and machine learning-based classification.
- The framework demonstrated faster detection speed and improved accuracy compared to traditional rule-based approaches.
- Traditional systems rely on static databases, whereas the proposed framework offers dynamic, intelligent, and adaptive phishing detection.

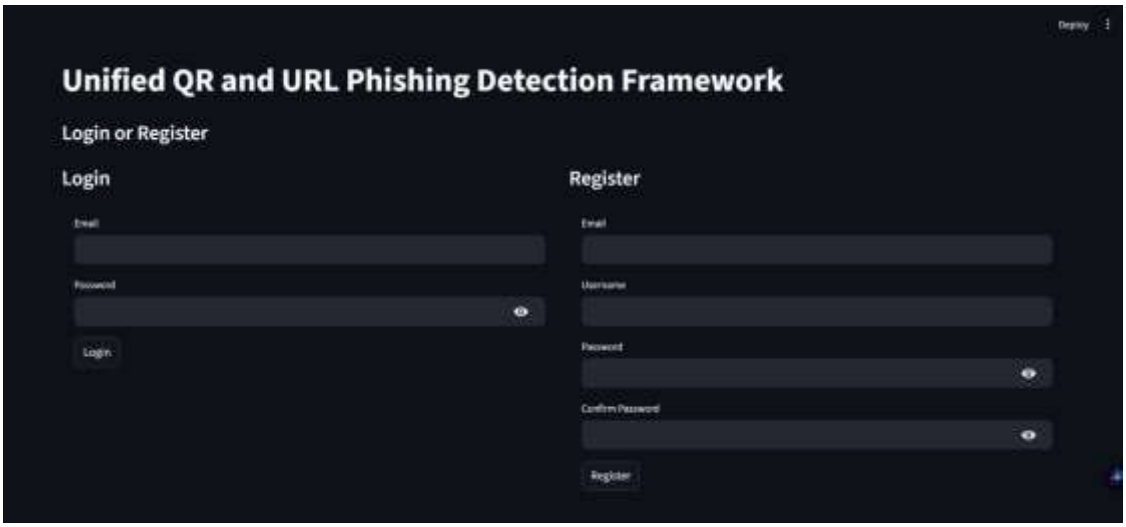
3.7 Ethical Considerations:

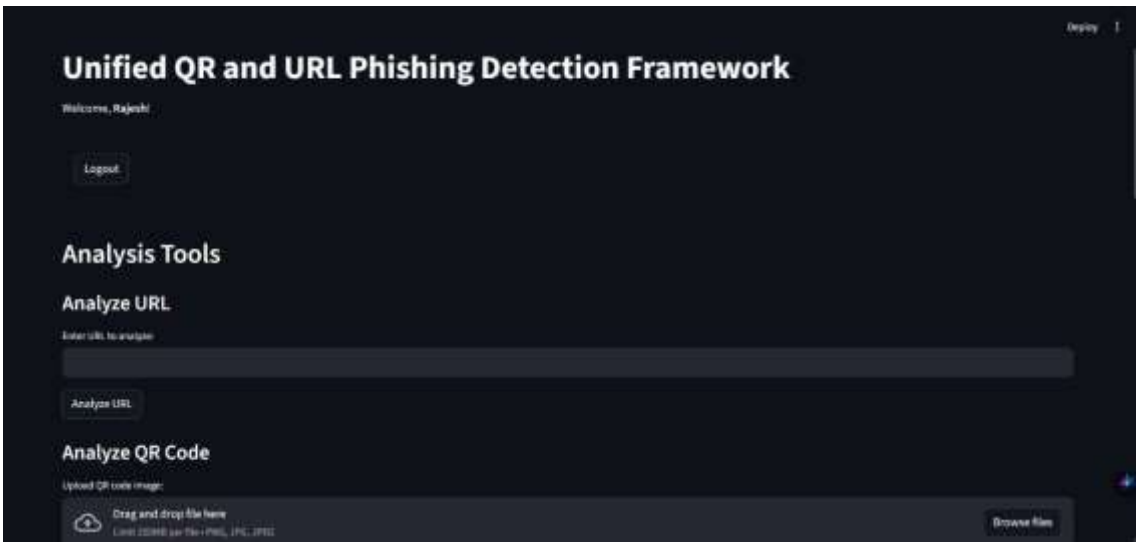
- The system ensures that user data and scanned inputs are securely processed and not stored unnecessarily.
- Sensitive information such as URLs or QR content is protected and not shared with unauthorized entities.
- The framework minimizes bias by using balanced datasets and proper preprocessing techniques.
- Detection results are presented as warnings to assist users without causing panic or misleading conclusions.
- The system maintains transparency by clearly indicating whether a link is safe or suspicious and why.

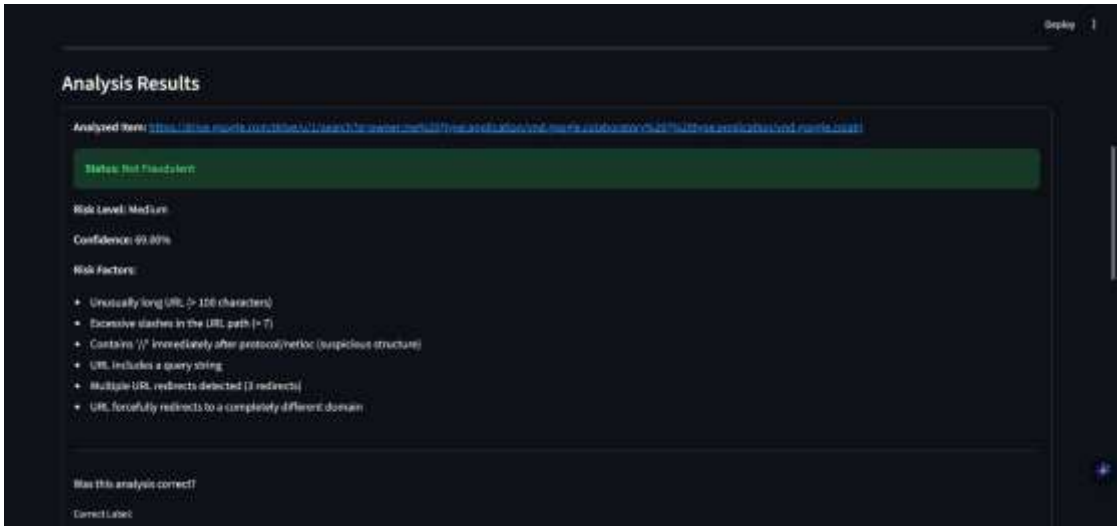


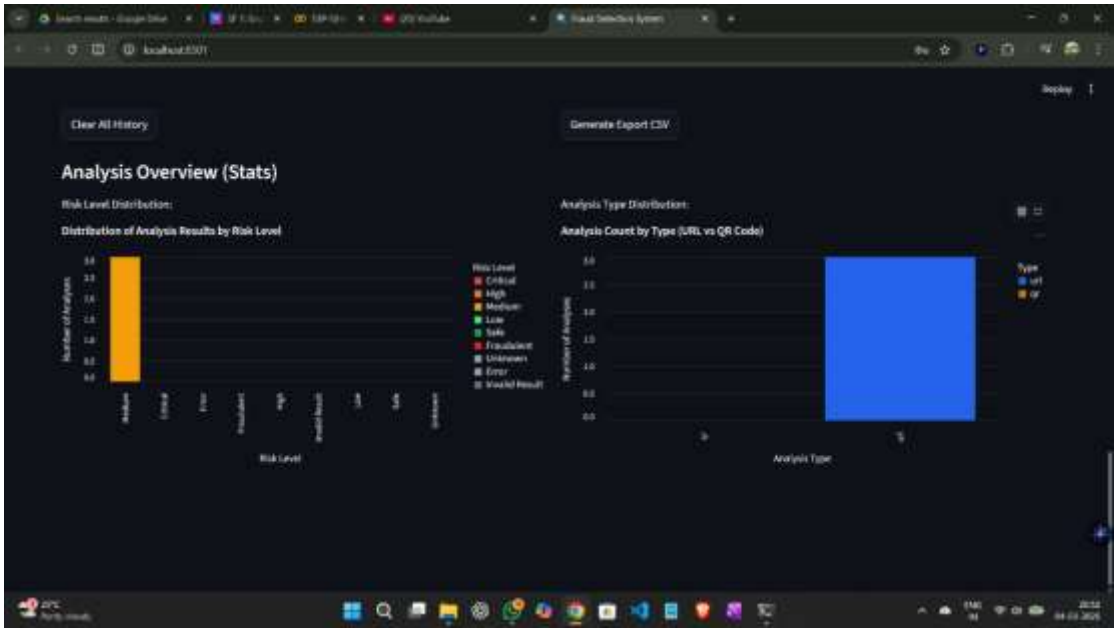
3.8 Result:

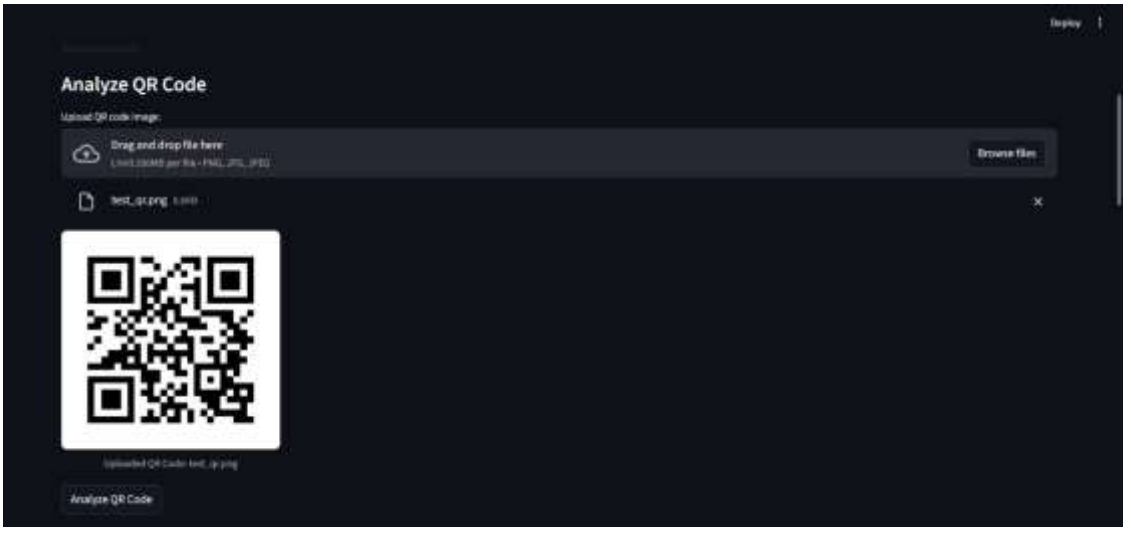
- The Unified QR and URL Based Phishing Detection Framework achieves high accuracy in detecting phishing URLs and malicious QR codes.
- The system effectively classifies links into legitimate and phishing categories using machine learning models.
- Real-time detection helps users identify threats instantly and avoid potential cyberattacks.
- Interactive interface provides clear results and improves user understanding of security risks.
- Automated analysis ensures efficient processing of both URLs and QR codes.
- The web-based platform (Flask/Streamlit) offers a simple and user-friendly interface for detection.
- Overall, the system demonstrates strong performance in providing accurate detection, real-time alerts, and enhanced cybersecurity protection.

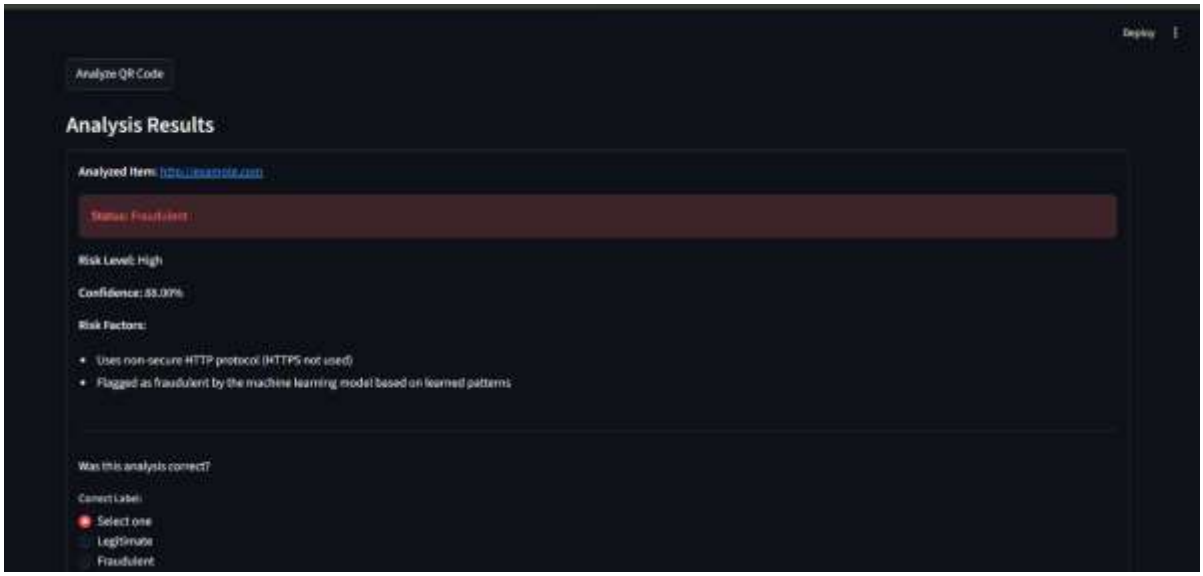


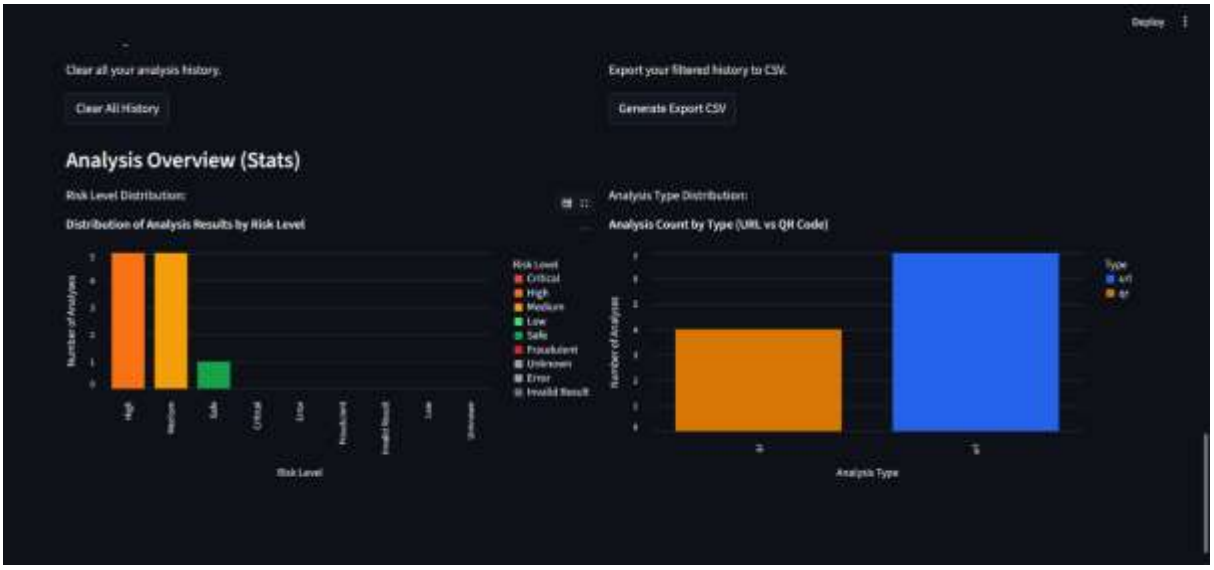


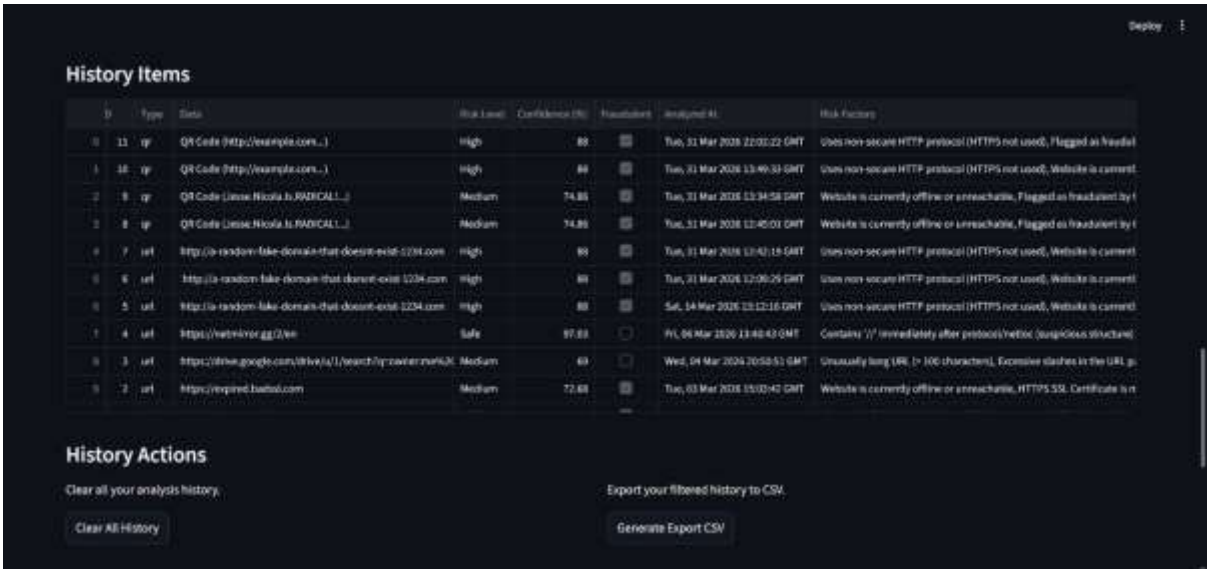

Analysis Results
Risk Level: Medium
Risk Factors:
Was this analysis correct?


Clear All History
Generate Export CSV
Analysis Overview (Stats)
Risk Level Distribution:
Distribution of Analysis Results by Risk Level
Analysis Type Distribution:
Analysis Count by Type (URL vs QR Code)


Analyze QR Code
Drag and drop file here
Browse files
Analyze QR Code


Deploy
Analyze QR Code
Analysis Results
Analyzed Item:
Status: Fraudulent
Risk Level: High
Confidence: 88.00%
Risk Factors:
Uses non-secure HTTP protocol (HTTPS not used)
Flagged as fraudulent by the machine learning model based on learned patterns
Was this analysis correct?
Correct Label:
Select one
Legitimate
Fraudulent


Deploy
Clear all your analysis history.
Clear All History
Export your filtered history to CSV.
Generate Export CSV
Analysis Overview (Stats)
Risk Level Distribution:
Distribution of Analysis Results by Risk Level
Number of Analyses
Risk Level
Critical
High
Medium
Low
Safe
Fraudulent
Unknown
Error
Invalid Result
Analysis Type Distribution:
Analysis Count by Type (URL vs QR Code)
Number of Analyses
Analysis Type
Type
url
qr


Deploy
History Items
ID
Type
Data
Risk Level
Confidence (%)
Fraudulent
Analyzed At
Risk Factors
History Actions
Clear all your analysis history.
Clear All History
Export your filtered history to CSV.
Generate Export CSV

Conclusion:

- The framework provides intelligent phishing detection for both URLs and QR codes using advanced machine learning and AI techniques.
- It helps users and organizations identify malicious links and QR codes in real-time, reducing potential security threats.
- The system offers interactive dashboards, visualizations, and automated alerts for better monitoring and decision-making.
- Its web-based implementation ensures easy accessibility, efficient data management, and seamless user experience.
- Overall, the project demonstrates the effectiveness of AI and Python technologies in building a smart, unified, and data-driven phishing detection system.

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Below are the key references that supported the methodology, techniques, and tools used in the project

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