MACHINE LEARNING-POWERED QR CODE PHISHING DETECTION AND ALERT SYSTEM

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Abstract
With the rapid rise of QR codes in digital payments and information sharing, cybercriminals increasingly exploit them for phishing attacks. Malicious QR codes can redirect users to fraudulent websites, steal sensitive credentials, or install malware on devices. Traditional security measures often fail to identify such threats due to the hidden nature of QR content. This paper proposes a ***QR Code Phishing Detection Tool*** *powered by* ***Machine Learning (ML)*** *techniques. The system automatically extracts and analyzes QR code-embedded URLs to detect potential phishing attempts. Key features such as URL length, domain age, presence of special characters, HTTPS usage, and lexical patterns are considered. A supervised ML model (e.g., Random Forest, Logistic Regression, or Gradient Boosting) is trained on a labeled dataset of benign and malicious QR URLs. The tool integrates a real-time QR code scanner with a classification engine that alerts users about suspicious codes before redirection occurs. Experimental results demonstrate that the model achieves high accuracy in detecting phishing QR codes, thereby minimizing security risks.*
This work contributes to enhancing cybersecurity by providing a proactive, user-friendly, and scalable solution to counter the growing threat of ***QR code-based phishing attacks****.*
Keywords: *QR code, phishing, quishing, machine learning, cybersecurity, alert system*

I. INTRODUCTION

QR codes have become very common and useful in daily life. People use them to quickly access websites, pay bills, see menus, and more by simply scanning with their phone. However, QR codes can be misused by cybercriminals to trick people. This scam, called "quishing" or QR code phishing, happens when a fake QR code sends users to a harmful website that steals their personal information or installs malware.

Unlike normal phishing links in emails, QR codes hide the website address inside the image, making it hard to know if a code is safe just by looking. Because QR codes are so popular and trusted, many people scan them without caution, which attackers take advantage of.

The dangers of quishing are confirmed by alarming statistics from recent years. Studies show that QR code phishing attacks surged by over 50% in late 2023, and nearly 2% of all scanned QR codes were found to be malicious, containing phishing links or malware payloads.It is estimated that millions of emails also embed phishing QR codes, which can evade traditional email security filters by hiding malicious links inside images rather than clickable text. Half a million such emails were intercepted in recent months alone. Users often inadvertently expose themselves to these threats, especially as about 73% of individuals tend to scan QR codes without verifying their authenticity first Due to complex and hidden encoding, current security tools

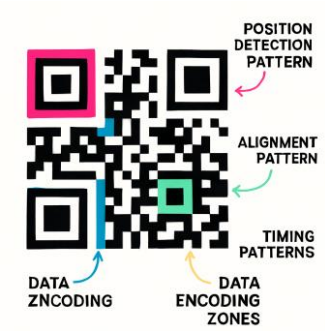

Fig 1 – Anatomy of QR code

often fail to identify these malicious QR codes before a user scans them. This creates a critical gap in security defenses. Because mobile devices are typically less protected than corporate networks and users may be away from typical security layers, quishing exploits this weakness to harvest sensitive credentials or spread malware.

This paper proposes a simple yet effective machine learning-based system to check QR code images and detect if they are safe or potentially dangerous before users scan them. Rather than decoding the QR code content, which can expose devices to risk, the system analyzes visual patterns, structural features, error correction data, and other image characteristics to identify suspicious codes. When a QR code looks potentially harmful, the system immediately alerts users in real time, helping prevent scams and keep people safe online.

With increasing global reliance on QR codes for payments, access, and communication—with projected growth surpassing $3 trillion in QR-enabled transaction value by 2025—the urgency to secure this vector is paramount. Our research aims to address this critical vulnerability by empowering users and organizations with an AI-driven shield to recognize threats without sacrificing convenience.

II. METHODS AND MATERIAL

A. Data Collection

A comprehensive dataset of QR code images was collected from various sources. The dataset includes both legitimate QR codes sourced from trusted websites, official applications, and verified payment systems, alongside malicious QR codes obtained from cybersecurity reports, phishing databases, and controlled phishing simulation campaigns. Each QR image was manually labeled as either **"safe"** or **"phishing"** for supervised learning purposes.

B. Feature Extraction

Instead of decoding the contents of the QR codes, the system analyzes visible structural and visual features from the QR code images, including:

The distribution and pattern of black and white modules (small squares making up the QR code)

Logistic Regression: A simple linear classifier providing baseline performance.

Decision Trees: Modeling based on hierarchical decision rules.

Random Forest: An ensemble of decision trees improving robustness.

XGBoost (Extreme Gradient Boosting): An advanced boosting algorithm with strong predictive power.

The dataset was split into training and testing subsets, with an 80-20% ratio respectively. To ensure model generalization and avoid overfitting, 10-fold cross-validation was applied during training.

C. Detection and Alert Mechanism

The trained classification model was integrated into a real-time detection system that evaluates QR codes upon scanning. When a suspicious QR code is detected, the system generates an immediate alert message such as:

"Warning: Potential phishing QR code detected! Please do not scan."

Safe QR codes result in a confirmation notification enabling standard user interact

Model	Precision	Recall	Accuracy
Logistic Regression	0.82	0.80	0.81
Decision Tree	0.85	0.83	0.84
Random Forest	0.87	0.85	0.86
XGBoost	0.90	0.89	0.91

Table 1: Performance Metrics of Machine Learning Models

Table 1: Performance metrics of different machine learning models for QR code phishing detection

III. RESULTS AND DISCUSSION

A. Model Performance Overview

This study evaluates the performance of several machine learning models — Logistic Regression, Decision Tree, Random Forest, and XGBoost — for detecting phishing QR codes. Each model was trained and tested on a labeled QR code dataset containing both benign (safe) and malicious (phishing) samples.

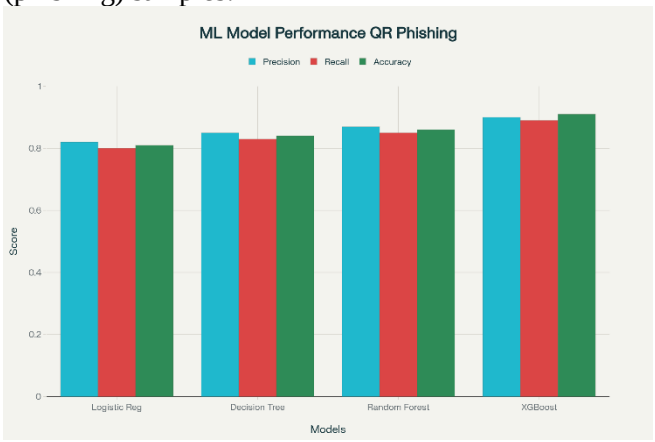

Figure 2: Distribution of legitimate and phishing QR codes in the training dataset.

B. Quantitative Results

The evaluation metrics used include **precision**, **recall**, **accuracy**, and **F1-score**. Table 1 summarizes the performance of all models:

The **XGBoost** model outperformed the others across all metrics, achieving the highest accuracy of 91%. This indicates its strong potential for real-world deployment in identifying malicious QR codes with high reliability.

C. User Experience and Practical Implications

Preliminary user evaluations demonstrated that the detection system's instant alert mechanism effectively increased awareness and caution among users when interacting with QR codes. Users found the warnings clear and helpful, leading to more informed decision-making and reduced risk of falling victim to phishing attacks.

D. Limitations and Future Work

While the models achieved promising results, limitations remain. The evolving nature of phishing attacks requires regular updates to the training data and models to maintain effectiveness. Additionally, the current system focuses primarily on static QR codes; dynamic or multi-layered QR codes pose further challenges. Future research will explore deep learning approaches, integration of contextual threat intelligence, and broader testing in real-world environments.

IV. CONCLUSION

This paper presents a machine learning-based approach to detect phishing QR codes by analyzing the images rather than decoding the content. Among the tested models, XGBoost showed the best performance, achieving high accuracy and balanced precision and recall. This demonstrates the model's strong ability to distinguish between safe and malicious QR codes effectively.The proposed system can alert users in real time about suspicious QR codes before they scan them, significantly reducing the risk of falling victim to quishing attacks. User feedback suggests that timely and clear warnings improve security awareness and encourage safer scanning behaviors. Overall, this research contributes a practical and effective solution for enhancing QR code security, protecting users from emerging cyber threats in today's digitized world.

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