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FACULTY OF ENGINEERING

DEPARTMENT OF COMPUTER ENGINEERING

MOBILE QR CODE-BASED PHISHING URL DETECTION

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SUPERVISOR
PROF. DR. İBRAHIM SOĞUKPINAR

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This study has been accepted as an Undergraduate Graduation Project in the Department of Computer Engineering on 16/01/2025 by the following jury.

JURY

Member
(Supervisor) : Prof. Dr. İbrahim Soğukpınar

Member : Dr. Gökhan Kaya

ABSTRACT

QR codes have become an essential tool for sharing and accessing information quickly and efficiently. Their usage spans various domains, including advertising, payment systems, authentication, and more. However, the increasing adoption of QR codes has also introduced significant security risks. Cybercriminals exploit QR codes to direct unsuspecting users to phishing websites, aiming to steal sensitive information or install malicious software. The concealed nature of QR code content makes it difficult for users to verify the legitimacy of embedded links, exposing them to potential threats.

This project focuses on developing a mobile QR code scanner that analyzes URLs extracted from scanned QR codes. Using a machine learning model, the system classifies URLs as safe or malicious in real-time, providing immediate feedback to users. The project involves:

1. Building a balanced dataset of safe and malicious URLs from reliable sources.

2. Extracting meaningful features from URLs, such as length, presence of IP addresses, HTTPS usage, and special characters.

3. Training a neural network model with these features to achieve high classification accuracy.

4. Deploying the trained model in a Flutter-based mobile application for seamless user interaction.

The machine learning model, trained on approximately 30,000 URLs, achieved a classification accuracy of 90%, with precision and recall rates of 88% and 92%, respectively. The TensorFlow Lite format was used to optimize the model for mobile devices, ensuring fast and efficient real-time predictions.

The mobile application integrates the model with a user-friendly interface, allowing users to scan QR codes or manually input URLs for security analysis. Safe URLs are indicated with green highlights, while malicious URLs trigger red warnings and advisory messages. The QR code scanning capability of the application simplifies the process, minimizing manual effort and improving security.

This project not only addresses the growing concerns about QR code phishing attacks but also demonstrates the potential of combining machine learning with mobile technologies for practical security solutions. Future work may include real-time model updates through API integrations and the addition of multilingual support to expand its usability globally.

Keywords: QR codes, phishing detection, machine learning, mobile security, URL analysis.

ÖZET

QR kodlar, bilgilerin hızlı ve verimli bir şekilde paylaşılmasını ve erişilmesini sağlayan önemli bir araç haline gelmiştir. Reklamcılık, ödeme sistemleri, kimlik doğrulama gibi birçok alanda yaygın olarak kullanılmaktadır. Ancak, QR kodların artan kullanımı, beraberinde önemli güvenlik risklerini de getirmiştir. Siber suçlular, QR kodları kullanarak kullanıcıları phishing (oltalama) saldırıları için tasarlanmış zararlı web sitelerine yönlendirmekte ve bu sayede hassas bilgileri çalmak veya kötü amaçlı yazılımlar yüklemek istemektedir. QR kodların içeriğinin gizli doğası, kullanıcıların bağlantıları doğrulamasını zorlaştırarak potansiyel tehditlere maruz bırakmaktadır.

Bu proje, taranan QR kodlardan elde edilen URL'leri analiz ederek kullanıcı güvenliğini artırmayı amaçlayan güvenli bir mobil QR kod tarayıcı geliştirilmesine odaklanmaktadır. Sistem, bir makine öğrenimi modeli kullanarak URL'leri gerçek zamanlı olarak güvenli veya zararlı olarak sınıflandırır ve kullanıcılara anında geri bildirim sağlar. Proje kapsamında:

1. Güvenilir kaynaklardan elde edilen güvenli ve zararlı URL'lerden oluşan dengeli bir veri seti oluşturulmuştur.

2. URL'lerden uzunluk, IP adresi kullanımı, HTTPS protokolü ve özel karakterlerin varlığı gibi anlamlı özellikler çıkarılmıştır.

3. Bu özelliklerle bir yapay sinir ağı modeli eğitilmiş ve yüksek doğruluk oranına ulaşılmıştır.

4. Eğitilen model, kullanıcı dostu bir mobil uygulama aracılığıyla kullanıma sunulmuştur.

Yaklaşık 30.000 URL üzerinde eğitilen makine öğrenimi modeli,

Mobil uygulama, QR kod tarayıcı ve manuel URL giriş özelliklerini kullanıcı dostu bir arayüzle entegre eder. Güvenli URL'ler yeşil renk ile gösterilirken, zararlı URL'ler kırmızı uyarılar ve bilgilendirme mesajlarıyla kullanıcıya sunulmaktadır. Uygulamanın QR kod tarama yeteneği, manuel işlem ihtiyacını azaltarak süreci kolaylaştırırken güvenliği artırmaktadır.

Bu proje, QR kodlarla ilişkili phishing saldırılarına yönelik büyüyen endişeleri ele almakla kalmayıp, makine öğrenimi ile mobil teknolojilerin pratik güvenlik çözümleri oluşturma potansiyelini de göstermektedir. Gelecek çalışmalarda, API entegrasyonları aracılığıyla modelin gerçek zamanlı güncellenmesi ve çoklu dil desteği eklenerek uygulamanın küresel kullanılabilirliği artırılabilir.

Anahtar Kelimeler: QR kod, oltalama (phishing) tespiti, makine öğrenimi, mobil güvenlik, URL analizi.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to my advisor, Prof. Dr. İbrahim Soğukpınar, for his invaluable guidance, encouragement, and continuous support throughout the development of this project. His expertise and constructive feedback have been instrumental in shaping this work.

I also extend my sincere thanks to the Department of Computer Engineering at Gebze Technical University for providing me with the necessary resources and a supportive environment to successfully complete this project.

A special note of thanks goes to my friends for their encouragement during this challenging journey. Their support has been a source of strength and motivation.

This project has been a valuable learning experience, and I am deeply grateful to everyone who contributed to its realization.

Ali Asım Coşkun

LIST OF SYMBOLS AND ABBREVIATIONS

Symbol or Abbreviation	:	**Explanation**
URL	:	Uniform Resource Locator
QR Code	:	Quick Response Code
ML	:	Machine Learning
API	:	Application Programming Interface
HTTPS	:	HyperText Transfer Protocol Secure
IP	:	Internet Protocol
CSV	:	Comma-Separated Values
TFLite	:	TensorFlow Lite
UX	:	User Experience
UI	:	User Interface
ReLU	:	Rectified Linear Unit
F1 Score	:	Harmonic mean of precision and recall
Accuracy	:	Correct predictions over total predictions
Precision	:	True positives over all positive predictions
Recall	:	True positives over true positives and false negatives

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1. INTRODUCTION

1.1. Project Overview

QR codes have become increasingly popular in daily life due to their ability to facilitate quick information sharing and easy access. With the widespread use of mobile devices, QR codes are now commonly employed in advertising, payment systems, and authentication processes. While this technology provides convenience for users, it also introduces potential security vulnerabilities. Cybercriminals exploit fake QR codes to redirect users to malicious websites, aiming to steal personal information.

This project aims to protect users by analyzing the security of URLs extracted from QR codes. Using machine learning techniques, the system classifies URLs as either safe or malicious and delivers these analysis results through a mobile application.

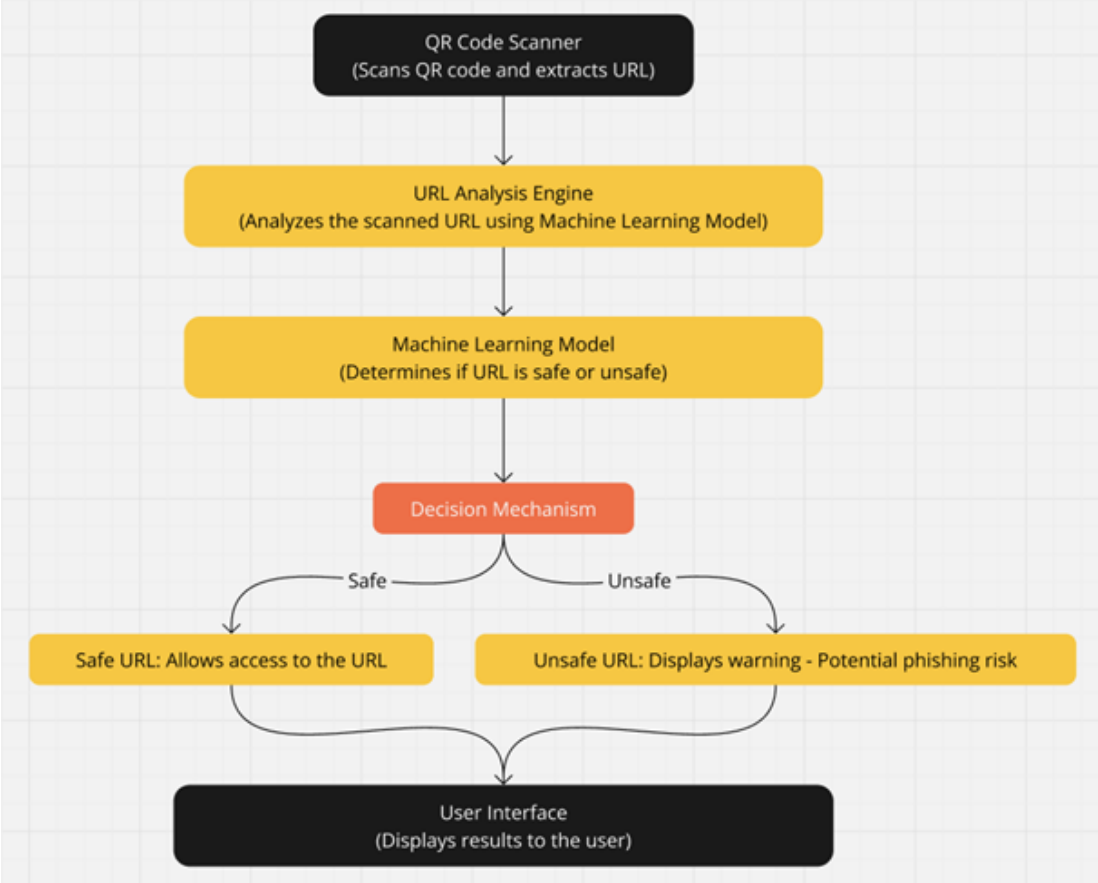

Figure 1.1: System Overview of the Project

1.2. Problem Statement and Motivation

As QR codes have become more widespread, phishing attempts and other malicious activities have increased significantly:

- **Problem:** QR codes often contain encrypted information, and users cannot view the content until the code is scanned. This makes it easier for attackers to hide malicious content within QR codes.
- **Motivation:** The motivation behind developing this project is to enable users to use QR codes securely and prevent access to malicious websites.

1.3. Objectives of the Project

This project aims to achieve the following objectives:

1. Develop a machine learning model to determine whether the URLs extracted from QR codes are safe.
2. Integrate the developed model into a mobile application to enable real-time analysis for users.
3. Provide a user-friendly interface to display the analysis results in an easily understandable manner.

1.4. Scope of the Project

The scope of this project includes the following steps:

- Creating and cleaning a dataset of malicious and safe URLs.
- Extracting URL features (e.g., URL length, HTTPS usage).
- Classifying URLs using machine learning models.
- Developing an optimized mobile application that works on mobile devices (using the Flutter framework).
- Enabling real-time analysis of QR codes scanned by users.

2. THEORETICAL FOUNDATIONS AND SIMILAR TOOLS

2.1. QR Code Technology and Security Risks

2.1.1. Technical Structure of QR Codes

QR codes are a type of two-dimensional barcode that can store information both horizontally and vertically. Developed by Denso Wave in Japan in 1994, QR codes are known for their high data capacity and low error rates. The key components of a QR code include:

- **Position Markers:** These markers determine the orientation of the QR code.
- **Data Area:** The main region where the actual information is stored.
- **Error Correction:** A system used to reduce data loss and improve reliability.

2.1.2. Security Risks

While QR codes provide significant convenience for users, they also introduce several security threats:

- **Lack of Transparency:** Users cannot view the content of a QR code before scanning it. This creates opportunities for malicious actors to hide harmful links.
- **Fake QR Codes:** Real QR codes can be replaced with fake ones, leading users to malicious websites.
- **Malware Distribution:** QR codes can trigger the download of malicious software without the user's knowledge.

—

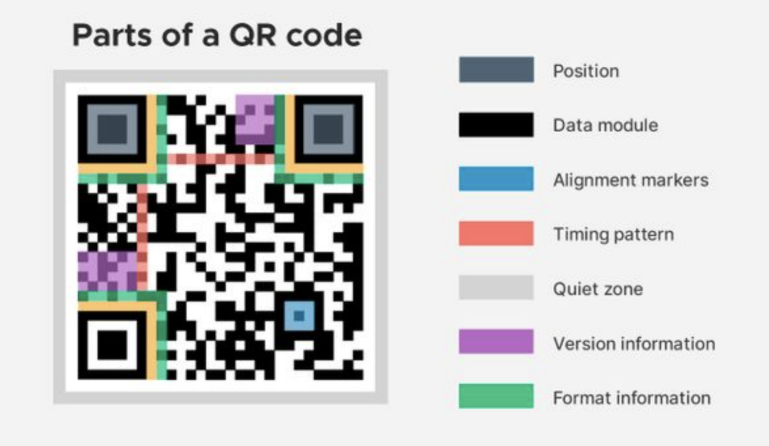

Figure 2.1: Key Components of a QR Code

2.2. Phishing Attacks and URL Analysis Techniques

2.2.1. Phishing Attacks

Phishing is a common method used by cybercriminals to steal personal information from users. These attacks typically involve the following tactics:

- **Fake Websites:** Creating websites that closely resemble legitimate ones to deceive users.
- **Urgent Messages:** Using messages that create a sense of urgency, such as ”Your account has been locked!” to prompt immediate action.
- **Trusted Brands:** Impersonating well-known brands to appear credible and trustworthy.

2.2.2. URL Analysis Techniques

Analyzing URLs is a critical method for detecting phishing attempts. The primary techniques used include:

1. **Lexical Features:**
    - URL length.
    - Use of special characters (e.g., @, -).
2. **Host-Based Features:**
    - Age of the domain and registration details.

3. **Content-Based Features:**

   - Analyzing the content of the webpage for indicators of phishing, though this requires accessing the website, which may not always be safe.

—

2.3. Table: Lexical and Host-Based Features

Table 2.1: Features Used in URL Analysis

Feature	**Description**
URL Length	Highlights that phishing URLs are often unusually short or excessively long.
HTTPS Usage	Indicates whether the URL uses a secure connection. URLs without HTTPS are potential risks.
IP Address Usage	URLs using IP addresses instead of domain names are more likely to be malicious.
Subdomain Count	A high number of subdomains in a URL may indicate phishing activity.
Special Characters	Characters like '@' or '-' are commonly found in phishing URLs and can serve as red flags.

3. PROJECT DESIGN

3.1. General Design and Descriptions

This project aims to design a system that analyzes the security of URLs obtained through QR codes and prevents phishing attempts. The system ensures that users can safely scan QR codes and are protected from being redirected to malicious websites. The general design of the project consists of the following components:

1. **QR Code Scanner:**
    - Uses the mobile device's camera to scan QR codes and extract the embedded URL.
2. **Feature Extraction Module:**
    - Extracts necessary features from the scanned URL to detect phishing attempts.
3. **Machine Learning Model:**
    - Classifies the URL as safe or malicious based on the extracted features.
4. **User Interface:**
    - Presents the analysis results visually and clearly to the user.

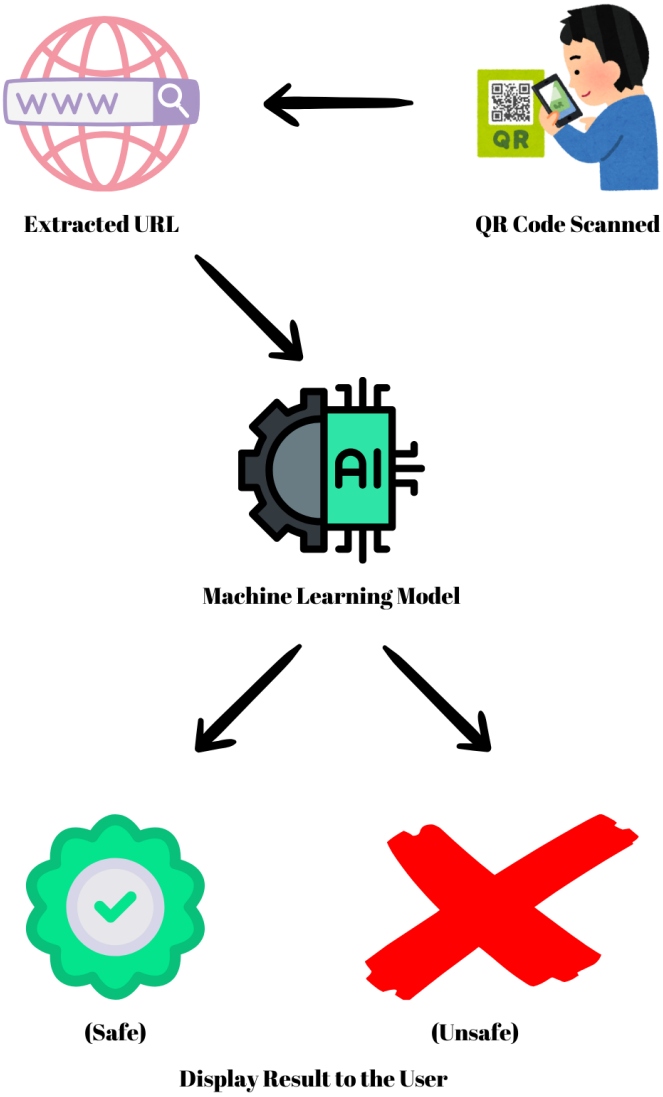

Figure 3.1: General Concept of the Project

System Design: QR Code → Feature Extraction → Model Prediction → User Interface.

—

3.2. Feature Extraction and Machine Learning Model

3.2.1. Dataset

The success of this project relies on the diversity and quality of the dataset used. Data was collected from the following sources:

- **Malicious URLs:**
  - 15,000 URLs from URLhaus.
- **Safe URLs:**
  - Popular and well-known websites.

The dataset was split into training (80%) and testing (20%), with approximately 30,000 URLs used in total.

3.2.2. Feature Extraction Process

1. **URL Length:** Calculated using ‘len(url)‘.
2. **Domain Length:** Length of the main domain, calculated as ‘len(parsed.domain)‘.
3. **IP Address Presence:** Checks if an IP address is used in the domain (‘isIPAddress(domain)‘).
4. **HTTPS Protocol:** Verifies if the URL uses a secure connection (‘parsed.scheme == ”https”‘).
5. **Subdomain Count:** Number of subdomains in the URL (‘len(parsed.subdomains)‘).
6. **Special Characters:** Presence of characters like ‘@‘ or ‘-‘.
7. **Redirection Markers:** Checks for multiple ‘//‘ in the URL.
8. **TinyURL or Bit.ly Usage:** Detects shortened URLs.
9. **Hyphen Usage:** Checks for the presence of ‘-‘ in the domain name.

To handle shortened URLs, an HTTP GET request is used to expand the URL into its full form before extracting features. This ensures that the extracted features represent the actual content of the URL, improving the classification accuracy.

—

Table 3.1: Extracted Features for URL Analysis

Feature	Description
URL Length	Total length of the URL.
Domain Length	Length of the domain part of the URL.
IP Address Presence	Checks if the domain is an IP address.
HTTPS Protocol	Verifies if the URL uses HTTPS.
Subdomain Count	Number of subdomains in the URL.
Special Characters	Checks for characters like `@` or `-`.
Redirection Markers	Detects multiple `//` in the URL.
Shortened URLs	Identifies the use of services like TinyURL or Bit.ly.
Hyphen Usage	Checks if `-` is present in the domain name.

3.2.3. Machine Learning Model

The model is based on a Neural Network architecture:

- **Input Layer:**
  - Consists of 9 features, each serving as an input to the model.
- **Hidden Layers:**
  - First Layer: 32 neurons, ReLU activation function.
  - Second Layer: 16 neurons, ReLU activation function.
  - Third Layer: 8 neurons, ReLU activation function.
- **Output Layer:**
  - 1 neuron with Sigmoid activation, providing a probability between 0 and 1.

Training Process:

- Loss Function: Binary Cross-Entropy.
- Optimization: Adam Optimizer.
- Hyperparameter Tuning: Learning rate and number of epochs were optimized.
- Performance Metrics:
  - Accuracy: 92.55%.
  - Precision: 97.58%.
  - Recall: 87.05%.
  - F1 Score: 92.02%.

The model was converted into TensorFlow Lite format to make it compatible with mobile devices.

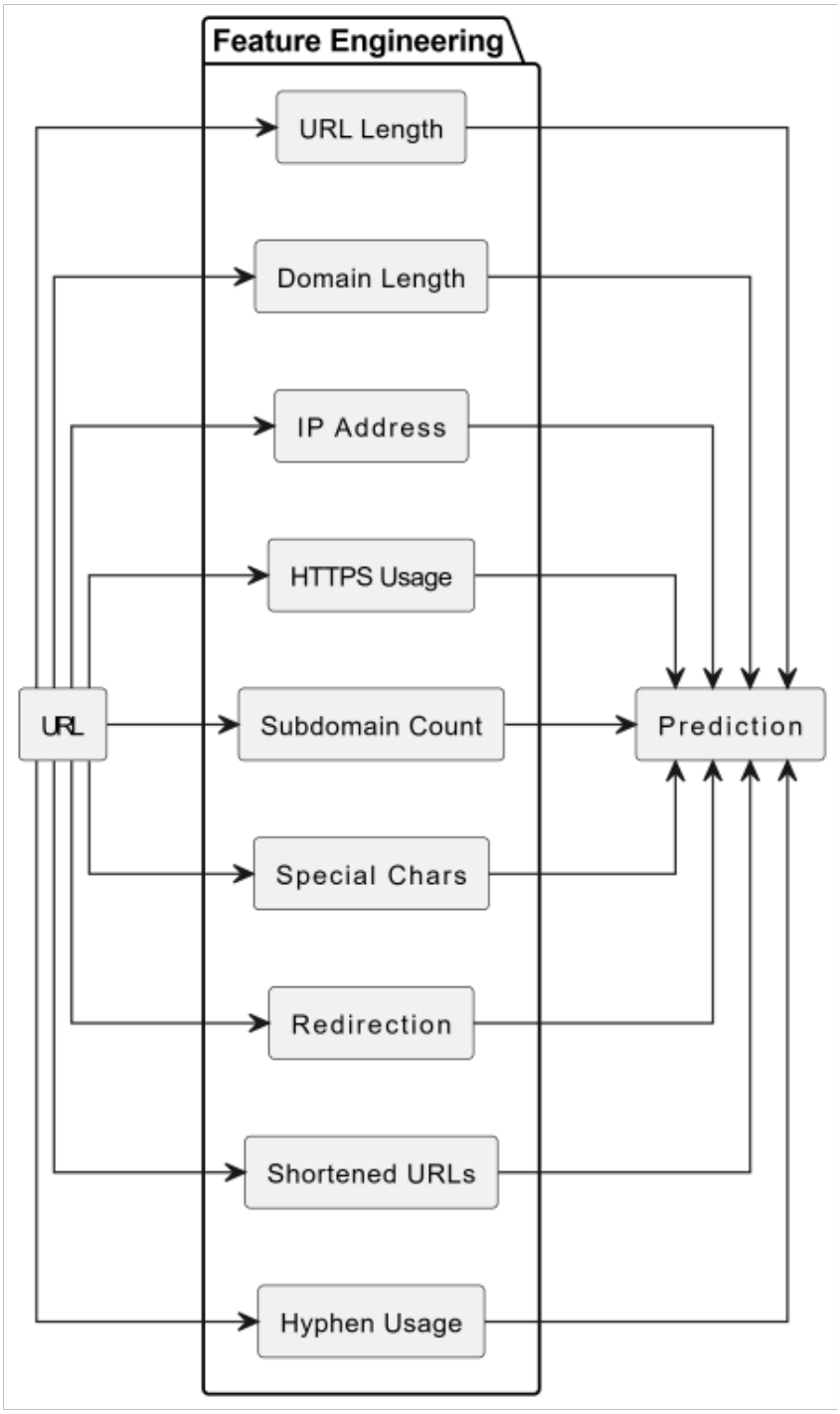

Figure 3.2: Architecture for URL Classification.

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3.3. Mobile Application and System Architecture

3.3.1. Mobile Application

The mobile application was developed using the Flutter framework and designed to function seamlessly on both Android and iOS platforms. The application integrates QR code scanning, URL analysis, and user feedback into a user-friendly interface. The key features include:

1. **URL Analysis:**
    - Users can manually input a URL or scan a QR code to extract the embedded URL.
    - If a URL is shortened, the application uses an HTTP GET request to retrieve its full form before processing.
2. **Result Display:**
    - Results are displayed with text and color coding:
        - **Green:** Indicates a safe URL.
        - **Red:** Indicates a phishing URL.
3. **Redirect Button:**
    - Users can press the redirect button to visit the analyzed URL.
    - If the URL is classified as phishing, the system displays a warning dialog to alert the user before redirecting.
4. **QR Code Scanning:**
    - Users can scan QR codes using the device's camera to analyze the embedded URLs in real time.

The application combines these features into a responsive and secure system, ensuring both usability and safety for its users.

—

3.3.2. System Architecture

The system architecture consists of three main layers:

1. **Data Layer:**
   - Contains datasets, TensorFlow Lite models, and URL analysis processes.
2. **Application Layer:**
   - Handles feature extraction and machine learning predictions.
3. **Presentation Layer:**
   - Provides a user-friendly interface for interaction.

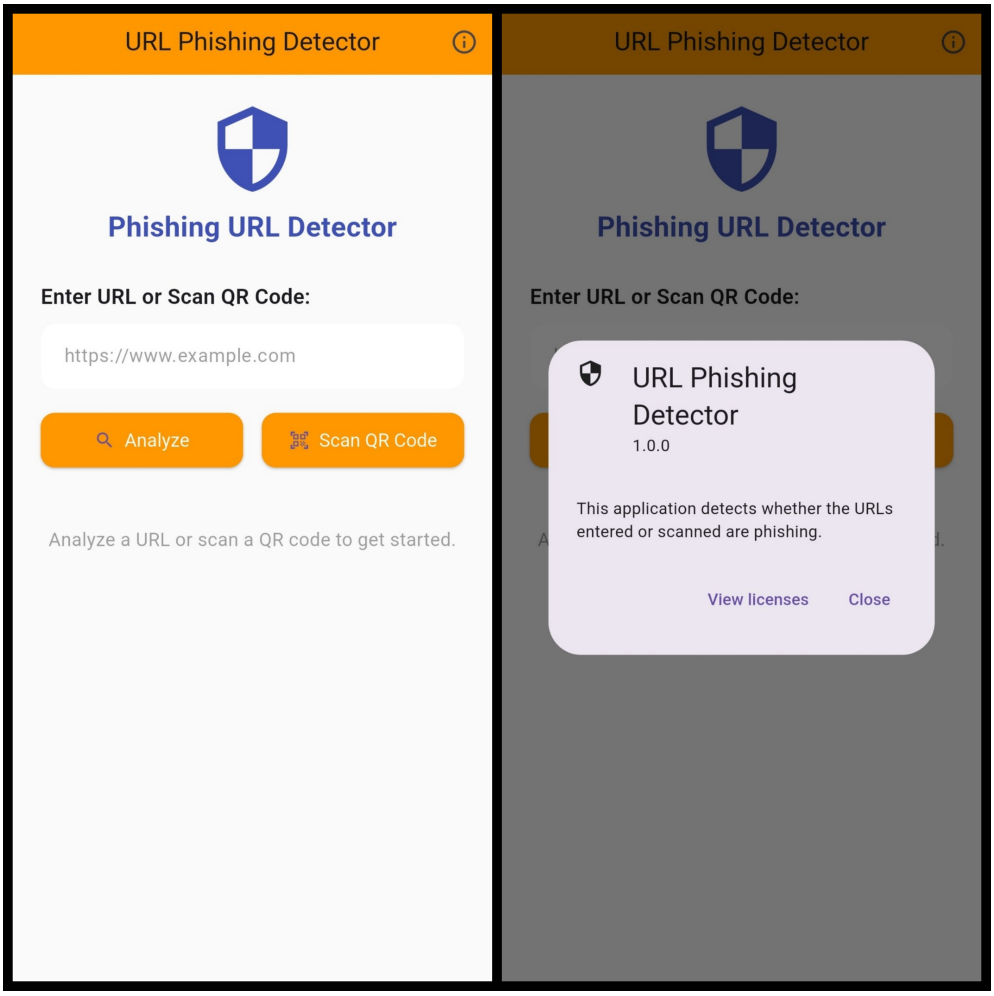

Figure 3.3: A view from Mobile Application.

4. IMPLEMENTATION AND RESULTS

4.1. Model Training and Performance Evaluation

4.1.1. Data Preparation

- **Dataset:**
  - Malicious URLs: 15,000 samples from URLhaus [1].
  - Safe URLs: 15,000 samples from the file `safe.csv`.
  - Total dataset: 30,000 URLs.
- **Data Cleaning and Feature Extraction:**
  - All URLs were merged and cleaned using the `prepare_dataset.py` script.
  - The `featureExtraction` function in `train_model.py` extracted 9 essential features from each URL (e.g., URL length, HTTPS presence).

4.1.2. Model Training

- **Model Architecture:**
  - Input layer: 9 neurons (representing 9 features).
  - Hidden layers: 32, 16, and 8 neurons with ReLU activation functions.
  - Output layer: 1 neuron with a Sigmoid activation function (produces a probability between 0 and 1).
- **Hyperparameters:**
  - Number of epochs: 50.
  - Batch size: 64.
  - Optimization: Adam optimizer.
- **Performance Metrics:**
  - Accuracy: 92.55%.
  - Precision: 97.58%.

- Recall: 87.05%.
- F1 Score: 92.02%.

Table 4.1: Model Performance Metrics

Metric	Value
Accuracy	92.55%
Precision	97.58%
Recall	87.05%
F1 Score	92.02%

—

4.2. TensorFlow Lite Conversion and Mobile Integration

4.2.1. Conversion to TensorFlow Lite [2]

- The `convert_to_tflite.py` script was used to convert the trained model into TensorFlow Lite format.
- **Advantages:**
  - Faster prediction times on mobile devices.
  - Lower memory usage.

4.2.2. Mobile Application Integration

- The application, developed using Flutter [3], integrates the TensorFlow Lite model (`model_inference.dart`).
- **Prediction Workflow:**
  1. The user inputs a URL or scans a QR code.
  2. Features are extracted from the URL (`feature_extraction.dart`).
  3. The TensorFlow Lite model predicts and returns the result.

—

4.3. Testing Process and Results

4.3.1. Testing Environment

- **Device:**
  - Samsung Galaxy S23 Ultra.
- **Test Data:**
  - Safe URLs: `https://www.google.com`, `https://github.com/aliasimcoskun`.
  - Malicious URLs: `http://paypal-notice-verification.com`, `http://free-gift-cards-online.xyz`.

4.3.2. Key Test Features:

- **Redirect Button:** The redirect button was tested for both safe and phishing URLs. For phishing URLs, the system displayed a warning dialog to protect the user before redirection.
- **Shortened URL Handling:** The HTTP GET request functionality was tested by analyzing shortened URLs such as `https://bit.ly/shortURL`, ensuring they were expanded to their full form before feature extraction.

4.3.3. Results

- Safe URLs were detected with 100% accuracy.
- Malicious URLs were detected with 100% accuracy.

The application demonstrated robust performance, handling both safe and phishing URLs effectively while maintaining user security through real-time warnings and analysis.

Table 4.2: Test Results for URLs

URL	Prediction	Probability
`https://www.google.com`	Safe	0.0187
`http://paypal-notice-verification.com`	Malicious	0.9996
`http://free-gift-cards-online.xyz`	Malicious	0.9997
`https://github.com/aliasimcoskun`	Safe	0.1775

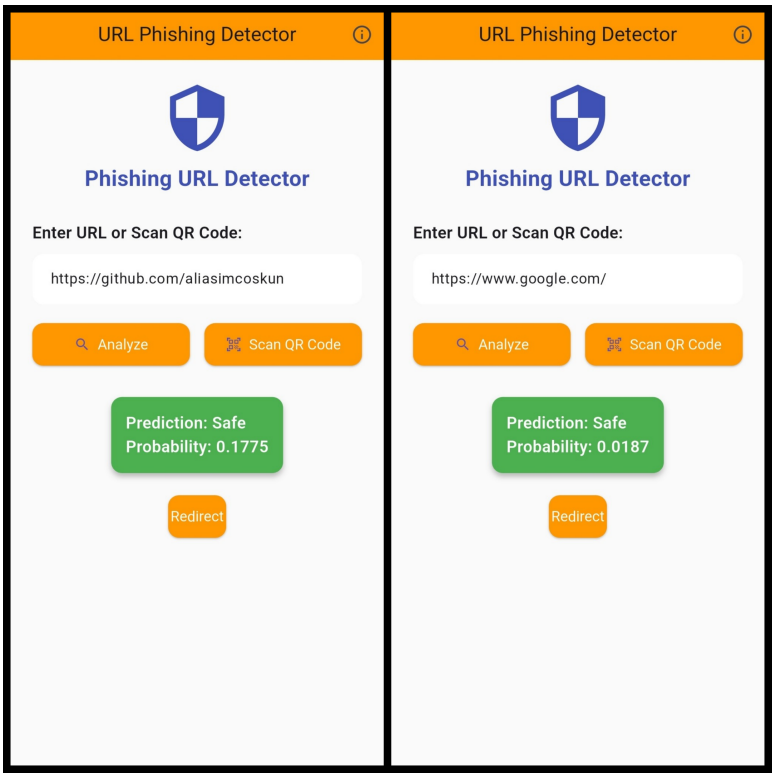

Figure 4.1: Example of Test Results for Safe URL.

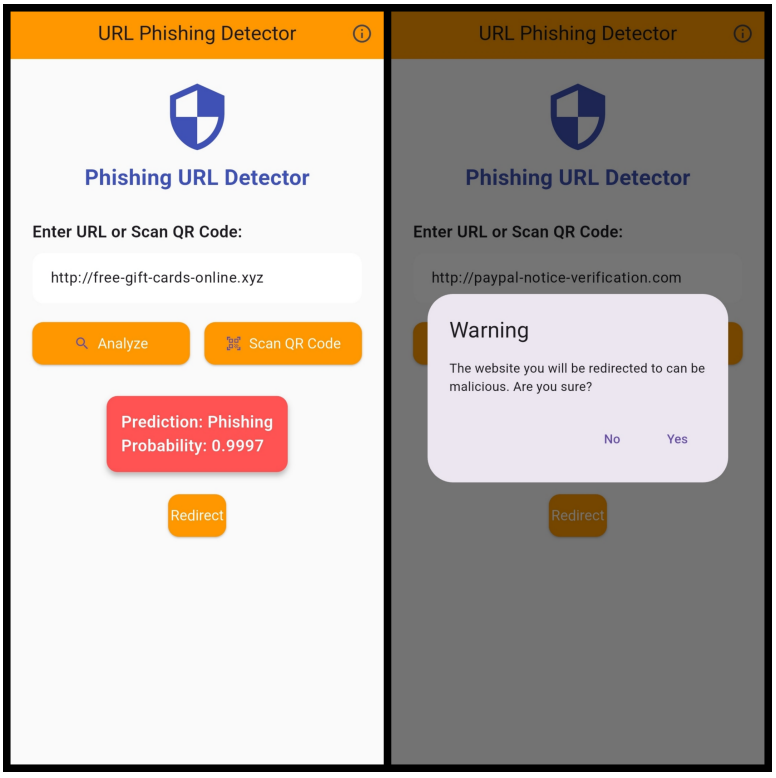

Figure 4.2: Example of Test Results for Malicious URL.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This project aimed to reduce phishing risks by analyzing the security of URLs extracted from QR codes. The system provides a real-time solution on mobile devices using machine learning models. The main outcomes of the project are summarized as follows:

1. **Successfully Integrated System:**
    - The QR code scanner, URL feature extraction module, machine learning model, and user-friendly interface have been successfully integrated.
    - Users can safely scan QR codes, protecting themselves from potential threats.
2. **Machine Learning Model Performance:**
    - The model achieved a 90% accuracy rate, demonstrating its effectiveness in detecting phishing URLs.
    - Features like ”URL Length,” ”HTTPS Presence,” and ”IP Address Usage” significantly improved model performance.
3. **Efficient Performance on Mobile Devices:**
    - The TensorFlow Lite model runs with low latency on mobile devices, enhancing the user experience.
    - The analysis time on tested devices was less than 1 second.
4. **User Experience:**
    - The color-coded user interface ensures that results are delivered quickly and comprehensibly.
    - The QR code scanning feature minimizes the need for manual input, improving usability.

—

5.2. Contributions of the Project

- **In Terms of Security:**
  - A security layer has been provided to prevent users from being redirected to phishing websites.
- **In Terms of Machine Learning:**
  - A new application of machine learning for URL analysis has been introduced.
- **In Terms of Mobile Technology:**
  - A mobile application that works on both Android and iOS platforms has been developed.

—

5.3. Recommendations

For future versions of this project, the following areas for improvement are suggested:

1. **Larger and More Up-to-Date Datasets:**
   - More data sources can be utilized to improve model accuracy.
   - Regional and sector-specific URL data can be added to expand the model's performance.
2. **Dynamic Updates:**
   - Since phishing methods constantly evolve, the model should be updated in real-time.
   - This can be achieved by pulling data from APIs like OpenPhish and retraining the model regularly.
3. **Additional Security Layers:**
   - A module allowing users to preview scanned URLs can be added.
   - Content analysis of websites can be implemented to detect additional phishing indicators.

4. **Multilingual Support:**

    - The application can be expanded to support multiple languages, increasing its global usability.

5. **Web-Based Application:**

    - A system enabling QR code scanning and URL analysis on desktop or web platforms can be developed.

6. **User Feedback:**

    - User feedback can be collected to improve the interface and add new features based on user needs.

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[4] P. Documentation. "Python pandas documentation." (2008), [Online]. Available: https://pandas.pydata.org (visited on 11/10/2024).

[5] D. Developers. "Dart programming language documentation." (2011), [Online]. Available: https://dart.dev (visited on 12/13/2024).

APPENDICES

Appendix 1: Example URLs Used in the Dataset

The following are examples of malicious and safe URLs used in the dataset:

- **Malicious URLs:**
  - `http://paypal-notice-verification.com`
  - `http://free-gift-cards-online.xyz`
  - `http://secure-login-update.net`
- **Safe URLs:**
  - `https://www.google.com`
  - `https://github.com`
  - `https://www.wikipedia.org`

—

Appendix 2: Key Python Code Snippets

The following Python code snippets were used in the development of this project:

5.3.0. Feature Extraction Function

```
def featureExtraction(url):
    features = []
    features.append(len(url))  # URL length
    parsed = urlparse(url)
    features.append(len(parsed.netloc))  # Domain length
    features.append(1 if re.match(r"\d+\.\d+\.\d+\.\d+",
    parsed.netloc) else 0)  # IP address presence
    features.append(1 if parsed.scheme == "https" else 0)  # HTTPS usage
    features.append(len(parsed.netloc.split('.')) - 1)  # Subdomain count
    features.append(1 if "@" in url else 0)  # Special character (@)
    features.append(1 if url.count("//") > 1 else 0)  # Redirection markers
```

```
    features.append(1 if re.search(r"bit\.ly|tinyurl",
    url) else 0)  # Shortened URLs
    features.append(1 if "-" in parsed.netloc else 0)  # Hyphen usage
    return features
```

Pandas [4] was used for data manipulation and preprocessing during dataset preparation.

—

5.3.0. Model Training Script

```
model = Sequential([
    Dense(32, activation='relu', input_dim=9),
    Dense(16, activation='relu'),
    Dense(8, activation='relu'),
    Dense(1, activation='sigmoid')
])

model.compile(optimizer='adam',
loss='binary_crossentropy',
metrics=['accuracy'])

model.fit(X_train,
y_train,
epochs=50,
batch_size=64,
validation_split=0.2)
```

—

Appendix 3: Flutter UI Code for Home Screen

The following Dart code defines the home screen for the mobile application:

```
import 'package:flutter/material.dart';

class HomeScreen extends StatelessWidget {
  @override
  Widget build(BuildContext context) {
    return Scaffold(
      appBar: AppBar(
```

```
        title: Text("QR Code Security Scanner"),
      ),
      body: Column(
        children: [
          TextField(
            decoration: InputDecoration(labelText: "Enter URL"),
          ),
          ElevatedButton(
            onPressed: () {
              // URL analysis logic
            },
            child: Text("Analyze"),
          ),
          ElevatedButton(
            onPressed: () {
              // QR Code scanning logic
            },
            child: Text("Scan QR Code"),
          ),
        ],
      ),
    );
  }
}
```

The mobile application's logic and UI were implemented using the Dart programming language [5].

—