UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

FACULTY OF PHYSICAL AND MATHEMATICAL SCIENCES



ADAPTIVE PHISHING DETECTION USING MACHINE LEARNING

BY

NAME

(ID. NO. XXXXXXX)

A DISSERTATION SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILMENT OF THE AWARD OF DEGREE OF MASTER OF SCIENCE IN COMPUTER SCIENCE

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# DECLARATION

I hereby declare that except where speciﬁc references are made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualiﬁcation in this, or any other University.

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DR. JUSTICE KWAME APPATI

# DEDICATION

# ACKNOWLEDGMENTS

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# ABSTRACT

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# CHAPTER 1 - INTRODUCTION

## 1.1 Background of Study

Phishing attacks are among the most persistent and damaging forms of cybercrime. They exploit both technical vulnerabilities and human psychology to deceive individuals into divulging sensitive information such as login credentials and financial data (Mosa et al., 2023; Opara et al., 2024). These attacks leverage sophisticated emails, websites, and instant messages that impersonate trusted organizations, using tactics such as spoofing, domain squatting, and URL obfuscation to evade detection (Atawneh & Aljehani, 2023; Karim et al., 2023).

The threat landscape has evolved with the emergence of advanced phishing techniques, including spear phishing (targeting specific individuals), whaling (targeting high-profile executives), vishing (voice phishing), and smishing (SMS phishing), all of which expand the attack surface and challenge traditional security solutions (Gholampour & Verma, 2023; Hassan, 2024). Attackers exploit weaknesses in email protocols, browser vulnerabilities, and user behaviour, often automating campaigns using readily available phishing kits (Al-Subaiey et al., 2024; Doshi et al., 2023).

Recent years have seen a surge in the use of machine learning and AI by both attackers and defenders, increasing the complexity and sophistication of phishing schemes (Gholampour & Verma, 2023). The proliferation of digital communications and online transactions has amplified the impact of phishing, resulting in significant financial losses, data breaches, and reputational harm (Doshi et al., 2023; Mosa et al., 2023). Phishing remains a leading vector for cyber incidents globally, highlighting the urgent need for adaptive, robust, and scalable detection mechanisms that leverage advanced machine learning techniques (Karim et al., 2023; Linh et al., 2024).

To address these evolving challenges, the development of adaptive phishing detection models is essential. Such models require comprehensive datasets, advanced feature engineering, and the integration of state-of-the-art machine learning algorithms to enhance detection accuracy and adaptability to emerging threats (Goud & Mathur, n.d.; Liu et al., 2021).

Despite the proliferation of machine learning and AI-based solutions, a persistent challenge in phishing detection research is the reliance on static or outdated datasets. Many existing studies use datasets that do not reflect the rapidly evolving tactics of attackers, resulting in models that may perform well in controlled experiments but fail to generalize to real-world scenarios. While this research acknowledges the importance of comprehensive and up-to-date datasets, it specifically addresses the need for advanced feature engineering and real-time adaptability to improve detection accuracy and resilience against emerging phishing threats.

## 1.2 Problem Statement

Despite advancements in phishing detection, attackers continuously adapt their tactics, making many existing systems ineffective against new and sophisticated threats. Current limitations include insufficient diversity in feature engineering and a lack of real-time adaptability. As a result, detection systems often suffer from high false positive rates, limited scalability, and poor generalization to novel phishing strategies. There is a critical need for a robust and adaptive phishing detection approach that leverages advanced feature engineering (including URL, HTML, and behavioural features), and rigorous validation to achieve high accuracy, low false positive rates, and resilience against evolving phishing techniques.

This research seeks to bridge these gaps by systematically integrating state-of-the-art machine learning and feature engineering methods to create a scalable and adaptive phishing detection system.

## Objectives

The objectives of this research are:

1. To design and implement advanced feature engineering methods, including URL, HTML, and behavioural features, to enhance model performance over established baselines.
2. To develop a machine learning-based phishing detection model using the engineered features and diverse datasets.
3. To deploy and evaluate the adaptive phishing detection system in a simulated real-time environment, assessing its scalability, adaptability, and response to emerging phishing tactics.

## Outline of Methodology

The methodology used directly builds on and extends the state-of-the-art in phishing detection. It consists of three subsections — a baseline replication and data preparation, advanced feature engineering and model enhancement, deployment and real-time evaluation. A baseline for phishing detection is replicated and data prepared. The dataset used is acquired from PhishTank, Kaggle repository. The data is cleaned, normalized, split into train and test data. The feature extraction techniques and baseline model (XGBoost) are used to establish a performance benchmark as described by Aljofey et al. (2022). The next is the feature engineering and model enhancement. Over here, we will design and implement additional feature extraction methods, including behavioural and language-independent features. Then we will integrate these with URL and HTML features. We will train and validate machine learning models, comparing results to the baseline and targeting measurable improvements in F1-score and accuracy. Finally, we will deploy and monitor in a simulated real-time environment. At this stage, only the best-performing model in a simulated real-time environment is deployed. We will also measure system scalability, latency, and adaptability to new simulated phishing tactics.

## Justification

Phishing remains one of the most prevalent and damaging cyber threats faced by businesses today. Existing detection systems often struggle to keep up with the rapidly evolving tactics of attackers, leading to costly breaches and loss of customer trust. This research directly addresses these challenges by developing an adaptive phishing detection system that leverages advanced feature engineering, including URL, HTML, and behavioural features as well as real-time adaptability. By providing a scalable and robust solution that can detect novel and sophisticated phishing attacks, this work offers industry practitioners a practical tool to enhance their cybersecurity posture, reduce false positives, and respond more effectively to emerging threats. The integration of user feedback mechanisms further ensures that the system can continuously learn and adapt, making it highly relevant for deployment in dynamic, real-world environments.

In addition, this research advances the academic field of cybersecurity and machine learning by systematically addressing gaps in feature diversity and model adaptability for phishing detection. The study introduces and rigorously evaluates new feature engineering strategies, including the integration of behavioural and language-independent features, which are underexplored in current literature. By benchmarking against established baselines and deploying the system in a simulated real-time environment, the research provides valuable empirical evidence and methodological innovations. These contributions not only extend the theoretical understanding of adaptive security systems but also offer a foundation for future research on robust, data-driven approaches to cyber threat detection.

## Outline of Dissertation

This dissertation is organized into seven chapters. Chapter 1 is introduction. It provides the background, problem statement, objectives, methodology overview, justification, and the overall structure of the dissertation. Chapter 2 is literature review. It reviews existing research on phishing detection, machine learning techniques, feature engineering, and highlights the gaps addressed by this work. Chapter 3 is methodology. It details the research design, data collection, feature engineering, model development, evaluation strategies, and user feedback integration. Chapter 4 is proposed model. It describes the architecture and workflow of the adaptive phishing detection system, including the integration of advanced features and machine learning algorithms. Chapter 5 is results and discussion. It presents the experimental setup, evaluation metrics, results, and a discussion comparing the findings with existing systems and literature. Chapter 6 is the conclusion and future works. It summarizes the main findings, contributions, and limitations of the research, and outlines directions for future work. Chapter 7 is research timeline. It provides a detailed timeline for the completion of the research project, including key milestones and deliverables.

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