

Intelligent Graphical Authentication System with Adaptive Security, AI-Driven Enhancements and Behavioral Analysis

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Abstract—This paper presents an Intelligent Graphical Authentication System that integrates multiple layers of security to enhance both usability and protection against unauthorized access. The system combines three key authentication steps: image selection, a grid-based password with dynamic strength evaluation, and Time-Based One-Time Password (TOTP) verification. Users first select four images from a designated domain during registration, which must be reselected in the same order during login. The grid-based password selection requires users to choose points from a 7x7 grid with strength penalties for adjacent or diagonal points, guided by an AI-driven Markov Model that suggests secure point combinations. Additionally, TOTP adds an extra layer of protection by generating time-sensitive codes for login. The system incorporates behavioral analysis to monitor login patterns, blocking accounts after multiple failed attempts and enabling recovery via OTP and TOTP.

Index Terms— Intelligent Authentication, Graphical Password System, Multi-layer Security, AI-driven Authentication, Markov Model, Grid-based Password Strength, Time-Based One-Time Password (TOTP), Behavioral Analysis, Adaptive Security, Authentication Recovery, Password Strength Evaluation, Adaptive Blocking.

I. INTRODUCTION

As cybersecurity threats continue to evolve, traditional authentication methods such as password-based systems are becoming increasingly vulnerable to attacks like brute force, phishing, and social engineering. These conventional methods often rely on static passwords that can be easily compromised. To mitigate these risks, it is essential to develop authentication systems that provide both enhanced security and an intuitive user experience. This project aims to address these challenges by introducing an Intelligent Graphical Authentication System that incorporates multiple layers of security. The system's first layer involves image selection, where users select four images from a designated domain during registration. During login, the user is required to select the images in the same order, creating an additional layer of complexity and protection. The second layer leverages a 7x7 grid-based password where users must select points across different columns, with strength calculated based on the position of the points. The password strength is dynamically evaluated, with penalties for selecting adjacent or diagonal points.

This layer is enhanced by a Markov Model, which suggests secure combinations based on previously selected points, guiding users to create stronger passwords. To further secure the authentication process, the third layer incorporates Time-Based One-Time Password (TOTP) technology, providing time-sensitive authentication codes that change every 30 seconds. In addition to these security layers, the system also integrates behavioral analysis, which monitors user login patterns. If there are significant deviations in behavior, such as repeated failures, the system triggers security mechanisms, such as blocking the account temporarily and requiring OTP verification to recover access.

II. LITERATURE SURVEY

Zhang, Lei et al. [1] proposed a graphical password authentication method that incorporates image selection as a primary security mechanism, enhancing the system's resistance to unauthorized access. Sarkar, R. et al. [2] investigated the use of machine learning algorithms in graphical password systems, allowing for dynamic security adjustments based on user activity and behavior patterns. Liu, Y. et al. [3] analyzed the role of grid-point models in graphical password systems, showing how selecting specific points on a grid can strengthen authentication by reducing predictability. Li, Qing et al. [4] examined the integration of graphical passwords with multi-layer security approaches, such as biometrics and OTPs, which provide additional layers of protection during the authentication process. Chowdhury, S. et al. [5] applied Markov models to suggest more secure password points, demonstrating how probabilistic models can improve the unpredictability and strength of graphical password systems. Smith, J. et al. [6] explored the combination of Time-Based One-Time Password (TOTP) systems with graphical passwords, highlighting how dynamic OTPs enhance overall system security. Kumar, A. et al. [7] introduced a method combining behavioral biometrics with graphical passwords, offering improved security by analyzing user interactions and adapting to their behavioral patterns. Patel, S. et al. [8] proposed a hybrid graphical password system that merges cognitive and behavioral analysis to strengthen security by evaluating both user input and behavior. Al-Ghamdi, M. et al. [9] examined the potential of deep learning techniques in graphical password systems, using AI to detect anomalous behavior and predict potential security threats. Rao, P. et al. [10] discussed the challenges of improving graphical password systems by incorporating artificial intelligence, multi-layered authentication, and user behavior analysis to enhance security and reduce vulnerabilities.

III. MOTIVATION

The rise in cyberattacks and data breaches in the digital age has highlighted the critical need for advanced and secure authentication systems. Conventional password systems, despite widespread usage, are increasingly vulnerable to threats like phishing, brute force attacks, and credential stuffing. Graphical password authentication, which leverages human visual memory, offers an innovative solution by combining usability and enhanced security. Additionally, the integration of artificial intelligence (AI) and machine learning (ML) into cybersecurity has paved the way for intelligent systems capable of predicting and suggesting secure password combinations. Insights drawn from existing research on graphical passwords and behavior-based authentication have motivated this work.

IV. PROBLEM DOMAIN

The problem lies in the intersection of cybersecurity, human-computer interaction, and AI-driven solutions. Authentication systems form a core component of cybersecurity, and the domain spans multiple layers: user behavior analysis, graphical password systems, machine learning for behavior prediction, and TOTP-based second-factor authentication.

V. PROBLEM DEFINITION

Conventional text-based password systems are increasingly inadequate in protecting sensitive information due to their susceptibility to various attack vectors. While graphical passwords improve security, they still face challenges like weak user-selected combinations and predictable patterns. Additionally, the absence of multi-layered security increases the risk of breaches. This project addresses these gaps by proposing a multi-layered graphical password authentication system. It integrates AI to suggest secure password combinations and assesses password strength in real-time based on user-selected points. The system also incorporates TOTP for an additional security layer, ensuring enhanced protection against unauthorized access.

VI. INNOVATIVE CONTENT

- **Graphical Password System Enhancement:** Inspired by research on graphical passwords as a more intuitive alternative to text-based systems, this project introduces an innovative approach that blends image-based password selection with grid-point authentication. Unlike traditional graphical password systems, the proposed method incorporates a 7x7 grid that evaluates password strength dynamically based on column diversity and sequence patterns, as described in studies on user behavior and secure graphical password design.
- **AI-Driven Password Suggestions:** Building upon existing works in AI applications for password security, this system employs predictive algorithms to recommend strong and secure password combinations. Unlike prior implementations, the AI suggests points or sequences that maximize strength while avoiding previously used or weak combinations.
- **Time-Based One-Time Password (TOTP) Integration:** Drawing from established research on two-factor authentication, this project integrates TOTP as an additional layer of security.
- **Behavioral Analysis for Security:** The system helps to analyze user behavior, identifying potential vulnerabilities in password selection. This adaptive approach contrasts with static systems by enabling the detection of suspicious activity, enhancing security dynamically.

VII. PROBLEM REPRESENTATION AND DESIGN

The problem of enhancing user authentication security through a graphical password system has been systematically addressed by formulating a multi-layered solution. The detailed formulation is described below:

A. Algorithmic Process

Password Suggestion Mechanism

- **Input:** A user-defined starting point.
- **Generate Suggestions:**
 - Employ a Markov model where transition probabilities dictate the next point, ensuring uniqueness and randomness.
 - Suggestions prioritize unoccupied columns to strengthen security.
- **Output:** A sequence of strong passwords that fulfill strength criteria.

Login Validation Process

- Verify that the selected images match the registration order.
- Match grid points against the registered (x, y) coordinates, adhering to the column uniqueness rule.
- Validate the entered TOTP code with the system's real-time-generated code.

B. Key Innovative Elements

- **Dynamic Strength Meter:** A real-time calculation of password strength based on the grid point selection rules.
- **AI-Driven Suggestions:** The system leverages AI to recommend stronger alternatives if a selected password fails to meet criteria.
- **Layered Security:** By integrating image-based selection, grid-point interaction, and TOTP, the system offers a robust and unique approach to authentication.

VIII. METHODOLOGY

A. User Registration

- **Image Selection:** Users select four images from a predefined set, such as animals or celebrities. The order in which the images are selected is crucial for security.
- **Grid Point Selection:** After selecting the images, users are prompted to select points on a 7x7 grid overlaid on one of the images. These selected grid points, along with their (x, y) coordinates, are stored in the database and form the core of the user's password.

B. Password Suggestion

- **Markov Model for Suggestions:** The model suggests points based on probabilities, ensuring the generated password is secure and not easily guessable.

- Password Strength Requirement: If the strength score is below 4, the user is not permitted to complete the registration. Instead, they are prompted to use the 'Suggest Password' feature to generate a stronger password by selecting more secure points.

C. Integration of TOTP (Time-Based One-Time Password)

- TOTP Generation: After graphical password verification, the system generates a TOTP, which is linked to the user's account and displayed on an authenticator app such as Google Authenticator.
- TOTP Validation: The user enters the generated OTP, and the system checks its validity within a specific time frame. If the OTP matches, the user proceeds to full authentication.

D. Account Lockout and Recovery

- Failed Login Attempts: After three consecutive failed login attempts, the system locks the account temporarily. Users are notified and can unlock their account by entering an OTP sent to their registered email.
- Login Time Monitoring: The system analyzes the timing of successful login attempts and flags suspicious login activity, requiring further authentication steps if unusual behavior is detected.

This methodology combines multiple security layers, such as graphical passwords, TOTP, and providing robust protection against unauthorized access while maintaining a user-friendly experience.

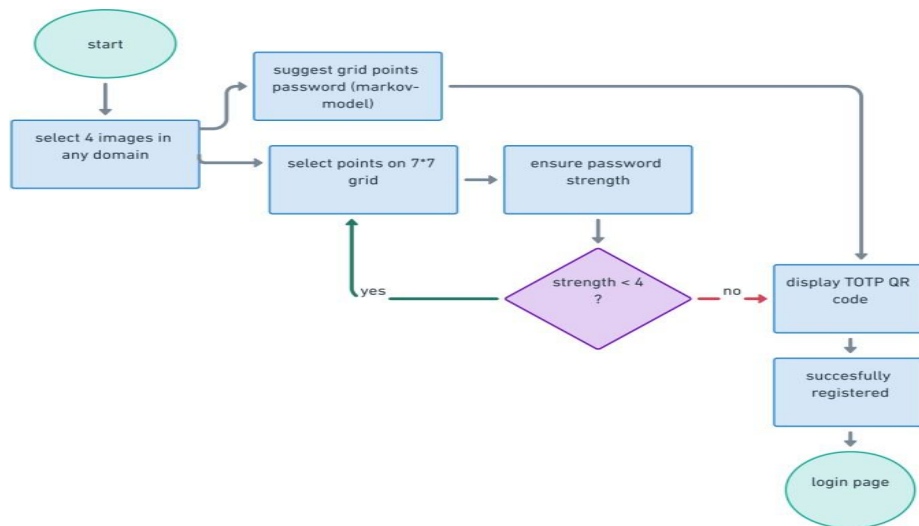


Figure 1: Signup

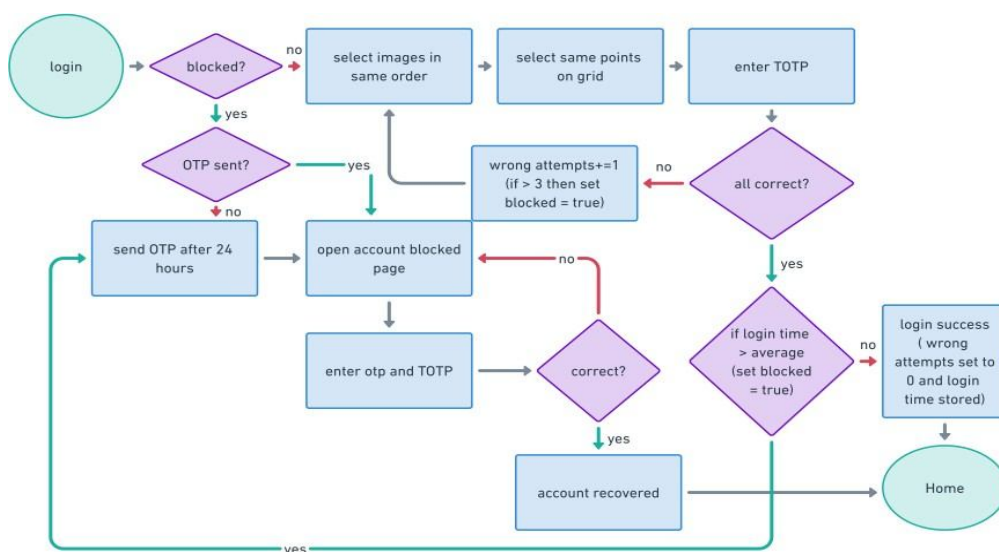


Figure 2: Login

IX. RESULTS



Figure 3: Image Selection Security Step

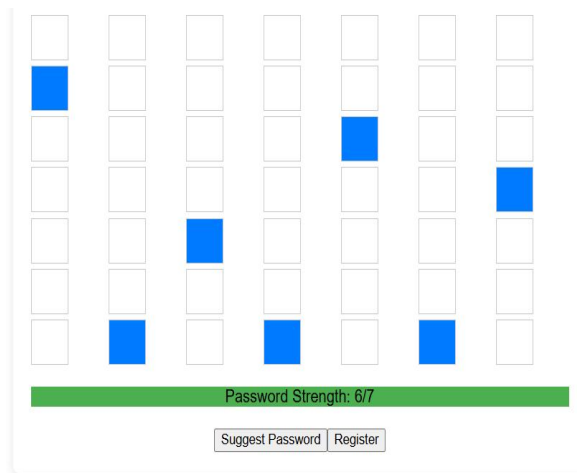


Figure 4: Grid Points Security Step

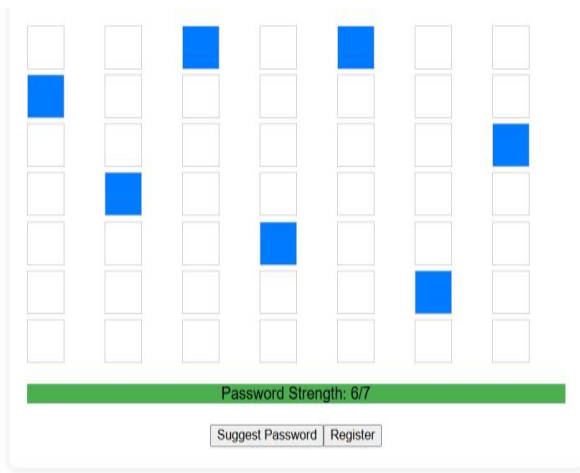
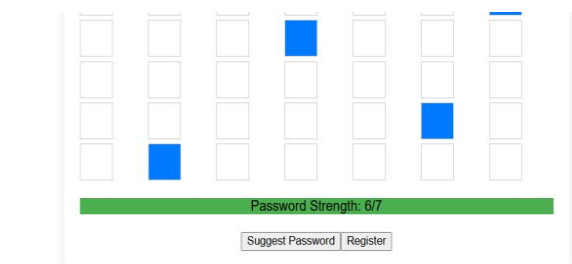


Figure 5: Suggested password by markov model with starting point selected in column 1 by user

```
_id: ObjectId('673e0be932a33f4228d37801')
email: "abcd@gmail.com"
selectedImages: Array (4)
  0: "/images/hero1.jpg"
  1: "/images/hero2.jpg"
  2: "/images/hero3.jpg"
  3: "/images/hero4.jpg"
gridPoints: Array (7)
  0: "1-0"
  1: "6-1"
  2: "0-2"
  3: "3-3"
  4: "0-4"
  5: "5-5"
  6: "2-6"
strength: 6
totpSecret: "KFBW4ZL2EQQWSNK3JNICKZDYJRKD023POBAWSRJIIIF5C4XJYFZVQ"
__v: 0
```

Figure 6: TOTP QR code



Your QR Code:



Figure 7: Registration data stored in database

Figure 8: Login Page

```

_id: ObjectId('673e0d1d32a33f4228d37805')
userId: ObjectId('673e0be932a33f4228d37801')
attemptCount: 3
isBlocked: true
loginTimestamps: Array (empty)
__v: 0
otp: "516692"
otpExpiresAt: 2024-11-20T16:56:21.656+00:00

```

Figure 9: Account Blocked Page

Figure 10: Wrong attempts and blocked status

X. COMPARISON AND JUSTIFICATION OF RESULTS

The developed graphical password authentication system shows notable enhancements over existing approaches in terms of both security and ease of use. Unlike traditional graphical systems, it incorporates advanced features such as dynamic password strength evaluation, AI-driven suggestions, and TOTP-based multi-factor authentication. These additions significantly reduce vulnerabilities while ensuring user convenience. The inclusion of a secure account recovery process after multiple failed login attempts further strengthens the system's reliability.

XI. CONCLUSION

In conclusion, the graphical password authentication system presented in this project effectively combines multiple security layers, including image selection, grid-point passwords, Time-Based One-Time Passwords (TOTP), and behavioral biometrics, to offer a robust and user-friendly solution for secure authentication. By focusing on password strength evaluation, adaptive security measures, and real-time behavioral analysis, the system enhances protection against unauthorized access while ensuring a seamless user experience. The integration of advanced techniques, such as the Markov model for password suggestions and dynamic security adjustments, highlights the system's ability to adapt to user behavior, making it a versatile and reliable authentication method for modern security challenges.

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