CipherShield - A Secure File Encryption Utility

1. Introduction

CipherShield is a desktop application developed in Python that provides a user-friendly graphical interface for securely encrypting and decrypting files. The primary objective of this project is to offer a robust and accessible tool for protecting sensitive data. By leveraging industry-standard cryptographic libraries, CipherShield ensures that files are protected against unauthorized access. The application uses password-based key derivation, meaning the security of the files is tied to a user-provided password, eliminating the need to manage separate key files.

2. Core Features

- Password-Based Encryption: Files are encrypted using a key derived from a user-provided password.
- Strong Encryption Standard: Utilizes the Fernet symmetric encryption scheme, which is built on AES-128 in CBC mode with PKCS7 padding.
- Tamper-Proofing: A SHA-256 hash of the original file is stored with the encrypted data. During decryption, this hash is verified to ensure the file has not been altered or corrupted.
- Salted Key Derivation: Employs the PBKDF2 algorithm with a random salt for each encryption. This mitigates dictionary and rainbow table attacks, ensuring that identical passwords result in different encryption keys.
- Intuitive Graphical User Interface (GUI): Built with PyQt5, the application features an easy-to-navigate interface, enabling users to encrypt or decrypt files with just a few clicks.
- Robust User Experience: Features include a password confirmation dialog to prevent typos and a safe-overwrite mechanism to prevent accidental data loss during decryption.

3. Technologies and Libraries Used

- Language: Python 3
- GUI Framework: PyQt5
- Cryptography: cryptography library (specifically Fernet and PBKDF2HMAC).
- Hashing: hashlib module for SHA-256 integrity checks.

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4. Key Code Snippets Explained

4.1 Password-Based Key Derivation (derive_key)

This function is the security core of the application. It takes a user's password and a random salt and runs them through the PBKDF2 algorithm 100,000 times. This computationally intensive process creates a secure 32-byte key that is extremely difficult to brute-force.

```
def derive_key(password: bytes, salt: bytes) -> bytes:
    """
    Derives a secure encryption key from a password and salt using PBKDF2.

    Args:
        password: The user's password in bytes.
        salt: A random salt in bytes.

    Returns:
        A URL-safe base64-encoded 32-byte key.
    """
    kdf = PBKDF2HMAC(
        algorithm=hashes.SHA256(),
        length=32,
        salt=salt,
        iterations=100000,
    )
    return base64.urlsafe_b64encode(kdf.derive(password))
```

4.2 File Encryption Process (encrypt_file)

The encryption process involves reading the file, calculating its hash, generating a new random salt, deriving the key, and then encrypting the data. The final output file is carefully structured by prepending the 16-byte salt to the encrypted ciphertext. This salt is not a secret and is required for decryption.

```
def encrypt_file(filename, password):
    """
    Encrypts a file using a password. The output file (.enc) contains:
    [16-byte salt][encrypted data]

    Args:
        filename: The path to the file to encrypt.
        password: The password to use for encryption.

    Returns:
        A string indicating the status of the operation.
    """
```

4.3 Secure Password Entry (PasswordDialog)

To enhance usability and prevent errors, a custom dialog was created. This dialog requires the user to enter their password twice. The "OK" button is only enabled when both fields are non-empty and the passwords match, providing immediate feedback to the user.

```
class PasswordDialog(QDialog):
    def __init__(self, parent=None):
        super().__init__(parent)
        self.setWindowTitle("Enter Password")
        self.layout = QVBoxLayout(self)

        self.pass_label = QLabel("Password:")
        self.pass_input = QLineEdit()
        self.pass_input.setEchoMode(QLineEdit.Password)

        self.confirm_label = QLabel("Confirm Password:")
        self.confirm_input = QLineEdit()
        self.confirm_input.setEchoMode(QLineEdit.Password)

        self.message_label = QLabel("") # To show error messages like "Passwords
        self.message_label.setStyleSheet("color: red")

        self.buttons = QPushButton("OK")
        self.buttons.setEnabled(False) # Start with OK disabled
```

5. Application Workflow and Output

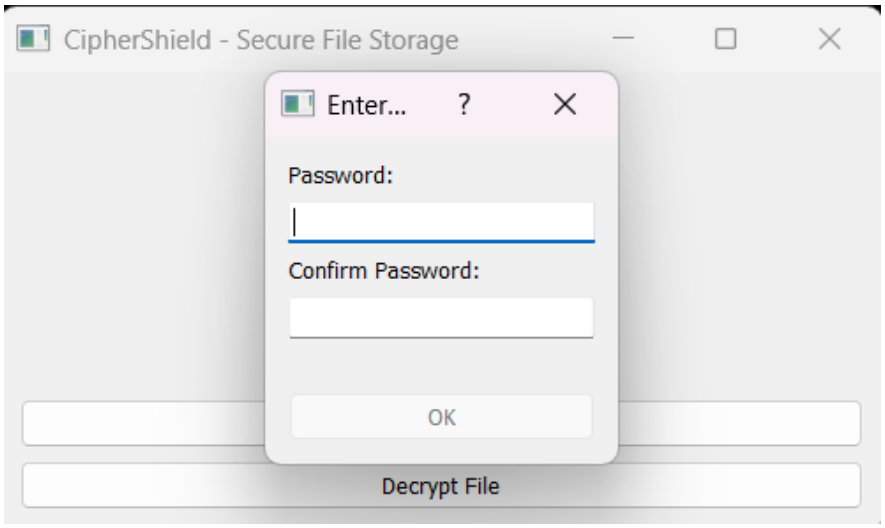
This section demonstrates the user's journey through the CipherShield application.

5.1 Main Window

The application opens to a clean and simple main window displaying the project name and the core actions.

5.2 Encryption Process

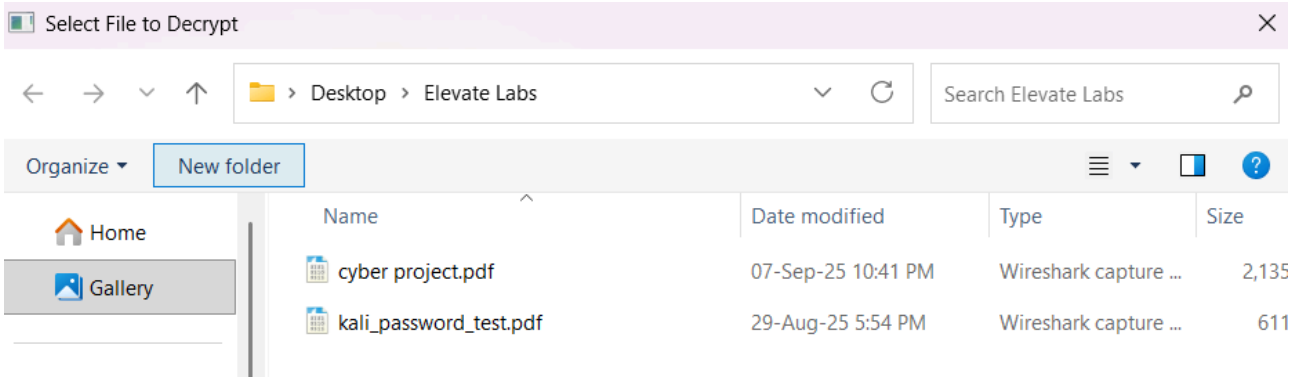
The user clicks "Encrypt File," selects a file, and is then prompted to enter and confirm a secure password.



Upon successful encryption, a status message confirms the operation, and the new .enc file appears in the directory.

5.3 Decryption Process

The user selects an encrypted (.enc) file and is prompted for the password.



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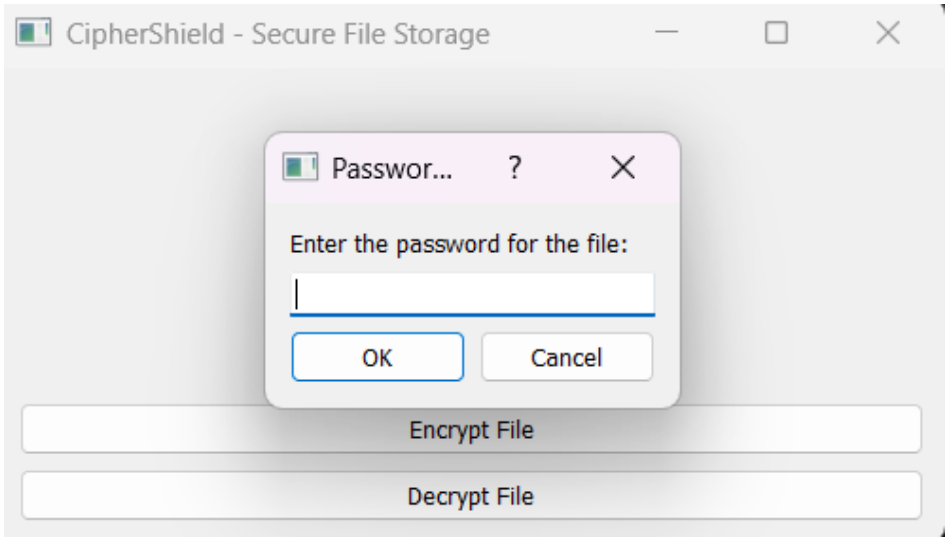
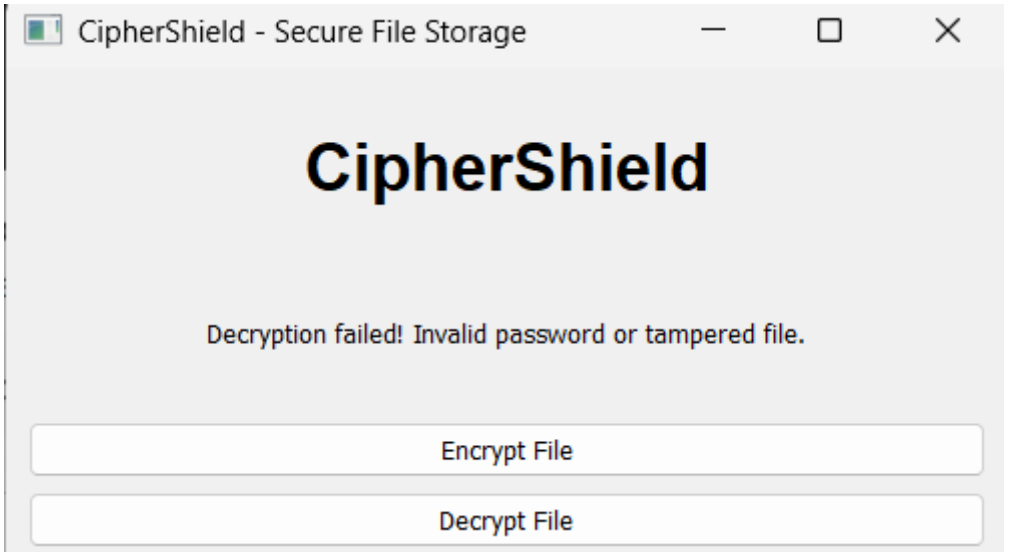


5.4 Handling Tampering and Incorrect Passwords

If the wrong password is used or if the encrypted file has been modified in any way, the application shows a clear error message, protecting the user from using corrupted data.



6. Conclusion

CipherShield successfully meets its goal of providing a secure and user-friendly file encryption tool. By implementing modern cryptographic principles and focusing on a seamless user experience, the project demonstrates a practical application of secure software development. Future enhancements could include support for encrypting entire folders or integrating alternative encryption algorithms.

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