Journal of Productive Discourse
Volume 3 Issue 1, 2025. pp. 23–38
Kathmandu, Nepal
DOI: https://doi.org/10.3126/prod.v3i1.78454

EasyPill: AI-Powered Pill Identification for Enhancing Medication Safety and Reducing Errors by Using Mobilenet CNNs

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Article History
Received: February 15, 2025
Accepted: April 18, 2025

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Cite
Jha, P. B., Mishra, A. K., Ansari, R., Khadka, S., Dahal, B., & Aryal, S. (2025). Easypill: AI-powered pill identification for enhancing medication safety and reducing errors by using Mobilenet CNNS. *Journal of Productive Discourse*, *3*(1), 23–38. *https://doi.org/10.3126/prod.v3i1.78454*

Abstract

Medication errors are a significant concern in healthcare, often arising from difficulties in identifying unlabeled pills. Patients, caregivers, and healthcare professionals need reliable tools for accurate pill identification to ensure safe medication practices. EasyPill aims to simplify pharmaceutical pill identification with high accuracy and precision by leveraging advanced AI technologies. The system addresses issues such as medication errors, unlabeled pills, and the need for efficient drug verification. EasyPill employs MobileNet, a Convolutional Neural Networks (CNNs) architecture, to analyze pill images uploaded by users based on attributes like color, shape, and size. These features are then matched against a comprehensive drug database. Additionally, the platform includes a search engine for direct pill name queries and offers user authentication options—such as account signup and login—to ensure secure access. The system provides detailed information about pills, making it a valuable tool for patients, caregivers, and healthcare professionals. EasyPill promotes health awareness and encourages responsible medication practices by serving as both an identification tool and an educational resource. Through its user-friendly design and reliable identification capabilities, EasyPill enhances public health by addressing key challenges in medication safety. It supports safe medication use while fostering greater health awareness among users.

Keywords: AI-powered, web-based system, pharmaceutical pill identification, MobileNet, convolutional neural networks (CNNs), image analysis, drug database

Introduction

Medication safety and adherence remain critical challenges in healthcare, with medication errors accounting for a significant proportion of medical mistakes (Mishra et al., 2023). These errors often stem from the improper identification of pills, especially when patients discard medication containers or fail to recognize unlabeled pills. Such issues highlight the need for reliable tools to ensure accurate pill identification, reduce errors, and promote safe medication practices (World Health Organization, 2019).

Artificial intelligence (AI) has emerged as a transformative solution in the pharmaceutical sector, offering advanced capabilities for drug identification and management. AI-powered systems like EasyPill leverage CNNs, such as MobileNet, to analyze pill images based on attributes like color, shape, and size (Howard et al., 2017). These visual features are matched against extensive drug databases to identify pills and provide critical information, including their name, usage instructions, recommended dosage, and potential side effects. This process helps reduce the risk of harmful drug interactions or medication misuse (Wang et al., 2020).

Pill identification tools play a vital role in enhancing medication safety by enabling accurate identification of drugs based on physical attributes and imprints. They assist patients, caregivers, and healthcare professionals in verifying medications, ensuring adherence to prescribed regimens, and preventing adverse reactions (Jain, 2025). Such tools are also invaluable in emergencies, where rapid pill identification can guide appropriate medical interventions (Jain, 2025).

EasyPill goes beyond image-based identification by incorporating a search engine that allows users to query pill names directly for detailed information. The platform also includes user authentication features, such as account signup and login, to ensure secure access. By serving as both an identification tool and an educational resource, EasyPill promotes informed decision-making and encourages responsible medication practices among users (Larios et al., 2019).

The importance of medication education is underscored by initiatives aimed at improving patient adherence through better communication and understanding. Studies have shown that non-adherence leads to significant healthcare costs—estimated at $100–300 billion annually in the United States alone (Larios et al., 2019). Factors contributing to non-adherence include lack of understanding, forgetfulness, and misconceptions about medication effectiveness. Tools like EasyPill address these challenges by providing accessible, reliable information and empowering users to manage their medications more effectively (Susanto et al., 2022).

In addition to addressing individual needs, EasyPill contributes to broader public health goals by enhancing medication safety and promoting the quality use of medicines (QUM). It aligns with educational efforts to improve healthcare provider training in safe prescribing and medication management. By integrating AI-driven solutions into pill identification systems, EasyPill demonstrates how technology can simplify time-consuming tasks, reduce errors, and improve healthcare outcomes (Howard et al., 2017; WHO, 2019). This innovative approach highlights the potential of AI to transform pharmaceutical practices and underscores its role in ensuring safe and effective medication use across diverse populations.

The Problem of the Statement

Misidentification of pills is a serious issue in healthcare, contributing to medication errors that affect millions of patients annually. These errors often result from confusion caused by look-alike pills or inadequate labeling practices (Institute of Medicine, 2019). Patients who rely on visual identification methods—such as pill color and shape—are particularly vulnerable to these mistakes. Studies have shown that reliance on visual pill identification can lead to adverse health outcomes, including hospitalization and poor adherence to prescribed regimens (Lenahan et al., 2013).

Consequences of Misidentification

Medication errors resulting from pill misidentification can have severe consequences, including accidental poisoning, harmful drug interactions, and delayed treatment. For instance, non-adherence due to confusion over the appearance of generic pills is estimated to cost the U.S. healthcare system between $100–300 billion annually (Sheth et al., 2025). Additionally, incorrect dosages or unintended drug combinations can lead to life-threatening reactions that require emergency medical intervention (Sheth et al., 2025).

Proposed Solution: EasyPill's AI-Driven Approach

To address these challenges, EasyPill employs deep learning models such as MobileNet along with advanced image recognition techniques. The system analyzes visual attributes—including color, shape, and size—to match pills with high accuracy against a comprehensive drug database (Howard et al., 2017).

Key Components and Benefits

Accurate Identification

EasyPill utilizes MobileNet's convolutional neural network architecture to achieve precise pill detection and classification. Research indicates that MobileNet-based systems can attain up to 98% accuracy in identifying pharmaceutical pills (Wang et al., 2020).

Comprehensive Drug Database

The platform integrates a robust medication database, enabling reliable identification even for generic drugs with differing appearances (Gao et al., 2024).

Medication Safety and Education

EasyPill provides detailed information about identified pills, including dosage guidelines, side effects, and usage instructions. Such tools have been shown to improve medication adherence rates by up to 30% (Komolafe et al., 2025).

Accessibility and Error Reduction

As a web-based platform accessible across multiple devices, EasyPill empowers both patients and healthcare providers to verify medications instantly. This reduces time-consuming manual checks and minimizes the risk of dispensing errors (Komolafe et al., 2025).

Technical Validation

Advancements in deep learning validate the effectiveness of this approach. For example, YOLOv8 has achieved precision rates above 99% in object detection tasks such as pill recognition (Kolli & Orsu, 2019). Similarly, MobileNet has demonstrated high validation accuracy in pharmaceutical applications (Howard et al., 2017; Mekatronika, 2024).

Research Objectives

EasyPill addresses the urgent need for a reliable solution to pill misidentification by combining AI-driven image analysis with educational resources. By reducing medication errors and improving adherence, it contributes meaningfully to patient safety and broader public health objectives. This research aims to develop a real-time, AI-powered pill identification framework optimized for use in emergency scenarios.

The Review of Literature

Medication errors remain a significant concern in healthcare, often stemming from the misidentification of pills. Such errors can lead to adverse health outcomes, including overdoses, harmful drug interactions, and non-adherence to prescribed regimens (Heo et al., 2023). The development of automated pill detection systems is therefore critical to improving medication safety and adherence. Recent advancements in artificial intelligence (AI), particularly deep learning, have enabled the creation of highly accurate image-based pill identification systems (Ou et al., 2018). This review examines current pill detection systems, highlighting their strengths, limitations, and potential for future development.

Automatic Drug Pill Detection Systems

Two-Stage Detection and Classification Systems

Modern pill detection systems often use a two-stage process: detection followed by classification. In the detection stage, deep CNNs are used to localize pills within images by extracting features and constructing feature pyramids with strong semantic representation. In the classification stage, the system categorizes the identified pill based on its visual characteristics, such as color, shape, size, and imprints (Ou et al., 2018). This approach has proven effective in identifying pills even when multiple drugs are randomly placed in an image. However, challenges persist, particularly in managing environmental variations and damaged pill packaging (Heo et al., 2023).

Digital Image Processing for Blister Analysis

Another innovative approach involves using digital image processing to analyze blister packs. Holtkötter et al. (2022), for example, developed a tool that processes blister pack images to detect missing pills and estimate medication adherence over time. While effective for self-monitoring systems, this method is limited to settings where blister configurations remain consistent (Lee & Youm, 2022).

Deep Learning-Based Systems

Deep learning models such as MobileNet are widely used in pill detection for their balance of efficiency and accuracy. MobileNet's lightweight architecture makes it suitable for deployment on mobile devices and in resource-constrained environments. For example, one study using MobileNet achieved a validation accuracy of 98%, indicating strong potential for real-world applications (Wang et al., 2020). Additionally, some systems incorporate language models to improve imprint recognition, further boosting identification accuracy (Heo et al., 2023).

Existing Pill Identifier Applications

- **Drugs.com Pill Identifier:** Allows users to input visual characteristics (e.g., color and shape) for pill identification, but lacks automated image recognition.
- **WebMD Pill Identifier**: Similar to Drugs.com, relies on manual user input and does not utilize machine learning.
- **AI-Powered Tools:** (e.g., ID My Pill by A.I. Cure): Uses AI for smartphone-based identification but is limited by database comprehensiveness and model accuracy.
- **PillSync:** Designed for institutional use in pharmacies and hospitals; improves accuracy but lacks accessibility for individual users.

Open-Source and Research Projects:

- **MobileNets for Pill Identification**: Shows promise using MobileNet architecture, though still largely experimental (Wang et al., 2020).
- **Pill Image Recognition Systems**: Research prototypes focus on machine learning but are not yet production-ready (Ou et al., 2018).

Strengths and Limitations of Current Approaches

Strengths

- High accuracy rates achieved through deep learning models like MobileNet and feature pyramid networks (Ou et al., 2018; Heo et al., 2023).
- Integration with mobile health solutions offers accessibility without the need for additional hardware (Holtkötter et al., 2022).
- Significant potential to reduce medication errors through automation (Heo et al., 2023).

Limitations

- Performance depends on high-quality images; poor lighting or damaged pills can impair accuracy (Wang et al., 2020).
- Limited generalizability due to regional differences in pill databases (Heo et al., 2023).
- Experimental systems often lack scalability and user-friendly interfaces (Lee & Youm, 2022).

The development of automated pill detection systems marks a major advancement in promoting medication safety and adherence. While current tools show high accuracy and efficiency, challenges remain in enhancing robustness under real-world conditions and achieving broader applicability. Future research should focus on expanding pill databases, increasing system resilience to environmental variability, and improving user accessibility through mobile integration. Addressing these issues will enable such systems to play a critical role in reducing medication errors and improving public health outcomes.

Methodology

The development of EasyPill, a pill detection system, followed the prototyping model, an iterative design approach that emphasizes early prototype creation, feedback, and continuous refinement before full-scale development (Sommerville, 2016).

Key Features of the Prototyping Model

- **Early Prototype Creation:** A basic version of the system was developed to test key features such as MobileNet-based image recognition and drug information retrieval.

- **Iterative Feedback Cycles:** Supervisors and stakeholders provided input in recurring review sessions to refine and improve system performance.
- **Requirement Clarification:** The process helped define user requirements clearly, ensuring alignment with real-world needs (Pressman, 2014).
- Risk Mitigation: Early testing reduced the likelihood of costly errors or misalignment during full-scale development.

Application to EasyPill Development

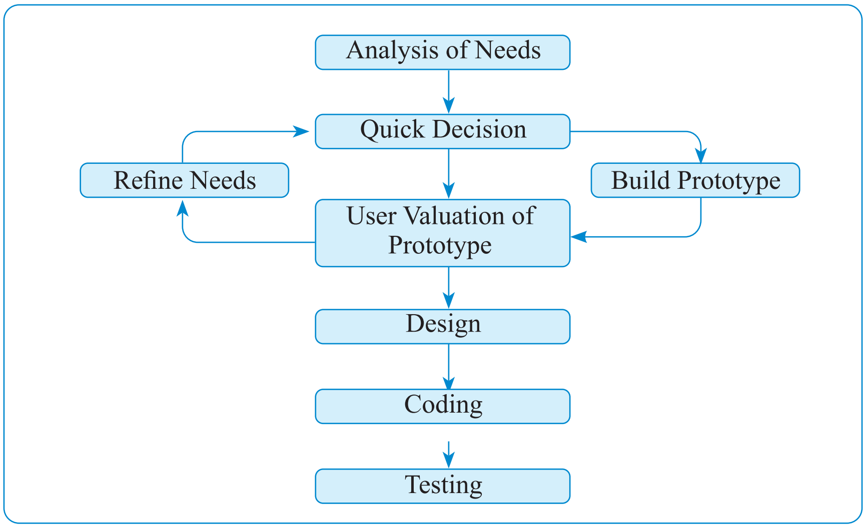
- **Initial Prototype**: Developed with core features including image upload, MobileNet-based pill recognition, and drug database integration.
- **Feedback and Refinement:** The prototype was tested by supervisors and healthcare professionals, who provided feedback on accuracy, usability, and functionality.
- **Iterative Improvements:** Based on feedback, multiple refinement cycles enhanced image recognition accuracy, improved the user interface, and expanded the drug database.
- **Validation:** The final prototype was tested in real-world scenarios, such as identifying damaged pills or handling emergency use cases, to ensure robustness and reliability.

Benefits of the Prototyping Model for EasyPill

- **User-Centric Design:** Ongoing feedback ensured the system met the needs of patients, caregivers, and healthcare professionals.
- **Early Issue Detection:** Challenges like recognition errors or missing database entries were addressed early.
- **Efficient Development:** Iterative refinement minimized rework and optimized resource allocation.
- **Alignment with Expectations:** The final system aligned closely with stakeholder expectations, resulting in high usability and reliability.

Figure 1

Prototyping Model



The prototyping model played a crucial role in the development of EasyPill, facilitating the creation of a robust, user-centric pill detection system. By iteratively refining the prototype based on stakeholder feedback, the development team ensured that the final product met high standards of accuracy, reliability, and functionality.

Requirements Analysis

Following an in-depth review of existing systems and a thorough literature survey, a detailed requirements analysis was conducted to define the key functionalities and technical specifications of EasyPill: A Pill Detection System. This process involved collecting input from a range of stakeholders, including patients, healthcare providers, pharmacists, and IT professionals, to ensure the system met the needs of its intended users. Requirements were organized into functional and non-functional categories, as outlined below.

Functional Requirements

Functional requirements specify what the system should do, focusing on its core features and behavior:

- **Registration and Login:** Users can create accounts through the Register function, with credentials securely stored in the Users Data Table. The Login function authenticates users by validating their credentials against the stored data.
- **Image Upload and Analysis:** Users can upload pill images in multiple formats (e.g., JPG, PNG). The system accepts various image qualities and preprocesses them for analysis.
- **Pill Identification:** The system uses MobileNet, a CNN, to analyze uploaded images and extract visual features such as color, shape, and size. These features are then matched against a comprehensive drug database for accurate identification.
- **Information Retrieval:** After a pill is identified, the system provides detailed information including its name, dosage, description, and potential side effects. This data is sourced from a reliable, regularly updated database.
- **Search Functionality:** Users can search for a pill by entering its name or visual attributes in a search bar. The system returns detailed information, including dosage instructions and side effects.
- **Database Management:** The system maintains an up-to-date medication database. Regular updates ensure inclusion of new medications and revised information.
- **User Interface:** A user-friendly, web-based interface offers intuitive navigation and includes features such as search, account management, and help/support options.
- **Error Handling:** The system displays clear error messages and guidance for issues like unidentifiable pills or upload failures, helping users correct problems efficiently.

Non-Functional Requirements

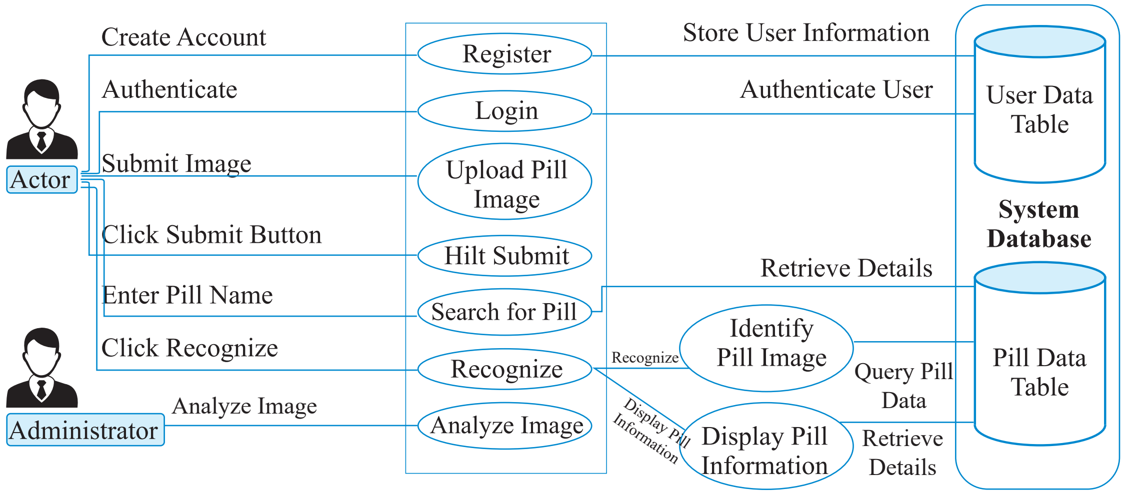
Non-functional requirements describe how the system should perform, focusing on attributes such as speed, usability, and security:

- **Performance:** The system processes image uploads and delivers identification results promptly. It can support high volumes of simultaneous users and image uploads without significant performance degradation.
- **Scalability:** The architecture supports efficient scaling to accommodate increasing numbers of users and database entries.
- **Usability:** The user interface is designed for ease of use, accommodating individuals with varying levels of technical proficiency. Features include intuitive navigation, clear instructions, and accessibility options.
- **Reliability:** The system is engineered for high availability with minimal downtime, supported by redundant infrastructure and regular maintenance.

- **Compatibility:** The system works seamlessly across major web browsers (e.g., Chrome, Firefox, Safari) and devices (e.g., desktops, tablets, smartphones).
- **Accuracy:** The pill identification engine achieves high levels of accuracy. MobileNet models and the drug database undergo routine validation and updates.
- **Cost-Efficiency:** Development and operational costs are kept within budget, leveraging cost-effective technologies and optimized resource allocation.

Figure 2

Use-Case Diagram for EasyPill: A Pill Detection System



A Use-Case Figure 2 illustrates the interactions between users and the system.

Table 1

Use Case, Actors, Users Description

Actor	Use Case	Description
User	Register	Users create an account by providing personal details.
User	Login	Users authenticate to access system features.
User	Search for Pill	Users search for a pill by name or attribute to retrieve information.
User	Upload Pill Image	Users upload an image of the pill for identification.
User	Hit Submit	Users submit the uploaded image for processing.
User	Click Recognize	Users initiate the pill recognition process.
System	Recognize	The system analyzes the image to extract visual features.
System	Identify Pill	The system matches extracted features with the database to identify the pill.
System	Display Pill Information	The system provides detailed information about the identified pill.
Administrator	Analyze Image (MobileNet)	Administrators perform advanced analysis of pill images for diagnostics.
Database	Store Pill Data	The database stores pill information for retrieval and recognition.
Database	Store User Data	The database stores user information for registration and login.

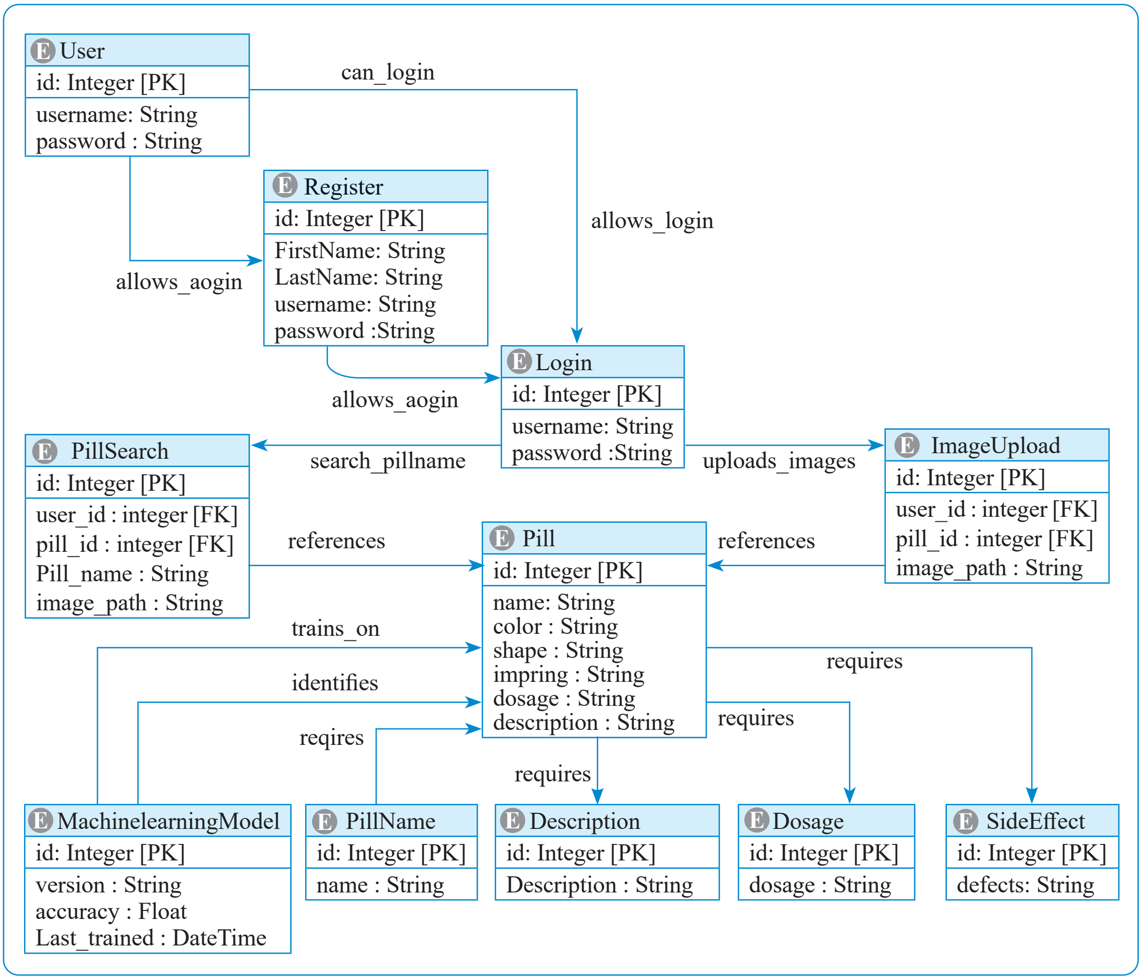
The requirements analysis for EasyPill focuses on delivering a robust, user-centric pill detection system. By addressing both functional and non-functional requirements, the system ensures high accuracy, usability, and scalability, making it a valuable tool for patients, healthcare providers, and pharmacists. The use-case diagram and accompanying descriptions provide a clear framework for system development and user interaction.

Object Modeling Using Class and Object Diagrams

The class diagram presents a structural overview of the pill detection system, outlining key entities and their relationships. At the core is the Machine Learning Model, responsible for identifying pills, with its accuracy improving through iterative training on diverse datasets. The Pill entity encapsulates essential attributes such as name, dosage, and description, and is linked to the Side Effects entity to provide comprehensive medication information. Users interact with the system via the Image Upload entity, enabling pill identification through uploaded images. This design supports efficient data management, accurate identification, and detailed medication insights, enhancing overall system reliability and usability.

Figure 3

Class Diagram of EasyPill: A Pill Detection System

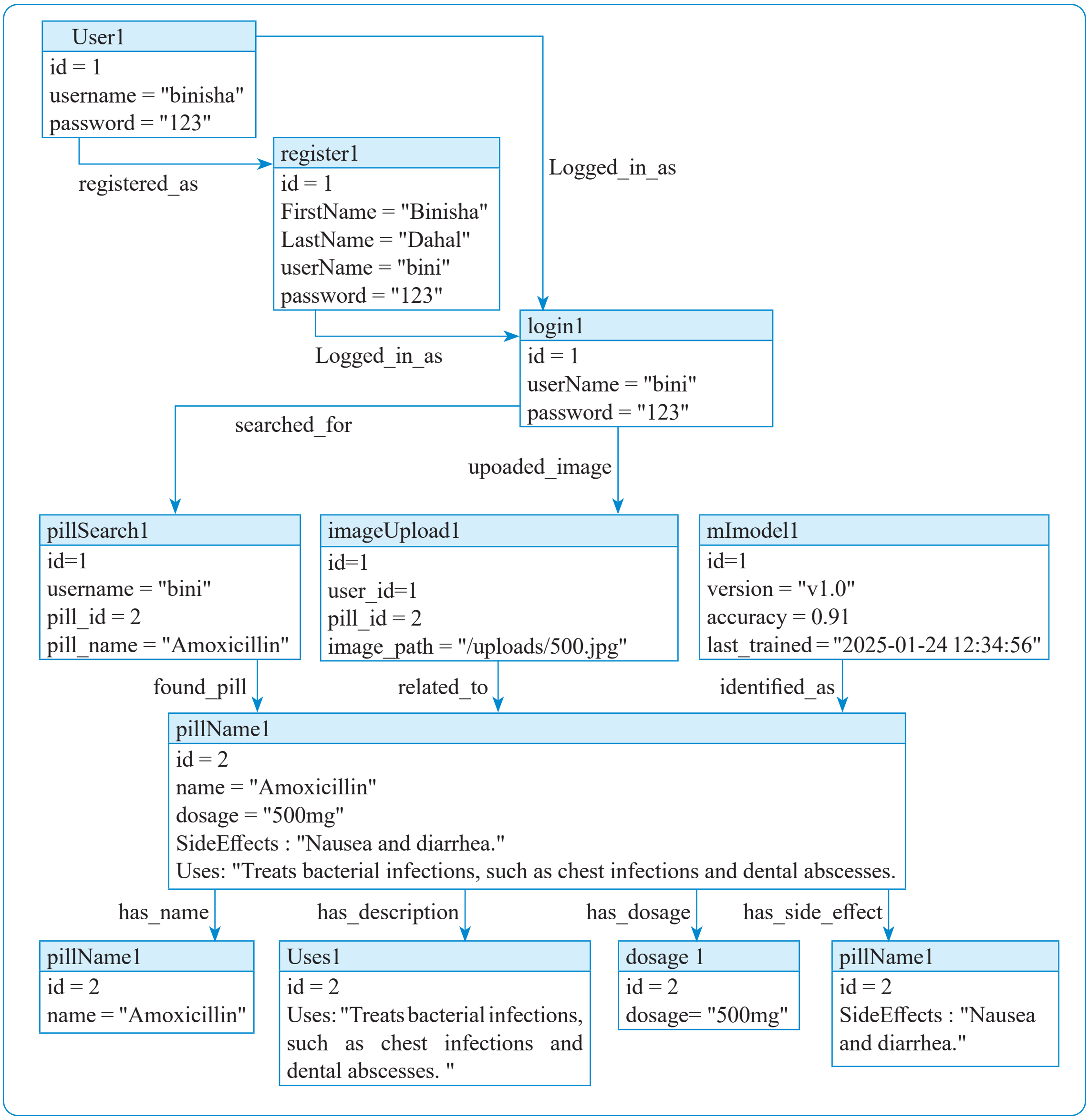


Object Diagram

The object diagram illustrates the functionality of the EasyPill system by showing its end-to-end workflow. A user initiates the process by registering and logging in. Once authenticated, the user uploads a pill image, which is processed by a machine learning model (e.g., MobileNet) trained for pill identification. The model extracts key attributes such as the pill's name, dosage, description, and potential side effects. The diagram depicts the interactions between key components—user registration, login, image upload, pill identification, and information retrieval—demonstrating the seamless data flow from user input to detailed pill information delivery.

Figure 4

Object Diagram for EasyPill: A Pill Detection System



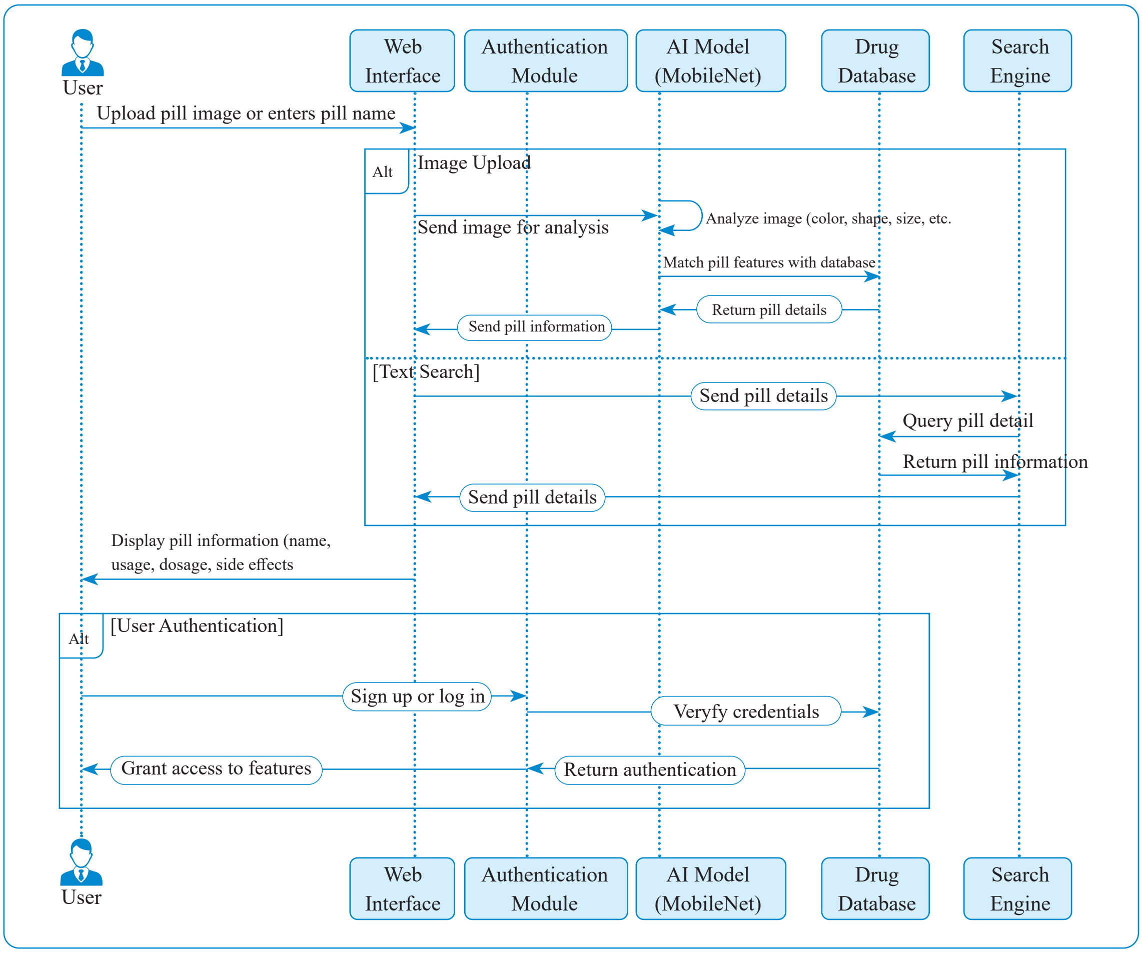
Dynamic Modeling Using a Sequence Diagram

Sequence Diagram

The sequence diagram outlines the workflow of the EasyPill system, beginning with user authentication via login or sign-up. The user then uploads a pill image, which is processed by an AI model (MobileNet). The model extracts visual features and queries the drug database for a match. Upon successful identification, the system retrieves and displays detailed pill information, including name, dosage, description, and side effects—ensuring a seamless and secure user experience.

Figure 5

Sequence Diagram of EasyPill: A Pill Detection System



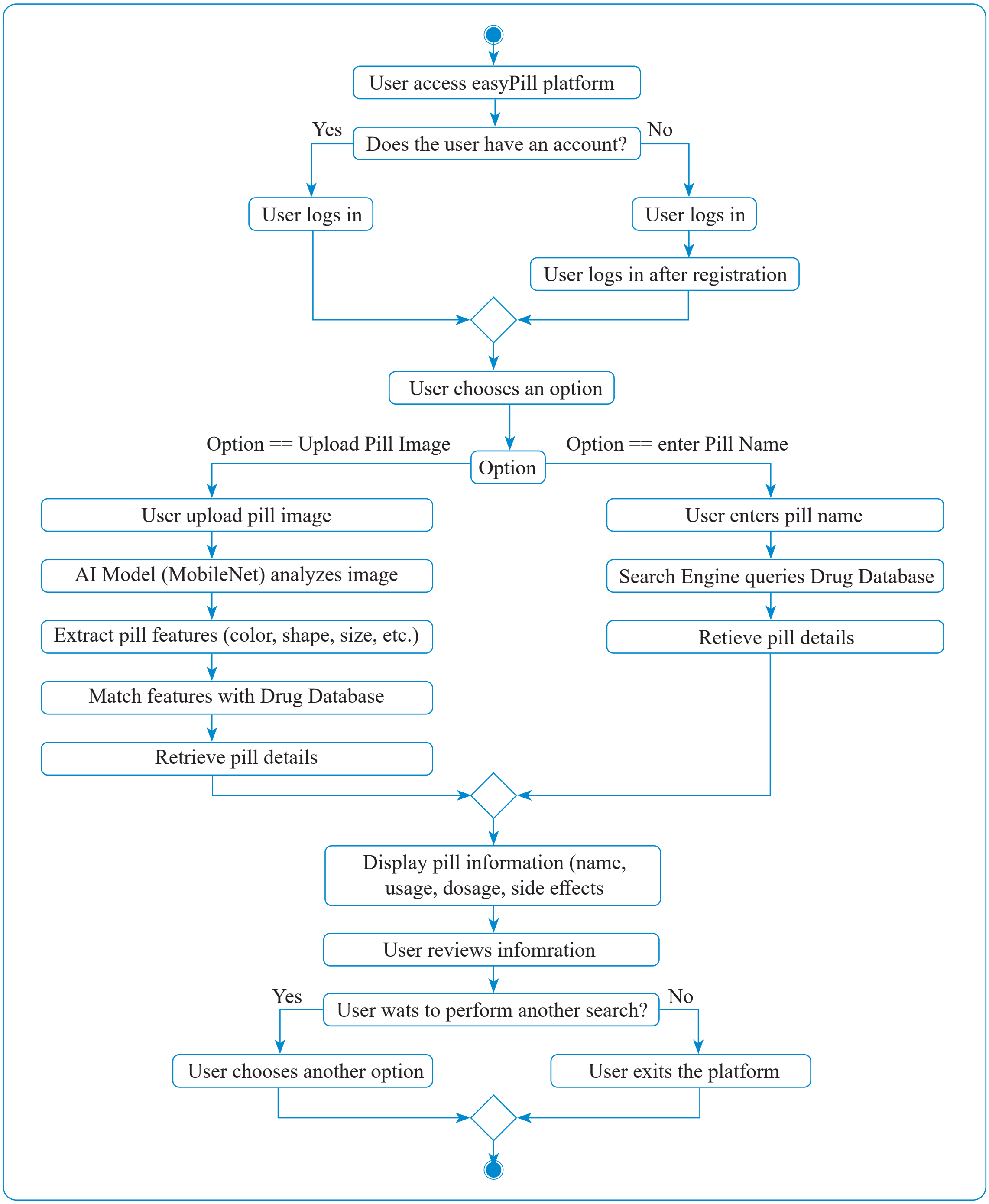
Process Modeling Using an Activity Diagram

Activity Diagram

The activity diagram illustrates the pill identification process, beginning when users upload pill images. The system validates the image, extracts features using a machine learning model, and cross-references them with a database. If a match is found, it displays detailed information such as name, dosage, uses, and side effects. If not, an appropriate error message is shown. This process ensures accurate and user-friendly identification, addressing issues like medication errors and unidentified pills.

Figure 6

Activity diagram of EasyPill: A pill detection system.



System Design

The architecture of the pill detection system, as depicted in the interaction model, involves users uploading pill images that are processed by a backend server. The backend utilizes a machine learning model for pill recognition, referencing a pharmaceutical database to retrieve key information, such as name, uses, dosage, and side effects. Administrators maintain system accuracy by managing the database and updating the machine learning model as needed.

The component diagram highlights essential elements of the system, including the User Interface, Backend Server, and Pill Database, which together ensure efficient pill identification and management. Core algorithms include CNNs and MobileNet. MobileNet uses depthwise separable convolutions for efficient image processing in resource-constrained environments. It incorporates techniques such as ReLU activation, pooling layers, batch normalization, and global average pooling to achieve reliable and accurate pill identification.

Figure 7

System Architecture Insights

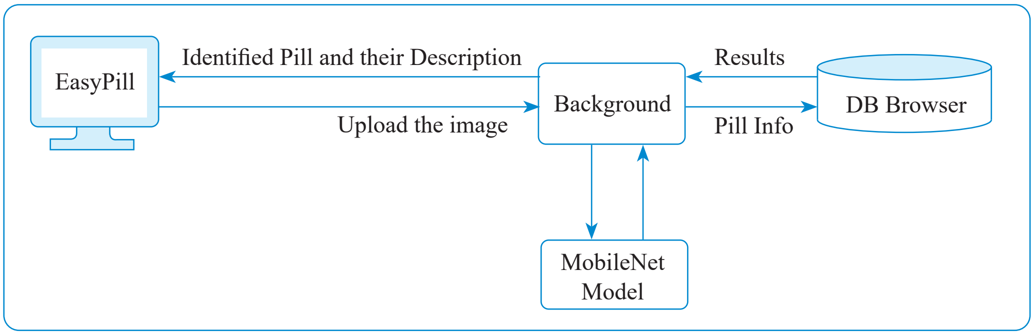


Figure 8

System Architecture Insights

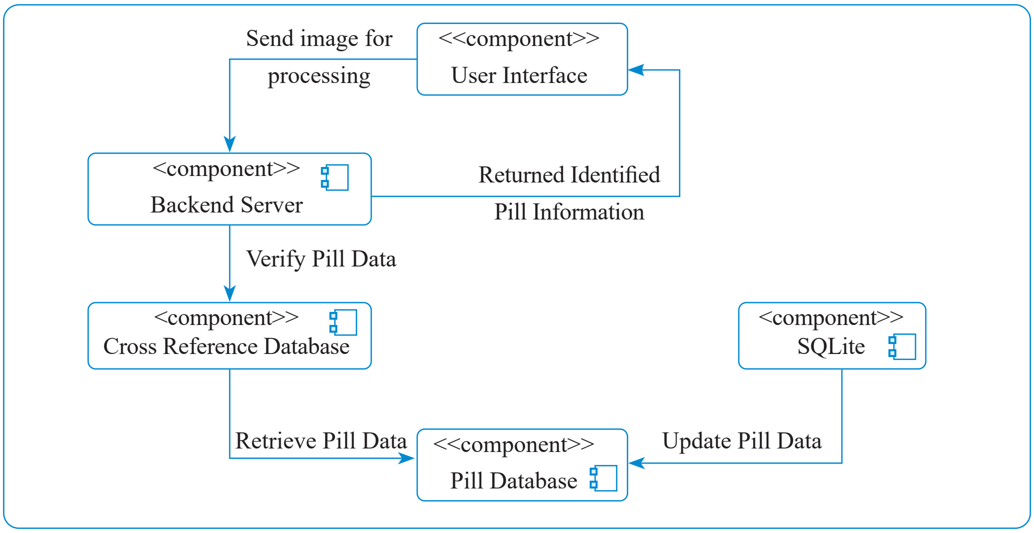
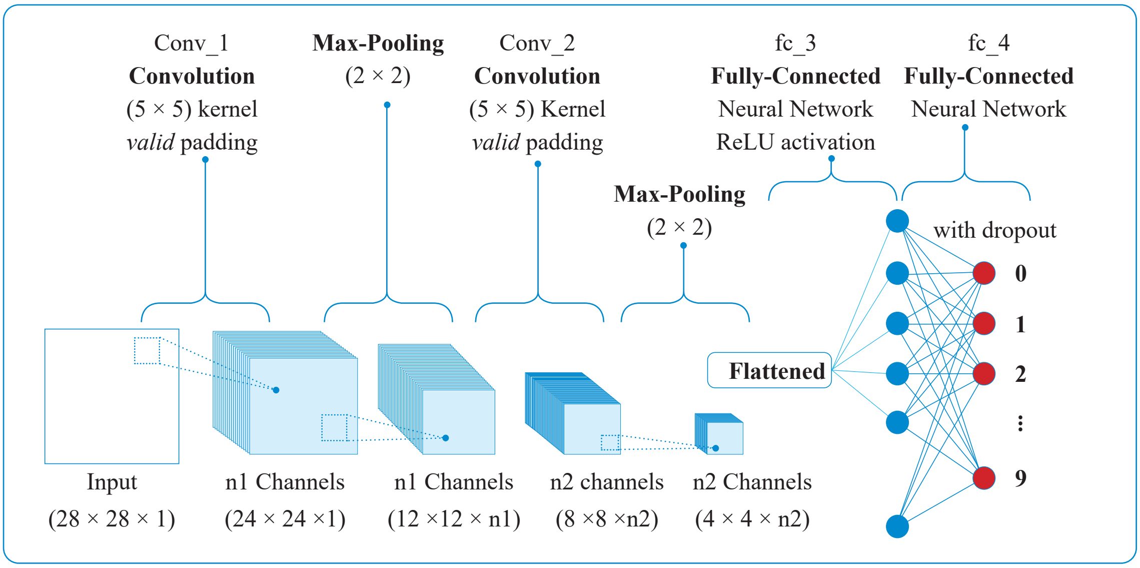


Figure 9

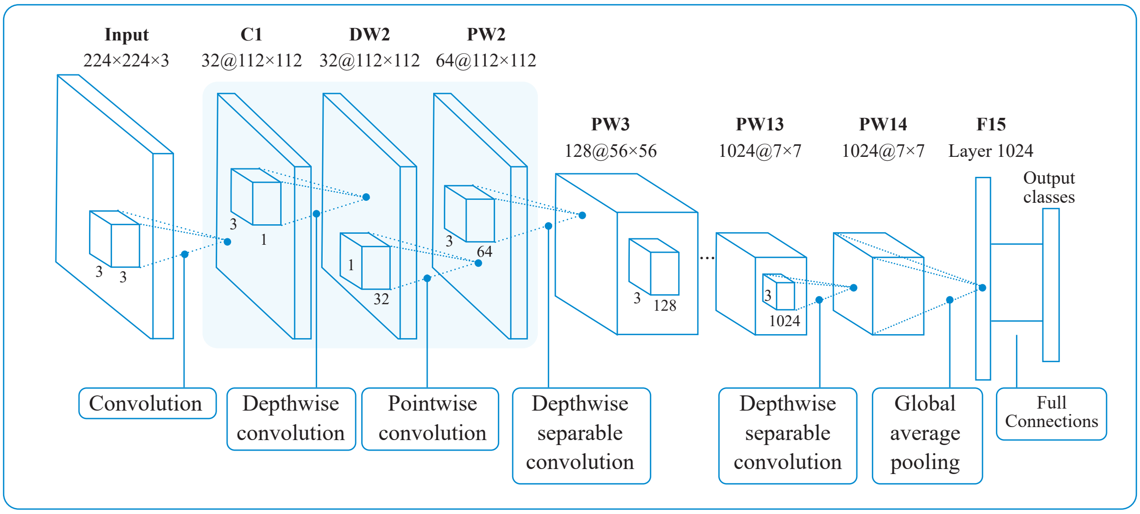
CNNS



The pill detection system's architecture comprises a user interface, a backend server, and a pill database. Users upload pill images, which the backend server processes using a machine learning model for recognition. This model cross-references with the pill database to retrieve details. The backend server leverages a machine learning model, particularly MobileNet, for efficient image processing, while administrators maintain accuracy by managing the database and updating the machine learning model. CNNs, with their structured layers and techniques like ReLU activation and pooling, are central to accurate and reliable pill identification. MobileNet employs depth-wise separable convolutions for optimized image processing in resource-constrained environments.

Figure 10

Understanding of MobileNet



The EasyPill system employs a client-server architecture. The backend server, powered by MobileNet, identifies pills from images uploaded by users. MobileNet uses depthwise separable convolutions for efficient image processing: depthwise convolutions filter each input channel independently, followed by pointwise convolutions that combine the outputs. Input images are preprocessed—resized to 224×224×3, normalized, and augmented—and pooling layers reduce spatial dimensions. Batch normalization and ReLU6 activation stabilize the training process. Global average pooling summarizes feature maps, and a softmax layer outputs class probabilities. This architecture ensures accurate and efficient pill identification, balancing performance with resource efficiency.

The EasyPill system utilizes Python for backend logic, leveraging frameworks such as Flask for API development and TensorFlow/Keras for model implementation. The front end is built with HTML, CSS, and JavaScript, providing structure, styling, and interactivity. SQLite is used to manage the pill database, storing information such as pill names, dosages, and side effects. The dataset, sourced from Kaggle, consists of labeled pill images that are preprocessed for training and validation. MobileNet—a lightweight convolutional neural network—conducts image analysis. Preprocessing includes resizing, normalization, and data augmentation. Depthwise separable convolutions efficiently extract image features, while batch normalization and ReLU6 activation contribute to training stability. Global average pooling reduces the feature maps to a lower-dimensional representation, and the softmax layer provides class predictions. These components are tightly integrated to support effective pill identification.

Testing

The EasyPill system underwent rigorous testing, including unit and system-level tests, to ensure its reliability and accuracy. Unit testing confirmed the proper functioning of individual modules, including user authentication, pill detection, and information retrieval, by verifying outcomes for both valid and invalid inputs. System testing validated end-to-end performance, ensuring seamless processes for registration, login, image upload, processing, and pill information display. Security tests confirmed that passwords are encrypted and access restrictions are enforced. The testing consistently showed successful outcomes, affirming the system's robustness and reliability in pill identification and information delivery.

The architecture—employing CNNs and MobileNet—ensures efficient image processing. MobileNet's use of depthwise separable convolutions and global average pooling enhances performance while minimizing computational demand. These techniques should be institutionalized as standards for improving patient care and medication safety (Mishra & Mishra, 2024; Mishra, 2019).

Conclusion

This research presents an intelligent pill detection system that offers a reliable and innovative solution to challenges in medication management. By enabling users to upload pill images and match them with a comprehensive pharmaceutical database, the system provides critical information such as the pill's name, uses, dosage, and potential side effects. This capability empowers individuals, caregivers, and healthcare professionals to accurately identify medications, significantly reducing the risk of errors.

The system's strength lies in its application of advanced machine learning techniques—particularly CNNs such as MobileNet—which continuously improve recognition accuracy through iterative training and updates. CNNs automatically extract hierarchical features from raw images, while MobileNet improves efficiency through depthwise separable convolutions and global average pooling. This combination supports high accuracy and effectiveness, making EasyPill a valuable tool for managing multiple medications across diverse settings. Rigorous testing—both unit and system—further validates its reliability and accuracy.

Looking ahead, several enhancements could improve the system's utility. Expanding the pharmaceutical database to include a broader range of pills, including rare and newly introduced medications, would increase its coverage. Integrating the system with Electronic Health Records (EHRs) could streamline verification processes in clinical settings, allowing healthcare professionals to cross-check prescribed medications and flag potential interactions. Additionally, real-time feedback and alerts for drug interactions based on identified pills could further improve patient safety. Developing a dedicated mobile application would enhance accessibility, enabling users to quickly upload pill images and receive information directly from their smartphones.

By continually refining its database, expanding functionalities, and integrating with healthcare infrastructures, the intelligent pill detection system developed in this research has the potential to significantly improve medication safety, reduce errors, and enhance public health outcomes.

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